APPENDIX 2: NATCON INFORMATION

Hot Channel Factors in the NATCON Code Version 1.0

The NATCON code version 1.0 [Ref. ANL/RERTR/TM-12] uses three hot channel factors (FQ, FW, FH). Using the source code and documentation, the factor FH used in NATCON is found to be the same as the factor FNUSLT used by E. E. Feldman. Table 1 shows the tolerances and uncertainties included in each of the six hot channel factors used by E. E. Feldman. The correspondence between the NATCON hot channel factors and E. E. Feldman's six hot channel factors is as follows.

Feldman's Hot Channel Factor		**NCATCON Input Variable**
System-wide Factors:		
FFLOW	a factor to account for the uncertainty in total reactor flow	FW (approximately)
FPOWER	a factor to account for the uncertainty in total reactor power	FQ
FNUSLT	a factor to account for the uncertainty in Nu number correlation	FH
Local Factors:		
FBULK	a hot channel factor for local bulk coolant temperature rise	FBULK (new input)
FFILM	a hot channel factor for local temperature rise across the coolant film	FFILM (new input)
FFLUX	a hot channel factor for local heat flux from cladding surface	FFLUX (new input)

Hot Channel Factors in the NATCON Code Version 2.0

Sections 2.1 and 2.2 develop, for laminar natural convection, two thermal-hydraulic relationships that are used in section 2.3 to obtain formulas for the hot channel factors from user-supplied manufacturing tolerances and measurement uncertainties. The results of section 2.3 are summarized here for convenience. The first three are local/random hot channel factors, and the last three are system-wide. An example of the use of these hot channel factors is given in section 4, with NATCON running instructions in section 3, and the new input description in section 5.

$$\text{FBULK} = 1 + \sqrt{\left\{(1+u_1)^{\frac{1}{2+\alpha}}(1+u_2)^{\frac{1}{2+\alpha}}\left(\frac{1}{1-u_5}\right)^{\frac{3}{2+\alpha}} - 1\right\}^2 + u_6^2}$$

FBULK is higher (conservative) if the temperature dependence of water viscosity is ignored.

$$\text{FFILM} = 1+\sqrt{u_1^2+u_2^2+u_3^2+u_4^2+u_5^2}$$

$$\text{FFLUX} = 1+\sqrt{u_1^2+u_2^2+u_3^2+u_4^2}$$

$FQ = 1 + u_7$

$FW = 1 + u_8$

$FH = 1 + u_9$

where

u_1 = Fractional uncertainty in neutronics calculation of power in a plate

u_2 = Fractional uncertainty in U-235 mass per plate = $\Delta m / M$

u_3 = Fractional uncertainty in local (at an axial position) fuel meat thickness

u_4 = Fractional uncertainty in U-235 local (at an axial position) homogeneity

u_5 = Fractional uncertainty in coolant channel thickness = $(t_{nc} - t_{hc}) / t_{nc}$

u_6 = Fractional uncertainty in flow distribution among channels

u_7 = Fractional uncertainty in reactor power measurement

u_8 = Fractional uncertainty in flow due to uncertainty in friction factor

u_9 = Fractional uncertainty in convective heat transfer coefficient, or in the Nu number correlation

M = Nominal mass of U-235 per plate, gram

Δm = Tolerance allowed in U-235 mass per plate, gram

The code obtains, for an input nominal reactor power CPWR, a thermal-hydraulic solution using the three systematic hot channel factors FW, FQ and FH. If the user-input reactor power is zero, then the code itself chooses the nominal power from a series of power levels (10 kW, 100 kW, 200 kW, and so on increasing in steps of 100 kW). This thermal-hydraulic calculation is done for a hot plate power of CPWR*FQ*(Radial power peaking factor RPEAK)/(Total number of fuel plates in standard and control assemblies). Also, the frictional resistance to flow is multiplied by FW^2, and the convective heat transfer coefficient found for laminar flow in a rectangular channel is divided by FH. The random hot channel factors FBULK, FFILM and FFLUX are not used in this solution.

Having obtained the above solution, the random hot channel factors FBULK, FFILM and FFLUX are applied to the temperatures obtained, using the following equations. The temperatures calculated with all six hot channel factors are printed after the above solution. The onset of nucleate boiling ratio, ONBR, is computed using the temperatures with all six hot channel factors applied (using the equation below). If the user-input nominal power is zero, then the last nominal power for which the code prints a solution is that at which the ONBR is 1.0.

$$T_{i,6hcf} = T_0 + (T_i - T_0)*FBULK$$

$$T_{wall,i,6hcf} = T_{i,6hcf} + (T_{wall,i} - T_i)*FFILM$$

$$T_{max,i,6hcf} = T_{wall,i,6hcf} + (T_{max,i} - T_{wall,i})*FFLUX$$

$$ONBR = \frac{\left(T_{incp,i} - T_0\right)}{\left(T_{wall,i,6hcf} - T_0\right)}$$

where

T_0 = Bulk water temperature at the coolant channel inlet, i.e., the pool temperature, °C

T_i = Bulk water temperature in node i of the channel with only systematic hot channel factors applied, °C

$T_{wall,i}$ = Cladding surface temperature in node i with only systematic hot channel factors applied, °C

$T_{max,i}$ = Fuel meat centerline temperature in node i with only systematic hot channel factors applied, °C

$T_{i,6hcf}$ = Bulk water temperature in node i of the channel with all six hot channel factors, °C

$T_{wall,i,6hcf}$ = Cladding surface temperature in node i with all six hot channel factors, °C

$T_{max,i,6hcf}$ = Fuel meat centerline temperature in node i with all six hot channel factors, C

$T_{incp,i}$ = Incipient boiling temperature in node i with only systematic hot channel factors applied, C

Flow Rate in a Coolant Channel versus Power of a Fuel Plate

NATCON is a laminar natural circulation code. The flow rate is calculated in the code by balancing the buoyancy pressure force to the laminar friction pressure drop. Following this concept, an analytical relationship is developed here (with some approximation) for the coolant flow rate in a single coolant channel in terms of the power generated in a fuel plate and the channel geometrical dimensions. The analytical relationship is needed for obtaining hot channel factors.

The hot channel factor FW used in the code to account for the uncertainty in coolant flow rate is actually applied to the laminar friction factor in the code, that is, the laminar friction factor is multiplied by FW^2. It is not applied directly to the flow rate. The relationship developed here explains how this technique works.

ρ_1 , T_1 at channel outlet

|

|

|

| L = Channel height containing hot coolant (hotter than pool), m

| P = Power in a single fuel plate or the two half plates, W

| W=Upward flow rate in a single channel, kg/s

|

|

ρ_0 , T_0 at channel inlet

Schematic of what the code analyses, that is, a single rectangular coolant channel heated by a half of a fuel plate on each side (right and left sides).

The above schematic shows what the code analyses, that is, a single rectangular coolant channel heated by a half of a fuel plate on each side (right and left sides). See Fig. 1 for details. The buoyancy pressure force is caused by the decrease in water density due to heating in the channel. The temperature dependence of water density can be written as

$$\rho(T) = \rho_0 - \rho_0 \beta (T - T_0) \tag{1}$$

where

T_1 = Bulk water temperature at channel outlet, C

ΔT = $T_1 - T_0$ = Temperature rise in channel from inlet to outlet, C

ρ_0 = Water density at channel inlet, i.e., the water density in the pool, kg/m^3

β = Volumetric expansion coefficient of water, per C

$\bar{\rho}$ = Average coolant density in the channel, kg/m^3

L = Channel height that contains hotter coolant (hotter than pool), m. It is the sum of heat generating length of fuel plate, non-heat generating fuel plate length at top, and the assembly duct length above the top of fuel plate

g = Acceleration due to gravity, 9.8 m/s^2

The buoyancy pressure force is given by

$$\text{Buoyancy}\ \Delta p = (\rho_0 - \bar{\rho})\, g\, L \tag{2}$$

The average coolant density $\bar{\rho}$ is given by

$$\bar{\rho} = 0.5\,(\rho_0 + \rho_1) = \rho_0 - 0.5\,\rho_0\,\beta\,(T_1 - T_0) = \rho_0 - 0.5\,\rho_0\,\beta\,\Delta T \tag{3}$$

$$\text{Buoyancy}\ \Delta p = 0.5\,\rho_0\,\beta\,\Delta T\, g\, L \tag{4}$$

The coolant temperature rise ΔT can be written in terms of the input power P generated in a fuel plate, as shown by Eq. (5) below, and then the buoyancy Δ p of Eq. (4) can be written in terms of the input power P, as shown by Eq. (6).

$$\Delta T = P/\,(W\,C_p) \tag{5}$$

$$\text{Buoyancy}\ \Delta p = \frac{\rho_0 \beta g L P}{2 W C_P} \tag{6}$$

Ignoring the minor losses at channel inlet and outlet, the laminar frictional pressure drop in the channel is written below as Eq. (9) after using the laminar friction factor given by Eq. (7), and after replacing the coolant velocity by mass flow rate using Eq. (8). The parameter C in Eq. (7) is a constant for a given channel cross section, but it depends upon the channel cross section aspect ratio width/thickness, and varies from 57 for aspect ratio 1.0 (square channel) to 96 for an infinite aspect ratio (infinitely wide channel).

$$f = C\,/\,R_e \tag{7}$$

$$W = \bar{\rho}\, A\, V \tag{8}$$

$$\text{Frictional } \Delta p = \frac{\bar{\rho} f L_C V^2}{2D} = \frac{C \bar{\mu} L_C W}{2 \bar{\rho} A D^2} \qquad (9)$$

where

f = Moody friction factor for laminar flow in the channel

R_e = Reynolds number in the channel = $\bar{\rho}$VD/$\bar{\mu}$

A = Flow area of the channel cross section, m^2

D = Equivalent hydraulic diameter of the channel cross section, m

L_C = Total coolant channel length causing frictional pressure drop, m.

V = Coolant velocity averaged over the channel cross section, m/s

W = Coolant mass flow rate in the channel, kg/s

$\bar{\mu}$ = Average coolant dynamic viscosity in the channel, N-s/m^2

μ(T) = Temperature-dependent dynamic viscosity of water, N-s/m^2

μ_0 = $\mu(T_0)$ = Coolant dynamic viscosity at the channel inlet temperature T_0

For the PUR-1 reactor, the temperature dependence of the dynamic viscosity of water over the temperature range 27 °C ≤ T ≤ 50 °C can be approximated as follows.

$$\mu(T) = \mu(T_0)\,(1+T-T_0)^{-\alpha} \qquad (10)$$

where α = 0.12, T_0 = 27 °C, $\mu(T_0) = 0.875 \times 10^{-3}$ N-s/m ^{2}

The average coolant dynamic viscosity $\bar{\mu}$ used in Eq. (9) can be set equal to the viscosity at the average coolant temperature (T_0 + 0.5ΔT) in the channel. Putting this temperature in Eq. (10), the average viscosity $\bar{\mu}$ is found to be

$$\bar{\mu} = \mu(T_0)\,(1+0.5\Delta T)^{-\alpha}. \qquad (11)$$

Equation (11) indicates that the average viscosity $\bar{\mu}$ can be set equal to $\mu(T_0)$ if ΔT is just a few °C (this is the case for the PUR-1 reactor at the operating power of 1 kW). If ΔT is greater than a few °C, i.e., 1 << 0.5ΔT (this is the case for the PUR-1 reactor at an ONB power of about 100 kW), then Eq. (11) simplifies to the following.

$\bar{\mu} = \mu(T_0)(0.5\Delta T)^{-\alpha}$ if $\Delta T >> 2$ °C (12a)

$\bar{\mu} = \mu(T_0)$ if $\Delta T << 2$ °C (12b)

Substituting Eq. (12a) into Eq. (9), the frictional Δp becomes

$$\text{Frictional } \Delta p = \frac{C\mu_0 (\Delta T)^{-\alpha} L_C W}{2^{1-\alpha}\bar{\rho} A D^2} = \frac{C\mu_0 L_C W}{2^{1-\alpha}\bar{\rho} A D^2}\left(\frac{WC_P}{P}\right)^{\alpha} \quad (13)$$

Equating the frictional Δp of Eq. (13) to the buoyancy Δp of Eq. (6) to find the steady-state coolant flow rate W in the channel, one obtains Eq. (14) below. Equation (14) can be rewritten as Eq. (15).

$$\frac{\rho_0 \beta g L P}{2WC_P} = \frac{C\mu_0 L_C W}{2^{1-\alpha}\bar{\rho} A D^2}\left(\frac{WC_P}{P}\right)^{\alpha} \quad (14)$$

$$W^{2+\alpha} = \frac{\rho_0 \bar{\rho} A D^2 \beta g L P^{1+\alpha}}{2^{\alpha} C \mu_0 L_C C_P^{1+\alpha}} \quad (15)$$

Equation (15) relates the fuel plate power to the channel flow rate in natural circulation. It is used to find the dependence of the flow rate on the parameter C in the laminar friction factor (at constant power). All parameters in this equation are constant ($\bar{\rho}$ is also practically constant) except the parameter C in the laminar friction factor. Based on Eq.(15), the relationship between the flow rate W and the parameter C is given by Eq. (16) below.

$$W \propto \left(\frac{1}{C}\right)^{\frac{1}{2+\alpha}} \quad (16)$$

Equation (16) shows that the friction factor parameter C is multiplied by a factor $(FW)^2$, the coolant flow rate W will be reduced by the factor $(FW)^{\frac{2}{2+\alpha}}$. This has been verified by actually running the NATCON code for the PUR-1 reactor. Since α is small (α = 0.12 for the PUR-1 reactor), 2/(2+α) is nearly 1.0, and the flow rate W is reduced approximately by the factor FW.

Bulk Coolant Temperature Rise versus Power of a Fuel Plate

Equation (5) expresses, for laminar natural circulation, the bulk coolant temperature rise in terms of fuel plate power, coolant flow rate and specific heat. Putting the value of flow rate obtained in Eq. (15) into Eq. (5), the bulk coolant temperature rise is given by Eq. (17) below, purely in terms of power and the geometrical dimensions of the channel. The right hand side of Eq. (17) is rearranged into two factors in Eq. (18), such that the second factor is sensitive to power and channel geometrical dimensions that usually have manufacturing tolerances and

measurement uncertainties, and the first factor is insensitive to power and channel geometrical dimensions.

$$\Delta T = \left(\frac{2^{\alpha} C \mu_0 L_C P}{C_P \rho_0 \bar{\rho} A D^2 \beta g L} \right)^{\frac{1}{2+\alpha}} \qquad (17)$$

$$\Delta T = \left(\frac{2^{\alpha} C \mu_0 L_C}{C_P \rho_0 \bar{\rho} \beta g L} \right)^{\frac{1}{2+\alpha}} \left(\frac{P}{A D^2} \right)^{\frac{1}{2+\alpha}} \qquad (18)$$

The nominal flow area and hydraulic diameter of a rectangular coolant channel are given by

$A = t_{nc}\ w_{nc}$ (19)

$P_w = 2\ (t_{nc} + w_{nc})$ (20)

$D = 4\ A/\ P_w = 2\ t_{nc}\ w_{nc}\ /\ (t_{nc} + w_{nc})$ (21)

where

t_c = Channel thickness (spacing between fuel plates), m

t_{nc} = Nominal channel thickness (spacing between fuel plates), m

t_{hc} = Minimum channel thickness in hot channel (spacing between fuel plates), m

w_c = Channel width, assumed not to change from its nominal value, m

P_w = Wetted perimeter of the nominal channel, m

P_{nc} = Power generated in a fuel plate, without applying manufacturing tolerances, W

P_{hc} = Power generated in a fuel plate, after applying manufacturing tolerances, W

Because the channel thickness t_c is much smaller than the channel width w_c in most experimental reactors, Eq. (21) reduces to

$D \approx 2\ t_c$ (22)

Using the channel area and hydraulic diameter given by Eqs. (19) and (22) into Eq. (18), the bulk coolant temperature rise can be written in terms of power, channel thickness, and channel width. This is the desired relationship for use in finding hot channel factors.

$$\Delta T = \left(\frac{2^{\alpha} C \mu_0 L_C}{C_P \rho_0 \bar{\rho} \beta g L} \right)^{\frac{1}{2+\alpha}} \left(\frac{P}{4 w_c t_c^{3}} \right)^{\frac{1}{2+\alpha}} \quad (23)$$

Formulas for Hot Channel Factors

For use in the NATCON version 2.0, six hot channel factors (three global/systemic and three local/random) are obtained from 9 manufacturing tolerances and measurement uncertainties u_1, u_2,.... u_9 that are defined below. These are fractional uncertainties rather than percent. Of these nine uncertainties, those affecting a particular hot channel factor are indicated in Table 1. The systemic hot channel factors are given by Eqs. (24) through (26), and the random hot channel factors are given by Eqs. (27) through (29). A utility Fortran computer program NATCON_HCF and a Microsoft spreadsheet NATCON.HotChanFactors.xls have also been developed to compute the hot channel factors using these formulas.

$$FQ = 1 + u_7 \quad (24)$$

$$FW = 1 + u_8 \quad (25)$$

$$FH = 1 + u_9 \quad (26)$$

The ratio of the power generated in hot plate to its nominal power, caused by the uncertainties in neutronics-computed power and in U-235 mass per plate, can be written as

$$\frac{P_{hc}}{P_{nc}} = (1+u_1)(1+u_2) \quad (27)$$

The ratio of bulk coolant temperature rise in hot channel to the temperature rise in the nominal channel, caused by the uncertainties in neutronics-computed power, U-235 mass per plate, and channel thickness, is obtained from Eq. (23). Only the quantity in the second parentheses is important here because the quantity in the first parentheses is insensitive to these uncertainties.

$$\frac{\Delta T_{hc}}{\Delta T_{nc}} = \left(\frac{P_{hc}}{P_{nc}} \right)^{\frac{1}{2+\alpha}} \left(\frac{t_{nc}}{t_{hc}} \right)^{\frac{3}{2+\alpha}} = (1+u_1)^{\frac{1}{2+\alpha}} (1+u_2)^{\frac{1}{2+\alpha}} \left(\frac{1}{1-u_5} \right)^{\frac{3}{2+\alpha}} \quad (28)$$

The uncertainty in flow distribution is assumed to reduce the channel flow to (1- u_6) times the flow without this uncertainty, and therefore the bulk coolant temperature rise is increased by the factor (1+ u_6). This uncertainty in bulk coolant temperature rise is statistically combined with that given by Eq. (28) to obtain the following formula for the hot channel factor FBULK for input to the NATCON version 2.0.

$$FBULK = 1 + \sqrt{\left\{ (1+u_1)^{\frac{1}{2+\alpha}} (1+u_2)^{\frac{1}{2+\alpha}} \left(\frac{1}{1-u_5} \right)^{\frac{3}{2+\alpha}} - 1 \right\}^2 + u_6^{2}} \quad (29)$$

The temperature drop across coolant film on the cladding surface at an axial location is given by Eq. (30). Here the heat flux q" (W/m^2) on the cladding surface is replaced by t_f q'''/2 in terms of the volumetric power density q''' (W/m^3) in the fuel meat.

$$\Delta T_{film} = \frac{q''}{h} = \frac{t_f\, q'''}{2h} \tag{30}$$

The convective heat transfer coefficient h (W/m^2-C) is given by Eq. (31). Here the laminar Nusselt number N_u is independent of flow rate, and varies only slowly with the aspect ratio (width/thickness) of coolant channel. The main variation of the heat transfer coefficient with channel thickness is due to the denominator of Eq. (31). The numerator of Eq. (31) is considered to be constant.

$$h = \frac{N_u K_{cool}}{D} = \frac{N_u K_{cool}}{2\, t_c} \tag{31}$$

Using Eq. (31) for the heat transfer coefficient, the temperature drop across coolant film can be written as Eq. (32).

$$\Delta T_{film} = \frac{q'''\ t_f\ t_c}{N_u\ K_{cool}} \tag{32}$$

Equation (32) states that ΔT_{film} is directly proportional to the fuel meat thickness (having uncertainty u_3), the channel thickness (having uncertainty u_5), and the power density in meat. The uncertainty in power density is caused by three uncertainties, that is, u_1, u_2 and u_4. Statistically combining these five uncertainties gives the following formula for the hot channel factor FFILM for input to the NATCON version 2.0.

$$\text{FFILM} = 1 + \sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_5^2} \tag{33}$$

The uncertainty in the heat flux at the cladding surface is included in the hot channel factor FFILM given by Eq. (33). A hot channel factor FFLUX for the heat flux alone can be found from Eq. (34) for heat flux in terms of the power density q''' in the fuel meat and the thickness of the meat. The fractional uncertainty in heat flux is the sum of fractional uncertainties in power density and meat thickness, as given by Eq. (35).

$$q'' = \frac{q''' t_f}{2} \tag{34}$$

$$\frac{\delta q''}{q''} = \frac{\delta q'''}{q'''} + \frac{\delta t_{fuel}}{t_{fuel}} \tag{35}$$

In Eq. (35), the uncertainty in power density is caused by three uncertainties, that is, u_1, u_2 and u_4. The uncertainty in the meat thickness is given by u_3. Statistically combining these four uncertainties gives the following formula for the hot channel factor FFLUX for input to the NATCON version 2.0.

FFLUX = $1+\sqrt{u_1^2+u_2^2+u_3^2+u_4^2}$ (36)

The uncertainty in the temperature drop ΔT_{metal} from fuel meat centerline to cladding surface is not important in the case of the PUR-1 reactor because ΔT_{metal} is very small compared to ΔT_{film}. For example, ΔT_{metal} is 0.05 °C and ΔT_{film} is 34.5 °C at 100 kW without any hot channel factors.

Table A2-1. Uncertainties Included in the Six Hot Channel Factors Used in NATCON Version 2.0 (X implies that an uncertainty affects a hot channel factor)

	Uncertainty Fraction	FQ	FW	FH	FBULK	FFILM	FFLUX
Local or random uncertainties							
1	Neutronics calculation of power in a plate, u_1				X	X	X
2	U-235 mass per plate, u_2				X	X	X
3	Local fuel meat thickness, u_3					X	X
4	U-235 axial homogeneity, u_4					X	X
5	Coolant channel thickness, u_5				X	X	
6	Flow distribution among channels, u_6				X	X	
System-wide uncertainties							
7	Reactor power measurement uncertainty, u_7	X					
8	Flow uncertainty due to uncertainty in friction		X				

	factor, u_8						
9	Heat transfer coefficient uncertainty due to uncertainty in Nu number correlation, u_9			X			

The following information was presented as answers to Requests for Additional Information (RAIs) during the conversion process. This information is not presented in the SAR chapters on thermal hydraulics.

Question 28

28. Appendix 1. From the information in Appendix 1 it is not clear how insignificant are the channel inlet and outlet losses when compared to the wall shear. Please clarify.

Response:

The information in Appendix 1 was used only to obtain hot channel factors for input to a more detailed thermal-hydraulic calculation using the NATCON code [Ref. 8 of the conversion proposal]. Therefore, Appendix 1 is a simplified modeling of what is calculated in detail in NATCON, and it is used only for the purpose of obtaining closed-form equations from which hot channel factors could be found. Appendix 1 does not include the minor losses. The minor losses calculated by NATCON are reported below, and found to be about 16% of the total frictional pressure drop in the HEU core, and 14% of the total frictional pressure drop in the LEU core (see Table Q27-1).

The pressure drop due to inlet and outlet losses were calculated (by the NATCON code) using loss coefficients of 0.5 and 1.0 respectively. The pressure drop due to wall shear along the channel length is found by summing the pressure drop for each axial mesh which is calculated using temperature-dependent coolant viscosity and density for the axial mesh (14 mesh intervals were used over the channel length in all calculations). The pressure drops are calculated by NATCON assuming fully developed laminar flow in a rectangular cross-section channel, and then multiplied by a factor FW^2 (FW squared) where FW is an input which may be used to account for the increased pressure drop due to hydrodynamically developing laminar flow. In the calculations presented in the conversion proposal, FW was always set to 1.0, and thus the increased pressure drop due to developing laminar flow was not included. It is included in the calculations presented here (Table Q27-1). The method used is described below.

For the most limiting fuel plate in Table 4-27 of the conversion proposal for each core (HEU and LEU), a comparison of the pressure drops due to inlet plus outlet loss and wall shear, with and without the effect of developing laminar flow, are tabulated in Table Q27-1.

NATCON calculates the Darcy-Weisbach friction factor $f = C/Re$ for laminar flow, using a built-in table of the parameter C for different aspect ratios of the rectangular channel cross section

(values of parameter C are given in the response to Question number 29). An apparent value of the parameter C averaged over the channel length, called C_{app}, was calculated using Eq. (576) of Shah and London [Ref. 2 listed at the end of all responses] to account for the increased pressure drop due to hydrodynamically developing laminar flow in the channel. The ratio C_{app}/C was found to be 1.1105 for the 207 mil HEU channel, 1.0985 for the 197 mil LEU channel. Since the NATCON code multiplies the fully developed friction factor by FW^2 as mentioned above, the input FW equals 1.054 and 1.048 for the HEU and LEU channels respectively. NATCON calculations were done using these values of FW, and the pressure drops due to inlet plus outlet loss and wall shear are compared in Table Q27-1 (column B for the HEU channel, and column F for the LEU channel).

Table Q27-1 shows that the pressure drops due to wall shear and minor losses are 84% and 16%, respectively, of the total pressure drop in the HEU channel at its ONB power; and the pressure drops due to wall shear and inlet plus outlet loss are 86% and 14%, respectively, of the total pressure drop in the LEU channel at its ONB power.

Question 29

29. Appendix 1. From the information in Appendix 1 it is not clear what is the functional dependency of the laminar friction parameter C to the channel cross-section dimensions. Provide a reference for the evaluation of C.

Response:

The following values (rows 1 and 2 of Table Q29-1) of the parameter C for fully developed laminar flow in a channel of *rectangular cross section* versus the width-to-thickness aspect ratio (w_c/t_c) of the channel are used in the NATCON code that was used in the thermal-hydraulics calculations. The table starts from the square cross section (aspect ratio = 1.0) and goes to the infinite value of the aspect ratio (parallel plates). In order to find the parameter C for the aspect ratio of the PUR-1 reactor, the NATCON code simply interpolates between the tabulated values. The original author of the code obtained these values from an old Reference [E. R. G. Eckert and T. F. Irvine, Heat Transfer Laboratory, University of Minnesota (1957)] but these values are also given in a textbook by Frank Incropera [Ref. 3]. These values are obtained from the closed-form analytical solution for the fully developed laminar velocity distribution in a rectangular channel summarized by R. K. Shah and A. L. London [Ref. 2]. Equation (341) in [Ref. 2] is a fitted equation to easily find the parameter C. It should be noted that the aspect ratio used in [Ref. 2] is channel thickness-to-width ratio (the reciprocal of that used in NATCON and shown below in Table A2-2), and the friction factor in [Ref. 2] should be multiplied by 4 to get the Darcy-Weisbach friction factor that is used in NATCON and tabulated below.

