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July 29, 1969

NIS:LJS-69/427

RECEIVED AUG 4 1969

Mr. Donald A. Nussbaumer, Chief
Source and Special Nuclear Materials Branch
Division of Material Licensing
4915 St. Elmo Place
Bethesda, Maryland 20014

Subject: Renewal of Special Nuclear Materials License SNM-777, Docket 70-820

Regulatory File Cy.

References:
1. Your Letter May 13, 1969, DML:RLL 70-820
2. Application for Renewal dated 10/31/68, NIS:CP:LJS-22

Gentlemen:

Receipt of your letter of May 13, 1969, Reference 1, is acknowledged. Your comments and request for additional information contained therein as well as those provided to Mr. Swallow during his visit to your office on April 22 and 23, 1969 have been reviewed.

The additional information and/or modifications you requested to the original application for renewal forwarded October 31, 1968, Reference 2, is included in the attached Response to AEC Comments on Renewal of Special Nuclear Material License SNM-777, Docket 70-820. Your review and approval is respectfully requested.

Within sixty days following your approval, the formally revised pages to the Manual, "General Information and Procedures Applicable to the Handling of Special Nuclear Material" incorporating these changes will be forwarded.

The Nuclear Criticality Safety Standards, Section 300, are always being reviewed in light of new data and other information being developed. Some additions and modifications have been included in the attachment. This review is being continued and it is expected that further modifications of the Tables and graphs of Subsection 309 will be completed by October 1, 1969. These will be forwarded for your review and approval at that time.

Crit. Br. 8/6/69 - PDR

D-23

ACKNOWLEDGED

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Materials License SNM-777

Page Two
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In regard to our request to withhold the report NBEO-1050 from public documentation, please review this request in light of the following: The disclosure of the information contained in this document within the public domain would permit competitors to use this information without the investment of budget funds required for its development. This document has been submitted as support information and does not materially affect the safety evaluation. The information which is disclosed to the publiv does enable an interested person to assure himself of the safety of the operations of the facilities within the scope of special nuclear material license 777.

If further clarification is needed, a meeting at your convenience is suggested.

Respectfully yours,

L. J. Swallow, Manager
Nuclear & Industrial Safety

jb
Attachment

cc: AEC 7 copies

NIS:LJS-69/427

July 29, 1969

RESPONSE TO AEC COMMENTS ON RENEWAL OF SPECIAL NUCLEAR MATERIAL LICENSE SNM-777, DOCKET 70-820

Subject: Renewal of Special Nuclear Material License SNM-777

Reference:

1. United Nuclear Corporation Application dated October 31, 1968, NIS:CP:LJS-22
2. Atomic Energy Commission Letter dated May 13, 1969, DML:RLL 70-820
3. Discussion between Messrs. Layfield, Stevenson and Swallow April 22, 23, 1969

Introduction: The following is in response to AEC comments received by references 2 and 3. They are listed in the same order as followed in manual "General Information and Procedures Applicable to the Handling of Special Nuclear Materials" submitted in reference 1. In the following, "Reference" is the affected paragraph in the manual; "Comment" is the AEC comment; "Answer" is the United Nuclear Corporation, Commercial Products Division (UNC) response.

Reference: Subpart 102.2

Comment: Clarify Commercial Products Division use of yard areas and building 9 H.

Answer: 1. Replace "9 H" with "first floor 9 H".
2. Please refer to Subsection 704, Handling of Incoming and Outgoing Shipments for description of procedures applicable to use of "yard areas".

Reference: Subsection 103, Summary of Activities

Comment: Clarify the use of slightly irradiated material.

Answer: Add to the footnote: "This material is in the form of fuel rods and assemblies and is only non-destructively modified and inspected."

Reference: Subsection 104, Special Nuclear Materials Possession Limits

Comment: Include source material.

Answer: Change title of this Subsection 104 to: Source and Special Nuclear Materials Possession Limits and delete the words "Special Nuclear Material" and "SNM" from Subparts 104.1 and 104.2 respectively.

Reference: Subpart 202.3, Personnel Qualifications

Comment: Minimum qualifications for persons performing nuclear safety assessments should specifically reflect experience closely related to such assessments.

Answer: 1. In the first paragraph describing qualifications of the department manager, change the last three lines to read:
"years of which have been in an activity in which he has performed nuclear criticality safety assessments and has developed an understanding of health physics and industrial safety problems and controls."
2. In the second paragraph describing qualifications of department specialists add:
"In addition, the Nuclear Safety Specialist will be required to have experience in performing nuclear safety assessments."

Reference: Subpart 202.4, Combined Activities

Comment: Delete the words "nuclear criticality".

Answer: Delete the words "nuclear criticality".

Reference: Subpart 204.1.1.2

Comment: Clarify responsibility for disciplinary action.

Answer: Add to the second sentence, "including implementation of disciplinary action against personnel failing to follow instructions".

Reference: Subpart 204.2.2.1

Comment: Define responsibility for administration of shipping procedures of Section 700.

Answer: Change the second sentence to read:
These departments have the responsibility for manufacture, engineering and shipment applicable to the production of products described in this application.

Reference: Subpart 205.1, General

Comment: Delete last paragraph.

Answer: Delete last paragraph.

Reference: Subpart 206.2.1, A Specific AEC License

Comment: Delete this subpart.

Answer: Delete subpart 206.2.1.

Reference: Subpart 206.2.2

Comment:
1. Is Nuclear and Industrial Safety Representative performing nuclear criticality safety calculations?
2. Clarify the definition of "overcheck".

Answer: Change "Nuclear Safety Specialist" in paragraph (a) to "Nuclear and Industrial Safety Representative".

Change paragraph (b) to read:
"The Nuclear and Industrial Safety Representative's evaluation has been reviewed by the Nuclear Safety Specialist or Nuclear and Industrial Safety Department Manager. This review is based on the criteria and standards of Section 300 and includes a verification of:

a) assumptions
b) correct application of criteria of Section 300
c) completeness and accuracy of the evaluation
d) familiarity of the installation.

In paragraph (c) change "or" to "of".

Delete paragraph (d).

Reference: Subpart 206.2.3, Records

Comment: Change the word "equipment" to "operation".

Answer: Change the word "equipment" to "operation".

Reference: Subpart 206.4, Suspension of Operations

Comment: What is "unsafe" operation?

Answer: Change last line to read:
"also have authority to suspend operations not being performed in accordance with approved procedures".

Reference: Subpart 207.3, Inspections

Comment:
1. Specify Specialist rather than the Representative as the inspector.
2. Add requirement that inspection frequency is increased when new operations are started.

Answer:
1. Replace the word "Representative" with the word "Specialist". Delete "or higher level personnel".
2. Add a foot-note to "Minimum Frequency":
The minimum frequency is increased when new operations are in the startup phase.
3. Delete reference to Nuclear Materials Management since the inspection requirement is discussed in Section 500.

Reference: Subpart 207.4, Audits

Comment: Clarify "Specialists".

Answer: Change last sentence to read:
"An audit is performed once a year by a team appointed by the General Manager".

Reference: Subpart 302.2.2

Comment: Add "under normal and abnormal circumstances".

Answer: Add "under normal and abnormal circumstances".

Reference: Subparagraph 303.2.2.1.2

Comment: Change "listed in" to "used and explicitly quoted in".

Answer: Change the paragraph to read:
"Keff values listed in Table XVII and footnote 6 on page 30, K-1019, Rev. 5, will be utilized except for specific values used and explicitly quoted in Sections 800 and 900."

Reference: Subpart 303.2.2.3, Criticality Zone

Comment: Justify safety afforded by 3 foot spacing.

Answer: Change last sentence to read:
"Interaction between storage devices and criticality zones is considered only when adjacent criticality zones are not isolated in accordance with the criteria of Subpart 303.2.2.4."

Reference: Nuclear Safety Evaluation - Safe Surface Density, Subpart 303.2.2.3

Comment:
1. Criteria of LA-3366 is not accepted across the board.
2. Application of 0.3 fraction critical criteria is incorrectly applied.

Answer: Delete last two sentences of Paragraph I.

Reference: Subpart 303.2.2.4, Isolation

Comment: Eight inch high density concrete is applicable only to units no more reactive than those listed in Table IV, TID-7016, Rev. 1.

Answer: Add to paragraph (a):
"This is applicable only to units no more reactive than those of Table 309-II".

Reference: Subparagraph 305.1.1.6

Comment: Delete since the preceeding criteria is not in complete agreement with the referenced ASA Standard.

Answer: Delete subparagraph 305.1.1.6.

Reference: Subpart 307.1, Criticality Limits

Comment: Criticality signs should be signed by NIS Representative and Production Manager.

Answer: Add new subparagraph 307.1.3:
"Criticality limit signs are signed in approval by the Nuclear and Industrial Safety Representative and the Production Manager."

Reference: Subsection 702, Shipping Standards

Comment: Who is responsible for administration of the shipping procedures?

Answer: Refer to previous answer on Subpart 204.2.2.1.

Reference: Subsection 703, Shipping Containers

Comment: Some discrepancy between amendment numbers and dates.

Answer: Correct amendment number and date for UNC 2600 and UNC 2800 as follows:

	Amendment	Date
UNC 2600	71-16	9/30/68
UNC 2800	71-17	1/31/69

Reference: Subpart 812.3, Nuclear Safety Evaluation - High Enriched Alloy Storage Racks

Comment: Solid angles were calculated based on a cylinder, but the tote box is more nearly a slab.

Answer: Replace first sentence of paragraph III with:
"The nuclear safety of these two arrays will be evaluated using the K-Ω method with the formulas and figures of Y-1272. The SNM in the shelves forms long rectangles with the width twice the thickness. The K-Ω method for slabs (Figure F 1.3 and F 1.4 Y-1272) does not describe these long thin rectangles where the length divided by the width, designated σ in Y-1272, exceeds 10. The σ values for these rectangles are 25 or greater. Therefore, the cylinder formulas and figures from Y-1272 will be used for this evaluation. The width of the SNM which the centermost unit sees from each shelf will be assumed to be the cylinder diameter. This is a conservative approach. For this evaluation,

$$\sigma = \frac{\text{edge to edge separation}}{\text{width of SNM}} \equiv \frac{\text{surface to surface}}{\text{diameter}}$$

$$\lambda = \frac{\text{length of SNM}}{\text{width of SNM}} \equiv \frac{\text{height}}{\text{diameter}}$$

General Answer: A similar comment was made for Nuclear Safety Evaluation Subparts 814.1 and 815.1. A review of these evaluations reveals that the interacting units have a square cross section and therefore the application of the cylindrical formulas is judged appropriate and any error is not significant in the overall safety factor.

Reference: Section 800

Comment: What are the administrative controls that insure proper application of safety criteria?

Answer: Reference is made to Subsection 206, Nuclear and Industrial Safety Controls and Subsection 307, Marking and Labeling.

Variation in the type of material, handling procedures, or equipment require prior review and approval before starting active processing.

Also, the NIS Department is cognizant of new orders received and the product specified. Any changes in product specifications requiring review of the existing approvals is known promptly. Finally, as stated in Subparagraph 206.4, Suspension of Operations, NIS Department members have authority to suspend operations performed without proper approvals.

Reference: Section 800

General Comment: How is material moved from one building to another?

Answer: Material is contained in the same "tote boxes" or container used in the production area. The "tote box" is moved by cart. Nuclear criticality safety of the cart is established in accordance with Section 300.

Reference: Subpart 821, Introduction

Comment: Add reference to Subparagraph 303.2.2.3 for surface density control.

Answer: Refer to Nuclear Safety Evaluation-Process Area Limits, Subpart 821.

Reference: Subparagraph 822.1.2

Comment: Define "normally" or provide examples of "abnormal" situations.

Answer: Delete the word "normally".

Reference: Subparagraph 822.2.2, Pickle Scrap Plates to Remove Clad

Comment: Define "autoradimetrically".

Answer: Replace "autoradiometrically" with "by gamma counting".

Reference: Subparagraph 822.2.6, Load and Evacuate Furnace

Comment: What makes the door open as a result of a water leak?

Answer: A leak in the cooling system will result in a loss of vacuum. The chamber door is kept closed by the vacuum. Loss of vacuum will allow the door to swing open sufficiently to permit the water to run out.

Reference: Subparagraph 822.2.46, Roll Swage

Comment: Clarify reference to Subpart 822.2.26 which set a limit of 700 grams U-235 or 40 grams U-235 per inch and the concurrent use of Keff.

Answer: During roll swaging, several loose plates are assembled into an element. Therefore, prior to swaging the mass limit is applicable to control the number of loose plates; while after swaging, the Keff of the element becomes the control.

Replace the last sentence with:
"After swaging, one element will be handled. The one element will have Keff (bare) $\leq$ 0.65 and Keff (reflected) $\leq$ 0.9".

Reference: Subparagraph 822.2.46 through 822.2.55

Comment: Relate use of Keff to Section 300.

Answer: Add to subparagraph 822.1.3:
"Two BAWTR fuel elements meet the criteria of Section 300 and requirements of Subpart 822.2 that Keff (bare) $\leq$ 0.65 and Keff (reflected) $\leq$ 0.9. Refer to Nuclear Safety Evaluation, BAWTR Fuel Elements, Subpart 822."

Reference: Subpart 823, Nuclear Safety Evaluation, Dresden Fuel Elements

Comment:
1. Extrapolation distance for bare elements is valid only for multiple array of elements.
2. The difference between 2.5 cm and 4 cm extrapolation distance is more than the quoted 10% relative to the single unit discussion.

