Development of a Low Enrichment Uranium Core for the MIT Reactor

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Submitted to the Department of Nuclear Science and Engineering in partial fulfillment of the requirements for the degree of

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Abstract

An investigation has been made into converting the MIT research reactor from using high enrichment uranium (HEU) to low enrichment uranium (LEU) with a newly developed fuel material. The LEU fuel introduces negative reactivity due to absorptions in ^{238}U, which need to be compensated by higher initial content of ^{235}U. Given that the new fuel density is much higher than the HEU density fuel, it is possible to obtain the necessary ^{235}U content in the same core volume. A design of the MIT Nuclear Reactor is made using high density monolithic uranium-molybdenum fuel in an attempt to eliminate the reductions in neutron flux available to experiments due to the conversion to LEU fuel, as well as increasing the flexibility for meeting the needs of in-core experiments. The optimum configuration of fuel plates was made by varying the plate number and thicknesses and using a full-core model of the MITR for the Monte-Carlo transport code MCNP to determine the effect on flux and reactivity. In addition, the use of different moderator and fuel dummy materials as well as fixed absorbers was evaluated to optimize the neutron fluxes, reactivity and neutron spectrum available for experiments. The optimum reactor design consisted of the use of half-sized fuel elements made up of nine U-7Mo LEU fuel plates of 0.55 mm thickness with 0.25 mm finned aluminum cladding. This design also utilized solid beryllium dummies with boron fixed absorbers or solid lead dummies, depending on the in-core experiment flux and spectrum needs.

Using MCODE, which links MCNP and the point depletion code ORIGEN, it was determined that the refueling interval of the LEU core would be about twice as long as the HEU core at the current power level of 5 MW. Thermal-hydraulic calculations using the multi-channel thermal-hydraulics analysis code MULCH-II indicated that the peak power channel will remain below the Onset of Nucleate Boiling under all normal operating conditions as well as loss of flow conditions. In addition, using MCNP and the thermal-hydraulics/point kinetics code PARET it was shown that all reactivity coefficients were negative and that the LEU core could withstand a step reactivity insertion of $3.69 without reaching cladding softening temperature, thus increasing the allowable reactivity for an in-core experiment. Finally, it is possible to use the proposed design to increase the neutron flux by increasing core power, but with a correspondingly reduced refueling cycle length.

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Chapter 1
Introduction

1.1 Objective

To avert the presence of weapons grade materials in civilian life, there is an effort to reduce the use of highly enriched uranium (HEU) in research reactors. It is envisaged that all research reactors worldwide will eventually use low-enriched uranium (LEU) fuel. However, of equal importance is to assure that the scientific usefulness of these reactors is not diminished through the use of LEU fuel. It is the objective of this thesis to develop a design of an LEU core for the MIT Nuclear Reactor and to optimize this design to deliver as high a neutron flux as possible to experimental facilities. In addition, the core configuration and design will be made to meet other in-core experimental needs such as neutron spectrum, reactivity, and physical size.

1.2 Reduced Enrichment for Research Reactors

In order to possibly limit the amount of weapons-grade uranium in the civilian world, interest in using low enriched uranium (LEU) in research reactors has been present for several decades. LEU has been defined as having less than 20% enrichment, which was seen to be a compromise between reducing the amount of ^{235}U available in fresh fuel and limiting the production of ^{239}Pu in spent fuel. Perhaps more importantly, such an enrichment makes the uranium less amenable to being used for weapons.

However, the use of LEU fuel does have its drawbacks. In addition to possible losses of useful neutron fluxes, the presence of large amounts of ^{238}U in the fuel creates more actinides than HEU fuel, in particular ^{239}Pu. Preliminary studies of high density LEU fuel in the MIT reactor, as discussed below, show that a spent fuel element will contain about an order of magnitude more ^{239}Pu and other higher actinides than the current HEU fuel. Since these higher actinides have very long half-lives as well as significant heat generation and chemical and radiological toxicity, this will make long term disposal more difficult, as well as lead to its own proliferation concerns if the ^{239}Pu is separated. The presence of fission products is not significantly different between LEU and HEU fuel, provided the same numbers of fissions is achieved in each. Despite these problems in using LEU fuels, current concerns about terrorists building an HEU weapon have promoted increased attention to LEU fuels.

As part of the Atoms for Peace program begun by the Eisenhower administration in the 1950s, many research reactors of varying power levels were built worldwide. Because of the small physical size of the reactor cores, many of these were built using HEU fuel.

In the 1970s, the Carter administration began a push in its nonproliferation policy to minimize the use of HEU in civilian nuclear programs worldwide. This included a policy of conversion of reactors from HEU to LEU fuel, which culminated in establishing the Reduced Enrichment for Research and Test Reactors (RERTR) Program in 1978, which was established to "develop the technical means to convert the reactors and isotope production processes from the use of HEU to the use of low enriched uranium through the development of new LEU fuels and targets." [1.1] The RERTR program accomplishes this by assisting in the safety analyses of reactors to be converted, by developing LEU fuels and targets for isotope production, and by assisting fuels suppliers to develop and market LEU fuels. The LEU fuels currently under development include high density dispersion and monolithic fuels which may be used for the higher-powered (i.e. multi-megawatt) reactors.

Out of 275 research reactors worldwide, there are a total of sixty-six reactors which currently use HEU fuel. While it can be argued that U.S. reactors are more secure from theft of nuclear material than many reactors in other countries, the U.S. Department of Energy has made it a goal to convert all U.S. reactors by 2014. It is doubtful that this date can be achieved, particularly for the higher power reactors (above 2 MW), since high density fuel must be developed and qualified for use to a higher burnup. Additionally, the safety of this fuel must be assured for each reactor and the reactor then licensed to use the new fuel.

Regardless of the date, conversion of all U.S. reactors will allow the U.S. government to put more pressure on other countries to convert their reactors. However, care must be taken not to compromise the scientific usefulness of reactors due to reduction of the neutron flux due to converting these reactors to LEU fuel. Unfortunately, this is not always a primary goal in government sponsored conversion studies.

Further pressure on foreign reactors to convert to LEU was brought about in 1992 through the Schumer Amendment to the U.S. Atomic Energy Act. This limits export of HEU fuel to all reactors unless no LEU fuel is available and a commitment is made to convert as soon as a suitable fuel material is available. In addition, it committed the U.S. RERTR program to develop high density fuels for this purpose.

In 2002, the U.S. and Russia announced a joint program aimed at accelerated development of LEU fuels for conversion of both U.S. and Russian supplied reactors worldwide. This will allow up to 19 additional reactors supplied by the former Soviet Union to convert to LEU.

The RERTR program was placed under the National Nuclear Security Administration in 2004 as part of the Global Threat Reduction Initiative (GTRI) [1.2] in an attempt to better coordinate several nonproliferation programs together under GTRI. It remains to be seen as to whether this will increase the effectiveness of the RERTR program.

Given the current technology of fuel available for use, the U.S. Government Accountability Office [1.3] estimates that about 90% of the reactors supplied by U.S. HEU fuel can be converted to LEU fuel. The remaining 10%, including the MIT Reactor, generally have cores that are of higher power density and have been optimized for high neutron flux delivery to experiments. As of 2005, 39 research reactors in 22 countries have converted to LEU fuel through the work of the RERTR program.

1.3 Reactors for conversion

In 1986, the U.S. Nuclear Regulatory Commission established regulations that require all research reactors to convert to LEU fuel once a suitable fuel is available unless specifically exempted. [1.4] As a result of this, and under the auspices of the RERTR program, a total of eleven U.S. reactors have thus far converted, a number larger than any other nation. A list of these reactors (all at universities) is shown in Table 1.1. It should be noted that half of these reactors have low power levels. The table also shows the decaying state of the U.S. reactor community, since over half of these eleven reactors have been shut down since their conversion.

Of the eleven reactors thus far converted, the Ohio State reactor [1.5] underwent a power increase and the Rhode Island reactor underwent a core redesign [1.6]. The Georgia Tech reactor never operated using LEU fuel, being shut down by its administration prior to fuel receipt. Although the reactor designs and methods of analysis for reactors undergoing conversion have varied widely, the predicted reactor parameters such as flux and reactivity have generally matched those measured after conversion. [1.5-1.9].

In addition to those that have converted, eight U.S. reactors are scheduled to be converted using currently developed LEU fuels. They are listed in Table 1.2.

Table 1.1 U.S. Research Reactors that have converted to LEU [1.3]

Facility	Power level (MW)	Year completed [1.10]
Univ. of Michigan*	2	1984
Ohio State University	0.5	1988
Rensselaer Polytechnic Institute*	critical	1988
Worcester Polytechnic Institute	0.010	1988
Manhattan College*	critical	1990
Iowa State University*	0.010	1991
Univ. of Missouri at Rolla	0.2	1992
Rhode Island Nuclear Science Center	2	1993
University of Virginia*	2	1994
Georgia Institute of Technology*	5	1996
Univ. of Massachusetts at Lowell	1	2000

* shut down before October 2005

Table 1.2 U.S. Research Reactors in the process of conversion to LEU [1.3]

Facility	Power Level (MW)	Year Scheduled [1.3,1.10]
Purdue University	0.001	2006
Texas A & M University	1	2006
University of Florida	0.1	2006
Oregon State University	1.1	2008
DOE NRAD reactor	0.25	2010
Univ. of Wisconsin [5]	1	2012
Washington State University	1	2014
General Electric NTR reactor	0.1	TBD

1.4 Reactors to be converted

There are six HEU-fueled U.S. reactors that have cores which have been optimized for delivery of neutrons to experimental facilities and because of the small core design and high power density, are unable to use currently qualified LEU fuels. They are listed in Table 1.3. Only two of these, the MIT reactor and the University of Missouri reactor are operated by universities. The other four are operated by the U.S. government, the NIST reactor being operated by the U.S. Department of Commerce, and the HFIR and ATR reactors being operated by the U.S. Department of Energy within the national lab structure at Oak Ridge National Laboratory and Idaho National Laboratory, respectively.

Table 1.3 U.S. Research Reactors currently using HEU fuel and needing high density LEU fuel to convert

Facility	Power Level (MW)	Primary use
Massachusetts Institute of Technology	5	In-core loops, BNCT
University of Missouri at Columbia	10	Isotope production
National Institute of Standards and Technology	20	Neutron scattering
High Flux Isotope Reactor (ORNL)	100*	Neutron scattering, isotope production
Advanced Test Reactor (INL)	250	In-core materials testing
ATRC (INL)	critical	ATR simulations

*Currently limited to 85 MW

1.5 Worldwide Reactors

In addition to the U.S. reactors, there are fifty-two reactors worldwide that currently use HEU fuel. Of these, there are 27 reactors that use HEU and are either planning conversion using currently qualified fuels, or are not planning conversion because of monetary or other policy reasons. It should be noted that of these, twenty use HEU fuel supplied by the United States and the other seven use HEU supplied by Russia. The remaining twenty-five worldwide reactors using HEU fuel, listed in Table 1.4, are of sufficient power density to require high density LEU fuel.

Table 1.4 Foreign Research Reactors currently using HEU fuel and needing high density LEU fuel to convert [1.3]

Country	Facility	Power Level (MW)
Belgium	BR-2	100
Czech Republic	LWR-15 (Rez)	10
	VR-1	0.005
France	ORPHEE	14
	RHF	58.3
Germany	FRM-II	20
Kazakhstan	VVR-K	10
	VVR-K critical facility	6
North Korea	IRT-DPRK	8
Poland	MARIA	30
Russia	IRT-ME Ph. Inst.	2.5
	IR-8	8
	IRT-T	6
	VVR-TS	15
	VVR-M	18
	IVV-2M	15
	MIR-M1	100
	CA.MIR-M1	critical
	SM-3	100
	CA.SM-3	critical
	RBT-6	6
	RBT-10/2	7
	PIK	critical
	PIK Physical Model	critical
Uzbekistan	VVR-CM	10

1.6 LEU fuels

A number of lower density LEU fuels have been qualified by the RERTR program. All of the reactors listed in Tables 1.1 and 1.2 have used these fuels. They include UAlx-Al fuel (uranium density of 2.3 g/cm^3), U_3O_8-Al fuel (up to 3.2 gU/cm^3), and $UZrH_x$ fuel (up to 3.7 gU/cm^3). [1.1]

Higher density U_3Si_2-Al dispersion fuel with a uranium density of up to 4.8 g/cm^3 has been developed and qualified for use in U.S. reactors and others around the world. [1.11] Even higher densities (up to 6.0 g/cm^3) are under development by CERCA in France and undergoing irradiation testing at the SILOE reactor. However, because of fuel swelling issues, densities beyond 6.0 g/cm^3 do not appear feasible using silicide fuels. Also, the use of silicide fuels requires significantly more work in reprocessing, since the silicon has very low solubility in concentrated nitric acid solutions, unlike other cladding and dispersion materials such as aluminum. [1.12] This reprocessing issue has lead fuel development efforts away from silicide. [1.13]

U_3Si-Al fuels with uranium densities above 6 g/cm^3 are under study by ANL and CNEA in Argentina. However, irradiation tests have shown that this fuel becomes amorphous under irradiation conditions, which makes further development unlikely. [1.1]

Densities high enough to enable higher powered reactors to convert to LEU appear possible using U-Mo fuels. These fuels can be either alloyed with dispersion agents such as aluminum or in a monolithic form with molybdenum weight percentages of 4 to 10 percent.

1.7 U-Mo fuels

U-Mo alloys are currently the fuels of interest to the RERTR program.[1.14] Dispersion fuels using an aluminum matrix with a uranium density of 6 to 8 g/cm^3 have undergone irradiation tests over the past several years. These tests have shown that swelling occurs with higher burnup due to interdiffusion between the U-Mo and the aluminum matrix [1.15]. Studies have indicated that an addition of a small amount of silicon to the matrix may inhibit the swelling phenomenon.

U-Mo fuels using monolithic foil, with a possible uranium density of up to 17.4 g/cm^3, thus far show the greatest promise for possible use in the world's remaining reactors. Other than high densities, the monolithic fuel has a much smaller surface area than dispersion fuels, leading to greater contact with cladding. This results in significantly less interdiffusion reactions and thermal insulation due to fuel-cladding gaps. As a result, the fuel will remain cooler for a given heat flux. In addition, this smaller surface area will allow thinner cladding to be used, resulting in further cooling and reduction of neutron absorption in the cladding. The cladding in a monolithic plate type fuel can be as thin as 0.25 mm, compared with the 0.38 mm cladding typically used in reactors, including the MITR-II.

The properties of U-Mo fuel, as compared with the UAl_x fuel currently used in the MIT Reactor, are listed in Table 1.5. Although the melting point and conductivity of U-Mo fuel are lower than that of UAl_x fuel, these are not seen as significant barriers to its use, since the fuel plates are thin, allowing a small temperature gradient and since the limiting condition is that of the softening point of the aluminum cladding, 450 °C. Although burnup is dependent on the temperature at which the fuel is operated, it is estimated that allowable fission product buildup will be about the same between UAl_x and U- Mo fuels. Calculation methods for these properties are listed in Appendix A.

Table 1.5 UAl_x and U-Mo Fuel Properties

Property	**UAl_x**	**U-Mo**
Melting point °C	1400	~1200
Unirradiated conductivity (W/m K)	42.5	17.6
Irradiated conductivity*	42.1	17.4
Allowable burnup (fissions/cm^3)	2 x 10^{21}	3 x 10^{21} (estimated)
Density (g/cm^3)	3.7	Up to 17.3

*Evaluated at 10^{21} n/cm^2. See Appendix A.

One issue in the manufacturing and use of monolithic fuel is the ability to bond the fuel foil to the cladding, since conventional roll-bonding will result in tearing of the fuel foil. A variety of options have been studied, with the most promising being a technique called friction stir welding which uses a small diameter pin with a milling machine to plastically deform the material, forming a weld bead. [1.16]

In order to qualify fuels for use, the RERTR program must supply all of the information to a regulatory authority (NRC in the U.S.) required to approve its use. [1.17] This includes thermal and material technical data, small scale and large scale irradiation testing and measurements, as well as qualification of fuel fabricators and fabrication processes [1.18]. It is also necessary to consider reprocessing parameters for the fuel. Once the fuel is qualified for use, a reactor must apply to the licensing authority to use the fuel in its facility. This will include further safety analyses specific to the reactor.

Since the U.S. Department of Energy has set a goal to convert U.S. reactors by 2014, high density dispersion and monolithic fuels are targeted to be qualified by 2010. It remains to be seen whether either of these ambitious goals can be met.

1.8 The MIT Reactor

The MIT Reactor has been in operation providing neutrons for research since 1958. The original reactor (MITR-I) was a D_2O moderated and cooled reactor using HEU aluminide fuel. After a reevaluation of needs and further core optimization studies, the current reactor design (MITR-II) was built and began operation in 1975.

1.8.1 Reactor Description

The MITR-II contains a hexagonal core that uses rhomboid-shaped fuel elements in up to twenty-seven positions, as shown in Figure 1.1. In the HEU core, three of the positions typically contain solid aluminum dummy elements to prevent power peaking and provide space for irradiation facilities. Two of these dummy elements are in the central A ring, where the fast flux is highest. Because of power peaking concerns, no more than one fuel element at a time can be used in the A-ring.

Each HEU fuel element, shown in Figure 1.2, contains fifteen aluminum-clad fuel plates using 93% enriched uranium in an aluminide cermet matrix with a fuel thickness of 0.76 mm (0.030 in.) and a length of 610mm (24 inches). The fuel plates, shown in Figure 1.2, have 0. 38 mm cladding with 0.25 mm x 0.25 mm (0.1 in. x 0.1 in) fins to increase heat transfer to the coolant. Coolant channels between the plates are 4.0 mm thick, with light water coolant allowing adequate cooling and moderation. This geometry results in the core being significantly undermoderated, both for safety and to maintain a harder neutron spectrum in-core for experiments.

The fuel originally used in the MITR-II had a fuel density of 3.4 g/cm^3, with a total loading of 445 g ^{235}U in each fuel element. Higher density fuel (3.7 g/cm^3) was used in cores after 1990 with a total fuel loading of 506 g ^{235}U per element.

The core is surrounded by a D_2O reflector. Boron-stainless steel control blades are present at the periphery of the core at each side of the hexagon. In addition, fixed absorbers of cadmium were originally installed in the upper twelve inches of the core in the "spider", a hexagonal space between the inner and second fuel rings as well as three radial arms extending to the edge of the core. The absorbers were installed to increase the neutron flux below the core at the tips of the reentrant thimbles to provide a boost to the neutron scattering research using the beam ports. These absorbers were removed after the first configuration because of swelling concerns. Fixed absorbers of boron-impregnated stainless steel were later installed in only the radial arms. The boron in these absorbers was allowed to gradually burn up in place since the thrust of research work became more focused on in-core materials irradiations. This resulted in less of an axial flux gradient and a greater excess reactivity, which are both beneficial for in-core irradiations.

Several reentrant thimbles are installed inside the D_2O reflector, allowing a larger neutron flux to be delivered to the beam ports outside the core region. Beyond the D_2O reflector, a secondary reflector of graphite exists in which several horizontal and vertical facilities are present for thermal neutron irradiation facilities. A thermal neutron beam for use in Boron Neutron Capture Therapy (BNCT) research is installed below the core. In addition, the MITR Fission Converter Facility is installed outside the D_2O reflector.

This facility contains ten or eleven partially spent MITR fuel elements for a delivery of a beam of primarily epithermal neutrons to the medical facility for use in BNCT therapy and research. Figure 1.3 shows a view of the reactor and reflector regions.