Table A2-2. Friction Parameter C Used in the NATCON Code

w_c/t_c	1.0	2.0	3.0	4.0	5.0	6.3	8.0	11.0	15.0	18.0	100.0
C in NATCON	58.0	63.0	69.0	72.5	77.0	80.0	83.0	85.0	88.0	89.0	96.0

C in Ref. 3	57.0	62.0	69.0	73.0			82.0				96.0
C in Ref. 2	56.9	62.2	68.4	72.9	76.3	79.5	82.4	85.6	88.1	89.3	94.7

Question 30

30. Appendix 1. From the information in Appendix 1 in both the calculation of the channel flow and the calculation of the bulk coolant temperature rise the ratio of the coolant kinematic viscosity to density (μ/ρ) was assumed to be insensitive to temperature. Please demonstrate the validity of this assumption.

Response:

The information in Appendix 1 was used only to obtain hot channel factors for input to a more detailed thermal-hydraulic calculation using the NATCON code [Ref. 8 of the conversion proposal]. NATCON does account for the temperature dependence of coolant viscosity and density in the calculation of the channel flow and the calculation of the bulk coolant temperature rise. Therefore, Appendix 1 is a simplified modeling of what is calculated in detail in NATCON, for the purpose of obtaining closed-form equations from which hot channel factors could be found.

As suggested in the question, water viscosity is temperature-dependent, i.e., it decreases with rising temperature. Appendix 1 was revised to account for the effect of temperature dependence of viscosity on hot channel factors, and the revised Appendix 1 is enclosed herewith. The temperature dependence of the dynamic viscosity of water over the temperature range 27 °C ≤ T ≤ 50 °C (adequate for the PUR-1 reactor) can be written as follows.

$$\mu(T) = \mu(T_0)\,(1+T-T_0)^{-\alpha} \quad \text{(A1)}$$

where $\alpha = 0.12$

T_0 = 27 °C = Pool temperature of PUR-1

$\mu(T_0) = 0.875\text{x}10^{-3}$ N-s/m^2

$\mu(T)$ = Temperature-dependent dynamic viscosity of water, N-s/m^2

As shown in the revised Appendix 1, the revised relationship between the flow rate W in a channel and the friction parameter C is given by Eq. (A2). The revised formula for hot channel factor FBULK for bulk coolant temperature rise is given by Eq. (A3).

$$W \propto \left(\frac{1}{C}\right)^{\frac{1}{2+\alpha}} \quad \text{(A2)}$$

$$\text{FBULK} = 1 + \sqrt{\left\{(1+u_1)^{\frac{1}{2+\alpha}}(1+u_2)^{\frac{1}{2+\alpha}}\left(\frac{1}{1-u_5}\right)^{\frac{3}{2+\alpha}} - 1\right\}^2 + u_6^2} \quad \text{(A3)}$$

The exponent on the right hand side of Eq. (A2) changed from 0.5 (in the conversion proposal ignoring temperature dependence of µ) to the revised value 1/2.12 = 0.4717. There exponents in Eq. (A3) for FBULK also changed, e.g., from 3/2 to 3/2.12 = 1.415. As a result of this revision, the hot channel factor FBULK decreased from 1.312 (in the conversion proposal) to 1.301 for the most limiting fuel plate 262 in the HEU core. Similarly, FBULK decreased from 1.321 (in the conversion proposal) to 1.308 for the most limiting fuel plate 1348 in the LEU core. The effect of ignoring the temperature dependence of viscosity is conservative.

NATCON calculations were done with these revised values of FBULK along with a value of FW > 1.0 to account for the increased friction due to developing laminar flow (in response to Question number 33). The results are shown in Table Q27-1 (column C for the HEU core, and column G for the LEU core).

As a consequence of the two effects (i.e., increased friction due to developing laminar flow and the temperature dependence of viscosity) on hot channel factors FW and FBULK, the ONB power of the HEU core changes from 76.3 kW (reported in the conversion proposal) to 75.9 kW, and the ONB power of the LEU core changes from 96.1 kW (reported in the conversion proposal) to 95.8 kW. The effect is small for the PUR-1 reactor.

Question 32

32. Appendix 1. Equation (30) has two terms and the conversion proposal states that the expression within the parenthesis on the right hand side of the equation varies slowly compared to the heat flux t_{fuel} q'''/2. Demonstrate the validity of the statement with reference to the PUR-1 fuel plate.

Response:

Equation (30) of Appendix 1 is for finding a hot channel factor for the temperature drop from the meat mid-plane to cladding surface (ΔT_{metal}). This temperature drop is very small compared to the temperature drop from the cladding surface to bulk coolant (ΔT_{film}). For example, in the PUR-1 HEU fuel plate 262 without hot channel factors, ΔT_{metal} is 0.07 °C and ΔT_{film} is 46.98 °C (at meat mid-height) at a high power of 100 kW. Similarly, in the PUR-1 LEU fuel plate 1348 without hot channel factors, ΔT_{metal} is 0.05 °C and ΔT_{film} is 34.5 °C at a power of 100 kW. Therefore, the hot channel factor for ΔT_{metal} is not important for PUR-1. The important hot channel factor is the factor FFILM for ΔT_{film}. In the case of PUR-1, ΔT_{film} is the bigger component (bigger than the bulk coolant temperature rise) in the total temperature rise from the inlet temperature to the cladding surface temperature at the axial level experiencing the onset of nucleate boiling. The hot channel factor FFILM found by Eq. (29) of Appendix 1 in the conversion proposal remains unchanged. It depends on the uncertainties in q'''t_{fuel} and channel thickness (as shown in Eq. 28), but not on the uncertainty in $[t_{fuel}/(4K_{fuel}) + t_{clad}/K_{clad}]$.

In short, PUR-1 is not limited by the fuel peak temperature, but by the onset of nucleate boiling, and the uncertainty in $[t_{fuel}/(4K_{fuel}) + t_{clad}/K_{clad}]$ is not important for PUR-1. We believe that the hot channel factor FFILM has been determined accurately.

Question 33

33. Section 4.7.2. According to Appendix 1 the systematic uncertainty in flow rate is accounted for by applying the hot channel factor Fw to the laminar friction factor C. Explain the reason for the value of the flow friction factor Fw being unity in Tables 4-25 and 4-26.

Response:

As suggested in the question, a value of FW (hot channel factor for flow) greater than 1.0 should be used to account for the increased frictional pressure drop due to the hydrodynamically developing laminar flow in the entrance region of the coolant channel, otherwise the code (NATCON) accounts only for the fully developed frictional pressure drop. This has been done now and the results are presented in Table Q27-1. Since each coolant channel creates its own buoyancy to drive its own coolant flow, there is no uncertainty due to *redistribution* of a total reactor flow rate. The loss coefficients of 0.5 and 1.0 at channel inlet and outlet are used in the calculations. To account for the reduction in flow rate due to the hydrodynamically developing laminar flow in the channel, the values of FW were calculated for the most limiting channels in the HEU and LEU cores as follows.

NATCON calculates the Darcy-Weisbach friction factor f = C/Re using a built-in table of the parameter C for different aspect ratios of the rectangular channel cross section (values of parameter C are given in the answer to Question number 29). These values of parameter C are for the fully developed laminar flow in a rectangular cross-section channel. An apparent value of the parameter C averaged over the channel length, called C_{app}, was calculated using Eq. (576) of Shah and London [Ref. 2] to account for the increased pressure drop due to hydrodynamically developing laminar flow in the channel. The ratio C_{app}/C was found to be 1.1105 for the 207 mil HEU channel, and 1.0985 for the 197 mil LEU channel. Since the NATCON code multiplies the fully developed frictional factor by FW^2, the input FW equals 1.054 and 1.048 for the HEU and LEU channels respectively. The flow reduction factor is input factor FW or more accurately $FW^{2/(2+\alpha)} = FW^{0.9434}$ (noting that α = 0.12 for the PUR-1 reactor as mentioned in the revised Appendix 1 enclosed herewith).

The results of using these values of FW in NATCON calculations (excluding the effect of temperature dependence of μ on hot channel factors) are shown in Table Q27-1. The ONB power of the HEU core changes to 75.8 kW from 76.3 kW reported in the conversion proposal. The ONB power of the LEU core changes to 95.7 kW from 96.1 kW reported in the conversion proposal.

The channel flow indeed gets reduced by the factor $FW^{0.9434}$ as expected. For the HEU plate 262, the flow reduces from 0.02083 kg/s to 0.01989 kg/s (see Table Q27-1) when the input hot channel factor FW is changed from 1.0 to 1.054. The expected reduced flow should be $0.02083/(1.054)^{0.9434}$ = 0.01982 kg/s which is close to the NATCON-calculated value of 0.01989 kg/s. For the LEU plate 1348, the flow reduces from 0.01912 kg/s to 0.01834 kg/s (see Table Q27-1) when the input FW is changed from 1.0 to 1.048. The expected reduced flow should be $0.01912/(1.048)^{0.9434}$ = 0.01829 kg/s which is close to the NATCON-calculated value of 0.01834 kg/s.

Question 36

36. Table 4-28. Define the parameter "margin to incipient boiling."

Response:

The margin to incipient boiling shown in Table 4-28 was calculated at the nominal operating power of PUR-1 (i.e., 1 kW), and it is the smallest value of the temperature difference (T_{ONB} - T_w) over the coolant channel length in the hottest channel where T_W is cladding surface temperature with all hot channel factors applied, and T_{ONB} is the local onset-of-nucleate-boiling temperature. This basically gives an idea of how far below the onset of nucleate boiling condition the reactor is operating. This definition can be written as an equation as follows:

Margin to ONB = Minimum $T_{incp}(p, q''(z)F_{flux}) - \left[F_{bulk}\left\{T(z) - T_0\right\} + F_{film}\left\{T_{wall}(z) - T(z)\right\}\right]$

where

$T(z)$	= Bulk coolant temperature at axial position z in the channel heated by the plate power of $P_{op}F_r$ F_Q/N and applying the global hot channel factors for flow and Nusselt number of F_w and F_h
$T_{wall}(z)$	= Cladding surface temperature at axial position z in the channel heated by a plate power of $P_{op}F_r$ F_Q/N and applying the global hot channel factors for flow and Nusselt number of F_w and F_h
$q''(z)$	= Heat flux at position z for the plate power of $P_{op}F_r$ F_Q/N and applying the global hot channel factors for flow and Nusselt number of F_w and F_h
$p(z)$	= Absolute pressure in the channel at axial position z
$T_{incp}(p(z), q''(z)F_{flux})$	= Onset of nucleate boiling temperature at absolute pressure p(z) and heat flux $q''(z)F_{flux}$
P_{op}	= Operating power of the reactor (e.g., 1 kW for PUR-1)
N	= Number of fuel plates in the core (e.g., 190 for PUR-1 LEU core)
T_0	= Coolant temperature at the channel inlet
F_r	= RPEAK = Radial power factor of the plate cooled by the channel
F_W	= Hot channel factor for flow in the channel
F_Q	= Hot channel factor for reactor power
F_h	= Hot channel factor for Nusselt number
F_{film}	= FFILM = Hot channel factor for temperature drop across the coolant film on cladding surface
F_{flux}	= FFLUX = Hot channel factor for heat flux
F_{bulk}	= FBULK = Hot channel factor for bulk coolant temperature rise in the channel

APPENDIX 3: FUEL SPECIFICATIONS

Pages Appendix 3-2 through Appendix 3-62 are the specification document *Specification for Purdue University Standard and Control Fuel Elements – Assembled for the Purdue University Reactor, Idaho National Laboratory*, SPC-382, Rev 1, January 27, 2007..

Pages Appendix 3-63 through Appendix 3-84 are engineering drawings of the PUR-1 fuel assemblies.

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Specification

Specification for Purdue University Standard and Control Fuel Elements - Assembled for the Purdue University Reactor

Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance.

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	05/31/06	All	New Document.
1	01/24/07	All	Revised to add Program Anneal requirements and update Drawing Titles

CONTENTS

FIGURES

1. SUMMARY

1.1 General

This *specification* (see def.) defines the materials, components, testing, inspection, certain processes, *quality control* (see def.) requirements and acceptance criteria for the fabrication of standard and control *fuel elements* (see def.) and fuel element containers for the Purdue University Reactor at Purdue University at West Lafayette, Indiana.

2. APPLICABLE CODES, PROCEDURES, AND REFERENCES

2.1 Standards, Specifications, Drawings and Attachments

The applicable portions of the following documents as defined herein, form a part of this specification. Where there is a conflict between the documents cited and the latest revision thereof, the *supplier* (see def.) shall notify the *purchaser* (see def.) of the conflict and use the latest revision in effect at the signing of the contract, unless otherwise directed by the purchaser.

2.1.1 Specifications and Standards

National Codes and Standards	
ASTM E 1742-00	Standard Practice for Radiograph Examination
ASTM E 1417-99	Standard Practice for Liquid Penetrant Examination
MIL-C-45662	Calibration System Requirements
RDT F6-2T	Welding of Reactor Core Components, Sections 1,2,3 and 6
American Society for Testing and Materials (ASTM)	
ASTM B 209-00	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B 210-04	Aluminum and Aluminum-Alloy Drawn Seamless Tubes
ASTM B 211-00	Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod and Wire
ASTM B 214-99	Standard Test Method for Sieve Analysis of Granular Metal Powders
ASTM B 221-00	Standard Specification for Aluminum

	and Aluminum-Alloy Extruded Bars, Rods, Wires, Profiles and Tubes
ASTM B 241-02	Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
ASTM E 8-00	Methods of Tension Testing of Metallic Materials
ASTM E 29-93a (1999)	Recommended Practice for Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values
ASTM E 2016-99	Standard Specification for Industrial Woven Wire Cloth

American Welding Society (AWS)

AWS A5.10-1995	Aluminum and Aluminum Alloy Welding Rod and Bare Electrodes

American National Standards Institute (ANSI)

ANSI B46.1-1994	Surface Texture
ANSI Y14.5-1994	Dimensioning and Tolerancing for Engineering Drawings

American Society of Mechanical Engineers (ASME)

ASME Section V – 2001, without addendum	Boiler and Pressure Vessel Code Section V
ASME Section IX - 2001	Boiler and Pressure Vessel Code Section IX
ASME NQA-1-1997	Quality Assurance Requirements for Nuclear Facility Applications

Idaho National Laboratory (INL)

TRTR-11	Specification for Low Enriched Uranium Metal in Test Reactor Fuel
TRTR-14	Specification for Reactor Grade Low Enriched Uranium Silicide Fuel Powder
IN-F-4-TRA	Specification for Aluminum Powder for Matrix Material in Test Reactor Fuel
STD 7022A	Cleanliness Acceptance Levels for Nuclear or Non-Nuclear Service Components

American Society for Nondestructive Test (ASNT)

SNT-TC-1A (1996 or later)	American Society For Nondestructive Testing (ASNT) Recommended Practice

2.1.2 Drawings (INL)

635454	Purdue University Test Research and Training Reactor Graphite Reflector Assembly and Source Drive Assembly
635455	Purdue University Test Research and Training Reactor Standard Fuel, Partial, & Dummy Element Assemblies
635456	Purdue University Test Research and Training Reactor Control Fuel Element Assembly and Dummy Control Fuel Element Assembly
635457	Purdue University Test Research and Training Reactor Fission Chamber Fuel Element Assembly
635458	Purdue University Test Research and Training Reactor Standard Fuel Container Assembly
635459	Purdue University Test Research and Training Reactor Control Fuel Container Assembly
635460	Purdue University Test Research and Training Reactor Irradiation Facility Assembly
635461	Purdue University Test Research and Training Reactor Capsule Holder and Capsule Insert Assemblies and Details
635462	Purdue University Test Research and Training Reactor Graphite Container Assembly, and Source Drive Container Assembly
635463	Purdue University Test Research and Training Reactor Fuel Plate Assembly and Dummy Fuel Plate Detail
635464	Purdue University Test Research and Training Reactor Container Tube Assembly and Details
635465	Purdue University Test Research and

	Training Reactor Graphite Block Detail And Graphite Capsule Holder Detail
635466	Purdue University Test Research and Training Reactor Miscellaneous Details
635467	Purdue University Test Research and Training Reactor Source Drive Nozzle Assembly and Source Drive Top
635468	Purdue University Test Research and Training Reactor Nozzle Preliminary Machined and Fission Chamber Top

3. TECHNICAL REQUIREMENTS

3.1 Production Qualification

The supplier is required to qualify the processes or portions of the process or be exempt from same by written approval of the purchaser. In *qualification* (see def.), only materials that comply with this specification shall be used. Qualification processes, equipment, and operator qualification/training programs shall be identical to those used during *production* (see def.). To qualify, the supplier must demonstrate, to the satisfaction of the purchaser, that the process is capable of producing a product, which satisfies all the requirements of the specifications. Assembly of production fuel elements shall not be initiated until: (1) all required data, to assure compliance with the qualification requirements, has been submitted to the purchaser; (2) data and records required by Section 6.3 have been submitted; and (3) written approval of qualification has been received by the supplier from the purchaser.

3.1.1 <u>Fuel Plate Qualification</u>:

Fuel plate (see def.) qualification shall be satisfied by supplier production of a minimum of two consecutively produced plate *lots* (see def.), in lot quantities of 24 *plates* (see def.). The plates shall be made using low enriched uranium in the form of *Silicide* (see def.) powder, which have a yield of no less than 65% acceptable fuel plates meeting all applicable requirements of this specification. The supplier may combine the results of two consecutive lots into a production run in determining the 65% yield requirement provided that there have been no changes in the *manufacturing* (see def.) *procedure* (see def.) between lots which would require *requalification* (see def.) in accordance with Section 3.1.3.

In the event that fuel plate qualification has been performed by the supplier meeting all the requirements of this specification during the past twelve months, and qualified operators are performing the fabrication, fuel plate qualification requirements listed above will be waived.

Fuel plates made in *development* (see def.) (prior to and including qualification runs that fail to meet the 65% yield requirements) will not be used in fabricating production fuel elements without prior approval of the purchaser.

3.1.2 Fuel Element Qualification:

The supplier shall fabricate 1 *dummy standard fuel element assembly* (see def.), which shall meet the requirements of this specification.

3.1.3 Requalification:

The supplier shall notify the purchaser of any proposed process change. A changed process may not be used in production until the supplier has met all the requirements of Section 3.1.3, submits the results and data of the requalification effort, and receives written approval from the purchaser.

Requalification for any fuel plate attribute to the requirements of the specification will be required when the processes, materials, fuel loadings, equipment or equipment operators (welding and rolling) which have been previously qualified are changed, unless the supplier can demonstrate to the satisfaction of the purchaser by engineering explanation or proof test that such changes will have no detrimental effect on the product.

Requalification for compacting, *pack* (see def.) assembly, and rolling mill operators can be less than qualification basis, since the procedure has already been established. Candidate operators who are not qualified for compacting operations, pack assembly operations, and hot/cold rolling mill operations must demonstrate their abilities in performing the individual operations they are assigned.

An operator must qualify by processing two lots of fuel plates with minimum lot size of 24, for the operation he is assigned to qualify, before performing any production operation independently. Each lot of fuel plates shall be processed through final inspection, with a minimum yield rate of 90% acceptable fuel plates required for the operator to be termed qualified.

NOTE: *Failure of an operator to qualify, because of fuel plate deviations, must be based on deviations related to the operation being qualified. The purchaser on a case-by-case basis will determine the quantities and sizes of requalification fuel plates selected to be destructively examined.*

3.1.4 Operator Qualification:

Operator qualification will be accomplished via an approved supplier internal qualification program for the following operations:

A. Arc melting

B. Compacting

C. Pack assembly

D. Hot rolling

E. Cold rolling

F. Final machining.

3.1.4.1 In addition to the operations specified above, the supplier shall also show evidence of the training and competency of those individuals who perform any of the following fuel element fabrication and inspection activities:

A. Powder sieving, weighing, and testing

B. Compact weighing, visual and dimensional inspection

C. Fuel plate/element and component cleaning

D. Fuel plate annealing operations

E. Dimensional inspection of plates, elements, and subcomponents

F. Metallographic sample preparation and inspection

G. Visual inspection of plates, elements, and subcomponents

H. Void volume inspection

I. Fluoroscope inspection of fuel plates

J. Radiography and inspection of fuel plate radiographs

K. Ultrasonic testing and interpretation.

The individuals performing these operations shall have specific requirements imposed on them that will demonstrate their knowledge and ability to perform their respective assignments. Documented evidence of the training of these individuals shall be maintained and shall be made available to the purchaser upon request.

3.2 Materials

The material requirements for the components comprising the fuel element are as specified on Drawings per Section 2.1.2 and requirements of this section.

3.2.1 Fuel Bearing Plates

3.2.1.1 Fuel Cores: The *fuel cores* (see def.) of the fuel plates shall be uranium silicide powder dispersed in aluminum alloy powder which meet the requirements of IN-F-4-TRA and TRTR-14, per Section 2.1.1 of this specification.

3.2.1.2 Frames and Covers: Aluminum for the frames and cover plates shall conform to ASTM B209, Alloy 6061-O. The aluminum plate stock used for frame and cover plates shall be certified by the supplier to contain less than 30 PPM boron, 80 PPM cadmium, and 80 PPM lithium.

The subcontractor shall furnish certified physical properties and chemical analyses of ingots or plates of the 6061 materials to INL.

3.2.2 Aluminum Weld Filler Metal:

All aluminum weld filler metal shall be ER4043 as required by Specification AWS A5.10-1995.

3.2.3 Dummy (Non-Fueled) Plate:

Dummy (non-fueled) plates (see def.) shall be fabricated from aluminum Type 6061-O, that meets the requirements of Section 3.2.1.2.

3.2.4 Material Requirements

All material used or contained in the product shall comply with all the requirements of this specification and Drawings per Section 2.1.2 unless exempted by written document by the purchaser.

3.3 Mechanical Requirements

3.3.1 Fuel Plate Requirements

3.3.1.1 Fabrication: The supplier shall furnish the details of his fuel plate rolling schedule and component cleaning process to the purchaser for approval prior to use in production per 6.3.1.

Compacting details shall include silicide – aluminum compacting pressure and compacting press dwell time.

After hot rolling, each fuel plate shall be blister annealed per Section 4.6.1 and then cold rolled to final thickness at room temperature. After cold rolling operation, the fuel plates shall be subjected to program annealing. The rolling schedule shall contain, at a minimum, the following:

A. Nominal plate reduction

B. Minimum number of hot roll passes

C. Nominal inter-pass reduction and target thickness

D. Hot rolling furnace temperature

E. Preheat time for all hot roll passes

F. Final hot roll plate thickness

G. Type and frequency of roll lubricant utilized

H. Nominal cold roll reduction.

I. Final cold roll thickness.

Fuel plate *cladding* (see def.) thickness required by Section 3.3.1.4 and fuel core homogeneity requirements of Section 4.4 are independent requirements that must be met.

3.3.1.2 Core Configuration: No fuel particles are allowed within the fuel free zones located at the ends of the plates as shown on Drawing 635463.

The nominally unfueled area of each fuel plate as defined by Drawing 635463 may contain random fuel particles defined as flaking and limited in size, location, and spacing per this Section, as determined by Section 4.5.

The presence of fuel particles detected between the maximum fuel core outline and fuel plate edges and ends is allowed provided they do not violate the following restrictions:

— One or more fuel particles, which fit in a rectangle whose area is not more than $4x10^{-4}$ in^2 is acceptable

AND

— The fuel particle(s) are no closer than 0.080 in. to any other particle edge to edge

AND

— No particle is closer to the plate edge or end than the major dimension of the particle.

Stray fuel particles (see def.) that violate the above requirements may be removed from fuel plate edges by filing, provided the following:

— The filed out area is no deeper into the edge of the plate than 0.050 in., no longer than 0.250 in.

AND

— Each filed area is at least 1.0 in. apart

Filing of fuel plate ends, for the removal of stray particles, is not allowed, unless previously approved by the purchaser.

3.3.1.3 Internal Defects and Bond Integrity: Metallurgical bond, as determined by Section 4.6 is required at interface areas of the finished fuel plates, specifically fuel core-to-clad and clad-to-frame. The presence of grain growth across the fuel

matrix-cladding interface and across the aluminum frame-cladding interface of at least 50% is required. Fuel core defects in excess of 0.06 in. in any dimension as determined by Section 4.7 are not allowed.

3.3.1.4 Cladding Thickness: During production, all plates will be subjected to UT min-clad inspection. The standard will be calibrated at the nominal 0.008-inch scan depth. The gage will then be adjusted to a 0.010 inch scanning depth and the fuel plates will be scanned at 0.010 inch. Fuel plate UT traces, which display min-clad indications at the 0.010-inch depth, shall be visually compared with the 0.008-inch Standard trace. Fuel plates for which the UT reports show a comparable density of indications, or worse, than the indications displayed on the standard UT report are unacceptable. Fuel plates, which fail the 0.010-inch UT scan, shall be rescanned at 0.008 inch. Only fuel plates which are acceptable when rescanned at 0.008 inch shall be submitted to the Purchaser and User for evaluation.

3.3.2 Non-fueled (dummy) plates:

The supplier shall use a cold rolling method to obtain plate thickness. Non-fueled (dummy) plates shall be subjected to program anneal.

3.3.3 Fuel Element Requirements

3.3.3.1 Welding: All welding shall be performed using procedures and welding personnel qualified in accordance with ASME Section IX or the criteria defined in Appendix B. Quality acceptance of production welds shall be in accordance with Appendix B, Section 5.

3.4 Physical Properties

Fuel plates shall have a core of U_3Si_2 and aluminum and completed fuel plates and fuel elements shall have fuel loadings per Sections 3.4.1.2, and 3.4.1.5.

3.4.1 Fuel Plate Requirements

3.4.1.1 Fuel Core: The fuel core shall consist of 19.75 ☚0.2 weight % enriched uranium silicide powder dispersed in aluminum powder. The uranium silicide powder shall be -100, +325 U.S. standard mesh particles. However, a blend may

contain up to 35 weight percent of -325 U.S. standard mesh particles. Any powder particles greater than 100 mesh particles shall be reground such that they will go thru the 100 mesh sieve. The fuel core shall be fabricated according to standard powder-metallurgical and roll-bonding techniques. The supplier shall provide to the purchaser, a written procedure for pack assembly and the initial rolling step which describes the method used to prevent excessive oxidation that causes non-bond of fuel core to the cladding.

3.4.1.2 Fuel Loading: By using the approved supplier's method of assigning U-235 content, per a detailed description as to the weighing procedure by which the supplier proposes to assign fuel plate U-235 content. Each fuel plate shall contain 12.5 ☚0.35 grams U-235. The weight of each core shall be measured and recorded to within 0.01 gram U-235 based upon weight of the final compact and chemical and isotopic analysis of the constituents.

3.4.1.3 Fuel Homogeneity: Fuel homogeneity requirements are located in section 4.4.

3.4.1.4 Void Volume: In the qualification process, all fuel plates shall be inspected for void volume using the method described in Section 4.2. The percent voids in the fuel cores of all fuel plates shall be determined by the inspection procedure developed by the supplier. The percent voids in the fuel cores shall be at least 3.0% and not more than 11.0%.

3.4.1.5 Fuel Element Requirements

3.4.1.6 Fuel Loading: Assigned fuel loading for each fuel element shall be 175.00☚4.90 grams of U-235. Each Control Fuel Element shall contain 100 ☚2.80 grams of U-235. Control limits for the method used to measure this weight are established at the 95% confidence level for a significant population of measurements of a particular standard. The U-235 enrichment shall be 19.75 ☚0.2 weight % of total uranium per specification TRTR-11.