Answer:
1. A review of the literature (NDEO-1050, Equation 9 page 6 and discussion page 66 and DP-532) does not suggest the inapplicability of the extrapolation distance as used in the context of this subpart. It does suggest an extrapolation distance greater than 2.5 for bare units may exist. This fact has been recognized (reference Paragraph II D) but the conclusions reached therein remain unchanged.
2. Delete last sentence of Paragraph II D of Nuclear Safety Evaluation Dresden Elements, Subsection 823 and Nuclear Safety Evaluation-Yankee Fuel Elements, Subpart 823.

Reference: Subparagraph 824.2.8

Comment: Grammatical

Answer: Change "will be" to "are".

Reference: Subparagraph 824.2.8, Machine Ingot

Comment: What assures safety of turnings before loading into one liter container?

Answer: Change Subpart 824.2.8 to read:
"Ingots are machined one at a time. Chips and turnings are transferred to one liter container after each machining pass. Each machining pass removes less than 350 grams U-235.

Reference: Subparagraph 825.1.2

Comment: Provide copy of drawing B 2098.

Answer: Replace drawing number "B 2098" with B 304236.

Reference: Subsection 826, Naval Products Rolling Area

Comment: Delete since this is included in Special Nuclear Material License SNM-368.

Answer: Delete Subparts 826.1 and 826.2.

Reference: Subparagraph 912.2, Storage in Permanent Storage Containers

Comment: What administrative control is applicable to safe cross sectional area?

Answer: Instructions carried on the criticality sign applicable to the equipment.

Also, above discussion on Section 800 is applicable.

Reference: Subpart 913.3, Wet and Dry Compounds and Solutions
Subpart 915.3, Bottle, Jar, Cans and Bay Carts

Comment: How is the actual material density known?

Answer: Uranium solutions processed within the scope of this license have uranium concentrations no greater than that of UO_2F_2.

Uranium compounds processed within the scope of this license have bulk densities not greater than that of UO_2 powder which has a bulk density not more than 4 grams U/cc. Refer to Figure 309-XXIV.

Reference: Table 921-I, Page 3 of 5

Comment: Check equipment locations. 1-L-9 A and B are in Bay XVI.

Answer: Change table accordingly.

Reference: Subpart 922.2

Comment: Why is the 2" deep tray safe?

Answer: Change last paragraph to read: "Other materials for calcining or further processing may be loaded into trays or into safe geometry containers; for example, high density oxide may be reduced in density by calcination. This is done by loading into trays that do not exceed 2" depth or 8" width for insertion into the calcining furnace. The cross sectional area of a calciner tray (2"x8") is less than that of a 5" diameter cylinder.

Reference: Subpart 922.9.3

Comment: Check interaction calculation. A 5" diameter stand pipe was not included as a replacement for a funnel. Also, the stand pipe is not shown on Sketch 922.9-I and II.

Answer: The stand pipe is 5" diameter x 18" long and is placed where the funnel was located outside the hood as shown on Sketch 922.9-I and II. The interaction calculations have been modified to include the effects of the funnel or stand pipe. The result and maximum total solid angle is less than 3.2 steradians and occurs at the centermost 4" diameter column for which the allowable solid angle, is greater than 3.2 steradians.

Reference: Subpart 922.14-V, Interaction Calculations

Comment: Page 3, Calculation #5, Ω = .84 steradians was not included in Table 922.14-II.

Answer: The effects of the storage bunker have been calculated. Change "2.36" to "2.62" in second paragraph on page 3 of 3 of subparagraph 922.14.3.6. Increase the totals by 0.26 steradians in the Solid Angle Summarization, Table 922.14-II.

Reference: Subparts 922.16, 922.17, 922.18 and 922.19

Comment: Justify nuclear safety after cutting is completed.

Answer: The "unit" referred to is a rejected or scrap fuel element. As each piece is cut off it is immediately removed to storage. Since the "units" themselves are subcritical, pieces removed from the "whole unit" are also subcritical.

Reference: Subpart 923.2, Tray Dissolver System

Comment: Where is assay tank 1-D-3?

Answer: This was a typographical error. Change the last sentence, second paragraph, subpart 923.2.1 to read, "When Tank 1-D-36 is filled, the solution is transferred to the assay tanks 1-D-34A through G or 3-D-12."

Reference: Sketch 923.2-II

Comment: Show the 1½" diameter overflow line if it, in fact, is there and include in the nuclear safety evaluation.

Answer: The overflow line connects to the Fume Scrubber 2-X-1 sump 5" from plenum. It discharges to a 5" diameter overflow bottle by the 1-L-3A hood. Change "return to the tray 1J5" in the fourth sentence of first paragraph of subpart 923.2.4 to "which discharges to the 5" diameter overflow bottle by the 1L3A Hood".

Add to second paragraph of subpart 923.2.4: "The intersection of the sump and overflow pipe has an effective diameter of 3.6" determined by the technique of page 20, TID-7016, Rev. 1 and is safe as per Table III, TID-7016, Rev. 1."

Reference: Subpart 923.7, Nuclear Safety Evaluation

Comment: Justify Keff = .65. As used in K-1019, Rev. 5, Keff = .65 applies to 350 grams U-235.

Answer: Refer to page 2 of 2, Nuclear Safety Evaluation - Large Tray Dissolver Subpart 923.7.

Change # 7, Allowable Interaction, to read:

Under normal conditions, the most reactive case occurs with a 16" Ø x 4" high cylinder (see Nuclear Safety Evaluation- Tray Dissolver, Subpart 923.2). The actual volume of a 16" Ø x 4" high cylinder is

$$V = 13.2 \text{ liters}$$

The charge of SNM is 1 kg U-235 so the actual density is

$$\rho A = \frac{1 \text{ kg U-235}}{13.2 \text{ liters}} = .0256 \text{ kg U-235/liter}$$

The effective multiplication factor will be calculated using the technique set forth in K-1380, Part I.

The corresponding moderation ratio is

H/U-235 = 350	Fig. I-4
then	
$\eta f = 1.785$	Fig. I-5
B^2 (fast) = .043 + .011 = .054 cm^2	Fig. I-6
$U_f = .37$	Fig. I-7
B^2 (thermal) = .083 + .0135 = .0965 cm^2	Fig. I-8
$U_t = .897$	Fig. I-9

$$Keff = \eta f U_f U_t = .592$$

The allowable interaction is

$$\Omega A = 9\text{-}10K = 3.08 \text{ steradians.}$$

Reference: Subpart 924.2.2, Equipment and Nuclear Safety, Pickle Liquor System

Comment: Second paragraph - some words were omitted during typing.

Answer: Change last sentence, second paragraph to read:

"The 55 gallon pickle liquor batch plus the required neutralizing volume of chemicals will exceed half the volume of the tank."

Reference: Subpart 924.6.1, General

Comment: What happened to pump 1-P-6? It used to be a multipurpose pump with a "pigtail" on discharge to prevent erroneously pumping to wrong tank. Is it still used that way?

Answer: Pump 1-P-6 is now used between the 1-D-12 raw liquor tank and 1-D-41 extraction feed tank. Pump 3-P-4 is used between the 1-D-6A strip acid tank and 1-D-28 aluminum nitrate makeup tank. As stated the 1-D-6A was originally a strip acid tank but is currently used as the aluminum nitrate storage tank. Change "Pump 1" in second paragraph to "Pump 3-P-4".

Reference: Subpart 926.2

Comment: Are there three pages or only two? Change page numbers or provide page three.

Answer: Page 3 of 3 as issued 10/31/68 is attached.

Reference: Subparts 926.4, ADU Precipitators and 926.12, ADU Precipitation Tanks

Comment: There used to be in-line filters. Have they been removed? If so, why cannot solids carry over to 1-D-24 A and B?

Answer: There is no line filter from the 1-D-19's to the 1-D-24's. There is a line between the 1-D-20's and the 1-D-24's, and the polishing filter 1-F-15 is in that line.

Add to second paragraph, Subpart 926.4,

"The filtrate is directed through a 4" diameter x 13 1/8" polishing filter 1-F-15 to the filtrate tanks 1-D-24 A and B or is collected in 4 liter flasks and transferred to eleven liter bottles."

3. Operating Controls (continued)

3.3 During startup, the shell side condensate will be drained into a 4" diameter sample container and checked for acidity (to indicate any possible leak into the shell side).

3.4 Immediately after turning steam off in shutdown, the drain valve from the shell side will be opened.

Reference: Subpart 926.13.2, Nuclear Safety

Comment: Use of Figure 22, TID-7016 is not conservative at allowable units less than 18. This can be demonstrated by graphing the experimental data for arrays of either metal units or solution units. Suggest using another interaction technique.

Answer: A replot of the data confirms your comment. The interaction effects have been calculated using the solid angle method.

Change Subpart 926.13.2, Nuclear Safety, to read:

"Nuclear safety is provided by having the SNM in a bottle or funnel with a volume not exceeding one gallon. This is a safe volume as shown on Table 309-I. Only one funnel may be in transit at any one time. Therefore there will be a maximum of one funnel in each of the drying ovens, one funnel in transit and one funnel and one bottle in the unloading hood. Individual funnels will be on 16" centers and the funnel and bottle in the 1-L-16B unloading hood are on 10" centers. The solid angle subtended by the centermost funnel in the 1-H-8 drying oven is approximately 1 steradian."

Add new "Nuclear Safety Evaluation ADU Drying and Unloading", Subpart 926.13.

I. Description

A. The funnel in the 1-H-8 oven is the centermost unit.
B. Each station will have one 10" diameter x 4" high filter funnel or one six inch diameter by 10" high one gallon bottle in it.
C. Material will be highly enriched ADU.

II. Assumptions

A. Individual filter funnels are safe as per Table XV, K-1019, Rev. 5.
B. One gallon bottles are safe as per Table 309-I.
C. Keff will be determined using Figure 4, K-1317.

III. Keff Value

The Keff of a filter funnel in the 1-H-8 oven will be approximately 0.6.

diameter = 10", height = 4"

$$\lambda = \frac{\text{height}}{\text{diameter}} = 0.4$$

From Figure 4, K-1317

Keff = 0.6

IV. Interaction Calculations

A. Contribution from funnel in 1-H-1

diameter = 10", lenght = 4", L/2 = 2", height = 21"

$$\tan\theta = \frac{L/2}{h} = .095$$
$$\sin\theta = .094$$

$$\Omega_1 = \frac{2\,d}{h}\sin\theta = .087 \text{ steradians}$$

B. Contribution from funnel in 1-H-2

Same as for 1-H-1

Ω_2 = .087 steradians

C. Contribution from funnel in 1-L-16B

d = 10", L/2 = 2", h = 54"

$$\tan\theta = \frac{L/2}{h} = .037$$
$$\sin\theta = .036$$
$$\Omega_3 = \frac{2\,d}{h}\sin\theta = .013 \text{ steradians}$$

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SUPERSEDES:	New

IV. Interaction Calculations (continued)

D. Contribution from one gallon bottle in bottom of 1-L-16B

d = 6", L = 10", L/2 = 5", h = 66"

$$\tan\theta = \frac{L/2}{h} = 0.76$$
$$\sin\theta = .075$$
$$\Omega_4 = \frac{2\,d}{h}\sin\theta = .013 \text{ steradians}$$

E. Contribution from funnel in 1-L-16A

d = 10", L/2 = 2", h = 32"

$$\tan\theta = \frac{L/2}{h} = .063$$
$$\sin\theta = .062$$
$$\Omega_5 = \frac{2\,d}{h}\sin\theta = .039 \text{ steradians}$$

F. Contribution from funnel in 1-L-16C

d = 10", L/2 = 2", h = 11"

$$\tan\theta = \frac{L/2}{h} = .182$$
$$\sin\theta = .179$$
$$\Omega_6 = \frac{2\,d}{h}\sin\theta = .326$$

G. Contribution from 1-D-19's

d = 5", L= 8' = 96", L/2 = 48', h = 8.5' = 102"

$$\tan\theta = \frac{L/2}{h} = .47$$
$$\sin\theta = .425$$
$$\Omega(1 \text{ unit}) = \frac{2\,d}{h}\sin\theta = .0416$$

Since 3 precipitators

$$\Omega_7 = 3 \times \Omega(1 \text{ unit}) = .125 \text{ steradians}$$

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IV. Interaction Calculations (continued)

H. Contribution from Overhead Tanks

$d = 5''$, $L = 60' = 720''$, $L/2 = 360''$, $h \approx 15' = 180''$

$$\tan\theta = \frac{L/2}{h} = 2$$
$$\sin\theta = .895$$
$$\Omega\,(1\ \text{tank}) = \frac{2\,d}{h}\sin\theta = .05$$

Since 6 tanks

$$\Omega_8 = 6 \times \Omega(1\ \text{tank}) = .3\ \text{steradians}$$

I. Contribution from other surrounding equipment.

All other equipment is greater than 15 feet away and are either one-gallon bottles, 11 liter bottles or similar small shapes or volumes. Therefore, their interaction effects are considered negligible and are neglected.

J. Total Interaction

$$\Omega_t = \Sigma\,\Omega_1 + \cdots + \Omega_8 \approx 1.0\ \text{steradians}$$

K. Allowable Interaction

$$\Omega_A = 9-10K = 9-6.0 = 3\ \text{steradians}$$

Reference: Subpart 926.15

Comment: 1-H-4B is in the same spot as the former 1-H-6, but the interaction calculation has not been changed accordingly.

Answer: The referenced calculations have been corrected. Change "0.82 steradians" to "1.06 steradians" in Subpart 926.15.

Replace "Interaction Calculations-Muffle Furnace 1-H-4" dated 10/31/68 with the following "Interaction Calculations - Muffle Furnace 1-H-4".