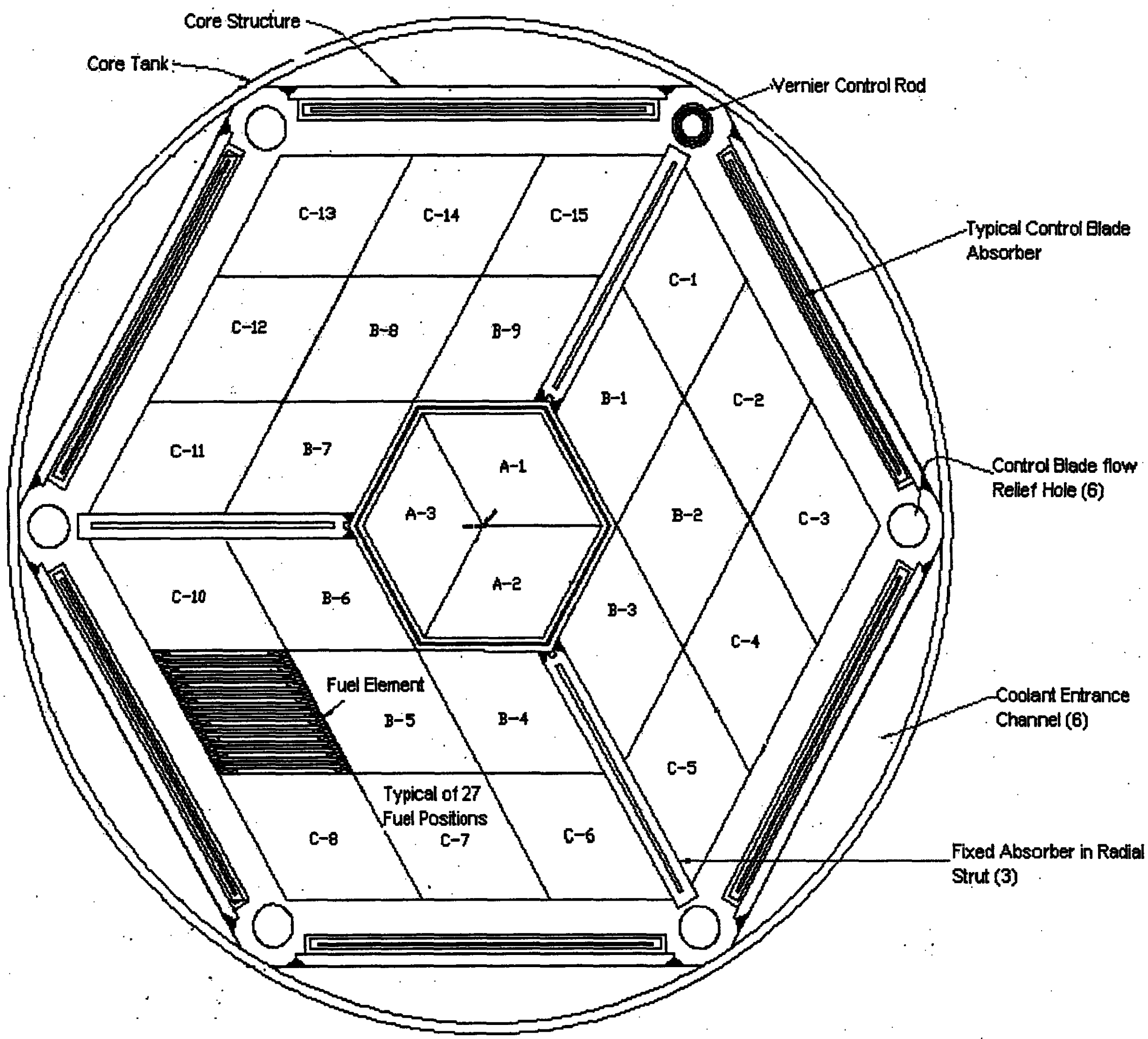

Figure 1.1. Plan view of the MITR-II core.

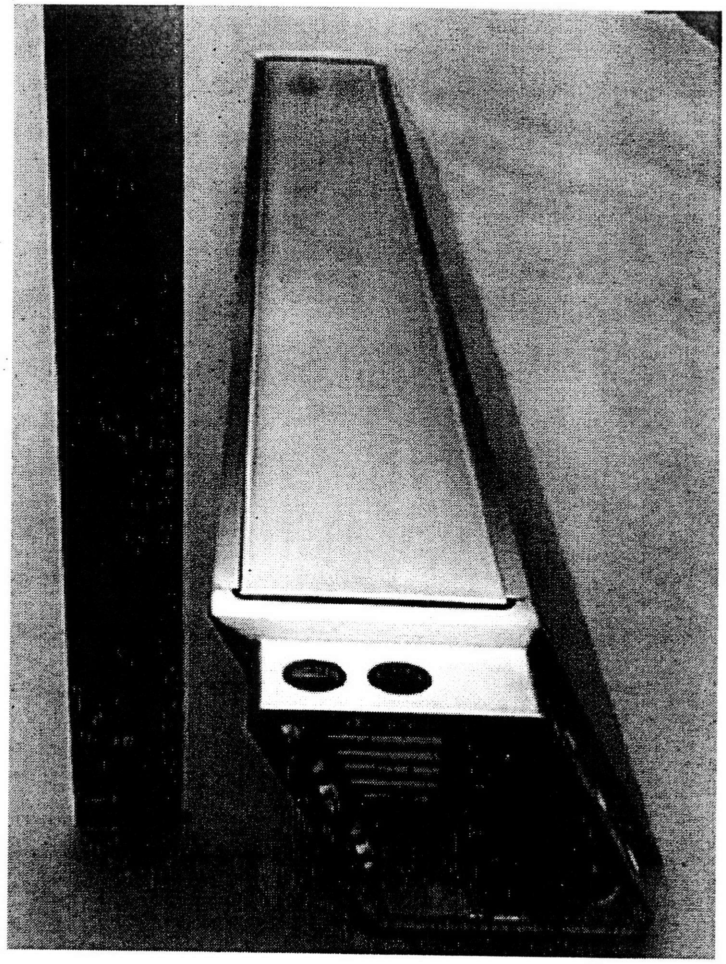

Figure 1.2 Photograph of MITR-II fuel element

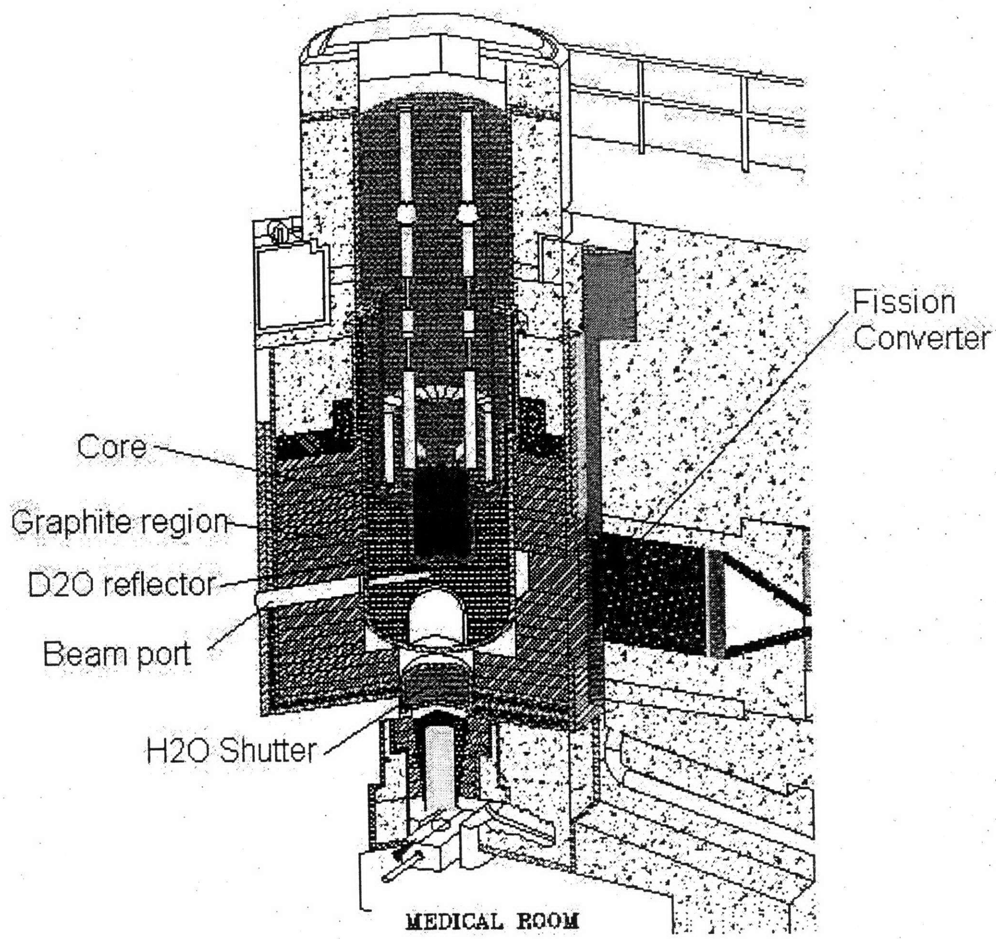

Figure 1.3 Isometric view of the MIT Reactor

1.9 MITR Enrichment Studies

Many reactors have had studies performed on the use of lower enrichment fuel in their reactors. For the MITR-II, only one study has been done to date. Gehret [1.19] analyzed the possibility of using lower enrichment fuel and its effect on thermal-hydraulic safety parameters. He concluded that using silicide LEU, the minimum uranium density possible for use in the MITR-II would be 8.6 g/cm^3, well beyond that approved for use currently.

With the advent of new fuel technology allowing higher density dispersion and monolithic fuels as discussed above, it will be possible to use lower enriched uranium in the MITR-II. U.S. plans are to only enrich fuels to slightly below 20%. Preliminary analyses using MCNP show that a minimum density of 14 g/cm^3 will be needed to operate the MITR-II under similar fuel cycle and reactivity limits with 20% enriched uranium. Given that U-Mo dispersion fuels will be developed to less than 10 g/cm^3, it is clear that monolithic U-Mo fuel will be the only option for use of LEU fuel in the MITR-II. However, once again, care must be taken to avoid a negative impact on experimental programs through loss of neutron fluxes in using LEU fuel. Thus, the LEU fuel and core must be further optimized for experimental neutron flux. A discussion of fuel studies and the constraints seen in fuel use is given in Chapter 3.

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Chapter 2
Modeling and Benchmarking

2.1 Neutronic Modeling of the MITR-II

Since the initiation of the design of the MITR-II, A number of neutronic models have been utilized for design studies, fuel management, and experimental design. Addae[2.1] initially modeled the MITR-II for physics design studies using EXTERMINATOR-II and PDQ-7 diffusion theory codes. These models, including the HARMONY depletion option of PDQ, were later used in a three group energy structure by Kadak [2.2] to develop a fuel management strategy. In addition, Dooley, Pilat, and Lanning used PDQ and HARMONY to evaluate flux synthesis techniques at the MITR. [2.3]

Because of fundamental changes in the MITR-II experimental programs, namely the emphasis on in-core irradiation facilities as opposed to beam port use for neutron scattering, it was decided to revamp the fuel management strategy and calculational methods. Bernard [2.4] developed a burnup and fuel management program using the finite difference diffusion code CITATION. This code was also benchmarked using flux and reactivity data by Allen [2.5] and Meagher [2.6]. The CITATION model remains in use for routine fuel management calculations.

Other codes developed for the MITR-II include the nodal analysis code SIMULATE, analyzed by Luniewski [2.7], and the diffusion code VENTURE-PC [2.8], among others. These latter codes have found only limited applicability for use at the MITR-II.

In this chapter, the ability of the MCNP model to predict the performance of the MITR-II will first be benchmarked. The depletion prediction of MCODE (MCNP coupled with ORIGEN) will then be checked against the MITR-II HEU cores. Although these models will be used in designing an LEU core for the MIT Reactor, benchmarking of LEU data, in particular for depletion calculations for ^{238}U and ^{239}Pu, is not possible given the lack of experimental data for LEU in the MITR.

2.2 MCNP Model

A model of the MITR-II using the Monte-Carlo transport code MCNP [2.9] was first made by Redmond, Yanch and Harling[2.10]. This model was established using core configuration number 2 as well as three separate depleted cores (core numbers 97E, 103, and 107B) using fuel data generated by the diffusion theory code CITATION using three energy groups (0 to 0.4 eV, 0.4 eV to 3 keV, and 3 keV to 10 MeV). These models were validated against measured values of K_{eff} and fast neutron flux in two in-core experimental facilities. Other than K_{eff}, no reactivity measurements were used to compare with calculations. Further validation of MITR-II models are described below.

In this and subsequent MITR-II models, each fuel plate was modeled discretely according to fuel specifications. However, differences in tolerances in manufacturing, such as the tapering of the ends of the fuel meat, are not modeled. All of the relevant reactor structures out to the outer edge of the graphite reflector are modeled explicitly. Except for temperature transient analyses, all cross-sections are evaluated at 300 K (using ENDF/B-V library .50c), since most reactor systems operate between 20 °C and 50 °C.

Two core configurations were chosen for further validation studies. Core configuration number one, shown in Figure 2.1, had new HEU fuel and used three solid aluminum dummies as well as a cadmium fixed absorber spider. This core was operated intermittently at low power for several months between November of 1975 and March of 1976, and consequently had a burnup of less than 2.5 MWd/kg. Core number two, shown in Figure 2.2, used five solid aluminum dummies with no fixed absorbers in-core, and operated at half power (2.5 MW) for several months in 1976.

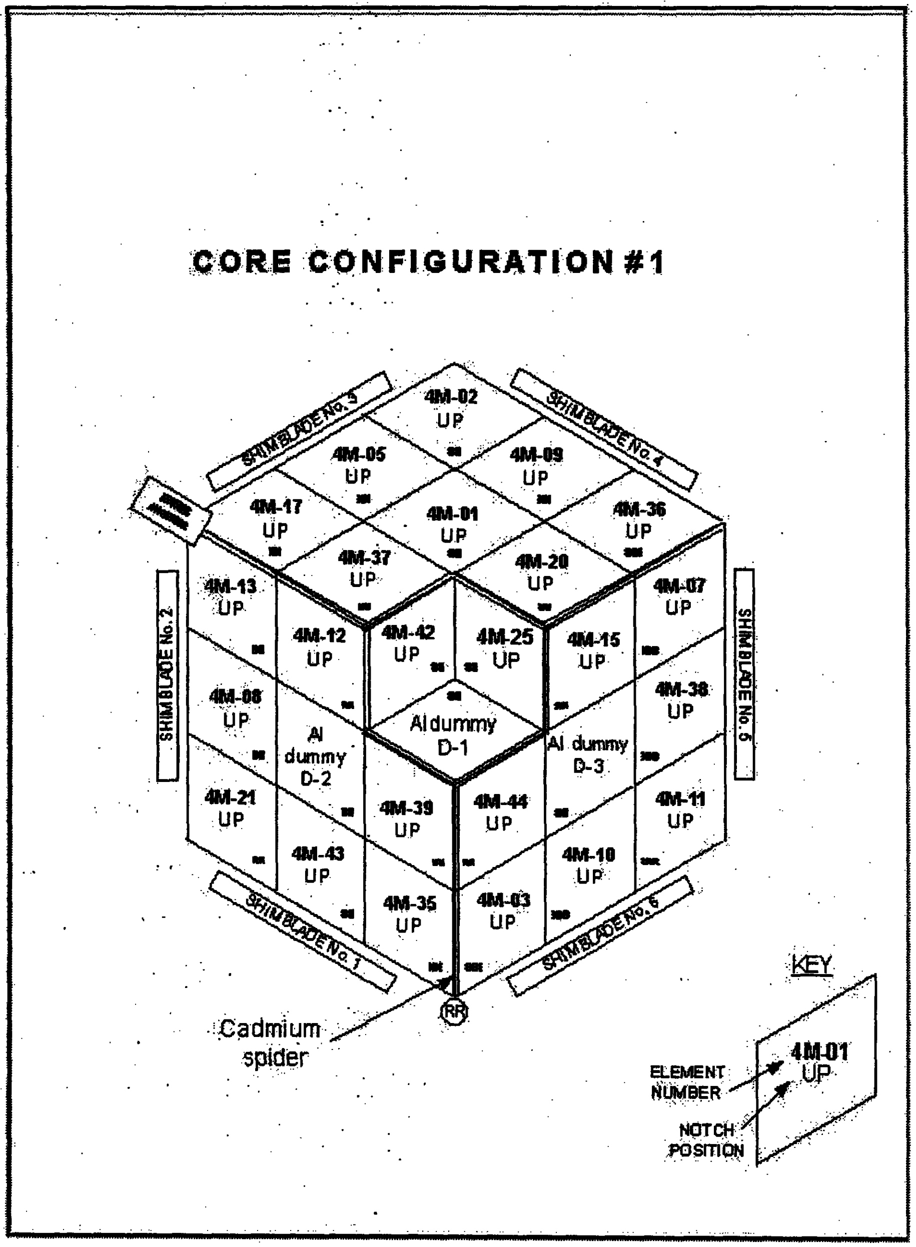

Figure 2.1 Core configuration number 1.

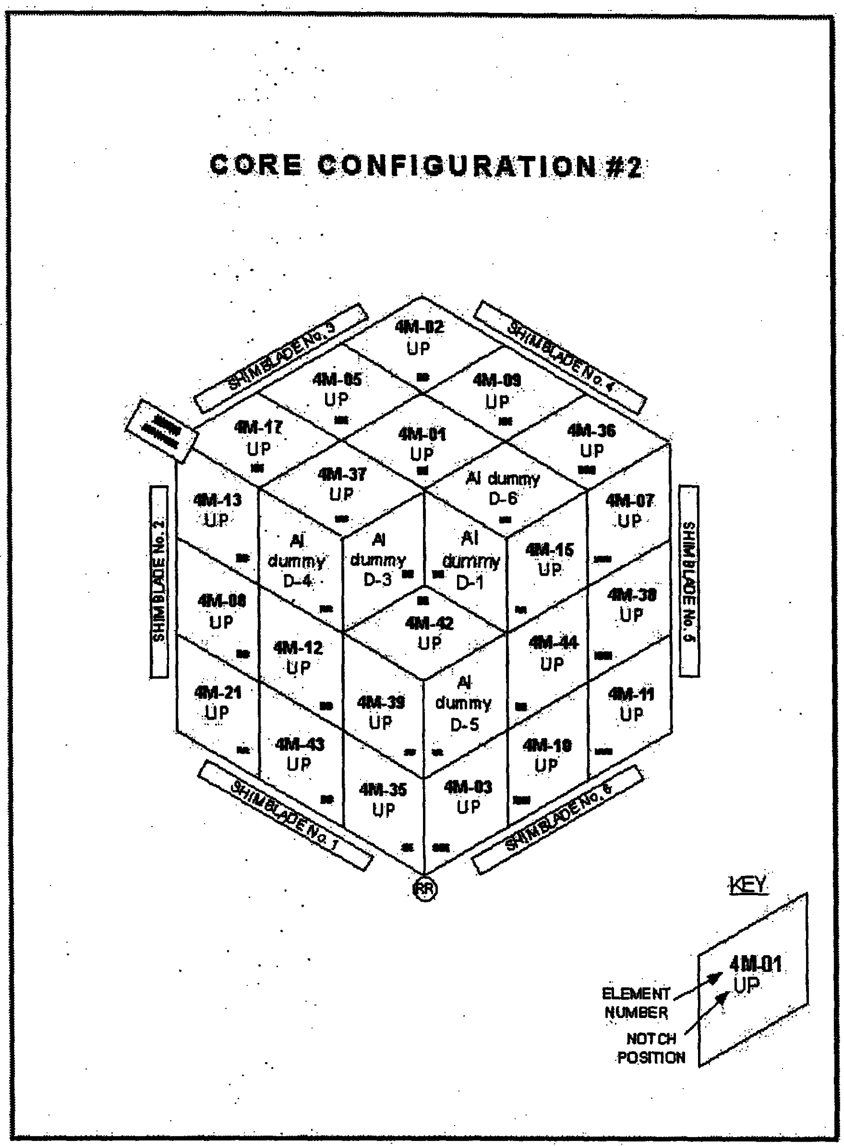

Figure 2.2 Core configuration number 2.

2.3 MCODE Model

For burnup calculations, the MCNP model was used with the MCNP-ORIGEN linkage code MCODE, developed by Xu, *et al.* [2.11]. Unlike other coupling codes, MCODE uses a predictor-corrector approach to burnup depletion, as opposed to single time step evaluations as in MONTEBURNS [2.12] or MOCUP [2.13]. In the initial version, unlike other predictor-corrector algorithms, MCODE performed flux calculations for both the predictor and corrector calculations. This resulted in increased accuracy and allowed greater time steps to be taken. The disadvantage of this is that each time step required two MCNP runs, essentially doubling the calculation time. A later version of MCODE eliminated the need for two MCNP runs.