3.5 Surface Condition

Fuel plates and completed fuel elements must comply with the surface condition requirements of Section 3.5.1, 3.5.2, and 3.5.3 and drawings of Section 2.1.2, per ANSI B46.1. Sanding, or any other finishing procedure that will smear the aluminum surface, will not be allowed on fuel plates unless approved by the purchaser.

3.5.1 Surface Defects

3.5.1.1 Compliance with surface finish and defect requirements shall be established by 100% visual inspection of all fuel plates and elements. The surface of the finished fuel plates shall be smooth and free of gouges, scratches, pits, or removal of metal in excess of 0.005 inch in depth. Dents in the fuel plate shall not exceed 0.012 inch in depth or 0.25 inch in diameter. If there is evidence of dogboning in the plates, surface defects in the *dogbone* (see def.) area shall not exceed 0.003 inch in depth. No degradation of the fuel plates beyond these limits shall be permitted.

3.5.1.2 Fuel Plates shall be free of stringiness, scabs, or cracks. Surface finish shall be as required by Drawing 635463. Compliance with requirements of this section shall be accomplished by visual inspection of all fuel plates and fuel elements.

3.5.1.3 Defects on fuel plate edges or ends are permissible provided they are evaluated and acceptable to the requirements of Paragraph 3.3.1.2.

3.5.1.4 Compliance with surface finish and defect requirements shall be established by 100% visual inspection of all fuel element containers. Fuel element containers shall be free of surface defects such as pits, dents, or scratches in excess of 0.010 inch in depth and 0.12 inch in diameter or equivalent area.

3.5.2 Cleanliness:

The suppliers fabrication, assembly, and storage areas used for the production of Purdue University fuel elements and/or components shall conform to the requirements of *"controlled work area"* (see def.) as defined in Paragraph 1.3.6 of INL Standard 7022A. Cleanliness shall be

in compliance with INL Standard 7022A, Paragraphs 1.1, 1.2.3, 3.1, 3.2-b, d, i, 3.3 - d, e, 4.1.3, 4.2, and 4.3. Freon shall not be used to clean fuel elements or components.

As determined by Section 4.10 of this specification, there shall be no foreign materials on the finished fuel plates or surfaces of the finished fuel elements. All oil, metal chips, turnings, dusts, abrasives and spatter, scale, and other particles shall be removed from the fuel surfaces by procedures which assure that the minimum cladding thickness has not been violated. All components shall be cleaned by a method approved by the purchaser.

3.5.3 Contamination:

The surfaces of each fuel plate shall be counted or smeared and counted for alpha-beta-gamma contamination. The alpha count shall be less than five dpm per 100 cm^2, and the beta-gamma count shall be less than 200 dpm per 100 cm^2.

Each fuel element shall be smeared and counted for radioactive contamination. The alpha count shall be less than five dpm per 100 cm^2, and the beta-gamma count shall be less than 200 dpm per 100 cm^2.

3.6 Marking

NOTE: *All fuel plates, fuel assemblies, and fuel element containers will be marked per this section.*

3.6.1 Fuel Plate Identification:

Each finished fuel plate shall be identified, as shown on Drawing 635463, by a combination of numbers and/or letters that will maintain positive identification relative to the complete traceability to the supplier fabrication history, including the basic material lots, heat or metal, manufacturing cycle, and quality control phases. The identification number shall be stamped, etched or vibro-peened at the location specified by Drawing 635463. The depth of the identification characters shall not exceed 0.010 in.

3.6.2 Fuel Assembly Identification:

Each fuel assembly shall have an identifying number such as 07-XX (07 signifying year of fabrication). The number shall be placed on the container assembly as shown on Drawings 635455, 635456 and 635457.

The identification shall be stamped or entered by a method approved by the purchaser, with two inch block characters not in excess of 0.010 inches in depth. Standard assemblies should be labeled: E2, F2, G2, H2, F3, H3, E4, F4, G4, H4, F5, H5. Control assemblies should be labeled: E3, G3, and E5. The fission chamber assembly should be labeled as G5. The source assembly shall be labeled as C3. The spare Standard Assemblies should be labeled: SP-1, SP-2, SP-3. The spare Control Assembly should be labeled as SP-4.

3.6.3 Dummy Element Identification:

The dummy standard fuel element assembly shall have the identifying number DUM-1. The number shall be placed on the container assembly as shown on Drawing 635455. The identification shall be stamped or entered by a method approved by the purchaser, with two inch block characters not in excess of 0.010 inches in depth.

3.7 Storage

All fuel plates, fuel assemblies, and fuel element containers that have received final cleaning per Section 3.5.2 shall be protected in clean polyethylene containers or other containers approved by the purchaser while (1) awaiting final assembly, (2) being transferred into or being maintained in storage, or (3) being prepared for packaging or shipment. Any material exposed to contamination shall be reinspected to the requirements of Section 3.5.

3.8 Fuel Element Surface Treatment

If boehmite treatment is required during fuel element fabrication, the following shall apply. After fuel elements are assembled and inspected they shall be subjected to an environment that will cause an evenly distributed boehmite layer of 0.00006 to 0.0003 in. thickness (averaged over the surface using eddy current instrumentation) to form on all surfaces of the entire assembly. The treatment process shall be performed under controlled conditions, which shall require the supplier to maintain a record of the thermal history of the autoclave. The records shall include heat charts of recorded time and temperature. Documented evidence of the controls placed on the autoclave shall be maintained by the supplier.

3.8.1 After the boehmite process has been qualified, one fuel element from every 2nd autoclave run shall be inspected following a procedure approved by the Purchaser.

3.8.2 Each fuel element shall have a corresponding aluminum plate coupon, made from fuel plate end crops, placed near the fuel element during the boehmite formation process. The aluminum plate coupon shall be subjected to the same environment as the fuel elements and each coupon measured for boehmite thickness.

3.8.3 Fuel elements and aluminum plate coupons subjected to the boehmite formation process must be carefully handled to preclude scratches, dents, and gouges that would cause removal of boehmite.

3.9 Graphite Reflectors and Graphite Radiation Baskets

Graphite reflector assemblies (see def.) and *irradiation facility assemblies* (see def.) shall be fabricated as per requirements contained in this section and in drawings 635454, 635460, 635461, and 635465.

3.9.1 Material:

All materials used shall comply with all the requirements of this specification and applicable drawings.

3.9.2 Assembly:

The assembly of the graphite reflector assemblies and irradiation facility assemblies shall be as shown on the applicable drawings.

3.9.3 Welding:

All welding shall be performed using procedures and welding personnel qualified in accordance with ASME Section IX or the criteria defined in Appendix B. Quality acceptance of production welds shall be in accordance with Appendix B, Section 5.

3.9.4 Identification:

The graphite reflector assemblies shall have identifying numbers such as GR-X placed on the side of the assembly as shown drawing 635454. The graphite reflector shall be labeled as follows: D1, D2, D3, D4, D5, E1, F1, G1, H1, I1, I2, I3, I4, and I5. The irradiation facility assemblies shall have identifying numbers such as IF-X placed on the side of the assembly as shown on drawing 635460. The irradiation facility assemblies shall be labeled as follows: D6, E6, F6, G6, H6, and I6. The identification shall be stamped or entered by a method approved by the purchaser, with two inch block not in excess of 0.010 inches in depth.

3.9.5 Dimensional Inspection:

Verification of all external dimensions of the graphite reflector assemblies and irradiation facility assemblies shall be by 100% inspection, in accordance with drawings 635454 and 635460. All dimensions of this specification shall apply at a temperature of 75°F ± 5°.

3.9.6 Surface Finish and Defects:

The graphite reflector assemblies and irradiation facility assemblies shall be free of surface defects such as pits, dents, scratches in excess of 0.010 inch deep and 0.12 inch diameter or equivalent area.

3.9.7 Storage:

All graphite reflector assemblies and irradiation facility assemblies shall have received final cleaning and shall be protected in clean polyethylene containers or other containers approved by the purchaser while (a) being transferred into storage, (b) being maintained in storage, or (c) being prepared for shipment or packaging.

4. QUALITY ASSURANCE

The supplier shall document, implement, and maintain a quality program in compliance with ASME NQA-1-1997.

The supplier shall permit the purchaser to conduct pre-award and continuing evaluation of the Quality Program.

Personnel performing NDE examinations, specifically radiographic, ultrasonic, liquid penetrant, and visual shall be certified to American Society for Nondestructive Testing (ASNT) Number SNT-TC-1A and certification documentation shall be made available to the purchaser.

Unless otherwise specified, the supplier shall be responsible for the performance of all tests and inspections required prior to submission to the purchaser of any fuel element for acceptance. Provided, however, that the performance of such tests and inspections is in addition to, and does not limit, the right of the purchaser to conduct such other tests and inspections as the purchaser deems necessary to assure that all fuel elements are in-conformance with all requirements of this specification. Except as otherwise specified, the supplier may use for inspection purposes either his own or any commercial laboratory acceptable to the purchaser. Records of all tests and examinations shall be kept complete

and available to the purchaser. All test and measuring equipment shall be calibrated per the requirements of Standard MIL-C-45662.

The following applies to specified limits for requirements on core density per Section 3.4.1.1 and 4.2 and all dimensional requirements of this specification. For purposes of determining conformance with this specification an observed value or a calculated value shall be rounded off to the nearest unit in the last right hand place of figures used in expressing the limiting value in accordance with the rounding-off method of the Recommended Practices for Designating Significant Places in Specified Limiting Values (ASTM E29).

The supplier shall prepare for his use and the purchaser's approval an integrated manufacturing and inspection test plan. The plan shall include all manufacturing operations, equipment and tooling used, inspection requirements and gaging used, and mandatory hold points established by the purchaser.

Any materials or fuel element components that are fabricated using equipment, personnel, or processes that are not in accordance with approvals as previously granted by the purchaser are subject to *rejection* (see def.). A report of any such incident must be submitted in accordance with Section 6.3.7.

Fuel element inspection for shipment or rejection will be made by the on-site purchaser's representative at the supplier's plant. Final fuel element acceptance will be made by the purchaser at the User's facility.

4.1 Materials

Compliance with the material requirements of Section 3.2 shall be established by supplier certification. A "Certification of Chemical Analysis" or a certified mill test report shall be supplied to the purchaser for each lot of material used in the fabrication of fuel elements. This certificate shall give the results of the chemical analysis for the material. All fuel element materials shall be traceable.

4.2 Core Density

The density of the fuel cores required in Section 3.4.1.3 shall be determined by the Archimedes principle. During qualification of the fuel plate core void density required by Section 3.4.1.3 shall be determined on all qualification fuel plates submitted. After the particular plate type has been qualified, 100% inspection for void density is not required for production lots of fuel plates. For production lots, three randomly selected fuel plates from each lot shall be inspected for void volume density. Should any one of these plates be discrepant, the entire lot must then be inspected for void volume density. If void density discrepancies appear regularly in the process, the purchaser may request 100% inspection.

The actual core volume shall be calculated by the following formula where: weight units are in grams and volumes in cubic centimeters.

$$V_c = V_p - \frac{W_p - W_c}{\rho_{AL}}$$

where:

V_c = immersion volume of fuel plate core

V_p = volume of fuel plate

ρ_{AL} = density of aluminum used for fuel plate cladding

= 2.715 gms/cc

W_p = weight of plate

W_c = deburred weight of fuel plate core compact

The theoretical core volume shall be calculated by the following formulas:

$$V_{ct} = \left(\frac{WU_3Si_2}{\rho U_3Si_2}\right) + \left(\frac{W_{Al}}{\rho_{Al}}\right)$$

where:

V_{ct} = calculated theoretical core volume

WU_3Si_2 = weight of U_3Si_2 powder in core

W_{Al} = weight of aluminum matrix powder in core

ρU_3Si_2 = density of U_3Si_2 powder as measured

ρ_{Al} = density of aluminum powder used for core matrix = 2.710 gms/cc

The void percent in the core shall be calculated using the following formula:

$$V\% = \frac{V_c - V_{ct}}{V_c} \times (100\%)$$

where:

V% = percent voids in the fuel plate core

4.3 Fuel Loading

Verification of the fuel loading as specified in Section 3.4.1.2 shall be in conformance to the supplier's procedure required in Section 6.3.1.

In order to determine compliance with the fuel density requirements of Section 4.4, the U-235 loading of the fuel plate, as determined in accordance with the procedures of Section 6.3.1, will be divided by the core volume (Vc) as calculated by the method described in the second paragraph of Section 4.2.

4.4 Fuel Homogeneity

Fuel core homogeneity requirements shall be complied with by a one-piece radiograph of all fuel plates from each fuel plate lot and evaluation of the radiograph by calibrated densitometer measurements. Purchaser approved density standards may be used by the supplier. Fuel plates and density standards shall be

exposed simultaneously. Fuel plate density variations shall be determined by comparison of fuel plate areas to corresponding areas of the standard.

All fuel plates shall be inspected for homogeneity. Homogeneity of the fuel plate core shall be determined by radiograph film density measurements with a densitometer having a 0.080 inch aperture.

When determining fuel core density from plate radiographs, the brighter the image on the radiograph, the more dense is the uranium and the lower the number indicated on the densitometer. The darker the image on the radiograph, the less dense is the uranium and the larger the number indicated on the densitometer. A +30% fuel core density and a +20% fuel core density is indicated by the densitometer readings in the suspect area being 30% or 20% lower than the average densitometer readings for all core locations. A –30% or a –20% fuel core density is indicated by the densitometer readings in the suspect area being 30% or 20% higher than the average densitometer readings for all fuel core locations.

Any one-half inch diameter or greater spot in the plate fuel core area, other than the dogbone area shall not be less in fuel density than –20% of the average fuel density for all fuel core locations. To determine the low density of a one-half inch diameter area, the film is maneuvered under the densitometer in the low-density area until the highest number possible is obtained on the densitometer. This number is recorded. Then four readings are taken one-fourth inch from this spot and symmetrical around it. The average of these five readings is compared to the average densitometer readings for all fuel core locations.

If density standards are used, the average densitometer readings of all fuel core locations will be replaced by the nominal density standard and comparisons will be determined between the suspect spot on the radiograph and the –30% and –20% standards. For the +30% and +20% homogeneity overload inspection, compare the nominal density standard to the suspect area. In this case densitometer units from nominal of the fuel plate represent the following percentages: -0.15 = +30%; -0.10 = +20%. Fuel plates exceeding these limits are discrepant.

For rectangular shaped, suspected discrepant areas that are evaluated to the one-half inch criteria, orient the four symmetrical readings such that worst case readings will be taken.

Between the minimum and maximum permissible fuel core length boundary, fuel underload condition shall not be evaluated.

Any indication of un-alloyed uranium as determined by radiography shall be cause for rejection.

Any 0.080 inch diameter spot in the fuel plate dogbone area (area within one inch of each fuel core end) shall not be greater in fuel density than +30% of the average fuel density for all core locations. Any one-half inch diameter area in the dogbone area shall not be less in fuel density than –30% of the average fuel density for all fuel core locations. The actual dogbone shall not be more than one-half inch in the longitudinal direction.

Other than the dogbone areas near ends of fuel core, any one-half inch diameter area shall not be greater in fuel density than +20% of the average fuel density for all fuel core locations. To determine the high density of a one-half inch diameter area, the film is maneuvered under the densitometer in the high-density area until the lowest number possible is obtained on the densitometer. This number is recorded. Then four readings are taken one-fourth inch from this spot and symmetrically around it. The average of these five readings is compared to the average densitometer readings for all fuel core locations.

Unless otherwise specified, purchaser approval of all radiographs is required prior to assembly of fuel plates into elements.

4.5 Core Configuration

Each finish-cut flat fuel plate shall be radiographed in accordance with Appendix A and evaluated for compliance with Section 3.3.1.2.

Visual radiograph inspections will be performed without magnification on a light table having a light intensity of 450 to 600 ft-candles at the table surface and the area darkened to give a light range of 5 to 15 ft-candles 18 in. above the light table with radiograph film in place on the table.

4.6 Bond Integrity

4.6.1 Blister Anneal:

After the fuel plate has been hot rolled, it shall be heated to 900°F±13°F, held at that temperature for a period of 2 hours, -15 minutes, +30 minutes, removed from furnace, and allowed to air cool.

Any blisters, in the fuel core region larger than a 0.060 in. diameter or any blister in the frame region of the fuel plate larger than 0.120 in. diameter shall result in rejection of the associated fuel plate. A maximum of two blisters less than 0.060 in. diameter is allowed in the fuel core area, provided they are more than 0.250 in. apart. A maximum of two blisters in any of the four sides of the *picture frame* (see def.)(a maximum of eight) region smaller than 0.120 in. can be tolerated providing that no blister is

any closer to the plate edge or end or to another blister than the major dimension of the blister and no blister is closer to the plate edge or end than 0.050 inch. When there is question as to size or location of the blisters, the acceptance or rejection of the plate shall be determined in the ultrasonic inspection of Section 4.6.2.

4.6.2 Ultrasonic Scanning:

The finished fuel plate area shall be ultrasonically inspected in compliance with ASME Boiler and Pressure Vessel Code, Section V, Article 5, Paragraphs T-110, T-510, T-520, T-521, T-522-a, b, c, e, g, i, j, k, l, o, T-523, T-523-1, and T-534. Any indication of discontinuity in the fuel core region equivalent to that indicated by a 0.060 in. diameter standard or any indication of a discontinuity in the frame region of the fuel plate equivalent to that indicated by a 0.120 in. diameter standard shall result in rejection of the associated fuel plate. Acceptance criteria for number of blisters revealed by ultrasonic scanning are per Section 4.6.1. Any discontinuities, inside the fuel plate, other than blisters and for which acceptance criterion is not already stated, shall be described by the supplier and evaluated by the purchaser.

4.6.3 Metallographic Examination.

During qualification, one fuel plate per lot selected for qualification per Section 3.1.1 will be sectioned per Figure 1, polished and etched, and examined at 50× or above for bond and clad-core-clad dimensions per the requirements of Sections 3.3.1.3 and 3.3.1.4, and Drawing 635463, respectively.

If the fuel plate fails the metallographic examination for grain growth, voids, laminations, core cracking or separation, or foreign particles or materials, then randomly selected another plate in the lot for metallographic examination. If this plate fails the examination, reject the lot.

Fuel plates selected for destruction tests may be rejected fuel plates, providing the attribute to be tested for is not affected by the cause for rejection. Reject fuel plates so used must have purchaser approval before destruct tests are performed.

4.7 Internal Defects

Any internal defect in excess of the requirement of Section 3.3.1.3 in the fuel core, including voids, laminations, U_3Si_2 segregation, clumping, core cracking or

separation, or foreign particles or materials, which is identified by any measurement technique, including radiography per Section 4.4, ultrasonic scanning per Section 4.6.2, or metallography per Section 4.6.3, shall be cause for rejection of the fuel plate.

4.8 Surface Finish and Defects

Compliance with requirements of Section 3.5 shall be established by visual inspection of all fuel plates and fuel elements. Out-of-specification defects shall be measured for size and depth and reported to the purchaser.

4.9 Clad-Core-Clad Dimensions

Fuel Plate Qualification requirements of section 3.1.1 shall be established by ultrasonic techniques using the purchaser-supplied, min-clad inspection gage. All fuel plates will be subjected to ultrasonic min-clad inspection with the fuel core region scanned for each plate. Ultrasonic min-clad inspection shall be accomplished by calibration of the min-clad gage, using the Advanced Test Reactor (ATR) Standard (8E0777) scanned at the normal mode of 0.008 inches. The min-clad gage will then be adjusted and the fuel plates will be scanned at a depth of 0.010 inches. Ultrasonic Test (UT) traces showing fuel at the 0.010 inch depth will be compared to the 0.008 inch standard to determine plate acceptability. If the density of indications from fuel plate exceeds the ATR standard density of indications, the plate is rejectable.

NOTE: *The ATR standard is a small piece of an ATR fuel plate that has fuel particles near the surface. It is used on the UT min-clad machine to indicate min-clad indications and compare the density of these indications to any indications noted from a fuel plate being inspected by UT.*

During the fuel plate qualification process, compliance with the requirements of Section 3.3.1.4 shall be established by destructive analysis of one fuel plate per lot in accordance with Figure 1.

After fuel plate qualification, all production plates shall be min-clad ultrasonic inspected at a depth of 0.010 inches. Those plates discrepant at 0.010 inches shall be rescanned at 0.008 inches. Plates which are acceptable when re-scanned at 0.008 inches shall be submitted on Information/Change Request (Form 540.33) to the purchaser.

4.10 Cleanliness

Fuel plate, fuel assembly, and fuel element container cleanliness requirements of Section 3.5.2 shall be established by visual inspection without magnification of all fuel plates, fuel assemblies, and fuel element containers.

4.11 Contamination

The surfaces of each fuel plate and fuel assembly shall be counted or smeared and counted for alpha-beta-gamma contamination and meet the requirements of Section 3.5.3.

4.12 Dimensional

It shall be the supplier's responsibility to assure that fabrication is performed in accordance with all dimensions delineated in the Drawings referenced in Section 2.1.2. Noncomplying design dimensions on fuel plates, fuel assemblies, and fuel element containers (actual measurements) shall be submitted to the purchaser for review and approval. Any discrepant component shall not be used in a fuel element assembly unless approved.

The supplier is to certify to compliance with the design dimensional requirements delineated in the Drawings referenced in Section 2.1.2.

All dimensions of finished fuel plates, fuel assemblies and fuel element containers apply at 75°F±5°F.

4.12.1 <u>Final Dimensional Inspection</u>.

Dimensions required by this specification and drawings of Section 2.1.2 shall be inspected using a purchaser approved sample plan and recorded on an inspection sheet with "in specification" dimensions recorded by check mark, "OK," or actual measurements and "out of specification" dimensions recorded as actual measurements.

4.13 Reactor Components and Spare Fuel Element Parts

Reactor components and spare fuel element parts not assembled into fuel element assemblies are required to be certified. The certification shall consist of material certification, fabrication verification, and supplier certificate of compliance to the specification and drawing requirements. The certification documents shall be submitted to the purchaser and user.

5. PACKAGING AND SHIPPING

Packaging and shipping of the fuel elements shall be performed using a Purchaser approved procedure in compliance with this section.

- The purchaser shall provide shipping containers to protect the fuel elements from damage during shipment and which conform to the applicable requirements of the Departments of Energy and Transportation, and other regulatory agencies having jurisdiction of the shipment of radioactive materials. Re-useable shipping containers will be returned to the Supplier by the User at the Purchaser's expense.
- The Supplier is responsible for loading the fuel elements into shipping containers in a sealed polyethylene sleeve in a cleaned dry condition and free of extraneous materials.
- The Supplier shall take necessary precautions during packaging to prevent damage to the fuel elements during shipment. Each container shall be provided with a tamper-proof seal. Loading and shipping documents for the container shall be prepared in accordance with the applicable regulatory requirements.
- The Supplier shall make arrangements for shipment to the User.

6. NOTES

6.1 Definitions

For the purpose of this specification, the following terms are identified:

Batch. The amount of silicide powder mixture which is handled as a unit or traceable to a common step.

Blended. To mix or mingle constituents of a batch.

Certification. The action of determining, verifying and attesting in writing (signed by a qualified party) to the qualifications of personnel and material.

Cladding. The aluminum covers bonded to the fuel core and the picture frame.

Control Fuel Element Assembly. An assembly consisting of the control fuel element container with eight fuel plates.

Controlled Work Area. A work area to which access of personnel, tools, and materials is limited and physically controlled. Temporary enclosures may be used where adjacent activities produce contamination which is detrimental to the job.

Development. A determination of processes, equipment, and parameters required to produce a product in compliance with this specification.

Dogbone Area. Thickening of the fuel core usually in the last 1/2 in. of the core, which may result in clad thinning in those areas.

Dummy Fuel Element Assembly. An assembly consisting of a fuel element container with unfueled simulated dummy fuel plates.

Dummy Fuel Plate. A non-fueled plate made entirely from the aluminum material specified in this document.

Edge Clad. The distance between the edge of the fuel core and the edge of the finished fuel plate, before any stray particles are removed, in the width direction as determined by radiography of a flat fuel plate.

Failure. A condition where the fabrication process appears to be out of control or a breakdown or damage to equipment creates excessive costs and/or schedule delays.

Fuel Compact. A quantity of uranium silicide powder and aluminum powder, cold compacted by pressing into a solid block for assembly into packs for hot roll and cold roll into fuel plates. The compacts are encased in frames and cover plates to form the pack.

Fuel Assembly. An assembly of fuel plates and hardware components. This includes both the standard and control fuel elements.

Fuel Core. The uranium-bearing region of each Fuel Plate.

Fuel Plate. The Fuel Core complete with aluminum frame and cladding.

Graphite Reflector Assemblies. A component consisting of a graphite container assembly with a graphite block inside.

In-Process Controls. Inspections and tests made during production to ensure that the manufacturing processes, equipment, and personnel are producing a product meeting specified requirements.

Irradiation Facility Assemblies. A component consisting of a round tube attached inside a graphite container assembly with graphite blocks filling the annulus between the tube and container. Inserted within the tube is the isotope capsule assemblies.

Lot. A group of pieces handled as a unit or material traceable to a common processing step.

Manufacture(ing). All fabrication, assembly, test, inspection and quality control processes. Fabrication is a synonym for Manufacture.

Pack. The fuel compact, picture frame, and cover plates, assembled together for hot rolling.

Picture Frame. The window shaped aluminum frame, which holds the fuel compact.

Plates. See Fuel Plates.

Procedure. The detailed description of the series of processes during manufacture and inspection, which follow a regular definite order (not to be construed as an outline).

Production. That phase of the program, following Qualification, during which the product is in Manufacture.

Purchaser. Idaho National Laboratory (INL).

Qualification. A demonstration that the Manufacturing process, equipment and personnel can produce a Product in compliance with this Specification.

Quality Control. The sampling plans, inspections, tests and records required and used during Production to assure that the Product is in compliance with this Specification.

Rejection. Materials, parts, components, or assembly products, which will not be accepted as fulfilling the contract requirements because of noncompliance with this Specification.

Requalification. A demonstration that a single or group of manufacturing processes, equipment and personnel can produce a product in compliance with this specification after the original qualification has been completed and becomes invalid.

Silicide. Uranium metal alloyed with silicon and fabricated per the requirements of Specification TRTR-14. The word "fuel" is a synonym for Silicide.

Specification. All parts and appendixes to this document, its references, drawings, and standards, as may be modified from time to time by contractual document.

Standard Fuel Element Assembly. An assembly consisting of the fuel element container with fourteen (14) fuel plates.

Stray Fuel Particles. Isolated fuel particles lying outside the maximum fuel core outline defined on Drawing 635463.

Supplier. The primary vendor selected by INL to manufacture the product.

User. Purdue University, at West Lafayette, Indiana.

6.2 Purchaser Tests

None

6.3 Submittals

The following data and records shall be supplied to the purchaser in the quantities stated. The purchaser's approval, prior to implementation, is required on those marked with an asterisk. All records and data shall be maintained by the supplier for the duration of the Purdue University fuel element contract.