I. Description

A. Both the 1-H-4A and the 1-H-4B will be evaluated as the centermost unit.
B. Each furnace will hold one muffle box.
C. Muffle boxes are 9"x9"x20" long or 9" diameter x 20" long.
D. Each muffle box will hold two trays, one above the other.
E. Trays will be no larger than 8¼"x15 5/8"x1¼".

II. Assumptions

A. The end cross sectional area of the trays are equivalent to or less than that of a 6" diameter circle.
B. A 6" diameter cylinder 17.6" long is safe as per Table XV, K-1019, Rev. 5.
C. Keff will be determined using Figure 4, K-1317.

III. Keff Value

The Keff of the two trays will be approximately 0.68.

diameter = 6", h = 17.6", $\lambda \frac{\text{height}}{\text{diameter}} = \frac{17.6"}{6"} = 2.94$
From Figure 4, K-1317
Keff = 0.68

IV. Interaction Calculations

A. 1-H-4A Centermost Unit

1. Contribution from 1-H-4B

d = 6", L≈18", L/2 = 9", h = 16" + 3" = 19"

$$\tan \theta = \frac{L/2}{h} = \frac{9"}{18"} = .474$$
$$\sin \theta = .431$$

$$\Omega_{A1} = \frac{2\ d}{h} \sin \theta = \frac{12"}{19"} (.475) = .3 \text{ steradians}$$

2. Contribution from 1-J-1

d = 6", L 116", L/2 = 58", h = 58"

$$\tan \theta = \frac{L/2}{h} = \frac{58"}{58"} = 1.0$$
$$\sin \theta = .707$$

$$\Omega_{A2} = \frac{2\ d}{n} \sin \theta = \frac{12"}{58"} (.707) = .$$

.146 steradians

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Interaction Calculations (continued)

3. Contribution from 1-D-34 A, B and C

d = 5", L = 132", L/2 = 66", h = 71.5"

$$\tan \theta = \frac{L/2}{h} = .922$$
$$\sin \theta = .678$$
$$\Omega_{A3} = \frac{2\ d}{h} \sin \theta = .095$$

Since 3 tanks,

$$\Omega_{A3}\ (\text{total}) = 3 \times \Omega_{A3} = 3 \times .095 = .284 \text{ steradians}$$

4. Contribution from other surrounding equipment.

All other equipment is greater than 10 feet away and either one-gallon bottles, 11 liter bottles or similar small shapes or volumes. Therefore, their interaction effects are considered negligible and neglected.

5. Total Interaction

$$\Omega_A\ (\text{total}) = \sum \Omega_{A1} + \Omega_{A2} + \Omega_{A3} = 1.03 \text{ steradians}$$

B. 1-H-4B Centermost Unit

1. Contribution from 1-H-4A

Same as IV.A.1

$$\Omega_{B1} = \Omega_{A1} = .3 \text{ steradians}$$

2. Contribution from 1-J-1

d = 6", L = 108", L/2 = 54", h = 100"

$$\tan \theta = \frac{L/2}{h} = .54$$
$$\sin \theta = .495$$
$$\Omega_{B2} = \frac{2\ d}{h} \sin \theta = .0594 \text{ steradians}$$

3. Contribution from 1-D-34 A, B and C

d = 5", L = 132", L/2 = 66", h = 37.5"

$$\tan \theta = \frac{L/2}{h} = 1.76$$
$$\sin \theta = .8695$$
$$\Omega_{B3} = \frac{2\ d}{h} \sin \theta = .696 \text{ steradians}$$

4. Contribution from other surrounding equipment.

   Same as IV.A.4

5. Total Interaction

   $\Omega_B(\text{total}) = \Sigma\ \Omega_{B1} + \Omega_{B2} + \Omega_{B3} = 1.055$ steradians

C. Allowable Interaction

Ω allowable = 9-10K = 9-6.8 = 2.2 steradians

Reference: Subpart 932.3, Equipment and Nuclear Safety

Comment: What is the administrative control of 350 grams U-235?

Answer: Lab chemist maintains an inventory log.

Reference: Sketch 935-I.

Comment: What is identification number of the new scale?

Answer: The new scale is the charge makeup scale 1-W-1. Add Subpart 935.1 as issued 10/31/68 to your manual. This was apparently inadvertantly omitted.

Reference: Subpart 935.1

Comment: Where is Scale 1-W-1 for which interaction calculations were made?

Answer: See above answer for Sketch 935-I.

LICENSE: SNM-7, ; DOCKET: 70-820
SECTION: 900 - RECOVERY OPERATION
SUBSECTION: 930 - Support Activities
SUBPART: 935 - Uranium Bearing Equipment
935.1 - Charge Make-up Scale 1-W-1

Approved

ISSUED Oct. 31, 1968

SUPERSEDES New

935.1 Charge Make-up Scale 1-W-1

1. General

When scale 1-W-1 is not in Hood 1-L-1 being used for the weighing of as received containers, it may be placed in one of two alternate locations and used for the weighing of process batches or charges.

One location is on the wall in front of the Foreman's Office, and the other is on a desk placed next to the 1 gallon bottle storage position on the north wall of the 1-L-1 Hood isolation wall.

The materials or containers to be weighed on this scale will be similar to those described for the 1-L-1 Hood (Subpart 922.2).

Details of the storage arrangement next to the 1-L-17 Hood are shown on Sketchs 935.1-I.

2. Nuclear Safety

Only one nuclearly safe container at a time will be weighed on this scale. The nuclear safety of these containers is shown in Subpart 913.

When used next to the 1-L-17 Hood, the solid angle subtended by the unit on the scale is approximately 1.2 steradians.

Reference: New Subsection 827

The new Subsection 827 will describe the processing of PuO_2-UO_2 rods and elements as approved by Amendment 51 to Special Nuclear Material License SNM-777 dated November 25, 1964.

Reference: Subpart 104.2

The special nuclear material possession limit includes 10 kg Pu contained in zirconium clad PuO_2-UO_2 pellets. This is as approved by Amendment 51 to Special Nuclear Material License SNM-777 dated November 25, 1964.

Reference: Subpart 309

Replace Tables 309-I and 309-II with attached revised tables and associated Nuclear Safety Evaluations. Add Figures 309-XXIV through 309-XXVIII and their associated Nuclear Safety Evaluations.

These are included to reflect AEC comment on density/moderator relationship.

Safe Limits for Individual Unit as Metal, Compound and Solution Systems

Safe Control Parameter	Safe Uranium Limits: Metal Systems	Compound Systems	Solution Systems
Mass	10 kgs. U-235	350 gms. U-235	350 gms. U-235
Cylinder Diameter	2.7 inches	5.0 inches	5.0 inches
Cross Sectional Area	5.725 sq. inches	19.64 sq. inches	19.64 sq. inches
Volume	1.0 liter	4.8 liters	4.8 liters
Slab Thickness	0.5 inches	1.5 inches	1.5 inches

Applicable Condition

1. Any U-235 enrichment
2. Full water reflection
3. For metal:
   a) Solid metal pieces with no re-entrant holes.
   b) Smallest individual piece is 4 kg U.
   c) Densities up to and including full density.
4. For compounds:
   a) Total U density vs. H/U ratio is not greater than that of UO_2 as per Figure 309-XXIV.
   b) Bulk density up to and including 4 kg U/liter.
5. For solutions:
   a) Total U density vs. H/U ratio is not greater than that of UO_2F_2 as per Figure 309-XXIV.
   b) Densities not exceeding 3.2 kg/liter.
6. Data from:
   a) Metal - Figures 1-4, TID-7016, Rev. 1.
   b) Compounds - Figures 309-XXV thru XXVIII.
   Nuclear Safety Evaluation, 4.8 liter sphere.
   c) Solutions - Figures 1-4, TID-7016, Rev. 1

I. DESCRIPTION

A. The maximum sized container for U compound handling and storage will be 4.8 liters

B. The maximum density (bulk) of material to be placed in these container will not exceed 4. Kg U/liter.

II. ASSUMPTIONS

A. The maximum "crystal" density of material to be placed in these containers will not exceed that of UO_2 (9.66 Kg U/liter).

B. The UO_2 – Water data of LA-3612 is applicable.

C. The calculational method set forth in Section 2.2, NDEO-1050, will be used to determine reflector savings(δ) and keff values.

D. The density vs. H/U ratio relationship will be per Fig 309-XXIV.

III. CALCULATIONS

See attached tables

IV CONCLUSIONS

This volume is sub critical when moderated and reflected for materials with densities not exceeding 4. Kg U/liter. The keff values at a density of 4 Kg U/liter are:

keff(reflected) = .960

keff (bare) = .780

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LICENSE: SNM-777, DOCKET: 70-820
SECTION: 300, SUB PART: 309-I
NUCLEAR SAFETY EVALUATION – KEFF'S OF 4.8 LITER UO_2 SPHERE
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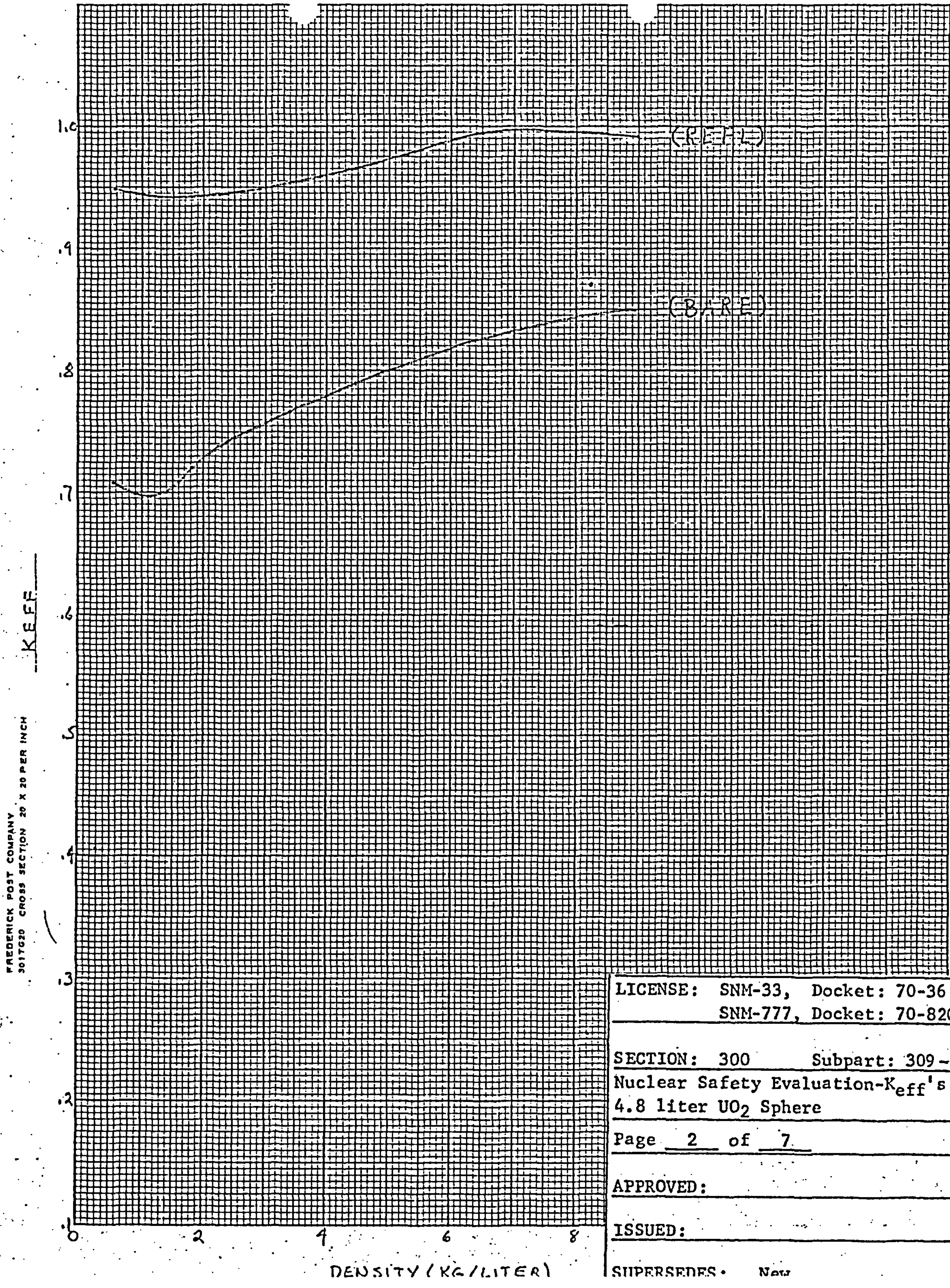

LICENSE:	SNM-33, Docket: 70-36 SNM-777, Docket: 70-820
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Nuclear Safety Evaluation-K_{eff}'s of 4.8 liter UO_2 Sphere	
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CRITICAL $(U93.5)O_2$ - WATER VOLUMES

H/U-235	ρ (Kg/l)	$r_{c,R}$ [1] (cm)	$V_{c,R}$ [2] (liters)	δ [3] (cm)	$B_{c,R}(s)$ [4] (cm^{-2})	$r_{c,B}$ [1] (cm)	$V_{c,B}$ [2] (liters)	δ [5] (cm)	$B_{c,B}(s)$ [6] (cm^{-2}
0	8.930	10.63	5.03	7.30	.0307	13.43	10.15	5.46	.0277
.98	6.700	10.49	4.84	7.26	.0313	13.90	11.25	5.32	.0267
2.94	4.470	11.14	5.79	7.18	.0294	14.87	13.78	5.03	.0249
8.96	2.230	11.75	6.80	6.94	.0288	15.85	16.68	4.13	.0247
20.60	1.120	11.53	6.42	6.50	.0304	15.60	15.91	2.50	.0301
43.90	0.558	11.39	6.19	6.50	.0308	15.27	14.92	2.50	.0313

