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AFCI Fuel Irradiation Test Plan Test Specimens AFC-1Æ and AFC-1F

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1. OBJECTIVE

The U. S. Advanced Fuel Cycle Initiative (AFCI) seeks to develop and demonstrate the technologies needed to transmute the long-lived transuranic actinide isotopes contained in spent nuclear fuel into shorter-lived fission products, thereby dramatically decreasing the volume of material requiring disposition and the long-term radiotoxicity and heat load of high-level waste sent to a geologic repository (DOE, 2003). One important component of the technology development is actinide-bearing transmutation fuel forms containing plutonium, neptunium, americium (and possibly curium) isotopes. There are little irradiation performance data available on non-fertile fuel forms, which would maximize the destruction rate of plutonium, and low-fertile (i.e., uranium-bearing) fuel forms, which would support a sustainable nuclear energy option. Initial scoping level irradiation tests on a variety of candidate fuel forms are needed to establish a transmutation fuel form design and evaluate deployment of transmutation fuels.

1.1 AFC-1 Fuel Irradiations

The AFCI program currently plans two parallel deployments of transmutation fuels. Deployment consists of mixed-oxide fuel forms with minor actinide elements to be irradiated in commercial light water reactors. The second implementation entails non-fertile and low-fertile metallic or nitride fuel forms with minor actinide elements irradiated in fast neutron spectrum reactors or accelerator driven systems. The AFC-1Æ and AFC-1F Irradiation Experiments are part of this fuel development effort. The AFC-1F Experiment consists of low-fertile metallic fuel compositions and is a follow on test to the AFC-1B and AFC-1D Irradiation Experiments which consist of metallic non-fertile fuel compositions. Experiment AFC-1Æ is a consolidation of the AFC-1A and AFC-1E experiments, which consist of fertile and non-fertile nitride fuels. The AFC-1Æ and AFC-1F experiments will be irradiated in the Advanced Test Reactor (ATR) at the Idaho National Engineering and Environmental Laboratory (INEEL). In summary, there are many fuel performance issues that depend primarily on temperature and power, which parameters can be varied by the experiment design, and the transmutation fuel performance data can be acquired at an accelerated schedule and for significantly lower costs.

The irradiation experiments on transmutation fuels are expected to provide irradiation performance data on non-fertile and low-fertile fuel forms specifically, irradiation growth and swelling, helium production, fission gas release, fission product and fuel constituent migration, fuel phase equilibria, and fuel-cladding chemical interaction. Experiments AFC-1B and AFC-1D will provide irradiation performance data on non-fertile, actinide-bearing metallic fuel forms and experiment AFC-1F will provide these data on low-fertile, actinide-bearing metallic fuel forms. Experiment AFC-1Æ will provide corresponding data on both non-fertile and low-fertile, actinide-bearing nitride fuel forms.

The results from these tests will be used in planning an irradiation experiment in a fast spectrum reactor, which is called FUTURIX (formerly designated AFC-3). FUTURIX is a collaborative irradiation test with the Commissariat à l'Energie Atomique of France (CEA) that is planned in the PHENIX reactor at Marcoule, France starting in April 2006. The irradiation performance data of AFC-1 (B, D) and AFC-1 (Æ, F) will provide assurance that the test fuels behave in accordance with design predictions and in conformance to the approved safety envelope and are part of the required safety data for the FUTURIX irradiation test.

Experiments AFC-1Æ and AFC-1F will have design and test conditions analogous to the AFC-1B and -1D tests. AFC-1Æ will contain a variety of nitride fuel compositions and AFC-1F will be identical in design but contain a variety of metallic fuel compositions. An overview of these two experiments and anticipated schedule for their insertion into the ATR is shown in Table 1.

ATR Experiment Designation	Fuel Form	ATR Insertion	Target Discharge Burnup †
AFC-1Æ	Nitride	Nov-2003	5-8 %
AFC-1F	Metallic	Nov-2003	5-8 %

† Burnup is defined as percent of initial Pu-239 and U-235 depleted.

Table 1. Overview of the AFC-1Æ and -1F Experiments.

2. TEST DESCRIPTION

2.1 Facility

The Advanced Test Reactor (ATR) located at the Idaho National Engineering and Environmental Laboratory (INEEL) is designed to evaluate the effects of intense radiation on material samples and nuclear fuels. The ATR was designed to provide large-volume, high-flux test locations. A unique serpentine fuel arrangement as seen in Figure 1, provides nine high-intensity neutron flux traps and 68 additional irradiation positions inside the reactor core reflector tank, each of which can contain multiple experiments.

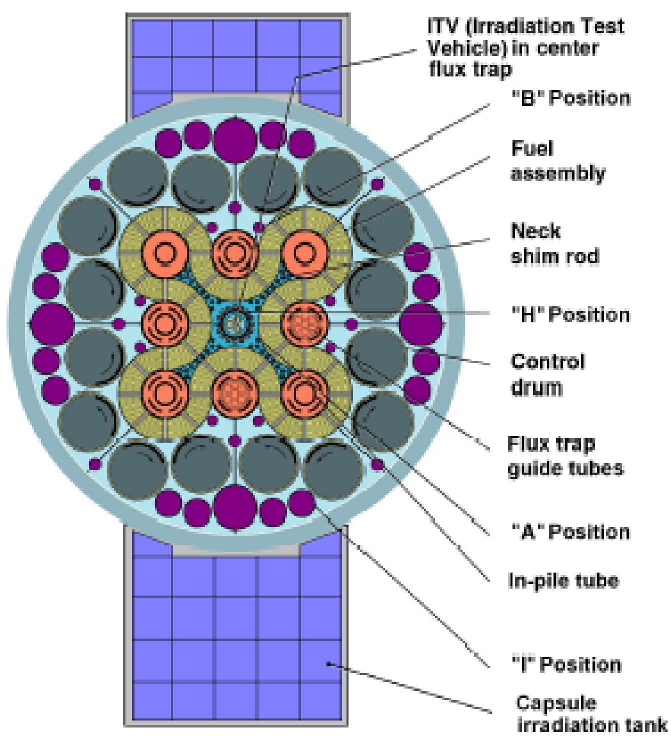


Figure 1. ATR Core Cross Sectional Diagram

The ATR is the most powerful research reactor operating in the U.S. and has larger test volumes in high flux areas than any other reactor. General characteristics of the ATR are listed in Table 2.

Reactor	
Thermal Power	$250\ MW_{th}$ l[a]
Power Density	1.0 MW/L
Maximum Thermal Neutron Flux	$1.0x10^{15}$ n/cm^2-sec[b]
Maximum Fast Flux	$5.0x10^{14}$ n/cm^2-sec[b]
Number of Flux Traps	9
Number of Experiment Positions	62
Core	
Number of fuel assemblies	40
Active length of Assemblies	1.2 m
Number of fuel plates per assembly	19
Uranium-235 content of an assembly[c]	1,075 g
Total core load[C]	43 kg
Coolant	
Design Pressure	2.7 MPa
Design Temperature	115◦C
Reactor coolant	Light water
Maximum Coolant Flow Rate	$3.09\ m^3/s$
Coolant Temperature (Operating)	<52◦C inlet, 71◦C outlet

a. Maximum design pow er. ATR is seldom operated above 110 MW_{th}

b. These parameters are based on the full 250 MWth pow er level and w ill be proportionally reduced for low er reactor pow er levels.

c. At beginning of life.

Table 2. ATR General Characteristics

The ATR's unique control device design permits large power shifts among the nine flux traps. The ATR uses a combination of control cylinders or drums and neck shim rods. The control cylinders rotate hafnium plates toward and away from the core, and the shim rods, which withdraw vertically, are individually inserted or withdrawn to adjust power. Within bounds, the power level in each corner lobe of the reactor can be controlled independently.

To meet the AFCI experiment requirements, the East Flux Trap (EFT) was chosen to house the AFC-1 experiments during the identified irradiation period in EFT positions 1, 2, 3, and 4 as noted in Table 3.

	Experiment ID	EFT Position
Cycle 131A		
	AFC-1B	1
	AFC-1D	2
	Dummy	3
	Dummy	4
Cycle 132A		
	AFC-1B	1
	AFC-1F	2
	AFC-1D	3
	AFC-1AE	4
Cycle 132C		
	AFC-1D	1
	AFC-1F	2
	AFC-1AE	3
	GFR Materials	4
Cycle 133B		
	Dummy	1
	AFC-1D	2
	Dummy	3
	GFR Materials	4

Table 3. AFC-1 Test Assembly Reactor Position

Figure 2 shows a representation of the EFT facility. The EFT is located in the east quadrant of the ATR and contains 7 guide tubes with inside diameters of 1.76 cm (0.694 in). The EFT approximate peak flux values for reactor power of 110 MW_{th} are thermal flux at 4.4×10^{14} n/cm^2-s and fast flux at 9.7×10^{13} n/cm^2-s.

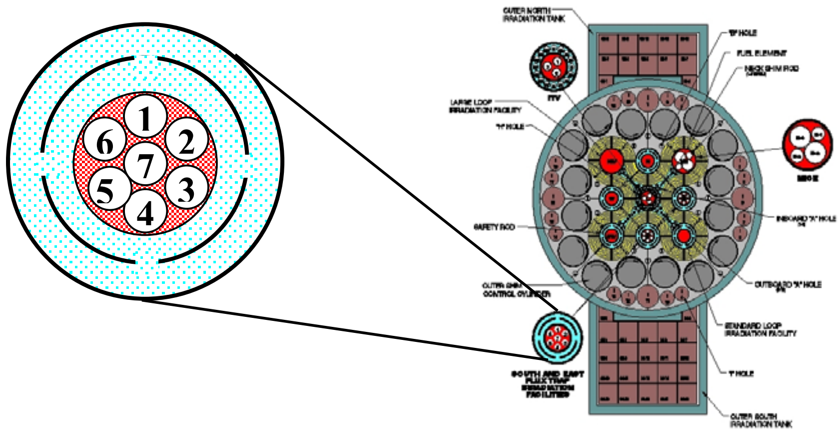


Figure 2. ATR East Flux Trap Facility

2.2 Instrumentation and Data Requirements

No in-core instrumentation is required. As-run operational physics analyses will be performed by the INEEL to determine fuel rodlet powers, burnups and actinide transmutation rates on a cycle-by-cycle basis.

2.3 Test Design

The irradiation test assembly consists of the experiment basket and capsule assembly, which contains six rodlet assemblies stacked vertically. The experiment basket of the test assembly is designed to interface the capsule assembly with the ATR and to act as a thermal neutron flux filter. The current basket design is an aluminum sheathed cadmium tube. For the AFC-1Æ and -1F experiments, the Cd thickness will be the same as the AFC-1B and -1D experiments design, which is 0.045 in. The decrease in the thermal neutron flux will have a commensurate reduction in the linear power, which is necessary to satisfy the experiment design conditions.

2.3.1 Capsule Assembly

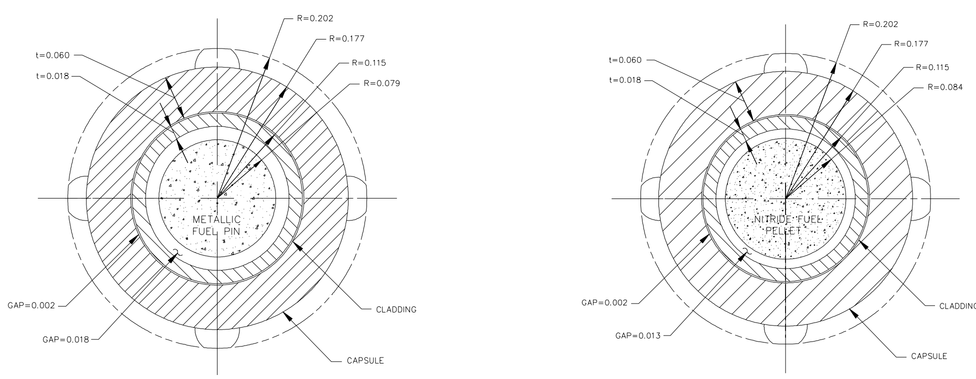
The capsule assembly will provide a second, reliable barrier between the water coolant and the fuel, sodium and fission products and will provide additional free volume for expansion of helium and fission gases should the cladding of any number of rodlets be breached during irradiation (this free volume is sufficient to reduce the gas pressure on the capsule to below 235 psi assuming all six rodlets are breached). The relevant design data of the capsule assembly is summarized in Table 4. The capsule assembly will be fabricated as an ASME, Section III, Class 1 pressure vessel that satisfies ANL-W Quality Level B requirements. The capsule assembly design will be identical in both experiments.

Design Parameter	Value
Capsule Material	316SS
Capsule O.D.	0.354-in.
Capsule I.D.	0.234-in.
Capsule Length	52.000-in.
Capsule Free Volume	15.56 cm^3
Capsule-Rodlet Gap	0.0022-in.

Table 4. Design Data for Capsule Assembly.

2.3.2 Fuel Rodlet Description

The fuel rodlet assembly is designed as a miniature length, fast reactor fuel rod. The rodlet assembly consists of the metallic or nitride fuel column, sodium bond, stainless steel Type 421 (HT-9) cladding and an inert gas plenum. A stainless steel capsule assembly will contain a vertical stack of six rodlet assemblies. The capsule and rodlet radial dimensions of the metallic and nitride fuel specimens are shown in Figure 3. The annular gap between the fuel column and rodlet inner diameter is initially filled by the sodium bond and is designed to accommodate fuel swelling during irradiation. The annular helium-filled gap between the rodlet outer diameter and capsule inner diameter is designed to provide the thermal resistance necessary to achieve the design irradiation temperature of the fuel specimen.



a) **b)**

Figure 3. Radial dimensions of capsule and fuel rodlet assemblies for a) metallic fuel and b) nitride fuel

Table 5 shows the materials used in constructing the rodlets along with their design dimensions. Figure 4 shows the fuel rodlet assembly axial dimensions for the metallic and nitride fuels. The design length of the metallic fuel column is 1.5-in.; the metallic fuel column may consist of a maximum of two pellets with a design diameter of 0.158-in. The design length of the nitride fuel column is 2.0-in. (consisting of seven to twelve pellets) with a design diameter of 0.168-in. The sodium bond is designed to exceed the fuel column length by 0.50-in. in length. The cladding for all rodlets is 6.0-in. in length (including welded endplugs) with 0.230-in. outer diameter and 0.194-in. inner diameter.

Design Parameter	AFC-1Æ	AFC-1F
Cladding Material	HT9	HT9
Cladding O.D.	0.230-in.	0.230-in.
Cladding I.D.	0.194-in.	0.194-in.
Bond Material	Sodium	Sodium
Fuel Type	Nitride	Metallic
Fuel Smear Density	75%	66%
Fuel Porosity	20%	0%
Fuel O.D.	0.168-in.	0.158-in.
Fuel Height	2.000-in.	1.500-in.

Table 5. Fuel Rodlet Design Data.

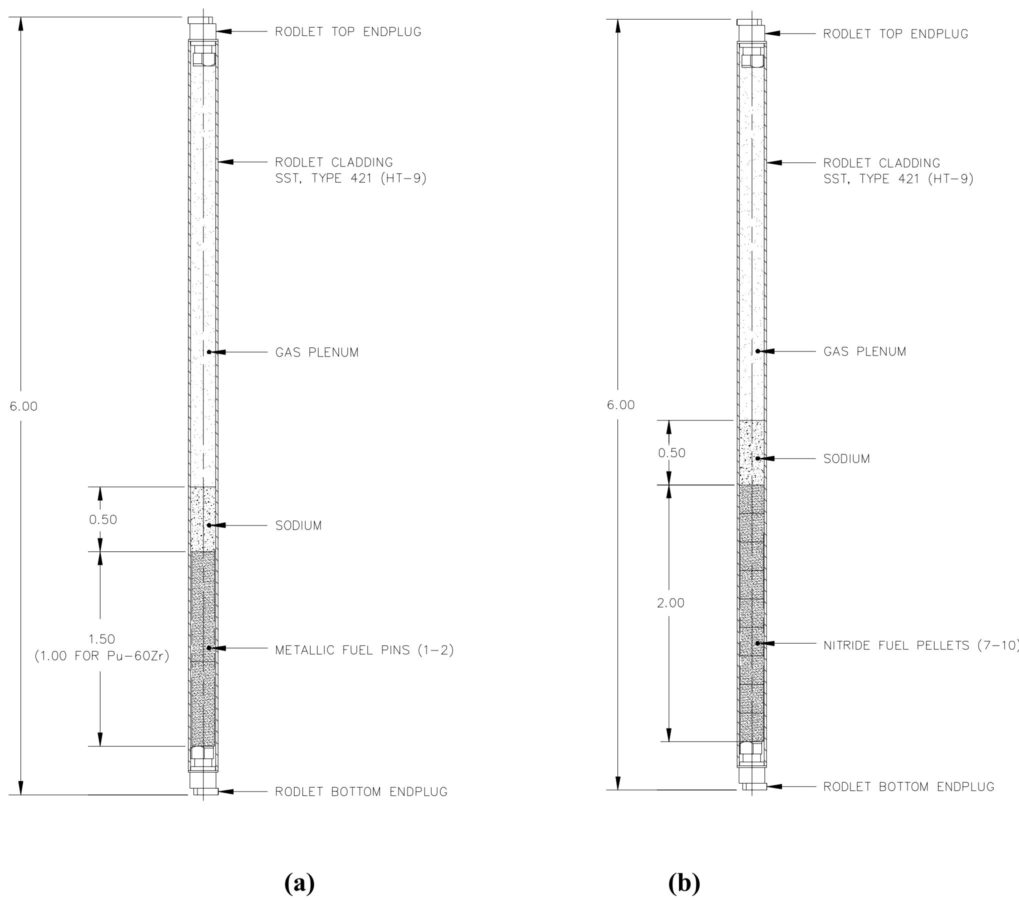


Figure 4. Rodlet assembly axial dimensions for a) metallic fuel and b) nitride fuel.

2.3.3 Test Matrix

The fuel compositions and positions of the nitride fueled rodlets in AFC-1Æ and of the metallic fueled rodlets in AFC-1F are shown in Table 6. Note that the metallic alloy compositions are expressed in weight percentage, and the nitride fuel compositions are expressed in mole percentage for transuranic content and in weight percentage for the zirconium-nitride content. The calculated as-built fuel constituent masses for each rodlet, as well as summed for each irradiation test assembly, are also given in Table 6.