The granting of approval by the purchaser of design, working drawings, specifications, requests, and other technical data submitted by the supplier under the provisions of the subcontract or specification shall not affect or relieve the supplier from such responsibility as the supplier has with respect to adequacy or correctness of the design, working drawings specifications, reports, and other technical data.

6.3.1 Preproduction:

Documents requiring approval must be submitted prior to production use. The number of copies shall be as specified by the Vendor Data Schedule. These documents include:

- *A detailed description as to the weighing procedure by which the supplier proposes to assign Plate U-235 content as required in Section 4.3.
- Included in the description must be sampling, analytical, and quality control procedures; a statement as to the established accuracy and precision of the assigned fuel plate and fuel element U-235 content; developmental and production data in support of the accuracy and precision estimate; and data which at the 95% confidence level, shows that the method used to assign U-235 values has a bias which is less than 0.2% relative
- *A detailed description as to the manner the supplier will use to verify the fuel Plate U-235 value as required by Section 4.3

- *All fabrication, assembly, cleaning, surface treating, handling, and decontamination procedures (not to be construed as an outline)

- *All production test, inspection, and quality control procedures, including all nondestructive and destructive tests and all standards and sampling section drawings. All data from these tests, including but not limited to: radiographs, metallographic samples, ultrasonic testing traces, and qualification yield rates

- *All packaging, storage and shipping procedures

6.3.2 Pre-repair:

*All repair programs and procedures prior to use.

6.3.3 Manufacturing Schedule:

*A schedule using a purchaser approved technique.

6.3.3.1 Reports.

1. Biweekly qualifications phase summary status report. The first such report shall be initiated 1 month after date of contract award.

2. Three (3) copies of a monthly report detailing program progress against a previously submitted schedule shall be supplied by the supplier to the purchaser. Report type, format and submittal schedule shall be as agreed upon between the purchaser and supplier.

6.3.4 Delivery Submittals:

Three copies (except as noted) of the following data and records shall be sent prior to or accompany the shipments. The supplier shall maintain copies of these records for at least 10 years and until the supplier has received written approval from the purchaser for disposition or disposal:

- Certification of product compliance to the requirements of this specification to include any test data pertaining thereto

- Supplier's core compact data sheets, with individual fuel plate uranium composition data including:

- Serial number with *batch* (see def.) identification

Uranium content
Fuel plate core weight
U-235 enrichment
Total quantity U-235 content
Core void density data

– Individual fuel element composition data, including:

  Uranium content
  U-235 content
  Serial number of each plate in the element

– Radiation count from fuel plate and fuel element exterior as required by Section 3.5.3 and 4.11. The counting period, counter, background, efficiency, and type of counter used shall be reported

– List of all applicable waivers and deviations and related fuel plates or fuel elements

– If performed, documented evidence of the performance and test results of the boehmite formation from the fuel element surface treatment per Section 3.8.

6.3.5 Fuel Plate Radiographs:

Fuel plate radiographs of all accepted fuel plates required by Sections 4.4 and 4.5 and Appendix A shall be sent to the user.

6.3.6 Core Compact Data Sheets:

Supplier's fuel core compact data sheets shall be supplied to the INL Quality Assurance Representative as they are generated.

6.3.7 Report of Production by Unapproved Process:

Whenever the supplier's previously submitted and approved process control limits are exceeded, or any material or fuel element components are fabricated using equipment, personnel, or processes which are not purchaser approved, the time, nature, description, corrective action to be taken, and proposed further corrective action shall be reported immediately by the supplier, with a written report to the purchaser to follow within 10 working days.

1. T Samples. Transverse to be taken equally space along Fuel Core length.
2. L Samples. Longitudinal to be taken at centerline and to include the Dogbone Area.

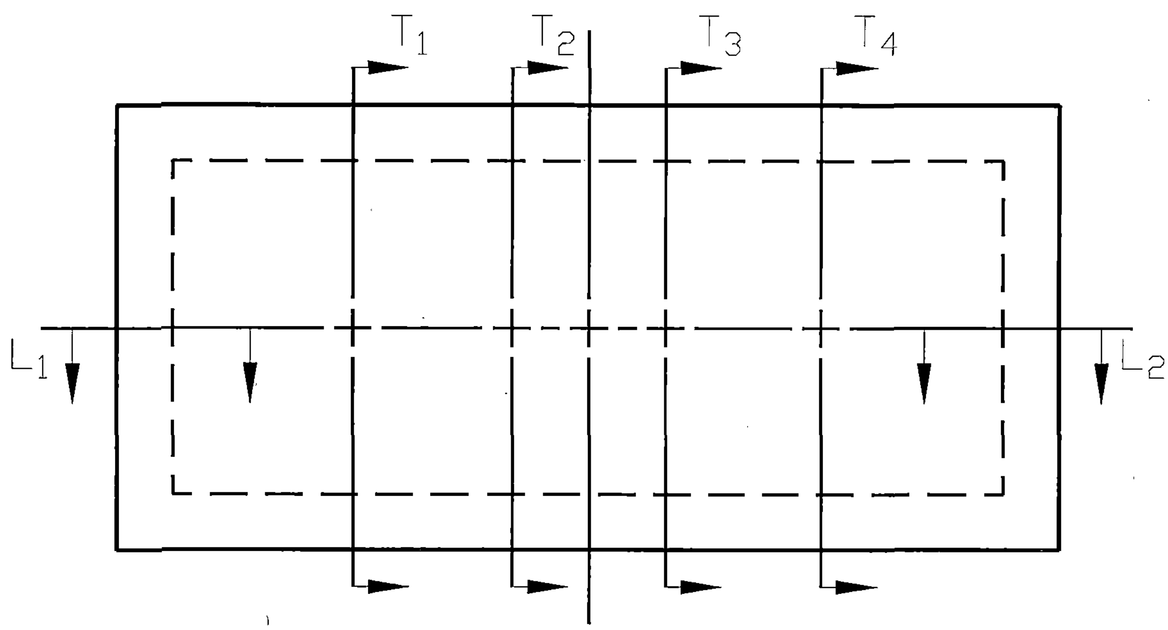


Figure 1. Purdue University Fuel Plate Sampling Procedures For Destructive Tests.

APPENDIX A

Requirements for Radiography of Purdue University Fuel Plates

1. Scope

This specification provides requirements for radiography of Purdue University reactor fuel plates, acceptable film quality and film identification.

2. Requirements

A procedure must be written to specify the details for achieving acceptable fuel plate radiographs. The procedure must include the requirements given in this specification.

2.1 Equipment Setup

The voltage shall be 100 k.v.p. with a focal spot size of 5 mm maximum. The distance between the focal point and the plate shall be at least twice the length of the plate. The focal point shall be centered laterally and longitudinally over the plate or group of plates.

2.2 Film

2.2.1 The image outline shall be clear and sharp; the film shall be free of runs, streaks, scratches, blurs, and cassette defect that will affect the area covered by the fuel plates.

2.2.2 The film density of all points of the radiograph that correspond to the fuel plate border locations outside the plate core shall provide densitometer readings between 1.5 and 2.7. Film density as read over the nominal density standards shall provide densitometer readings between 0.9 and 1.5.

2.2.3 The film shall be extreme sensitivity, extra fine grain, high contrast, double emulsion, industrial x-ray type, (Kodak type M or equal) which is acceptable to the purchaser. Development of the film shall be in accordance with the manufacturer's recommendation.

2.2.4 Film Identification

2.2.5 A system of identification of the film shall be provided by the supplier, which shall show as a minimum:

A. Plate lot number

B. Plate type and serial number

C. Orientation of density standard

D. Density standard identification

E. Date of radiography.

APPENDIX B

Welding Requirements and Qualification for Purdue University Fuel Elements

1. Scope

The requirements for welding and for the evaluation of welds applicable to the Purdue University Fuel Element Container and components are established by this Appendix.

1.1 Application. This document defines requirements for the following:

1.1.1 Welding procedure qualification.

1.1.2 Performance qualification of welders, welding equipment, and special fixturing.

1.1.3 Information to be included in welding procedure specifications.

1.1.4 Application of qualified procedures to production welding.

1.1.5 Destructive testing and nondestructive examination for qualification and for production welding.

1.2 Special Limitations for Applicability. The requirements contained in this appendix are to some degree based on RDT F6-2T. Those requirements applicable to Manual, GTAW, single pass, welding of Plug Joint welds, Corner Joint welds, and Partial Penetration Butt Joint welds have been included in this appendix. The introduction of a new weld design or weld process requiring a change in these limited parameters would require an appropriate review of RDT F6-2T for requirements applicable to the new parameters.

1.3 Definitions.

Arc Strike. Any localized melting, heat affected zones, or change in the contour of the surface of the finished weld or adjacent base metal resulting from an arc or heat generated by the passage of electrical energy between the weld or base metal and a current source; such as welding electrodes, electron beams, ground clamps, high frequency arc, etc.

Automatic Welding. Welding with equipment which performs the entire welding operation without constant observation and adjustment of controls by an operator. The equipment may or may not perform the loading and unloading of the work.

Face of Weld. The exposed surface of a weld on the side from which welding was done.

Face Reinforcement. Reinforcement of weld at the side of the joint from which welding was done.

Heat. A single homogeneous melt of metal or alloy.

Joint Penetration. The minimum depth a groove or flange weld extends from its face into a joint, exclusive of reinforcement.

Machine Welding. Welding with equipment which performs the welding operations under the constant observation and control of an operator. The equipment may or may not perform the loading and unloading of the work.

Position of Welding. The terms related to positions of welding for joint types and welding processes and the position limits are defined in Section IX, ASME Boiler and Pressure Vessel Code.

Repair. The process of restoring a nonconforming item characteristic to an acceptable condition, although it does not conform to a specified requirement.

Rework. The process by which a nonconforming item is made to conform to specified requirements.

Root of a Joint. That portion of a joint to be welded where the members approach closest to each other. In cross section the root of the joint may be a point, a line or an area.

Root of a Weld. The points, as shown in cross section, at which the back of the weld intersects the base metal surfaces.

Root Penetration. The depth a groove weld extends into the root of a joint measured on the centerline of the root cross section.

Root Reinforcement. Reinforcement of weld at the side opposite that from which welding was done.

Root Surface. The exposed surface of a weld on the side opposite that from which welding was done.

Size of a Groove Weld. The joint penetration (depth of chamfering plus root penetration when specified).

Undercut. A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

Underfill. A depression on the face of the weld or root surface extending below the surface of the adjacent base metal.

Welder and Welding Operator Performance Qualification. The tests to demonstrate a welder's or welding operator's ability to produce welds meeting prescribed standards.

Welder. One who is capable of performing a manual or semiautomatic welding operation (sometimes erroneously used to denote a welding machine).

Welding Operator. One who operates machine or automatic welding equipment.

Welding Procedure Qualification. The test to demonstrate that welds made by a specified procedure can meet prescribed standards.

Welding Procedure Specification. A written welding procedure which specifies the detailed methods and practices to be used in the production of a weldment and how they shall be carried out. A specification includes all elements of a procedure necessary to produce a satisfactory weldment. Examples of some of the elements included in a specification are: material used, preparation of base materials, preheat and postheat cleaning, assembly method and sequence, fixturing, heat treatments, joint welding procedures, preweld and postweld nondestructive examinations, repair, rework, etc.

Welding Procedure. The detailed methods and practices including all joint welding procedures.

2. Reference Document

The following documents are a part of this appendix to the extent specified herein. The issue of a document in effect on the date of the invitation to bid, including any amendments also in effect on that date, shall apply unless otherwise specified. Where this appendix appears to conflict with the requirements of a reference document, such conflict shall be brought to the attention of the purchaser for resolution.

2.1 American Society for Testing and Materials (ASTM) Standards

2.1.1 ASTM E2, Preparation of Micrographs of Metals and Alloys

2.1.2 ASTM E3, Preparation of Metallographic Specimen

2.2 American Society of Mechanical Engineers (ASME) Codes

2.2.1 ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

2.3 American Welding Society (AWS) Standards

2.3.1 AWS A2.2, Nondestructive Testing Symbols

2.3.2 AWS A3.0, Terms and Definitions

3. Weld Qualification Requirements

3.1 General Requirements

3.1.1 All welding procedures, welders, or welding machine operators shall be qualified in accordance with the provisions identified in this Appendix.

3.1.2 Weld Procedure and Performance Qualification Testing previously qualified to these requirements under other contracts may be used. Existing records to support previously qualified procedures and personnel are subject to review by the purchaser.

3.1.3 Base materials and filler material shall comply with the requirements of the drawings.

3.1.4 Welding processes which satisfy the specified requirements and produce the quality required by this Appendix are permissible. Welding procedures which utilize fluxes and coatings shall not be used.

3.1.5 Fixtures: The capability of fixtures for aligning parts shall be demonstrated before welding of production parts is initiated. If chill bars or blocks are used, the type of material and their location with respect to the joint shall be included in the procedure specification.

3.1.6 Position of Qualification Welds. All procedure and performance qualification test welds shall be made in the same positions as for production welds.

3.1.7 Special Conditions for Qualification Welds: All procedure and performance qualification test welds shall be made under conditions which simulate the actual production welding conditions. These conditions shall include space limitations, joint accessibility, degree of comfort due to heat, position and other handicaps or environmental factors which the welder or welding operator will endure during actual production welding.

3.1.8 Heat Treatment. Weld preheat and postheat treatments shall not be used without prior approval by the purchaser.

3.1.9 Interpass Temperature. For multi-pass weld, the weld interpass temperature shall not be less than 60° F or greater than 350° F without prior approval by the purchaser.

3.1.10 Records. Records of welding, associated processing, and inspection shall be maintained for all welds. Complete records may consist of inspection forms, routings, or reference to Operating Procedures or other documents. These records shall include at least the following:

1. Base Material (Type, material specification, heat or lot number).
2. Filler Material (Type, material specification, heat or lot number).
3. Cleaning procedures.
4. Joint identification and weld maps when applicable.
5. Welding machine type and identification.
6. Welding procedure specification.
7. Welder or welding operator qualification.
8. Procedure and performance qualification.
9. Current-voltage data for machine or automatic welding.
10. Date welds are made.
11. Inert gas mixture, when applicable.
12. Nondestructive examination procedure.
13. Nondestructive examination personnel identification.
14. Examinations and tests (nondestructive and destructive) and the results.
15. Photomacrographs and photomicrographs.
16. Metallographic specimens.
17. If applicable, rework and repair of welds.
18. Disposition of welds.

3.2 Welding Procedure Specification

3.2.1 The welding procedure specification shall meet the requirements of this Appendix, and shall be submitted to the purchaser for information.

3.2.2 The welding procedure specification shall include all essential elements and details, as required by this section, to cover each joint to be welded by the supplier. Each joint shall be identified in the welding procedure specification. The specification shall include a joint design sketch for

each joint welding procedure even if the specification references drawing numbers.

3.2.3 The following basic information and essential variables shall be included in sufficient detail to assure that compliance with the requirements of the specification can be verified:

1. Basic Information

   a. Joint Design: (the joint geometry, fit-up, and other required dimensions of the welded joint) tolerances and material thickness.

   b. Method of arc initiation

   c. Electrode size (for gas tungsten arc welding)

   d. Gas type and flow rate (shielding and backing gas)

   e. Welding current range for manual welding

   f. Whether tack welds or fixtures are used for assembly of the joint for welding

   g. Method and frequency of cleaning

   h. Number of weld layers and passes

   i. Whether stringer beads or weave beads are used

2. Essential Variables

   a. General, All Welding Processes.

      i. A change from a base material type or grade (materials of the same nominal chemical analysis and mechanical property range, even though a different product form) to any other base material type or grade. When joints are made between two different types or grades of base material, a procedure qualification shall be made for the applicable combinations of materials, even though procedure qualification tests have been made for each of the two base materials welded to itself.

ii. A change of filler metal type or classification to any other type of classification

iii. A change in welding position.

iv. A change in vertical welding direction, i.e., from upward to downward or vice versa.

v. The addition or omission of integral backing (e.g., "butt-lap" type joint).

vi. The addition or omission of nonfusing metal retainers.

vii. The addition or omission of filler metal to the joint.

viii. Any change in the method by which filler is added, such as preplaced shims, preplaced wire, preplaced consumable inserts, wire feed, or prior weld metal surfacing ("buttering") of one or both joint faces.

ix. The addition or omission or any type of preplaced consumable inserts or joint surfacing.

x. A change in the shape or size of preplaced consumable inserts or joint surfacing.

xi. A change from multiple pass welds to single pass welds.

xii. The omission of inert gas backing during welding, except that requalification is not required where a qualified welding procedure is changed to omit the inert gas backing and then is used only for a single welded butt joint with a backing strip, or a fillet weld. For multiple pass welding, the omission of inert gas backing during welding until three layers or 3/16 of weld metal thickness has been deposited, whichever is greatest.

xiii. A change from one welding process to any other process or combination of welding processes.

b. Manual Welding, All Welding Processes.

i. An increase in the standard size of filler metal from that stated and qualified in the procedure specification.

ii. A change in joint geometry which violates the tolerances given for the joint geometry elements listed below:

Bevel Angle: State in procedure specification. Tolerance: Minus 5%.

Groove Angle: State in procedure specification. Tolerance: Minus 5%

Alignment Tolerance: Assign value in procedure specification. Qualify procedure for single welded joints using maximum permissible misalignment in a portion of the joint.

c. Gas Tungsten Arc Process.

i. A change of electrode material type.

ii. A change in arc starting methods.

iii. A change from a single shielding gas to any other shielding gas or to a mixture of shielding gases or a change in specified composition of gas mixture.

iv. A decrease in shielded gas flow rate of more than ten percent.

3.3 Welding Procedure Qualification

3.3.1 The welding procedure shall be qualified to the requirements of this section.

3.3.2 All welding used in qualifying a welding procedure shall be performed in accordance with a welding procedure specification.

3.3.3 Before any welding is performed on production components, the supplier shall qualify each proposed welding procedure by:

1. Recording all essential elements of the welding procedure in a welding procedure specification (see Section 3.2)

2. Verifying the welding procedure specification by welding test specimens representing each joint to be welded in production and performing nondestructive examination and destructive tests in accordance with the requirements of this Appendix.

3. Submitting to the purchaser, for information, the welding procedure specification and a certified copy of the detailed results obtained from the tests performed on the test welds. The metallographic sections required by this Appendix shall also be submitted to the purchaser.

3.3.4 Essential Variables. The welding procedure shall be set us as a new welding procedure specification and shall be completely re-qualified when any of the changes listed in Section 3.2.3.2 are made in the procedure.

3.3.5 Chart Recordings. Current-voltage-time charts shall be used for each procedure qualification weld for automatic or machine welding. Calibrated current and voltage indicating meters may be substituted for trace chart type equipment for manual welding. The current and voltage ranges shall be recorded for manual welding.

3.4 Welder Performance Qualification

3.4.1 Performance qualification weld tests shall meet the requirements of this section, except that any welder used to qualify the welding procedure shall also be considered qualified and additional performance weld tests are not required.

3.4.2 General.

1. The performance qualification tests are intended to determine the ability of welders to make sound welds.
2. The performance test may be terminated at any stage of the testing procedure whenever it becomes apparent to the supervisor conducting the tests that the welder does not have skill required to produce satisfactory results. In this event, the welder may be re-tested at the discretion of the supplier in accordance with 3.4.3.
3. Each supplier shall maintain a record of the procedures, including the essential variables, under which welders are examined and the results of the examinations.

3.4.3 Qualification of Welders.

1. Each welder shall pass the tests prescribed for procedure qualification except that tensile tests are not required. The essential variables and the test results obtained by each welder shall be recorded in a Performance Qualification Test Report. Any welder who performs acceptable welding procedure qualification tests shall be considered qualified.
2. Renewal of Qualification. Requalification of a welder is required when:

a. 90 or more days have elapsed since he last produced acceptable welds using the specific welding process, or

b. He has not performed acceptable welds using the production welding procedure.

c. Any time there is a specific reason to question a welder's ability to make welds meeting the requirements of this Appendix, requalification shall be required. Only one test weld shall be required for renewal of qualification. If this test weld fails to meet all of the original requirements, then a complete performance requalification shall be required.

3.4.4 Chart Recordings. Current-voltage-time charts shall be used for each procedure and performance qualification weld for automatic or machine welding. Calibrated current and voltage indicating meters may be substituted for trace chart type equipment for manual welding. The current and voltage ranges shall be recorded for manual welding.

3.5 Welding Machine Qualification

3.5.1 Performance qualification weld tests shall meet the requirements of this section, except that any welding machine used to qualify the welding procedure shall also be considered qualified and additional performance weld tests are not required.

1. The performance qualification tests are intended to determine the ability of welding machines to make sound welds.

2. Any time there is a specific reason to question a welding machine's ability to make welds meeting the requirements of this Appendix, requalification shall be required. Only one test weld shall be required for renewal of qualification. If this test weld fails to meet all of the original requirements, then a complete performance requalification shall be required. Welding machines used for the manual welding of any successful procedure or welder qualification tests shall be considered qualified for manual welding of all core components covered in this Appendix.

3.5.2 Welding machines used for the manual welding of any successful welder performance qualification tests shall be considered qualified for manual welding of all components covered in this session.

3.6 Examination & Tests

3.6.1 Type of Test Required. The following tests shall be used for the qualification of welding procedures and / or welders as applicable:

1. Nondestructive examination by a liquid penetrant method.

2. Nondestructive examination by Visual to test for soundness and surface characteristics of the weld.

3. Destructive examination by sectioning for metallographic examination of weld joints and adjacent areas to test for fusion, weld geometry, weld reinforcement, and soundness of the weld.

4. When the purchaser has reason to believe that the quality of any weldment is doubtful, he may require additional inspection.

5. Nondestructive Examination and Tests

   a. Visual. The test weld shall be examined visually prior to welding and after welding in accordance with Section 5.1

   b. Liquid Penetrant. The test weld shall be examined after the final layer in accordance with Section 3.6.2.2 using a color contrast method.

   c. Unless otherwise specified, inspection of procedure and performance qualification welds shall be performed in the final surface condition.

6. Destructive Examination. Each test weld shall be sectioned transversely to metallographically examine a minimum of:

   a. Three section faces for welds on cylindrical components less than 1¼ inch in diameter or for welds that are one to four inches long on non-cylindrical components.

   b. Four sections faces for welds in cylindrical components that are greater than 1¼ inch in diameter or for welds that are greater than four inches long on non-cylindrical components.

c. One section face for plug welds, arc spot welds, and welds that are less than one inch long on non-cylindrical components.

d. The cross section shall be polished and etched to provide clear definition of the structure in the fusion zone and the heat-affected zones.

e. For welds in (a) and (b) of this paragraph, one cross section shall be made through a weld start and a weld stop area and the remaining sections shall be made at random. For weld described in (c) of this paragraph, the cross section shall be made at the approximate centerline of the weld. Examination of the welds shall be in accordance with Section 3.6.2.3.

3.6.2 Acceptance Criteria for Qualification Test Welds

1. Visual Examination. Visual examination shall be in accordance with Section 5.1.

2. Liquid Penetrant Examination. Unless otherwise specified, final weld surfaces shall be examined using a color contrast method.

   a. For welded joints in materials less than 1/8 inch thick the following relevant indications are unacceptable.

      i. Any cracks.

      ii. Linear indications.

      iii. Indications with dimensions exceeding 1/64 inch.

      iv. Rounded indication separated by ¼ inch or less edge-to-edge.

      v. Five or more rounded indications in any six square inches of weld surface with the major dimension of this area not to exceed six inches with the area being taken in the most unfavorable location relative to the indication being evaluated.

   b. For all welds in materials 1/8 inch thick or greater, the following relevant indications are unacceptable. (Only

those indications with major dimensions greater than 1/64 inch are considered relevant for item (iii).)

i. Any cracks.

ii. Any linear indications.

iii. Rounded indications with dimensions exceeding 10 percent of the nominal weld thickness or 1/8 inch, whichever is smaller. Rounded indications separated by 1/16 or less edge-to-edge shall be evaluated as a single indication.

iv. Four or more rounded indications in a line separated by 1/16 inch or less edge-to-edge.

v. Six or more indications in any six square inches of weld surface with the major dimension of this area not to exceed six inches with the area taken in the most unfavorable location relative to the indications being evaluated.

vi. Aligned indications in which the average of the center-to-center distance between any one indication and the two adjacent indications in a straight line is less than 3/16 inch.

3. Metallographic Examination Metallographic examinations shall be performed on qualification test welds at not less than 50X on test welds as required in this Section in accordance with ASTM E.2. Any cross section which is shown by metallographic examination to contain any of the following relevant defects shall be cause for rejection of the test welds.

   a. Any cracks.

   b. Incomplete fusion, or insufficient joint or root penetration.

   c. Any tungsten inclusions, slag inclusions, or porosity having a maximum dimension greater than 20 percent of the weld thickness or 1/32 inch, whichever is smaller.

   d. More than four tungsten inclusions or pores which have a maximum dimension less than in (c) above.

e. Any deviation from specified weld geometry or weld reinforcement.

3.6.3 Test Welds.

1. Procedure and / or welder performance qualification shall be made on test welds which duplicate the production weld joint type and which simulate the conditions to be used in production with respect to orientation, the essential variables listed in Section 3.2.3.2, and the dimensions of the parts to be joined to the extent that they affect heat requirements, relative motions, and distortions. All welding used in qualifying a welding procedure and / or welder performance shall be performed in accordance with the procedure specification.

2. For manual welding, two consecutive test welds shall be made when the weld joint is less than six inches in length. Only one test weld shall be required when the weld joint is 6 inches or greater in length.

3. All test welds shall be tested using the required tests listed in Section 3.6.1. To qualify the procedure specification used in making the test welds, each weld shall pass the required tests.

4. Repair of procedure or performance qualification test weld(s) is prohibited.

4. Production Welding

All production welding shall be accomplished using approved welding procedure specifications and qualified welders and/or welding operators.

5. Quality Acceptance of Production Welds

5.1 All completed production welds shall be visually examined in accordance with the following requirements:

5.1.1 General Visual Inspection Requirements. All visual examinations shall comply with the following:

1. Visual examination shall be made under direct daylight-type fluorescent lighting of at least 100 foot-candles at the work examination area.

2. Visual examination shall be performed with the aid of a 5x (minimum) magnifying glass.

3. The inspection required by this standard shall not be performed by the welder who made the welds. However, if the welder is qualified in accordance with this standard, he may visually inspect his own welds prior to the inspections required by this standard.

4. Personnel performing visual inspection shall have 20-20 vision, natural or corrected, stereo acuity, and shall not be color-blind.

5.1.2 Visual Acceptance Criteria (except for porosity). Visual examination of weld joint preparations and welds shall be performed in accordance with the following requirements to verify conformance to the written welding procedure, the design requirements, and the requirements of this standard:

1. Prior to welding, the weld joint edges and adjacent surfaces shall be examined for:

    a. Proper edge preparation, dimensions, and finish.

    b. Alignment and fitup of the pieces being welded.

    c. Verification of correct material by check of records.

    d. Verification of the cleanliness requirements.

