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UNITED NUCLEAR
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FUELS DIVISION

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NLS-141

Mr. Donald A. Nussbaumer, Chief
Source & Special Nuclear Materials Branch
Division of Materials Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Subject: Amendment to SNM 777

Dear Mr. Nussbaumer:

Attached are six (6) copies of a proposed revision to SNM 777. These revised pages describe new equipment installed to augment our processing capabilities.

I request that this license be amended to incorporate these additions.

Very truly yours,

D. F. Cronin

D. F. Cronin
Director of Licensing

DFC:rd

attachments

DOCKETED USAEC APR 5 1965 REGULATORY MAIL SECTION DOCKET CLERK

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302.9 Destructive Distillation Unit

302.9.1 Process Description

Material flow through shipper's weight verification will follow plant procedure as detailed in other sections of the license.

Combustible wastes such as rags, sponges, mops, paper, air filters up to 24" x 24" square and other material will be charges to the DDU retort (2-R-2). The unit is vacuumed (2-x-6) clean of any previous residue and visually inspected prior to loading. The lid is bolted tight with a gasket seal and a low flow of nitrogen is (less than 4 CFM) passed into the DDU by means of a nozzle which extends through the lid and rests on top of the charge. The external temperature of the DDU is raised to approximately 600 C. from the furnace surrounding it (2-H-1). The organic matter in the charge is decomposed to various volatile hydrocarbons which dist[illegible] and exit from the DDU retort through a 4" outlet noz[illegible] nitrogen gas acts as a sweep. The volatile tars, etc. scrubbed in a water filled scrubber tank (2-F-4) downstrea[illegible] of the unit. An overflow 11-liter bottle catches the soluti[illegible] overflow. The non-condensed gases are then blended with ventilation exhaust air from the hoods surrounding the equipment and cleaned of any entrained particulate matter as it is passed through a 30" x 24" x 12" air filter (2-F-5).

After completion of the distillation step, the nitrogen gas flow is shut off and a flow of air and/or oxygen is introduced to the unit through the same nozzle. An internal thermocouple permits regulation of the oxygen flow and hence, the internal combustion temperature. When additional increases of oxygen do not produce a temperature rise within the DDU, the run is complete and the unit is cooled to room temperature. The lid is removed, and the residual ash is vacuumed into a vacuum cleaner (2-x-6) prior to reloading.

The ashes are collected in 1 gallon bottles and transferred to a milling hood (1-L-14) after which it is sampled. The ashes will be transferred to the weighing and counting hood (1-L-1) prior to leaching in either the stainless steel dissolver (1-J-4) or beakers in the 1-L-18 hood. When the consistency of the ashes warrants it, the ashes will be calcined (1-H-7) and/or milled (1-L-9b) prior to transfer to the weighing and counting hood (1-L-1). After acid leaching, the solution will be sampled for accountability.

302.9.2 Process Equipment (Refer to UNC drawing E-7528, Rev. 2)

302.9.2.1 D.D.U.

A box-shaped retort (2-R-2) fabricated of 1/4" plate, type 316 stainless steel and open at the top. External dimensions of the box are 25" x 25" x 41 1/2" high. A 4" schedule 40 type 316 stainless steel outlet nozzle is mounted 4 1/2" on center from the top and the vertical wall. A square lid 29" x 29" x 3/4" thick fastens to the top to seal the unit. The lid is equipped with a 2 1/2" D packing gland for the internal 3/4" ID Inconel gas nozzle, which can slide in a vertical direction only down on top of the charge. A three-inch diameter knife-edged nozzle, 4" long, and off center on the lid, is fitted with a hinged lid to serve as a pressure relief port.

302.9.2.2 Furnace (2-H-1)

A standard 60 kw electrical commercial furnace lined on the bottom and sides with fire brick with an interior dimension of 36" x 36" x 30" deep. The brick is 9 1/2" thick. GLObar elements will be used for heating.

302.9.2.3 Off-Gas Condensing Unit (2-F-4)

The 4" ID schedule 40 stainless steel vent pipe from the DDU is flanged to a 4" tee mounted on top of a 5" schedule 10 vertical tank, 3'-4" long. A 4" diameter schedule 10 dip leg extends 1'-4 1/8" down into the 5" pot for providing passage of the distillate vapors to bubble through water. The bottom of the 5" D pot is reduced to 1" diameter with a drain valve at the bottom. The tank is filled with water through a 1/2" nozzle at the top and the level is set visually by means of a sight glass mounted in the side of the pot. A 2" schedule 10 pipe nozzle attached perpendicular to the wall of the 5" pot and 3" above the bottom of the dip leg serves as an overflow for excess water and condensed organic materials. The overflow solution will be caught in an 11-Liter bottle fastened to a permanent rack.

