IAEA/ANL
Interregional Training Course

Technical and Administrative Preparations Required for Shipment of Research Reactor Spent Fuel to Its Country of Origin

Argonne National Laboratory
Argonne, IL
13 - 24 January 1997

Lecture L.3.1a

Savannah River Site Appendix A Agreement Preparation Guidelines

Sample SRS Review Calculations

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Subject: Material Test Reactor (MTR) Fuel Assembly Review

Purpose: To verify weight's of the MTR fuel assembly's components and constituents as identified by the referenced Appendix A agreement.

References:

1. Appendix A, DOESRAA-97-MTR.1, Rev.0, 1/06/97.
2. MTR Drawings 5001 through 5008.
3. CRC Manual, 61st Edition.
4. Marks Handbook, 9th Edition.
5. Chart of the Nuclides, 14th Edition.

Calculations:

A. Fuel Elements

1. Type 9 (outer fuel plate):

   a. Calculate the nominal volume of the fuel plate:

      Volume (plate) = length x width x thickness

      Volume (plate) = 68.9 cm x 7.1 cm x 0.164 cm

      Volume (plate) = 80.23 cc

   b. Calculate the nominal volume of the fuel meat:

      Per Fuel Compact Dwg. 5006

      Volume (meat) = 6.005 cm x 6.385 cm x 0.51 cm

      Volume (meat) = 19.55 cc

   c. Calculate weight of fuel meat and individual constituents:

      From Dwg. 5006, nom. weight of ^{235}U in meat is 11.58 g

      From Appendix A, nom. weight of Total U in meat is 12.45 g

      Chemical Form of meat is U_3O_8 in an Aluminum matrix

      Using stoichiometry, find weight of oxide:

      moles of (U) = 12.45 g / 238.029 g per mole = 0.0523 moles

c. Calculate weight of fuel meat and .... : (cont.)

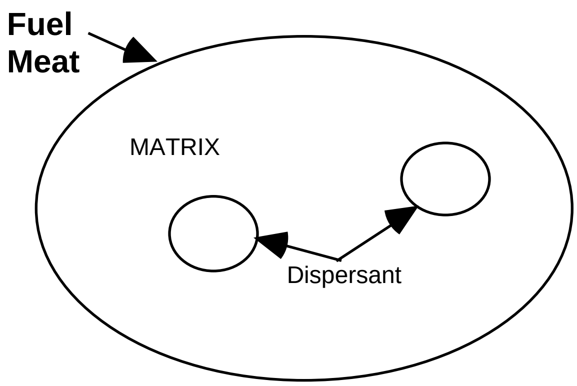
moles of (O) = 8/3 x (0.0523 moles) = 0.1395 moles

grams of (O) = 15.9994 g per mole x 0.1395 moles = 2.23 g

Total weight of U_3O_8 = 12.45 g + 2.23 g = 14.68 g

Find weight of Al matrix:

Volume (meat) = Volume (matrix) + Volume (dispersant)



Volume (meat) = Volume (Al) + Volume (U_3O_8)

From CRC, pg B161, density of U_3O_8 = 8.3 g/cc

From Marks, pg 6-11, ~ density of Al = 2.7 g/cc
(Note: the 2.7 g/cc Al density value will be used for aluminum forms in this review)

19.55 cc = (wgt U_3O_8 / density U_3O_8) + (wgt Al / density Al)

19.55 cc = (14.68 g / 8.3 g/cc) + (wgt Al / 2.7 g/cc)

Weight of Al matrix = 48.01 g

Weight (fuel meat) = Weight (matrix) + Weight (dispersant)

Weight (fuel meat) = 48.01 g + 14.68 g

Weight (fuel meat) = 62.69 g

d. Calculate weight of fuel plate cladding:

Volume (cladding) = Volume (plate) - Volume (meat)

Volume (cladding) = 80.23 cc - 19.55 cc

Volume (cladding) = 60.68 cc

Weight (cladding) = density (Al) x Volume (cladding)

Weight (cladding) = 2.7 g/cc x 60.68 cc

Weight (cladding) = 163.84 g

e. Calculate weight of fuel plate:

Weight (plate) = Weight (cladding) + Weight (meat)

Weight (plate) = 163.84 g + 62.69 g

Weight (plate) = 226.53 g

2. Type 8 (inner fuel plate):

a. Calculate the nominal volume of the fuel plate:

Volume (plate) = 62.55 cm x 7.10 cm x 0.1275 cm

Volume (plate) = 56.62 cc

b. Calculate nominal volume of the fuel meat:

Same as A.1.b;

Volume (meat) = 19.55 cc

c. Calculate weight of fuel meat and individual constituents:

Same as A.1.c;

Weight (total U) = 12.45 g

Weight (^{235}U) = 11.58 g

Weight (U_3O_8 dispersant) = 14.68 g

Weight (Al matrix) = 48.01 g

c. Calculate weight of fuel meat and ... : (cont.)