Because of the limitation on the number of points able to be tallied in MCNP (99), each individual plate could not be discretely depleted by the use of MCODE. In addition, since the orientation of each fuel element in the reactor required separate transformations in the MCNP model, similar plates in separate elements could not be grouped for use in MCODE. Instead, each of the twenty-two fuel elements was initially modeled so that all fifteen plates in an element were assumed to have identical material compositions. A single axial zone was used for each plate. Separate MCODE runs were made for individual plates in a C-ring element (which has the highest radial and axial flux gradients) and across ten axial zones to determine the effect on depletion. These runs indicated that the fluxes and absorption and fission cross-sections for a depleted core varied radially by about 15% and axially by almost a factor of two. However, the fuel element average of these were within 1% of the MCODE values as modeled in single fuel elements, as above. Thus, in overall core calculations such as reactivity values, the MCODE model should give an adequate representation. It should not, however, be used for flux validations or fuel management in depleted cores.

MCODE allows the user to choose the isotopes are to be used in MCNP for cross-section and reaction rate generation. The remainder will be left for ORIGEN to calculate and would presumably be chosen to be the less reactive isotopes. The materials specified in the MCNP model included forty of the most reactive fission product isotopes and seventeen actinide isotopes, shown in Table 2.1. The remaining 520 fission product isotopes were generated using the ORIGEN libraries. The actinide isotopes generated by ORIGEN are also shown in Table 2.1. The K_{eff} results of MCODE are generated from the MCNP output.

MCNP uncertainties come from the stochastic nature of the calculation. Even though with fresh fuel, precise information about the core composition can be assumed, the statistical variations from calculating the reaction rates as well as any burnup variation within a fuel element will be propagated into deterministic burnup calculations, in this case via MCODE into ORIGEN. However, Takeda, *et al* [2.14] determined that MCNP uncertainties from statistical variations tend to cancel each other as burnup increases, particularly for a large number of neutron histories. One possible reason might be that these statistical uncertainties are almost independent at different burnup points. As observed in practice, the burnup curve oscillates; and the magnitude of this oscillation implies the goodness of the MCNP reaction rates. In this calculation, the relative error (defined as one standard deviation divided by the average value) of ^{235}U fission reaction rate is typically less than 0.001. The k_{eff} oscillation is almost not visible.

Table 2.1 Isotopes used by MCNP and ORIGEN

MCNP Fission Products				MCNP Actinides		ORIGEN Actinides
Kr-83	Pd-105	Cs-135	Sm-147	Th-232	Np-237	Th-230
Zr-91	Pd-107	La-139	Sm-149	Pa-231	Np-238	U-237
Zr-93	Ag-109	Pr-141	Sm-150	Pa-233	Np-239	U-239
Mo-95	In-113	Nd-143	Sm-151	U-232	Pu-238	Np-240
Mo-97	I-129	Nd-144	Sm-152	U-233	Pu-239	Am-241
Mo-98	Xe-131	Nd-145	Eu-151	U-234	Pu-240	
Tc-99	Xe-133	Nd-148	Eu-153	U-235	Pu-241	
Ru-101	Xe-135	Pm-147	Eu-154	U-236	Pu-242	
Rh-103	Cs-133	Pm-148	Eu-155	U-238		
Rh-105	Cs-134	Pm-149	Gd-157			

2.4 Validation Methods and Results

2.4.1 Flux profiles

In order to validate the MCNP model for flux, the copper wire axial flux profile measurements made by Allen, *et al* [2.15] for core configuration number 1 were compared with MCNP thermal flux tallies at each of the measured positions. Four in-core positions were chosen at accessible locations between plates in elements in the A and C rings. Coolant channel number 2 (out of 15) was used in both the A2 location and the C8 location. Channel number 10 was used for the C8 location and channel number 11 used for A2. In addition, three water holes at the corners of the core (hole nos. 2, 4 and 5) were chosen by Allen for flux evaluation. These locations are shown in Figure 2.3. Although Redmond, *et al* [2.10] chose to further benchmark the model using flux measurements from depleted cores as listed above, it was felt that reliance on CITATION depletion values, particularly through over a hundred core changes, caused an additional source of error in flux validation.

For validation of core configuration No. 2, the fuel elements reused for core two were assumed to have the same material concentrations as in core configuration No. 1. This is reasonable since the burnup of core configuration No. 1 was so low (less than 2.5 MWd/kg). In addition, core configuration No. 2 had a relatively large operating period (eight months) over which reactivity data, including blade worth measurements, was taken. Unfortunately, no flux measurements were taken for core configuration No. 2.

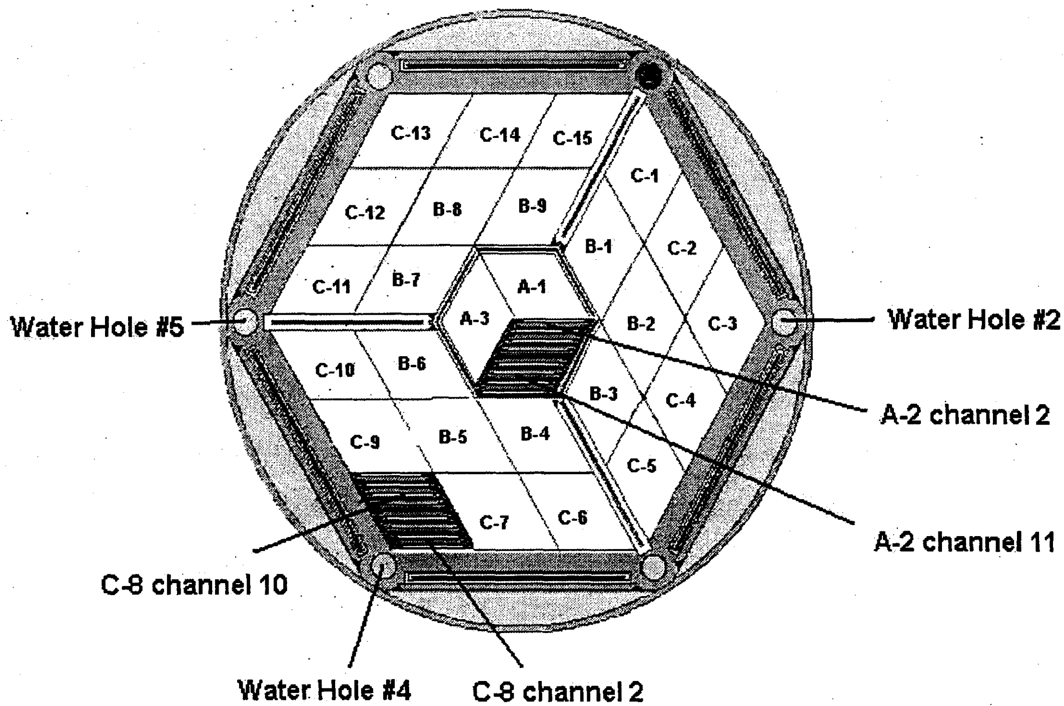

Figure 2.3 Locations of Cu wire flux measurements and calculations for Core No.1

Flux comparisons in core No.1 are shown in Figures 2.4 through 2.10. Because of the nature of the data presentation by Allen *et al* [2.15] and lack of tabular data, determination of the measured fluxes had to be inferred from axial plots of copper activation with the flux conversion factor given. No measurement error estimation was given. As a result, the measurement error shown is an estimation by this author taken to be about 10% at a flux level of 2×10^{13}. This error includes not only possible counting statistical and positioning error, but error involved in interpretation and conversion of the graphical data.

The flux profiles in the A-2 fuel element are shown in Figure 2.4 and 2.5. These both show reasonable agreement, both in shape and magnitude, between the copper foil measured values and the MCNP calculations. This shape includes the approach to the reflector peak below the fuel as well as the effect of the control blades, positioned at 19 cm (7.5 inches). The largest difference is about 20% at about 10 cm above the bottom of the fuel. Both channel 2 and channel 11 plots show these differences near the same axial locations. It is interesting to note that CITATION calculated values, as discussed by Allen, *et al* [2.15], showed very similar differences between calculated and measured values, suggesting that the measured data may contain some systematic errors.

The C-8 fuel element axial profiles are shown in Figures 2.6 and 2.7. The profile of channel 2, nearest the edge of the core, shows the higher fluxes towards the core periphery, as well as a stronger control blade effect, as would be expected. The profile of channel 10 reflects the lower fluxes away from the edge of the core. The calculated and measured values in both cases again show fairly good agreement. CITATION calculations also showed similar differences with measured values.

Flux profile comparisons for the three water holes are shown in Figures 2.8 through 2.10. The MCNP calculations show good agreement in the 30 to 60 cm range for all three holes, but start to show lower values in the regions below 30 cm where the fluxes increase, being up to 60% less at the peak. The reasons for this are unclear, although the CITATION values also showed this trend. Allen attributes this to the inadequacies of diffusion theory, upon which CITATION is based. However, if this were the case, MCNP should give values closer to the measured values. In order to check whether spectral differences in copper activation account for the discrepancies, copper wires were included in the MCNP model and the copper activation reaction rates determined. Since actual reaction rates could not be determined from the measurement data, a flux shape was determined using a flux factor taken at 56 cm to equate the MCNP determined copper reaction rate to the MCNP determined flux at this height. This height was used since the measured and calculated flux values agree at this point. The flux factor was then applied to the MCNP generated copper reaction rates at all other heights to generate a flux profile from copper activation. It should be noted that the copper activation flux values are added solely in order to determine a flux shape. Actual flux values are reflected only in the measured or MCNP calculated flux. The figures show virtually no difference between the calculated flux shapes directly from MCNP or via calculated copper activation.

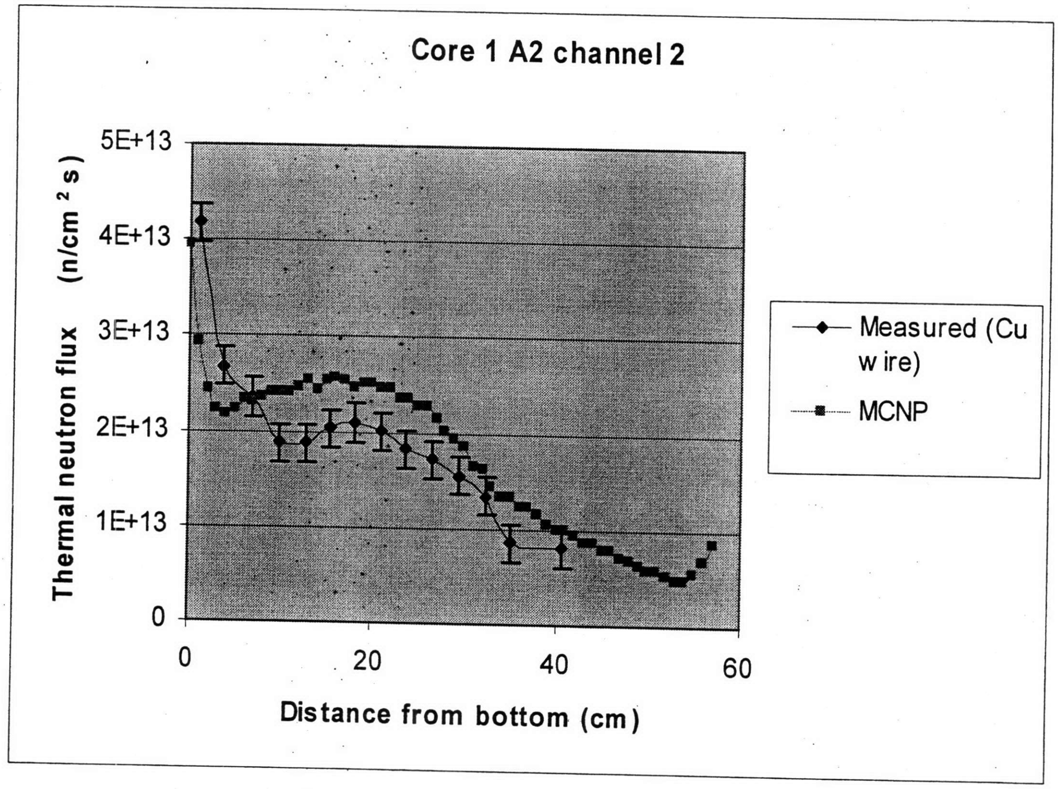

Figure 2.4. Measured and calculated thermal fluxes in core position A-2 channel 2.

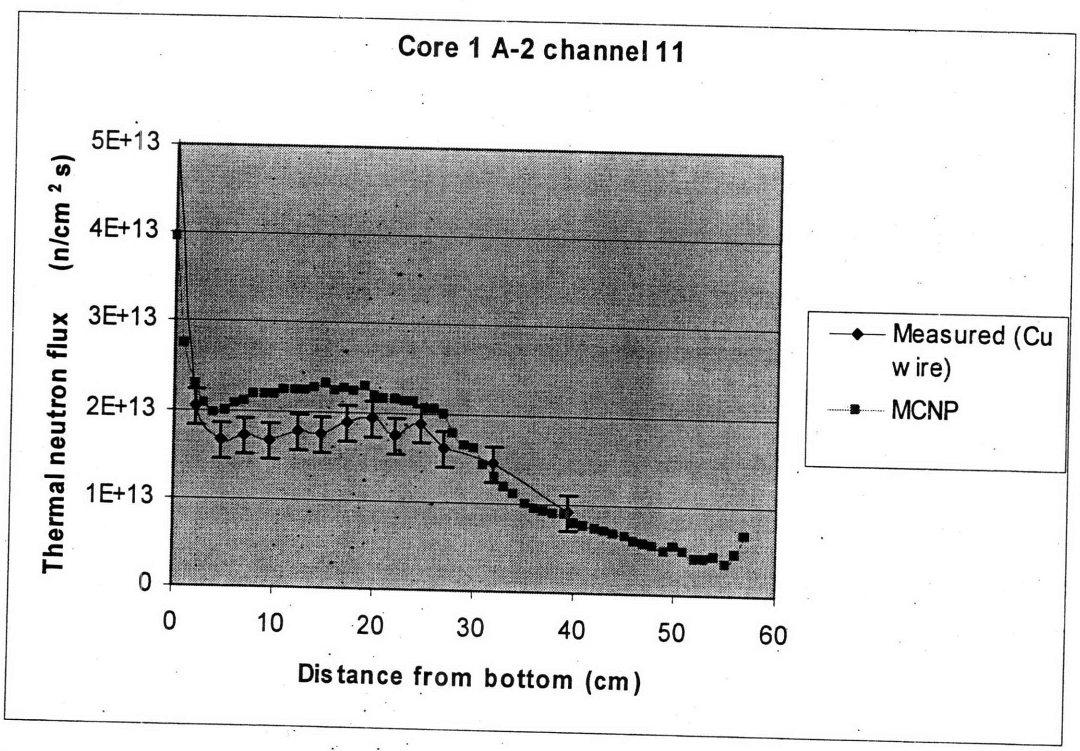

Figure 2.5. Measured and calculated thermal fluxes in core position A-2 channel 11.

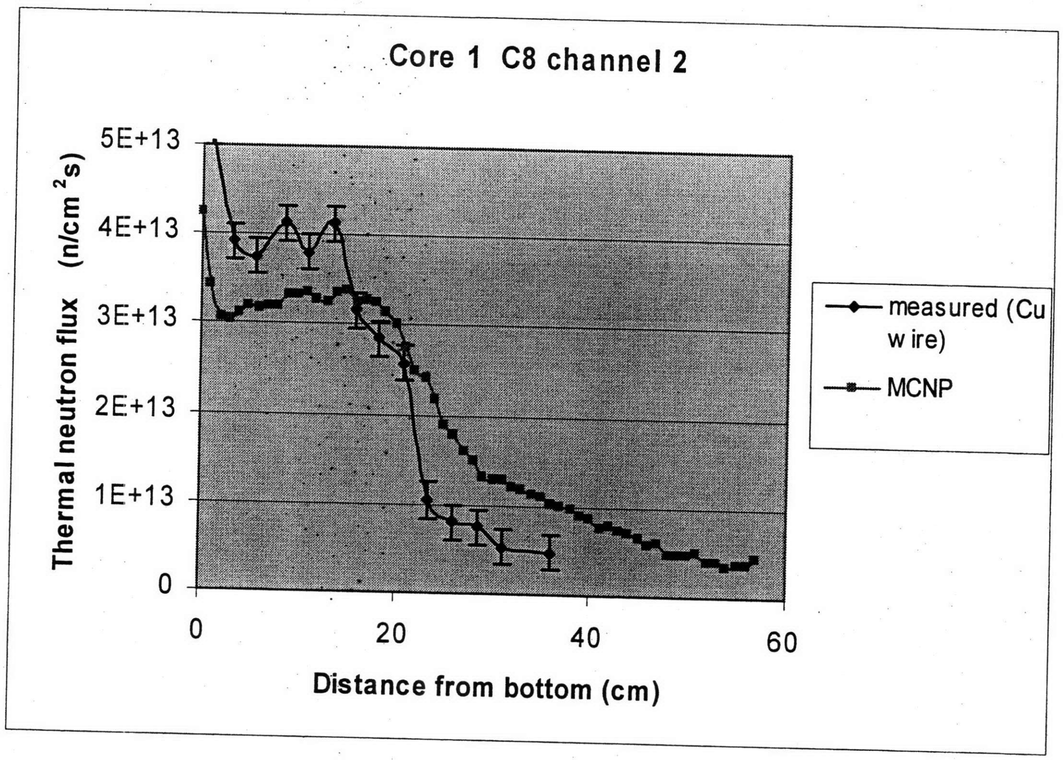

Figure 2.6. Measured and calculated thermal fluxes in core position C-8 channel 2.

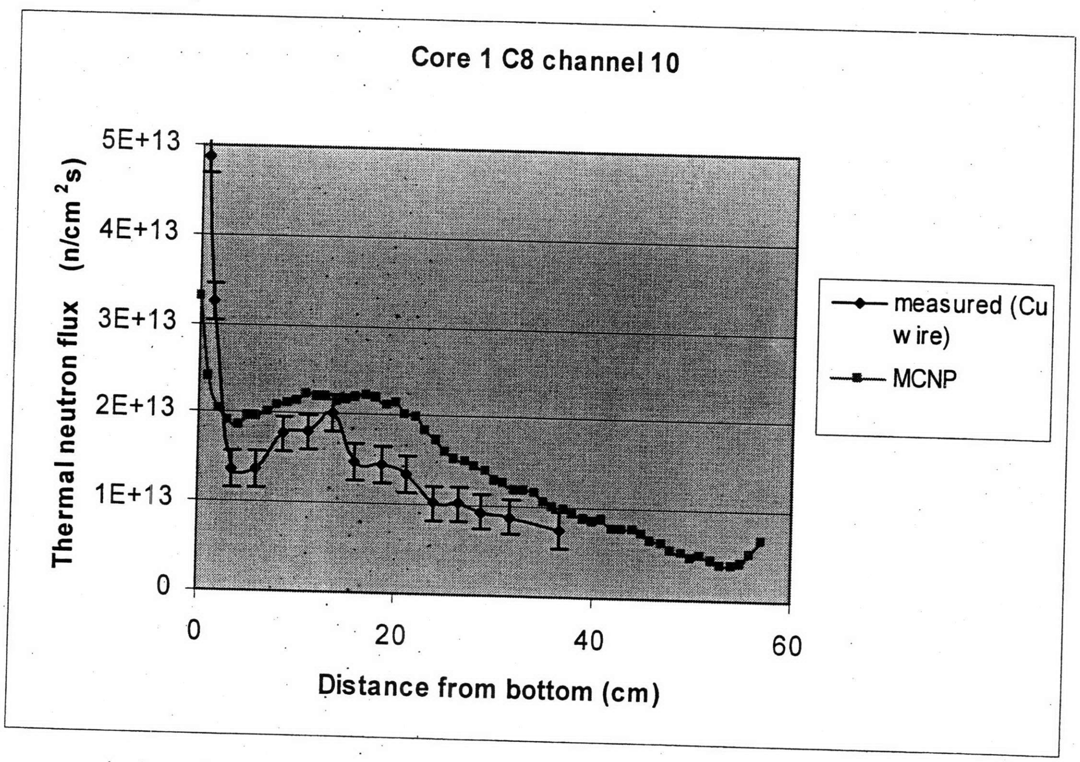

Figure 2.7. Measured and calculated thermal fluxes in core position C-8 channel 10.