The overflow solution will be tested for uranium content. If the uranium content is below discard limits, the solution will be transferred to either of the neutralization tanks (1-D-14 A and B). If the uranium content is above discard limits, the solution will be transferred to approved safe storage bottles and stored for future recovery. The scrubbed gas will be exhausted to the atmosphere through a 30" x 24" x 12" absolute filter (2-F-5) by the fan (2-B-1) on the roof.

SUBJECT: PROCESSING - FACILITIES AND EQUIPMENT

Head Ends Processing

ISSUED March 30, 1965

SUPERSEDES

302.9.2.4 Nuclear Safety Considerations

The amount of U_{235} will always be less than 550 gms, determined from shippers estimate and visual inspection. As shown by Drawing E 7528 Rev. 2 an isolation distance of approximately 4 feet is maintained around this retort 2 R2.

The combustible material will be visually inspected during charging, and all visible contamination will be segregated and calcined in 1-H-7 as outlined previously.

302.10 Uranium Scrap Containing Chlorine

302.10.1 Process Description

Uranium compounds containing chlorine will be weighed and loaded into one gallon containers in glove box 1-L-1 or in hood 1-L-14. The one-gallon containers will be hand carried to the dissolving hood (2-L-1) and will be unloaded into the attached 6" pyrex pot (2-J-1). Nitric acid solution will be added until all feed material is dissolved. Additional acid will be added to increase the volume of solution in the column to approximately 8 gallon total. The gases generated in dissolution will be exhausted through the plastic hood (2-L-1) above the pyrex pot into the DDU duct upstream of the absolute filter (2-F-5). The dissolved feed material will be drained by gravity to a vertical column 3'-9" on centers distance. The solution will enter the 6" pyrex column (2-C-1) through a 1" side inlet located 11 3/4" above the second floor platform. Approximately 1 to 2 gallons of liquid N_2O_4 will be pressurized with nitrogen gas from a container stored outside into the bottom of the column and permitted to react with the liquid already in the column. Once the reaction has been completed, the excess N_2O_4 will be sparged with compressed air and the dechlorinated solution will be sampled for chloride content before transfer to the assay tanks (1-D-34's). Pump (2-P-1) transfers the solution to the assay tanks 1-D-34 A, B, C. The off gases from the pyrex column will be scrubbed in two parallel 5" D caustic scrubbers (2-F-3A and 2-F-3B), the nearest of which is 3"-1" on centers from the 6" column. The scrubber columns are on 30" centers. Caustic solution is added to the scrubber through a funnel and is recycled by pump (2-P-2) to the two scrubbers. Each scrubber has two spray nozzles. The scrubbed gas will be vented to the atmosphere through exhaust fan 2-B-1. The scrubber solution is periodically analyzed for uranium content.

If this solution is below uranium discard limits, it will be pumped to the neutralization tanks 1-D-14A or 1-D-14B. If above discard limits the scrubber will be drained into 4 liter containers for recovery. The 6" column is fitted with a 1" overflow which drains to an 11-liter bottle permanently attached at floor level to the right of the column at a minimum distance of four feet on centers.

302.10.2 Equipment (Refer to A-602 Rev. 2 for relative location of equipment)

302.10.2.1 Column (2-C-1)

A vertical column approximately 14 1/2 feet in height consists of 6 sections of standard conical end 6-inch pyrex Corning type 7740 pipe (double tough).

The bottom section, a 6" x 1" bell reducer, rests on an S.S. plate which supports the column. Above this piece is a 6" x 6" x 1" x 1" reducer cross. Next is a 6' straight section, with a 6" x 6" x 1" tee above it. The 1" nozzle serves as a feed inlet from the dissolving tank. Above this section is another straight piece, four feet in length. A 6" x 6" x 2" reducer tee mounted at the top of the column serves as a gas outlet and overflow. Each tee and cross is 18" in length with the nozzles mounted in the longitudinal center of the piece.

The pump (2-P-1) is connected to the column by a 1" line and to the assay tanks by a 1/2" stainless steel line. The pump itself will have a 1" drain line.

The overflow line will immediately, upon exiting from the top of the column, pass through a 2" tee and a 2" x 1" reducer; overflow line drains by gravity into the permanently located 11-liter overflow bottle. The solution in the 11-liter bottle will be transferred to 1-gallon bottles when necessary and either first stored or transferred directly to the dissolving hood (2-L-1) and re-introduced into the pyrex pot (2-J-1).

302.10.2.2 Dissolver

The dissolver (2-J-1) unit is a pyrex pot of dimensions 12" x 6" I.D. A Teflon basket liner fits within the Pyrex pot. The top of the dissolver Pyrex pot is flanged to the bottom of the UPUC hood (2-L-1). The dimensions of the hood are 12" x 18" x 24".

The gases pass through an absolute filter (2-F-5). HNO_3 solution is introduced through the side of the hood in a 1/2" stainless steel pipe. The face of the hood is open and under negative pressure. A Pyrex 6" x 1" reducer at the bottom of the pot is attached to a 1" flexible hose and then to 30" of 1" Pyrex to the column (2-C-1) nozzle.