AFC-1Æ: NON-FERTILE AND LOW-FERTILE, NITRIDE-FUELED EXPERIMENT															
	Fuel Density (g/cm^3)	Rodlet Constituent Masses (g)													
		Np-237	Total U	U- 235	U- 238	Total Pu	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241	N	Zr	Na
AFC-1Æ															
Rodlet 1	8.91	0.073	0	0	0	1.923	0	1.806	0.115	0.002	0.001	1.336	0.29	1.992	0.479
Rodlet 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodlet 3	8.63	0.068	0	0	0	1.937	0	1.819	0.116	0.002	0.001	1.586	0.317	2.044	0.46
Rodlet 4	7.45	0.017	0	0	0	0.666	0	0.625	0.04	0.001	0	0.43	0.105	0.694	0.27
Rodlet 5	8	0.695	0	0	0	1.805	0	1.695	0.108	0.002	0.001	0.718	0.325	1.887	0.425
Rodlet 6	11.01	0.643	3.908	1.771	2.135	1.994	0	1.871	0.119	0.002	0.001	0.965	0.346	0.016	0.425
Total		**1.497**	**3.908**	**1.771**	**2.135**	**8.325**	**0.001**	**7.816**	**0.497**	**0.009**	**0.002**	**5.035**	**1.383**	**6.632**	**2.059**
AFC-1F: LOW-FERTILE, METALLIC FUELED EXPERIMENT															
	Fuel Density (g/cm^3)	Rodlet Constituent Masses (g)													
		Np-237	Total U	U- 235	U- 238	Total Pu	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241	N	Zr	Na
Rodlet 1	11.63	0.097	1.485	1.158	0.328	1.254	0.001	1.037	0.205	0.006	0.004	0.157	0	1.267	0.43
Rodlet 2	13.12	0.1	1.975	0.69	1.285	1.687	0.001	1.396	0.276	0.009	0.006	0.201	0	0.962	0.49
Rodlet 3	10.63	0.093	1.501	1.397	0.104	1.226	0.001	1.014	0.2	0.006	0.004	0.114	0	1.972	0.48
Rodlet 4	11.44	0.077	1.29	1.006	0.284	1.051	0.001	0.87	0.172	0.005	0.004	0.133	0	1.159	0.42
Rodlet 5	11.41	0.007	1.59	1.48	0.11	1.301	0.001	1.074	0.214	0.006	0.004	0.244	0	1.382	0.44
Rodlet 6	10.43	0.103	1.428	1.328	0.1	1.221	0.001	1.01	0.199	0.006	0.004	0.137	0	1.993	0.5
Total		**0.478**	**9.269**	**7.059**	**2.21**	**7.74**	**0.005**	**6.402**	**1.267**	**0.039**	**0.027**	**0.986**	**0**	**8.735**	**2.76**

Table 6. AFC-1Æ and AFC-1F Rodlet Constituent Masses.

The compositions were selected to accomplish two objectives: 1. Provide the requisite irradiation performance data on the fuel compositions that are proposed for irradiation in the FUTURIX experiment and 2. Investigate effects of variable materials parameters within range of the design values. The fertile, actinide-bearing compositions of AFC-1Æ an AFC-1F have all been designed with a uranium to transuranic (i.e., plutonium, neptunium, and americium) ratio of 1:1. This ratio ensures that the neutronic characteristics of the fuels are consistent with stable operation in a reactor system. At this constant U-TRU ratio, the higher actinide content is varied to test compositions predicted for different transmutation deployment scenarios. Zirconium is varied in the metallic fuels to investigate the dependence of material properties and irradiation stability.

The uranium enrichments of AFC-1Æ and AFC-1F were selected to achieve the LHGR design objective. The number of different enrichment values were minimized to simplify the fabrication processes. Duplicate rodlet compositions are designed with the same enrichment and are located at different axial positions in the reactor core to provide irradiation performance data at different LHGR, fission density (burnup) and temperature. For AFC-1Æ, a single enrichment of 45-wt% U-235 was selected for the two low-fertile nitride fuel compositions. For AFC-1F, 3 enrichments were selected for the 4 metallic fuel compositions tested. The U-235 enrichment for the metallic fuels are 78 wt% for Rodlets 1 and 4, 33 wt% for Rodlet 2, and 93 wt% for Rodlets 3, 5, and 6.

3. PRE-TEST ANALYSIS RESULTS

3.1 Limiting Test Specifications

The maximum allowable test conditions specified for experiment safety as well as programmatic relevance are given in Table 7. AFC-1Æ and -1F should be discharged from the ATR after reaching 5% burnup and should not be irradiated beyond 10% burnup. In all cases, burnup is defined for these experiments to be percent depletion of initial Pu-239 and U-235.

For the nitride fueled AFC-1Æ experiment and the metallic fueled AFC-1F experiment, the experiments should be discharged, or the aluminum-sheathed cadmium baskets replaced, before the peak rodlet linear heat generation rate (LHGR) exceeds 33.0 kW/m.

During normal, steady-state operation, the peak cladding temperatures should not exceed 550°C to remain programmatically relevant. The off-normal limit on cladding temperature should be considered to be 650°C. This value is the maximum temperature at which U-26Pu-10Zr alloys and HT-9 stainless steel diffusion couples showed no signs of liquid phase formation after a minimum of 300 hours of annealing (Hofman and Walters, 1994). The cladding for the nitride-fueled experiments could withstand higher temperatures, but is also restricted to 650°C for program consistency.

Solidus temperatures for the metallic alloys to be irradiated have not yet been determined experimentally. Assessed binary phase diagrams with limited experimental data for Pu-Zr, Pu-Am and Pu-Np are given in Figures 5 and 6 (Kassner and Peterson, 1995). The ternary solidus/liquidus diagram for U-Pu-Zr alloy system is given in Figure 7 (Leibowitz, 1988). Plutonium is the lowest-melting element among U, Pu, Am, Np and Zr at 640˚C, with Np close at 645°C. In the binary systems, alloying Pu with either Am or Zr serves to increase the solidus temperature significantly, while alloying Pu with Np only slightly affects the solidus temperature. Pu-40Zr has a solidus temperature of over 1200°C. Solidus and liquidus temperatures for the four metallic fuel compositions were conservatively estimated assuming the TRU content to be equivalent to Pu. The solidus temperatures ranged between 1120 and 1360˚C. Therefore, until an experimental determination of the solidus temperatures of U-Pu-Am-Np-Zr alloys has been completed, a conservative limit of 1100°C should be used as an estimate of the solidus temperature and limiting fuel temperature for the metallic alloys during off-normal events; the peak fuel temperature during normal, steady-state operations should remain below 900°C.

For the nitride fuels, the melting points of UN, PuN and ZrN are 2580˚C, 2540°C and 2930°C (Johnson, 1976; Weast and Astle, 1982) , respectively. However, dissociation of PuN may have been observed at a temperature as low as 2100°C (Suzuki and Arai, 1998). Therefore, a maximum limiting temperature of 2100°C is adopted for the nitride fuels; the design limit peak fuel temperature during normal, steady-state operation is established as 1400°C to minimize Am mobility in the fuel.

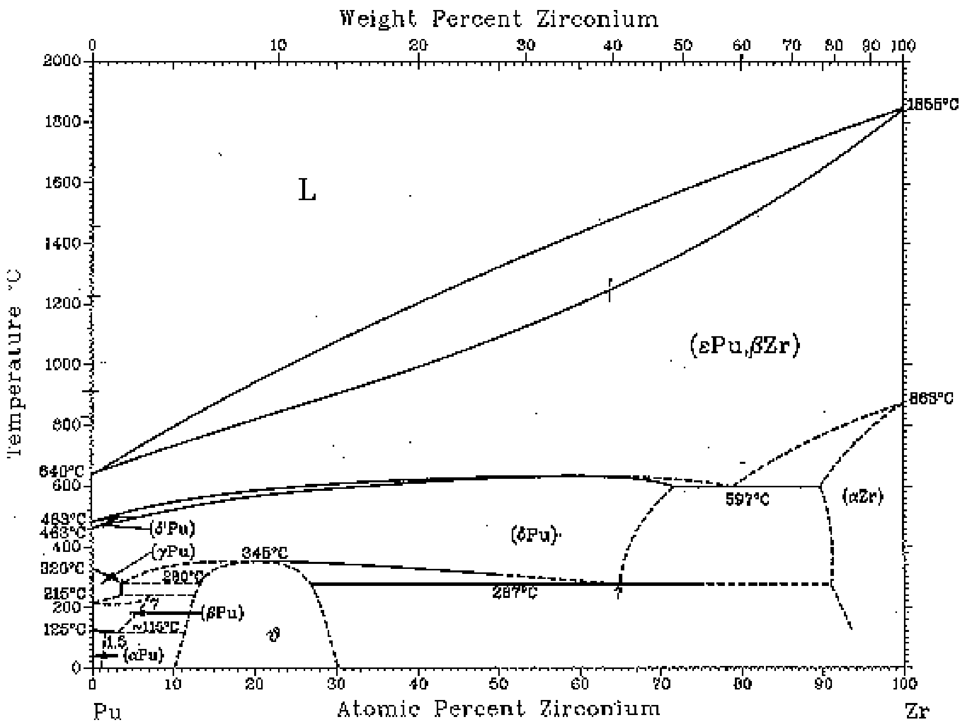


Figure 5. Pu-Zr Phase Diagram

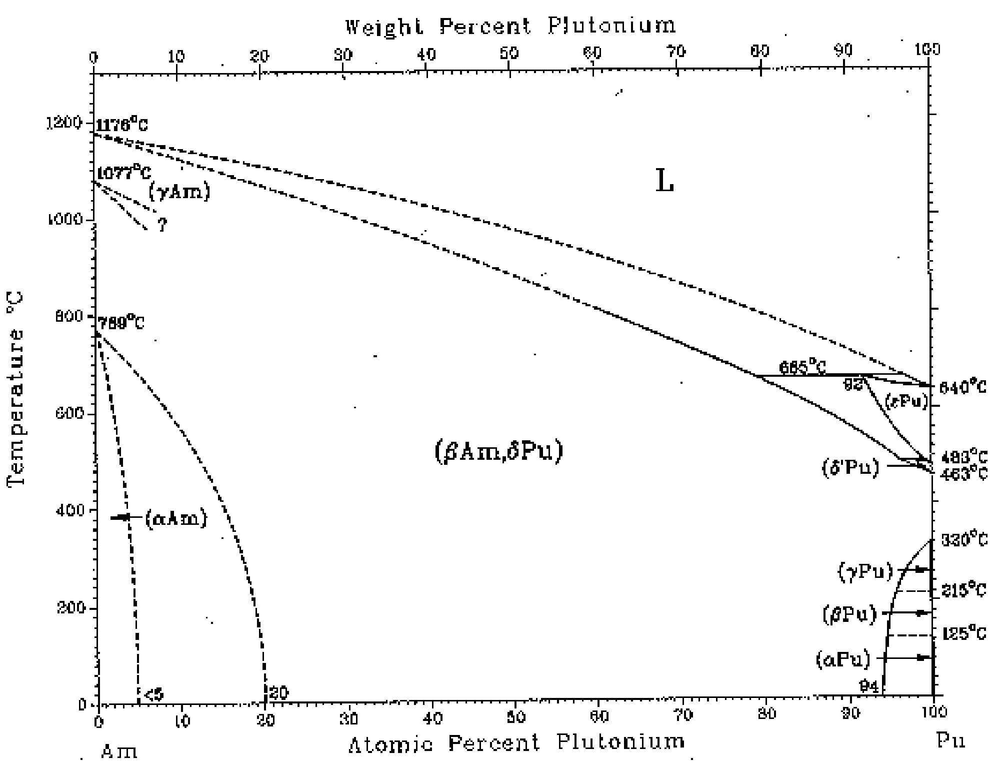


Figure 6. Am-Pu Phase Diagram

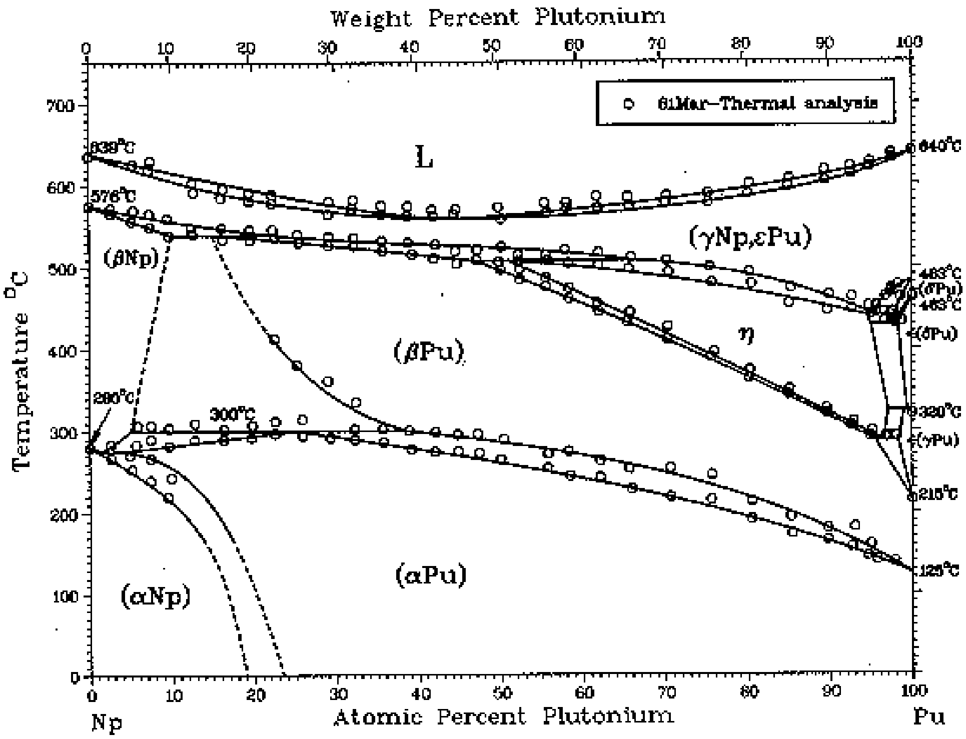


Figure 7. Pu-Np Phase Diagram

3.2 Nominal Irradiation Performance

The experiments AFC-1Æ and -1F have been designed for irradiation in the east flux trap of the ATR. The two tests will be distributed in the ATR east flux trap drop-in positions as: AFC-1Æ in position 4 and AFC-1F in position 2. The linear heat generation rates of the rodlet assemblies in these flux trap positions have been calculated by the INEEL for nominal ATR conditions using their detailed MCNP full core physics model. The maximum powers of the fuel rodlets increase with time due to depletion of the neutron absorber in the special aluminum basket. A maximum basket lifetime to ensure the LHGR limits in Table 7 are not exceeded in any of the experimental fuels has been established by analysis performed at the INEEL to be 110 effective full power days of irradiation. For conservatism, the LHGR design limits are used in the following analyses except where noted.

3.3 Peak Rodlet Temperatures

The temperature of each fuel rodlet was calculated using the LHGR design limits in Table 7 assuming a uniform radial power profile and applying the calculated radial power profile at beginning of cycle. The one-dimensional heat conduction equation was solved in the fuel and bond sodium, and the cladding inner diameter temperature was calculated from a two-dimensional model. These assumptions make the calculated temperatures extremely conservative and over-estimate the actual temperatures the rodlet will experience in the reactor for a number of reasons. First, a calculated one-dimensional temperature will be higher than a realistic, three-dimensional temperature. Second, the energy deposition will not be uniform in the fuel, but preferentially deposited near the fuel periphery and some even deposited outside of the fuel. Lastly, if the peak LHGR in the hottest rodlet is held to 33.0 kW/m for normal operation and 39.6 kW/m for the overpower conditions (near core axial midplane), the other rodlets LHGR will generally be below this value; nevertheless, all linear powers were assumed to be at this peak value.

These calculations were performed on an MS Excel spreadsheet, with the results shown in Appendices A and B. The peak nitride fuel temperature of 937.5°C in AFC-1Æ occurs in Rodlet 4; this peak fuel temperature is far below the 1400°C temperature limit given for nitride fuels in Table 7. The peak metallic alloy fuel temperature of 878.9°C in AFC-1F occurs in Rodlet 6; this peak fuel temperature is below the 900°C temperature limit given for metallic fuels in Table 7. The peak cladding inside temperatures of 539.1°C in AFC-1Æ and of 537.2˚C in AFC-1F occur in Rodlet 6; this peak cladding inside temperature is below the 550°C temperature limit given in Table 7.

Performance Parameter	Experiment Specifications for Irradiation in the ATR	
	AFC-1Æ (Nitride Fuel)	AFC-1F (Metallic Fuel)
Peak Burnup †	10%	10%
Peak Rodlet Linear Power		
Normal Operation	33.0 kW/m	33.0 kW/m
Off-Normal Limit	39.6 kW/m	39.6 kW/m
Peak Cladding Temperature		
Normal Operation	550˚C	550˚C
Off-Normal Limit	650˚C	650˚C
Fuel Temperature		
Normal Operation	1400˚C	900˚C
Off-Normal Limit	2100˚C	1100˚C

Table 7. AFC-1Æ and -1F Fuel Experiment Design Limit Specifications.

The values for the material properties used in the calculations are shown on the spreadsheets; their sources are summarized here. A value of 0.22 W/cm-°C was used for the thermal conductivity of HT-9 stainless steel (Nuclear Systems Materials Handbook, 1984). The correlation used for the thermal conductivity of liquid sodium is from Foust (1972). The thermal conductivity used for the nitride fuels is 0.11 W/cm-°C; this is the value for PuN (Suzuki and Arai, 1998). The thermal conductivity of UN and the inert phase ZrN are higher than PuN, so the lower value of PuN is taken as conservative. The porosity correction factor of Cunningham and Peddicord (1981) is used to account for fabrication porosity and its effect on thermal conductivity. The nitride fuels as-built porosity ranged between 11.6 and 22. 8% (Margevicius, 2003). The thermal conductivity of the metallic fuel alloys was taken to be 0.162 W/cm-°C (Kim, 2002); a 0.5 correction factor was applied to this nominal conductivity to account for the extensive porosity that develops during the irradiation of metallic alloy fuels (Bauer, 1991).

The density of liquid sodium was taken to be 0.966 g/cm^3 (Cordfunke and Konings, 1990). Fuel densities of the actual fuel compounds and alloys have not been measured. Therefore, fuel densities were calculated as a mole-fraction weighted sum of the fuel constituent densities. Constituent densities employed for the AFC-1Æ nitride fuels were 14.32, 14.22, 13.82, 14.14 and 7.09 g/cm3 for UN, PuN, AmN, NpN and ZrN, respectively. Constituent densities employed for AFC-1F metallic alloy fuels were 18.9, 15.4, 13.7, 20.4 and 6.5 g/cm^3 for metallic U, δ-Pu, Am, Np and Zr, respectively. These density values were obtained from common literature sources (Cordfunke and Konings,1990; Katz et al., 1986; Weast and Astle, 1982)

3.4 Fuel Swelling

The swelling behavior of the fuels to be tested in these irradiation experiments is not known. Fertile analogs of the metallic alloy fuels are known to be high-swelling. Presumably, the high level of helium production in these minor actinide-bearing transmutation fuels induces high rates of gas-driven swelling even in fuels that are usually resistant to this behavior. Therefore, it is assumed that the metallic alloy fuels will exhibit high gas-driven swelling rates.