NOTES: (1) Data from Table V K, LA-3612

(2) $V = 4.19\, r^3$

(3) $\delta = 7.3 - .040\,(H/U\text{-}235)$, cm; for thick water reflector at $H/U\text{-}235 \leq 20$; $\delta = 6.5$ cm at $H/U\text{-}235 > 20$

(4) $B_{c,R}(s) = \left(\frac{\pi}{r_{c,R}(s)+\delta}\right)^2$

(5) $\delta = 5.46 - .148\,(H/U\text{-}235)$, cm; for bare systems at $H/U\text{-}235 \leq 20$; $\delta = 2.5$ cm at $H/U\text{-}235 > 20$

(6) $B_{c,B}(s) = \left(\frac{\pi}{r_{c,B}(s)+\delta}\right)^2$

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LICENSE: SNM-777, DOCKET: 70-8:
SECTION: 300, SUB PART: 304-I
NUCLEAR SAFETY EVALUATION -
KEFF'S OF 4.8 LITER UO_2 SPHE
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CRITICAL BUCKLINGS

REFLECTED

At H/U-235 = 0, ρ = 8.930 Kg/l

$$B^2 = \frac{9.87}{(10.63+7.3)^2} = \frac{9.87}{(17.93)^2} = \frac{9.87}{321.48} = .0307$$

At H/U-235 = .98, ρ = 6.700 Kg/l

$$B^2 = \frac{9.87}{(10.49+7.26)^2} = \frac{9.87}{(17.75)^2} = \frac{9.87}{315.06} = .0313$$

At H/U-235 = 2.94, ρ = 4.470 Kg/l

$$B^2 = \frac{9.87}{(11.14+7.18)^2} = \frac{9.87}{(18.32)^2} = \frac{9.87}{335.62} = .0294$$

At H/U-235 = 8.96, ρ = 2.230 Kg/l

$$B^2 = \frac{9.87}{(11.75+6.74)^2} = \frac{9.87}{(18.49)^2} = \frac{9.87}{342} = .0288$$

At H/U-235 = 20.60, ρ = 1.120 Kg/l

$$B^2 = \frac{9.87}{(11.53+6.5)^2} = \frac{9.87}{(18.03)^2} = \frac{9.87}{325.08} = .0304$$

At H/U-235 = 43.90, ρ = 0.558 Kg/l

$$B^2 = \frac{9.87}{(11.39+6.5)^2} = \frac{9.87}{(17.89)^2} = \frac{9.87}{320.05} = .0308$$

BARE

At H/U-235 = 0, ρ = 8.930 Kg/l

$$B^2 = \frac{9.87}{(13.43+5.46)^2} = \frac{9.87}{(18.89)^2} = \frac{9.87}{356.83} = .0277$$

At H/U-235 = .98, ρ = 6.700 Kg/l

$$B^2 = \frac{9.87}{(13.90+5.32)^2} = \frac{9.87}{(19.22)^2} = \frac{9.87}{369.44} = .0267$$

At H/U-235 = 2.94, ρ = 4.470 Kg/l

$$B^2 = \frac{9.87}{(14.87+5.03)^2} = \frac{9.87}{(19.90)^2} = \frac{9.87}{396.01} = .0249$$

At H/U-235 = 8.96, ρ = 2.230 Kg/l

$$B^2 = \frac{9.87}{(15.87+4.13)^2} = \frac{9.87}{(19.98)^2} = \frac{9.87}{399.20} = .0247$$

At H/U-235 = 20.60, ρ = 1.120 Kg/l

$$B^2 = \frac{9.87}{(15.6+2.5)^2} = \frac{9.87}{(18.10)^2} = \frac{9.87}{327.61} = .0301$$

At H/U-235 = 43.90, ρ = 0.558 Kg/l

$$B^2 = \frac{9.87}{(15.27+2.5)^2} = \frac{9.87}{(17.77)^2} = \frac{9.87}{315.77} = .0313$$

KEFF VALUES FOR 4.8 LITER SPHERICAL VOLUME $U(93.5)O_2$-WATER MIXTURES

H/U-235	ρ (Kg/ℓ)	$r_{4.8\ell s}$ (cm)	δ_R (cm)	$B^2_{S,R}$ (1) (cm^{-2})	τ (2) (cm^2)	Keff (3)	δ_B (cm)	$B^2_{S,B}$ (1) (cm^{-2})	τ (2) (cm^2)	keff (3)
0	8.930	10.45	7.30	.0313	28.0	.991	5.46	.0390	28.0	.849
.98	6.700		7.26	.0315		.997	5.32	.0397		.828
2.94	4.470		7.18	.0318		.965	5.03	.0412		.789
8.96	2.230		6.94	.0326		.944	4.13	.0462		.738
20.60	1.120		6.50	.0344		.943	2.50	.0589		.696
43.90	0.558		6.50	.0344		.949	2.50	.0589		.708

NOTES: (1) $B^2 = \frac{\pi^2}{(r_s+\delta)^2}$

(2) τ = 28 cm from Section 2.2, NDEO-1050.

(3) $k_{eff} = \frac{1+\tau B_o^2}{1+\tau B_s^2}$

LICENSE: SNM-33, DOCKET: 70-3
LICENSE: SNM-777, DOCKET: 70-8
SECTION: 300, SUBPART: 309
NUCLEAR SAFETY EVALUATION
KEFF'S OF 4.8 LITER UO_2 SPHER
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SUPERSEDS: NEW

4.8 LITER SPHERE BUCKLING

REFLECTED

At H/U-235 = 0, ρ = 8.930 Kg/l

$$B^2 = \frac{9.87}{(10.45+7.3)^2} = \frac{9.87}{(17.75)^2} = \frac{9.87}{315.06} = .0313$$

At H/U-235 = .98, ρ = 6.700 Kg/l

$$B^2 = \frac{9.87}{(10.45+7.26)^2} = \frac{9.87}{(17.71)^2} = \frac{9.87}{313.64} = .0315$$

At H/U-235 = 2.94, ρ = 4.470 Kg/l

$$B^2 = \frac{9.87}{(10.45+7.18)^2} = \frac{9.87}{(17.63)^2} = \frac{9.87}{310.82} = .0318$$

At H/U-235 = 8.96, ρ = 2.230 Kg/l

$$B^2 = \frac{9.87}{(10.45+6.94)^2} = \frac{9.87}{(17.39)^2} = \frac{9.87}{302.41} = .0326$$

At H/U-235 = 20.60, ρ = 1.120 Kg/l

$$B^2 = \frac{9.87}{(10.45+6.5)^2} = \frac{9.87}{(16.95)^2} = \frac{9.87}{287.30} = .0344$$

At H/U-235 = 43.90, ρ = 0.558 Kg/l

B^2 = .0344 (same as for ρ = 1.120)

BARE

At H/U-235 = 0, ρ = 8.930 Kg/l

$$B^2 = \frac{9.87}{(10.45+5.46)^2} = \frac{9.87}{(15.91)^2} = \frac{9.87}{253.13} = .0390$$

At H/U-235 = .98, ρ = 6.700 Kg/l

$$B^2 = \frac{9.87}{(10.45+5.32)^2} = \frac{9.87}{(15.77)^2} = \frac{9.87}{248.69} = .0397$$

At H/U-235 = 2.94, ρ = 4.470 Kg/l

$$B^2 = \frac{9.87}{(10.45+5.03)^2} = \frac{9.87}{(15.48)^2} = \frac{9.87}{239.63} = .0412$$

At H/U-235 = 8.96, ρ = 2.230 Kg/l

$$B^2 = \frac{9.87}{(10.45+4.13)^2} = \frac{9.87}{(14.58)^2} = \frac{9.87}{212.58} = .0462$$

At H/U-235 = 20.60, ρ = 1.120 Kg/l

$$B^2 = \frac{9.87}{(10.45+2.5)^2} = \frac{9.87}{(12.95)^2} = \frac{9.87}{167.70} = .0589$$

At H/U-235 = 43.90, ρ = 0.558 Kg/l

B^2 = .0589 (same as for ρ = 1.120)

4.8 LITER SPHERE KEFF'S

REFLECTED

At H/U-235 = 0, ρ = 8.93 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0307)}{1+(28\times.0313)} = \frac{1.860}{1.876} = .991$$

At H/U-235 = .98, ρ = 6.700 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0313)}{1+(28\times.0315)} = \frac{1.876}{1.882} = .997$$

At H/U-235 = 2.94, ρ = 4.470 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0294)}{1+(28\times.0318)} = \frac{1.823}{1.890} = .965$$

At H/U-235 = 8.96, ρ = 2.230 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0288)}{1+(28\times.0326)} = \frac{1.806}{1.913} = .944$$

At H/U-235 = 20.60, ρ = 1.120 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0304)}{1+(28\times.0344)} = \frac{1.851}{1.963} = .943$$

At H/U-235 = 43.93 ρ = 0.558 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0308)}{1+(28\times.0344)} = \frac{1.862}{1.963} = .949$$

BARE

At H/U-235 = 0, ρ = 8.93 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0277)}{1+(28\times.0390)} = \frac{1.776}{2.092} = .849$$

At H/U-235 = .98, ρ = 6.700 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0267)}{1+(28\times.0397)} = \frac{1.748}{2.112} = .828$$

At H/U-235 = 2.94, ρ = 4.470 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0249)}{1+(28\times.0412)} = \frac{1.697}{2.154} = .789$$

At H/U-235 = 8.96, ρ = 2.230 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0247)}{1+(28\times.0462)} = \frac{1.692}{2.294} = .738$$

At H/U-235 = 20.60, ρ = 1.120 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0301)}{1+(28\times.0589)} = \frac{1.843}{2.649} = .696$$

At H/U-235 = 43.90, ρ = 0.558 Kg/ℓ

$$k_{eff} = \frac{1+(28\times.0313)}{1+(28\times.0589)} = \frac{1.876}{2.649} = .708$$

Maximum Sized Individual Units
of Metal and Compounds which are
Subcritical when Immersed in Water

Degree of Moderation (H/X) More Than	Degree of Moderation (H/X) Not More Than	Mass Limits (Kgs. U-235)	Bare Reflected	Keff Bare
-	2	10.0	.896	.708
2	3	9.0	.899	.715
3	5	7.3	.897	.708
5	10	5.2	.904	.697
10	20	3.6	.913	.675
		Volume Limits (Liters)		
20	-	3.6	.947	.721

Applicable to:
1. All enrichments.
2. Data from TID-7016, Rev. 1 Table IV (modified).
3. All U metal and compounds with density vs. H/U as per Figure 309-XXIV.

Nuclear Safety Evaluation for Table 309-II follows:

LICENSE:	SNM-33, Docket: 70-36 SNM-777, Docket: 70-820
SECTION: 300, Subpart 309	
Table 309-II, Maximum Size of Individual Units	
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SUPERSEDES: October 31, 1968	

I. DESCRIPTION

A. Units will be as described in Table 309-II (taken from Table IV modified, TID-7016, Rev. 1)

II. ASSUMPTIONS

A. Critical values will be determined from data in TID-7028
B. Reflector savings and keff calculations will be obtained using the technique in Section 2.2, NDGO-1050.
C. A τ value of 28 cm will be used.
D. Formulas used are

1. $\delta_R = 7.3 - .04\,(H/X)$

2. $\delta_B = 5.46 - .148\,(H/X)$

3. $B^2 = \left(\frac{\pi}{r+\delta}\right)^2$

4. $k_{eff} = \frac{1+\tau B_c^2}{1+\tau B_A^2}$ where B_c^2 = critical buckling, B_A^2 = actual buckling

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SECTION: 300, SUBPART: 309-II
NUCLEAR SAFETY EVALUATION - TABLE 309-II BUCKLINGS & KEFF'S
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For U Metal - Water Mixture @ H/X ≐ 2

$V_{c,R} = 2.4\ l$, $V_{c,B} = 5.4\ l$, $\rho_c = 7.48$ Kg/l from Fig. 9, TID-7028

$$r_{c,R} = \sqrt[3]{\frac{3V_{c,R}}{4\pi}} = \sqrt[3]{\frac{2400}{4.19}} = \sqrt[3]{573} = 8.32\ cm$$

$$r_{c,B} = \sqrt[3]{\frac{3V_{c,B}}{4\pi}} = \sqrt[3]{\frac{5400}{4.19}} = \sqrt[3]{1290} = 10.88\ cm$$

$$\delta_R = 7.3 - .04\,(H/X) = 7.3 - .08 = 7.26\ cm$$

$$\delta_B = 5.46 - .148\,(H/X) = 5.46 - .396 = 5.064\ cm$$

$$B^2_{c,R} = \frac{\pi^2}{(r_{c,R}+\delta_R)^2} = \frac{9.87}{(8.32+7.26)^2} = \frac{9.87}{(15.58)^2} = \frac{9.87}{242.74} = .0407\ cm^{-2}$$

$$B^2_{c,B} = \frac{\pi^2}{(r_{c,B}+\delta_B)^2} = \frac{9.87}{(10.88+5.064)^2} = \frac{9.87}{(15.944)^2} = \frac{9.87}{254.21} = .0388\ cm^{-2}$$