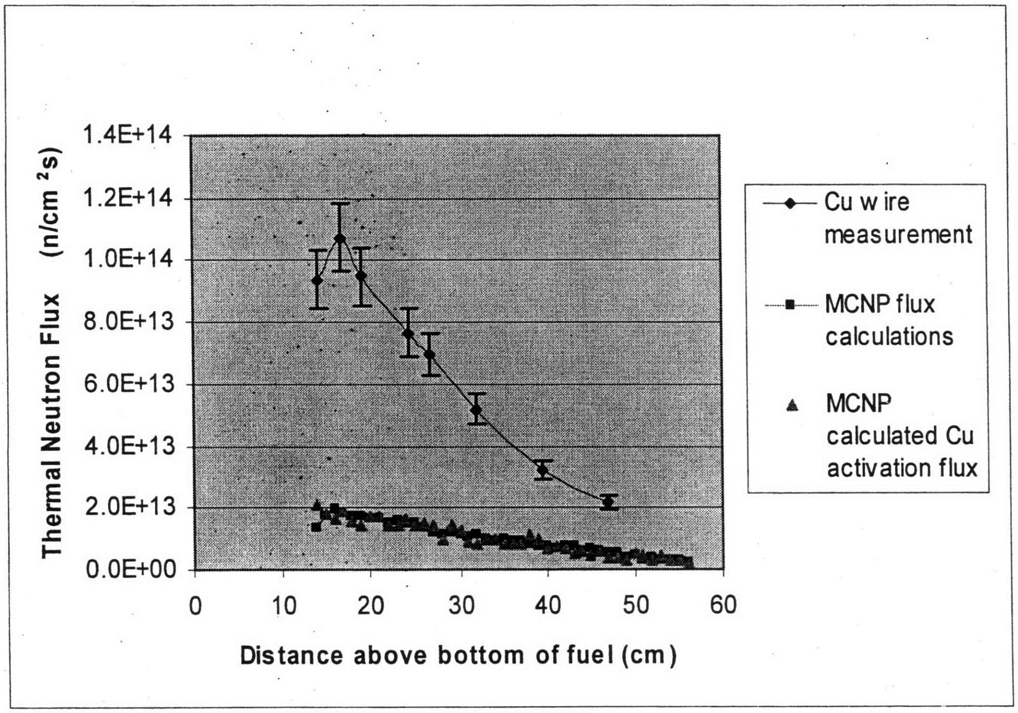

Figure 2.8. Measured and calculated flux profiles in water hole no. 2

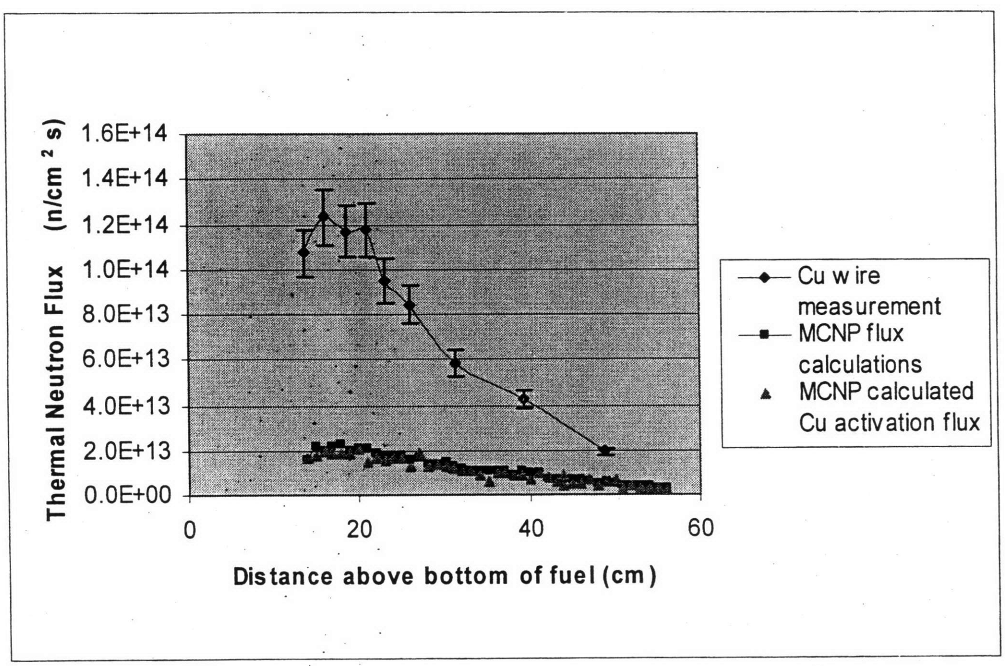

Figure 2.9. Measured and calculated flux profiles in water hole no. 4

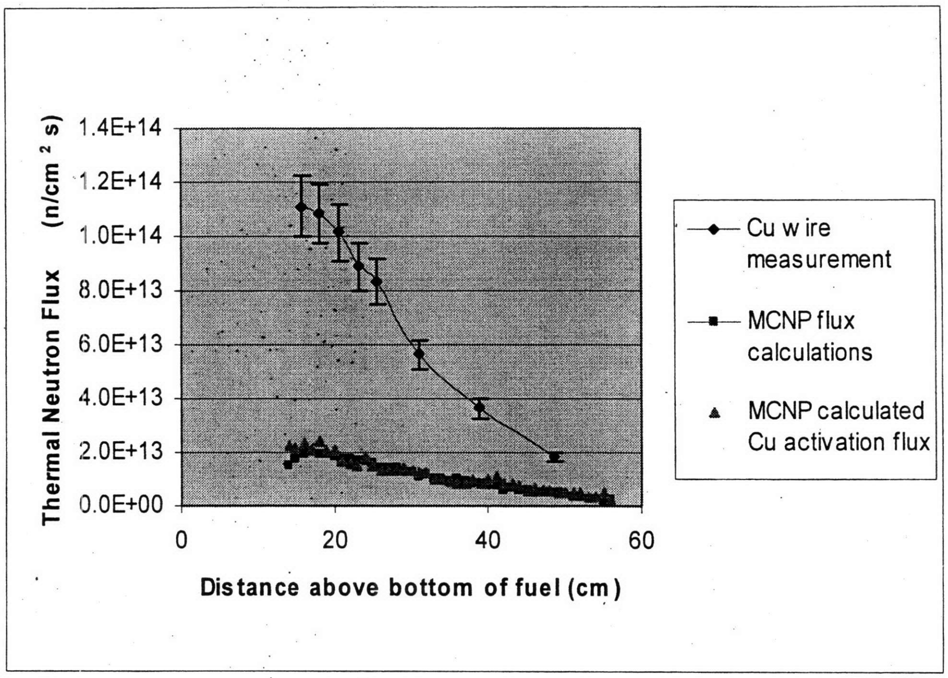

Figure 2.10. Measured and calculated flux profiles in water hole no. 5

2.4.2 Reactivity Validation

Both MCNP core models were validated by comparing the calculated K_{eff} at a blade height equivalent to the critical (K_{eff} =1) blade height initially used. As a further validation of reactivity, the blade positions in core No. 2 were varied in the model and the reactivity worths compared with measured blade worth curves. Initially, core No. 2 was operated with cadmium control blades. Because of swelling concerns, these blades were replaced with boron impregnated stainless steel blades. Both cadmium and boron blade worths were modeled in core No. 2 and their reactivity worths compared. In order to keep uncertainties low, 3×10^6 to 1×10^7 particles were used in each MCNP run. This kept the K_{eff} standard error below 5×10^{-4} in all cases.

The calculated and measured values of K_{eff} are shown in Table 2.2. This table shows good agreement between the two values, with a slightly lower calculated value possibly due to the absence of fuel tapering in the MCNP model. The core 2 value also matches values that were calculated by Redmond [2.10].

Table 2.2. K_{eff} validation of core Nos. 1 and 2.

Core number	Critical blade height (inches)	Measured K_{eff}	Calculated K_{eff}
1	7.5	1.00	0.99948 +/- 0.00024
2	8.5	1.00	0.99000 +/- 0.00018

In addition to the critical positions above, reactivity values for Core 2 as compared with blades fully inserted were taken at blade positions at the operating ranges from the critical height to 34.3 cm (13.5 in.) and compared with reactivity worth measurements made upon installation of the blades. Results for both the cadmium and boron blades are shown in Figure 2.11. Depicted here are estimated measurement errors of 5%, based on typical MITR-II worth curve uncertainties. MCNP statistical errors are all below 0.05%. The plot shows agreement within the error between the measured and calculated values. In addition, very little reactivity difference can be seen between the two materials, since both are essentially black to thermal neutrons, as are prevalent in the blade region.

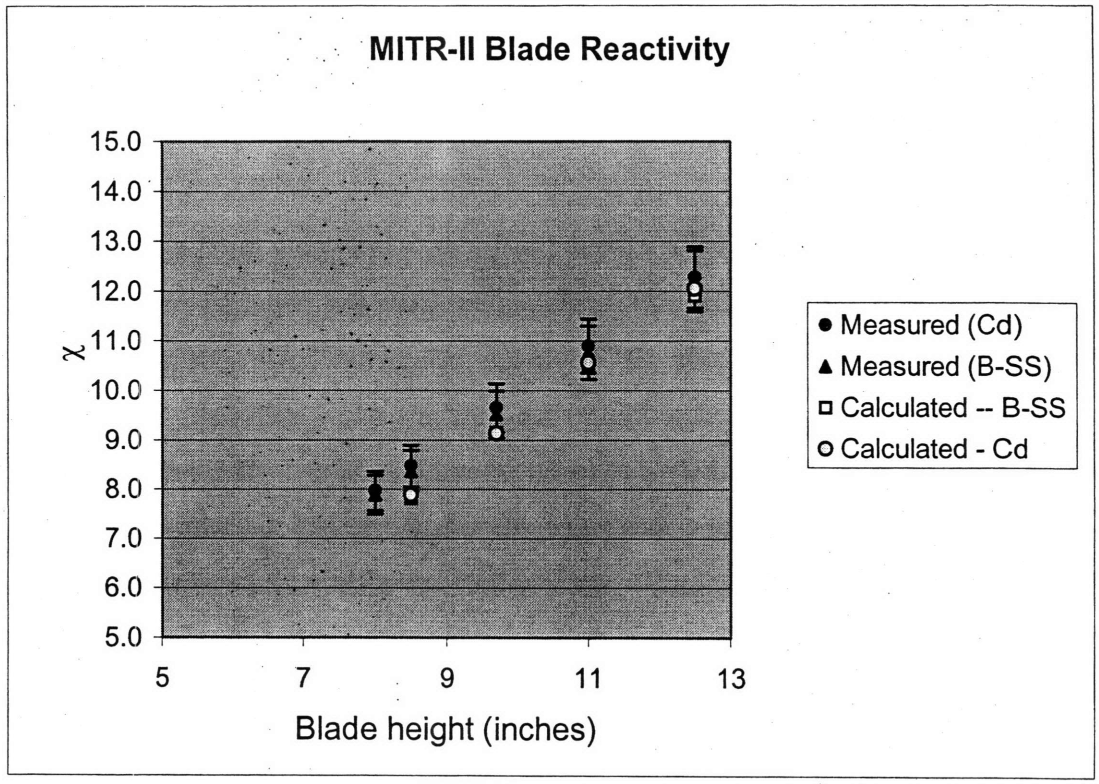

Fig. 2.11 Measured and calculated cadmium and boron-stainless steel blade reactivity worths

An additional validation of reactivity values was made by Xu and Newton [2.16] in support of the High Temperature Irradiation Facility (HTIF), installed in the MITR-II in 2005. Because this facility had a high negative reactivity worth, measurements using tungsten rods in the A-1 position were compared with values calculated using an MCNP model of Core #107 in which CITATION generated uranium depletion values and fission product concentrations were used. Even though the input values were calculated by a number of generations of CITATION diffusion calculations, and thus subject to the errors mentioned above, it was felt that this was the most efficient method of determining a reactivity value of a recent core. The fission product concentrations used in MCNP were modeled with the average fission product library (50120.35c). Two tungsten rod experiments were performed, one with a 3.8 cm (1.5 inch) diameter 30.5 cm (12 inch) long tungsten rod positioned with the bottom of the rod at 15 cm (6 inches) above the core centerline and one with a 3.21 cm (1.265 inch) diameter hollow rod running the entire length of the core. The former was intended to give an intermediate value of reactivity worth and the latter a higher worth since the MITR-II technical specifications do not allow insertion of an experiment worth more than 1.8% ΔK/K into the reactor. Both tungsten rod experiments were modeled explicitly in the MCNP model. Results of these are shown in Table 2.3.

The negative reactivity values for the full length rod show good agreement between measured and calculated values, while the values taken for the larger rod at the top of the core do not show as good agreement. Because the reactivity worth of a partial length rod can vary significantly for a positioning change of just a few millimeters, the difference in values for the top rod are likely due to positioning accuracy. The errors shown for the calculations are the statistical errors for Monte-Carlo calculations, while the measurement errors are an estimate mainly due to uncertainties in the shim blade worth curves.

Table 2.3 High negative reactivity worth validation for the HTIF

	Reactivity worth (% ΔK/K)	
	MCNP Calculation	**Measurement**
3.8 cm dia. solid rod in top 15 cm of core	-0.82 +/- 0.03	-0.94 +/- 0.07
3.21 cm diameter hollow rod full length	-1.44 +/- 0.04	-1.39 +/- 0.07

2.4.3 Burnup Calculations

The MCODE model was run for core No. 2 at a power density of 36 kW/l, which is equivalent to a reactor power level of 2.5 MW. This was the nominal power under which core No. 2 was run. Burnup was calculated up to 20 MWd/kg, the point at which core No. 2 ended. Burnup steps of 0.1, 2.7, 5, 10, 15 and 20 MWd/kg were used, with each step divided into five depletion substeps. Changes in K_{eff} (*i.e.* reactivity) with burnup were calculated and compared with measured reactivity changes (from blade position changes taken from operating logs throughout the operation of core No. 2). In addition, in order to determine the effect of neutron spectra, the sensitivity of the burnup calculations to the choice of ORIGEN cross-section libraries was evaluated.

Burnup calculations from MCODE are compared with measured reactivity data in Figure 2.12. A normal operating schedule would consist of startup at the beginning of a week and run until the weekend. There were some cases in which the operating schedule did not allow for xenon poisoning to reach equilibrium. All values in Figure 2.12 were taken at the end of an operating week when xenon is most likely to be at or near equilibrium. This figure shows good agreement between measured and calculated values with non-equilibrium reactivity values obviously being smaller. The slight offset at the zero reactivity point is due to the 2.3 MWd/kg generated in Core No. 1. The steeper dropoff initially is due to the buildup of shorter-lived fission products, such as ^{135}Xe, ^{105}Rh and ^{143}Pr. A burnup of 20 MWd/kg is equivalent to about a 4% burnup of ^{235}U, a point at which fuel reshuffling typically takes place.

The results of two vastly different ORIGEN cross-section libraries, that of a PWR library (PWRU) and that of an LMFBR (FFTFC) in the use of a theoretical LEU MITR-II core with 12 plate elements is shown in Figure 2.13. This shows no significant difference in reactivity values in library use for the fission product isotopes and actinide isotopes used by ORIGEN. Note however that the effective one-group cross sections used in the ORIGEN depletion for the most reactive isotopes are obtained directly from the MCNP calculations, and therefore reflect the local neutron spectra in the MITR-II core.

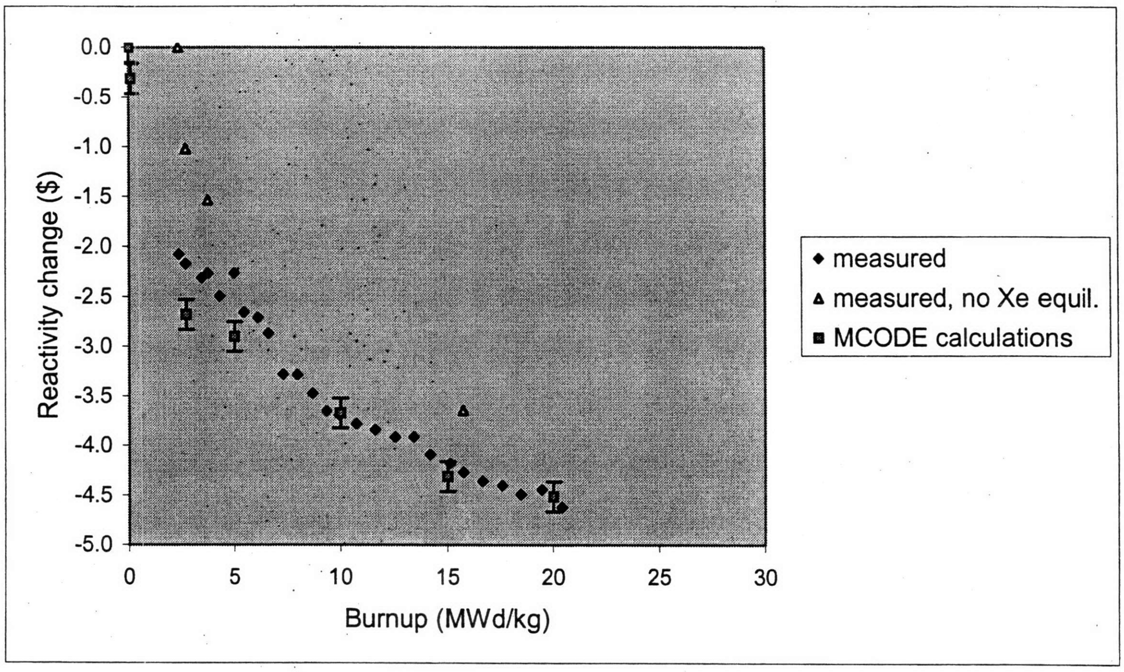

Fig. 2.12. Burnup reactivity values of MITR-II Core #2

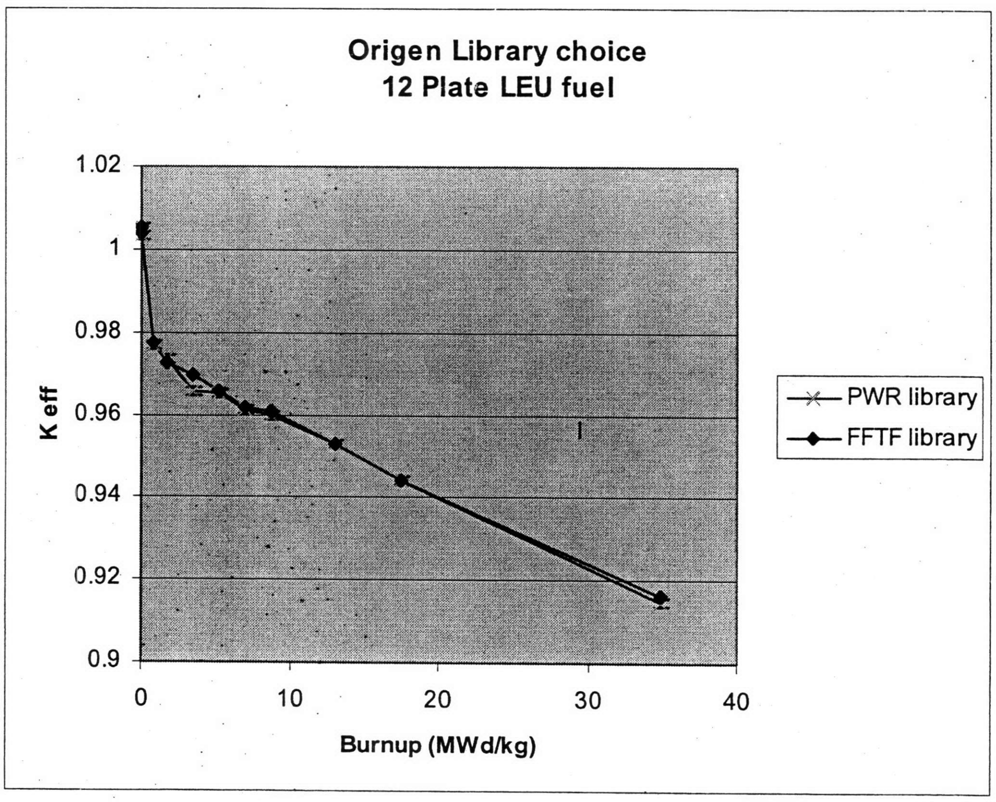

Fig. 2.13. Effect of ORIGEN cross-section library on K_{eff}

2.4.4 Thermal Hydraulic and Transient Analysis Validation

A multichannel thermal-hydraulics analysis code, MULCH-II, used for thermal-hydraulics analyses in Chapter 6, was developed and benchmarked by Hu, Bernard, and McGuire [2.17]. This code uses a model of the MITR-II, coupling power distributions with momentum and energy conservation equations to obtain system design parameters and safety limits. It was benchmarked against steady state MITR-II conditions, empirical relations of onset of flow instabilities, and loss of flow transient experiments performed at the MITR-II.