To accommodate this expected behavior, the fuel-cladding gaps in these fuels have been made large. The smeared density, which is the fraction of the transverse cross-sectional area within the cladding inner wall that is filled with material, is 0.69 for the metallic alloy fuels. These smeared densities allow for over 30% diametral swelling of these fuels before contact is made with the inner cladding wall. It has long been known from both theoretical considerations (Blake 1961; Beck 1968) and by observation during 30 years of irradiation testing of high-swelling metallic alloy fuels in EBR-II (Hofman and Walters, 1994) that the driving force for gas-driven swelling is essentially eliminated due to the release of a high fraction of entrained gases once the fuel has swollen to ~30%; the theoretical treatments of this effect are based on geometrical considerations alone and are material independent. These low smeared density test rodlets, therefore, are designed to accommodate expected high swelling fuels without allowing for fuel-cladding mechanical interaction.

3.5 Cladding Creep

The thermal and irradiation creep of HT-9 cladding has been extensively studied as part of U.S. fast reactor programs over the past 30+ years. Its behavior is well known, and widely-used creep rate correlations exist for primary, steady-state and tertiary creep that are functions of time, temperature, stress and fast neutron fluence (Hofman, 1988). The fast neutron fluences and cladding temperatures to be experienced by the rodlet cladding in these tests are far below nominal fast reactor cladding conditions. As a result, the irradiation creep correlation for HT-9 is not valid below 600°C since irradiation creep is non-existent. Therefore, irradiation creep for the rodlet cladding is ignored.

Thermal creep of HT-9 is calculated as the sum of the primary (TP), steady-state (TS) and tertiary (TT) creep correlations, given as:

$$\dot{\varepsilon}_{TP} = \left[C_1 \exp\left(\frac{-Q_1}{RT}\right)\sigma + C_2 \exp\left(\frac{-Q_2}{RT}\right)\sigma^4 + C_3 \exp\left(\frac{-Q_3}{RT}\right)\sigma^{0.5} \right] C_4 \exp(-C_4 t) \quad (1)$$

$$\dot{\varepsilon}_{TS} = C_5 \exp\left(\frac{-Q_4}{RT}\right)\sigma^2 + C_6 \exp\left(\frac{-Q_5}{RT}\right)\sigma^5 \quad (2)$$

$$\dot{\varepsilon}_{TT} = 4C_7 \exp\left(\frac{-Q_6}{RT}\right)\sigma^{10} t^3 \quad (3)$$

where $\dot{\varepsilon}$ is the thermal creep strain rate (%/sec), t is time (sec), T is temperature (K), σ is cladding stress (MPa), R is the ideal gas constant, and the C_i and Q_i are empirically determined fit coefficients (defined in Appendix F).

These creep rate correlations were used in an MS Excel spreadsheet to calculate the cladding diametral strain due to thermal creep as a function of irradiation time; this spreadsheet is included as Appendix F. It was conservatively assumed that the LHGR was the design limit for normal operation for the entire length of irradiation (110 days). The internal pressurization of the rodlet by fission gases and helium was assumed to occur linearly with time up to a maximum of 613 psi, which is the peak plenum pressure calculated for any rodlet. As seen in Appendix F, there is no discernable cladding diametral strain resulting from thermal creep at normal operation for these experimental rodlets.

3.6 Total Heat Rate Distribution

Physics analysis of AFC-1Æ and AFC-1F will be performed using the INEEL verified computer code MCNP. This code is a general Monte Carlo n-particle code written at the Los Alamos National Laboratory. The code and the ATR core model have also been benchmarked for heat rate evaluations by comparison of measured to predicted temperatures in instrumented ATR experiments.

There are four major tallies used in the MCNP model calculation process. The first tally in the model computes the neutron flux (particles/cm^2) averaged over the target cells. The second tally calculates the cell average fission reaction rate. The third tally calculates the neutron energy and the fourth tally calculates the prompt gamma deposition (MeV/g) averaged over the target cells. It also includes the capture gamma and inelastic gamma energy deposition in the test assembly. A conservative approximation for delayed gamma heating equal to 20% of the prompt gamma heating is included in the total heat rates.

The following tally normalization factor was used with the total core power corresponding to E-lobe power (23.0 MW) to convert the MCNP tallies to heat rates in W/g. Heat rate normalization factor = (fission neutron / fission) x (fission /MeV) x (w per MW)

$$= (2.42) \times (1/200.6) \times 1.0\text{X}10^6 \quad (4)$$

$$= 12064 \text{ per core MW} \quad (5)$$

All the MCNP-calculated fission and total heat rate distributions are based on the beginning of cycle condition without fuel depletion, which is conservative for the thermal analyses.

MCNP core model includes a detailed ATR full core model and the test vehicle that is located in the EFT. The proposed irradiation contains 6 fuel rodlets, designated as rodlet 1 to rodlet 6, in each of the capsule assemblies vehicles. To hold down the linear heat rate more effectively, a Cd shroud with a .045" wall thickness is used.

The results of the detailed MCNP ATR full core model physics analysis will be utilized to provide the test assembly volume average neutron/fission and prompt gamma heat rate distribution data in the AFC-1, at beginning of life, at the end of 50 EFPDs irradiation, and at the end of 100 EFPDs irradiation.

The total heat rate is the sum of the neutron heating, prompt γ-heating, and fission product γ-heating. The neutron heating and prompt γ-heating will be calculated in the n,p-mode.

4. MATERIAL AND COMPONENT SPECIFICATIONS

4.1 Weld Qualification

All fuel rodlet end plug welds and capsule closure welds are completed at ANL-W, qualified according to the current revision of the Welding Program for Fuel Elements and Containment Capsules (W7520-0474-ES) and documented per the AAA Welding Procedure Qualification Record (W7520-0487-ES). Weld procedure specifications for top and bottom fuel rodlet end plug welds are given in ANL-W Fuel Element Plug Welding

Procedure Specification (W7520-0475-ES) and ANL-W Fuel Element Closure Plug Welding Procedure Specification (W7520-0476-ES).

Weld procedure specifications for the containment capsule top and bottom closure welds are given in the Capsule Plug Welding Procedure Specification (W7520-0477-ES). This specification falls within the range given in the Idaho National Engineering Laboratory Welding Procedure Specification S4.2.

Data relating to weld qualification for each weld type is available for inspection from the AFC welding engineer. Weld inspection data for each weld, including the weld qualification package and process control specimen inspection data will be included in the AFC-1Æ and AFC-1F as-built data package.

4.2 Fuel Rodlet Welds

The fuel rodlet endplug to tubing joint is considered to be a butt joint with integral backing, which conforms to a Category C joint on a Class 3 vessel per ASME Boiler and Pressure Vessel Code Section III ND-3351.3. The joint has been fabricated as a Type 2 joint as required by ND-4243. The joint has been fabricated to allow for 100% penetration. Qualified personnel shall make all welding and inspections with approved procedures.

4.3 Containment Capsule Welds

The containment vessel design will be identical in all four experiments. The assembly is shown in drawing W7520-0479-EC. The experiment capsule is constructed to meet the intent of the ASME section III, Class 1 pressure vessel code. Design criteria are specified in the Design Specification: Advanced Accelerator Applications ATW-1 Fuel Test Specimen Drop-In Capsule (BBWI SPC390).

5. EXPERIMENT REQUIREMENTS

5.1 Fuel Specimen Fabrication and Specification

5.1.1 Fuel Slugs Fabricated at ANL-W

Metallic fuel slugs will be fabricated, analyzed and inspected at ANL-W according to procedures referenced in section 7.1 of this document.

Specifications and acceptance criteria for fuel are found in the Fuel Test Specimen Specification for the AFC-1F low-fertile Metal Fuel Irradiation in the ATR (W7520-0527-ES). This specification calls out requirements for cladding material, fuel chemistry, fuel isotopics, bond sodium, welding, dimensions, and inspections for the fuel pins.

5.1.2 Fuel Pellets Fabricated at LANL

LANL will fabricate, analyze and inspect nitride fuel pellets according to the requirements and procedures of the applicable LANL documents (refer to section 7.1 of this document). The Fuel Test Specimen Specification for the AFC-1Æ and AFC-1G Nitride Fueled Capsule Irradiations in the ATR (W7520-0553-ES) will incorporate these specifications by reference. The activities conducted for the AFC-1 experiments shall be performed in accordance with an approved Quality Assurance Program encompassing the AFC-1Æ and AFC-1F experiments, reviewed and approved by ANL-W in accordance with the schedule provided in Section 6 of this document.

LANL will package and ship nitride pellets to ANL-W. LANL must verify pellet integrity prior to shipment using radiographic inspection of the individual fuel shipping containers. Fuel pellets shall not be shipped to ANL-W prior to successful completion of a review of LANL QA documents and procedures relevant to nitride fuel pellet fabrication to be performed by ANL-W.

LANL shall provide a final data package approved by LANL management and consisting of dimensional and physical inspection data and chemical and isotopic analysis data and any other required data for the nitride fuel pellets shipped to ANL-W, in compliance with the requirements set forth in the Fuel Test Specimen Specification for the AFC-1Æ Low Fertile Nitride Fueled Capsule Irradiations in the ATR (W7520-0553-ES).

Non-conformances shall be reported to ANL-W via the LANL non-conformance reporting procedure. Fabrication and inspection records and fuel pellet radiographs will be reviewed at ANL-W for completeness and conformance with specifications prior to opening the fuel shipping container. The nitride fuel pellet final data package shall be reviewed and approved by ANL-W according to the requirements and procedures of the applicable documents. Contingent upon ANL-W approval, the nitride fuel pellet final data package will be incorporated into the As-built Data Package.

LANL will be notified of the schedule for fuel loading into rodlets approximately one week in advance. Prior to loading pellets into rodlets, fuel pellets will be visually inspected at ANL-W for obvious physical defects to ensure that the standards set forth in the Fuel Test Specimen Specification for the ATW-1Æ Low Fertile Nitride Fueled Capsule Irradiations in the ATR (W7520-0553-ES) are met, and that the fuel pellets were not damaged during shipment. LANL will be notified of any nonconformances as soon as possible after discovery.

5.1.3 Fuel Encapsulation in Rodlets

Fuel encapsulation into rodlets will be performed at ANL-W in accordance with approved procedures for AFC-1 loading and welding.

All rodlets will meet final inspection criteria as detailed in the AAA Fuel Rodlet and Capsule Final Inspection Procedure (W7520-499-ES) and documents referenced therein. No fuel test specimen that fails to meet the criteria specified in the Fuel Test Specimen Specifications (W7520-0527-ES metal and W7520-0844-ES nitride) or Final Inspection Procedure (W7520-0499 ES) will be accepted for in-reactor testing without appropriate justification.

5.2 Non-Fueled Reactor Hardware

5.2.1 Experiment Containment Capsule

In each experiment assembly, six fuel rodlets will be stacked vertically within a single, type 316L stainless steel (ASME SA479) secondary containment vessel designated the containment capsule. The containment capsule serves two purposes: 1) to provide a second barrier between the water coolant and the fuel, sodium and fission products, and 2) to provide a free volume for expansion of helium and fission gases should the cladding of any number of rodlets be breached during irradiation. The containment capsule is filled with helium to transfer heat from the fuel pins to the reactor coolant. The purity of the gas used to fill the capsule will be 99.5% + 0.5%; the final capsule gas content specification is nominally 99% with a minimum of 97% He content.

Unused surplus capsule tubes obtained for the AFC-1A – AFC-1D experiments will be used for this experiment. The material of construction for the containment capsule is ASME SA479 316L stainless steel rod stock, certified by the vendor to ASME section III, Class 2 standards. The material was volumetrically inspected using x-ray radiography at ANL-W to upgrade the material to ASME section III, Class 1 standards. The as-received material certification includes vendor supplied chemical analysis conducted by an independent laboratory for each serialized piece. Upon material receipt at ANL-W, unique serial numbers were engraved on both ends of each piece of stock to maintain traceability. The material was sent to an outside vendor for centerless grinding to the final outside diameter. Upon receipt after grinding, the component serial numbers were verified and dimensional inspection was performed at ANL-W. New serial numbers were chemically etched on the outer diameter of the rods at three locations chosen to maintain traceability after cutting the stock to final length. One serialized nineteen-inch section from each piece of rod stock was removed at ANL-W for fabrication of capsule end caps at ANL-W and for use as archival material.

The centerless ground material was transferred to BBWI (due to budgetary reasons) for boring of the inner diameter by an outside vendor. BBWI added capsule standoffs and bored the tubing to the dimensional requirements called out in drawing W7520-0495-EC (Capsule Tube). BBWI inspected the dimensions of the finished tube as called out in these drawings. Bored tubes were then delivered by BBWI to ANL-W for use in experiment assembly.

5.2.2 Experiment Basket

Outboard of the containment capsule is an aluminum basket containing a burnable poison used both to hold the experiment in position and act as a thermal neutron filter to reduce rodlet powers. The thickness of the basket and the absorber are specified to produce the target fuel powers in the rodlets. INEEL has responsibility for design, component procurement, and fabrication of the experiment basket. Figure 13 is a detailed drawing of the AFC-1 baskets fabricated to house the AFC-1 experiments during irradiation in the ATR.

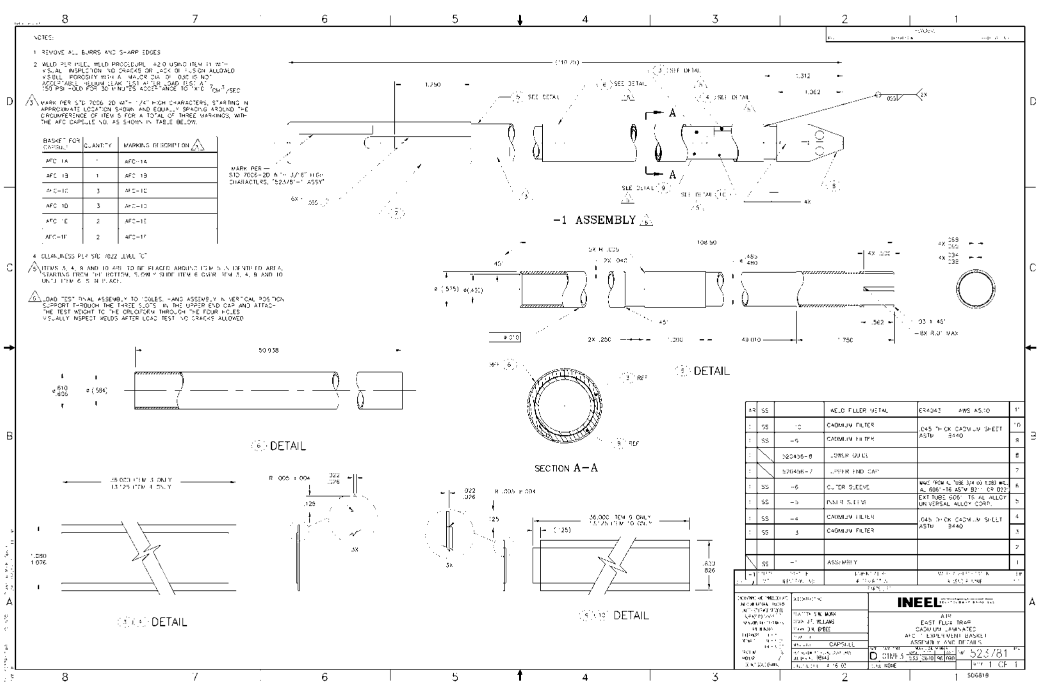


Figure 8. AFCI Cadmium Basket Drawing

5.2.3 Basket Engineering Design Requirements

5.2.3.1 Civil and Structural

The basket structure shall be designed to hang from the lip in the east flux trap housing. The basket is not designed as a pressure vessel but must withstand operational forces at the maximum anticipated operating temperatures/pressures from deadweight, parallel fluid flow and the pressure differential that exists across the reactor core. ASME Section III, Subsection NG, Core Support Structures or equivalent criteria should be used to determine structural adequacy in response to these loads. Analysis was performed using the information in Table 8.

Basket Deadweight	2 lb
Capsule Deadweight	2 lb
Parallel Flow Velocity	19.4 ft/sec
Core Differential Pressure	130 psid
Operating Temperature	240 F

Table 8. AFC-1 Experiment Assembly Structural Analysis Data

The basket shall be designed such that any axial or radial vibration is minimized during normal (condition 1) operations and that failure of the basket will not initiate an off-normal plant condition or adversely impact core performance in the event of a design basis accident.

5.2.3.2 Mechanical and Materials

The basket designed for use in the EFT experimental facility will maintain the same interfaces at regions of support, will be the same total length, and will have equivalent vibration characteristics as the current EFT baskets. The inner diameter of the basket will allow for the experiment capsule to fit inside of the basket and provide sufficient cooling for the test.

The basket will be designed with a neutron-absorbing zone in the active fuel region to provide a thermal neutron shield. This shield modifies the flux spectra to more nearly represent a fast reactor spectra, and results in the LHGR of less than 330 W/cm with the east quadrant power of 26.8 MW or less to meet programmatic requirements.

The basket reactivity worth shall be such that it may be replaced by existing capsules or fillers without exceeding 0.25$ difference between the basket reactivity and any replacement capsule/filler worth and will not result in perturbation of the axial fission rate profile as described in EDF-TRA-ATRC-1546.

5.2.3.3 Inspections and Testing

The effect of the basket on the axial fission rate profile and reactivity measurements were performed in the ATRC in accordance with an approved test plan. The axial and azimuthal power profiles in fuel elements adjacent to the AFC-1 experiments were measured for various combinations of beginning-of-life and end-of-life cadmium representations.

The axial power profile data is shown in Figure 9 with the non-perturbed axial profile identified in the Advanced Test Reactor Critical Facility Axial Fission Profile Acceptance.