With a 10 Kg U^{235} limit

$$V_A = \frac{10\ Kg}{7.48\ Kg/l} = 1.34\ l$$

$$r_a = \sqrt[3]{\frac{3V_A}{4\pi}} = \sqrt[3]{\frac{1340}{4.19}} = \sqrt[3]{320} = 6.85\ cm$$

$$B^2_{A,R} = \frac{\pi^2}{(r_A+\delta_R)^2} = \frac{9.87}{(6.85+7.26)^2} = \frac{9.87}{(14.11)^2} = \frac{9.87}{199.09} = .0496\ cm^{-2}$$

$$B^2_{A,B} = \frac{\pi^2}{(r_A+\delta_B)^2} = \frac{9.87}{(6.85+5.064)^2} = \frac{9.87}{(11.914)^2} = \frac{9.87}{141.94} = .0695\ cm^{-2}$$

The keff's are calculated using

$$k_{eff} = \frac{1+\gamma B^2}{1+\gamma B^2}$$ where $\gamma = 28\ cm^2$ from Pg. 24, Sect. 22, NDEO-1

$$k_{eff,R} = \frac{1+(28\times.0407)}{1+(28\times.0496)} = \frac{2.1396}{2.3888} = .896$$

$$k_{eff,B} = \frac{1+(28\times.0388)}{1+(28\times.0695)} = \frac{2.0864}{2.946} = .708$$

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SECTION: 300, SUB PART: 309-II
NUCLEAR SAFETY EVALUATION — TABLE 309-II BUCKLINGS & KEFF'S
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For U Metal-Water Mixture @ $2 \le H/X \le 3$

$V_{c,R} = 2.7\ l$, $V_{c,B} = 6.0\ l$, $\rho_c = 5.8\ Kg/l$ from Fig. 9, TID-7028

$$r_{c,R} = \sqrt[3]{\frac{3V_{c,R}}{4\pi}} = \sqrt[3]{\frac{2700}{4.19}} = \sqrt[3]{645} = 8.65\ cm.$$

$$r_{c,B} = \sqrt[3]{\frac{3V_{c,B}}{4\pi}} = \sqrt[3]{\frac{6000}{4.19}} = \sqrt[3]{1430} = 11.28\ cm.$$

$$\delta_R = 7.3 - .04(H/X) = 7.3 - .12 = 7.18\ cm$$

$$\delta_B = 5.46 - .148(H/X) = 5.46 - .444 = 5.016\ cm$$

$$B^2_{c,R} = \frac{\pi^2}{(r_{c,R}+\delta_R)^2} = \frac{9.87}{(8.65+7.18)^2} = \frac{9.87}{(15.83)^2} = \frac{9.87}{250.59} = .0394\ cm^{-2}$$

$$B^2_{c,B} = \frac{\pi^2}{(r_{c,B}+\delta_B)^2} = \frac{9.87}{(11.28+5.016)^2} = \frac{9.87}{(16.296)^2} = \frac{9.87}{265.56} = .0372\ cm^{-2}$$

With a 9 Kg U^{235} limit

$$V_A = \frac{9\ Kg}{5.8\ Kg/l} = 1.55\ l$$

$$r_A = \sqrt[3]{\frac{3V_A}{4\pi}} = \sqrt[3]{\frac{1550}{4.19}} = \sqrt[3]{370} = 7.19\ cm$$

$$B^2_{A,R} = \frac{\pi^2}{(r_A+\delta_R)^2} = \frac{9.87}{(7.19+7.18)^2} = \frac{9.87}{(14.37)^2} = \frac{9.87}{206.50} = .0478\ cm^{-2}$$

$$B^2_{A,B} = \frac{\pi^2}{(r_A+\delta_B)^2} = \frac{9.87}{(7.19+5.016)^2} = \frac{9.87}{(12.206)^2} = \frac{9.87}{148.99} = .0662\ cm^{-2}$$

The keff's are calculated using

$$k_{eff} = \frac{1+\tau B_c^2}{1+\tau B^2}$$ where $\tau = 28\ cm^2$ from Pg. 24, Sect. 2.2, NDCO-1050

$$k_{eff,R} = \frac{1+(28\times.0394)}{1+(28\times.0478)} = \frac{2.1032}{2.3384} = .899$$

$$k_{eff,B} = \frac{1+(28\times.0372)}{1+(28\times.0662)} = \frac{2.0416}{2.8536} = .715$$

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NUCLEAR SAFETY EVALUATION - TABLE 309-II BUCKLINGS & KEFF'S
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For U Metal - Water Mixture @ $3 \le H/X \le 5$

$V_{c,R} = 3.2\,\ell$, $V_{c,B} = 7\,\ell$, $\rho_c = 4\ Kg/\ell$ from Fig. 9, TID-7028

$$r_{c,R} = \sqrt[3]{\frac{3200}{4.19}} = \sqrt[3]{765} = 9.16\ cm$$

$$r_{c,B} = \sqrt[3]{\frac{7000}{4.19}} = \sqrt[3]{1675} = 11.9\ cm$$

$$\delta_R = 7.3 - .04(H/X) = 7.3 - .2 = 7.1\ cm$$

$$\delta_B = 5.46 - .148(H/X) = 5.46 - .74 = 4.72\,cm$$

$$B^2_{c,R} = \frac{9.87}{(9.16+7.1)^2} = \frac{9.87}{(16.26)^2} = \frac{9.87}{264.39} = .0373\ cm^{-2}$$

$$B^2_{c,B} = \frac{9.87}{(11.9+4.72)^2} = \frac{9.87}{(16.62)^2} = \frac{9.87}{276.22} = .0357\ cm^{-2}$$

With a 7.3 Kg U^{235} limit

$$V_A = \frac{7.3\ Kg}{4\ Kg/\ell} = 1.825\,\ell$$

$$r_a = \sqrt[3]{\frac{1825}{4.19}} = \sqrt[3]{436} = 7.59\,cm$$

$$B^2_{A,R} = \frac{9.87}{(7.59+7.1)^2} = \frac{9.87}{(14.69)^2} = \frac{9.87}{215.80} = .0457\ cm^{-2}$$

$$B^2_{A,B} = \frac{9.87}{(7.59+4.72)} = \frac{9.87}{(12.31)^2} = \frac{9.87}{151.54} = .0651\ cm^{-2}$$

The Keff's are

$$k_{eff,R} = \frac{1+(28\times.0373)}{1+(28\times.0457)} = \frac{2.0444}{2.2796} = .897$$

$$K_{eff,B} = \frac{1+(28\times.0357)}{1+(28\times.0651)} = \frac{1.9996}{2.8228} = .708$$

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NUCLEAR SAFETY EVALUATION - TABLE 309-II BUCKLINGS & KEFF'S
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For U-Metal-Water Mixture @ $5 \le H/X \le 10$

$V_{c,R} = 3.9\ l$, $V_{c,B} = 8.6\ l$, $\rho_c = 2.25\ Kg/l$ From Fig. 9, TID-7028

$$r_{c,R} = \sqrt[3]{\frac{3V_{c,R}}{4\pi}} = \sqrt[3]{\frac{3900}{4.19}} = \sqrt[3]{931} = 9.76\ cm$$

$$r_{c,B} = \sqrt[3]{\frac{3V_{c,B}}{4\pi}} = \sqrt[3]{\frac{8600}{4.19}} = \sqrt[3]{2055} = 12.72\ cm$$

$$\delta_R = 7.3 - .04(H/X) = 7.3 - .4 = 6.9\ cm$$

$$\delta_B = 5.46 - .148(H/X) = 5.46 - 1.48 = 3.98\ cm$$

$$B^2_{c,R} = \frac{9.87}{(9.76+6.9)^2} = \frac{9.87}{(16.66)^2} = \frac{9.87}{277.56} = .0356\ cm^{-2}$$

$$B^2_{c,B} = \frac{9.87}{(12.72+3.98)^2} = \frac{9.87}{(16.70)^2} = \frac{9.87}{278.89} = .0354\ cm^{-2}$$

With a 5.2 Kg U^{235} limit

$$V_A = \frac{5.2\ Kg}{2.25\ Kg/l} = 2.31\ l$$

$$r_A = \sqrt[3]{\frac{2310}{4.19}} = \sqrt[3]{552} = 8.22\ cm$$

$$B^2_{A,R} = \frac{9.87}{(8.22+6.9)^2} = \frac{9.87}{(15.12)^2} = \frac{9.87}{228.61} = .0432\ cm^{-2}$$

$$B^2_{A,B} = \frac{9.87}{(8.22+3.98)^2} = \frac{9.87}{(12.20)^2} = \frac{9.87}{148.84} = .0663\ cm^{-2}$$

The keff's are

$$k_{eff,R} = \frac{1+(28 \times .0356)}{1+(28 \times .0432)} = \frac{1.9968}{2.2096} = .904$$

$$k_{eff,B} = \frac{1+(28 \times .0354)}{1+(28 \times .0663)} = \frac{1.9912}{2.8564} = .697$$

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NUCLEAR SAFETY EVALUATION - TABLE 309-II BUCKLINGS & KEFF'S
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For U Metal - Water Mixture @ $10 \leq H/X \leq 20$

$V_{c,R} = 4.7\,l$, $V_{c,B} = 10\,l$, $\rho_c = 1.2\ Kg/l$ — From Fig. 9, TID-7028

$$r_{c,R} = \sqrt[3]{\frac{3V_{c,R}}{4\pi}} = \sqrt[3]{\frac{4700}{4.19}} = \sqrt[3]{1120} = 10.4\ cm$$

$$r_{c,B} = \sqrt[3]{\frac{3V_{c,B}}{4\pi}} = \sqrt[3]{\frac{10000}{4.19}} = \sqrt[3]{2390} = 13.35\ cm$$

$$\delta_R = 7.3 - .04(H/X) = 6.5\ cm$$

$$\delta_B = 5.46 - .148(H/X) = 2.5\ cm$$

$$B^2_{c,R} = \frac{9.87}{(10.4+6.5)^2} = \frac{9.87}{(16.9)^2} = \frac{9.87}{285.61} = .0346\ cm^{-2}$$

$$B^2_{c,B} = \frac{9.87}{(13.35+2.5)^2} = \frac{9.87}{(15.85)^2} = \frac{9.87}{251.22} = .0393\ cm^{-2}$$

With a 3.6 Kg U^{235} limit

$$V_A = \frac{3.6\ Kg}{1.2\ Kg/l} = 3\ l$$

$$r_A = \sqrt[3]{\frac{3000}{4.19}} = \sqrt[3]{718} = 8.95\ cm$$

$$B^2_{A,R} = \frac{9.87}{(8.95+6.5)^2} = \frac{9.87}{(15.45)^2} = \frac{9.87}{238.70} = .0413\ cm^{-2}$$

$$B^2_{A,B} = \frac{9.87}{(8.95+2.5)^2} = \frac{9.87}{(11.45)^2} = \frac{9.87}{131.10} = .0753\ cm^{-2}$$

The Keffs are

$$k_{eff,R} = \frac{1+(28 \times .0346)}{1+(28 \times .0413)} = \frac{1.9688}{2.1564} = .913$$

$$k_{eff,B} = \frac{1+(28 \times .0393)}{1+(28 \times .0753)} = \frac{2.1004}{3.1084} = .675$$

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For a 3.6 liter volume @. H/≙ 20

$V_A = 3.6\ \ell$

$$r_A = \sqrt[3]{\frac{3600}{4.19}} = \sqrt[3]{860} = 9.52\ cm$$

$$B^2_{A,R} = \frac{9.87}{(9.52+6.5)^2} = \frac{9.87}{(16.02)^2} = \frac{9.87}{256.64} = .0385\ cm^{-2}$$

$$B^2_{A,B} = \frac{9.87}{(9.52+2.5)^2} = \frac{9.87}{(12.02)^2} = \frac{9.87}{144.48} = .0683\ cm^{-2}$$

The keff's are

$$k_{eff,R} = \frac{1+(28 \times .0346)}{1+(28 \times .0385)} = \frac{1.9688}{2.078} = .947$$

$$k_{eff,B} = \frac{1+(28 \times .0393)}{1+(28 \times .0683)} = \frac{2.1004}{2.9124} = .721$$

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NUCLEAR SAFETY EVALUATION — TABLE 309-II BUCKLINGS & KEFF'S
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K+E SEMI-LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