Weight (meat) = <u>62.69 g</u>

d. Calculate weight of fuel plate cladding:

Volume (cladding) = Volume (plate) - Volume (fuel meat)

Volume (cladding) = 56.62 cc - 19.55 cc

Volume (cladding) = 37.07 cc

Weight (cladding) = 2.7 g/cc x 37.07 cc

Weight (cladding) = <u>100.1 g</u>

e. Calculate weight of fuel plate:

Weight (plate) = Weight (cladding) + Weight (meat)

Weight (plate) = 100.1 g + 62.69 g

Weight (plate) = 162.79 g

B. <u>Side Plate</u>

1. Calculate nominal volume of side plate:

a. Calculate side plate as solid piece:

Volume (solid) = length x width x thickness

Volume (solid) = 68.9 cm x 8.05 cm x 0.475 cm

Volume (solid) = <u>263.46 cc</u>

b. Calculate volume of outer slots (o.s):

Volume (o.s.) = 2 slots x length x width x depth

Volume (o.s) = 2 x 68.9 cm x 0.18 cm x 0.22 cm

Volume (o.s.) = <u>5.46 cc</u>

c. Calculate volume of inner slots (i.s.):

Volume (i.s.) = 17 slots x length x width x depth

c. Calculate volume of inner slots (i.s.): (cont.)

Volume (i.s.) = 17 x ~66.9 cm x 0.14 cm x 0.22 cm

Volume (i.s.) = 35.03 cc

d. Calculate volume of side plate end cut-outs (c.o.):

Volume (c.o.) = 2 ends x length x width x thickness

Volume (c.o.) = ~(68.9 - 66.9) cm x 7.24 cm x 0.305 cm

Volume (c.o.) = 8.83 cc

e. Calculate volume of side plate:

Volume (s. plate) = Volume (solid - o.s - i.s - c.o.)

Volume (s. plate) = 263.46 cc - 5.46 cc - 35.03 cc - 8.83 cc

Volume (s. plate) = 214.14 cc

2. Calculate weight of side plate:

Weight (s. plate) = density (Al) x Volume (s. plate)

Weight (s. plate) = 2.7 g/cc x 214.14 cc

Weight (s. plate) = 578.18 g

C. End Boxes

1. Calculate nominal volume of end box:

Note: Calculated values are approximated due to machining and irregular shapes

a. Calculate volume of circular nose section (c.s.):

Volume (c.s.) = length x circular area

Volume (c.s.) = (20.875 cm - 7.725 cm) x
π[(6.35 cm / 2)^2 - (5.1 cm / 2)^2]

Volume (c.s.) = 13.15 cm x 11.24 cm^2

Volume (c.s.) = 147.81 cc

b. Calculate volume of transitional squared section (s.s.):

Volume (t.s.) = length x (area square - area circular)

Volume (t.s.) = (7.725 cm - 1/385 cm) - [(6.605 cm x 6.82 cm) - π(6.195 cm / 2)^2]

Volume (t.s.) = 6.34 cm x [45.05 cm^2 - 30.14 cm^2]

Volume (t.s.) = 94.53 cc

c. Calculate volume of fitted squared section (f.s.):

Volume (f.s.) = 1.385 cm x [(7.425 cm x 7.235 cm) - π(6.195 cm / 2)^2]

Volume (f.s.) = 32.66 cc

2. Calculate weight of end box:

Weight (end box) = density (Al) x Volume (c.s. + t.s. + f.s.)

Weight (end box) = 2.7 g/cc x (147.81 cc + 94.53 cc + 32.66 cc)

Weight (end box) = 742.50 g

D. Other Structural Materials

There are eight (8) 6 mm x 8 mm structural pins in the fuel assembly connecting the outer fuel plates to the end boxes and the side plates to the end boxes. Weights of the pins, as with other assemblies, are expected on the order of < 1.0 g per pin.

E. Summary Weight of Fuel Assembly

Weight (fuel assembly) = Weight (outer fuel plate) x 2 + Weight (inner fuel plate) x 17 + Weight (side plate) x 2 + Weight (end box) x 2

Since the pin holes were not accounted for in the component weight calculations, weights of the structural pins are not included.

Weight (fuel assembly) = (226.53 g) x 2 + (162.79 g) x 17 + (578.18 g) x 2 + (742.50 g) x 2

Weight (fuel assembly) = 5,861.85 g

F. Appendix A Comparisions

	Appendix A	Calculated Value
Type 9 element Wgt.	227.0	226.53
Type 8 / 9 fuel meat Wgt.	62.0	62.69
Type 8 / 9 matrix Wgt.	47.0	48.01
Type 9 clad Wgt	165.0	163.84
Type 8 element Wgt.	164.0	162.79
Type 8 clad Wgt	102.0	100.1
Over-all Assembly Wgt.	6026.8	5861.85
Side plate Wgt.	580.0	578.18
End box Wgt.	760.0	742.5
Pin Wgt.	0.6	< 1.0

Typical range of acceptable uncertainty between the stated Appendix A values and the SRS review calculations is ± 5%.