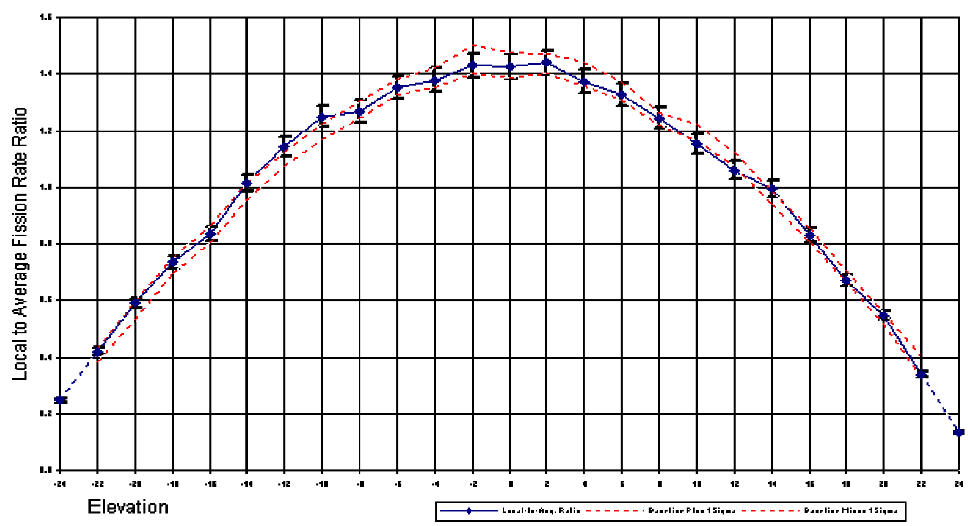


Figure 9. ATRC Measured Center Lobe Axial Profile for AFC-1B and –1D

Reactivity worth of the AFCI-1 experiments for normal operation was also measured in the ATRC. This information is used to evaluate the core neutronics (i.e., fuel loading and fuel element power peaking limits) for each ATR operating cycle. The calculated reactivity worth of the experiment, relative to water and LSA cobalt indicated that LSA cobalt is a reactivity duplicate, and total worth relative to water is –0.77$. Based on this information, the AFCI project has identified LSA cobalt as a backup test to be inserted into the EFT when the AFC-1 tests are removed.

5.2.3.4 Basket Quality Assurance

Quality assurance associated with basket design and fabrication shall meet the requirements specified in the SAR. Codes and standards of the latest published issue noted below shall apply to the intent specified herein for the AAA-AFC flux trap basket drawings, fabrication, welding inspection and examination unless otherwise exempted by drawings or other referenced documents.

- ASME Boiler and Pressure Vessel Code Sections VIII and IX
- ASME NQA-1 Quality Assurance for Nuclear Facility Applications
- ASTM Standards B440, B210 and B241 Material specifications
- ANSI Y14.5M Dimensioning and Tolerancing

- AWS "American Welding Society" A5.10 weld filler specifications
- STD-11 INEEL Drafting Practices Manual
- ASME SECTION III, SUBSECTION NG
- INEEL Welding Manual

The irradiated baskets will be shipped to the ANL-W HFTF facility for PIE. Following PIE the baskets will be sent by ANL-W to a permitted treatment, storage and disposal facility.

5.2.4 Experiment Assembly

The experiment assembly will be conducted in accordance with the ANL-W procedure "Assembling Rodlets into Capsules (NRP-FMF-005)". Loading of the experiment stack will be witnessed and verified as detailed in this procedure. The experiment containment capsule is filled with helium and welded inside of a He-filled chamber in accordance with this procedure. Helium purity in the capsule is guaranteed through process knowledge, process qualification, and sampling of process control specimens. Gas process control specimens are collected prior to and after welding of each lot of outer containment capsules. The helium gas content of all process control specimens is analyzed by mass spectrometry at ANL-W.

Welding of the capsule top and bottom closures will be in accordance with ANL-W document; Capsule Welding Procedure Specification (W7520-0477-ES). All welds made on process control specimens will be non-destructively inspected according to AAA Fuel Rodlet and Capsule Final Inspection Procedure (W7520-0499-ES), and the documents referenced therein. Welds made on process control samples will be destructively inspected according to Welding Program for Welding Fuel Elements and Containment Capsules, W7520-0474-ES.

The experiment containment capsule(s) will be inserted into the experiment basket(s) by BBWI after delivery of the finished capsules to the Test Reactor Area.

5.3 Non-Conformances

Any fuel rodlets and capsule hardware delivered to ATR that do not meet the requirements stated in ANL-W documents; Fuel Test Specimen Specification for the AFC-1A – AFC-1D Capsule Irradiations in the ATR (W7520-0473-ES), the AAA Fuel Rodlet and Capsule Final Inspection Procedure (W7520-0499-ES) and documents incorporated by reference therein will be reported via the ANL-W Nonconformance Report (NCR). Materials or components will be rejected, reworked, or accepted as-is with justification.

All nonconformance reports for in-reactor components will be included in the AFC-1 As-Built Data Package. All nonconformances will be orally discussed with the BBWI AFC Project Manager prior to acceptance for in-reactor use. Approval during this discussion will constitute BBWI's approval of the nonconformance justification, except for those non-conformances that are determined to have implications for reactor safety. Nonconformance justifications are attached to the NCR and must be approved (as a minimum) by the experimenter and project manager. Those nonconformances that have ATR reactor safety implications must have documented BBWI concurrence with the resolution.

5.4 As-Built Data

As-built Fuel Pin Summary Data Sheets and Fuel Pin Summary Final Inspection Sheets will be provided for each fuel rodlet to be inserted in reactor. Requirements for these data sheets are called out in ANL-W document; Fuel Test Specimen Specification for the AFC-1A – AFC-1D Capsule Irradiations in the ATR (W7520-0473-ES).

As-built data sheets will be provided for the assembled experiment capsules as detailed in ANL-W document AAA Fuel Rodlet and Capsule Final Inspection Procedure, Appendix B (W7520-0499-ES).

A data package will travel with each fuel rodlet and capsule through the fabrication process. This traveler will be used to record completion of each fabrication activity, and data related to fabrication and quality assurance. Data extracted from the traveler is used in the As-Built Data Package.

A complete set of as-built drawings will be provided for all component parts of this experiment, and for the final, assembled test capsule.

5.5 Safety Requirements

5.5.1 Overpower Evaluation

The spreadsheets showing the calculation results for the overpower condition are included in Appendices C and D. All fuel powers were multiplied by 1.2 to simulate a 120% overpower condition. All the additional assumptions leading to very conservative calculated temperatures that were discussed in Section 3.1 also apply here. In the overpower conditions, the peak nitride fuel temperature of 1084.6°C in AFC-1Æ occurs in Rodlet 4; this peak fuel temperature is far below the 2100°C temperature limit given for nitride fuels in Table 7. The peak metallic alloy fuel temperature of 1014.7°C in AFC-1F occurs in Rodlet 6; this peak fuel temperature is below the 1100°C temperature limit given for metallic fuels in Table 7. The peak cladding inside temperatures of 605.6°C in AFC-1Æ and of 603.4˚C in AFC-1F occur in Rodlet 6; this peak cladding inside temperature is below the 650°C temperature limit given in Table 7.

5.5.2 Internal Pressure Generation

The internal pressure calculations for each individual rodlet are contained in the spreadsheets included in Appendices A-D. The calculation assumptions and methodology are summarized and applied to the experiment as a whole (i.e., including the outer stainless steel pressure vessel). Since the primary containment boundary is the stainless steel outer capsule assembly, it has been assumed that all six fuel rodlets fail during irradiation; this would subject the outer capsule to the maximum pressurization. Only the 120% overpower conditions are evaluated as a bounding scenario. The pressure is estimated at the maximum allowable burnup for the experiments of 10%, measured as the percent depletion of initial Pu-239 and U-235 present in each fuel rodlet; the peak burnup at the end of 110 days of irradiation is predicted to be 8% (Chang, 2003). Because of the axial power profile within the ATR core, the burnups of the fuel rodlets above and below the core axial midplane will be less than the peak rodlet burnup of 8%, therefore this analysis provides a very conservative bound on the maximum internal pressure.

The free volumes in each of the fuel rodlets and the stainless steel capsule assembly were calculated from the set of experiment design drawings listed in Table 8. Small free volumes such as the annular space between endplugs and cladding tubes, and between the rodlets and capsule, were ignored. By doing this, conservative minimum free volumes for gas expansion were obtained for the following components shown in Table 9. The total fuel volumes (sum of fuel volumes from all six rodlets) were calculated from the design drawings to be 4.362 and 2.880 cm3 for AFC-1Æ and AFC-1F, respectively.

Drawing	Component
W7520-0479-PL-01	Capsule Assembly
W7520-0478-PL-01	Nitride Fuel Rodlet Assembly
W7520-0468-PL-00	Metallic Fuel Rodlet Assembly
W7520-0478-EB-02	Nitride Fuel Rodlet Assembly
W7520-0466-EA-01	Tube
W7520-0468-EB-02	Metallic Fuel Rodlet Assembly
W7520-0469-EB-01	Metallic Fuel
W7520-0470-EB-01	Nitride Fuel
W7520-0493-EC-02	Endplug, Top and Bottom (Metallic Fuel)
W7520-0479-EC-03	Capsule Assembly
W7520-0495-EC-06	Capsule Tube, Mod II
W7520-0472-EA-01	Capsule Lower Endcap
W7520-0485-EB-02	Capsule Upper Spacer
W7520-0486-EA-01	Capsule Bottom Space
W7520-0490-EB-01	Capsule Upper Endcap
W7520-0520-EC-00	Endplug, Top and Bottom (Nitride Fuel)
W7520-0522-PL-00	Dummy Rodlet Assembly
W7520-0522-EB-00	Dummy Rodlet Assembly

Table 9. Drawings of the Experimental Components.

	Free Volume for Gases (cm^3)	
Component	AFC-1Æ	AFC-1F
Fuel Rodlets 1-6	7.99	9.45
Outer Capsule	11.31	11.31
Total	**19.31**	**20.76**

Table 10. Calculated Free Volumes for AFC-1Æ and AFC-1F.

Fuel theoretical densities were calculated as a mole-fraction weighted sum of the fuel constituent densities. Constituent densities employed for AFC-1Æ fuels were 14.32, 14.22, 13.82, 14.14 and 7.09 g/cm^3 for UN, PuN, AmN, NpN and ZrN, respectively. Constituent densities employed for AFC-1F fuels were 18.9, 15.4, 13.7, 20.4 and 6.5 g/cm^3 for metallic U, δ-Pu, Am, Np and Zr, respectively. The measured density and the theoretical calculated densities were used to estimate porosity of the nitride fuels. The metallic fuel alloys were assumed to be fully dense.

It is assumed that all fuels in these experiments are irradiated to a uniform burnup of 10% of <u>all</u> plutonium and uranium present in the fabricated fuels; that is, 10% of all plutonium isotopes and uranium isotopes present in the fuels are assumed to fission, producing fission products. This assumption will be conservative for two reasons: 1) the discharge burnup of many of these fuels will be less than 10% due to the axial dependence of flux within the ATR, and 2) only the fissile isotopes of plutonium and uranium will readily fission. Furthermore, the fission product yields of the Kr and Xe fission gases are assumed to total 10% of all fission products (Olander, 1976). Finally, six moles of helium is assumed to be produced for every mole of fission gases produced, weighted by the mole fraction of Am-241 in the fuel compound or alloy (since this is the isotope chiefly responsible for He production); this assumption was taken from the results of recent minor actinide irradiations in the High Flux Reactor at Petten [Konings et al., 2000]. Thus, the number of fission gas and helium atoms produced in the fuel is calculated as:

$$N_{FG} = x_{FG} \cdot B \cdot \left(\frac{w_{TRU} \cdot \rho \cdot N_A}{A} \right) \cdot V_{fuel} \tag{6}$$

$$N_{He} = 6 \cdot N_{FG} \cdot w_{Am} \tag{7}$$

where N_{FG} and N_{He} are the number of atoms of fission gas and helium produced in the fuel, respectively, x_{FG} is the yield of gas atoms per fission, B is burnup, w_{TRU} is the weight fraction of actinides in the fuel compound or alloy, ρ is the density of the fuel alloy or compound (g/cm^3), N_A is Avogadro's number (6.023×10^{23} atoms/mole), A is the fuel alloy or compound molecular weight (g/mole), V_{fuel} is the fuel volume (cm^3), and w_{Am} is the weight fraction of actinide content in the fuel that is americium. Results from Eqns. (6) and (7) are used to compute the total gas released to the experiment free volume as:

$$n_{gas} = \frac{R_{FG} \cdot N_{FG} + R_{He} \cdot N_{He}}{N_A} \tag{8}$$

where n_{gas} is the total quantity of gas released to the experiment free volume (moles), and R_{FG} and R_{He} are the release fractions for fission gases and helium, respectively. For nitride fuel, these release fractions are conservatively assumed to be 0.25 for fission gases and 0.50 for helium (Konings et al., 2000 measured 0.05 and 0.20 in oxide fuel). For metallic fuel, the release fractions are well established as 0.80 for fission gases [Hofman and Walters, 1994] and assumed to be 1.00 for helium. Finally, pressure on the experiment capsule inner boundary is calculated as:

$$P = \frac{n_{gas} \cdot \left(82.056 \frac{\text{cm}^3 \cdot \text{atm}}{\text{mole} \cdot \text{K}} \right) \cdot \left(14.7 \frac{\text{psi}}{\text{atm}} \right) \cdot T}{V_{capsule}} \tag{9}$$

where P is the capsule internal pressure (psi), T is the gas temperature (K), and $V_{capsule}$ is the capsule free volume (cm^3). The gas temperature was assumed to be an average of the peak cladding temperature and a maximum conceivable primary coolant temperature, since more than half of the internal free volume is contained in the outer capsule located above the experimental fuel rodlets and exposed to direct cooling by the reactor primary coolant. Pressures were calculated for AFC-1Æ and AFC-1F using Eqns. (6) to (9), data from Tables 5 and 8, and the assumptions outlined in this section. The results are shown in Table 10.

Thus, even under the most conservative assumptions of burnup, temperature and gas production/release, the peak internal pressures that could be produced inside the experiment outer capsules (assuming all rodlets breach at end-of-life) will remain well below 235 psi, which is less than the ATR primary coolant pressure at discharge from the core.

	AFC-1Æ (Nitride Fuel)	AFC-1F (Metallic Fuel)
Total Free Volume (cm^3)	19.31	20.76
Total Fissions	8.36E+21	6.28E+21
Total FG Atoms	2.09E+21	1.57E+21
Total He Atoms	3.22E+21	5.75E+20
Gas in Free Volume (mol)	3.54E-03	3.04E-03
Max. Internal Pressure (psi)	**150.0**	**119.4**

Table 11. Maximum Internal Pressure in AFC-1Æ and AFC-1F.Accident Analysis

A safety analysis report will be completed that addresses scenarios leading to consequences of significance that involve failure of both the outer stainless steel containment vessel (which is considered unlikely) in addition to breach of one or more fuel rodlets. Failure of only one of these boundaries would not have any significant reactor safety implications.

The safety analysis report will also demonstrate that the experiment operation complies with the ATR requirements contained in the UFSAR and TSR's.

6. POST-IRRADIATION EXAMINATION

The post-irradiation examinations (PIE) of Experiments AFC-1B, AFC-1D, AFC-1Æ, and AFC-1F will be performed in a single campaign. PIE of these irradiation fuel experiments will provide irradiation performance data for non-fertile and fertile actinide-bearing metallic and nitride fuel compositions at an intermediate burnup of 5-7 at% and additionally for the non-fertile metallic fuel compositions at a final burnup of 20 at%. The PIE of 20 at% burnup nitride and fertile metallic fuels will be planned for a subsequent campaign.

The PIE subtasks will provide comprehensive fuel irradiation performance data on the non-fertile and fertile, actinide-bearing fuel forms at an intermediate burnup of 5-7 at%. These data will support actinide transmutation fuel testing in the FUTURIX irradiation experiment currently scheduled to commence in April 2006.

The initial objectives of the PIE campaign are to confirm the condition of the test assembly internals, finalize the rodlet unloading process based on observations, and unload the fuel rodlet assemblies. The second objective of the PIE is to investigate the macroscopic behavior of the fuel and prepare for fuel rodlet segmenting. The third objective of the PIE is to characterize the microscopic features of the irradiated fuel and to relate these features to macroscopic behavior.

The PIE workscope will be conducted as appropriate at the Hot Fuel Examination Facility (HFEF), Analytical Laboratory (AL), Electron Microscopy Laboratory (EML) and Alpha Gamma Hot Cell Facility (AGHCF). Because of the chemical reactivity of the sodium and irradiated metallic fuels, all destructive examinations must be performed in an inert atmosphere.

The PIE will be performed according to approved procedures. Work will satisfy the requirements of NQA-1, being conducted in accordance with the ANL-W AFC-1 Fuel Development Project Quality Assurance Project Plan, W7520-0496-QM-00, the ANL-W Quality Assurance Program, W0001-0929-QM and appropriate facility quality assurance plans. All work will be performed in accordance with the appropriate facility ES&H guidelines and facility and division Conduct of Operations requirements.

6.1 Capsule Visual Examination

Upon receipt, the capsule mass will be measured and the capsule will be visually examined to determine its mechanical integrity and surface appearance. The examination will record deviations from the as-built condition. Deviations to be noted include capsule tube and end cap failures, cracks, deformations, blisters, areas of discoloration, corrosion, and loss of material by wear. Deviations from as-built conditions will be examined by close-up photography and reported to the project manager prior to performing subsequent PIE tasks. The examination results will be documented according to approved procedures using controlled logbooks or project forms.

The visual examination will be performed using a standard in-cell examination stage with a modified Kollmorgan throughwall shielded periscope coupled to a high resolution Leaf Volare digital camera back. The apparatus has three levels of optical magnification (N.B., nominally 4X, l0X, and 25X) and a digital resolution of 3072 x 2048 pixels. The apparatus is equipped with special planar optics that maintain the entire surface of a flat object (oriented normal to the optical axis of the system) in focus at the film plane; commercial photographic strobe lights with built-in halogen modeling lamps; and a dimensional grid background for optics alignment and specimen dimensional scaling.

6.2 Capsule Neutron Radiography

Neutron radiography will be used to examine the internal condition of the capsule assembly prior to removing the fuel rodlet assemblies. This non-destructive technique is able to detect the presence of water or sodium within the capsule cavity indicating a capsule leak or fuel rodlet failure, respectively; it will provide data on the general condition of the fuel rodlets including fuel rodlets axial position, fuel rodlets radial position and gap between capsule, distortion or bow, and the fuel column length and sodium level within the rodlet assemblies.

Neutron radiography will be performed at the ANL-W Neutron Radiography Facility, which interfaces through the floor of the HFEF Main Cell as seen in Figure 9. A 250 kW Training Research Isotope General Atomics (TRIGA) reactor located below the Main cell generates the neutron beam. The capsule and fuel rodlet assemblies will be imaged at the East Radiography Station (Sub-Cell Area).