302.10.2.3 <u>Scrubbers (2-F-3A, 2-F-3B)</u>

The vent gases will exit from the 6" x 6" x 2" Pyrex tee on the column (2-C-1) to a pair of 5" diameter scrubbers six feet high on 30" centers. The exhaust line is 2" stainless steel and ties into a 2" cross piece connecting the two scrubbers. NaOH is introduced in a 4" funnel into a vertical 3/4" line that connects to the 1" bottom cross piece connecting the two scrubbers. The bottom cross piece runs into the pump (2-P-2) and re-introduces the solution to the scrubbers through 4 spray nozzles and two 1/2" cross pieces. The 2" exhaust cross-piece is at the top of the scrubbers and passes through a 2" x 3" expansion to the duct work leading to the blowers (2-B-1) on the roof.

The scrub solution will be sampled for uranium content and if within discard limits, it will be pumped to neutralization tanks (1-D-14A & B). If solution is above discard limits, the solution will be drained into 1-gallon bottles and stored for further processing.

302.10.2.4 <u>Nuclear Safety Considerations</u>

The Pyrex glass column 2-C-1 has been calculated to have a maximum k_{eff} of 0.83 with optimum moderation and reflection. An unreflected but moderated system had a k_{eff} of 0.72. A multigroup transport theory code DTF was used to calculate the reactivity for a range of solutions. The same code was used to calculate a critical 6" diameter pipe (no boron) and a 6" diameter cylinder wrapped with cadmium sheet 0.020" thick. The cadmium-wrapped pipe was found to have a higher k_{eff} than the boron-containing glass pipe.

The results of these calculations are submitted separately as Appendix 1 to this section.

Interaction between this column (2C1) and other units (refer to layout Dwg. E-7528 Rev. 2) are as follows:

to filler 2F1

diameter = 4"
height = 8 feet
separation = 98"
Ω = 0.359

to reactor 2R1

diameter = 5"
separation = 117.5"
height = 96"
Ω = .0323

(cont'd)

302.10.2.4 (cont'd)