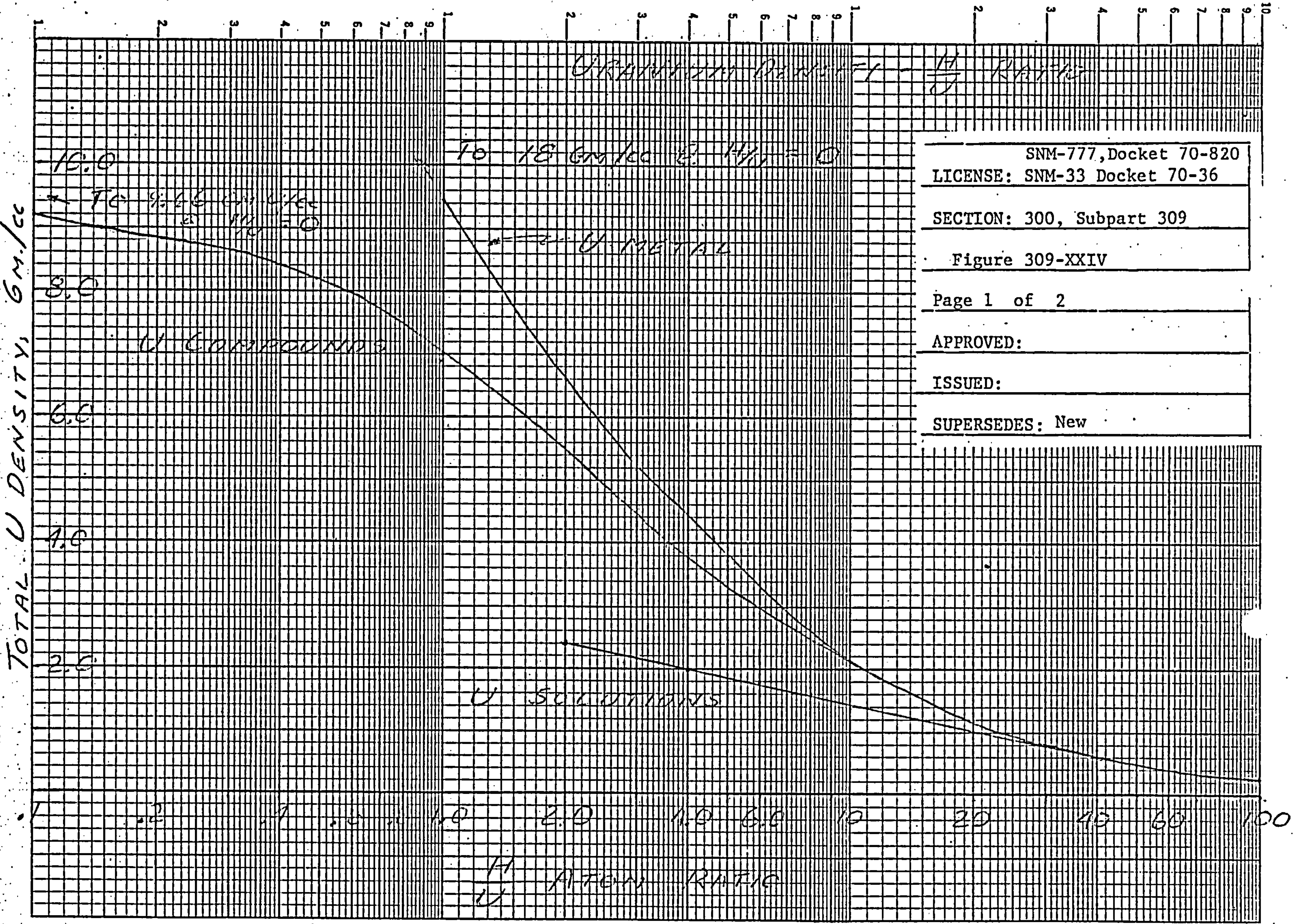

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Figure 309-XXIV

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Figure 309-XXIV

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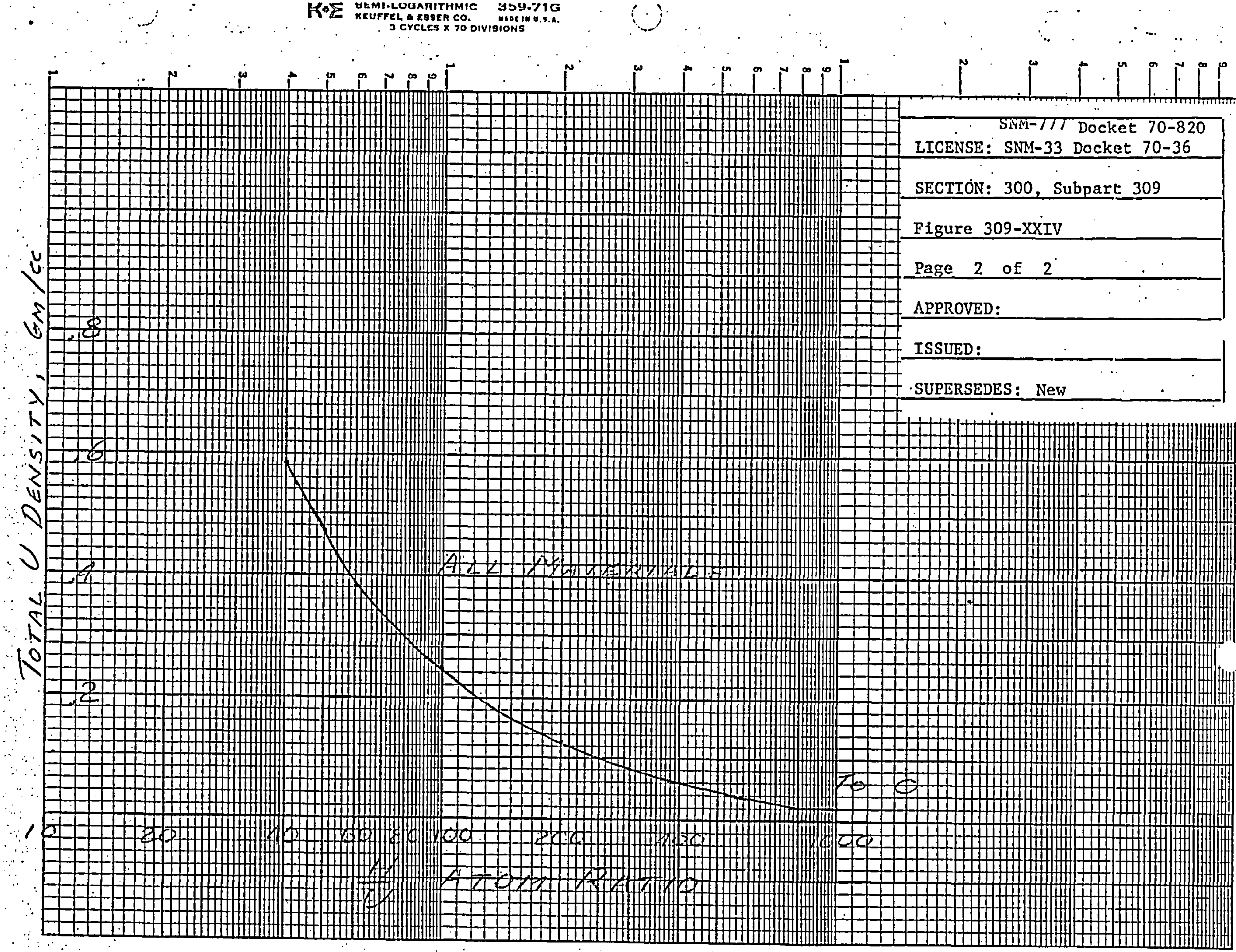


Uranium Density vs. H/U Ratio

I. General

Nuclear criticality safety parameters are a function of uranium density and the degree of moderation of neutrons within the uranium system. Unless specifically stated otherwise, hydrogen in water is the most efficient moderator for which nuclear safety parameters have been established. The degree of moderation is measured by the ratio of the hydrogen to uranium atoms ($\frac{H}{U}$) of the system considered. Generally throughout the literature, the U-235 isotope is used as the reference for defining the density and moderation effects; however individual publications are usually confined to one enrichment level and use of U-235 as the reference is convenient. At the Commercial Products Division plants, uranium of all enrichments is processed. To standardize nuclear safety parameters, it is more convenient to work in terms of total uranium as it applies to density and degree of moderation; therefore, unless specifically stated otherwise, total uranium will be used in all discussions and data involved in the relationship between density and H/U ratio.

II. Material Types

The types of material processed at Commercial Products Division facilities falls into four physical categories:

- Solutions
- U Metal and compound water mixtures
- U Metal
- U alloys with aluminum, zirconium and stainless steel

The relationship of uranium density and H/U ratio for water mixtures of metal and compounds and solution is shown on Figure 1. Based on this figure, there are three standard curves for uranium density and H/U ratio. These are for:

- Uranium Metal
- Uranium Compounds
- Uranium Solutions

A. Uranium Compounds

The density vs. H/U relationship of UO_2 is the maximum for uranium compounds processed by CPD.

Uranium Compounds (continued)

Water mixtures of uranium compounds are subject to the most variation of the density and H/U relationship which is caused by the variation of the maximum theoretical density of the individual compounds and weight fraction of uranium in the compound. The typical compounds processed by CPD are UO_2, U_3O_8, UF_4, UO_2F_2, UO_4, and ADU (ammonium diuranate). Of these UO_2 has the maximum density for a given H/U level. This is illustrated on Figure 1 and Table 1. For purposes of establishing standard nuclear criticality safety parameters for compounds, the total uranium density vs. H/U relationship for UO_2 is established as the upper limit for which such standards are applicable.

The maximum theoretical density has been used to develop the data of Table 1 and Figure 1. These maximum densities can be achieved only by special ceramic processing such as the process of making UO_2 pellets from UO_2 powder. These densities are not possible from the chemical process of converting UF_6 to UO_2 or recovery of uranium from scrap and residues; these processes result in a UO_2 powder having a maximum bulk density of 4 kg U/liter corresponding to an H/U of 4. Accordingly, standards for compounds in homogeneous form are applicable to this level. Standards for compounds having bulk densities in excess of 4 kg U/liter are applicable to densities up to the theoretical maximum.

There may be a slight increase in density when water is added to a dry powder. This effect is included in the maximum density limit specified above.

B. Uranium Solutions

The density vs. H/U relationship for UO_2F_2 solutions is the maximum for uranium solutions processed at CPD.

Historically, UO_2F_2 solutions have been used in experimental measurements of critical parameters because it permitted the highest concentration and lowest non-fissioning absorption cross section of solutions generally processed. A review of solutions processed at CPD confirms this; the most typical solution being uranyl nitrate. These data are also illustrated in Figure 1 and Table 1.

For purposes of establishing standard nuclear criticality safety parameters for solutions the density vs. H/U relationship of UO_2F_2 solutions is established as the upper limit for which the standards will be applicable.

C. Uranium Metal

The relationship of metal density versus H/U shown on Figure 1 is that obtained from Figures 1 through 4 of TID-7016, Rev. 0. This is the maximum possible density for any form of uranium. Safe parameter standards for uranium metal are based on this relationship.

D. Alloys

The effect of the relationship of uranium density to H/U ratio for alloys has been included in the special calculations (NDEO 1050) performed for the alloys. Safe parameters are reported as a function of the U-235 content of the alloy.

III. Development of the Density vs. H/U Ratio

A. Compounds and Water Mixtures

The relationship for uranium compounds and water mixture is based on the maximum theoretical density of the compound and the volume additive mixtures of the compound with water. Specifically H/U ratios were calculated from the formula:

$$\frac{H}{U} = \frac{\text{Weight } H_2O \times 2\,\frac{\text{atom H}}{\text{mole } H_2O} \times 238\,\frac{\text{weight U}}{\text{mole U}}}{18\,\frac{\text{weight } H_2O}{\text{moles } H_2O} \times \text{weight U} \times 1\,\frac{\text{atom U}}{\text{mole U}}}$$

$$= 26.45 \left(\frac{\text{weight } H_2O}{\text{weight U}}\right)$$

The data plotted on Figure 1 and calculated by the above formula is tabulated on Table 1.

B. Metal Water Mixtures

The relationship for uranium metal and water mixtures has been obtained from the data of Figures 1 through 4, TID-7016, Rev. 1.

C. Solutions

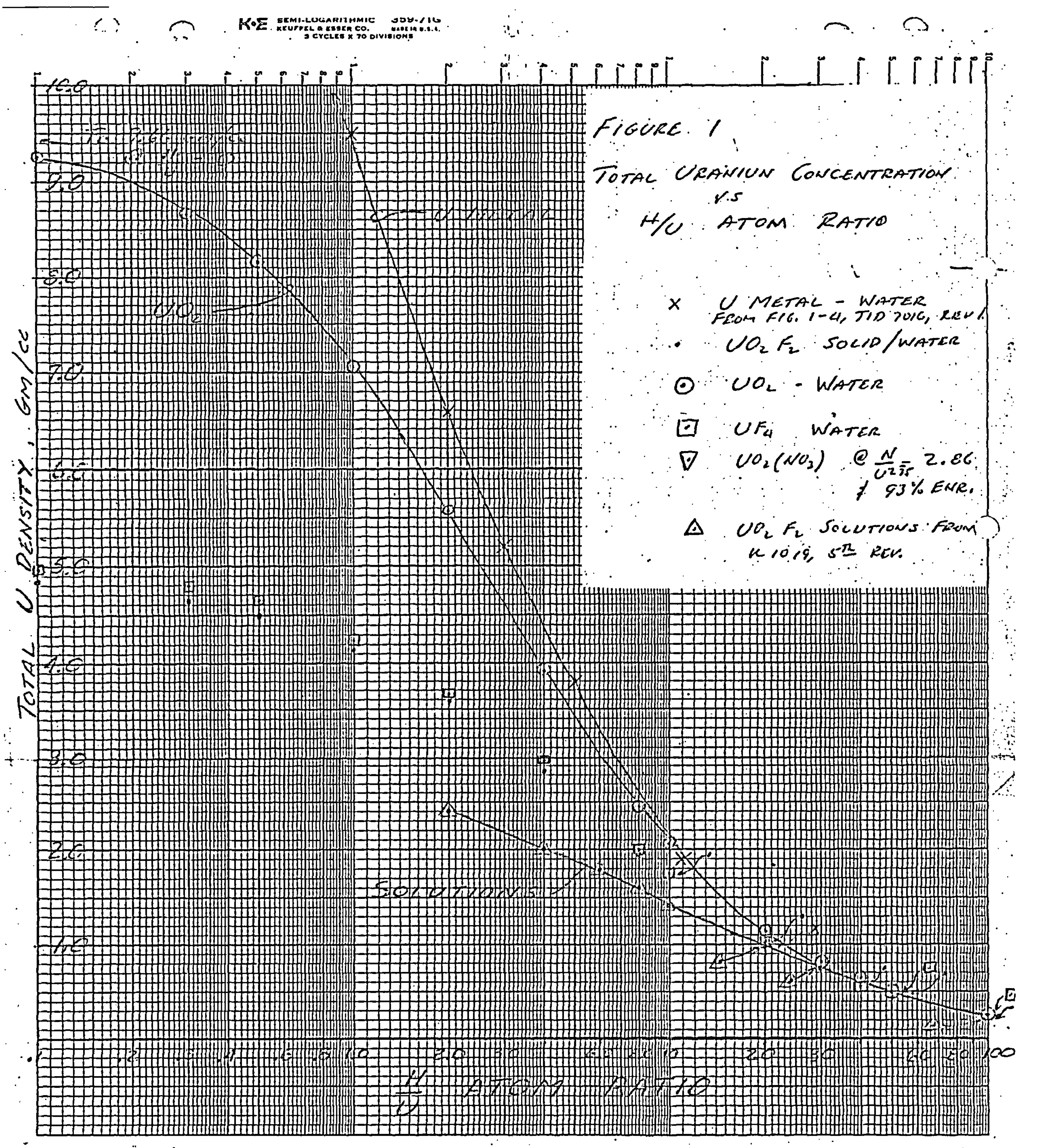
The data for solutions has been obtained from Figure 1, K-1019, 5th Revision.