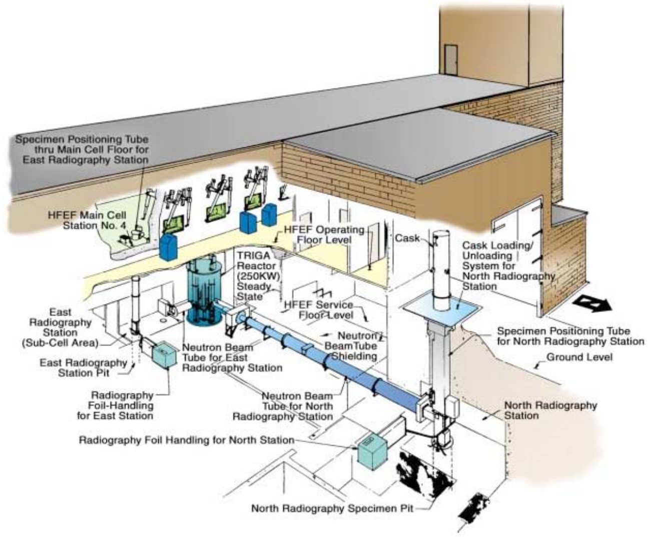


Figure 10. Neutron radiography facility at ANL-W

The specimens are imaged using an indirect radiography method, which eliminates the effects of the high gamma-ray background emitted from the radioactive fuels and components. Two types of neutron detector foils are used to image details of structural materials and fuel features.

6.3 Capsule Internal Gas Pressure and Void Volume Analyses

The capsule assembly will be laser-punctured to determine the internal gas pressure and internal void volume and to collect gas samples for radiochemistry analyses. The internal gas pressure and void volume will provide an indication of a fuel rodlet failure; in the event of a fuel rodlet failure, the radiochemistry analyses will assist in identifying the specific rodlet assembly and provide additional fuel performance data for the failed rodlet.

The capsule internal gas samples will be analyzed for isotopic and total elemental composition. The Gas Assay, Sample, and Recharge System (GASR) will be used to puncture the capsule assembly and fuel rodlet assembly, to measure the free volume and internal gas pressure and to collect samples for gas composition and isotopic analyses. The system will provide internal void volume and gas pressure data to an accuracy within ± 5% in a pressure – volume range of 0.03 to 60 liter-atmosphere.

The system is comprised of a 150 W pulsed laser, shielded cell-wall feed-throughs for optics and gas lines, a mechanical vacuum pump, calibrated volumes, gages and controls. A neoprene gasket is used to form the leak tight seal between the object to be assayed and the sealing/puncture chamber.

6.4 Rodlet Unloading from Capsule

The rodlet assemblies are planned to be unloaded using a method similar to that used for the loading process. The capsule will be sectioned at the top and bottom endcaps and the rodlets will be removed one at a time using a push rod. If there is not a sufficient gap between the rodlet outer diameter and the capsule inner diameter to facilitate removal, then the capsule will be sectioned at positions corresponding to the rodlet interfaces. The as-fabricated interface positions are noted on the design drawings. The precise section positions will be verified using results from the capsule neutron radiography.

6.5 Experiment Basket Cadmium Depletion

A select number of the Experiment Baskets will be sectioned for depletion analysis of the cadmium. This will provide confirmatory data for the physics analyses performed to determine the neutron flux and linear powers in the fuel tests. These data with the burnup measurements will be used to determine nuclear cross sections of the higher actinides, which currently have a relatively high uncertainty.

6.6 Rodlet Visual Examination

After unloading, the rodlet assembly will be weighed and visually examined to identify deviations from the as-built condition, such as cladding tube and end cap failures, deformations, cracks, blisters, areas of discoloration, corrosion, and loss of material by wear. Deviations will be examined by close-up photography and reported to the project manager prior to performing subsequent PIE tasks. Results of the rodlet visual examination will be documented according to approved procedures using laboratory notebooks or project forms.

6.7 Rodlet Assembly Dimensional Inspections

The dimensional inspection of the fuel rodlet assembly will provide requisite data to determine the radial and axial cladding strain (i.e., swelling) that occurs during in-reactor service. The cladding strain data with the AFC-1 irradiation test operational data (i.e., temperature, linear power, and fuel burnup) will be used to improve the irradiation swelling model and benchmark fuel performance predictive computer codes.

The length of the fuel rodlet will be measured with an accuracy of ±0.010 in. The bow of the fuel rodlet will be measured to an accuracy of ±0.020 in. The diameter profile of the fuel rodlet will be measured at intervals not greater than 0.1 in. (2.54 mm) to an accuracy of ±0.0003 in. (7.6 µm). The diameter inspection instrument is calibrated to NIST traceable standards. The percentage swelling of the fuel rodlet will be derived from the diameter measurements. The instrument can measure percentage swelling over a range of 0.13 – 8.7%. There will be at least four diameter profiles 45 degrees apart measured on each fuel rod to detect ovality.

The diameter inspections will be performed with the Element Contact Profilometer (ECP), which is a remotely operated, continuous-contact profilometry gauge for measuring axial and spiral diameter profiles of cylindrical elements and capsules. The rodlet assembly is inspected vertically using an element positioning stage. Horizontally opposed contact probes connected to linear transducers sense the diameter signal. The spring loaded guide rollers maintain the vertical alignment between the rodlet and the contact probes.

6.8 Rodlet Gamma Scan

The fuel rodlet will be gamma scanned over the entire accessible length. The total activity and isotopic activity of select fission products and activation products in the structural materials will be measured. The gamma spectra will be used to determine fuel pellet or fuel pin separations in the fuel column, fuel redistribution, fission product migration, and the relative axial burnup profile.

The major components of the apparatus are a solid germanium crystal detector surrounded by a sodium-iodide (NaI) crystal detector to eliminate background due to Compton scattering, a collimator with an adjustable slit width for optimizing count rates, a multichannel analyzer and software for spectra collection and analyses, and a positioning stage with four degrees of freedom (X-Y-Z and theta). A dedicated, secure computer is used to remotely operate the positioning stage and record the spectra data.

6.9 Rodlet Neutron Radiography

Neutron radiography will be used to non-destructively examine the general integrity of the fuel column and rodlet cladding and the internal features of the fuel rodlets, specifically, fuel axial growth, fuel pellet separations, fuel central-void formation, pellet cracking, fuel melting, and sodium level. Figure 10 shows a neutron radiograph image of a metallic fuel rod after irradiation to ~10 at% burnup. The figure demonstrates some of the internal features of the fuel rod that are readily examined by neutron radiography: fuel column length (dark gray) which varies in the six fuel rods due to differences in irradiation induced swelling, fuel restructuring at top of fuel column (medium gray with texture), sodium level (light gray) and gas plenum region (white).

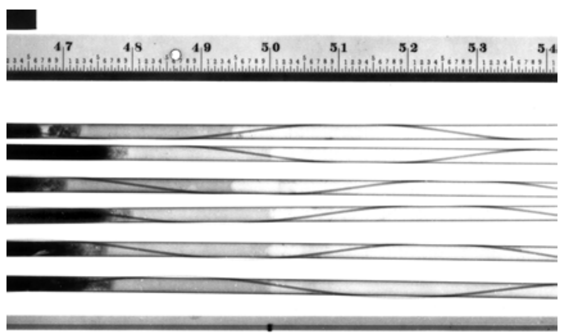


Figure 11. Example of neutron radiography of uranium-plutonium-zirconium fuel rods irradiated to 10 at% burnup displaying general integrity of cladding and internal features of the fuel rod

6.9.1 Rodlet Internal Gas Analyses

The rodlet assembly will be punctured using the GASR laser puncturing system to determine the internal gas pressure and internal free volume and to collect samples for radiochemistry analyses.

The rodlet internal gas samples will be analyzed for elemental and isotopic composition using a gas mass spectrometer. The elemental composition will be compared with as-built fill gas composition to verify the integrity of the rodlet cladding. Using the as-built characterization data and calculated helium produced, the fractional helium release from the actinide-bearing fuel forms will be determined. The fission gas release will be derived from the isotopic composition and the fuel burnup and independently from the elemental gas composition using the internal void volume, internal gas pressure, and the fuel burnup.

6.9.2 Rodlet Sectioning

Based on the results of rodlet neutron radiography, gamma scanning and dimensional inspections, the rodlet assembly will be sectioned.

6.9.3 Optical and Scanning Electron Microscopy and Radiochemical Analyses

Optical and scanning electron microscopy will be used to analyze microscopic features such as fuel restructuring, pore density and size distribution, fuel-cladding chemical interaction, grain size and structure in the fuel and cladding, precipitates and cladding integrity. Fuel rodlet samples will be prepared in transverse and longitudinal sections to perform the optical and scanning electron microscopy analyses. Figures 11 and 12 show examples of metallography of irradiated metallic fuel rods illustrating the microscopic fuel features that will be observed by optical microscopy.

The fuel burnup of a representative number of fuel samples will be determined by radiochemical analyses. These measurements will be used to benchmark the depletion calculation computer model, particularly the minor actinide reaction rates, and the relative axial burnup profiles obtained by gamma scanning.

a) **b)**

Figure 12. Examples of transverse cross sectional metallography of uranium-plutonium-zirconium metallic fuel rod (S/A X421-T108) irradiated to 10 at% burnup a) at low magnification (35X) showing fuel restructuring with central dense zone and porous annular zone, fuel swelling leading to fuel-cladding contact and integrity of the cladding, and b) at higher magnification (200X) showing details of fuel transition region between central dense fuel zone and porous annular zone

a) **b)**

Figure 13. Metallography examples of etched samples of fuel rod depicting the cladding a) with carbide precipitation along grain boundaries and slip planes and a fuel-cladding interaction layer of 25 µm depth; and b) with carbide precipitation as in a), but no fuel-cladding interaction layer.

Sample preparation will be performed in an inert, argon atmosphere sub-cell of the HFEF Main Cell, which has an independent atmosphere control system as seen in Figure 13. The sample preparation sub cell has facilities for sectioning, mounting, grinding, polishing and etching. The optical microscopy, scanning electron microscopy and radiochemistry samples will be transferred by a pneumatic transfer system.

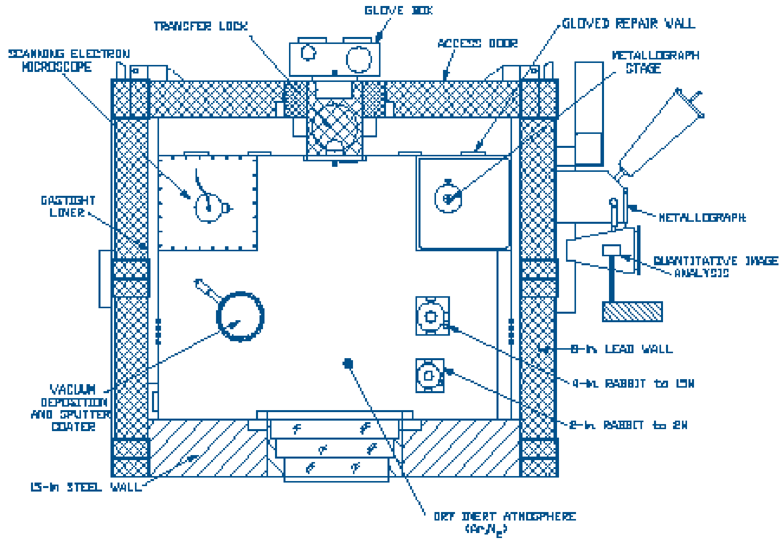


Figure 14. Inert atmosphere hot cell used for optical and electron microscopy

The optical and electron microscopy samples will be analyzed using a Leitz metallograph and Amray scanning electron microscope (SEM), which have been modified for remote operation in a dedicated inert atmosphere (argon or nitrogen) hot cell. The Leitz metallograph is equipped with a projection screen and high resolution digital camera for recording images.

6.9.4 Mechanical Property, Phase Distribution, Microchemistry and Microstructure Examinations

Hardness and tensile tests, neutron diffraction and analytical electron microscopy will be used to analyze the mechanical properties, phase distribution, microchemistry and microstructure of the metallic and nitride fuel forms and cladding. Micro-hardness measurements of the rodlet cladding and fuel-cladding interaction layer will be performed using a Vickers-type diamond indenter hardness tester. Based on these results, cladding samples may be selected for tensile testing. The microchemistry and fission product migration of the fuel will be determined by electron microprobe analyses on selected fuel cross sections. Selected rodlet assemblies may have neutron diffraction samples prepared and analyzed for phase composition. The neutron diffraction samples will be analyzed at the Intense Pulsed Neutron Source (IPNS) Facility as necessary.

Transmission electron microscopy samples of cladding from selected rodlets may be prepared and analyzed for irradiation-induced microstructure such as, dislocations, defects, voids and precipitates.

6.10 PIE Schedule

The capsule assemblies will be transported in a single shipment to the hot cell from the ATR, since they all will be discharged at the same time with the exception of one experiment. A preliminary PIE report will be submitted approximately 6 months after the PIE campaign is initiated. A PIE report on the fuel compositions to be tested in the FUTURIX Irradiation Experiment will be completed approximately 12 months after receipt of the capsule assemblies. A final PIE report on AFC-1B, -1D, -1Æ and -1F will be completed approximately 18 months after receipt of the capsule assemblies.

7. Applicable Documents

The program under which this work was conceived and conducted was previously known as the AAA program (Advanced Accelerator Applications) and the ATW program (Accelerator Transmutation of Waste). Some referenced documents contain references to these program titles. The current program title is the Advanced Fuel Cycle (AFC) program.

7.1 Argonne National Laboratory West

- ANL-W AAA QA Project Plan (W7520-0496-QM)
- AFC-1Æ & -1F Experiment Description (W7520-0529-ES)
- Fuel Test Specimen Specification for the AFC-1Æ and AFC-1G Low Fertile Nitride Fueled Capsule Irradiation
- in the ATR (W7520-0553-ES)
- Fuel Test Specimen Specification for the AFC-1F Low Fertile Metal Fueled Capsule Irradiation in the ATR (W7520-0527-ES)
- Orbital Welding System (W0650-0053-OP)
- Welding Program for Welding Fuel Elements and Containment Capsules (W7520-0474-ES)
- Welding Procedure Qualification Record (PQR) (W7520-0487-ES)
- Capsule Welding Procedure Specification (W7520-0477-ES)
- AAA Fuel Rodlet and Capsule Final Inspection Procedure (W7520-0499-ES)
- Fuel Element First Plug Welding Procedure Specification (W7520-0475-ES)
- Fuel Element Closure Plug Welding Procedure Specification (W7520-0476-ES)
- Assembling Rodlets into Capsules (NRP-FMF-005)
- ANL-W Quality Assurance Plan (W0061-0929-QM Rev. 8)
- Nonconformance Reporting (AWP 4.7)
- Inspection and Acceptance Testing (AWP 2.10)
- Welding and Special Processes (AWP 2.4)

7.2 Los Alamos National Laboratory

- Actinide Analytical Chemistry Quality Management Plan QA-1, R.2.1
- Nonconformance Reporting of Fuel Elements NMT11-AP-QA-022, R0
- Fabrication, Inspection, and Test Plan for AFC-1Æ and AFC-1G Fuel Pellet Preparation (not approved at the time of revision) NMT11-AP-021, R0
- LANL's Fabrication of the Ceramic Pellets for the AFC-1Æ and AFC-1G Capsule Irradiations in the ATR (not approved at the time of revision) NMT11-AP-020, R0

7.3 Idaho Nation Engineering and Environmental Laboratory

- Design Specification: Advanced Accelerator Applications ATW-1 Fuel Test Specimen Drop-In Capsule (BBW1 SPC-390)
- MCP–2811 – Design Control
- MCP–9217 – Design Verification
- MCP–540 – Documenting The Safety Category Of Structures, Systems And Components
- MCP–2377 – Development, Assessment, And Maintenance Of Drawings
- MCP–2374 – Analyses And Calculations
- MCP–9185 – Technical And Functional Requirements
- SP 10.2.2.8 – Engineering Change Form Preparation And Use
- LST-95 – Reference Design Codes And Standards

- LST-99 – Facility Hazards Identification And Control Information List
- RCRA 40 CFR 261.2 & 261.34
- ATSDR – 1999 – Toxicological Profile For Cadmium.
- PRD-5074 – Design Control
- SAR-153 – TRA – ATR UFSAR Nuclear Safety Basis
- STD-7006 – Marking Methods for Equipment, Components, and Materials
- STD-7020 – Preservation and Protection Requirements for Nuclear and Reactor Components
- STD-7022 – Cleanliness Acceptance Levels for Nuclear or Non-nuclear Service Components
- ID 4700.A1 – INEEL Welding Program
- PRD 183 – Radiation Protection – INEEL Radiological Control Manual
- PRD 186 – Occupational Safety Program
- PRD 1002 – Safeguards and Security
- 29 CFR 1910 – Occupational Health Safety Standards (OSHA)
- DOE N 441.1 – Radiological Protection for DOE Activities
- ID 5480.6A – Safety of Department of Energy-Owned Reactors
- ID-12044 – Operational Safety Design Criteria Manual
- 20 CFR 8330.120 – Quality Assurance
- DOE-5480.4 – Environmental Protection, Safety, and Health Protection Standards
- TSR-186 – TRA – ATR Nuclear Safety Basis – Technical Safety Requirements
- Drawing – 523781
- Current EFT basket (DWG 443958)

7.4 Drawings

- AFC-1Æ Nitride Fuel Rodlet Assembly W7520-0547-EB
- AFC-1F Metallic Fuel Rodlet Assembly W7520-0549-EB
- Tube W7520-0466-EA
- Endplug W7520-0493-EC
- Metallic Fuel W7520-0469-EB
- AFC-1Æ Nitride Fuel W7520-0548-EB
- Top Endplug W7520-0520-EC
- AFC-1Æ and AFC-1F Capsule Assembly W7520-0546-EC
- Capsule Tube W7520-0495-EC
- Capsule Lower Endcap W7520-0472-EA
- Capsule Upper Spacer W7520-0485-EB
- Capsule Bottom Spacer W7520-0551-EA
- Capsule Upper Endcap W7520-0490-EB
- ATR East Flux Trap Cadmium Laminated AFC-1 Experiment Basket BBWI DWG-523781

8. AFCI Program Schedule

The schedule shown below is proposed to meet the required deadlines prior to insertion of experiments AFC-1Æ and AFC-1F into the ATR for irradiation beginning in November 2003.

Deliverable to ATR	Date
Draft Experiment Description of AFC-1(Æ,F)	April 28, 2003
Final Experiment Design and Design & Data Package	November 2003
Fabrication Data Package	November 2003
AFC-1(Æ,F) Irradiation Test Assemblies	December 2003

The current irradiation schedule for the AFC-1 Æ, AFC-1B, AFC-1D, AFC-1F and the proposed GFR Material test are shown in Figure 14. This schedule lists the reactor cycles, high power palm cycles, and outages up to Core Internal Changout (CIC) scheduled for May 2004. Note: This schedule will change in accordance with the ATR reactor test plan.