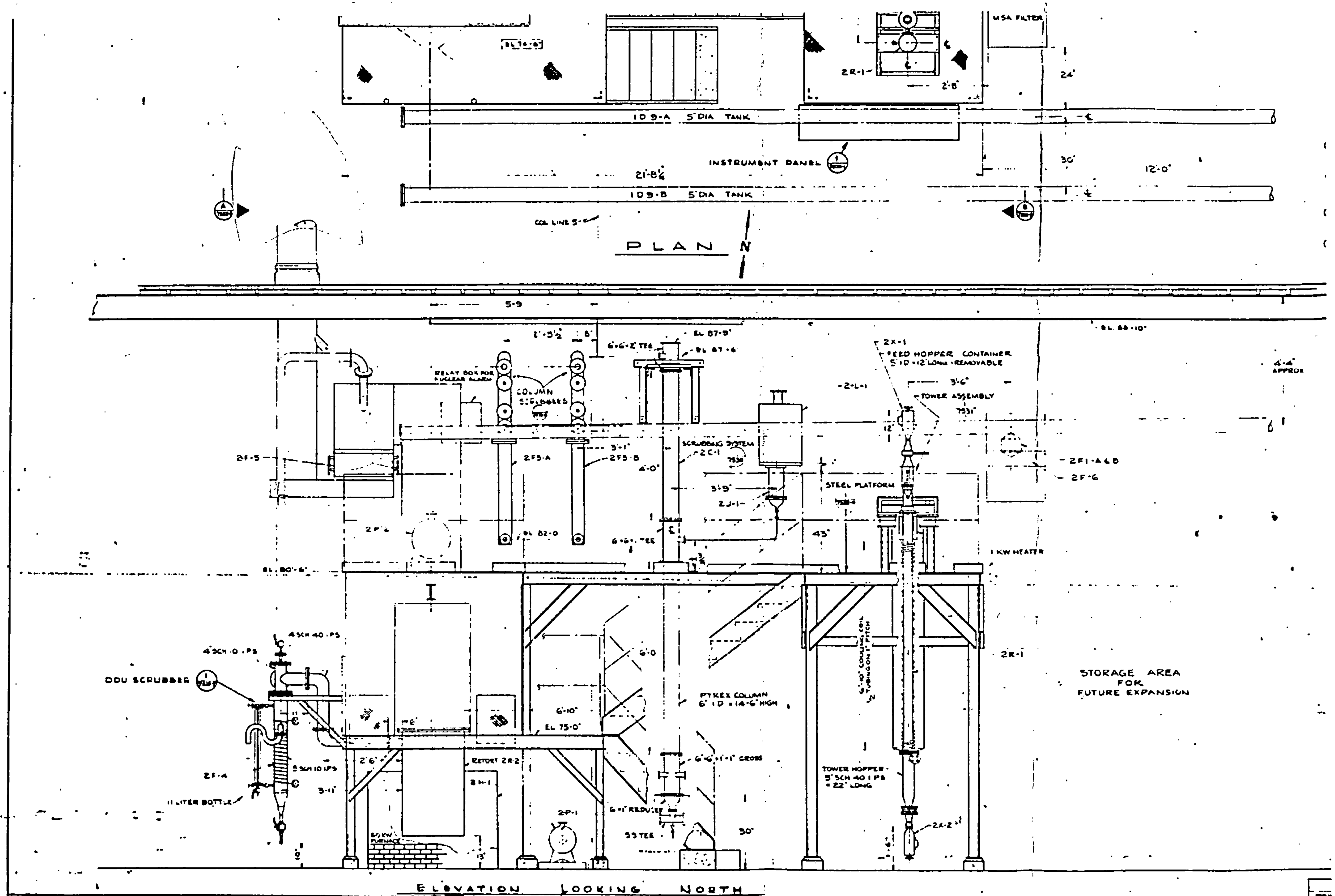
to dissolver 2J1

diameter = 6"
height = 12"
separation = 44"
Ω = .0368

Total Ω = 0.198

to 11L bottle (overflow)

diameter = 5"
height = 48"
separation = 48"
Ω = 0.093



PLAN
N
1D 9-A 5' DIA TANK
1D 9-B 5' DIA TANK
INSTRUMENT PANEL
21'-8¼"
30"
12'-0"
24"
2'-8"
2R-1
MSA FILTER
COL LINE 5
5-9
ELEVATION LOOKING NORTH
STORAGE AREA FOR FUTURE EXPANSION
FEED HOPPER CONTAINER 5' I.D. × 12' LONG - REMOVABLE
2X-1
TOWER ASSEMBLY
3'-6"
2-L-1
4'-4" APPROX
2F1-A & B
2F-6
STEEL PLATFORM
1 KW HEATER
45°
2R-1
TOWER HOPPER - 5" SCH 40 IPS × 22" LONG
2X-2
PYREX COLUMN 6" I.D. × 14'-6" HIGH
6'-0"
6'-10"
EL 75'-0"
6"-6"×1"×1" CROSS
6"×1" REDUCER
SS TEE
2P-1
30"
RETORT 2R-2
3H-1
2'-6"
3'-11"
DDU SCRUBBER
4" SCH 40 IPS
5" SCH 10 IPS
2F-4
11 LITER BOTTLE
EL 80'-6"
2F-2
EL 82'-0"
6"-6"×1" TEE
2F5-A
2F5-B
3'-1"
4'-0"
SCRUBBING SYSTEM 2C-1
5'-9"
2J-1
2F-5
RELAY BOX FOR NUCLEAR ALARM
COLUMN SCRUBBERS
2'-5½"
8"
6"-6"×2" TEE
EL 87'-9"
EL 87'-6"
EL 88'-10"

APPENDIX I

EFFECTS OF WALL MATERIAL ON THE REACTIVITY OF 6-INCH DIAMETER CYLINDER CONTAINING URANIUM SOLUTION.

BY

Marvin Raber
D. F. Cronin

1. INTRODUCTION AND SUMMARY

This study was performed to determine whether the boron contained in commercially available boro-silicate glass pipe would reduce the reactivity of enriched (93.5% U_{235}) uranium solutions contained in a 6-inch diameter cylinder sufficiently for its use in chemical processing plants.

A maximum value of k_{eff} of 0.83 was obtained for a range of UO_2F_2 solution concentrations in 6-inch diameter boro-silicate glass pipe. It was assumed to be reflected by an effectively infinite water reflector. The maximum k_{eff} for an unreflected system was 0.72.

Comparison was made between the boro-silicate glass pipe, and a 6-inch diameter cylinder of UO_2F_2 solution wrapped with 0.020 inches of cadmium and surrounded by effectively infinite water reflector. The latter was found to have a slightly higher k_{eff} (0.836) than the maximum value obtained for the standard boro-silicate glass pipe.

The DTF multi-group transport theory code was used with the Hansen-Roach cross-section library except for silicon cross-sections (not in the Hansen-Roach library). Silicon cross-sections were computed using the GAM-1 code for the top 14 energy groups. Hand calculations were made of the bottom two groups from thermal neutron cross-section data.

2. DESCRIPTION OF STANDARD 6-INCH BORO-SILICATE GLASS PIPE

ID = 6.0 ± 1/32 inches
OD = 6.656 inches
Wall thickness = 0.328 inches
Weight of glass per linear foot = 6.3 lb.
Density = 2.23 gm/cm^3
Typical Analysis (Corning 7740 or Kimble KG-33)

MATERIAL	WT. % IN GLASS
SiO_2	80.6
B_2O_3	11.9
Al_2O_3	2.0
Na_2O	3.8
CaO	0.8
K_2O	0.2

The above weight percent B_2O_3 corresponds to 3.7 weight percent B in the glass.