2. After welding, the joint shall be examined in the final surface condition for:

    a. Contour, reinforcement and surface finish of welds.

    b. Degree of underfill, undercut, and overlap.

    c. Arc strikes, weld spatter and impression marking.

    d. Burn-through and fuse-through

3. Weld joints and surfaces which are shown by visual examination to have any of the following defects or areas of nonconformance are unacceptable:

    a. Any nonconformance revealed by 5.1.2.1.

b. Any zone of incomplete fusion.

c. Insufficient joint or root penetration.

d. Any undercutting, underfill, or burn through.

e. Any concavity on the face side of groove welds.

f. Any arc strikes, weld spatter, and impression marking.

g. Any visible inclusions, porosity, cracks, and unfilled craters.

4. Machined welds shall meet the drawing requirements.

5. All welds shall be free from surface markings resulting from mishandling, punching, scratching, etc., which exceed the specified surface requirements.

6. All welds shall be free of dross, or slag.

7. All welds shall be free of oxidation due to improper shielding and overheating which produce black or gray spalling or loose particles. Iridescent temper films and the dark metallic vapor deposits which may occur adjacent to the welds are acceptable. These films and deposits shall be removed by approved cleaning procedures when accessible.

5.1.3 Visible unacceptable porosity is as follows:

1. Four or more pores with a major dimension of 0.048 inches or more randomly positioned.

2. A single pore with a major dimension of 0.064 inches or more.

3. Six or more pores with a major dimension of 0.016 inches or greater in one weld.

4. Four or more porosity with a major dimension of 0.016 inches or greater, in line separated by less than 0.063 inches from edge to edge.

5.2 Repair of a defective weld by welding shall be limited to two attempts. Unacceptable defects shall be removed and re-examination made using liquid penetrant color contrast method to assure complete removal of the defect. If the

removal of the defects results in reducing the thickness of the weld metal below the thickness of the base metal, the area shall be rewelded using a welding repair procedure which has been approved by the Purchaser. Whenever a defect is removed and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface to remove any sharp notches, crevices or corners. Completed repairs shall be visually re-examined per Section 5.1. Records shall be maintained on all repairs and shall include the following:

5.2.1 Location of joint.

5.2.2 Location of defect.

5.2.3 Description of defect, including type and size.

5.2.4 Reference to approved repair procedure.

5.2.5 Inspections before and after repair and the results thereof.

5.2.6 Identification of repair welders or welding operators.

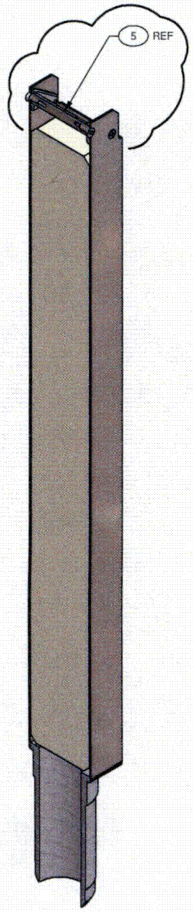
NOTES:

1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. MARK ASSEMBLY IDENTIFICATION PER SPECIFICATION SPC-382.
3. REMOVE ALL BURRS AND SHARP EDGES.

REV STATUS OF SHEETS		
SHEET	2	1
REV	2	2

REVISIONS

REV	DESCRIPTION	EFFECTIVE DATE:
1	REVISED DESCRIPTION OF ITEM 3; ADDED SHEET 2; ADDED ITEMS 2, 6, & 8; SEE DAR-509420	1/24/07
2	ADDED ITEM 9, CHANGED MATERIAL ITEM 7 CHANGED ITEM 5, SEE DAR-514751	4/4/07



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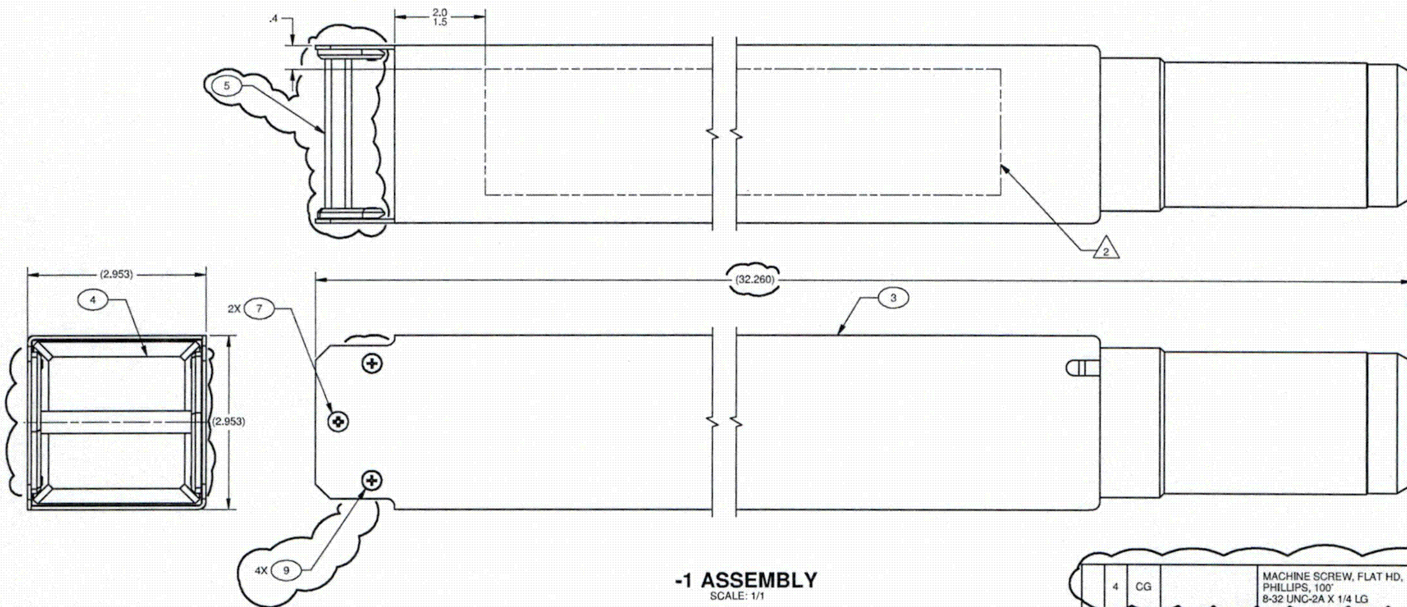

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SCALE: 1/1

PARTS LIST

QTY REQD -2	QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
	4	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 1/4 LG	316 SST OR 304 SST	9
1			635467-2	SOURCE DRIVE TOP		8
6	2	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 1/2 LG	316 SST OR 304 SST	7
1			635462-3	SOURCE DRIVE CONTAINER ASSEMBLY		6
	1		635464-2	BAIL ASSEMBLY		5
	1		635465-1	GRAPHITE BLOCK		4
	1		635462-1	GRAPHITE CONTAINER ASSEMBLY		3
		SC	-2	SOURCE DRIVE SUPPORT ASSEMBLY		2
		SC	-1	GRAPHITE REFLECTOR ASSEMBLY		1

DASH NO.	NEXT ASSY
-2	FINAL
-1	FINAL
APPLICATION	

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: .X = ± .1
DECIMALS: .XX = ± .03
.XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
GRAPHITE REFLECTOR ASSEMBLY AND
SOURCE DRIVE ASSEMBLY

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG-	REV
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SCALE: NOTED
SHEET 1 OF 2
SD8032

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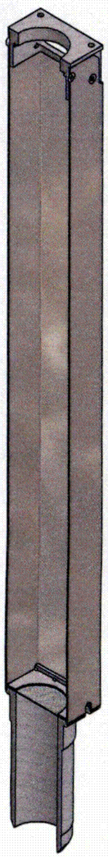

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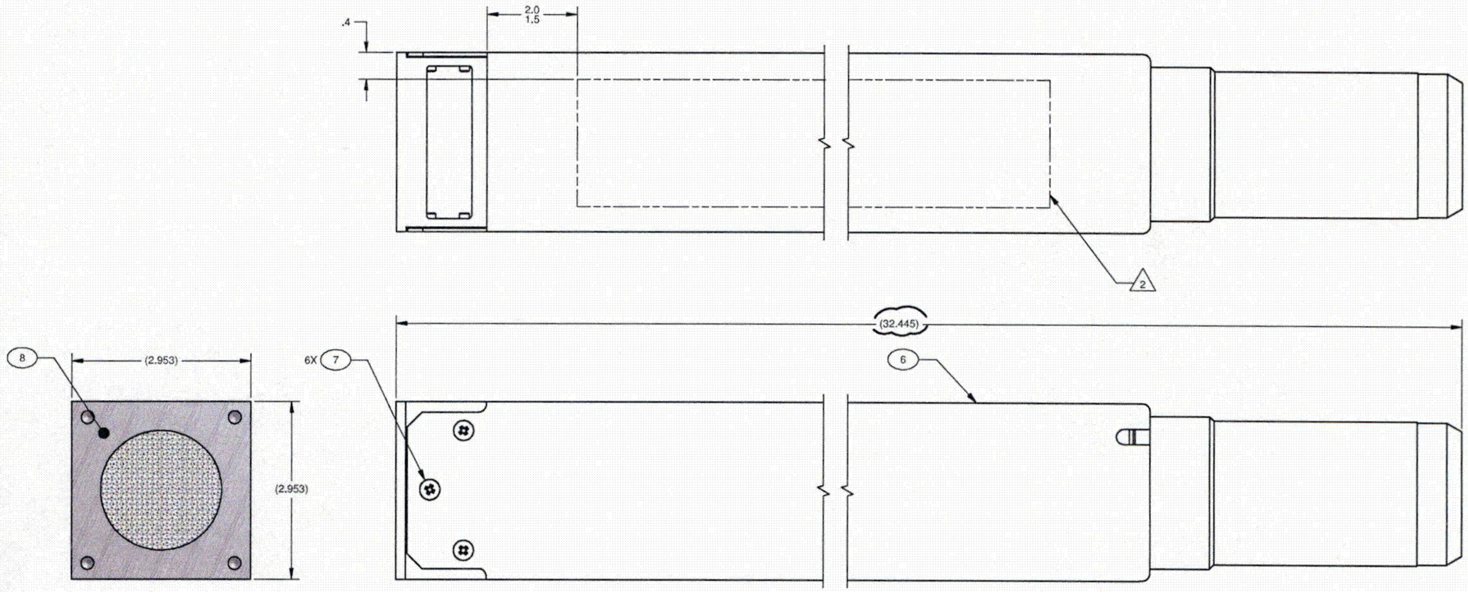

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SCALE: 1/1

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG-	REV
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SCALE: NOTED SHEET 2

SD8032

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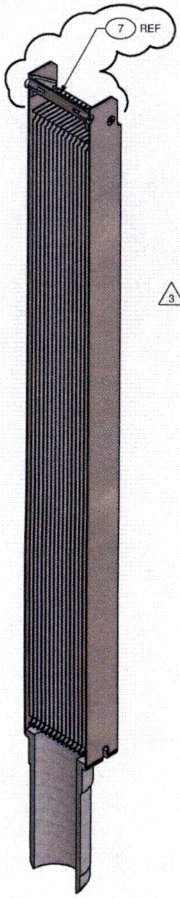
File: 635454-2
Date: 9/26/06

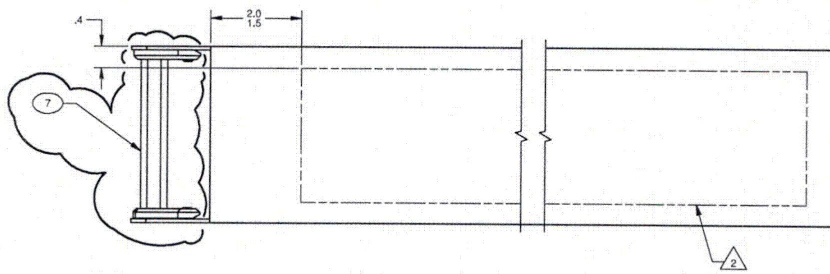
NOTES:

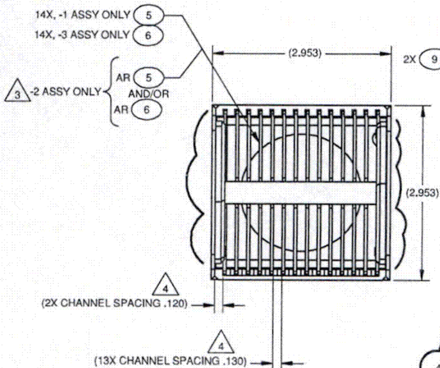
1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. (Note 2, in triangle) MARK ASSEMBLY IDENTIFICATION PER SPECIFICATION SPC-382.
3. (Note 3, in triangle) QUANTITY OF ITEM 5 (FUEL PLATES) AND ITEM 6 (DUMMY FUEL PLATES) USED IN -2 ASSEMBLY (PARTIAL FUEL ASSEMBLY) TO BE DETERMINED BY THE USER.
4. (Note 4, in triangle) CHANNEL SPACING IS CONTROLLED BY SIDE PLATE GROOVE LOCATIONS AND WIDTHS, AND FUEL PLATE THICKNESS. DIRECT MEASUREMENT IS NOT REQUIRED.
5. REMOVE ALL BURRS AND SHARP EDGES.

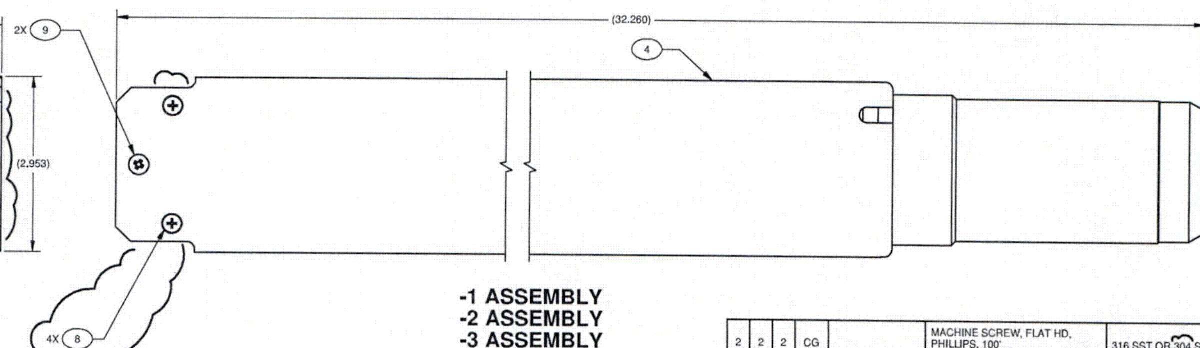
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:
1	ADDED NOTE 3 & -3 ASSY; REVISED TITLE; CHANGED TO SHOW NEW FUEL PLATE DESIGN; SEE DAR-509420	1/24/07
2	ADDED ITEM 8, CHANGED MATERIAL ITEM 9, CHANGED ITEM 7 & NOTE 4, SEE DAR-514751	4/4/07



-1 SECTIONED ISOMETRIC REFERENCE ONLY
SCALE: NONE







-1 ASSEMBLY
-2 ASSEMBLY
-3 ASSEMBLY
SCALE: 1/1

QTY REQD -3	QTY REQD -2	QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
2	2	2	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 1/2 LG	316 SST OR 304 SST	9
4	4	4	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 1/4 LG	316 SST OR 304 SST	8
1	1	1		635464-2	BAIL ASSEMBLY		7
14	AR			635463-3	DUMMY FUEL PLATE		6
	AR	14		635463-1	FUEL PLATE ASSEMBLY		5
1	1	1		635458-1	STANDARD FUEL CONTAINER ASSEMBLY		4
			SC	-3	DUMMY FUEL ELEMENT ASSEMBLY		3
			SC	-2	PARTIAL FUEL ELEMENT ASSEMBLY		2
			SC	-1	STANDARD FUEL ELEMENT ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-3	FINAL
-2	FINAL
-1	FINAL

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: .X = ± .1
DECIMALS: .XX = ± .03
.XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

INL Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
STANDARD FUEL, PARTIAL,
& DUMMY ELEMENT ASSEMBLIES

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG-	REV
D	01MF3	540	9999	43	081	635455	2

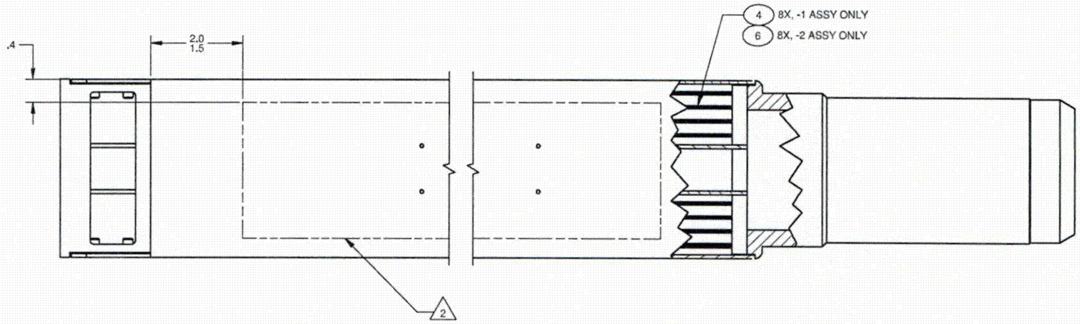
SCALE: NOTED
SHEET 1 OF 1
SD8032

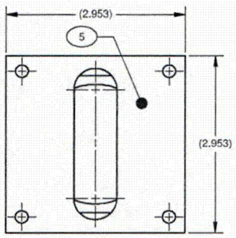
Path: C:\Vault Local Projects\Other\Purdue University\635455.idw
File: 635455-2
Date:

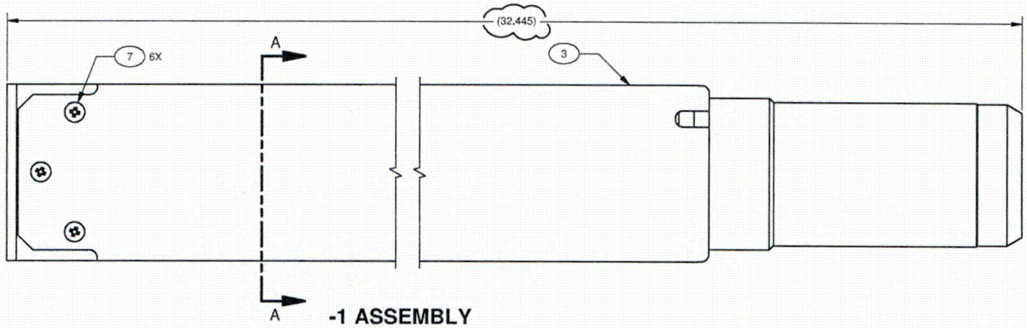
NOTES:

1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. (△) MARK ASSEMBLY IDENTIFICATION PER SPECIFICATION SPC-382.
3. (△) CHANNEL SPACING IS CONTROLLED BY SIDE PLATE GROOVE LOCATIONS AND WIDTHS, AND FUEL PLATE THICKNESS. DIRECT MEASUREMENT IS NOT REQUIRED.
4. REMOVE ALL BURRS AND SHARP EDGES.

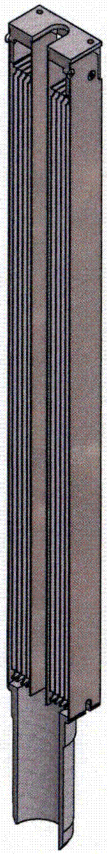
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE
1	CHANGED TO SHOW NEW FUEL PLATE DESIGN; ADDED -2 ASSEMBLY, SECTION A-A, & ITEM 6; SEE DAR-509420	1/24/07
2	CHANGED MATERIAL ITEM 7, CHANGED NOTE 3, SEE DAR-514751	4/4/07



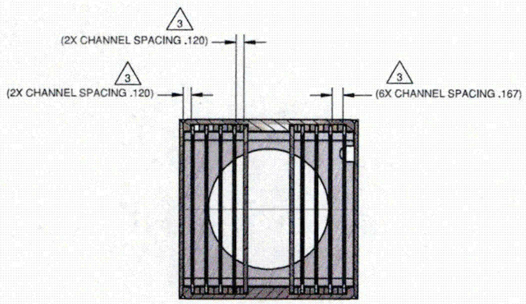




-1 ASSEMBLY
-2 ASSEMBLY
SCALE: 1/1



-1 SECTIONED ISOMETRIC REFERENCE ONLY
SCALE: NONE



SECTION A-A
SCALE: 1/1

QTY REQD -2	QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
6	6	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 5/16 LG	316 SST OR 304 SST	7
8			635463-3	DUMMY FUEL PLATE		6
1	1		635466-11	CONTROL TOP		5
	8		635463-1	FUEL PLATE ASSEMBLY		4
1	1		635459-1	CONTROL FUEL CONTAINER ASSEMBLY		3
		SC	-2	DUMMY CONTROL FUEL ELEMENT ASSEMBLY		2
		SC	-1	CONTROL FUEL ELEMENT ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-2	FINAL
-1	FINAL

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD
UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: .X = ± .1
DECIMALS: .XX = ± .03
.XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
CONTROL FUEL ELEMENT ASSEMBLY AND
DUMMY CONTROL FUEL ELEMENT ASSEMBLY

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 540, TYPE 9999, CL 43, ORIG 081 | DWG-635456 | REV 2
SCALE: NOTED | SHEET 1 OF 1

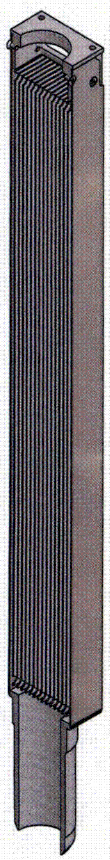
SD8032

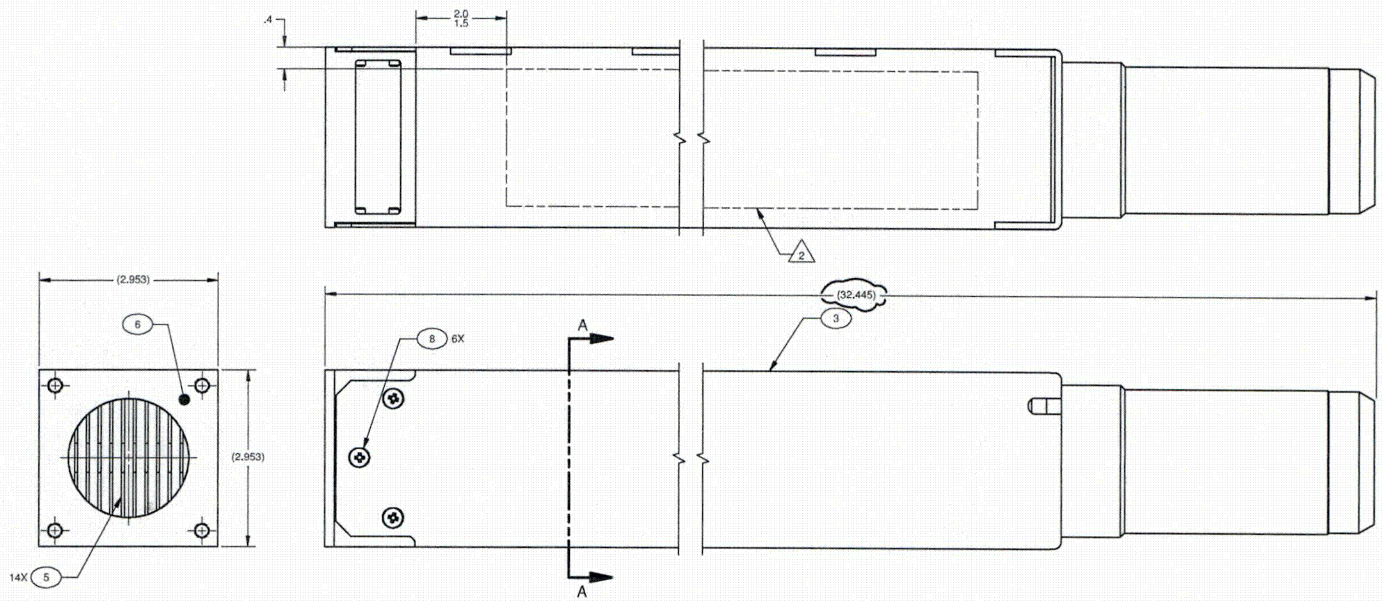
Path: C:\vault Local Projects\Other\Purdue University\635456.idw
File:635456-2 Date: 9/25/06

NOTES:

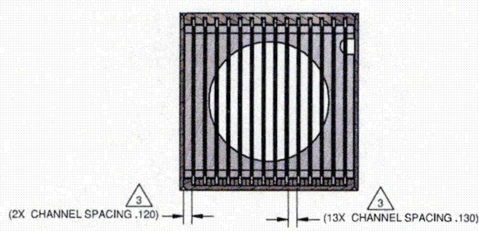
1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. MARK ASSEMBLY IDENTIFICATION PER SPECIFICATION SPC-382.
3. CHANNEL SPACING IS CONTROLLED BY SIDE PLATE GROOVE LOCATIONS AND WIDTHS, AND FUEL PLATE THICKNESS. DIRECT MEASUREMENT IS NOT REQUIRED.
4. REMOVE ALL BURRS AND SHARP EDGES.