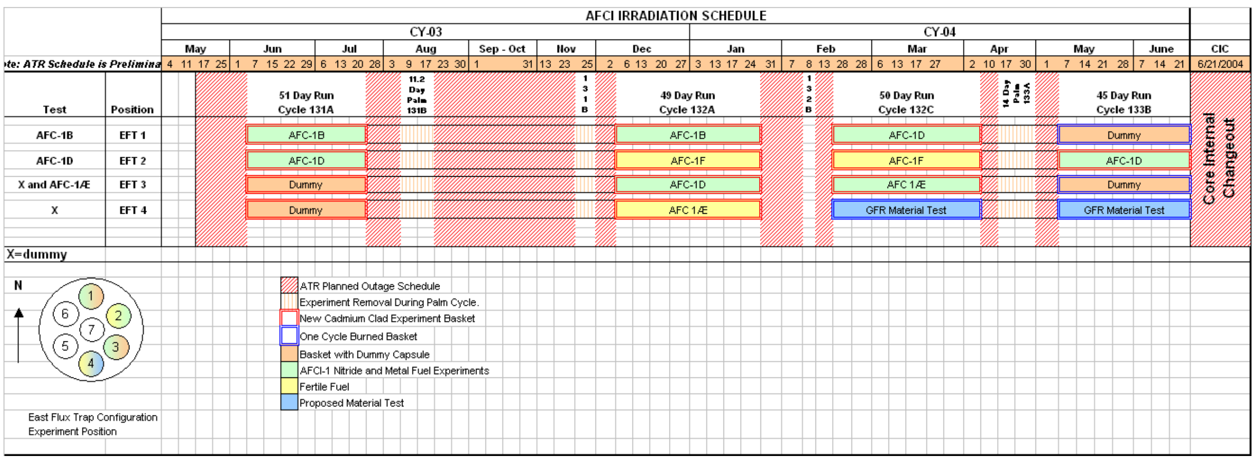


Figure 15. Irradiation Schedule

9. Roles And Responsibilities

Argonne National Laboratory will fabricate and deliver the irradiation vehicles to the ATR; fabrication of the experimental fuels will be performed at ANL-W and at LANL. ANL-W will supply the rodlet input data/analysis needed for the Experiment Safety Assurance Package. The INEEL will procure the shipping cask for transport of the discharged experiments to the hot cell facility; ANL-W has responsibility for the cask arrangements. ANL-W has overall responsibility for these irradiation experiments.

The Idaho National Engineering and Environmental Laboratory will provide project management and project engineering for all activities from the point of initiation of the experimental process through the disassembly and shipment of the experiments. The INEEL will also be responsible for fabrication of the thermal neutron flux baskets that will house the AFC-1 Æ and –1F experiments in the east flux trap of the ATR.

AFC-1Æ Normal Operation

APPENDIX A

SUMMARY RESULTS FOR EXPERIMENT AFC-1Æ NORMAL OPERATION										
			Surface	Discharge	Plenum	PEAK TEMPERATURES			
	Fuel	LHGR	Heat Flux	Burnup	Pressure	Coolant	Capsule	Clad	Fuel
Rodlet	Type	(W/cm)	(W/cm^2)	(at.%)	(psi)	(°C)	(°C)	(°C)	(°C)
1	(Pu0.5,Am0.5)N-36ZrN	330.0	116.7	10.0	505.9	53.7	177.0	532.3	869.2
2	DUMMY	0.0	0.0	0.0	16.1	53.7	53.7	53.7	53.7
3	(Pu0.5,Am0.5)N-36ZrN	330.0	116.7	10.0	490.9	55.4	178.7	533.7	889.6
4	(Pu0.5,Am0.5)N-36ZrN	330.0	116.7	10.0	424.3	57.2	180.4	535.0	985.8
5	(Pu0.5,Am0.25,Np0.25)N-36ZrN	330.0	116.7	10.0	263.5	58.9	182.1	536.4	942.7
6	(U0.50,Pu0.25,Am0.15,Np0.10)N	330.0	116.7	10.0	444.7	60.6	183.9	537.7	936.8

AFC-1Æ Normal Operation **APPENDIX A**

EXPERIMENT AFC-1Æ

RODLET 1

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.50E-03	W/cm-°C			
Gap Conductance:	5.68E-01	W/cm2-°C			
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.646	W/cm-°C			
Fuel Conductivity:	0.081	W/cm-°C			
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.144				
UN Mole Fraction:	0.000	**0.000**	g U		
PuN Mole Fraction:	0.500	**1.957**	g Pu		
AmN Mole Fraction:	0.500	**1.957**	g Am		
NpN Mole Fraction:	0.000	**0.000**	g Np		
ZrN Wt. Fraction:	0.360	**2.330**	g ZrN		
	---	**0.482**	g Na		
Sodium Density:	0.966				
Fuel Density:	10.40	g/cm3			
ACT Density:	5.56	g/cm3			
ACT Atom Density:	1.19E+22	atoms/cm3			
Am Fraction in ACT:	0.50				
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	
Cold Capsule ID:	0.5954	cm	0.2344	in.	
Hot Capsule OD:	0.9020	cm	0.3551	in.	
Hot Capsule ID:	0.5966	cm	0.2349	in.	
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	
Hot Clad ID:	0.4958	cm	0.1952	in.	
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	
Fuel OD:	0.4267	cm	0.1680	in.	
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.0	°C			
Coolant Exit Temp:	53.7	°C			
Average Coolant Temp:	52.9	°C			
Equivalent Diameter:	0.1920	cm			
Flow Area:	0.3005	cm2			
Coolant Volumetric Flow Rate:	235.5	cm3/s			
Coolant Mass Flow Rate:	232.5	g/s			
Surface Heat Flux:	116.7	W/cm2			
Power to Coolant:	1676.4	W			
Re:	2.81E+04				
Pr:	3.42				
Nu:	136.4				
Film Coefficient:	4.58	W/cm2-°C			
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	78.3	°C			
Capsule Inner Temp:	177.0	°C			
Clad Surface Temp:	491.7	°C			
Clad Inner Temp:	**532.3**	°C			
Avg. Fuel-Clad Gap Temp:	538.4	°C			
Fuel Surface Temp:	544.5	°C			
Fuel Centerline Temp:	**869.2**	°C			
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				
Plenum Volume:	1.211	cm3			
Fuel Volume:	0.727	cm3			
Burnup:	0.10				
Total Fissions:	8.68E+20	fissions			
Fission Gas Atoms Produced:	2.17E+20	atoms			
Helium Atoms Produced:	6.51E+20	atoms			
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	6.31E-04	mol			
Plenum Pressure:	**505.9**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ Normal Operation **APPENDIX A**

EXPERIMENT AFC-1Æ					
	RODLET 2				
	MATERIALS				NOTES:
Capsule:	Steel				
Gap:	Helium				
Clad:	HT9				
Bond:	None				
Fuel:	DUMMY				
	PHYSICS DATA				
LHGR:	0.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	1.53E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	2.71E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.002	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.110	W/cm-°C			
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.000				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.000		**0.000**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.000		**0.000**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000		**0.000**	g ZrN	
	---		**0.000**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	0.00	g/cm3			
ACT Density:	0.00	g/cm3			
ACT Atom Density:	0.00E+00	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.00				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9010	cm	0.3547	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5959	cm	0.2346	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0057	cm	0.0022	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5846	cm	0.2301	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4931	cm	0.1941	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	0.0000	cm	0.0000	in.	
Bond Height:	0.0000	cm	0.0000	in.	=D54+0.0
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	12.7000	cm	5.0000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.7	°C			='Rodlet 1'!B62
Coolant Exit Temp:	53.7	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	53.7	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	0.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	0.0	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	53.7	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	53.7	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	53.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**53.7**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	53.7	°C			=0.5*(B79+B81)
Fuel Surface Temp:	53.7	°C			=B79
Fuel Centerline Temp:	**53.7**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	#DIV/0!				=(B58-B55-2*B56)/B54
Plenum Volume:	2.422	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.000	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.00				
Total Fissions:	0.00E+00	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	0.00E+00	atoms			=0.25*B89
Helium Atoms Produced:	0.00E+00	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	9.90E-05	mol			=(B92*B90+B93*B91)/6.023E+23 + B86/82.056/298
Plenum Pressure:	**16.1**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ Normal Operation **APPENDIX A**

EXPERIMENT AFC-1Æ

RODLET 3

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.50E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	5.69E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.645	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.076	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.170				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**1.896**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500		**1.896**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360		**2.257**	g Zr	
	---		**0.482**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.40	g/cm3			
ACT Density:	5.56	g/cm3			
ACT Atom Density:	1.16E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9021	cm	0.3551	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5966	cm	0.2349	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.7	°C			='Rodlet 2'!B62
Coolant Exit Temp:	55.4	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	54.6	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	1676.4	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	80.0	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	178.7	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	493.0	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**533.7**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	539.8	°C			=0.5*(B79+B81)
Fuel Surface Temp:	545.9	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**889.6**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	8.41E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	2.10E+20	atoms			=0.25*B89
Helium Atoms Produced:	6.31E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	6.11E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**490.9**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ Normal Operation **APPENDIX A**

EXPERIMENT AFC-1Æ
RODLET 4

					NOTES:
	MATERIALS				
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5}Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.51E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	5.69E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.645	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.060	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.284				
UN Mole Fraction:	0.000	**0.000**	g U		=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500	**3.778**	g Pu		=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500	**3.778**	g Am		=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000	**0.000**	g Np		=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360	**2.720**	g Zr		
	---	**0.482**	g Na		=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.40	g/cm3			
ACT Density:	5.56	g/cm3			
ACT Atom Density:	9.99E+21	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9021	cm	0.3552	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5966	cm	0.2349	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	55.4	°C			='Rodlet 3'!B62
Coolant Exit Temp:	57.2	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	56.3	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	1676.4	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	81.7	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	180.4	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	494.4	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**535.0**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	541.1	°C			=0.5*(B79+B81)
Fuel Surface Temp:	547.2	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**985.8**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	7.26E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	1.81E+20	atoms			=0.25*B89
Helium Atoms Produced:	5.44E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	5.27E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**424.3**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ Normal Operation **APPENDIX A**

EXPERIMENT AFC-1Æ
RODLET 5

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.25},Np_{0.25})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.51E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	5.70E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.644	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.067	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.234				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**3.797**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.250		**1.898**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.250		**1.898**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360		**2.734**	g ZrN	
	---		**0.483**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.45	g/cm3			
ACT Density:	5.64	g/cm3			
ACT Atom Density:	1.08E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.25				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9021	cm	0.3552	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5967	cm	0.2349	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	57.2	°C			='Rodlet 4'!B62
Coolant Exit Temp:	58.9	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	58.0	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	1676.4	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	83.5	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	182.1	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	495.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**536.4**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	542.5	°C			=0.5*(B79+B81)
Fuel Surface Temp:	548.6	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**942.7**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	7.88E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	1.97E+20	atoms			=0.25*B89
Helium Atoms Produced:	2.95E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	3.27E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**263.5**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ Normal Operation **APPENDIX A**

	EXPERIMENT AFC-1Æ				
	RODLET 6				
	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(U_{0.50}Pu_{0.25}Am_{0.15}Np_{0.10})N$**				
	PHYSICS DATA				
Nominal LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.52E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	5.71E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.643	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.068	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.226				
UN Mole Fraction:	0.500	**3.776**	g U		=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.250	**1.889**	g Pu		=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.150	**1.134**	g Am		=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.100	**0.755**	g Np		=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000	**0.000**	g ZrN		
	---	**0.483**	g Na		=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	14.21	g/cm3			
ACT Density:	13.42	g/cm3			
ACT Atom Density:	2.61E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.15				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9021	cm	0.3552	in.	=D39*(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5967	cm	0.2349	in.	=D40*(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	58.9	°C			='Rodlet 5'!B62
Coolant Exit Temp:	60.6	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	59.8	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	1676.4	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	85.2	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	183.9	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	497.1	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**537.7**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	543.8	°C			=0.5*(B79+B81)
Fuel Surface Temp:	550.0	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**936.8**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	1.90E+21	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	4.74E+20	atoms			=0.25*B89
Helium Atoms Produced:	4.26E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	5.51E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**444.7**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1F Normal Operation **APPENDIX B**

SUMMARY RESULTS FOR EXPERIMENT AFC-1F NORMAL OPERATION										
			Surface	Discharge	Plenum	PEAK TEMPERATURES			
	Fuel	LHGR	Heat Flux	Burnup	Pressure	Coolant	Capsule	Clad	Fuel
Rodlet	Type	(W/cm)	(W/cm^2)	(at.%)	(psi)	(°C)	(°C)	(°C)	(°C)
1	U-29Pu-4Am-2Np-30Z	330.0	116.7	10.0	310.5	53.3	176.8	532.1	873.8
2	U-34Pu-4Am-2Np-20Z	330.0	116.7	10.0	386.0	54.6	178.1	533.2	874.8
3	U-25Pu-3Am-2Np-40Z	330.0	116.7	10.0	234.7	55.9	179.3	534.2	875.8
4	U-29Pu-4Am-2Np-30Z	330.0	116.7	10.0	306.7	57.2	180.6	535.2	876.9
5	U-28Pu-7Am-30Zr	330.0	116.7	10.0	375.3	58.5	181.9	536.2	877.9
6	U-25Pu-3Am-2Np-40Z	330.0	116.7	10.0	231.2	59.8	183.2	537.2	878.9

AFC-1F Normal Operation **APPENDIX B**

EXPERIMENT AFC-1F
RODLET 1

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-29Pu-4Am-2Np-30Zr**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.50E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	5.68E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.645	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.350	**1.951**	g U		=(1-B29)/2
Plutonium Wt. Fraction:	0.290	**1.617**	g Pu		=B25-B27-B28
Americium Wt. Fraction:	0.040	**0.223**	g Am		
Neptunium Wt. Fraction:	0.020	**0.112**	g Np		
Zirconium Wt. Fraction:	0.300	**1.673**	g Zr		
	---	**0.484**	g Na		=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966				
Fuel Density:	11.63	g/cm3			
ACT Density:	8.14	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.04E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.06				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9020	cm	0.3551	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5966	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.0	°C			=tinlet
Coolant Exit Temp:	53.3	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	52.6	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1257.3	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	78.1	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	176.8	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	491.5	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**532.1**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	540.9	°C			=0.5*(B78+B80)
Fuel Surface Temp:	549.6	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**873.8**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	9.79E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	2.45E+20	atoms			=0.25*B88
Helium Atoms Produced:	8.40E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	4.65E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**310.5**	psi			=B93*82.056*14.7*(B78+273)/B85

EXPERIMENT AFC-1F

RODLET 2

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-34Pu-4Am-2Np-20Zr**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.50E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	5.68E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.644	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.400	**2.517**	g U		=(1-B29)/2
Plutonium Wt. Fraction:	0.340	**2.140**	g Pu		=B25-B27-B28
Americium Wt. Fraction:	0.040	**0.252**	g Am		
Neptunium Wt. Fraction:	0.020	**0.126**	g Np		
Zirconium Wt. Fraction:	0.200	**1.259**	g Zr		
	---	**0.484**	g Na		=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	13.12	g/cm3			
ACT Density:	10.50	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.63E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.05				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9021	cm	0.3551	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5966	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.3	°C			='Rodlet 1'!B61
Coolant Exit Temp:	54.6	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	53.9	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1257.3	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	79.4	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	178.1	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	492.5	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**533.2**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	541.9	°C			=0.5*(B78+B80)
Fuel Surface Temp:	550.6	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**874.8**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	1.26E+21	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	3.16E+20	atoms			=0.25*B88
Helium Atoms Produced:	9.48E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	5.77E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**386.0**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F Normal Operation **APPENDIX B**

EXPERIMENT AFC-1F

RODLET 3

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-25Pu-3Am-2Np-40Zr**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.50E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	5.69E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.644	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.300	**1.529**	g U		=(1-B29)/2
Plutonium Wt. Fraction:	0.250	**1.274**	g Pu		=B25-B27-B28
Americium Wt. Fraction:	0.030	**0.153**	g Am		
Neptunium Wt. Fraction:	0.020	**0.102**	g Np		
Zirconium Wt. Fraction:	0.400	**2.038**	g Zr		
	---	**0.484**	g Na		=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.63	g/cm3			
ACT Density:	6.38	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	1.60E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.05				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9021	cm	0.3551	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5966	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	54.6	°C			='Rodlet 2'!B61
Coolant Exit Temp:	55.9	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	55.2	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1257.3	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	80.7	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	179.3	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	493.5	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**534.2**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	542.9	°C			=0.5*(B78+B80)
Fuel Surface Temp:	551.6	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**875.8**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	7.67E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	1.92E+20	atoms			=0.25*B88
Helium Atoms Produced:	5.76E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	3.50E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**234.7**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F Normal Operation **APPENDIX B**

	EXPERIMENT AFC-1F				
	RODLET 4				
	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-29Pu-4Am-2Np-30Zr**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.51E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	5.69E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.643	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.350		**1.920**	g U	=(1-B29)/2
Plutonium Wt. Fraction:	0.290		**1.591**	g Pu	=B25-B27-B28
Americium Wt. Fraction:	0.040		**0.219**	g Am	
Neptunium Wt. Fraction:	0.020		**0.110**	g Np	
Zirconium Wt. Fraction:	0.300		**1.646**	g Zr	
	---		**0.484**	g Na	=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	11.44	g/cm3			
ACT Density:	8.01	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.01E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.06				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9021	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5966	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	55.9	°C			='Rodlet 3'!B61
Coolant Exit Temp:	57.2	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	56.5	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1257.3	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	81.9	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	180.6	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	494.5	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**535.2**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	543.9	°C			=0.5*(B78+B80)
Fuel Surface Temp:	552.6	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**876.9**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	9.64E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	2.41E+20	atoms			=0.25*B88
Helium Atoms Produced:	8.26E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	4.57E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**306.7**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F Normal Operation

APPENDIX B

EXPERIMENT AFC-1F

RODLET 5

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-28Pu-7Am-30Zr**				
	PHYSICS DATA				
LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.51E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	5.70E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.643	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.350		**1.916**	g U	=(1-B29)/2
Plutonium Wt. Fraction:	0.280		**1.533**	g Pu	=B25-B27-B28
Americium Wt. Fraction:	0.070		**0.383**	g Am	
Neptunium Wt. Fraction:	0.000		**0.000**	g Np	
Zirconium Wt. Fraction:	0.300		**1.642**	g Zr	
	---		**0.484**	g Na	=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	11.41	g/cm3			
ACT Density:	7.99	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.01E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.10				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9021	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5967	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	57.2	°C			='Rodlet 4'!B61
Coolant Exit Temp:	58.5	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	57.8	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1257.3	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	83.2	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	181.9	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	495.6	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**536.2**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	544.9	°C			=0.5*(B78+B80)
Fuel Surface Temp:	553.7	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**877.9**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	9.62E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	2.40E+20	atoms			=0.25*B88
Helium Atoms Produced:	1.44E+20	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	5.59E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**375.3**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F Normal Operation **APPENDIX B**