In examining Figure 1 it can be seen that all of the curves converge into a single curve at an H/U ratio of approximately 20 and a density of approximately 1. This single curve follows that of the solution curve for H/U ratios in excess of 20. Unless specifically stated otherwise, safe parameters for all systems with H/U ratios greater than 20 will therefore follow those of solutions.

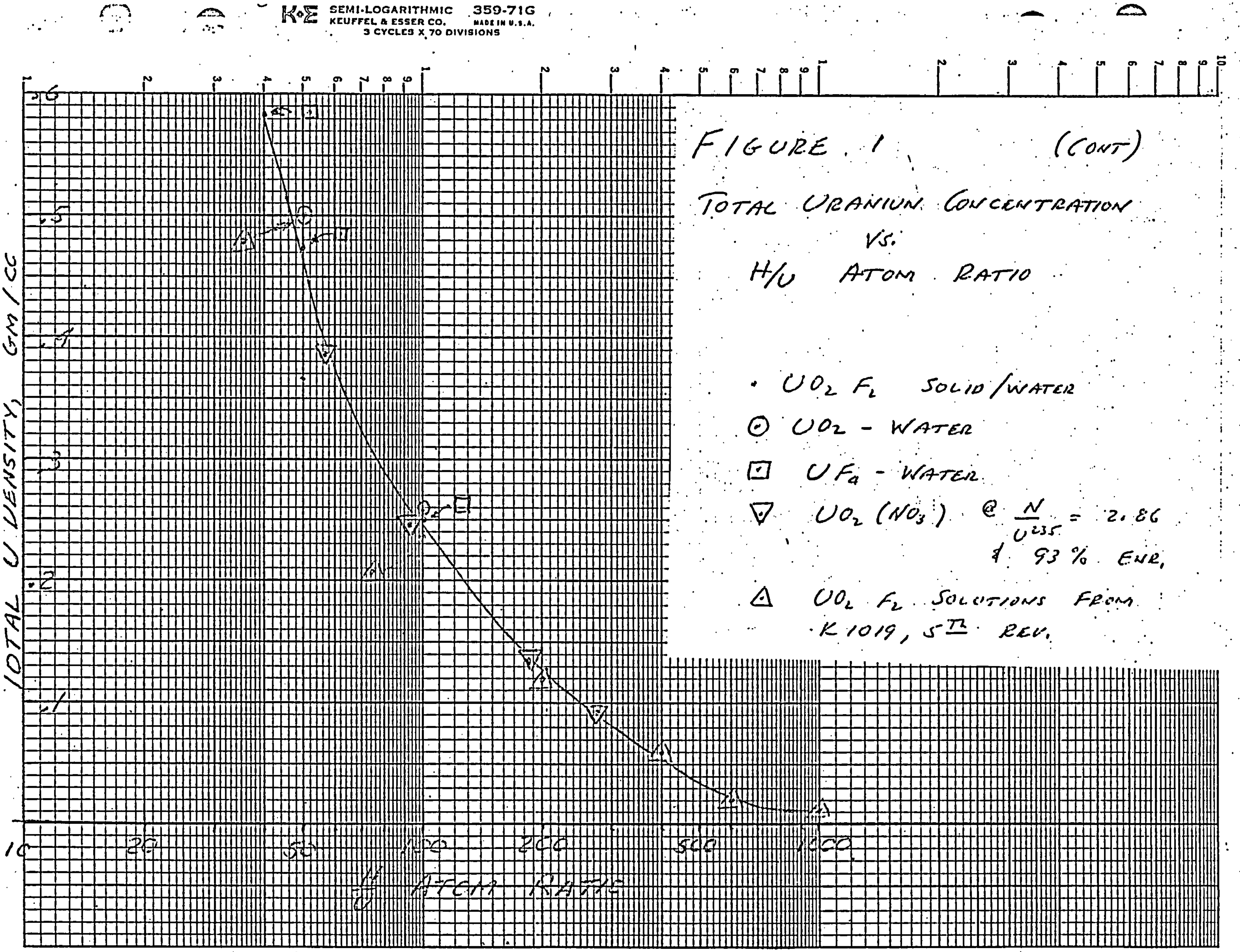
TABLE 1

$\frac{H}{U}$	Density, grams U/cc					
					(UO_2) (NO_3) @ N/U-235 = 2.86 93% Enriched *	
	UO_2	UF_4	UO_2F_2 Solid	UO_2F_2 Solution (2)	H/U	Density
0	9.66 (1)	5.07 (1)	4.93 (1)		58	.387
.1	9.24	4.99	4.84		93	.247
.3	8.69	4.80	4.64		186	.135
.5	8.16	4.64	4.50		279	.092
1	7.06	4.26	4.15			
2	5.59	3.67	3.6	2.4		
4	3.92	2.99	2.82	2.0		
8	2.46	2.00	1.98	1.6		
10	2.08	1.74	1.72	1.4		
20	1.16	1.04	1.04	1.0		
30	.81		.748	.75		
40	.66	.585	.582			
50	.50	.479	.477			
100	.258	.251	.25	.25		
200				.12		
600				.02		
1000				.01		

(1) Based on maximum theoretical density of compound reported by Katz & Rabinowitch, The Chemistry of Uranium, First Edition.
(2) Figure 1, K-1019, 5th Rev.
* Figure 2.5 NDEO-1050

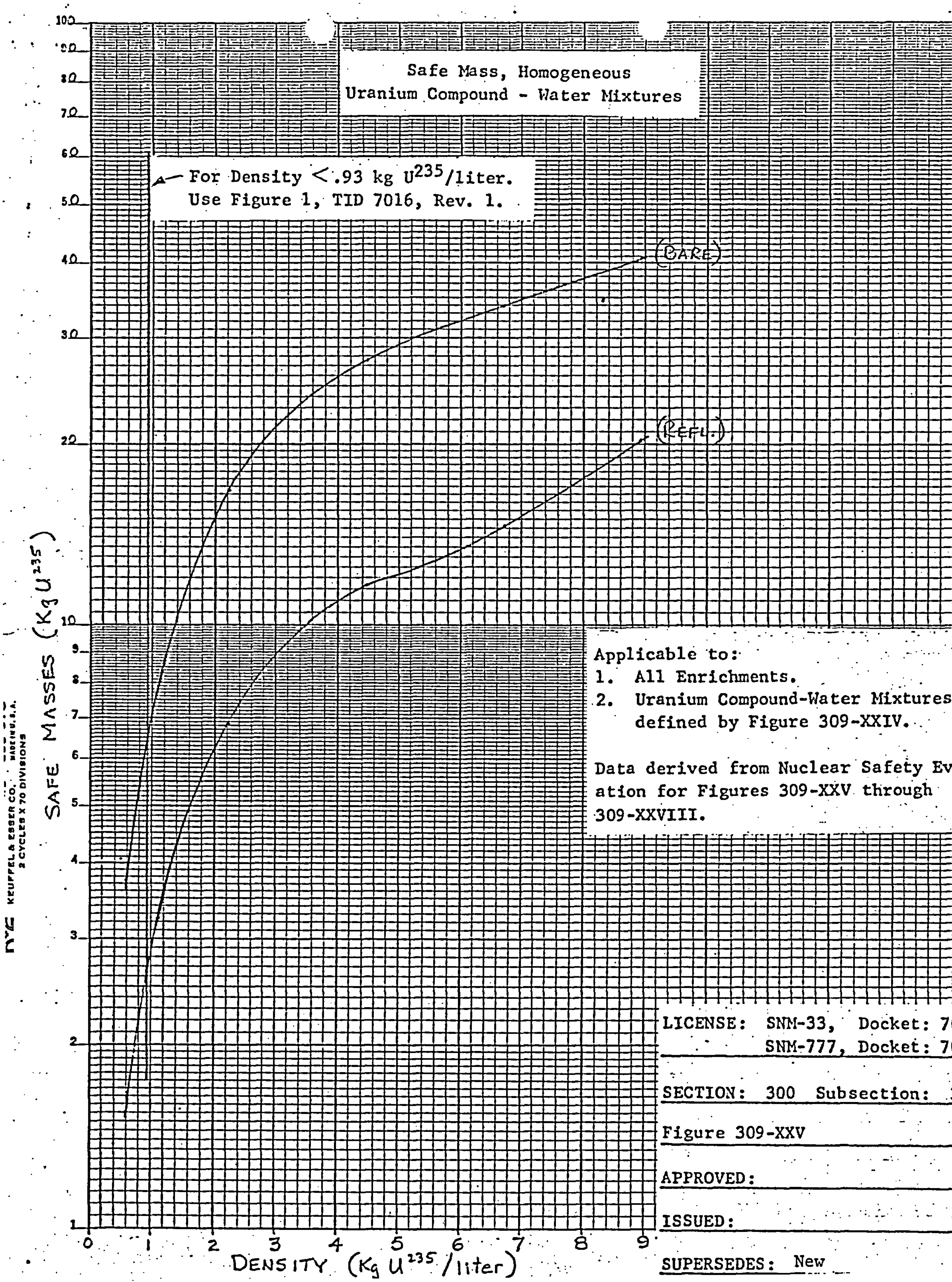


K+E SEMI-LOGARITHMIC 359-71G KEUFFEL & ESSER CO. MADE IN U.S.A. 3 CYCLES X 70 DIVISIONS
FIGURE 1
TOTAL URANIUM CONCENTRATION VS H/U ATOM RATIO
× U METAL - WATER FROM FIG. 1-4, TID 7016, REV 1
• UO2 F2 SOLID/WATER
⊙ UO2 - WATER
⊡ UF4 WATER
▽ UO2(NO3) @ N/U235 = 2.86 & 93% ENR.
△ UO2 F2 SOLUTIONS FROM K 1019, 5th REV.
U METAL
UO2
SOLUTIONS
TOTAL U DENSITY, GM/CC
H/U ATOM RATIO



K&E SEMI-LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
FIGURE 1 (CONT)
TOTAL URANIUM CONCENTRATION VS. H/U ATOM RATIO
• UO2 F2 SOLID/WATER
⊙ UO2 - WATER
⊡ UF4 - WATER
▽ UO2 (NO3) @ N/U235 = 2.86 & 93 % ENR.
△ UO2 F2 SOLUTIONS FROM K 1019, 5TH REV.
TOTAL U DENSITY, GM / CC
.6
.5
.4
.3
.2
.1
10
20
50
100
200
500
1000
H/U ATOM RATIO

Safe Mass, Homogeneous Uranium Compound - Water Mixtures



Applicable to:

1. All Enrichments.
2. Uranium Compound-Water Mixtures defined by Figure 309-XXIV.

Data derived from Nuclear Safety Evaluation for Figures 309-XXV through 309-XXVIII.