REV	DESCRIPTION	EFFECTIVE DATE
1	REVISE TO SHOW NEW FUEL PLATE DESIGN; REMOVED ITEMS 2, 4, & 7; REVISED TITLE; SEE DAR-509420	1/24/07
2	REVISED NOTE 3 & MATERIAL ON ITEM 8 SEE DAR-514751	4/4/07





-1 ASSEMBLY
SCALE: 1/1



SECTION A-A
SCALE: 1/1

PARTS LIST

QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
6	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 5/16 LG	316 SST OR 304 SST	8
					7
1		635468-2	FISSION CHAMBER TOP		6
14		635463-1	FUEL PLATE ASSEMBLY		5
					4
1		635458-1	STANDARD FUEL CONTAINER ASSEMBLY		3
		-2	REMOVED		2
	SC	-1	FISSION CHAMBER FUEL ELEMENT ASSEMBLY		1

DASH NO.	NEXT ASSY
-1	FINAL

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: DECIMALS .X = ± .1, .XX = ± .03, .XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
FISSION CHAMBER FUEL ELEMENT ASSEMBLY

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 540, TYPE 9999, CL 43, ORIG 081 | DWG-635457 | REV 2

SCALE: NOTED | SHEET 1 OF 1

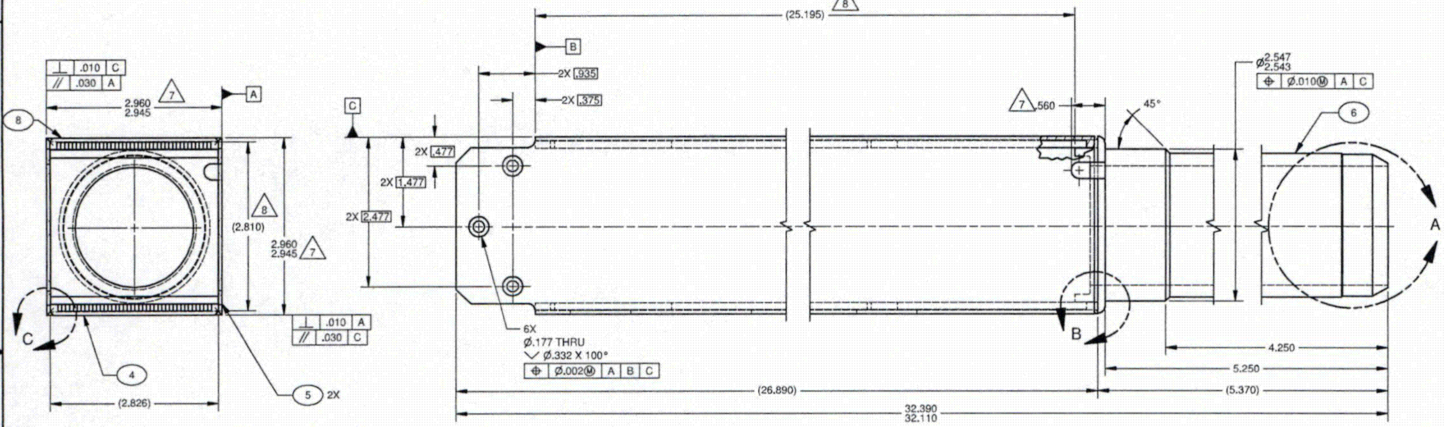
SD8032

Path: C:\vault Local Projects\Other\Purdue University\635457.idw
File:635457-2
Date: 9/25/06

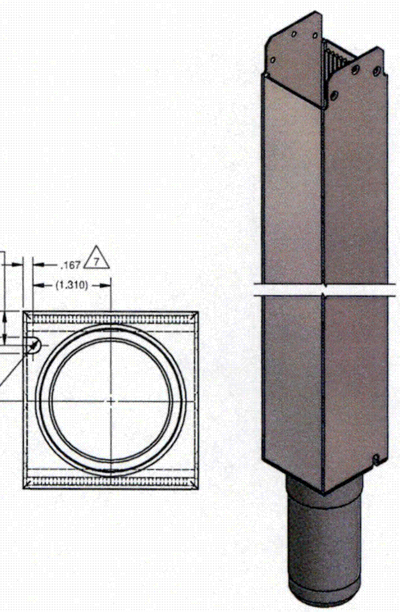
REV	DESCRIPTION	EFFECTIVE DATE
4	REMOVED PRIOR REV HISTORY SEE ECR-551872	7/2/07

NOTES:

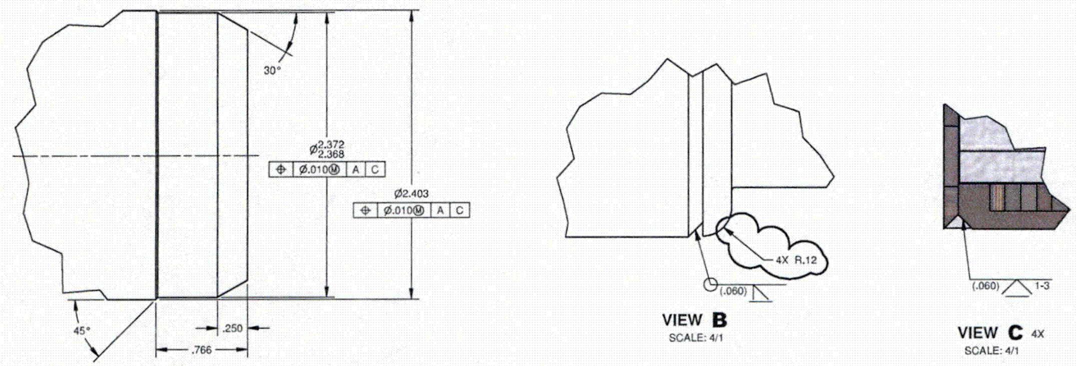
1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. REMOVED
3. REMOVED
4. REMOVE ALL BURRS AND SHARP EDGES.
5. WELD PER SPECIFICATION SPC-382 APPENDIX B, USING ITEM 7 (WELD FILLER METAL).
6. ALL CORNER AND FILLET RADII .030 UNLESS OTHERWISE NOTED.
7. CRITICAL INTERFACE DIMENSIONS SHALL BE ADHERED TO.
8. VERIFY RECTANGULAR CAVITY AND SLOT SIZE WITH GO-NO-GO GAUGE. GFE PROVIDED GO-NO-GO GAUGE SHALL SLIDE FREELY THROUGHOUT ENTIRE DESIGNATED CAVITY (OR SLOT) LENGTH FOR ALL SLOTS WITHOUT HANG-UP, STICKING, OR DISENGAGEMENT FROM SLOT.



-1 ASSEMBLY
SCALE: 1/1



-1 ISOMETRIC VIEW REFERENCE ONLY
SCALE: NONE



VIEW A
SCALE: 2/1

VIEW B
SCALE: 4/1

VIEW C 4X
SCALE: 4/1

QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
1		635466-12	STANDARD SIDE PLATE RIGHT HAND		8
AR	SC		WELD FILLER METAL	ER 4043 AWS A 5.10	7
1		-6	NOZZLE	MAKE FROM 635468-1	6
2		-5	EDGE PLATE	MAKE FROM 635466-8	5
1		635466-6	STANDARD SIDE PLATE LEFT HAND		4
					3
		-2	REMOVED		2
	SC	-1	STANDARD FUEL CONTAINER ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-1	635457
-1	635455

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED. SURFACE ROUGHNESS. DIMENSIONS AND TOLERANCES ARE IN INCHES. TOLERANCES: DECIMALS .X = ± .1, .XX = ± .03, .XXX = ± .010; FRACTIONS ± 1/8; ANGULAR ± 2°. DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

INL Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
STANDARD FUEL CONTAINER ASSEMBLY

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 540, TYPE 9999, CL 43, ORIG 081 | DWG-635458 | REV 4
SCALE: NOTED | SHEET 1 OF 1

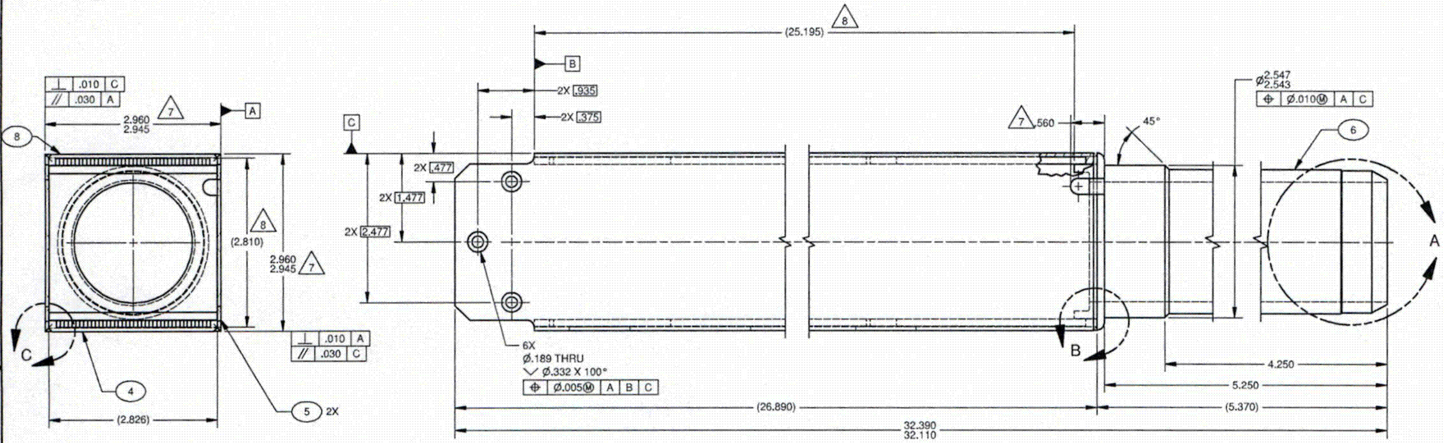
SD8112

Path: C:\vault\Local\Projects\Other\Purdue University\635458.idw
File: 635458-4
Date: 1/21/07

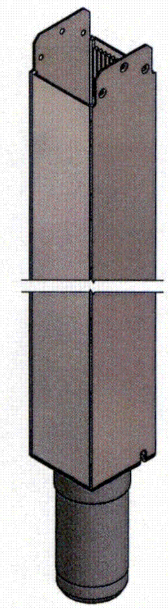
REV	DESCRIPTION	EFFECTIVE DATE:
6	REMOVED PRIOR REV HISTORY SEE ECR-553363	8/16/07

NOTES:

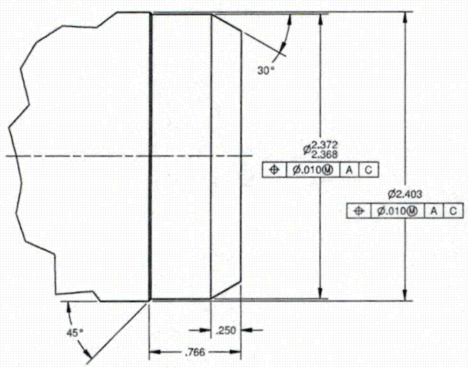
1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. REMOVED
3. REMOVED
4. REMOVE ALL BURRS AND SHARP EDGES.
5. WELD PER SPECIFICATION SPC-382 APPENDIX B, USING ITEM 7 (WELD FILLER METAL).
6. REMOVED.
7. CRITICAL INTERFACE DIMENSIONS SHALL BE ADHERED TO.
8. VERIFY RECTANGULAR CAVITY AND SLOT SIZE WITH GO-NO-GO GAUGE. GFE PROVIDED GO-NO-GO GAUGE SHALL SLIDE FREELY THROUGHOUT ENTIRE DESIGNATED CAVITY (OR SLOT) LENGTH FOR ALL SLOTS WITHOUT HANG-UP, STICKING, OR DISENGAGEMENT FROM SLOT.



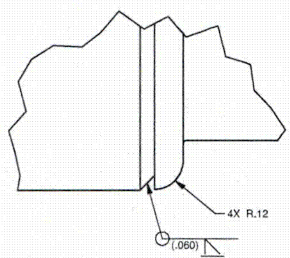
-1 ASSEMBLY
SCALE: 1/1



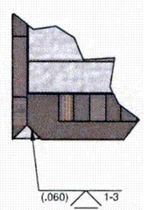
-1 ISOMETRIC VIEW REFERENCE ONLY
SCALE: NONE



VIEW A
SCALE: 2/1



VIEW B
SCALE: 4/1



VIEW C 4X
SCALE: 4/1

QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
1		635466-12	STANDARD SIDE PLATE RIGHT HAND		8
AR	SC		WELD FILLER METAL	ER 4043 AWS A 5.10	7
1		-6	NOZZLE	MAKE FROM 635468-1	6
2		-5	EDGE PLATE	MAKE FROM 635466-8	5
1		635466-6	STANDARD SIDE PLATE LEFT HAND		4
					3
		-2	REMOVED		2
	SC	-1	STANDARD FUEL CONTAINER ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-1	635457
-1	635455

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125/
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: .X = ± .1
DECIMALS: .XX = ± .03
.XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
STANDARD FUEL CONTAINER ASSEMBLY

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 540, TYPE 9999, CL 43, ORIG 081 | DWG-635458 | REV 6

SCALE: NOTED | SHEET 1 OF 1

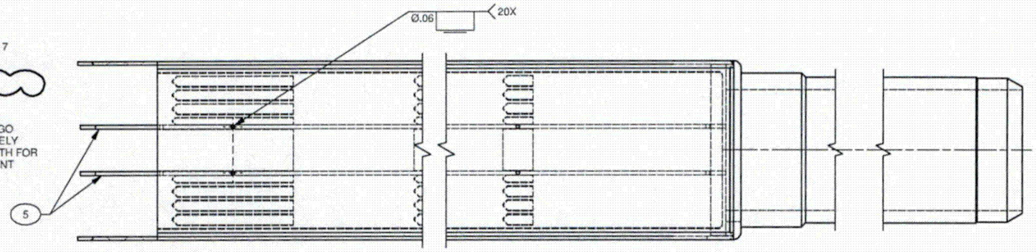
SD8163

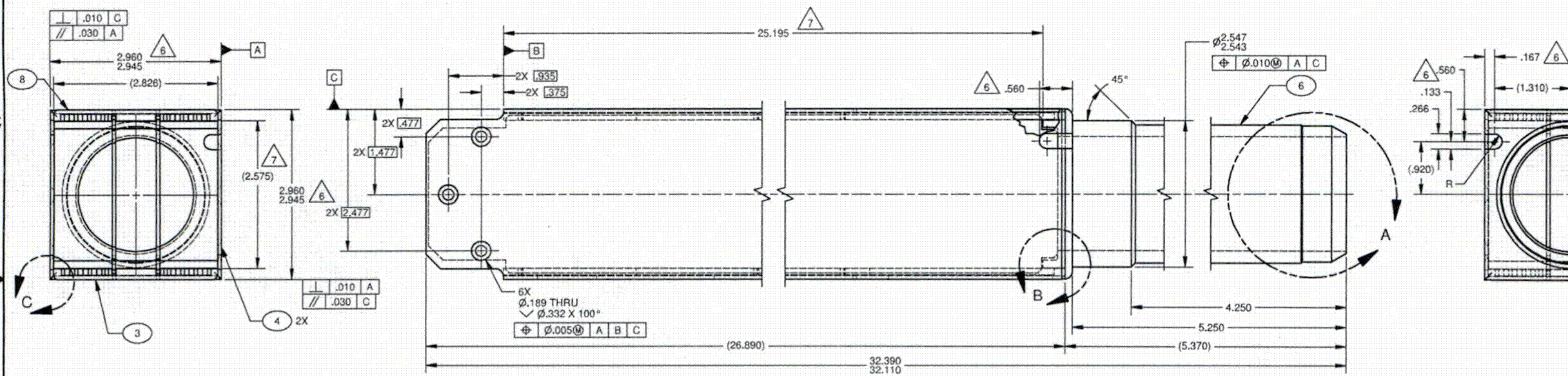
Path: C:\vault\Local\Projects\Other\Purdue University\635458.idw
File:635458R6
Date: 8/15/07

NOTES:

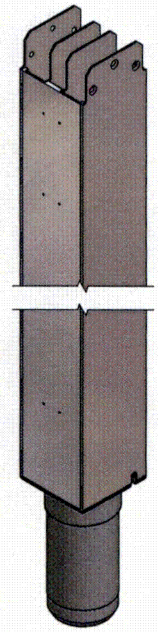
1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. REMOVED
3. REMOVE ALL BURRS AND SHARP EDGES.
4. WELD PER SPECIFICATION SPC-382 APPENDIX B, USING ITEM 7 (WELD FILLER METAL).
5. REMOVED.
6. CRITICAL INTERFACE DIMENSIONS SHALL BE ADHERED TO.
7. VERIFY RECTANGULAR CAVITY AND SLOT SIZE WITH GO-NO-GO GAUGE. GFE PROVIDED GO-NO-GO GAUGE SHALL SLIDE FREELY THROUGHOUT ENTIRE DESIGNATED CAVITY (OR SLOT) LENGTH FOR ALL SLOTS WITHOUT HANG-UP, STICKING, OR DISENGAGEMENT FROM SLOT.

REV	DESCRIPTION	EFFECTIVE DATE
6	REMOVED PRIOR REV HISTORY SEE ECR-553636	8/16/07

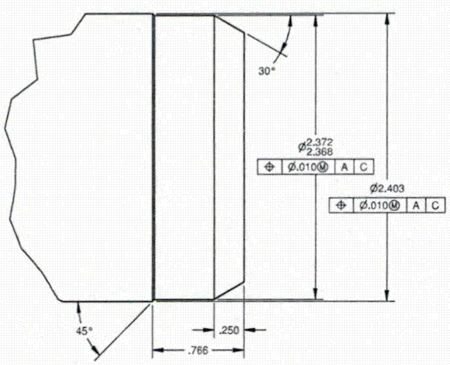




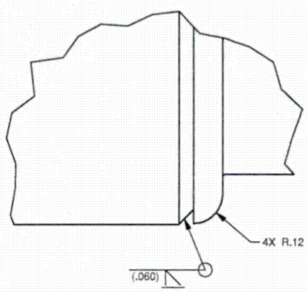
-1 ASSEMBLY
SCALE: 1/1



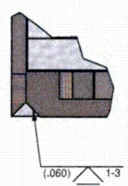
-1 ISOMETRIC VIEW REFERENCE ONLY
SCALE: NONE



VIEW A
SCALE: 2/1



VIEW B
SCALE: 4/1



VIEW C 4X
SCALE: 4/1

QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
1		635466-13	CONTROL SIDE PLATE RIGHT HAND		8
AR	SC		WELD FILLER METAL	ER 4043 AWS A 5.10	7
1		-6	NOZZLE	MAKE FROM 635468-1	6
2		635466-9	SPACER PLATE		5
2		-4	EDGE PLATE	MAKE FROM 635466-8	4
1		635466-7	CONTROL SIDE PLATE LEFT HAND		3
					2
	SC	-1	CONTROL FUEL CONTAINER ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-1	635456

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD. UNLESS OTHERWISE SPECIFIED SURFACE ROUGHNESS 125. DIMENSIONS AND TOLERANCES ARE IN INCHES. TOLERANCES: DECIMALS .X = ±.1, .XX = ±.03, .XXX = ±.010; FRACTIONS ±1/8; ANGULAR ±2°. DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

INL Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
CONTROL FUEL CONTAINER ASSEMBLY

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 540, TYPE 9999, CL 43, ORIG 081 | DWG-635459 | REV 6

SCALE: NOTED | SHEET 1 OF 1

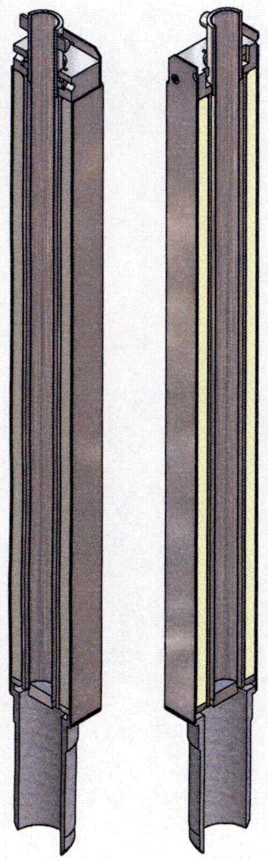
SD8163

Path: C:\vault\Local\Projects\Other\Purdue University\635459.idw
File:635459(6)
Date: 8/15/07

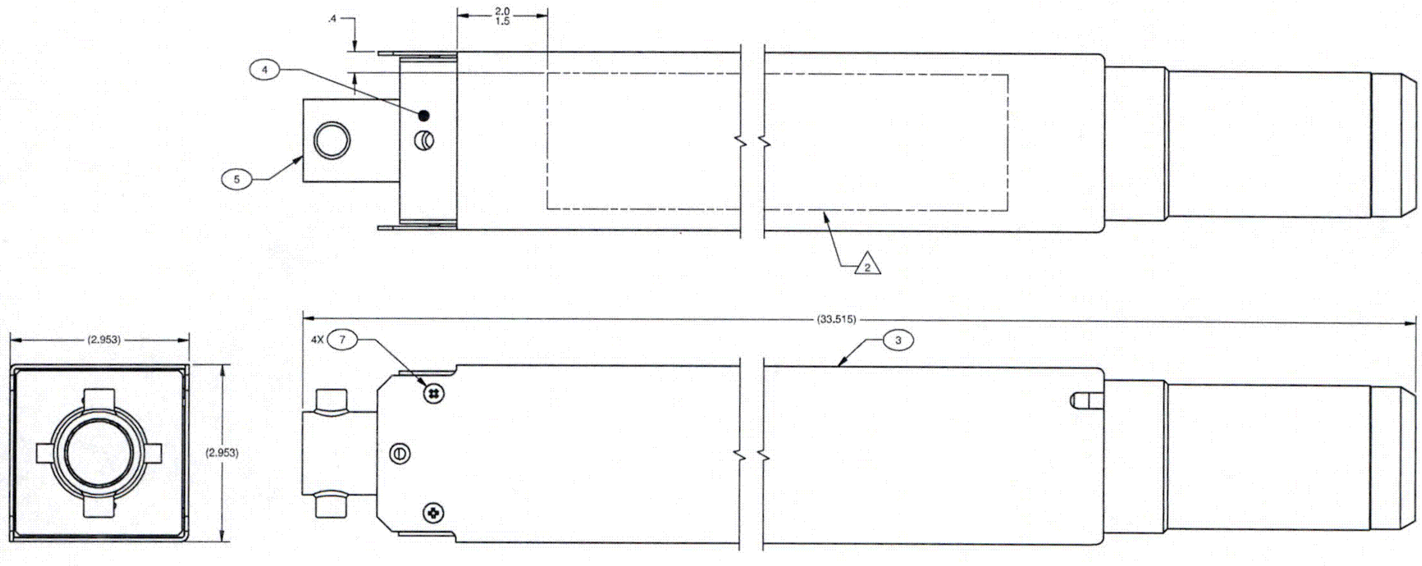
NOTES:

1. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
2. (2) MARK ASSEMBLY IDENTIFICATION PER SPECIFICATION SPC-382.
3. REMOVE ALL BURRS AND SHARP EDGES.

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE
1	REVISED THE DESCRIPTION OF ITEM 3 SEE DAR-509420	1/24/07
2	CHANGED MATERIAL ITEM 7 SEE DAR-514751	4/4/07



-1 SECTIONED ISOMETRIC REFERENCE ONLY
SCALE: NONE



-1 ASSEMBLY
SCALE: 1/1

QTY REQD -1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
4	CG		MACHINE SCREW, FLAT HD, PHILLIPS, 100° 8-32 UNC-2A X 1/2 LG	316 SST OR 304 SST	7
					6
1		635461-2	CAPSULE INSERT ASSEMBLY		5
1		635461-1	CAPSULE HOLDER ASSEMBLY		4
1		635462-1	GRAPHITE CONTAINER ASSEMBLY		3
					2
	SC	-1	IRRADIATION FACILITY ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-1	FINAL

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: DECIMALS .X = ± .1, .XX = ± .03, .XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

INL Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
IRRADIATION FACILITY ASSEMBLY

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG-	REV
D	01MF3	540	9999	43	081	635460	2

SCALE: NOTED SHEET 1 OF 1
SD8032

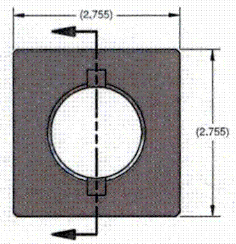
File: 635460-2 Date: 9/28/06
Path: C:\Vault Local\Projects\Other\Purdue University\635460.idw

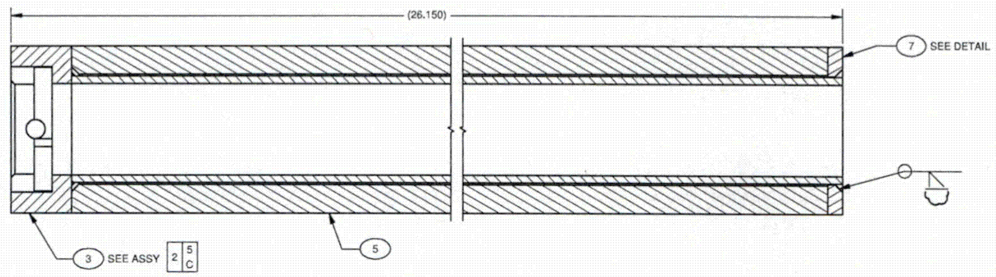
NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES.
2. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
3. WELD PER SPECIFICATION SPC-382 APPENDIX B, USING ITEM 17 (WELD FILLER METAL).
4. ALL CORNER AND FILLET RADII .030 UNLESS OTHERWISE NOTED.