EXPERIMENT AFC-1F
RODLET 6

	MATERIALS				NOTES:
Capsule:	Steel				
Gap:	Helium				
Clad:	HT9				
Bond:	Sodium				
Fuel:	U-25Pu-3Am-2Np-40Zr				
	PHYSICS DATA				
Nominal LHGR:	330.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.52E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	5.70E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.642	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.300	**1.500**	g U		=(1-B29)/2
Plutonium Wt. Fraction:	0.250	**1.250**	g Pu		=B25-B27-B28
Americium Wt. Fraction:	0.030	**0.150**	g Am		
Neptunium Wt. Fraction:	0.020	**0.100**	g Np		
Zirconium Wt. Fraction:	0.400	**2.000**	g Zr		
	---	**0.484**	g Na		=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.43	g/cm3			
ACT Density:	6.26	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	1.57E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.05				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9021	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5967	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0044	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5878	cm	0.2314	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4958	cm	0.1952	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	58.5	°C			='Rodlet 5'!B61
Coolant Exit Temp:	59.8	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	59.1	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	116.7	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1257.3	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	84.5	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	183.2	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	496.6	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**537.2**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	546.0	°C			=0.5*(B78+B80)
Fuel Surface Temp:	554.7	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**878.9**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	7.53E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	1.88E+20	atoms			=0.25*B88
Helium Atoms Produced:	5.65E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	3.44E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**231.2**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1Æ 120 % Overpower **APPENDIX C**

SUMMARY RESULTS FOR EXPERIMENT AFC-1Æ 120% OVERPOWER									
			Surface	Discharge	Plenum	PEAK TEMPERATURES			
	Fuel	LHGR	Heat Flux	Burnup	Pressure	Coolant	Capsule	Clad	Fuel
Rodlet	Type	(W/cm)	(W/cm^2)	(at.%)	(psi)	(°C)	(°C)	(°C)	(°C)
1	(Pu0.5,Am0.5)N-36ZrN	396.0	140.0	10.0	546.8	54.1	202.0	597.5	1002.6
2	DUMMY	0.0	0.0	0.0	16.1	53.7	53.7	53.7	53.7
3	(Pu0.5,Am0.5)N-36ZrN	396.0	140.0	10.0	530.6	55.8	203.7	598.9	1026.9
4	(Pu0.5,Am0.5)N-36ZrN	396.0	140.0	10.0	458.7	57.9	205.8	600.5	1142.2
5	(Pu0.5,Am0.25,Np0.25)N-36ZrN	396.0	140.0	10.0	284.9	59.9	207.8	602.1	1090.5
6	(U0.50,Pu0.25,Am0.15,Np0.10)N	396.0	140.0	10.0	480.9	62.0	209.9	603.7	1083.5

AFC-1Æ 120 % Overpower **APPENDIX C**

EXPERIMENT AFC-1Æ

RODLET 1

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.63E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	6.18E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.613	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.081	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.144				
UN Mole Fraction:	0.000	**0.000**	g U		=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500	**1.957**	g Pu		=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500	**1.957**	g Am		=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000	**0.000**	g Np		=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360	**2.330**	g ZrN		
	---	**0.484**	g Na		=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966				
Fuel Density:	10.40	g/cm3			
ACT Density:	5.56	g/cm3			
ACT Atom Density:	1.19E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D39*(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5968	cm	0.2349	in.	=D40*(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5882	cm	0.2316	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.0	°C			=tinlet
Coolant Exit Temp:	54.1	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	53.0	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	2011.7	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	83.5	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	202.0	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	548.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**597.5**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	605.2	°C			=0.5*(B79+B81)
Fuel Surface Temp:	613.0	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1002.6**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	8.68E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	2.17E+20	atoms			=0.25*B89
Helium Atoms Produced:	6.51E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	6.31E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**546.8**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ 120 % Overpower **APPENDIX C**

EXPERIMENT AFC-1Æ
RODLET 2

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**None**				
Fuel:	**DUMMY**				
	PHYSICS DATA				
LHGR:	0.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	1.53E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	2.71E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.002	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.110	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.000				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.000		**0.000**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.000		**0.000**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000		**0.000**	g ZrN	
	---		**0.000**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	0.00	g/cm3			
ACT Density:	0.00	g/cm3			
ACT Atom Density:	0.00E+00	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.00				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9010	cm	0.3547	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5959	cm	0.2346	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0057	cm	0.0022	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5846	cm	0.2301	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4931	cm	0.1941	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	0.0000	cm	0.0000	in.	
Bond Height:	0.0000	cm	0.0000	in.	=D54+0.0
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	12.7000	cm	5.0000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.7	°C			='Rodlet 1'!B62
Coolant Exit Temp:	53.7	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	53.7	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	0.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	0.0	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	53.7	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	53.7	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	53.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**53.7**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	53.7	°C			=0.5*(B79+B81)
Fuel Surface Temp:	53.7	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**53.7**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	#DIV/0!				=(B58-B55-2*B56)/B54
Plenum Volume:	2.422	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.000	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.00				
Total Fissions:	0.00E+00	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	0.00E+00	atoms			=0.25*B89
Helium Atoms Produced:	0.00E+00	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	9.90E-05	mol			=(B92*B90+B93*B91)/6.023E+23 + B86/82.056/298
Plenum Pressure:	**16.1**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ 120 % Overpower **APPENDIX C**

EXPERIMENT AFC-1Æ
RODLET 3

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.64E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	6.19E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.613	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.076	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.170				
UN Mole Fraction:	0.000	**0.000**	g U		=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500	**1.896**	g Pu		=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500	**1.896**	g Am		=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000	**0.000**	g Np		=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360	**2.257**	g Zr		
	---	**0.484**	g Na		=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.40	g/cm3			
ACT Density:	5.56	g/cm3			
ACT Atom Density:	1.16E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5968	cm	0.2349	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5882	cm	0.2316	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.7	°C			='Rodlet 2'!B62
Coolant Exit Temp:	55.8	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	54.8	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	2011.7	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	85.3	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	203.7	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	550.1	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**598.9**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	606.6	°C			=0.5*(B79+B81)
Fuel Surface Temp:	614.4	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1026.9**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	8.41E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	2.10E+20	atoms			=0.25*B89
Helium Atoms Produced:	6.31E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	6.11E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**530.6**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ 120 % Overpower **APPENDIX C**

EXPERIMENT AFC-1Æ					
RODLET 4					
	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.64E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	6.19E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.612	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.060	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.284				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**3.778**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500		**3.778**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360		**2.720**	g Zr	
	---		**0.484**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.40	g/cm3			
ACT Density:	5.56	g/cm3			
ACT Atom Density:	9.99E+21	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	55.8	°C			='Rodlet 3'!B62
Coolant Exit Temp:	57.9	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	56.8	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	2011.7	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	87.3	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	205.8	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	551.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**600.5**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	608.2	°C			=0.5*(B79+B81)
Fuel Surface Temp:	616.0	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1142.2**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	7.26E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	1.81E+20	atoms			=0.25*B89
Helium Atoms Produced:	5.44E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	5.27E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**458.7**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ 120 % Overpower

APPENDIX C

EXPERIMENT AFC-1Æ

RODLET 5

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.25},Np_{0.25})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.65E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	6.20E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.611	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.067	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.234				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**3.797**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.250		**1.898**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.250		**1.898**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000		**0.000**	g ZrN	
	---		**0.484**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.45	g/cm3			
ACT Density:	5.64	g/cm3			
ACT Atom Density:	1.08E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.25				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9023	cm	0.3553	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4962	cm	0.1954	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	57.9	°C			='Rodlet 4'!B62
Coolant Exit Temp:	59.9	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	58.9	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	2011.7	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	89.4	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	207.8	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	553.3	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**602.1**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	609.9	°C			=0.5*(B79+B81)
Fuel Surface Temp:	617.7	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1090.5**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	7.88E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	1.97E+20	atoms			=0.25*B89
Helium Atoms Produced:	2.95E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	3.27E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**284.9**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ 120 % Overpower

APPENDIX C

EXPERIMENT AFC-1Æ

RODLET 6

	MATERIALS				NOTES:
Capsule:	Steel				
Gap:	Helium				
Clad:	HT9				
Bond:	Sodium				
Fuel:	$(U_{0.50},Pu_{0.25},Am_{0.15},Np_{0.10})N$				
	PHYSICS DATA				
Nominal LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.65E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	6.21E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.610	W/cm-°C			=0.907-0.000485*B80
Fuel Conductivity:	0.068	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.226				
UN Mole Fraction:	0.500		**3.776**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.250		**1.889**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.150		**1.134**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.100		**0.755**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000		**0.000**	g ZrN	
	---		**0.484**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	14.21	g/cm3			
ACT Density:	13.42	g/cm3			
ACT Atom Density:	2.61E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.15				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9024	cm	0.3553	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4962	cm	0.1954	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	59.9	°C			='Rodlet 5'!B62
Coolant Exit Temp:	62.0	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	61.0	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	2011.7	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	91.5	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	209.9	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	555.0	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**603.7**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	611.5	°C			=0.5*(B79+B81)
Fuel Surface Temp:	619.3	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1083.5**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	1.90E+21	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	4.74E+20	atoms			=0.25*B89
Helium Atoms Produced:	4.26E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	5.51E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**480.9**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1F 120 % Overpower

APPENDIX D

SUMMARY RESULTS FOR EXPERIMENT AFC-1F 120% OVERPOWER

Rodlet	Fuel Type	LHGR (W/cm)	Surface Heat Flux (W/cm^2)	Discharge Burnup (at.%)	Plenum Pressure (psi)	PEAK TEMPERATURES Coolant (°C)	Capsule (°C)	Clad (°C)	Fuel (°C)
1	J-29Pu-4Am-2Np-30Z	396.0	140.0	10.0	335.6	53.6	201.7	597.3	1008.4
2	J-34Pu-4Am-2Np-20Z	396.0	140.0	10.0	417.3	55.1	203.3	598.5	1009.7
3	J-25Pu-3Am-2Np-40Z	396.0	140.0	10.0	253.8	56.7	204.8	599.7	1010.9
4	J-29Pu-4Am-2Np-30Z	396.0	140.0	10.0	331.6	58.2	206.4	601.0	1012.2
5	U-28Pu-7Am-30Zr	396.0	140.0	10.0	405.9	59.8	207.9	602.2	1013.4
6	J-25Pu-3Am-2Np-40Z	396.0	140.0	10.0	250.1	61.3	209.5	603.4	1014.7

AFC-1F 120 % Overpower

APPENDIX D

	EXPERIMENT AFC-1F				
	RODLET 1				
	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-29Pu-4Am-2Np-30Zr**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.63E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	6.18E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.612	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.350		**1.951**	g U	=(1-B29)/2
Plutonium Wt. Fraction:	0.290		**1.617**	g Pu	=B25-B27-B28
Americium Wt. Fraction:	0.040		**0.223**	g Am	
Neptunium Wt. Fraction:	0.020		**0.112**	g Np	
Zirconium Wt. Fraction:	0.300		**1.673**	g Zr	
	---		**0.486**	g Na	=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966				
Fuel Density:	11.63	g/cm3			
ACT Density:	8.14	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.04E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.06				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5967	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5882	cm	0.2316	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.0	°C			=tinlet
Coolant Exit Temp:	53.6	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	52.8	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1508.8	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	83.3	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	201.7	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	548.5	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**597.3**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	608.3	°C			=0.5*(B78+B80)
Fuel Surface Temp:	619.4	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**1008.4**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	9.79E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	2.45E+20	atoms			=0.25*B88
Helium Atoms Produced:	8.40E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	4.65E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**335.6**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F 120 % Overpower

APPENDIX D

	EXPERIMENT AFC-1F				
	RODLET 2				
	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-34Pu-4Am-2Np-20Zr**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.63E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	6.18E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.611	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.400	**2.517**	g U		=(1-B29)/2
Plutonium Wt. Fraction:	0.340	**2.140**	g Pu		=B25-B27-B28
Americium Wt. Fraction:	0.040	**0.252**	g Am		
Neptunium Wt. Fraction:	0.020	**0.126**	g Np		
Zirconium Wt. Fraction:	0.200	**1.259**	g Zr		
	---	**0.486**	g Na		=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	13.12	g/cm3			
ACT Density:	10.50	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.63E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.05				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5968	cm	0.2349	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5882	cm	0.2316	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.6	°C			='Rodlet 1'!B61
Coolant Exit Temp:	55.1	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	54.3	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1508.8	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	84.8	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	203.3	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	549.7	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**598.5**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	609.6	°C			=0.5*(B78+B80)
Fuel Surface Temp:	620.6	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**1009.7**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	1.26E+21	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	3.16E+20	atoms			=0.25*B88
Helium Atoms Produced:	9.48E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	5.77E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**417.3**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F 120 % Overpower

APPENDIX D

EXPERIMENT AFC-1F

RODLET 3

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-25Pu-3Am-2Np-40Zr**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.64E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	6.19E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.611	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.300		**1.529**	g U	=(1-B29)/2
Plutonium Wt. Fraction:	0.250		**1.274**	g Pu	=B25-B27-B28
Americium Wt. Fraction:	0.030		**0.153**	g Am	
Neptunium Wt. Fraction:	0.020		**0.102**	g Np	
Zirconium Wt. Fraction:	0.400		**2.038**	g Zr	
	---		**0.486**	g Na	=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.63	g/cm3			
ACT Density:	6.38	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	1.60E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.05				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	55.1	°C			='Rodlet 2'!B61
Coolant Exit Temp:	56.7	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	55.9	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1508.8	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	86.4	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	204.8	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	551.0	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**599.7**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	610.8	°C			=0.5*(B78+B80)
Fuel Surface Temp:	621.9	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**1010.9**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	7.67E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	1.92E+20	atoms			=0.25*B88
Helium Atoms Produced:	5.76E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	3.50E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**253.8**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F 120 % Overpower

APPENDIX D

EXPERIMENT AFC-1F
RODLET 4

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-29Pu-4Am-2Np-30Zr**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.64E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	6.20E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.610	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.350		**1.920**	g U	=(1-B29)/2
Plutonium Wt. Fraction:	0.290		**1.591**	g Pu	=B25-B27-B28
Americium Wt. Fraction:	0.040		**0.219**	g Am	
Neptunium Wt. Fraction:	0.020		**0.110**	g Np	
Zirconium Wt. Fraction:	0.300		**1.646**	g Zr	
	---		**0.486**	g Na	=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	11.44	g/cm3			
ACT Density:	8.01	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.01E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.06				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9023	cm	0.3552	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4962	cm	0.1953	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	56.7	°C			='Rodlet 3'!B61
Coolant Exit Temp:	58.2	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	57.4	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1508.8	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	87.9	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	206.4	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	552.2	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**601.0**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	612.0	°C			=0.5*(B78+B80)
Fuel Surface Temp:	623.1	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**1012.2**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	9.64E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	2.41E+20	atoms			=0.25*B88
Helium Atoms Produced:	8.26E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	4.57E-04	mol			=(B91*B89+B92*B90)/6.023E+23

AFC-1F 120 % Overpower **APPENDIX D**

EXPERIMENT AFC-1F
RODLET 5

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-28Pu-7Am-30Zr**				
	PHYSICS DATA				
LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.65E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	6.20E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.610	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.350		**1.916**	g U	=(1-B29)/2
Plutonium Wt. Fraction:	0.280		**1.533**	g Pu	=B25-B27-B28
Americium Wt. Fraction:	0.070		**0.383**	g Am	
Neptunium Wt. Fraction:	0.000		**0.000**	g Np	
Zirconium Wt. Fraction:	0.300		**1.642**	g Zr	
	---		**0.486**	g Na	=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	11.41	g/cm3			
ACT Density:	7.99	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	2.01E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.10				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9023	cm	0.3553	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4962	cm	0.1954	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	58.2	°C			='Rodlet 4'!B61
Coolant Exit Temp:	59.8	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	59.0	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1508.8	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	89.5	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	207.9	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	553.4	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**602.2**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	613.3	°C			=0.5*(B78+B80)
Fuel Surface Temp:	624.4	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**1013.4**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	9.62E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	2.40E+20	atoms			=0.25*B88
Helium Atoms Produced:	1.44E+20	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	5.59E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**405.9**	psi			=B93*82.056*14.7*(B78+273)/B85

AFC-1F 120 % Overpower

APPENDIX D

EXPERIMENT AFC-1F
RODLET 6

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**U-25Pu-3Am-2Np-40Zr**				
	PHYSICS DATA				
Nominal LHGR:	396.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.65E-03	W/cm-°C			=0.0000158*((0.5*(B76+B77)+273)^0.79)
Gap Conductance:	6.21E-01	W/cm2-°C			=B16/B44
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.609	W/cm-°C			=0.907-0.000485*B79
Fuel Conductivity:	0.081	W/cm-°C			=0.5*0.162
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Uranium Wt. Fraction:	0.300	**1.500**	g U		=(1-B29)/2
Plutonium Wt. Fraction:	0.250	**1.250**	g Pu		=B25-B27-B28
Americium Wt. Fraction:	0.030	**0.150**	g Am		
Neptunium Wt. Fraction:	0.020	**0.100**	g Np		
Zirconium Wt. Fraction:	0.400	**2.000**	g Zr		
	---	**0.486**	g Na		=B31*(0.25*PI()*(B53*(B48^2-B50^2)+(B54-B53)*(B48^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.43	g/cm3			
ACT Density:	6.26	g/cm3			=(B25+B26+B27+B28)*B32
ACT Atom Density:	1.57E+22	atoms/cm3			=B33*6.023E+23/240
Am Fraction in ACT:	0.05				=B27/(B25+B26+B27+B28)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D39+2*D42
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D45+2*D43
Hot Capsule OD:	0.9024	cm	0.3553	in.	=D38+(1+B21*0.5*(B75+B76))
Hot Capsule ID:	0.5968	cm	0.2350	in.	=D39*(1+B21*0.5*(B75+B76))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0043	cm	0.0017	in.	=0.5*(D41-D47)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5883	cm	0.2316	in.	=D45*(1+B22*0.5*(B77+B78))
Hot Clad ID:	0.4962	cm	0.1954	in.	=D46*(1+B22*0.5*(B77+B78))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D45-D46)/2
Fuel OD:	0.4003	cm	0.1576	in.	=SQRT(D51*(D46^2))
Fuel Smeared Density:	0.6600		0.6600		
Fuel-Clad Gap:	0.0462	cm	0.0182	in.	=B52/2.54
Fuel Height:	3.8100	cm	1.5000	in.	
Bond Height:	5.0800	cm	2.0000	in.	=D53+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	7.6200	cm	3.0000	in.	=D57-D54-2*D55
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	59.8	°C			='Rodlet 5'!B61
Coolant Exit Temp:	61.3	°C			=B60+B68/(B66*'Coolant Properties'!E6)
Average Coolant Temp:	60.5	°C			=0.5*(B60+B61)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B38^2)/('General Input'!B16+B38)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B38^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B64
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B64*'Coolant Properties'!F6
Surface Heat Flux:	140.0	W/cm2			=pf*B12/(2*PI()*(0.5*B38))
Power to Coolant:	1508.8	W			=pf*B12*B53
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B63/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B69^0.8)*(B70^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B71*'Coolant Properties'!D6/'Rodlet 1'!B63
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	91.0	°C			=B62+pf*B12/(2*PI()*B72*(0.5*B40))
Capsule Inner Temp:	209.5	°C			=B75+pf*B12*LN(B40/B41)/(2*PI()*B15)
Clad Surface Temp:	554.6	°C			=B76+pf*B12/(2*PI()*B17*(0.5*B47))
Clad Inner Temp:	**603.4**	°C			=B77+pf*B12*LN(B47/B48)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	614.5	°C			=0.5*(B78+B80)
Fuel Surface Temp:	625.6	°C			=B78+pf*B12*LN(B48/B50)/(2*PI()*B19)
Fuel Centerline Temp:	**1014.7**	°C			=B80+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	2.000				=(B57-B54-2*B55)/B53
Plenum Volume:	1.453	cm3			=0.25*PI()*(B46^2)*(B57-B54-2*B55)
Fuel Volume:	0.480	cm3			=0.25*PI()*(B50^2)*B53
Burnup:	0.10				
Total Fissions:	7.53E+20	fissions			=B87*B34*B86
Fission Gas Atoms Produced:	1.88E+20	atoms			=0.25*B88
Helium Atoms Produced:	5.65E+19	atoms			=B89*B35*6
Fission Gas Release:	0.80				
Helium Release:	1.00				
Total Gas in Plenum:	3.44E-04	mol			=(B91*B89+B92*B90)/6.023E+23
Plenum Pressure:	**250.1**	psi			=B93*82.056*14.7*(B78+273)/B85