3. REACTIVITY CALCULATION METHOD

The DTF code (Reference 2) is a one-dimensional multigroup program written in FORTRAN for solving the neutron transport equation utilizing the Sn approximation. The program can determine the regular or adjoint solution for slab, cylindrical, or spherical geometry. Isotropic or anisotropic scattering may be considered. The allowable maximum order of Sn is 23 for slabs and spheres, and 8 for cylinders due only to computer memory limitations. This code is the DTK code adapted to FORTRAN 63 for the Control Data Corporation 1604-A computer.

Various boundary conditions are allowed so that cell calculations or time absorption calculations may be performed. Finite as well as infinite cylinders and slabs may be treated. As many as 75 space intervals, 75 materials, and 18 velocity groups may be specified. The program also contains a number of search options whereby one can vary dimensions or concentrations in order to arrive at a predetermined eigenvalue. Distributed or shell sources may be specified at any position in the configuration.

The program supplies as output, the eigenvalue, angular fluxes, total fluxes, fission distributions and other quantities of interest.

A library of cross sections is available on magnetic tape. Cross sections may be read in from the library tape and/or from cards.

All calculations were performed using the Hansen and Roach cross section library described in Reference 3. This is a sixteen group cross section set for use in DSN calculations. The cross sections are averaged as follows: The first five (high energy) groups are obtained by fission spectrum weighting. The next ten groups are obtained essentially by flat collision density weighting except for the heavy element resonance cross sections. The heavy element resonance cross sections are obtained from the resonance integral and therefore account can be taken of resonance self-shielding. The thermal group is a Maxwellian average.

Table 1 presents a description of the group structure used in this library.

Several sets of nuclide cross sections are provided for U-235 and U-238. The choice of a proper set depends on the potential scattering cross section of the medium per atom of U-235 or U-238. In computing the scattering cross section of the medium, the following epithermal microscopic scattering cross sections were used.

	σ_s, barns
U-235	10
U-238	8.3
H	20
O	3.8
F	3.4

The following cross section sets were used.

H/U-235 atom ratio	U-235 set no.	U-238 set no.
27.1	7R	12
55.4	8R	13
83.1	9R	14

The DTF code, together with the Hansen-Roach library has been checked against a wide variety of critical experiments, including UO_2F_2 solution experiments. In general, this code is capable of predicting the reactivity of these experiments to within + 2% for both fast and thermal systems. Table 2 presents the results of some checks against UO_2F_2 solution experiments. The experimental data were obtained from Reference 4.

Table 1. SIXTEEN GROUP SPECIFICATIONS FOR HANSEN-ROACH LIBRARY

Group	Energy Range	Δu	Fission Spectrum
1	3 - Mev		.204
2	1.4 - 3 Mev	.762	.344
3	0.9 - 1.4 Mev	.442	.168
4	0.4 - 0.9 Mev	.811	.180
5	0.1 - 0.4 Mev	1.386	.090
6	17 - 100 Kev	1.772	.014
7	3 - 17 Kev	1.735	
8	0.55 - 3 Kev	1.696	
9	100 - 550 ev	1.705	
10	30 - 100 ev	1.204	
11	10 - 30 ev	1.099	
12	3 - 10 ev	1.204	
13	1 - 3 ev	1.099	
14	0.4 - 1 ev	.916	
15	0.1 - 0.4 ev	1.386	
16	Thermal (.025)		

Table 2. CALCULATION OF UO_2F_2 SOLUTION CRITICAL EXPERIMENTS, ALUMINUM-WALLED SPHERES. (EXPERIMENTAL DATA FROM REF. 4)

Core Diameter, cm	H/U^{235} Atom Ratio	U^{235} Concentration, g/cm^3 sol.	Critical* Mass kg U^{235}	Reflector**	Sphere Wall Thickness, cm	Calculated keff (Using S_4 and Anisotropic H)
23.0	76.1	0.325	2.08	H_2O	0.16	0.997
23.6	126.5	0.199	1.39	H_2O	0.16	0.991
55.8	1112	0.0234	2.13	None	0.20	1.010
55.8	1270	0.0205	1.86	H_2O	0.20	1.009
69.2	1393	0.0186	3.25	None	0.32	1.009

Uranium 93.2% enriched in U^{235}; spheres constructed of type 1100 aluminum; no correction made for container thickness.

* Volume known to within ± 0.5%; concentration to within ± 1%.