The coupled point kinetics-hydrodynamics-heat transfer code PARET was used for reactivity transient calculations, as discussed in Chapter 7. This code was validated by comparison with experimental results from the Spert-III experiments. These validations, made by Obenchain [2.18], were performed for both a 4.8% enriched oxide core (Spert III E) and a 93.5% enriched plate core (Spert III C). Although there are some differences between the Spert III C core and the MITR-II such as fuel type (the Spert III C core contained fuel plates of UO_2 and stainless steel), the fuel plate dimensions were similar to those of the MITR-II and should fairly closely reflect the thermal-hydraulic and heat transfer conditions of the MITR-II. Validation results for the Spert III C core showed close agreement between PARET calculations and experiment results for the initial stages of the transients analyzed, but reactor powers differed by as much as 30% in the latter stages of the transients. Thus, a baseline 30% uncertainty should be applied to PARET results.

2.5 Conclusions

The MCNP model of MITR-II core configuration No. 1 has been developed and used to compare initial criticality values and in-core and near core flux profiles for HEU measured values. Both the K_{eff} values and flux profiles show good agreement between calculated and measured data, with the exception of some of the flux profile measurements at the core corners. Additionally, both the MCNP and MCODE models for HEU core configuration No. 2 were compared with initial criticality, control blade worths, and burnup against available measured data. Depletion validation of ^{238}U and ^{239}Pu was not possible because of the lack of experimental data for the MITR-II. These calculational models also showed good agreement with measurements. These validations, as well as validations of thermal-hydraulics code MULCH-II and point kinetics/hydrodynamics code PARET indicate the appropriateness in use of these models in data verification, proposed core modifications and safety analyses.

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Chapter 3
LEU Core Design Objectives and Constraints

3.1 Constraints

The conversion of the MIT Reactor will be funded, at least in part, by the U.S. Department of Energy under the RERTR program. Because the resources of any conversion or reactor program are not limitless, the conversion of the MIT Reactor will have to be made with funding constraints.

Modification of the reactor beyond the existing core structure would be expensive and most likely not fundable within RERTR guidelines. Such a modification was made in the conversion of the reactor from MITR-I to MITR-II, which involved complete renovation of all spaces inside the graphite region. Although significant gains were made for experimental needs, the reactor was shut down for over three years and the renovation cost was approximately $3 million in 1975 dollars. Furthermore, it is unlikely that, short of building a completely new reactor, such experimental gains could again be made, particularly with conversion to LEU fuel. Thus, it appears to be more cost effective that any modifications as part of the LEU conversion of the MITR-II will have to be made within the existing core structure.

3.2 Criteria for LEU Fuel Selection

In a core fueled with high density LEU fuel, the amount of ^{235}U in the core will be greater than that in an HEU-fueled core at a given reactor power. Given that the majority of fissions are caused by thermal neutrons, the thermal flux to maintain this power level would be lower, even with the absorption of thermal neutrons in ^{238}U, which has a thermal absorption microscopic cross-section about fifty times smaller than that of ^{235}U.

Since there will be four times more ^{238}U than ^{235}U in the core, the macroscopic absorption cross-section for thermal neutrons in ^{235}U remains about an order of magnitude higher than that of ^{238}U. In addition, the resonance absorption in the larger amounts of ^{238}U decreases the resonance escape probability, causing the spectrum to be harder. The loss in thermal flux is somewhat tempered through the harder spectrum in that there will be an increase in fast fissions in both ^{235}U and ^{238}U, which may account for 2 to 3% of all fissions.

In order to select an LEU fuel and core design, a number of criteria should be met. These include both safety and utilization goals and are listed below:

1. Thermal flux. Ideally, the thermal flux in an LEU-fueled MITR should be equivalent to or greater than the HEU core at the same power level. This would include all ex-core experimental facilities such as the beam ports and the thermal medical beam as well as any in-core experiments designed for thermal flux irradiations.

2. Fast flux. Fast neutron experimental facilities are primarily used for materials studies. Again, the fast flux in an LEU core would ideally be equivalent to that in an HEU core. However, given criterion 1, this may not be achievable using fuel design alone. Since the majority of experiments needing fast flux for materials studies are performed in core, any in-core facilities should be designed to enhance the fast flux. This will avoid lengthening the irradiation time, and thus the cost, of any materials experiment.

3. Negative moderator temperature and void coefficients. This is a necessary criterion both for safety and for licensing. Any changes made in moderation to optimize an LEU core will also affect these reactivity coefficients. While a full safety analysis may reveal that a small amount of positive reactivity can be tolerated, it is more conservative to avoid any positive reactivity coefficients.

4. Fuel cycle length equivalent or longer than the HEU core. A shorter fuel cycle would adversely affect the availability of the reactor which is important in meeting experimental needs. It would also necessitate more frequent refueling, increasing personnel dose as well as increasing the quantity of spent fuel.

5. Adequate blade worths and shutdown margins. Any core design must have adequacy of control. Within the MITR core structure, the control blades are present at the core periphery. The blade worths must be sufficient to allow adequate control under all conditions, from new cores to burned cores with high fission product poisoning. In addition, the reactor must be able to meet the shutdown margin, defined as being shut down by at least 1% $\Delta K/K$, with the most reactive blade and regulating rod fully out of the core under the most reactive conditions (cold, xenon free, and with in-core samples in their most reactive state). These criteria are necessary in assuring both safety and licensability of the reactor.

6. Sufficient excess reactivity to overcome xenon poisoning and Doppler broadening, under restart conditions. In addition to control issues as discussed in Criterion no. 5 above, the LEU core should be flexible enough to be able to deliver adequate fluxes to experiments under all normal operating conditions.

7. Adequate subcooled margin in all channels. It is important to assure adequate cooling to all channels under all conditions. The criterion in an LEU core, as it is in the current HEU core, is to avoid the onset of nucleate boiling (ONB) even in the hottest channels and the channels with lowest coolant flow.

8. Adequate natural convection cooling for low power and shutdowns. During shutdowns and low power operations with primary pumps off, adequate natural convection cooling is necessary.

3.3 LEU Model

As a comparison to HEU Core No. 2, various proposed LEU cores were initially evaluated under the same operating conditions as Core No. 2. These are:

1. Blade height at 21.5 cm (8.5 inches). This is the critical height of Core No. 2 and is used mainly for reactivity comparisons between HEU Core No. 2 and proposed LEU cores.
2. Regulating rod at 5 cm (2 inches) from the reference "in" position (the "in" position is actually 15.2 cm {6 inches} from the bottom of the core).
3. Moderator and reflector temperatures at 25 °C. Both the light water moderator and heavy water reflector were modeled at a density corresponding to 25 °C. Cross-sections were also evaluated at this temperature.
4. Fuel temperatures at 50 °C. This reflects cold operating conditions.
5. Water in the spider positions. Since, unlike Core No. 1, Core No. 2 was run with no spider, this was the reference condition for evaluation.
6. Identical neutron cross section libraries. Except for library evaluations and temperature reactivity coefficient evaluations, all cores were evaluated using ENDF-B-V cross-sections (MCNP library .50c). There were minor instances where some materials were not in MCNP library .50c. In these cases, a library most similar to .50c was selected.

In addition to reactivity (K_{eff}) comparisons, neutron fluxes were evaluated at selected in-core positions (typically within an in-core experimental facility in the A-3 position), as well as at four experimental facilities outside of the core, shown in Figure 3-1. The A ring in-core sample assembly (ICSA) was modeled as a helium-filled 5 cm (2 inch) diameter tube surrounded by solid aluminum within the A-3 core position. In actuality, any ICSA tube would be filled with experimental material, which would have a significant effect on flux in and around the ICSA tube, but the tube was modeled as empty for comparative purposes. The four ex-core facilities were as follows:

1. Twelve inch beam port (12SH1). This facility is representative of beam port facilities located just below the core, used in neutron scattering and other

applications. To increase statistical accuracy, the fluxes were tallied in the entire port volume within the graphite region.

2. Six-inch radial port containing high flux pneumatic facility (2PH1). This facility is used for neutron activation analysis and isotope production. The port (6RH1) is positioned closer to core centerline than the horizontal ports such as 12SH1. In addition to a relatively high thermal flux, it also has a fast component useful in some applications. Again, as above, the fluxes were tallied in the entire port volume within the graphite region. Since this is an average of the fluxes within the port volume, the fluxes here will be lower than those actually in the pneumatic facility, which is closer to the core.
3. Fourteen inch square window in graphite reflector directly adjacent to the fission converter facility. This area is representative of the thermal flux impingent upon the fission converter fuel tank and is directly proportional to the epithermal flux available to the medical facility used for BNCT clinical trials.
4. The below core beam line leading to the thermal BNCT facility in the medical room. Again, for statistical accuracy, fluxes were tallied in the water-filled water shutter. Since the facility is now in use as a thermal beam, the D_2O shutter above was modeled full of D_2O.

Although other facilities could have been included, it was felt that these were representative of most experimenters' needs. In fact, it was found that in almost all cases, any changes in core design affected all ex-core facilities in a similar fashion.

For comparative purposes, fluxes were generally tallied in three energy bins, thermal (<0.4 eV), epithermal (0.4 eV – 3KeV), and fast (>3KeV). Thermal neutrons are of most interest in the ex-core experimental facilities, while fast neutrons are most likely applicable in the in-core region. It should be noted that although most materials studies are interested in neutron energies above 100 KeV, the 3 KeV lower cutoff for the fast neutron bin was seen to be inclusive of most higher energy experimental needs. In addition, this energy structure also corresponds to the three-group energy structure used by Bernard [3.1] and others in the diffusion theory-based fuel management program for the MITR-II and could, if needed, be used for later comparisons.

The neutron fluxes output by MCNP are given as a track length estimate of flux (cm^{-2}). In order to convert this to actual flux in n/cm^2 s, one must multiply by the neutron emission rate of the reactor. At 5 MW and assuming a fission yield of 2.43 neutrons per fission, this is 3.97×10^{17} n/s. Fission yields were calculated as part of MCNP evaluations for LEU fuel and it was determined that the neutron yield per fission did not significantly change between the HEU and LEU fuel.

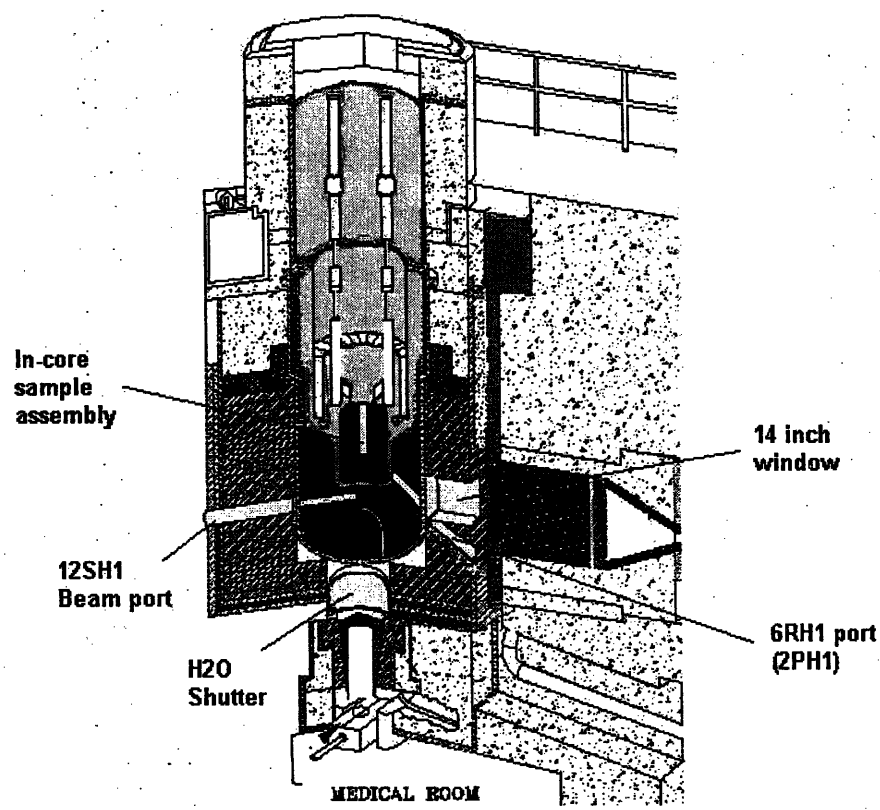

Figure 3.1 Locations of MITR facilities for neutron MCNP evaluations.

3.4 LEU Fuel

As explained in chapter 1, monolithic U-Mo fuel is the only viable option for LEU fuel that has sufficient density to be used in the MITR. A variety of alloys are under development, with molybdenum content varying between 4 and 10%. Meyer, *et al*, [3.2] performed irradiation tests on U-Mo dispersion fuels and concluded that alloys with a molybdenum content above 6% showed good performance, while those below 6% exhibited fission gas bubble growth leading to swelling of fuel. Further tests [3.3] on monolithic fuels also concluded that fuels with molybdenum content above 6% performed well under irradiation. For this reason, it was decided to design the LEU MITR using 7% molybdenum fuel (U-7Mo). This fuel has a density of 17.5 g/cm^3. Use of fuels with higher molybdenum content (therefore with a slightly lower density) is also possible. However, the addition of a percentage or two of molybdenum will have little effect on either neutronic performance or thermal performance.

3.5 Various approaches to meet objectives

As an initial attempt at evaluation of an LEU core, the water-to-fuel ratios were varied to try and optimize the K_{eff} and fluxes deliverable to the experimental facilities. This was done by varying the number of plates per element and the plate thicknesses in the Core No. 2 configuration. Fins were modeled as half-thickness (0.13 mm) of solid aluminum. Since the surface characteristics of the U-Mo fuel allow for thinner cladding, the effect of changing the cladding thickness from 0.38 mm to 0.25 mm was also evaluated.

A further attempt to increase fluxes, in particular the in-core facility fluxes, was made by evaluating the effect of a change in moderating material. Since a change to a solid moderator or changing the reactor to a fast reactor without moderation would require a complete rebuilding of the reactor and thus not be within the constraints listed above, it was decided to add D_2O to the H_2O moderator. The percentage of D_2O in the H_2O moderator was varied, while evaluating in-core and ex-core experimental fluxes, as well as K_{eff}.

Although HEU Core No. 2 was operated without an in-core absorber spider (described in Section 1.7.1) and current operations have trended away from using the spider, the effect of using both a full-length and partial-length spider in an LEU core was evaluated. A number of materials were studied, including boron-stainless steel, cadmium, hafnium, and LEU fuel. In addition, changes in core configuration, namely the number and material content of solid dummy elements were also studied.

3.6 In-Core Experiment Designs

In addition to overall fuel and core design evaluations, a number of attempts were made to improve the attributes of in-core experimental facilities. These were made to meet the anticipated needs of in-core experiments, in particular those of experimental size and neutron spectrum.

The U.S. Nuclear Regulatory Commission spells out the conditions under which experiments can be run at research reactors. [3.4] It should be noted that reactors defined as test reactors must meet much more stringent regulatory requirements than research reactors, which make test reactors more difficult to use and are generally beyond the financial capabilities of most universities. 10CFR50.2 lists the conditions under which licenses can remain under this threshold of test reactors:

1) Reactor power must be less than 10 MW.
2) Reactor power must not exceed 1 MW if the reactor contains:
   i. Experiments greater than sixteen square inches in cross-section, or
   ii. Experiments containing fissile material with separate circulating loop, or
   iii. Liquid fuel loading

Thus, the 5 or 6 MW MITR must have experiments less than 16 in^2, and any fueled experiment must be cooled using only the MITR primary flow.

Because the fast neutron flux is greatest in the A ring, it is desired to use as much of the A ring for experiments as possible. The cross section of the maximum available space in the A ring is 15.9 in^2, making the entire A ring available for a single experiment, if needed. Of course, all other reactor requirements such as power peaking and shutdown margin must continue to be met under all circumstances.

To meet anticipated experiment spectrum requirements, a number of different options were explored, with the most promising being division of each fuel element space into two, allowing for either a "double" fuel element, being equivalent to a conventional MITR fuel element, or a combination of fuel and other material to meet the reactivity and flux needs for a nearby experiment. A number of materials were evaluated, including aluminum, beryllium, and graphite, as well as insertion of fixed absorbers to adjust the flux shape and spectrum. Further discussion of these options is given in Chapter 5.

3.7 Conclusions

Under the constraint that the LEU core must be designed to fit within the current core structure, a number of design criteria were established, including experimental fluxes being equivalent to the HEU core, equivalent or greater fuel cycle length, as well as cooling and reactivity safety criteria.

The MCNP modeling conditions as used in HEU core No. 2 were used in initial evaluations of U-7Mo monolithic LEU cores. Various approaches in design of the LEU core were proposed, including optimizing fuel plate number and thicknesses, moderator and absorber spider materials, and core design optimization for increasing the in-core fast flux.

References

3.1. J. Bernard, "MITR-II Fuel Management, Core Depletion, and Analysis: Codes Developed for the Diffusion Theory Program CITATION," M.S. Thesis, MIT 1979.

3.2. M. Meyer, G. Hofman, S. Hayes, C. Clark, T. Wiencek, J. Snelgrove, R. Strain, and K. Kim, "Low Temperature Irradiation Behavior of Uranium-Molybdenum Alloy Dispersion Fuel," Journal of Nuclear Materials, **304**, 2-3, August 2002.

3.3. C. Clark, S. Hayes, D. Wachs, M. Meyer, T. Wiencek, G. Hofman, and M. Finlay, "Irradiation Testing of Monolithic Fuel at Argonne National Laboratory," Proceedings of the Research Reactor Fuel Management Conference, Budapest, Hungary, March, 2005.

3.4. Code of Federal Regulations, Title 10, Chapter 50.2

Chapter 4
Evaluations of Design Options

4.1 Introduction

Design of an LEU core utilizing the U-7Mo fuel selected in Chapter 3 presents a challenging problem because of the multiple objectives of providing reactivity, in-core fluxes and ex-core fluxes equal to those of the HEU core. The following design options were considered:

a. Direct substitution of U-7Mo fuel plates for the existing HEU fuel;
b. Variations in the number and thickness of fuel plates containing the U-7Mo fuel;
c. Reduction of the fuel plate cladding thickness;
d. Addition of D_2O to the moderator/coolant;
e. Use of different materials in the cladding, spider, or solid dummy assemblies; and
f. Use of half-width fuel elements to allow optimization of inner reflector locations

Each of these options are discussed below.

4.2. Direct substitution of U-7Mo fuel plates for existing HEU fuel

As stated in Section 3.3, LEU core options were compared with HEU Core Configuration No. 2. Table 4.1 shows initial results whereby monolithic U-7Mo LEU fuel was directly substituted in the same geometry (fifteen 0.76 mm plates with 0.38 mm clad) as HEU fuel used in Core No. 2. Although no in core sample assembly (ICSA) facility was actually installed in HEU Core No. 2, one was included in the model for purposes of comparing the effect of fuel and core design on a possible in-core facility. Because of this inclusion, the K_{eff} of HEU Core No. 2 differs slightly from the calculated value listed in Section 2.4.2. All fluxes are evaluated at a reactor power of 5 MW and the fast fluxes listed are of energies greater than 3 keV. All fluxes have a statistical error of less than 2%.