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SNM-777, Docket: 70-82

SECTION: 300 Subsection: 309

Figure 309-XXV

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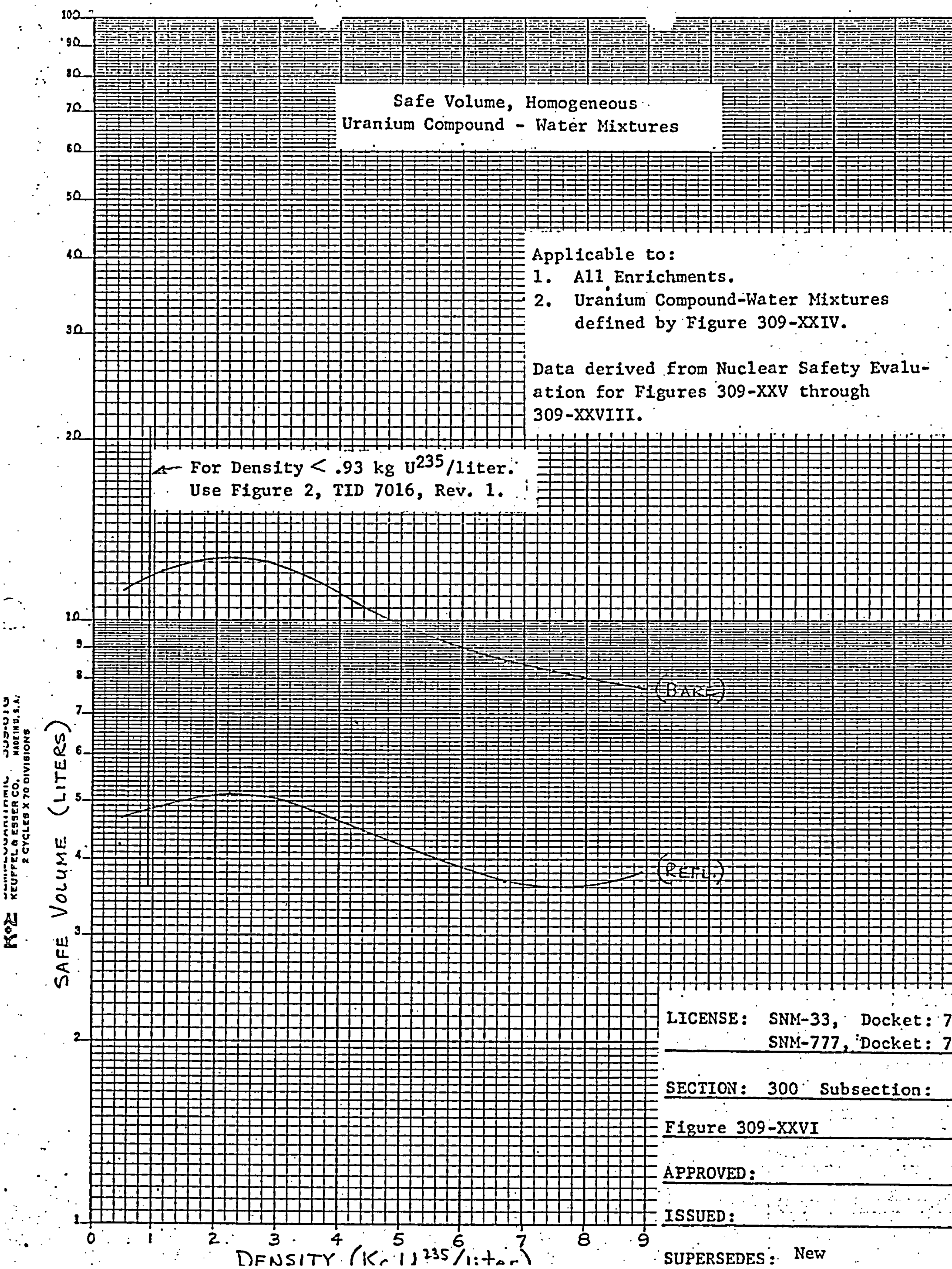

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SNM-777, Docket: 70-82

SECTION: 300 Subsection: 309

Figure 309-XXVI

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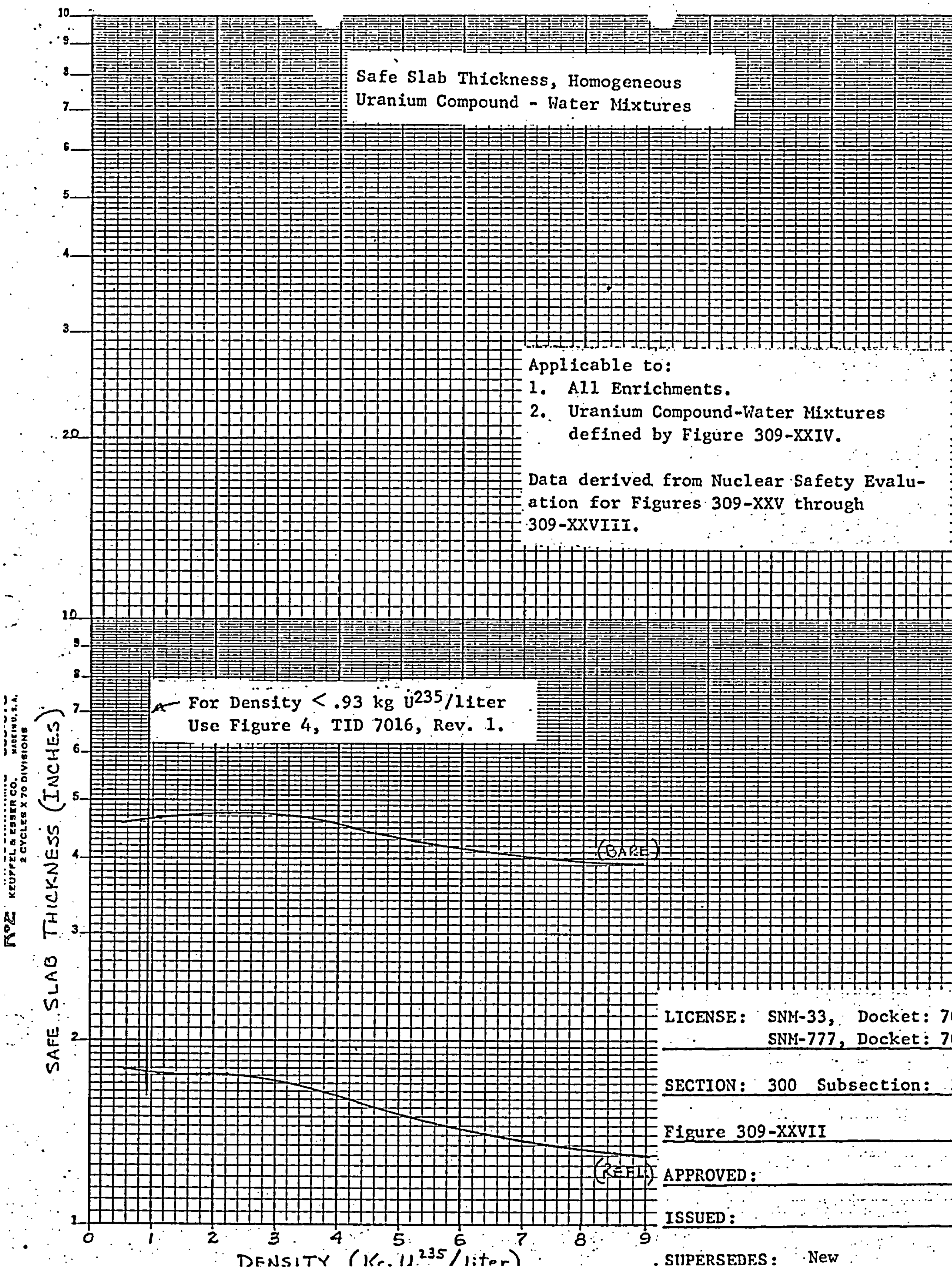
SUPERSEDES: New



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SECTION: 300 Subsection: 309

Figure 309-XXVII

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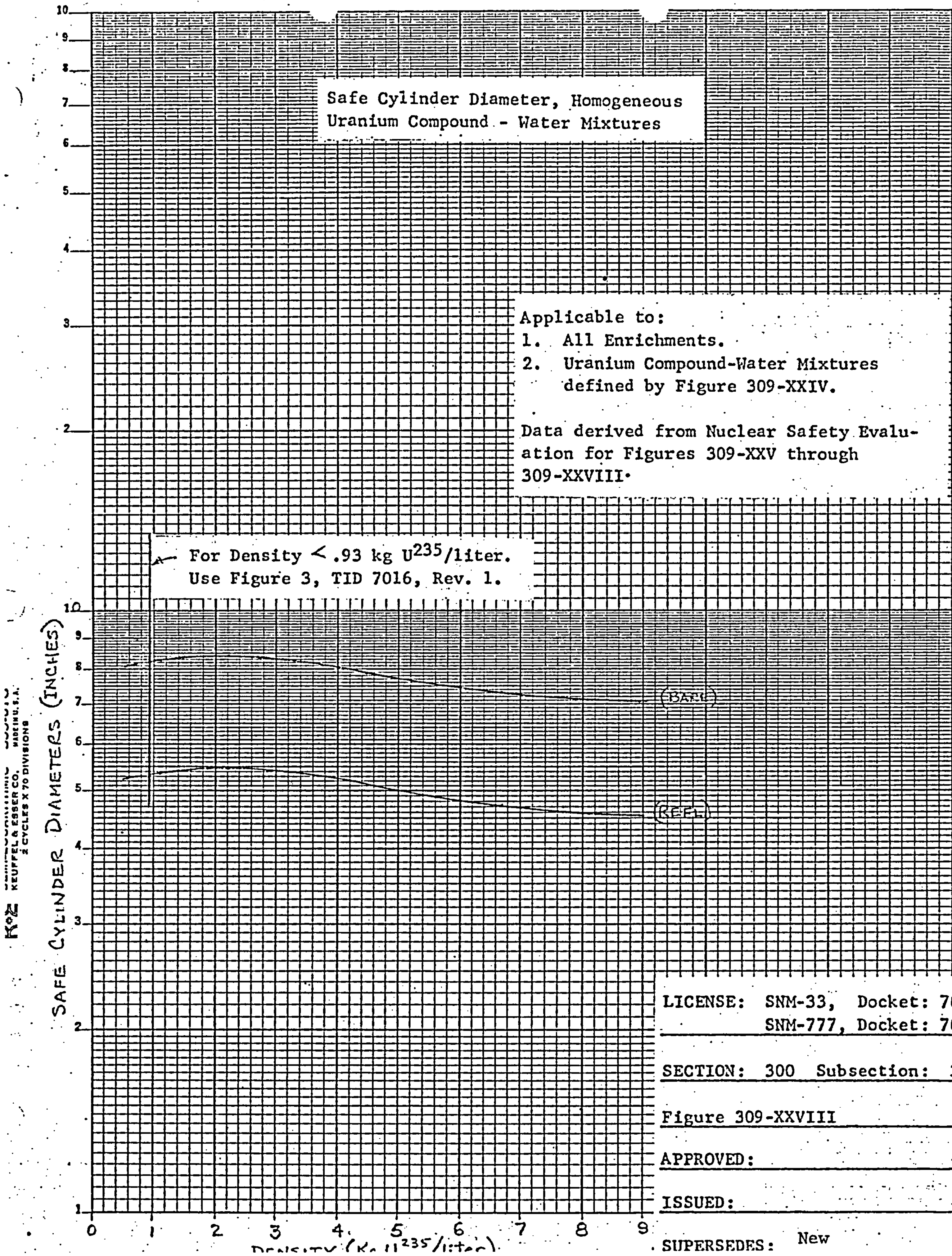

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SECTION: 300 Subsection: 309

Figure 309-XXVIII

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SUPERSEDES: New

CRITICAL AND SAFE HOMOGENEOUS URANIUM COMPOUND - WATER VOLUMES AND MASSES AT ALL ENRICHMENT

H/U-235	ρ (Kg/ℓ)	$V_{C,R}$ (1) (Liters)	$V_{S,R}$ (2) (Liters)	$V_{C,B}$ (1) (Liters)	$V_{S,B}$ (2) (Liters)	$M_{C,R}$ (3) (Kg U^{235})	$M_{S,R}$ (4) (Kg U^{235})	$M_{C,B}$ (3) (Kg U^{235})	$M_{S,B}$ (4) (Kg U^{235})
0	8.930	5.03	3.82	10.15	7.71	44.93	20.22	90.63	40.78
0.98	6.700	4.84	3.68	11.25	8.55	32.41	14.58	75.39	33.93
2.94	4.470	5.79	4.40	13.78	10.47	25.89	11.65	61.58	27.71
8.96	2.230	6.80	5.17	16.68	12.68	15.16	6.82	37.21	16.74
20.60	1.120	6.42	4.88	15.91	12.09	7.19	3.24	17.82	8.02
43.90	0.558	6.19	4.70	14.92	11.34	3.45	1.55	8.32	3.74

NOTE: (1) $V_c = 4/3 \pi r_c^3$ where r_c values are obtained from Table V K, LA-3612

(2) $V_s = .76 V_c$

(3) $M_c = V_c \rho$

(4) $M_s = .45 M_c$

SUBSCRIPTS: C - Critical, S - Safe, B - Bare, R - Full Water Reflector

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SECTION: 300, SUBPART: 309
NUCLEAR SAFETY EVALUATION - DATA FOR FIGS. 309-XXV & -XXVI
PAGE 1 OF 1
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ISSUED
SUPERSEDES: New

CRITICAL AND SAFE HOMOGENEOUS URANIUM COMPOUND - WATER
CYLINDER DIAMETERS AND SLAB THICKNESSES AT ALL ENRICHMENTS

H/U-235	ρ (Kg/l)	$r_{c,R}$ (cm)	$D_{s,R}$ (1) (in)	$r_{c,B}$ (cm)	$D_{s,B}$ (1) (in)	$T_{c,R}$ (cm)	$T_{s,R}$ (2) (in)	$T_{c,B}$ (cm)	$T_{s,B}$ (2) (in)
0	8.930	6.21	4.53	9.69	7.06	3.748	1.29	11.35	3.92
0.98	6.700	6.49	4.73	10.06	7.33	3.990	1.38	11.86	4.09
2.94	4.470	7.00	5.10	10.78	7.86	4.549	1.57	12.78	4.41
8.96	2.230	7.51	5.47	11.53	8.41	5.114	1.76	13.74	4.74
20.60	1.120	7.34	5.35	11.34	8.27	5.098	1.76	13.55	4.67
43.90	0.558	7.22	5.26	11.13	8.11	5.197	1.79	13.32	4.60

NOTE: (1) $D_s = \frac{2\, r_c (cm)}{2.54 (cm/in) \times 1.08\ SF} = .729\, r_c$ where r_c values are obtained from Table V K, LA-3612

(2) $T_s = \frac{T_c (cm)}{2.54 (cm/in) \times 1.14\ SF} = .345\, T_c$ where T_c values are obtained from Table V K, LA-3612

SUBSCRIPTS: C - Critical, S - Safe, B - Bare, R - Full Water Reflector

LICENSE: SNM-33, DOCKET: 70-36
LICENSE: SNM-777, DOCKET: 70-820
SECTION: 300, SUBPART: 309
NUCLEAR SAFETY EVALUATION - DATA FOR FIGS. 309-XXVII & XXVIII
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