** When present, water reflector was effectively infinite.

4. CROSS SECTIONS FOR SILICON

The Hansen-Roach library discussed above does not contain cross sections for silicon, a major constituent of glass. Silicon cross sections for use in DTF were computed using the GAM-1 code. (Reference 5) GAM-1 is a multigroup code for the calculation of fast neutron spectra and multigroup constants. Silicon cross sections for the top 14 energy groups of the Hansen-Roach scheme were computed by running a GAM problem on a system that consisted of the 6-inch diameter boro-silicate glass pipe filled with UO_2F_2 solution at a concentration of 437 gm U-235/cm^3 (H/U-235 = 55.4) and surrounded by a 2-inch thick water reflector. These three regions were homogenized in the GAM problem. The silicon cross sections obtained in this manner are averaged over a neutron spectrum computed by GAM for this homogeneous system.

Silicon cross sections for the bottom two groups of the Hansen-Roach scheme were computed by hand from thermal neutron cross section data.

The multigroup silicon cross sections were supplied to the DTF code on cards. The same cross sections were used for all solution concentrations.

The effect on reactivity of possible inconsistencies between the silicon cross section set and the Hansen-Roach library was investigated and found to be negligible. (See Section 6.2).

5. CALCULATIONS AND RESULTS

Table 3 presents a summary of the reactivity calculations performed in this study. Unless otherwise specified in the table, the following assumptions were made in each calculation:

1. The pipe I.D. was taken to be 6 1/32 inches, the conservative value within tolerance limits.
2. The pipe O.D. was taken to be 6.656 inches.
3. The pipe is surrounded by a 15 cm. thick reflector of water.
4. A uranium enrichment of 93.5% U-235 was assumed.
5. The small quantities of Ca and K in glass were neglected.

Table 3. SUMMARY OF DTF CALCULATIONS

Prob. No.	Prob. Specification	H/U-235	U-235 Concen. gm/cm^3	Si Cross Section Source	k_{eff}
1	UO_2F_2 sol'n. in pipe	55.4	0.437	GAM-1	0.8172
2	UO_2F_2sol'n. in pipe	27.1	0.8828	GAM-1	0.8217
3	UO_2F_2 sol'n. in pipe	83.1	0.300	GAM-1	0.8059
4	UO_2F_2 sol'n. in pipe	55.4	0.437	Hansen-Roach Al cross sections	0.8175
5	UO_2F_2 sol'n. in pipe	55.4	0.437	Al cross sections from GAM-1	0.8184
6	Critical infinite cylinder, 5.7 in. diam., UO_2F_2 sol'n.	27.1	0.8828	None	0.9922
7	UO_2F_2 sol'n. in pipe, no reflector	55.4	0.437	GAM-1	0.700
8	UO_2F_2 sol'n. in pipe, no B in glass	55.4	0.437	GAM-1	1.0341
9	UO_2F_2 sol'n. in pipe, 1/16" stainless wall, wrapped with 0.020 inch cadmium	31.6	0.724	None	0.836

All problems were run in the S_4 approximation, and anisotropic scattering by hydrogen was taken into account.

5.1 Maximum k_{eff} for Reflected Pipe

Problems 1, 2, and 3 yield k_{eff} as a function of solution concentration for reflected conditions. These data are plotted in Figure 1. The maximum value of k_{eff} is 0.83. Even allowing for a 3% non-conservative calculational bias, which is not warranted by the results of the checks against UO_2F_2 solution critical experiments, the maximum k_{eff} would be 0.855. This is sufficiently below unity to assure a sub-critical system regardless of solution concentration or presence of a water reflector.

It should be noted that the use of UO_2F_2 solutions in these calculations is conservative because $UO_2(NO_3)_2$ solutions, rather than UO_2F_2 solutions, will actually be processed in the proposed equipment at the Fuels Recovery Plant. $UO_2(NO_3)_2$ solutions are less reactive than UO_2F_2 solutions.

5.2 Effect of Cross Section Incompatibility

Problems 4 and 5 (See Table 3) were run to determine the effect on reactivity of possible incompatibilities between the silicon cross sections obtained from GAM-1 and the Hansen-Roach library. In Problem 4, the Hansen-Roach cross sections for aluminum were used for silicon. In Problem 5, aluminum cross sections obtained from the same GAM-1 problem that the silicon cross sections came from were used for silicon. The eigenvalues obtained from the two problems are virtually identical, indicating that incompatibilities between Si or Al cross sections obtained from GAM-1 and those of the Hansen-Roach library have a negligible effect on reactivity in this particular situation. The close agreement among the eigenvalues from Problems 1, 4 and 5 indicates that reactivity is not sensitive to moderate variations in the scattering and absorption cross sections of the glass constituents other than boron.