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

SUMMARY RESULTS FOR NITRIDE FUELS WITH LOSS OF BOND SODIUM AT B-O-L

Rodlet	Fuel Type	LHGR (W/cm)	Surface Heat Flux (W/cm^2)	Discharge Burnup (at.%)	Plenum Pressure (psi)	PEAK TEMPERATURES Coolant (°C)	Capsule (°C)	Clad (°C)	Fuel (°C)
1	(Pu0.5,Am0.5)N-36ZrN	129.5	45.8	10.0	357.6	52.7	101.0	291.3	1250.7
2	DUMMY	0.0	0.0	0.0	16.1	52.7	52.7	52.7	52.7
3	(Pu0.5,Am0.5)N-36ZrN	177.4	62.7	10.0	387.3	53.6	119.9	357.8	1560.2
4	(Pu0.5,Am0.5)N-36ZrN	178.5	63.1	10.0	335.4	54.5	121.2	359.9	1618.4
5	(Pu0.5,Am0.25,Np0.25)N-36ZrN	169.8	60.0	10.0	203.3	55.4	118.8	349.3	1541.1
6	(U0.50,Pu0.25,Am0.15,Np0.10)N	247.1	87.4	10.0	393.9	56.7	149.0	445.1	1987.2

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

EXPERIMENT AFC-1Æ

RODLET 1

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	129.5	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.01E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	4.03E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.004	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.081	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.144				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**1.957**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500		**1.957**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360		**2.330**	g ZrN	
	---		**0.476**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966				
Fuel Density:	10.40	g/cm3			
ACT Density:	5.61	g/cm3			
ACT Atom Density:	1.21E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9014	cm	0.3549	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5962	cm	0.2347	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0050	cm	0.0020	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5862	cm	0.2308	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4944	cm	0.1947	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.0	°C			=tinlet
Coolant Exit Temp:	52.7	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	52.3	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	45.8	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	657.6	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	62.3	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	101.0	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	275.3	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**291.3**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	707.3	°C			=0.5*(B79+B81)
Fuel Surface Temp:	1123.3	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1250.7**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	8.76E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	2.19E+20	atoms			=0.25*B89
Helium Atoms Produced:	6.57E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	6.36E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**357.6**	psi			=B94*82.056*14.7*(B79+273)/B86

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

EXPERIMENT AFC-1Æ

RODLET 2

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**None**				
Fuel:	**DUMMY**				
	PHYSICS DATA				
LHGR:	0.0	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	1.53E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	2.70E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.002	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.110	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.000				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.000		**0.000**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.000		**0.000**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000		**0.000**	g ZrN	
	---		**0.000**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	0.00	g/cm3			
ACT Density:	0.00	g/cm3			
ACT Atom Density:	0.00E+00	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.00				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9009	cm	0.3547	in.	=D39*(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5959	cm	0.2346	in.	=D40*(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0057	cm	0.0022	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5846	cm	0.2301	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4931	cm	0.1941	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	0.0000	cm	0.0000	in.	
Bond Height:	0.0000	cm	0.0000	in.	=D54+0.0
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	12.7000	cm	5.0000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.7	°C			='Rodlet 1'!B62
Coolant Exit Temp:	52.7	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	52.7	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	0.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	0.0	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	52.7	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	52.7	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	52.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**52.7**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	52.7	°C			=0.5*(B79+B81)
Fuel Surface Temp:	52.7	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**52.7**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	#DIV/0!				=(B58-B55-2*B56)/B54
Plenum Volume:	2.422	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.000	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.00				
Total Fissions:	0.00E+00	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	0.00E+00	atoms			=0.25*B89
Helium Atoms Produced:	0.00E+00	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	9.90E-05	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**16.1**	psi			=B94*82.056*14.7*(B79+273)/B86

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

EXPERIMENT AFC-1Æ

RODLET 3

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	177.4	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.15E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	4.45E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.004	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.076	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.170				
UN Mole Fraction:	0.000	**0.000**	g U		=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500	**1.896**	g Pu		=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500	**1.896**	g Am		=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000	**0.000**	g Np		=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360	**2.257**	g Zr		
	---	**0.478**	g Na		=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.40	g/cm3			
ACT Density:	5.61	g/cm3			
ACT Atom Density:	1.17E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9015	cm	0.3549	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5963	cm	0.2348	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0048	cm	0.0019	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5866	cm	0.2310	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4948	cm	0.1948	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	52.7	°C			='Rodlet 2'!B62
Coolant Exit Temp:	53.6	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	53.1	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	62.7	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	901.1	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	66.8	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	119.9	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	335.9	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**357.8**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	866.6	°C			=0.5*(B79+B81)
Fuel Surface Temp:	1375.4	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1560.2**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	8.49E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	2.12E+20	atoms			=0.25*B89
Helium Atoms Produced:	6.36E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	6.16E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**387.3**	psi			=B94*82.056*14.7*(B79+273)/B86

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

EXPERIMENT AFC-1Æ

RODLET 4

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.5})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	178.5	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.15E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	4.47E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.004	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.060	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.284				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**3.778**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.500		**3.778**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.000		**0.000**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.360		**2.720**	g Zr	
	---		**0.478**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.40	g/cm3			
ACT Density:	5.61	g/cm3			
ACT Atom Density:	1.01E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.50				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9016	cm	0.3549	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5963	cm	0.2348	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0048	cm	0.0019	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5867	cm	0.2310	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4948	cm	0.1948	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	53.6	°C			='Rodlet 3'!B62
Coolant Exit Temp:	54.5	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	54.1	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	63.1	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	906.8	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	67.8	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	121.2	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	338.0	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**359.9**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	870.6	°C			=0.5*(B79+B81)
Fuel Surface Temp:	1381.2	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1618.4**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	7.32E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	1.83E+20	atoms			=0.25*B89
Helium Atoms Produced:	5.49E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	5.32E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**335.4**	psi			=B94*82.056*14.7*(B79+273)/B86

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

EXPERIMENT AFC-1Æ

RODLET 5

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(Pu_{0.5},Am_{0.25},Np_{0.25})N$-36ZrN**				
	PHYSICS DATA				
LHGR:	169.8	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.13E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	4.40E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.004	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.067	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.234				
UN Mole Fraction:	0.000		**0.000**	g U	=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.500		**3.797**	g Pu	=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.250		**1.898**	g Am	=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.250		**1.898**	g Np	=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000		**0.000**	g ZrN	
	---		**0.478**	g Na	=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	10.45	g/cm3			
ACT Density:	5.66	g/cm3			
ACT Atom Density:	1.09E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.25				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9015	cm	0.3549	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5963	cm	0.2348	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0048	cm	0.0019	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5866	cm	0.2309	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4948	cm	0.1948	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	54.5	°C			='Rodlet 4'!B62
Coolant Exit Temp:	55.4	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	55.0	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	60.0	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	862.6	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	68.1	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	118.8	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	328.4	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**349.3**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	843.8	°C			=0.5*(B79+B81)
Fuel Surface Temp:	1338.3	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1541.1**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	7.90E+20	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	1.98E+20	atoms			=0.25*B89
Helium Atoms Produced:	2.96E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	3.28E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**203.3**	psi			=B94*82.056*14.7*(B79+273)/B86

Nitride Fuels with Loss of Bond Sodium at B-O-L **APPENDIX E**

EXPERIMENT AFC-1Æ

RODLET 6

	MATERIALS				NOTES:
Capsule:	**Steel**				
Gap:	**Helium**				
Clad:	**HT9**				
Bond:	**Sodium**				
Fuel:	**$(U_{0.50},Pu_{0.25},Am_{0.15},Np_{0.10})N$**				
	PHYSICS DATA				
Nominal LHGR:	247.1	W/cm			
	MATERIAL PROPERTIES				
Capsule Conductivity:	0.220	W/cm-°C			
Gap Conductivity:	2.33E-03	W/cm-°C			=0.0000158*((0.5*(B77+B78)+273)^0.79)
Gap Conductance:	5.04E-01	W/cm2-°C			=B16/B45
Clad Conductivity:	0.220	W/cm-°C			
Bond Conductivity:	0.005	W/cm-°C			=0.0000158*((0.5*(B79+B81)+273)^0.79)
Fuel Conductivity:	0.068	W/cm-°C			=EXP(-2.14*B25)*0.11
Capsule Thermal Expan:	1.6180E-05	1/°C			
Clad Thermal Expan:	1.2062E-05	1/°C			
	FUEL PROPERTIES				
Fuel Porosity:	0.226				
UN Mole Fraction:	0.500	**3.776**	g U		=(1-B25)*B33*(1-B30)*B26*B87*(238/252)
PuN Mole Fraction:	0.250	**1.889**	g Pu		=(1-B25)*B33*(1-B30)*B27*B87*(240/254)
AmN Mole Fraction:	0.150	**1.134**	g Am		=(1-B25)*B33*(1-B30)*B28*B87*(241/255)
NpN Mole Fraction:	0.100	**0.755**	g Np		=(1-B25)*B33*(1-B30)*B29*B87*(237/251)
ZrN Wt. Fraction:	0.000	**0.000**	g ZrN		
	---	**0.480**	g Na		=B32*(0.25*PI()*(B54*(B49^2-B51^2)+(B55-B54)*(B49^2)))
Sodium Density:	0.966	g/cm3			
Fuel Density:	14.21	g/cm3			
ACT Density:	13.42	g/cm3			
ACT Atom Density:	2.61E+22	atoms/cm3			=(1-B25)*B34*6.023E+23/240
Am Fraction in ACT:	0.15				=B28/(B26+B27+B28+B29)
	GEOMETRICAL DATA				
Cold Capsule OD:	0.9002	cm	0.3544	in.	=D40+2*D43
Cold Capsule ID:	0.5954	cm	0.2344	in.	=D46+2*D44
Hot Capsule OD:	0.9018	cm	0.3550	in.	=D39+(1+B21*0.5*(B76+B77))
Hot Capsule ID:	0.5965	cm	0.2348	in.	=D40+(1+B21*0.5*(B76+B77))
Cold Capsule Wall Thickness:	0.1524	cm	0.0600	in.	
Cold Capsule-Clad Gap:	0.0056	cm	0.0022	in.	
Hot Capsule-Clad Gap:	0.0046	cm	0.0018	in.	=0.5*(D42-D48)
Cold Clad OD:	0.5842	cm	0.2300	in.	
Cold Clad ID:	0.4928	cm	0.1940	in.	
Hot Clad OD:	0.5872	cm	0.2312	in.	=D46*(1+B22*0.5*(B78+B79))
Hot Clad ID:	0.4953	cm	0.1950	in.	=D47*(1+B22*0.5*(B78+B79))
Cold Clad Wall Thickness:	0.0457	cm	0.0180	in.	=(D46-D47)/2
Fuel OD:	0.4267	cm	0.1680	in.	=SQRT(D52*(D47^2))
Fuel Smeared Density:	0.7500		0.7500		
Fuel-Clad Gap:	0.0330	cm	0.0130	in.	=B53/2.54
Fuel Height:	5.0800	cm	2.0000	in.	
Bond Height:	6.3500	cm	2.5000	in.	=D54+0.5
End Plug Length:	1.2700	cm	0.5000	in.	
Plenum Length:	6.3500	cm	2.5000	in.	=D58-D55-2*D56
Pin Length:	15.2400	cm	6.0000	in.	
	COOLANT CALCULATIONS				
Coolant Entrance Temp:	55.4	°C			='Rodlet 5'!B62
Coolant Exit Temp:	56.7	°C			=B61+B69/(B67*'Coolant Properties'!E6)
Average Coolant Temp:	56.1	°C			=0.5*(B61+B62)
Equivalent Diameter:	0.1920	cm			=('General Input'!B16^2-B39^2)/('General Input'!B16+B39)
Flow Area:	0.3005	cm2			=0.25*PI()*('General Input'!B16^2-B39^2)
Coolant Volumetric Flow Rate:	235.5	cm3/s			=ff*vel*B65
Coolant Mass Flow Rate:	232.5	g/s			=ff*vel*B65*'Coolant Properties'!F6
Surface Heat Flux:	87.4	W/cm2			=pf*B12/(2*PI()*(0.5*B39))
Power to Coolant:	1255.3	W			=pf*B12*B54
Re:	2.81E+04				=ff*vel*'Rodlet 1'!B64/'Coolant Properties'!C6
Pr:	3.42				='Coolant Properties'!G6
Nu:	136.4				=0.023*(B70^0.8)*(B71^0.4)
Film Coefficient:	4.58	W/cm2-°C			=B72*'Coolant Properties'!D6/'Rodlet 1'!B64
	NOMINAL EXPERIMENT TEMPERATURES				
Capsule Surface Temp:	75.1	°C			=B63+pf*B12/(2*PI()*B73*(0.5*B41))
Capsule Inner Temp:	149.0	°C			=B76+pf*B12*LN(B41/B42)/(2*PI()*B15)
Clad Surface Temp:	414.7	°C			=B77+pf*B12/(2*PI()*B17*(0.5*B48))
Clad Inner Temp:	**445.1**	°C			=B78+pf*B12*LN(B48/B49)/(2*PI()*B18)
Avg. Fuel-Clad Gap Temp:	1071.3	°C			=0.5*(B79+B81)
Fuel Surface Temp:	1697.5	°C			=B79+pf*B12*LN(B49/B51)/(2*PI()*B19)
Fuel Centerline Temp:	**1987.2**	°C			=B81+pf*B12/(4*PI()*B20)
	PRESSURE CALCULATIONS				
Plenum-to-Fuel Height Ratio:	1.250				=(B58-B55-2*B56)/B54
Plenum Volume:	1.211	cm3			=0.25*PI()*(B47^2)*(B58-B55-2*B54)
Fuel Volume:	0.727	cm3			=0.25*PI()*(B51^2)*B54
Burnup:	0.10				
Total Fissions:	1.90E+21	fissions			=B88*B35*B87
Fission Gas Atoms Produced:	4.74E+20	atoms			=0.25*B89
Helium Atoms Produced:	4.26E+20	atoms			=B90*B36*6
Fission Gas Release:	0.25				
Helium Release:	0.50				
Total Gas in Plenum:	5.51E-04	mol			=(B92*B90+B93*B91)/6.023E+23
Plenum Pressure:	**393.9**	psi			=B94*82.056*14.7*(B79+273)/B86

AFC-1Æ and 1-F Cladding Creep Calculations **APPENDIX F**

AFC-1Æ and -1F Cladding Creep Calculations

INPUT

Clad I.D.	0.194	in
	0.49276	cm
Clad t	0.018	in
	0.04572	cm
Peak Rod Pressure	505.9	psi

CREEP CORRELATION PARAMETERS

const1	13.4
const2	8.43E-03
const3	4.08E+18
const4	1.60E-06
const5	1.17E+09
const6	8.33E+09
const7	9.53E+21
act1	15027
act2	26451
act3	89167
act4	83142
act5	108276
act6	282700
rgas	1.987

Time		Time-Step		Internal Pressure	Clad Stress	Temp.	THERMAL STRAIN RATE (%/sec)				Total Strain	Cladding O.D.	
(days)	(sec)	(days)	(sec)	(psi)	(MPa)	(K)	Primary	Steady-State	Teriary	Total	(%)	(in)	(cm)
10	864000	10	864000	46.0	0.0	823.0	1.27E-13	2.32E-21	1.59E-73	1.27E-13	1.10E-07	398.5405	1012.2928
20	1728000	10	864000	92.0	0.0	823.0	5.77E-14	9.27E-21	1.30E-69	5.77E-14	1.60E-07	398.5405	1012.2928
30	2592000	10	864000	138.0	0.0	823.0	2.07E-14	2.09E-20	2.53E-67	2.07E-14	1.78E-07	398.5405	1012.2928
40	3456000	10	864000	184.0	0.0	823.0	6.71E-15	3.71E-20	1.06E-65	6.71E-15	1.84E-07	398.5405	1012.2928
50	4320000	10	864000	230.0	0.0	823.0	2.06E-15	5.80E-20	1.93E-64	2.06E-15	1.85E-07	398.5405	1012.2928
60	5184000	10	864000	275.9	0.0	823.0	6.11E-16	8.35E-20	2.07E-63	6.11E-16	1.86E-07	398.5405	1012.2928
70	6048000	10	864000	321.9	0.0	823.0	1.77E-16	1.14E-19	1.54E-62	1.77E-16	1.86E-07	398.5405	1012.2928
80	6912000	10	864000	367.9	0.0	823.0	5.01E-17	1.48E-19	8.71E-62	5.03E-17	1.86E-07	398.5405	1012.2928
90	7776000	10	864000	413.9	0.0	823.0	1.40E-17	1.88E-19	4.03E-61	1.42E-17	1.86E-07	398.5405	1012.2928
100	8640000	10	864000	459.9	0.0	823.0	3.88E-18	2.32E-19	1.59E-60	4.12E-18	1.86E-07	398.5405	1012.2928
110	9504000	10	864000	505.9	0.0	823.0	1.07E-18	2.81E-19	5.47E-60	1.35E-18	1.86E-07	398.5405	1012.2928