Table 4.1 HEU vs. LEU K_{eff} and fluxes for core configuration No. 2

	HEU Core No. 2	LEU Core No. 2
K_{eff}	0.99873 +/- 0.00036	0.98715 +/- 0.00087
A ring ICSA fast flux (n/cm^2s)	1.85×10^{14}	1.51×10^{14}
12SH1 thermal flux (n/cm^2s)	7.36×10^{12}	6.76×10^{12}
2PH1 thermal flux (n/cm^2s)	9.74×10^{12}	8.62×10^{12}
2PH1 fast flux (n/cm^2s)	8.19×10^{10}	7.26×10^{10}
Fission converter window thermal flux (n/cm^2s)	8.48×10^{11}	7.56×10^{11}
H_2O shutter thermal flux (n/cm^2s)	1.51×10^{11}	1.35×10^{11}

The results in Table 4.1 clearly show the effect of the LEU fuel. Even though the fuel density, and therefore the uranium loading is much higher (26.1 kg of ^{235}U for the LEU core vs. 10.7 kg for the HEU core), the neutron absorption by the ^{238}U in the LEU core results in a negative reactivity of about 1.2% $\Delta k/k$, which is roughly equivalent to about two inches of control blade height. Although it is certainly possible to attain criticality at this higher blade height, the core life may be more limited and could require more frequent refuelings.

Similarly, the use of LEU fuel decreases the available flux in every experimental facility. The in-core fast flux decreases by almost 20%, whereas the ex-core facilities show an across-the-board decrease of fluxes of about 10%.

This indicates that the use of LEU fuel in the MITR-II Core No. 2 configuration leads to undesirable fluxes and some negative reactivity effects. Thus, optimization of the configuration of fuel will be necessary to maintain reactor viability in using LEU fuel. The optimization will essentially serve to reduce parasitic absorption and increase moderation.

4.3 Variations in the number and thickness of U-7Mo fuel plates

In order to optimize an LEU core, the Core No. 2 model with U-7Mo fuel was used to assess the effect of varying the number and thickness of plates on K_{eff} and both the thermal and fast fluxes. The geometry was made so that fuel plates remained centered in a fuel element and the water gaps adjusted to consistently fit the number of plates within an element. In the initial runs, the cladding remained at 0.38 mm (0.015 inches) with 0.25 mm (0.01 inches) fins, modeled as a half thickness (0.125 mm) of solid aluminum. The effect of changing plate thickness in a fifteen-plate HEU Core No. 2 was also evaluated.

The K_{eff} results are shown in Figures 4.1 and 4.2. These show not only the effect of increasing the moderation, but also the geometry. K_{eff} clearly increases when the thickness and number of plates is reduced, since the core is undermoderated. The LEU cores also need more moderation than the HEU core to reach a maximum K_{eff}, generally seen at a hydrogen to heavy metal (H/HM) ratio of about 10 to 12. It should be noted that the initial heavy metal consists of only uranium. The LEU H/HM value for maximum K_{eff} is much lower than the HEU H/HM of 63, which is due to the absence of ^{238}U in the HEU fuel. Because of the differences in fuel design and composition and harder spectrum, these H/HM values are higher than those conventionally seen in LWRs. Since the LEU fuel consists of 20% ^{235}U, the $H/^{235}U$ ratio would be comparable between the HEU and LEU fuels.

The effect of this variation on ex-core experimental thermal flux is shown in Figure 4.3. The flux tallied in the 12SH1 beam port is representative of all ex-core experimental facilities. This shows that, due to a harder in-core spectrum, a lower H/HM causes the thermal flux outside the core to increase because of the large amount of moderation in the reflector regions. As opposed to K_{eff}, the fluxes increase with the number of plates for a given H/HM ratio, although this effect is not a strong one, since the fluxes only increase by about 5% for a given H/HM ratio. However, in this case, no LEU configuration was found to approach the 12SH1 flux of 7.36×10^{13} in the HEU core. Thermal fluxes could be further increased with more water, but that would come at the expense of available fast fluxes and the possibility of overmoderating the core. In principle there is about 70% more ^{235}U in the LEU core which implies that 70% less thermal flux is needed to maintain the same power level.

Fast fluxes in the ICSA are shown in Figure 4.4. These show a slight increase due to hardening of the spectrum with lower H/HM ratio and larger number of plates, but the latter effect is not significant. Again, no configuration was found to approach the HEU ICSA fast flux of 1.85 x 10^{14}. Other options must be explored to try and increase available fluxes.

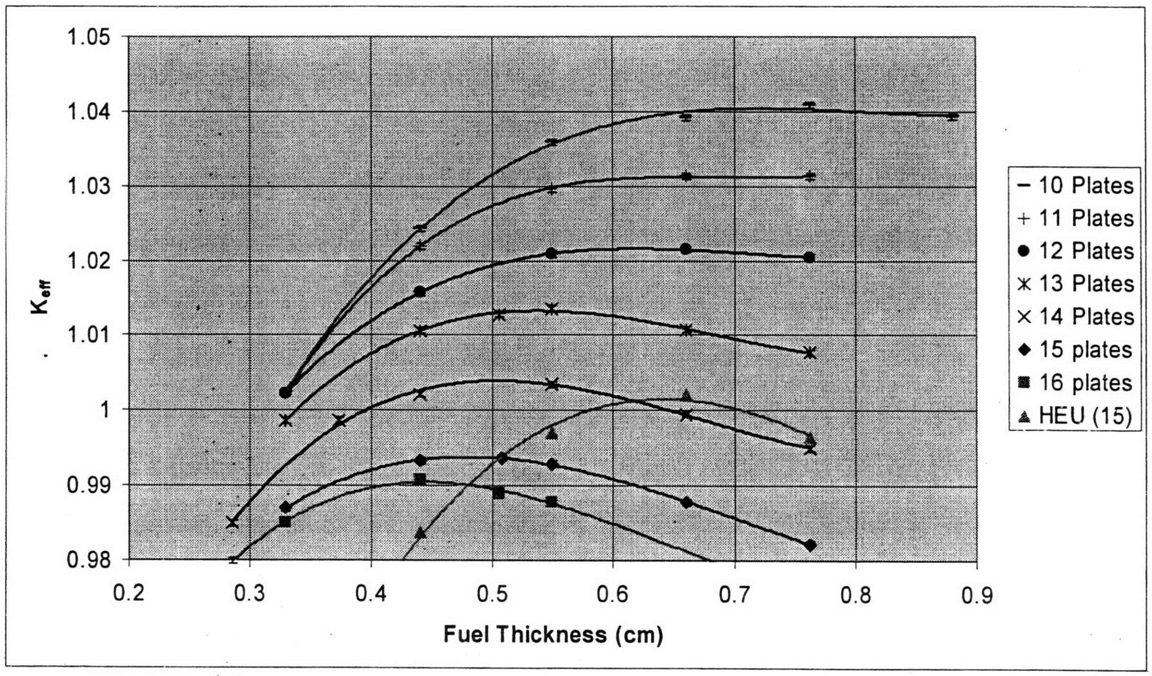

Figure 4.1 K_{eff} vs. fuel thickness for U-7Mo LEU fuel.

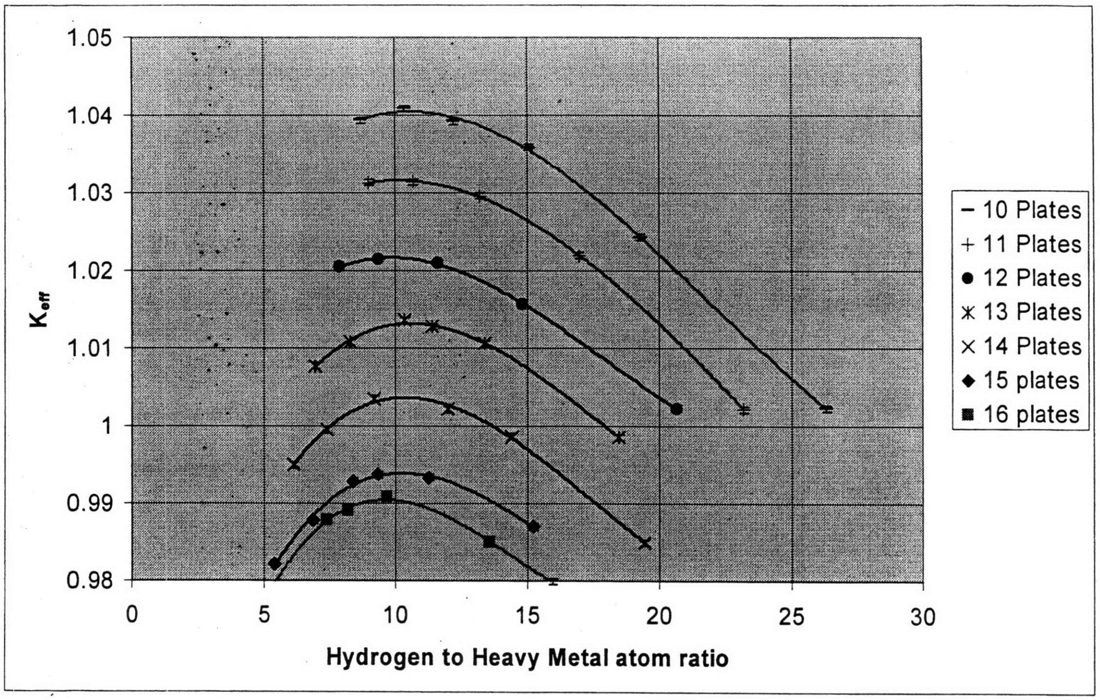

Figure 4.2 K_{eff} vs. H/HM for U-7Mo fuel

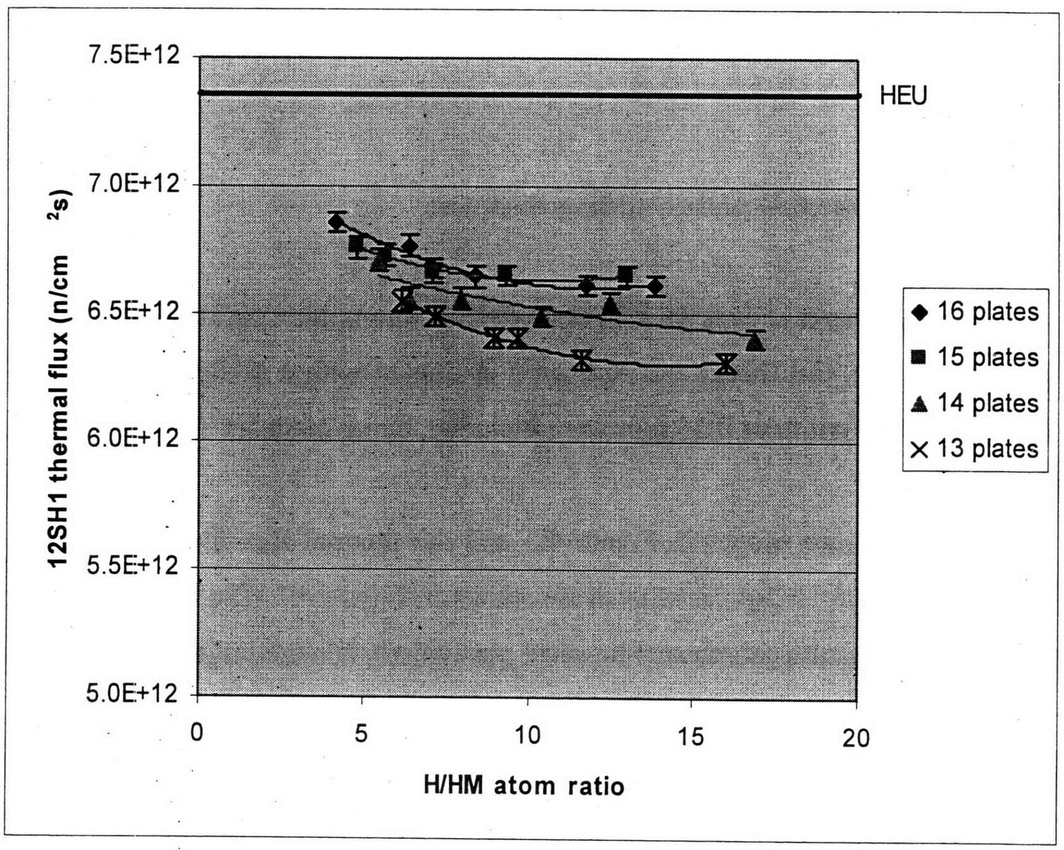

Figure 4.3 12SH1 thermal flux vs. H-HM for U-7Mo fuel

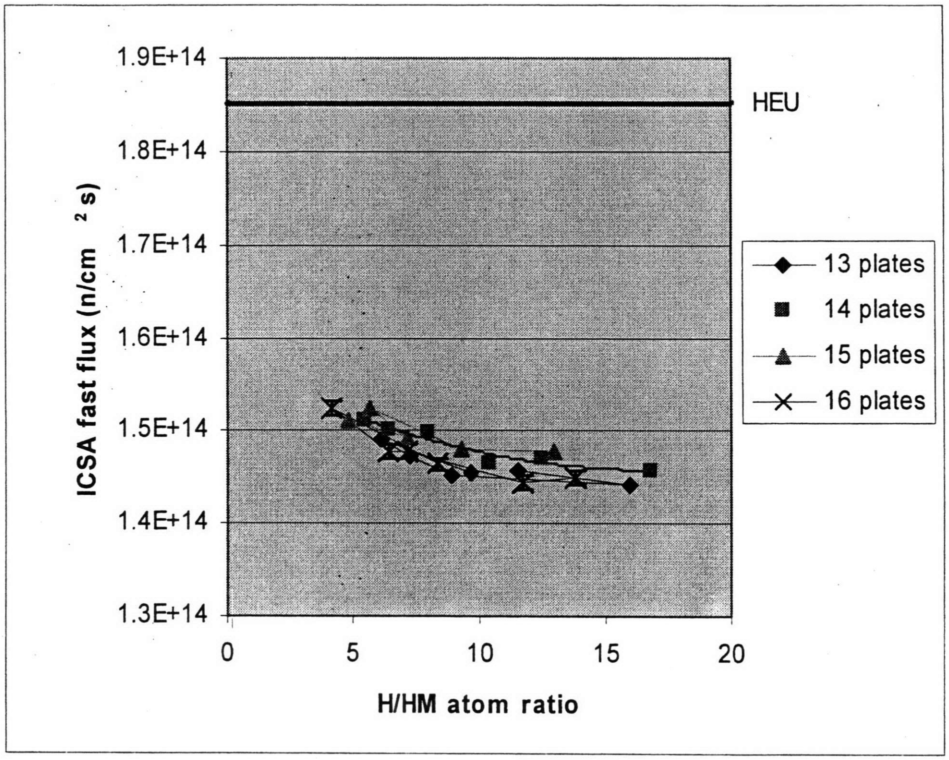

Figure 4.4 ICSA fast flux vs. H/HM for U-7Mo fuel

4.4 Reduction of the fuel plate cladding thickness

In an effort to increase available fluxes, and since monolithic fuel will allow the use of a thinner cladding, the fluxes and K_{eff} were evaluated with a 0.25 mm thick cladding. Fins of height and width of 0.25 mm were included, being modeled as solid aluminum of half height.

The K_{eff} results are shown in Figure 4.5 and the thermal flux results for 12SH1 are shown in Figure 4.6. ICSA fast fluxes are shown in Figure 4.7. The differences with the thicker cladding results can clearly be seen, particularly for the larger number of plates, since a larger amount of aluminum is being replaced by fuel and/or water in the core. The major effect of reducing the cladding is to increase K_{eff}, since the in-core spectrum is somewhat softer with the aluminum being replaced with water. In all cases, K_{eff} is increased by about 5 % $\Delta K/K$. However, this comes at the expense of the ex-core thermal fluxes, since the thinner cladding results show an across-the-board decrease of about 10%. This is as expected, since a softer spectrum would imply a higher fission cross-section, resulting in more thermal absorptions in fuel, increasing the reactivity. The in-core fast fluxes show an increase of about 10% for the thinner cladding. Thus, the core configuration must change in a way to use the available reactivity to enhance the experimental fluxes.

The trending of the results is similar to those using thicker cladding. That is, K_{eff} is larger for a smaller number of plates. However, cooling becomes more difficult with fewer plates since, for a given power level, more energy is generated per plate. Thus, it is generally advantageous to use a larger number of plates when possible. As in the thicker cladding results, K_{eff} peaks at an H/HM of around 10.

Fluxes, particularly the ex-core fluxes, show little variation with number of plates and show a slow trend upward with reduced moderation. The in-core fast flux, as expected, has a similar upward trend with less moderation and has somewhat larger fluxes with reduced number of plates, but does not vary more than 5% for a given H/HM. Other locations of experimental facilities show identical flux trends.