5.3 k_{eff} of Unreflected Pipe

Under normal conditions, the pipes will not be reflected by water. It will be necessary to take into account interaction between a given pipe and other nearby fuel-containing pieces of equipment. In order to do this, it may be convenient to utilize the interaction criteria of TID-7016 Rev. 1. The use of these interaction criteria requires the knowledge of k_{eff} for each unit when it is unreflected. A single DTF calculation was run (Problem No. 7) to provide an estimate of the maximum k_{eff} of the 6-inch diameter boro-silicate glass pipe when it is not reflected. An H/U-235 ratio of 55.4 (437 gm U-235/liter) was specified. This should be close to the optimum value, and since k_{eff} is not a

very strong function of uranium concentration, the k_{eff} value obtained should be close to the maximum value. (It is expected that the optimum H/U-235 ratio for the bare pipe will be somewhat higher than that for the reflected pipe. This is born out by critical experiment data in Reference 6. For the reflected pipe, the optimum H/U-235 ratio, corresponding to 725 gm U-235/liter, is about 31. See Figure 1.) The value of bare k_{eff} computed by the DTF code at an H/U-235 ratio of 55.4 is 0.70.

Figure 4 of Reference 7 shows k_{eff} values for bare cylinders with an H/U-235 ratio of 44.3. This figure yields a k_{eff} value of 0.72 for an infinitely long 6-inch diameter cylinder. This is in close agreement with the result obtained for the boro-silicate glass pipe using DTF. It is recommended that a k_{eff} value of 0.72 be used in interaction calculations in order to be conservative.

It should be noted that the boron in the glass has almost no effect on the reactivity of an unreflected pipe.

5.4 Other Calculations

The check calculations on UO_2F_2 solution critical experiment data discussed in Section 4 cover a range of H/U-235 ratios above 76. Since the optimum reactivity of the boro-silicate glass pipe occurred at an H/U-235 ratio of about 30, it was considered desirable to check the DTF code against critical experiment data for very concentrated UO_2F_2 solutions. Figure 13 of Reference 8 presents estimated critical diameters for infinite cylinders of UO_2F_2 solutions. These data were obtained from critical experiments on finite cylinders by transformations of buckling to convert these finite cylinders to infinite cylinders. For an H/U-235 ratio of 27.1, this figure gives a critical diameter of 5.7 inches for an infinite cylinder surrounded by a thick water reflector. This system was calculated with the DTF code. (See Problem No. 6 of Table 3.) The computed value of k_{eff} was 0.992. Since this is very close to the expected value of 1.0, this calculation demonstrates the ability of the DTF code to accurately predict the reactivity of concentrated UO_2F_2 solution systems.

A final calculation was performed on a reflected boro-silicate glass pipe containing UO_2F_2 solution at an H/U-235 ratio of 55.4 with no boron in the glass. The k_{eff} of this system was computed to be 1.034. The DTF code predicts that a reflected 6-inch diameter Pyrex pipe can be made critical. The glass constituents other than boron are not strong enough neutron poisons to provide criticality safety in the event of full reflection. This points out the necessity of firmly establishing that the specified concentration of boron is present in the glass pipes installed in the plant.

6. COMPARISON WITH UO_2F_2 SOLUTION CYLINDER WRAPPED WITH CADMIUM

The safety of a 6-inch diameter, fully reflected, infinite cylinder of uranium solution is generally accepted for all uranium concentrations in solution when the cylinder is wrapped with a sheet of cadmium 0.020 inches or more thick. Experimental data presented in Reference 6 show that the minimum critical diameter of a cadmium-wrapped infinite cylinder would be 7 inches or more. In order to further demonstrate the safety of the proposed 6-inch boro-silicate glass pipe, a DTF calculation was performed on a cadmium-wrapped cylinder of UO_2F_2 solution, and the K_{eff} obtained for this cylinder was compared with the maximum value obtained for the boro-silicate glass pipe.

The boron surface density of the Pyrex pipe was computed from data given in Section 3 to be:

$$\frac{2.23 \text{ gm glass}}{\text{cm}^3} \times \frac{0.037 \text{ gm B}}{\text{gm glass}} \times \left[\frac{6.656 \text{ in.} - 6.03125 \text{ in.}}{2}\right] \times 2.54 \frac{\text{cm}}{\text{in.}} = 0.0655 \frac{\text{gm}}{\text{cm}^2}$$