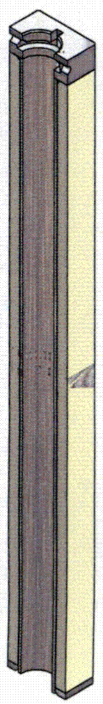
3	2	1	SHEET	REV STATUS OF SHEETS
1	1	1	REV	

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE
1	REVISED TOLERANCES ON ITEM 8 SEE DAR-514751	4/4/07

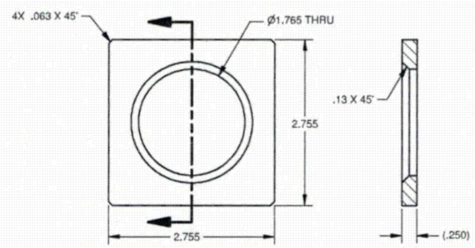




-1 ASSEMBLY
SCALE: 1/1



-1 ISOMETRIC REFERENCE ONLY
SCALE: NONE



7 DETAIL
SCALE: 1/1

AR	AR	AR	AR	SC		WELD FILLER METAL	ER 4043 AWS A5.10	17
		AR		SC			BAR, Ø1/2 AL 6061-T651 ASTM B211	16
		AR		SC			BAR, Ø1/4 AL 6061-T651 ASTM B211	15
AR				SC			BAR, Ø1/8 AL 6061-T651 ASTM B211	14
								13
		AR		SC			TUBING, 1 1/8 OD X .058 WALL AL 6061-T6 ASTM B210	12
	AR			SC			TUBING, 1 3/4 OD X .125 WALL AL 6061-T6 ASTM B210	11
		1		SC	-10	PLUG	PLATE, 1/2 THK AL 6061-T651 ASTM B209	10
		1		SC	-9	CAPSULE UPPER TUBE	BAR, Ø1 3/8 AL 6061-T651 ASTM B211	9
1				SC	-8	CAPSULE HOLDER TOP PLATE	PLATE, 1 THK AL 6061-T651 ASTM B209	8
			1	SC	-7	CAPSULE HOLDER BOTTOM PLATE	PLATE, 1/4 THK AL 6061-T651 ASTM B209	7
								6
			1		635465-2	GRAPHITE CAPSULE HOLDER		5
	1			SC	-4	CAPSULE HOLDER TOP PLATE ASSEMBLY		4
			1	SC	-3	CAPSULE HOLDER WELDMENT ASSEMBLY		3
				SC	-2	CAPSULE INSERT ASSEMBLY		2
				SC	-1	CAPSULE HOLDER ASSEMBLY		1
-4	-3	-2	-1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
QTY REQD								

PARTS LIST

DASH NO.	NEXT ASSY
-2	635460
-1	635460
APPLICATION	

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD
UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: DECIMALS: .X = ± .1, .XX = ± .03, .XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

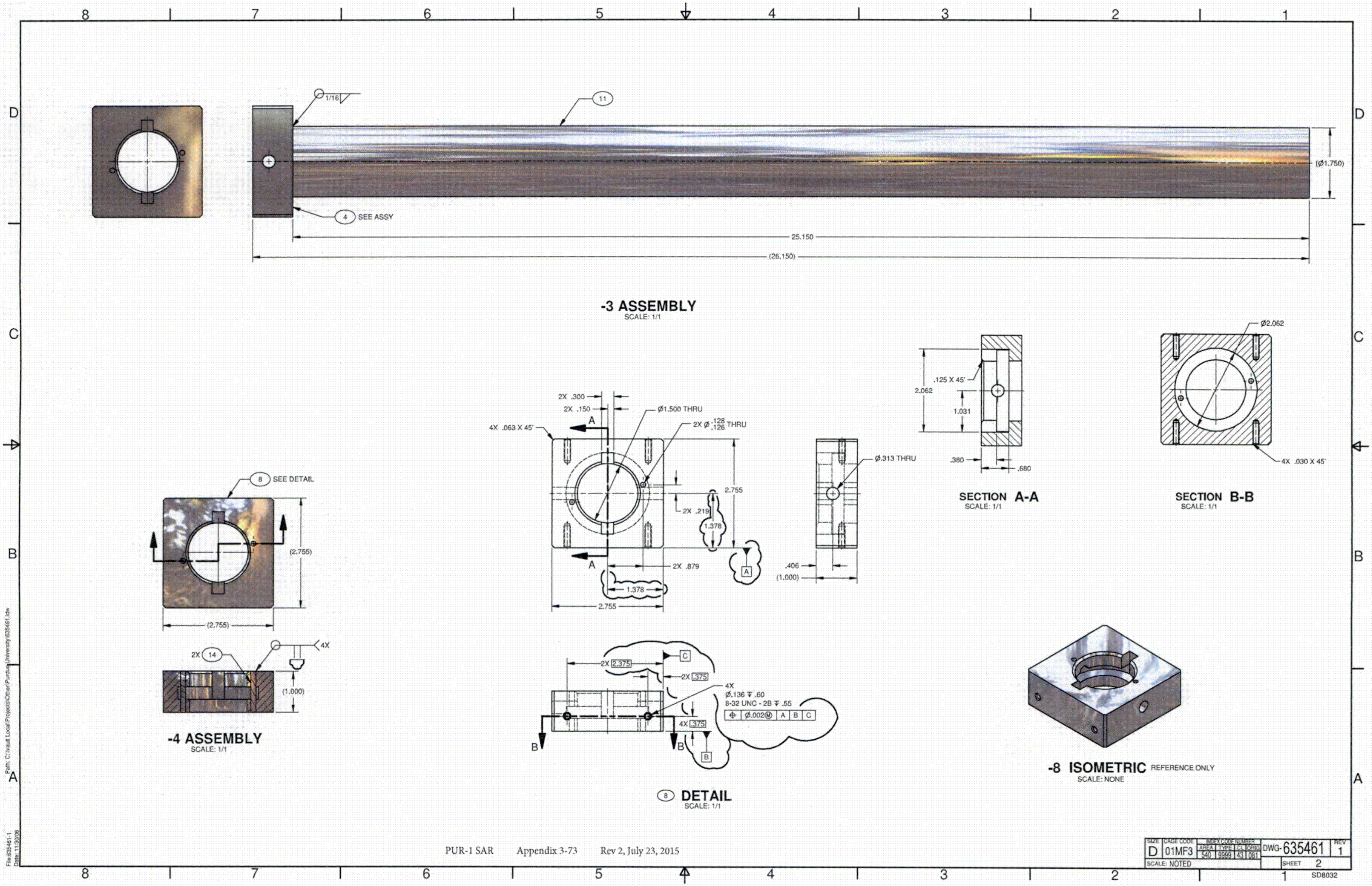
Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
CAPSULE HOLDER AND CAPSULE INSERT
ASSEMBLIES AND DETAILS

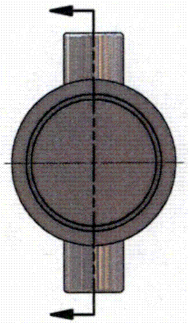
SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG	REV
D	01MF3	540	9999	43	081	DWG-635461	1

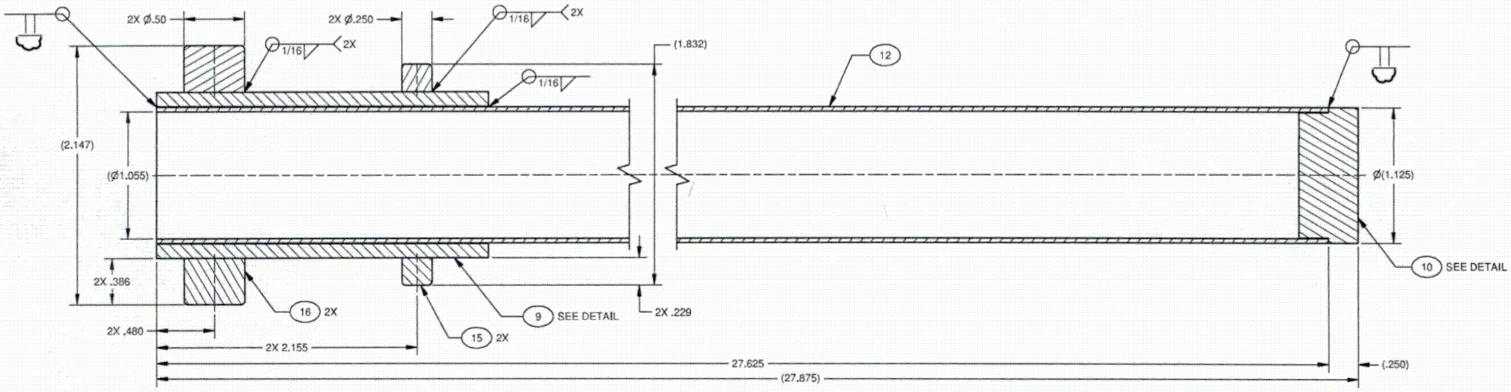
SCALE: NOTED
SHEET 1 OF 3
SD8032

Path: C:\vault Local Projects\Other\Purdue University\635461.idw
File:635461-1
Date: 11/30/06

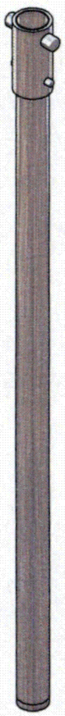


-3 ASSEMBLY
SCALE: 1/1
SEE ASSY
25.150
(26.150)
(Ø1.750)
-4 ASSEMBLY
SCALE: 1/1
SEE DETAIL
(2.755)
(1.000)
SECTION A-A
SCALE: 1/1
SECTION B-B
SCALE: 1/1
DETAIL
SCALE: 1/1
-8 ISOMETRIC REFERENCE ONLY
SCALE: NONE
Ø1.500 THRU
Ø.313 THRU
8-32 UNC - 2B ⊽ .55
DWG-635461
SHEET 2
SD8032

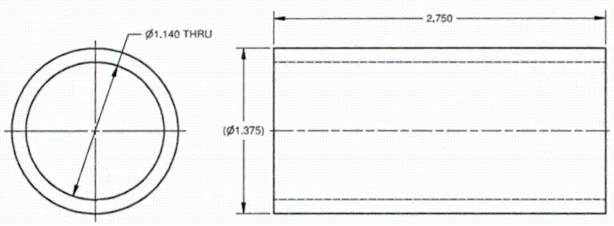




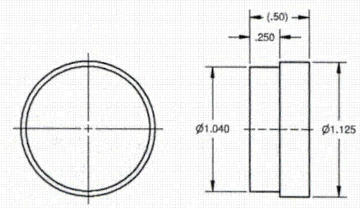
-2 ASSEMBLY
SCALE: 2/1



-2 ISOMETRIC REFERENCE ONLY
SCALE: NONE



9 **DETAIL**
SCALE: 2/1



10 **DETAIL**
SCALE: 2/1

SIZE	CAGE CODE	INDEX CODE NUMBER				DWG-	REV
D	01MF3	AREA 540	TYPE 9999	CL 431	DOMAIN 061	635461	1
SCALE: NOTED						SHEET 3	

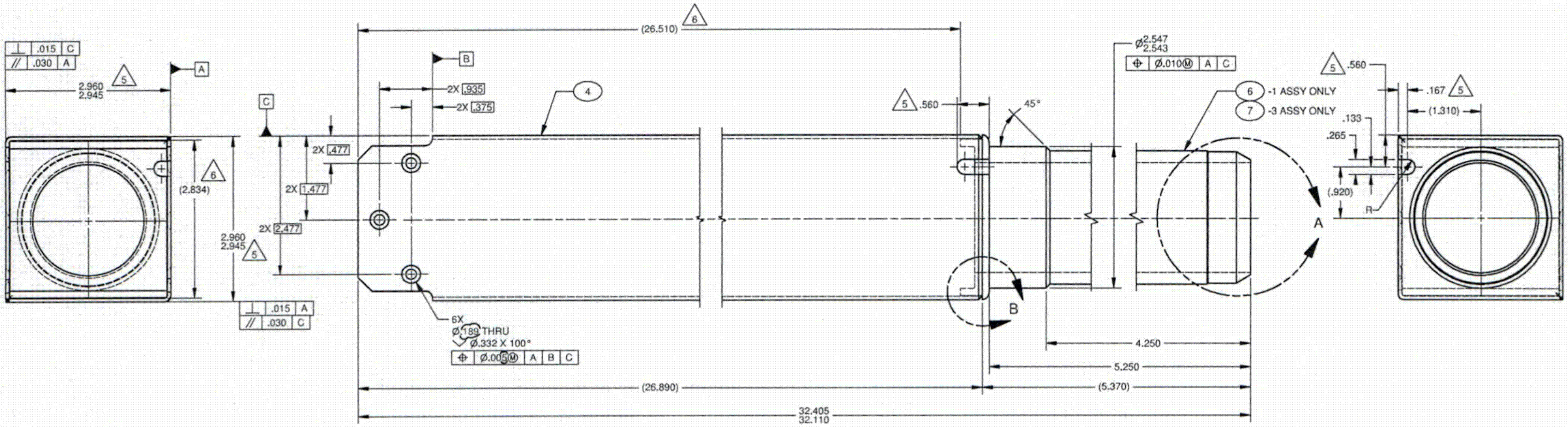
SD8032

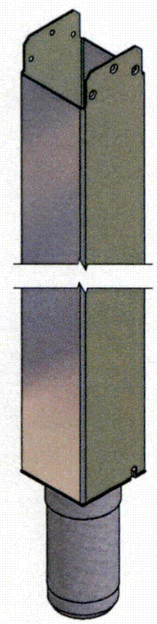
Path: C:\Vault Local Projects\Other\Purdue University\635461.idw
File: 635461-1
Date: 11/30/06

NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES.
2. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
3. WELD PER SPECIFICATION SPC-382 APPENDIX B, USING ITEM 8 (WELD FILLER METAL).
4. ALL CORNER AND FILLET RADII .030 UNLESS OTHERWISE NOTED.
5. CRITICAL INTERFACE DIMENSIONS SHALL BE ADHERED TO.
6. VERIFY RECTANGULAR CAVITY AND SLOT SIZE WITH GO-NO-GO GAUGE. GFE PROVIDED GO-NO-GO GAUGE SHALL SLIDE FREELY THROUGHOUT ENTIRE DESIGNATED CAVITY (OR SLOT) LENGTH FOR ALL SLOTS WITHOUT HANG-UP, STICKING, OR DISENGAGEMENT FROM SLOT.

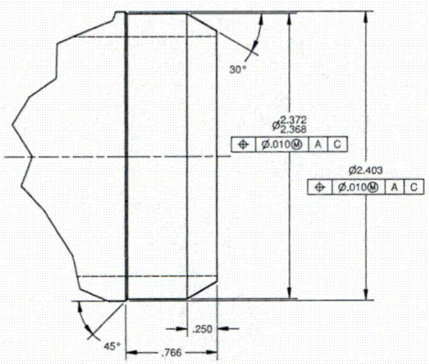
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE
4	REMOVED PRIOR REV HISTORY SEE ECR-551872	7/2/07
5	REVISED DIMENSIONS SEE ECR-553787	9/6/07



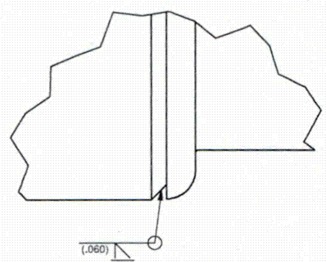


-1 ISOMETRIC REFERENCE ONLY
SCALE: NONE

-1 ASSEMBLY (SHOWN)
-3 ASSEMBLY (SIMILAR)
SCALE: 1/1



VIEW A
SCALE: 2/1



VIEW B
SCALE: 4/1

-3	-1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
AR	AR	SC		WELD FILLER METAL	ER 4043 AWS A5.10	8
	1		-7	SOURCE DRIVE NOZZLE ASSEMBLY	MAKE FROM 635467-1	7
1			-6	NOZZLE	MAKE FROM 635467-3	6
						5
1	1		-4	CONTAINER TUBE ASSEMBLY	MAKE FROM 635464-1	4
		SC	-3	SOURCE DRIVE CONTAINER ASSEMBLY		3
			-2	REMOVED		2
		SC	-1	GRAPHITE CONTAINER ASSEMBLY		1

QTY REQD — PARTS LIST

DASH NO.	NEXT ASSY
-3	635454
-1	635460
-1	635454

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED. DIMENSIONS AND TOLERANCES ARE IN INCHES. DO NOT SCALE DRAWING.

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

INL Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
GRAPHITE CONTAINER ASSEMBLY
AND SOURCE DRIVE CONTAINER ASSEMBLY

SIZE D — CAGE CODE 01MF3 — INDEX CODE NUMBER 540 9999 43 061 — DWG-635462 — REV 5
SCALE: NOTED — SHEET 1 OF 1

SD8179

File:635462-5 Date: 1/31/07

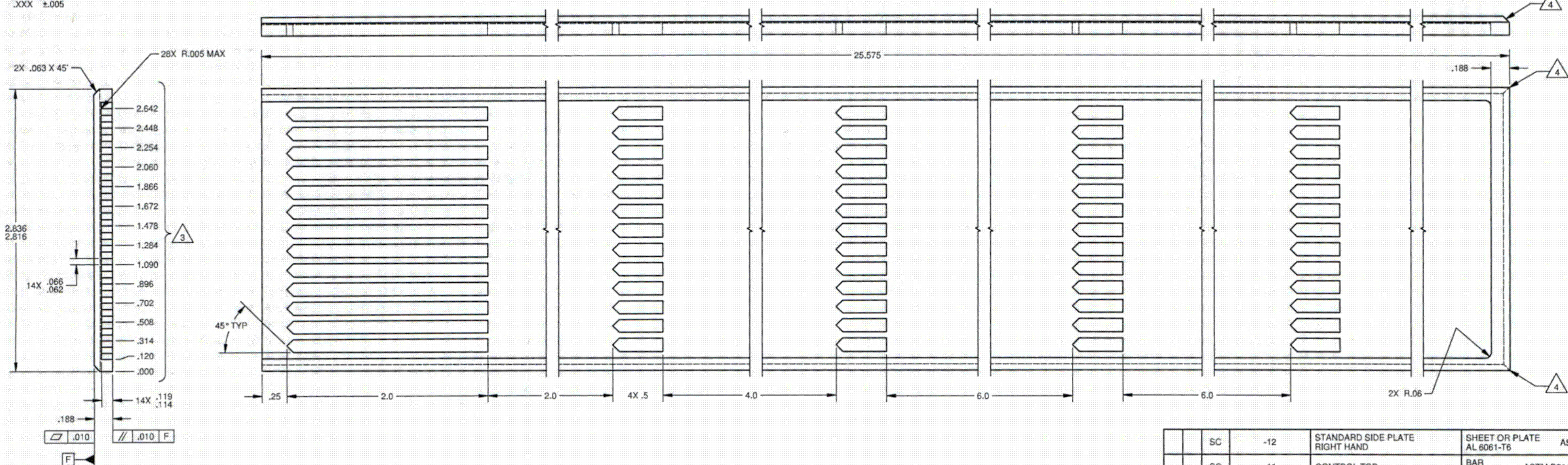
NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES.
2. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
3. (△) ALL GROOVE LOCATIONING DIMENSIONS ARE ± .002 AND TOLERANCE SHALL NOT BE ACCUMULATIVE UNLESS OTHERWISE SPECIFIED.
4. (△) WELD PREP AS NECESSARY.
5. REMOVED
6. (△) TOLERANCE:
   .XX ±.01
   .XXX ±.005

4	3	2	1	SHEET	REV STATUS OF SHEETS
6	6	6	6	REV	

REVISIONS

REV	DESCRIPTION	EFFECTIVE DATE
4	REMOVED PREVIOUS REV HISTORY SEE ECR-551872	7/2/07
5	SEE ECR-552925	8/1/07
6	SEE ECR-553363	8/16/07



(6) DETAIL LEFT HAND (SHOWN)

(12) DETAIL RIGHT HAND (OPPOSITE)

QTY REQD		SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
		SC	-12	STANDARD SIDE PLATE RIGHT HAND	SHEET OR PLATE AL 6061-T6 ASTM B221	12
		SC	-11	CONTROL TOP	BAR AL 6061-T651 ASTM B211 OR B221	11
			-10	REMOVED		10
		SC	-9	SPACER PLATE	SHEET AL 6061-T6 ASTM B209	9
		SC	-8	EDGE PLATE	SHEET AL 6061-T6 ASTM B221	8
		SC	-7	CONTROL SIDE PLATE LEFT HAND	SHEET OR PLATE AL 6061-T6 ASTM B221	7
		SC	-6	STANDARD SIDE PLATE LEFT HAND	SHEET OR PLATE AL 6061-T6 ASTM B221	6
			-5	REMOVED		5
			-4	REMOVED		4
			-3	REMOVED		3
			-2	REMOVED		2
			-1	REMOVED		1

PARTS LIST

QTY REQD		SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
		SC	-13	CONTROL SIDE PLATE RIGHT HAND	SHEET OR PLATE AL6061-T6 ASTM B221	13

PARTS LIST CONTINUED

DASH NO.	NEXT ASSY	DASH NO.	NEXT ASSY
		-12	635458
		-11	635456
		-9	635459
		-8	635459
		-8	635458
		-7	635459
-13	635459	-6	635458
APPLICATION		APPLICATION	

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD
UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: DECIMALS .X = ± .1, .XX = ± .03, .XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

INL Idaho National Laboratory

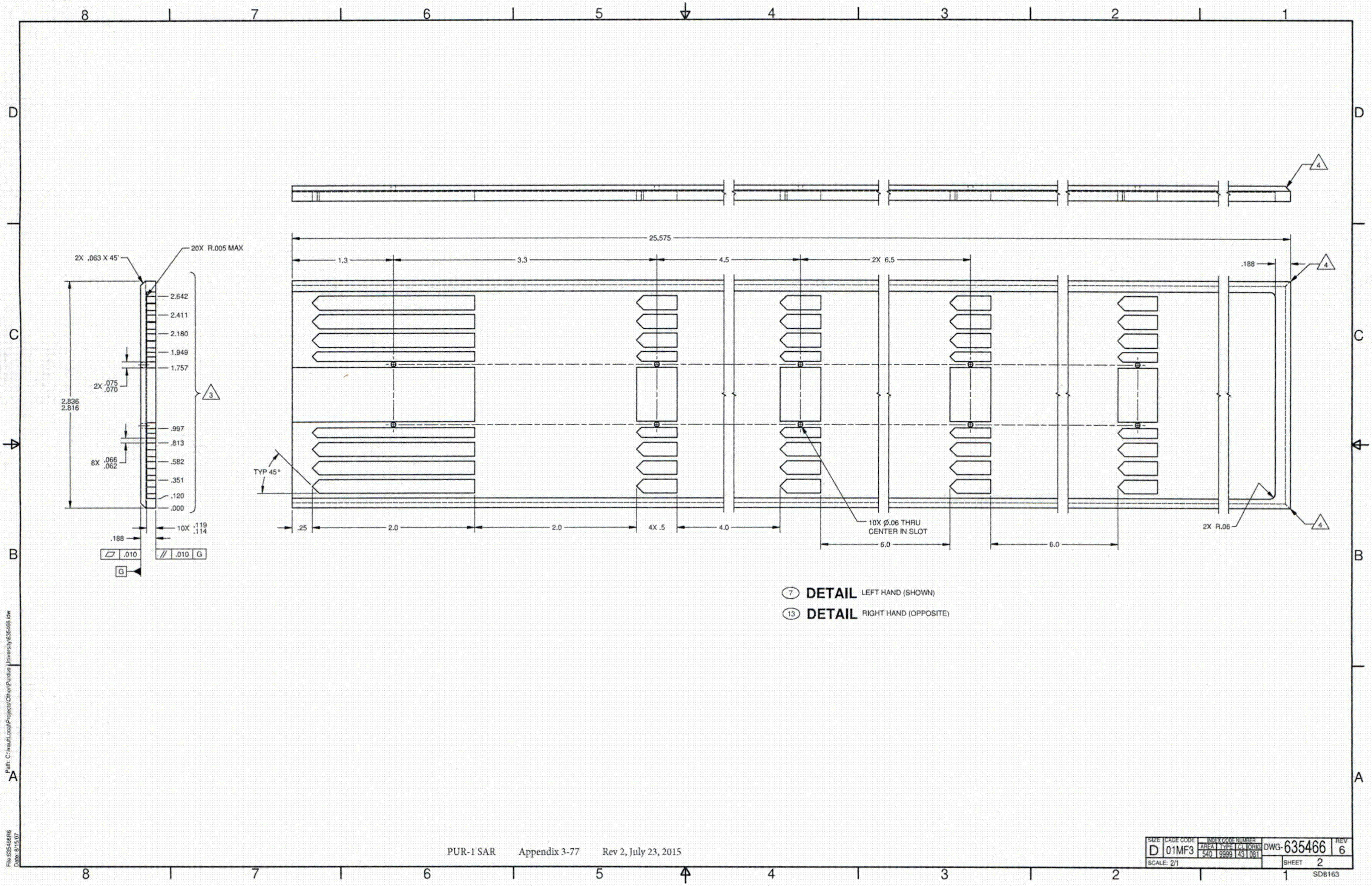
PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
MISCELLANEOUS DETAILS

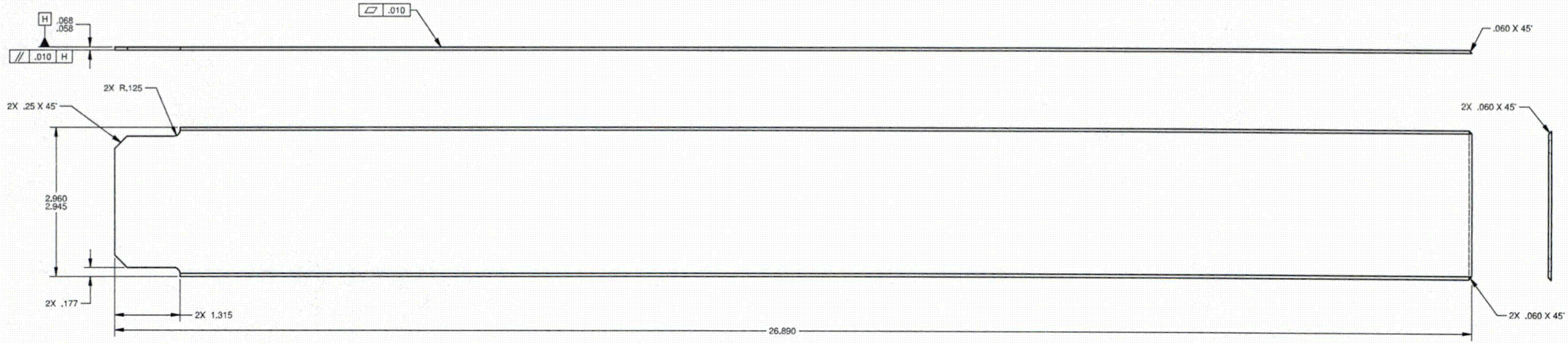
SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG-	REV
D	01MF3	540	9999	43	081	635466	6

SCALE: 2/1 SHEET 1 OF 4

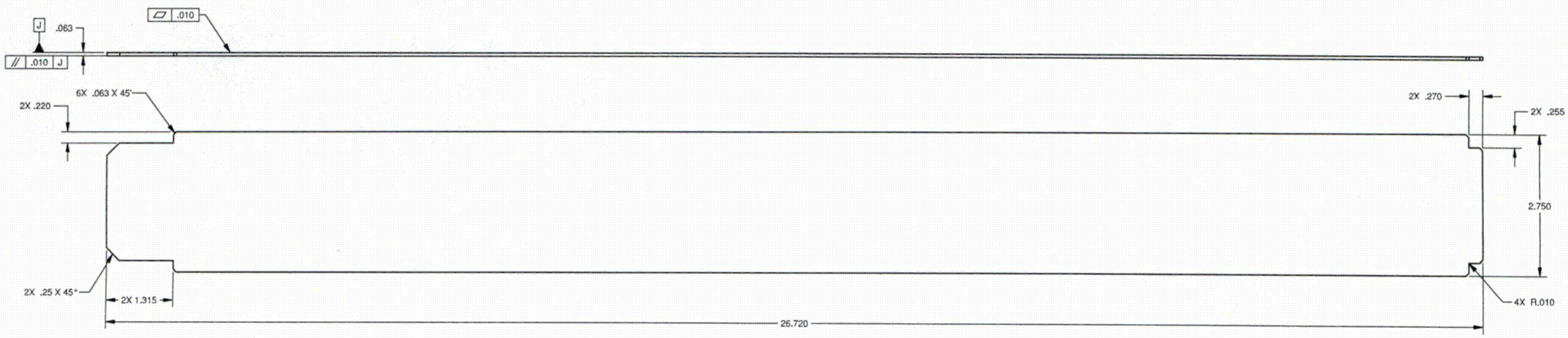
SD8163

File: 635466R6 Date: 8/15/07
Path: C:\vault\Local\Projects\Other\Purdue University\635466.idw


2X .063 X 45°
20X R.005 MAX
2.642
2.411
2.180
1.949
1.757
2X .075 .070
2.836 2.816
.997
.813
.582
.351
.120
.000
8X .066 .062
10X .119 .114
.188
.010
.010 G
G
25.575
1.3
3.3
4.5
2X 6.5
.188
TYP 45°
.25
2.0
2.0
4X .5
4.0
10X Ø.06 THRU
CENTER IN SLOT
6.0
6.0
2X R.06
7 DETAIL LEFT HAND (SHOWN)
13 DETAIL RIGHT HAND (OPPOSITE)
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER
AREA 540
TYPE 9999
CL 43
DRW 081
DWG- 635466
REV 6
SCALE: 2/1
SHEET 2
SD8163
File:635466R6
Date: 8/15/07
Path: C:\vault\Local\Projects\Other\Purdue University\635466.idw