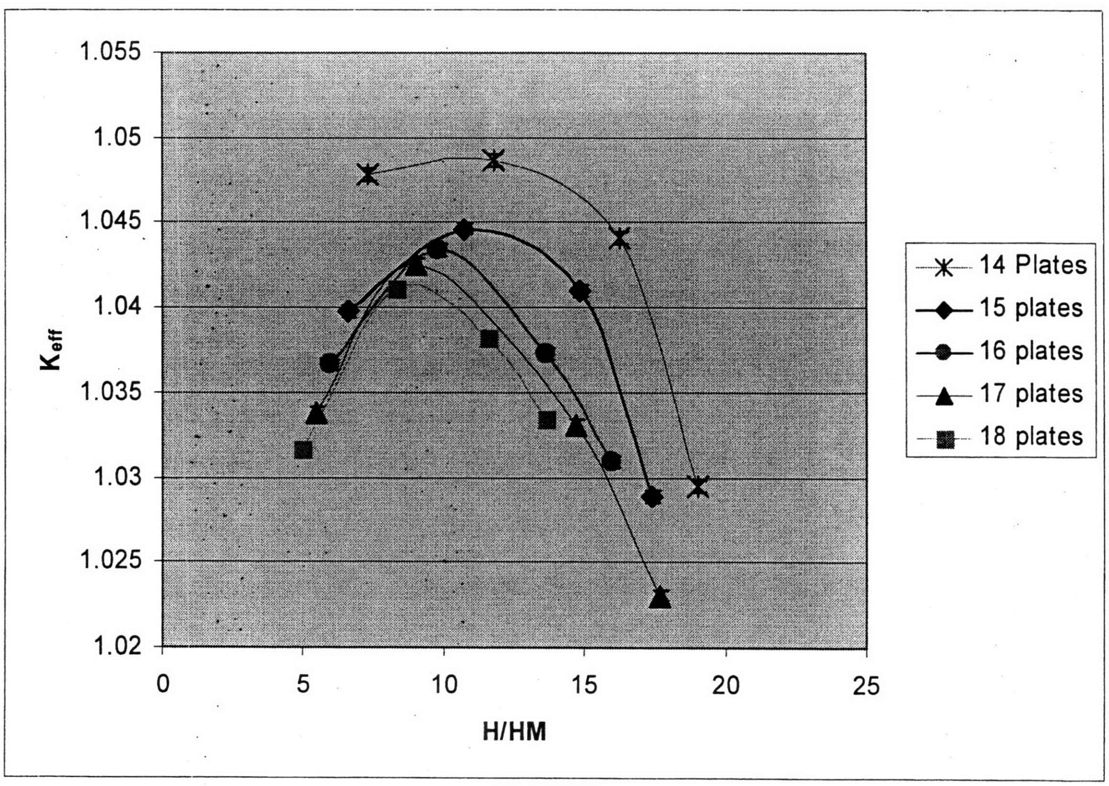

Figure 4.5 K_{eff} of U-7Mo LEU fuel with 0.25 mm cladding

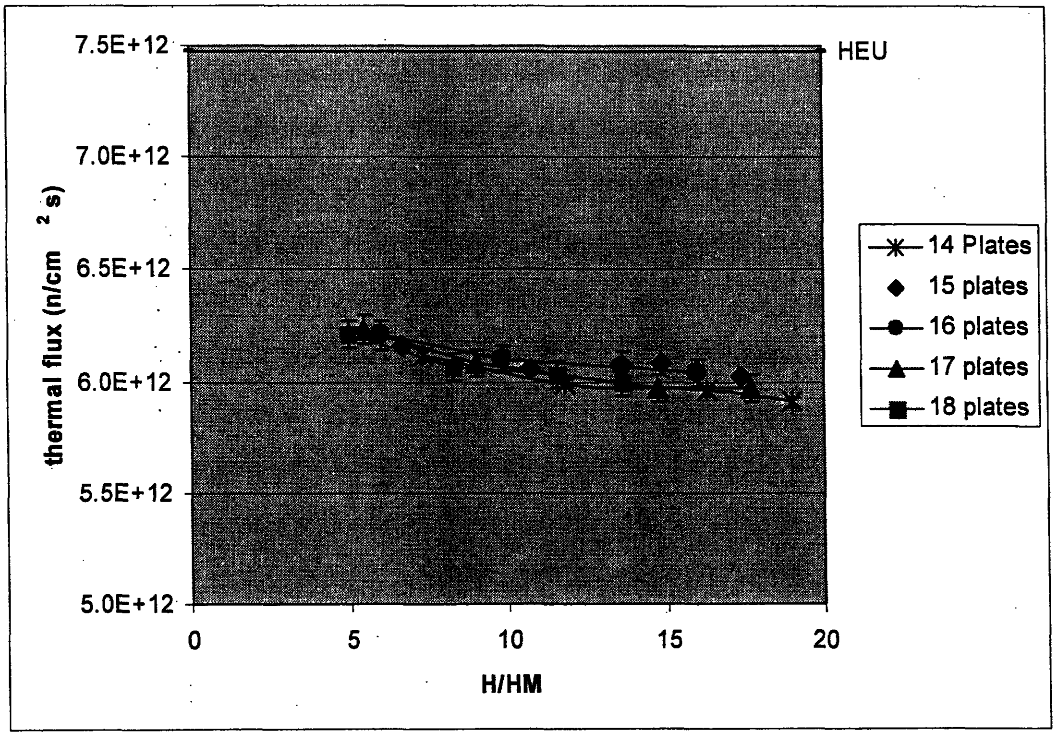

Figure 4.6 12SH1 thermal fluxes of U-7Mo LEU fuel with 0.25 mm cladding

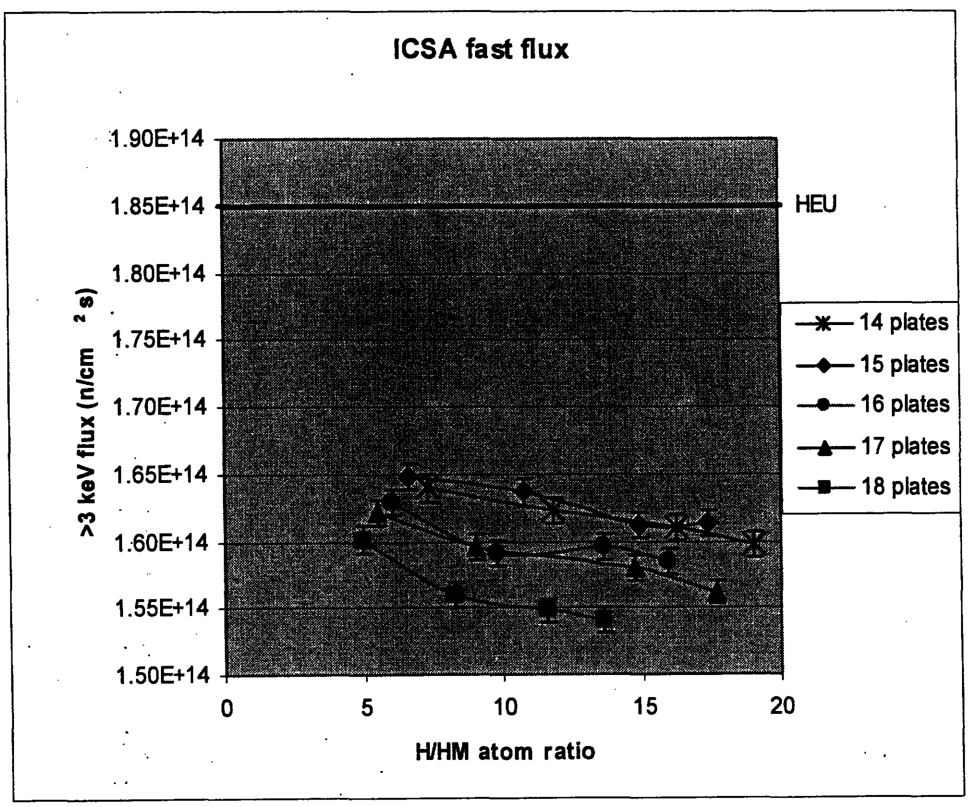

Figure 4.7 Fast fluxes in ICSA of U-7Mo LEU fuel with 0.25 mm cladding

Although there remains room for further in-core optimization, none of the experimental (i.e. external) fluxes can match those of the HEU core, as the thermal flux needed to maintain a certain fission rate is less in the LEU core. Fortunately, the larger K_{eff}s for the LEU cores give some margin to use to better optimize the core design for experiments.

Thus, for an H_2O moderated LEU core, the peak H/HM for K_{eff} is between 10 and 12. This corresponds to a core with fuel elements of eighteen plates with fuel thickness of about 0.43 mm. However, as stated above, in order to reach the stated goal of reaching experimental fluxes equivalent to the HEU core, further design changes of the reactor must be made. In particular, those involving re-distribution of ^{235}U away from the experimental space near the center will help increase the fluxes at the core center.

4.5 Addition of D_2O to the moderator/coolant

In an effort to increase fluxes, a change in the moderator material was studied. Again, under the constraint that the reactor will not undergo major reconstruction, the only options for a moderator/coolant would be H_2O, D_2O, or a combination of both. Unfortunately, an MITR-II with a complete D_2O moderator is highly subcritical under all conditions. Even a core with a moderator of 50% D_2O and 50% H_2O has a K_{eff} of less than 0.9, evaluated under the Core No. 2 conditions. Thus, any change in moderation would have to remain mostly H_2O. However, because of the larger diffusion length of D_2O, some amount of D_2O in the moderator will help enhance experimental fluxes.

The effect on 12SH1 fluxes with the use of D_2O is shown in Figure 4.8. For consistency and to reduce geometry effects, a plate thickness of 0.33 mm with a 0.25 mm finned cladding was chosen. This corresponds to an 18 plate H/HM of about 13. A slightly higher H/HM was chosen to try to offset any moderation decrease with the use of D_2O. Fluxes were evaluated at D_2O concentrations of 0, 20%, and 25%. A moderator of 25% D_2O clearly enhances the experimental fluxes to the point of reaching the HEU reference case. As can be seen even with the 20% case, any amount of D_2O in the moderator will help enhance the experimental fluxes.

However, as is shown in Figure 4.9, the effect on K_{eff} of the reactor is significant with the addition of D_2O. At a 25% D_2O concentration, it is difficult to approach criticality, although a larger number of plates have a slightly advantageous effect. In both the flux and K_{eff} effects, a larger number of plates per element (in this case a smaller moderator-to-fuel ratio) seem to have a small advantage.

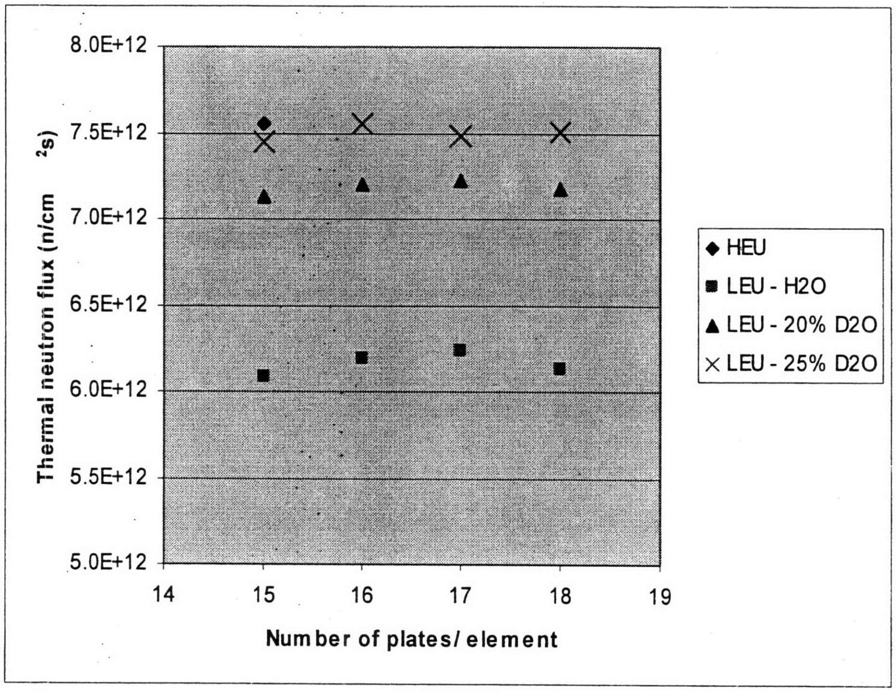

Figure 4.8 12SH1 fluxes with partial D_2O moderator

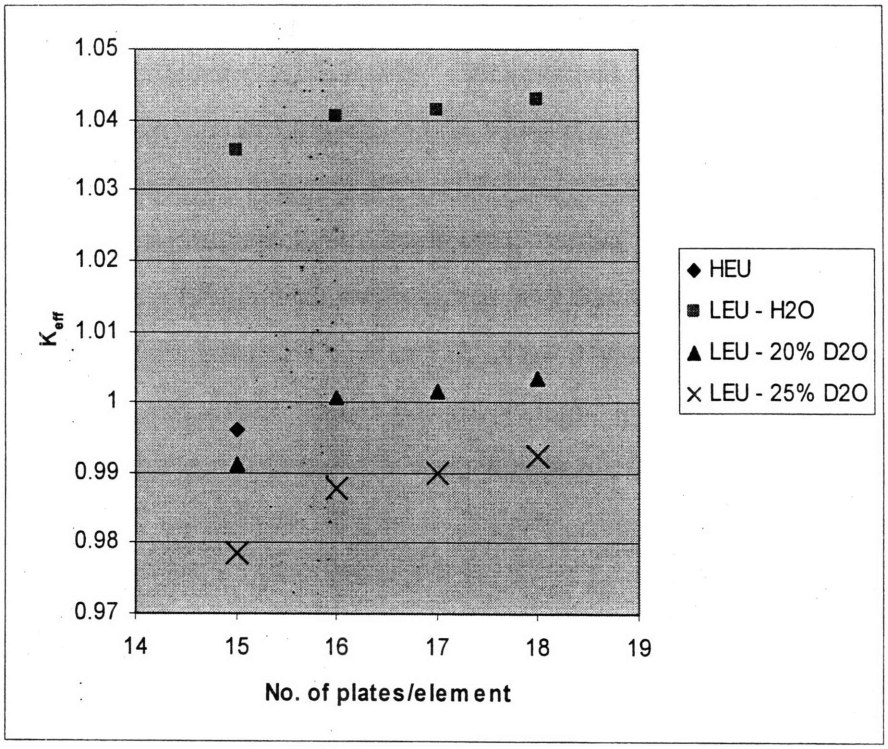

Figure 4.9 K_{eff} with partial D_2O moderator

The use of D_2O has problems, however. There could be considerable difficulty in maintaining a constant H_2O/D_2O ratio during operation. In addition, a sudden insertion of H_2O from a leak or emergency cooling action could result in a significant reactivity insertion. Also, the buildup of tritium in the primary system could make in-core maintenance and refueling operations more difficult and significantly increase personnel exposure. Because of these issues, the addition of D_2O was not considered immediately practical, and the idea was shelved in favor of other options.

4.6 Use of different cladding, spider, or solid dummy materials

Most of the results discussed above using an H_2O moderator showed a large K_{eff} at the expense of available flux. In an effort to better enhance the available flux, the use of different materials in cladding or solid dummies as well as insertion of absorbing materials in the spider was studied.

Table 4.2 shows the effect of different cladding materials using an 18-plate model with 0.55 mm (0.0217 inch) fuel thickness with 0.25 mm cladding. This arrangement corresponds to an H/HM of 7.5 and is a fairly close optimum. Although the zirconium cladding has a positive effect on K_{eff} because of the smaller absorption cross-section as compared with aluminum, neither zirconium nor beryllium cladding showed any enhanced flux effects for the ICSA, and, in fact had slightly lower ex-core fluxes. Although most of the materials work in the RERTR program has been focused on aluminum cladding, zirconium could be considered if available reactivity is at a premium. Beryllium was evaluated only for effectiveness. It is not seen as a practical alternative to aluminum.

Table 4.2 Cladding options using 18 plate U-7Mo LEU fuel with 0.55 mm fuel and 0.25 mm cladding

Cladding	K_{eff}	ISCA fast flux (n/cm^2 s)	12SH1 thermal flux (n/cm^2 s)
Aluminum	1.0491	2.22E+13	6.24E+12
Zirconium	1.0554	2.25E+13	6.16E+12
Zr + Zr side plates	1.0653	2.25E+13	5.95E+12
Beryllium	1.1004	2.22E+13	5.79E+12

Several alternatives using the absorber spider and solid dummies are presented in Table 4.3. Although a fully loaded absorber spider had low K_{eff} and had lower ex-core fluxes in all cases, an absorber in the inner section of the spider assembly results in an increase in the fluxes to the experimental facilities. The use of hafnium inserts is seen to be slightly more effective in increasing thermal fluxes. In addition, the use of an additional dummy in the A-ring also increases the flux to the ex-core experiments. Helium was also modeled in the A-ring to determine the possible effect on ICSA fast fluxes of voiding the dummy spaces. The actual use of helium dummies would present some operational difficulties.

The use of additional U-7Mo fuel in the spider was also considered. Although this did somewhat increase the ICSA fast fluxes, it resulted in a significant decrease in ex-core fluxes. Adequate cooling of these plates could also be difficult.

The combination of both an inner spider and unfueled A-ring caused a flux depression in the core fueled region while enhancing the flux below the core where the beam reentrant thimbles are located as well as at the core edges, near the graphite region. However, increasing the fluxes to the ex-core facilities will most likely come at the expense of the in-core facilities. It is clear that flexibility must be designed into the core to best meet the experimental needs at the time.

While the neutron fluxes are closer to meeting the goals of being equivalent to the HEU thermal neutron fluxes, no configuration has been found to be equivalent. Thus, the fuel arrangement within the core structure will be further modified.

Table 4.3 A-ring and spider materials effects on K_{eff} and fluxes for 18 plate U-7Mo LEU fuel elements

A-ring materials	Spider material	K_{eff}	ICSA fast flux (n/cm^2 s)	12SH1 thermal flux (n/cm^2 s)
HEU reference (1/3 fuel)	Water	0.9987	1.85E+14	7.36E+12
all Al	Water	1.0086	1.55E+14	6.67E+12
1/3 fuel	B inner, H_2O outer	1.0195	1.25E+14	6.71E+12
all Al	B inner, H_2O outer	0.9917	1.46E+14	6.99E+12
all Al	Hf inner, H_2O outer	0.9820	1.37E+14	7.28E+12
all Al	Cd inner, H_2O outer	0.9887	1.43E+14	7.04E+12
all He	Water	0.9858	1.60E+14	7.12E+12
all Al	U-7Mo LEU fuel	1.0157	1.78E+14	6.47E+12
all He	U-7Mo LEU fuel	0.9865	1.78E+14	6.91E+12

4.7 Use of half-width fuel elements

In order to better deliver the fluxes to experimental facilities, the core and fuel was redesigned into the configuration shown in Figure 4.9. In this design, fuel elements are reduced to half size so that, except for the A-ring fuel for ICSA flux enhancement, the center of the B ring is the inner edge of the fuel within the reactor. This radial location is also approximately the inner edge of the beam port reentrant thimbles below the core. The reduction in the amount of ^{235}U forces the thermal flux to increase to provide the same power on a core-wide basis. Local spectrum changes, however, lead to changes in the effective cross-sections which would alter the flux as well.

This core design offers a number of advantages in addition to experimental flux increases:

1. It allows greater flexibility in configuration of the core to accommodate in-core experiments, including the possibility of using the entire A-ring for one or more experiments. Fuel can also be placed near the experimental facilities if needed for flux enhancement.
2. It allows greater flexibility in refueling in that peaking may be reduced by placing a partially spent element in roughly twice the number of locations. In addition, the symmetry of the core may allow easier refueling calculations and refueling strategies.
3. Through the use of different solid dummy materials, the spectrum for in-core experiments may be adjusted.

This configuration, with the addition of the absorber spider, serves to increase fluxes both outward and downward towards the locations of all ex-core experimental facilities.

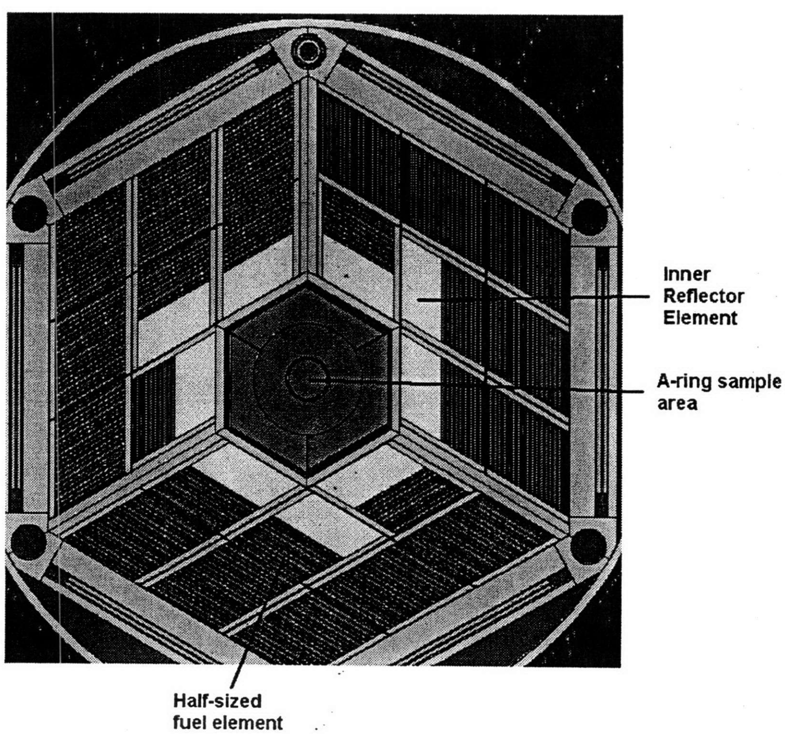

Figure 4.10. MITR half-element core design

Initial results of some options for this configuration using a 9 plate half-element with 0.55 mm thick fuel and 0.25 mm clad are presented in Table 4.4. In these results, the materials in the A ring dummy elements, the inner B ring and corner B ring elements (B-2, B-5, and B-8), and the spider were varied to determine the effect on K_{eff} and ex-core thermal fluxes. The optimization of the interior of the core for in-core experiments is discussed in Chapter 5.

Varying the materials in the inner reflector region yielded some improvement in ex-core fluxes, but HEU fluxes could not be reached without the use of the spider. The use of graphite increased the ex-core fluxes some, but it was later found to decrease ISCA fast fluxes more than beryllium, as well as decrease K_{eff}. These results indicate that the HEU ex-core fluxes can be approached using this LEU configuration with absorber spider, particularly when using beryllium in the A ring as well.

Because of the lack of fuel in the inner part of the core, it was found that use of the inner spider alone had little reactivity and ex-core flux effects. Thus, when used, either the outer or the entire spider structure contained absorbent material.