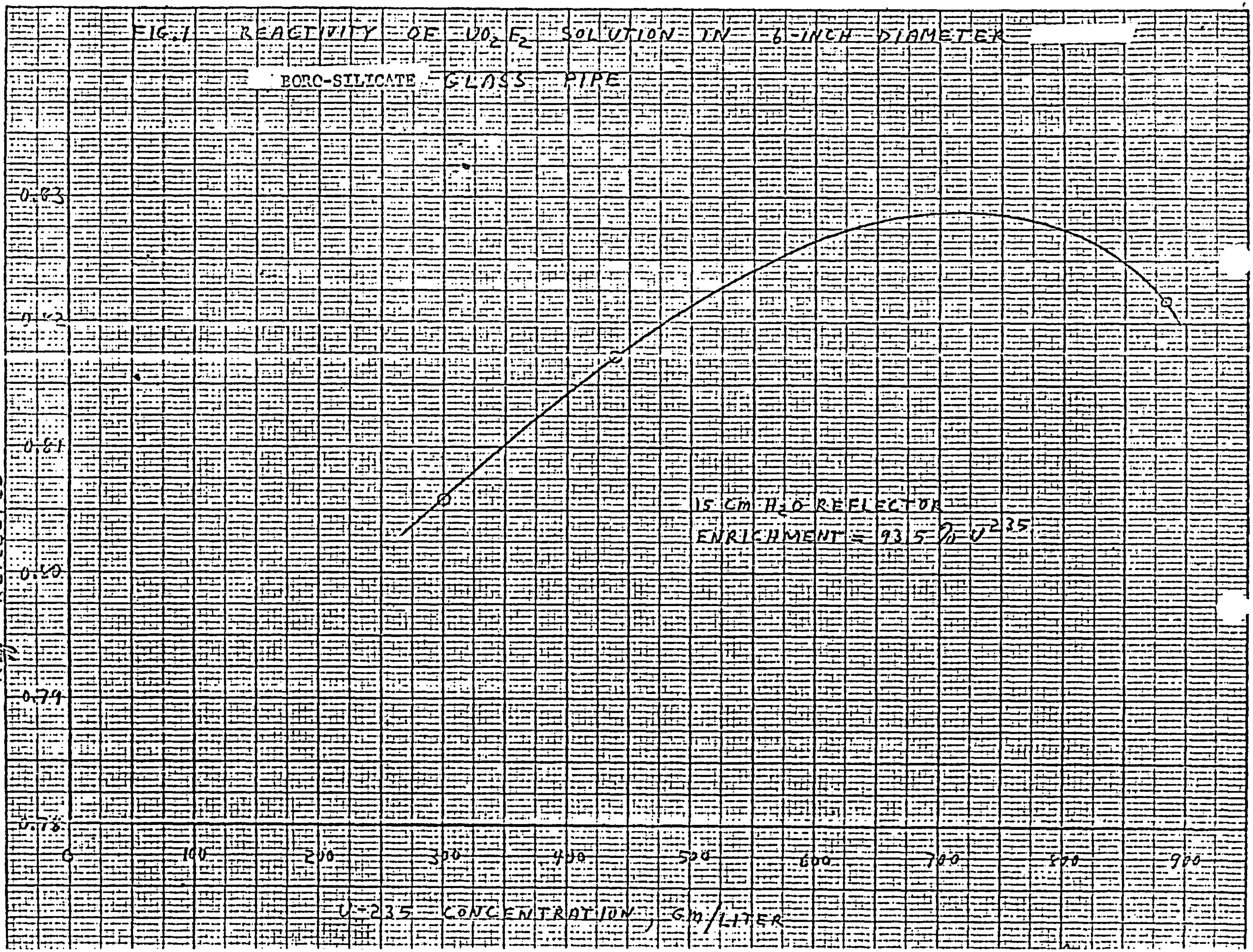
Experimental data on relative effectiveness of various control materials, including cadmium and borosilicate glass of the type used in Pyrex pipe, are given in Reference 9. These data show that borosilicate glass having this boron surface density is a slightly more effective absorber than a 0.020 inch thick cadmium sheet. Since the difference in effectiveness is not large, however, it may be expected that the maximum K_{eff} for a cadmium-wrapped cylinder will occur at approximately the same uranium concentration in solution that gives the maximum K_{eff} for this glass pipe. (See Fig. 1). A value of 724 gm U-235/cm^3 solution was selected for this calculation. This corresponds to an H/U-235 ratio of 31.6.

A DTF problem was run on a system that consisted of the following concentric regions

1. UO_2F_2 solution core, with H/U-235 = 31.6; outer radius = 7.660 cm (diameter = 6-1/32 in., same as pyrex pipe)
2. 1/16-inch thick stainless steel wall, with composition assumed to be 71% Fe, 11% Ni and 18% Cr by weight.
3. A 0.020 inch thick cadmium region, with a cadmium density of 8.65 gm/cm^3. This corresponds to a cadmium surface density of 0.44 gm/cm^2.
4. A 15-cm. thick reflector of liquid water, density = 1.0 gm/cm^3.

A k_{eff} value of 0.836 was predicted by DTF. This is greater than the maximum value of 0.829 given by Figure 1 for the boro-silicate glass pipe. It is, therefore, concluded that the proposed boro-silicate glass pipe is at least as safe for uranium solutions as a 6-inch diameter cylinder wrapped with cadmium. The results of this comparison are also consistent with the relative effectiveness data given in Reference 9.

KΣE 10 X 10 TO THE ½ INCH 359-12 KEUFFEL & ESSER CO.



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