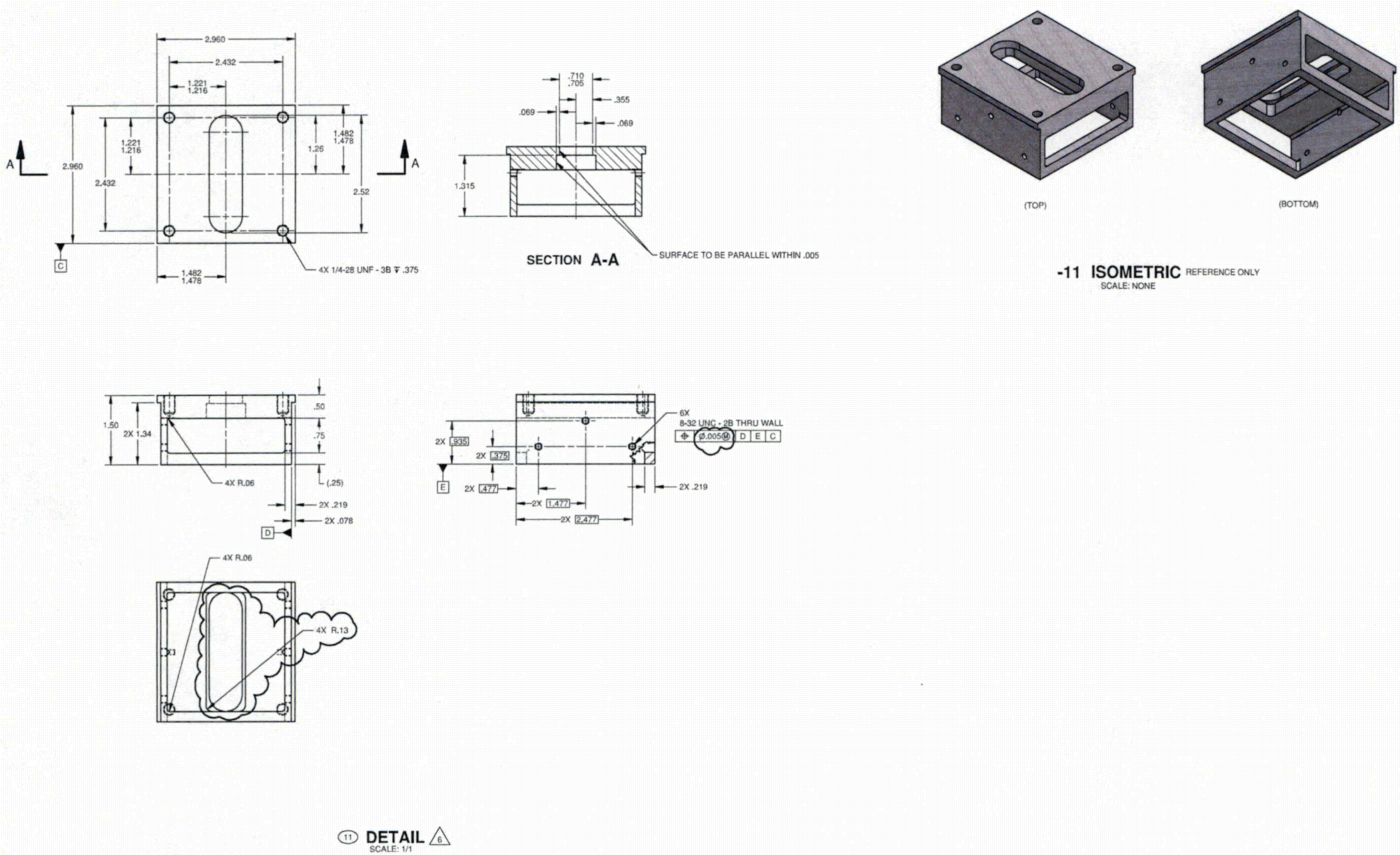
⑧ DETAIL



⑨ DETAIL

SIZE	CAGE CODE	INDEX CODE NUMBER	DWG-	REV
D	01MF3	540 9999 43 081	635466	6
SCALE: 1/1			SHEET 3	

SD8163



SIZE	CAGE CODE	INDEX CODE NUMBER AREA / TYPE / C.L./ORIG	DWG-	REV
D	01MF3	540 / 9999 / 451 / 061	635466	6
SCALE: NOTED			SHEET 4	

SD8163

Path: C:\vault\Local\Projects\Other\Purdue University\635466.idw
File:635466R6 Date: 8/15/07

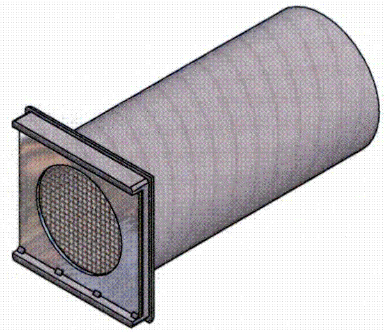
NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES.
2. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
3. WELD PER SPECIFICATION SPC-382 APPENDIX B USING ITEM 8 (WELD FILLER METAL).
4. (△) ALL CORNER AND FILLET RADII .030 UNLESS OTHERWISE NOTED.
5. REMOVED
6. (△) TOLERANCE:
   .XX ±.01
   .XXX ±.005
7. (△) MACHINE FOR A MINIMAL CLEARANCE FIT WITH THE INSIDE OF CONTAINER TUBE ASSY 635464-1.

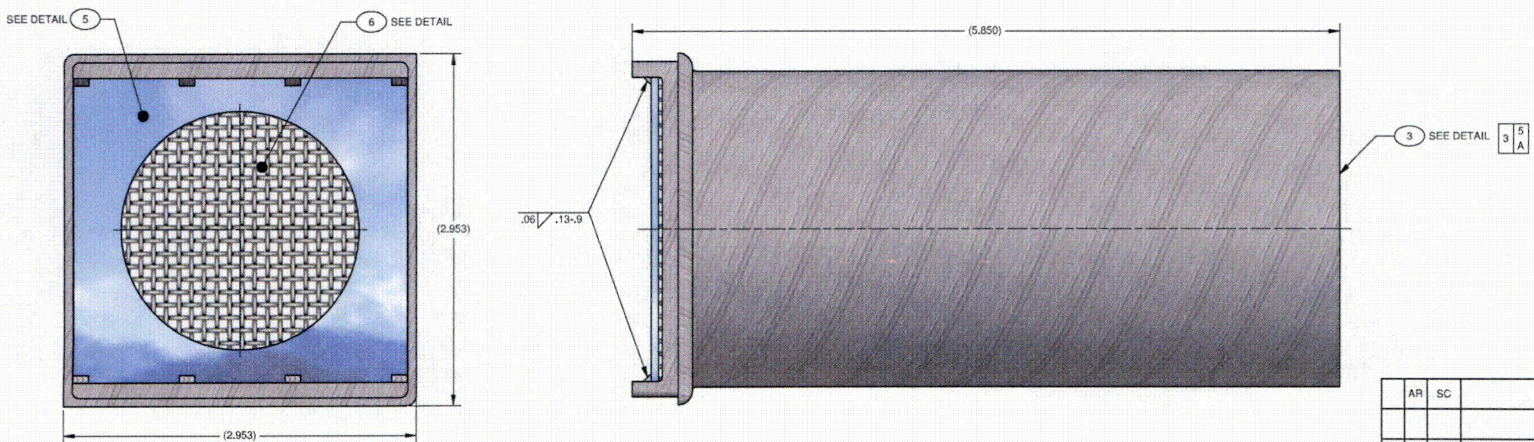
SHEET	3	2	1	REV STATUS OF SHEETS
REV	4	4	4	

REVISIONS

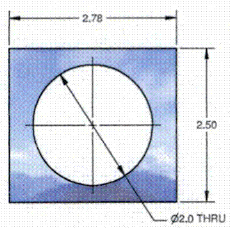
REV	DESCRIPTION	EFFECTIVE DATE
1	REVISED TITLE; REVISED ITEM 3; ADDED NOTE 4; ADDED SHEET 2 & 3; ADDED ITEM 2; SEE DAR-509420	1/18/07
2	TOTALLY REVISED SHEET 2, REMOVED CHAMFER FROM DETAIL 2, ADDED RADIUS DIMENSION TO ITEM 3, REMOVED NOTE 5, SEE DAR-514751	4/4/07
3	SEE ECR-551872	7/2/07
4	ADDED NOTE 7, SEE ECR-557045	12/17/07



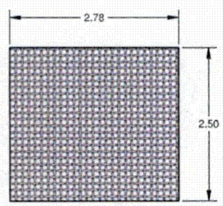
-1 ISOMETRIC REFERENCE ONLY
SCALE: NONE



-1 ASSEMBLY
SCALE: 2/1



5 DETAIL
SCALE: 1/1



6 DETAIL
SCALE: 1/1

QTY REQD	-1	SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
	AR	SC		WELD FILLER METAL	ER 4043 AWS A5.10	8
						7
	1	LSC	-6	MESH	WOVEN WIRE CLOTH, 16 X 16 MESH PER INCH, AL ASTM E 2016	6
	1	SC	-5	BACKING PLATE	SHEET, .063 THK AL 6061-T6 ASTM B209	5
						4
	1	SC	-3	NOZZLE PRELIMINARY MACHINED	BAR ASTM B211 OR B221 AL 6061-T6 OR AL 6061-T6511 OR AL 6061-T651	3
		SC	-2	SOURCE DRIVE TOP	PLATE AL 6061-T651 ASTM B209	2
	\	SC	-1	SOURCE DRIVE NOZZLE ASSEMBLY		1

PARTS LIST

DASH NO.	NEXT ASSY
-3	635462
-2	635457
-1	635462

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD
UNLESS OTHERWISE SPECIFIED
SURFACE ROUGHNESS 125/
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: .X = ± .1
DECIMALS .XX = ± .03
.XXX = ± .010
FRACTIONS ± 1/8
ANGULAR ± 2°
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 1/24/07

INL Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
SOURCE DRIVE NOZZLE ASSEMBLY
AND SOURCE DRIVE TOP

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG-	REV
D	01MF3	540	9999	43	081	635467	4

SCALE: NOTED
SHEET 1 OF 3
SD8259

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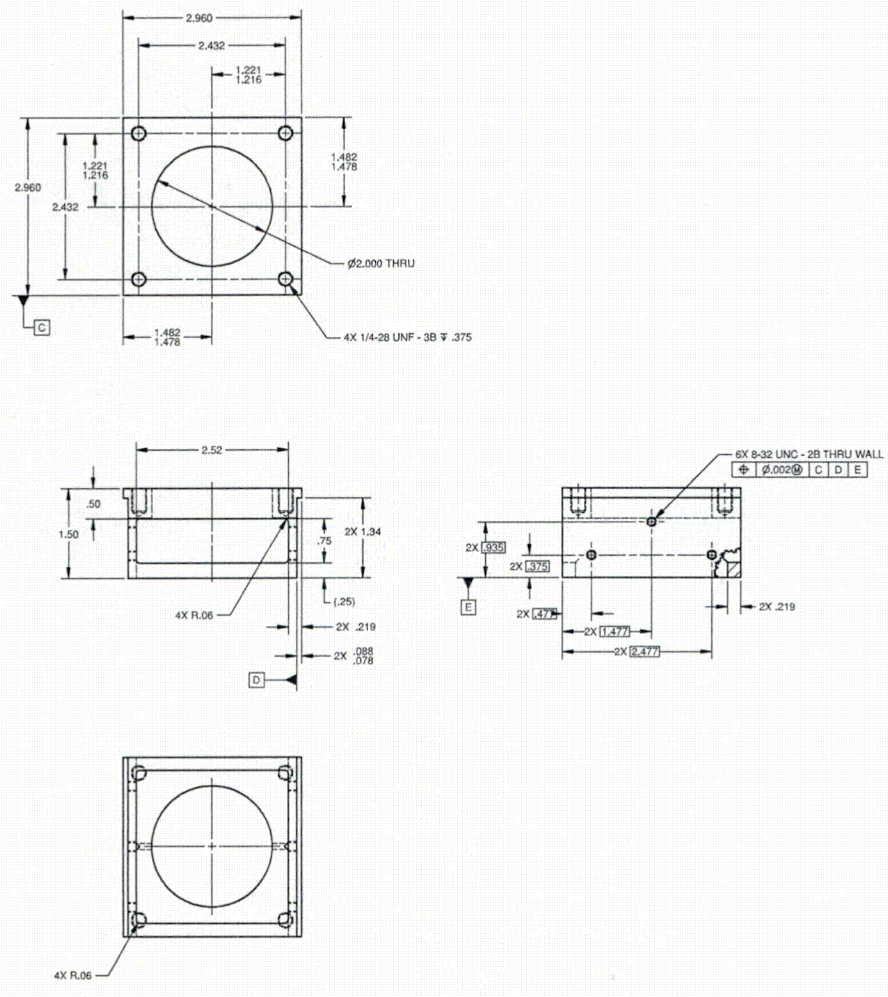
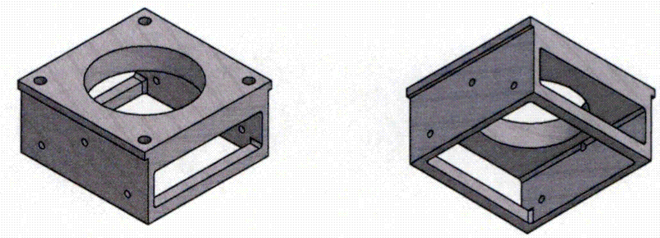
File:635467R4
Date: 12/17/07



② DETAIL 6
SCALE: 1/1



(TOP)

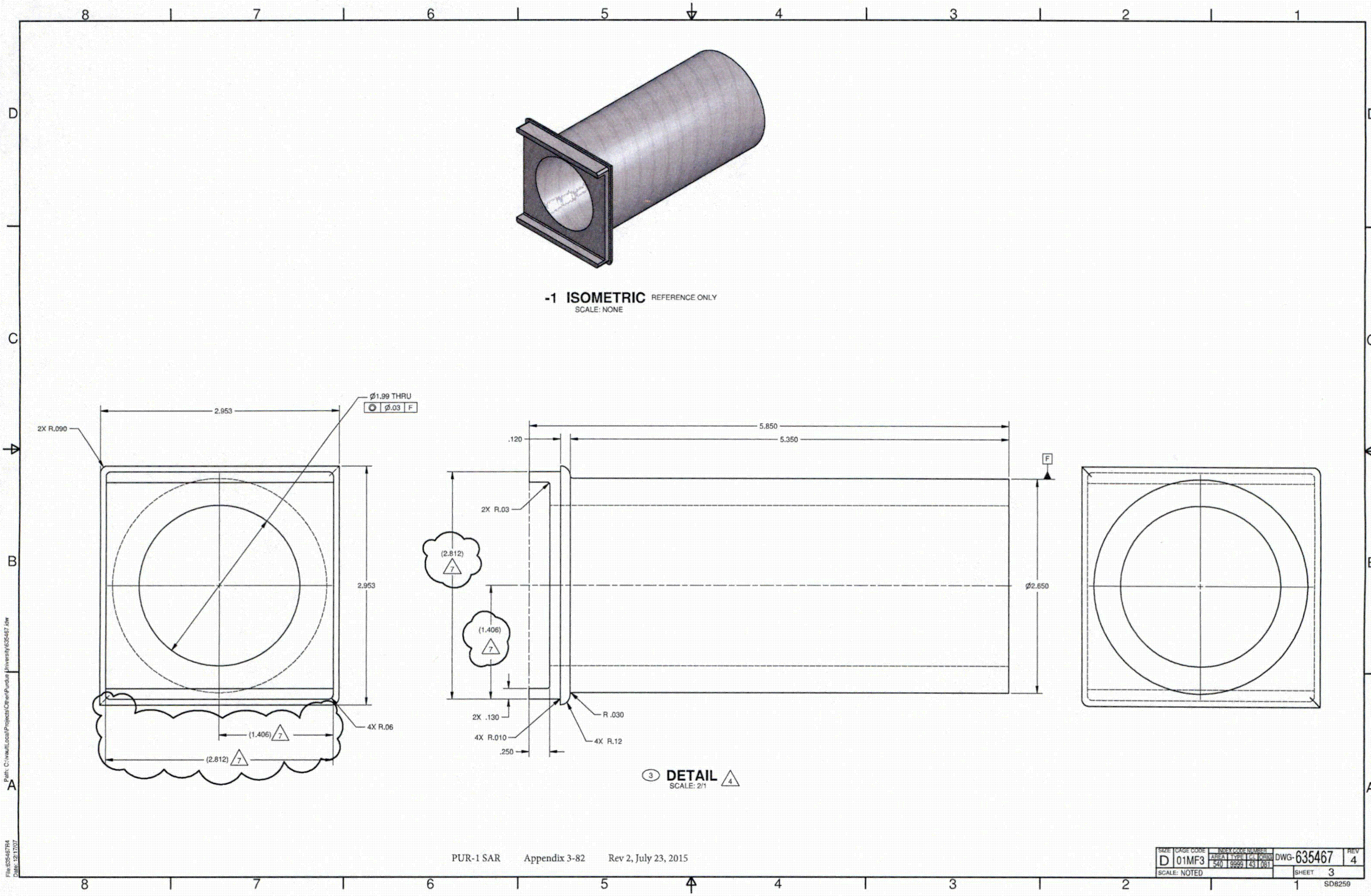
(BOTTOM)

-2 ISOMETRIC REFERENCE ONLY
SCALE: NONE

SIZE	CAGE CODE	INDEX CODE NUMBER	DWG-	REV
D	01MF3	AREA 540 / TYPE 9999 / CL 43 / ORIG 081	635467	4
SCALE: NOTED			SHEET 2	

SD8259

Path: C:\vault\Local\Projects\Other\Purdue University\635467.idw
File:635467R4
Date: 12/17/07



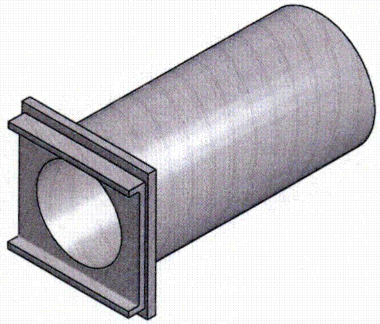
-1 ISOMETRIC REFERENCE ONLY
SCALE: NONE
Ø1.99 THRU
Ø.03 F
2.953
2X R.090
2.953
4X R.06
(1.406) 7
(2.812) 7
5.850
5.350
.120
F
2X R.03
(2.812) 7
(1.406) 7
Ø2.650
2X .130
4X R.010
.250
R .030
4X R.12
3 DETAIL 4
SCALE: 2/1
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER
AREA 540
TYPE 9999
C.L. 43
DWG 081
DWG-635467
REV 4
SCALE: NOTED
SHEET 3
SD8259

NOTES:

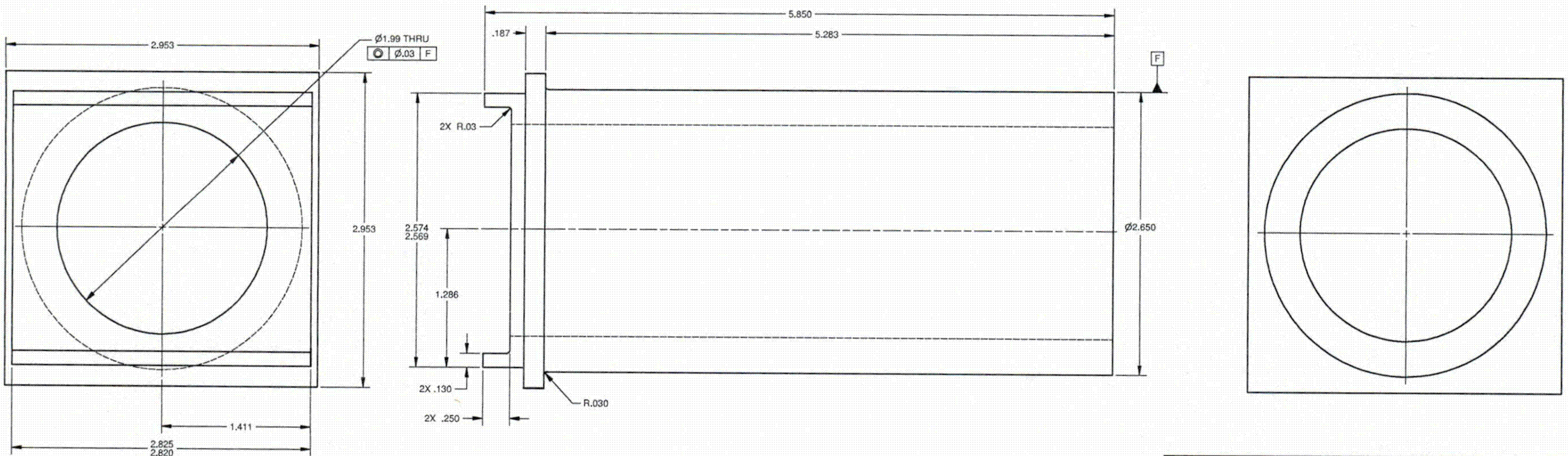
1. REMOVE ALL BURRS AND SHARP EDGES.
2. PROCURE, FABRICATE, AND INSPECT PER SPECIFICATION SPC-382.
3. (3) ALL CORNER AND FILLET RADII .030 UNLESS OTHERWISE NOTED.
4. REMOVED
5. (5) TOLERANCE:
   .XX ±.01
   .XXX ±.005

2	1	SHEET	REV STATUS OF SHEETS
4	4	REV	

REV	REVISIONS DESCRIPTION	EFFECTIVE DATE
1	REVISED TO FIT INTO NEW FUEL ELEMENT CONTAINER DESIGN; ADDED SHEET 2; ADDED DETAIL 2; REVISED TITLE; SEE DAR-509420	1/24/07
2	TOTALLY REVISED SHEET 2, REMOVED NOTE 4, SEE DAR-514751	4/4/07
3	SEE ECR-551872	7/2/07
4	SEE ECR-553363	8/16/07



-1 ISOMETRIC REFERENCE ONLY
SCALE: NONE



(1) **DETAIL** (3)
SCALE: 2/1

QTY REQD		SAFETY CAT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION OR VENDOR NAME	ITEM NO.
		SC	-2	FISSION CHAMBER TOP	BAR AL 6061-T651 ASTM B211 OR B221	2
		SC	-1	NOZZLE PRELIMINARY MACHINED	BAR AL 6061-T6 OR AL 6061-T651 ASTM B211 OR B221	1

PARTS LIST

DASH NO.	NEXT ASSY
-2	635457
-1	635459
-1	635458

APPLICATION

DIMENSIONING AND SYMBOLOGY ARE AMERICAN NATIONAL STANDARD UNLESS OTHERWISE SPECIFIED
~~SURFACE ROUGHNESS~~
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES: .X ± .1
DECIMALS: .XX ± .03
.XXX ± .010
FRACTIONS ± 1/8
ANGULAR ± 2
DO NOT SCALE DRAWING

SUBCONTRACT NO.
REQUESTER: T. VINNOLA
DESIGN: D. MORRELL
DRAWN: N. OLDHAM
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. 505051
EFFECTIVE DATE: 6/1/06

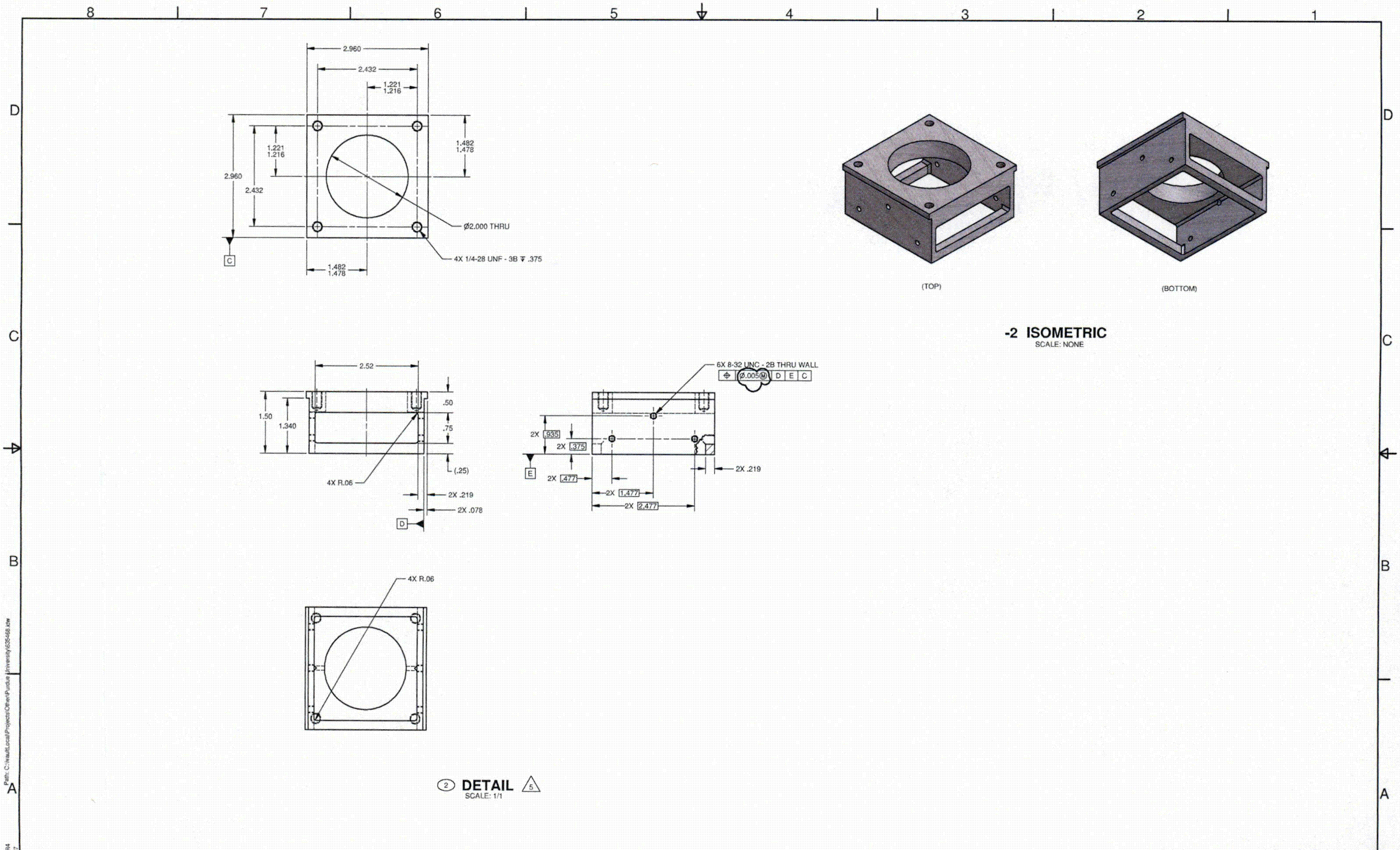
Idaho National Laboratory

PURDUE UNIVERSITY
TEST RESEARCH AND TRAINING REACTOR
NOZZLE PRELIMINARY MACHINED
AND FISSION CHAMBER TOP

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 540, TYPE 9999, CL 43, DRW 081 | DWG-635468 | REV 4
SCALE: NOTED | SHEET 1 OF 2

SD8163

Path: C:\vault\Local\Projects\Other\Purdue University\635468.idw
File: 635468R4
Date: 8/15/07


2.960
2.432
1.221
1.216
1.482
1.478
Ø2.000 THRU
4X 1/4-28 UNF - 3B ⊽ .375
C
2.52
.50
.75
1.50
1.340
(.25)
4X R.06
2X .219
2X .078
D
6X 8-32 UNC - 2B THRU WALL
⌖ Ø.005Ⓜ D E C
2X .935
2X .375
E
2X .477
2X 1.477
2X 2.477
2X .219
4X R.06
(TOP)
(BOTTOM)
-2 ISOMETRIC
SCALE: NONE
2 DETAIL 5
SCALE: 1/1
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 540 TYPE 9999 CL 43 ORIG 081
DWG-635468
REV 4
SCALE: NOTED
SHEET 2
SD8163