Table 4.4. Results using U-7Mo LEU fuel with 9 plate (0.55 mm thick) half-elements

A ring dummy elements	Inner B ring material	B ring corner elements	spider material	K_{eff}	12SH1 thermal flux (n/cm^2 s)
HEU reference (Al/fuel)			water	0.9987	7.36E+12
Aluminum	Beryllium	fuel	water	1.0362	6.35E+12
Aluminum	Beryllium	1/2 Be	water	1.0132	6.59E+12
Aluminum	Graphite	½ graphite	water	1.0019	6.79E+12
Aluminum	Fuel	fuel	full B-SS	1.0492	6.47E+12
Aluminum	Beryllium	1/2 Be	full B-SS	1.0055	7.11E+12
Aluminum	Beryllium	Solid Be	full B-SS	0.9703	7.74E+12
Beryllium	Beryllium	Solid Be	outer B-SS	0.9943	7.19E+12
Beryllium	Beryllium	Solid Be	full B-SS	0.9741	7.62E+12

Again, as in the conventional core designs, the half-element configuration was used to determine the optimum fuel element design. The thickness of the 8, 9, and 10 plate half-elements was varied, and K_{eff} and 12SH1 thermal fluxes were evaluated for a core consisting of a full boron-stainless steel spider and beryllium in the A-ring and inner B ring and with solid beryllium elements in the B ring corner elements, as shown in Figures 4.11 and 4.12. Similar to analyses above, the K_{eff} was larger for fewer plates, being at 0.96 or less for 10 plate half-elements and at almost 0.99 for 8 plate half-elements. Because of the increase of moderation in the inner reflector region, the peak of K_{eff} occurs an H/HM of about 7, which is somewhat smaller than the peak H/HMs of 10 for the more conventional cores discussed above. It should be noted that, as also seen in Table 4.4 above, a number of options exist to increase the K_{eff} values.

In contrast to the K_{eff} results, the 12SH1 thermal fluxes, shown in Figure 4.12, were larger for a greater number of plates. The HEU value of 7.36×10^{12} n/cm^2 s was exceeded in all cases, peaking at an H/HM of about 5.

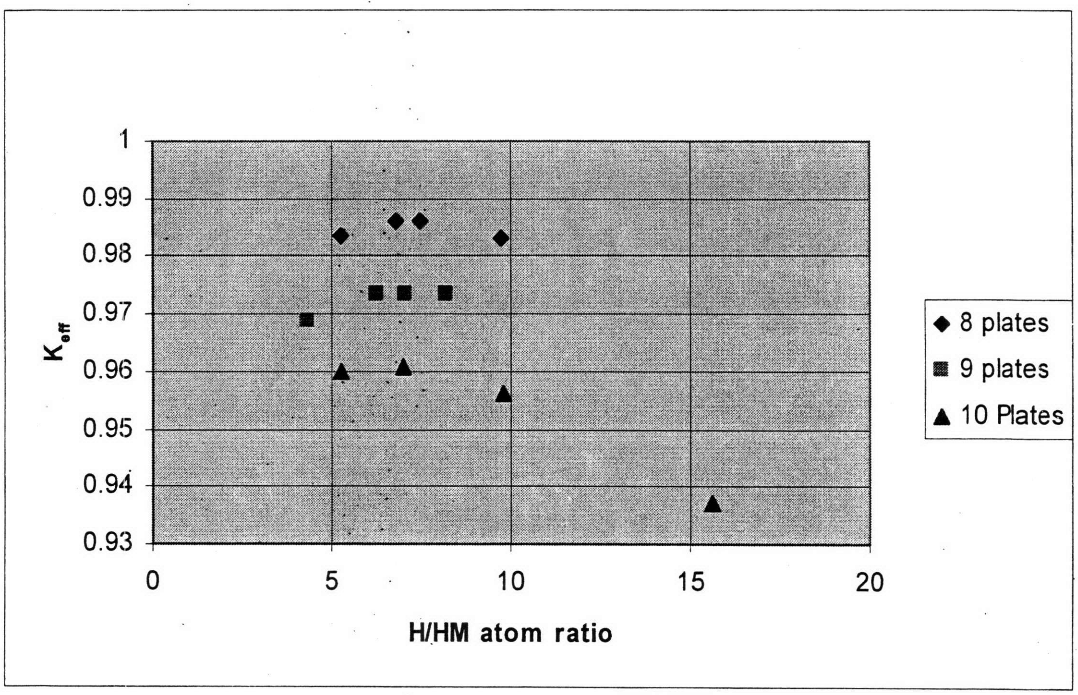

Figure 4.11. K_{eff} results of half-element core configuration

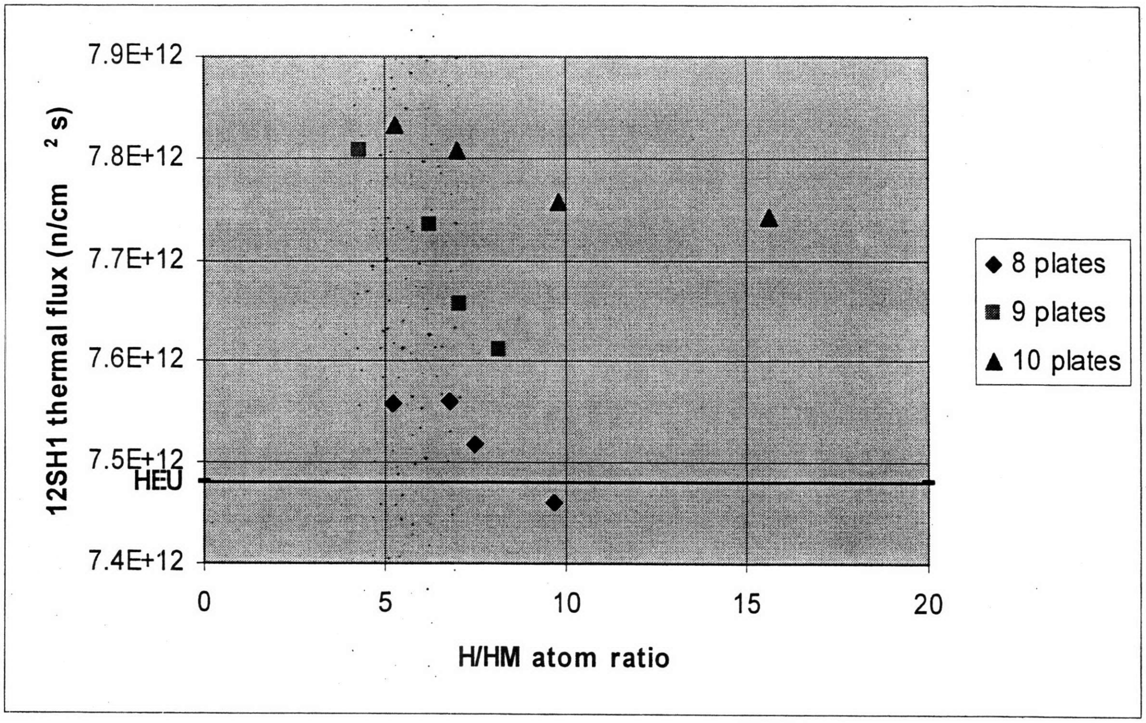

Figure 4.12. 12SH1 thermal flux results of half-element core configuration

Table 4.5 shows the results of use of a 9 plate half element core with 0.55 mm fuel and internal beryllium reflector with full boron-stainless steel spider. This shows considerable improvement in all ex-core fluxes as compared with the HEU reference case. However, it is also about 3% subcritical, again demonstrating that there remains a trade-off between reactivity and available fluxes.

Table 4.5. K_{eff} and flux comparisons with the use of LEU 9 plate half-element core

	HEU Core No. 2	LEU 9 plate half element core
K_{eff}	0.99873 +/- 0.00036	0.97354 +/- 0.00030
12SH1 thermal flux (n/cm^2s)	7.36×10^{12}	7.61×10^{12}
2PH1 thermal flux (n/cm^2s)	9.74×10^{12}	9.85×10^{12}
2PH1 fast flux (n/cm^2s)	8.19×10^{10}	9.45×10^{10}
Fission converter window thermal flux (n/cm^2s)	8.48×10^{11}	8.57×10^{11}
H_2O shutter thermal flux (n/cm^2s)	1.51×10^{11}	1.52×10^{11}

In addition to the experimental facilities evaluated as shown in Table 4.5, there is concern that, since the MITR Fission Converter facility uses fuel from the MIT Reactor, there could be some degradation of the beam intensity and quality as delivered to the patient position in the FC medical room. Figure 4.13 shows a comparison of spectra from the actual initial loading of the Fission Converter with ten partially spent HEU fuel elements, and from a twenty half-element loading of fresh 9 plate U-7Mo LEU fuel for both an HEU and LEU fueled reactor. Since the configurations are so similar and there is significant moderation of fast neutrons in the beam, the use of LEU fuel in the Fission Converter causes no degradation of the epithermal beam.

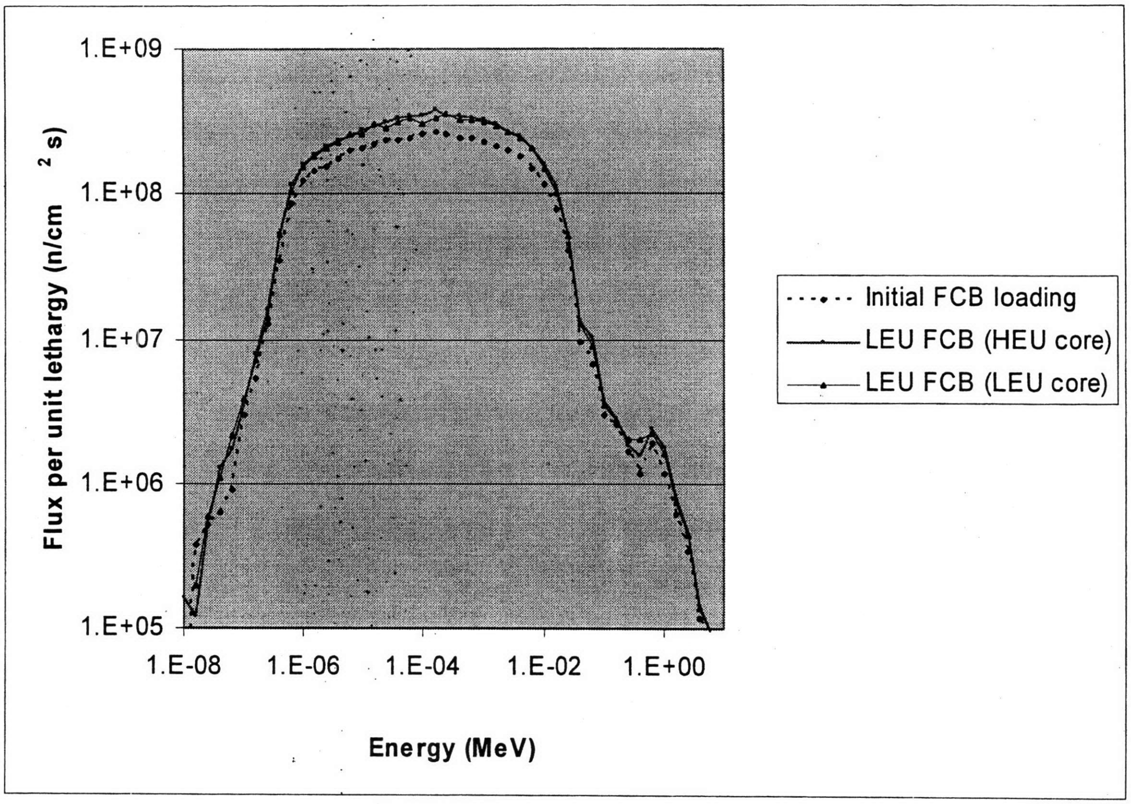

Figure 4.13 Neutron spectra at patient position of fission converter beam

4.8 Conclusions

The options explored above are summarized in Table 4.6, which shows the effect on experiment fluxes for the best results in the cases considered.

Direct replacement of HEU with U-7Mo monolithic LEU fuel results in a negative reactivity of about 1.2 %ΔK/K, as well as a 10% to 20% loss in experimental neutron fluxes. Optimization of an LEU core, with both 0.38 mm clad and 0.25 mm clad, results in a peak of K_{eff} at a hydrogen-to-heavy metal ratio of about 10, but with little improvement in experimental fluxes. Use of the thinner cladding results in a reactivity addition of about 5%ΔK/K, leaving room for some core improvements.

Changing the moderator/coolant in the reactor to partial D_2O results in improvement of fluxes, but at a considerable reactivity loss. Because of operational issues, a use of a H_2O/D_2O mixture was not considered immediately practical.

A number of options for improving fluxes were considered, including use of different materials in the absorber spider. Some of these options showed limited improvement in enhancing the experimental fluxes, but none attained the HEU fluxes. Thus, a new core configuration with internal reflector and absorber spider was evaluated. This core was able to produce fluxes outside the core that were equivalent to or greater than the HEU fluxes. Fluxes to the in-core facility, particularly fast fluxes will need to be improved by a choice of materials designed to enhance these fluxes.

Table 4.6 Summary of LEU design options

Option	Ratio of 12SH1 thermal flux to HEU core	Ratio of ICSA fast flux to HEU core	Comments
Direct substitution	0.92	0.82	
Optimization of fuel thickness	0.92	0.83	Little improvement
Reduction of cladding thickness	0.85	0.89	Some reactivity addition
Use of D_2O in moderator	1.0	0.96	Difficulties in implementation; reactivity loss
In-core materials optimization	0.99	0.96	Some improvement
Half-element configuration with Be inner reflector	1.04	0.84	ICSA to be further optimized

Chapter 5
In-core Flux Optimization

5.1 Introduction

Although the half-element core configuration proposed in Chapter 4 shows promise for ex-core fluxes, the needs of in-core experiments must be met through the placement of materials near the experiment itself. Table 5.1 shows the fluxes available in the in-core sample assembly (ICSA), a 5 cm diameter helium-filled tube located in the A ring (in this case the A-3 position). The LEU core is the nine-plate half element configuration with 0.55 mm plates featured in Table 4.5, and contains beryllium in the inner B ring elements with solid beryllium (1.82 g/cm^3) in the corner B ring elements and two A ring elements and with boron-stainless steel spider inserts.

It is interesting to note that although all of the ex-core fluxes are higher than the HEU reference case, the in-core fluxes are significantly lower, particularly the thermal flux which is adversely affected by the absorber spider. The fast flux is almost 20% lower than the HEU reference case.

Table 5.1 ICSA flux comparisons between HEU reference core and nine plate half- element LEU core

Neutron Energy	HEU reference flux (n/cm^2 s)	Nine plate half element LEU flux (n/cm^2 s)
Thermal (<0.4 eV)	4.31E+13	2.39E+13
Epithermal (0.4 eV-3keV)	7.96E+13	6.71E+13
Fast (>3 keV)	1.85E+14	1.56E+14

5.2 ICSA Fueled Annulus

Although a number of configuration changes were evaluated, none was found to increase the ICSA fast flux to near HEU levels without the use of fuel in the A ring. In order to increase the fast flux, a 1/16 inch (1.59 mm) annulus of U-7Mo LEU fuel surrounding the ISCA tube in the center of the A-ring was modeled. This fuel was surrounded by a 1 cm annulus of water for cooling. An MCNP generated diagram of this is shown in Figure 5.1.

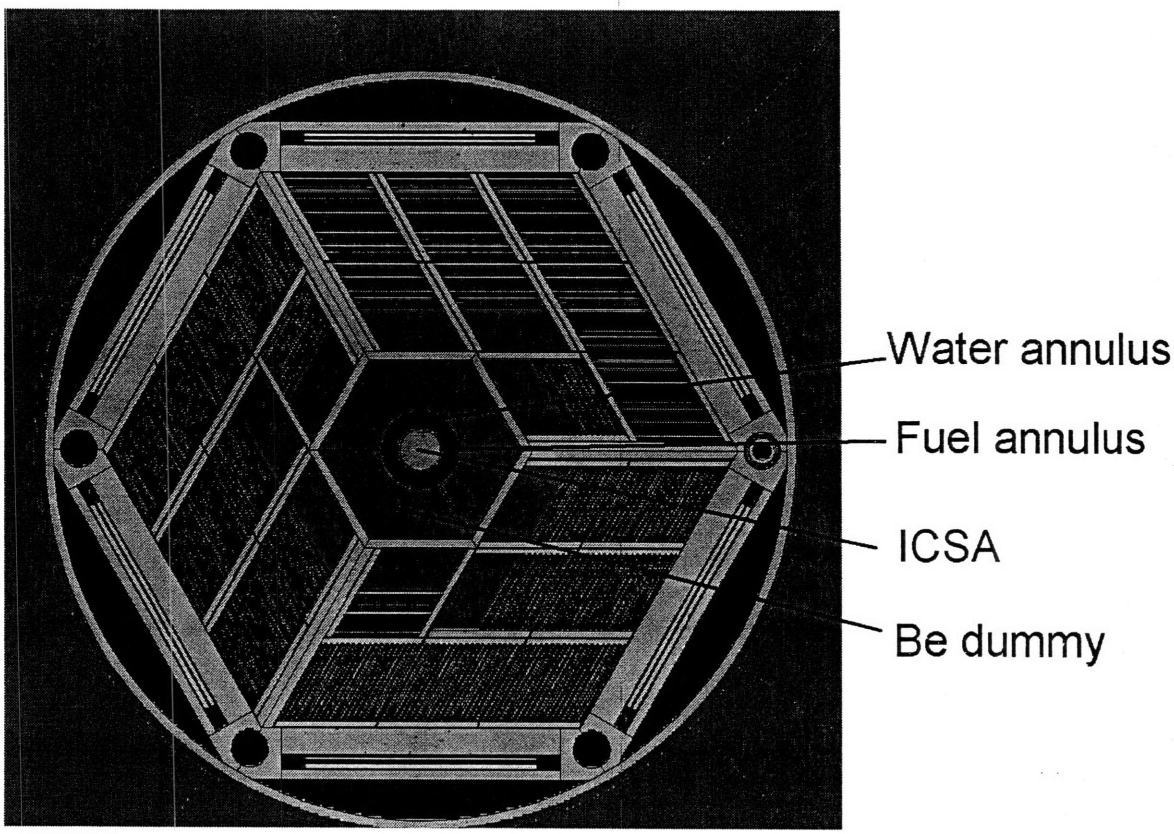

Figure 5.1 LEU core with fueled annulus around ICSA

Results of several permutations with varying spider configurations are shown in Table 5.2. This shows the K_{eff}, 12SH1 thermal flux and ICSA fast flux. In order to reduce B ring peaking, in two cases a boron lining was added to the B ring inner beryllium section adjacent to the B ring fuel. These results show the effect of the fueled annulus. The ICSA fast flux is enhanced with the use of a fueled annulus, particularly when only a partial spider is used.

A trade-off between ex-core and in-core fluxes can also be seen when a full spider is not used. The use of a boron lining in the beryllium reflector helps to both reduce the B ring power peaking and enhance the ICSA fast flux to the point of exceeding the HEU flux.

However, considerable uncertainties exist as to whether a fueled annulus of monolithic, U-7Mo can be manufactured. The possibility of using 5% enriched UO_2 in an annulus around the ICSA was explored. However, the fast flux within the ICSA was about 30% less than the HEU case.

In addition, power peaking in a fueled annulus was unacceptably high, being almost five times higher than in an average fuel plate. Thus, other options of placing fuel near the ICSA must be explored. The use of 0.84 mm flat plates located on the edges of the A ring was explored. These fluxes, shown in the last two rows of Table 5.2, show some improvement, being just shy of the HEU values. However, it was also found that heat generation within these plates could lead to cooling problems, with the peaking being three times higher here than in an average plate. Power peaking and heat transfer is discussed further in Chapter 6.

Table 5.2 K_{eff} and flux results of use of fueled annulus around ICSA

Description	Spider	K_{eff}	12 SH1 Thermal flux (n/cm^2 s) (HEU = 7.55E+12)	ICSA fast flux (n/cm^2 s) (HEU=1.85E+14)
Fueled annular ICSA	Boron in all	0.99756	7.30E+12	1.55E+14
Fueled annular ICSA	Hafnium in all	0.9816	7.72E+12	1.48E+14
Fueled annular ICSA	Hafnium in B arms only	1.0108	7.02E+12	1.90E+14
0.038 cm Boron lined Be B-ring reflector	Hafnium in upper B arms only	1.00064	6.67E+12	2.00E+14
Thicker Boron lining (0.06 cm)	None	0.99111	6.67E+12	2.01E+14
Fuel plates on outer A flats	Boron in all but C arms	0.98057	7.55E+12	1.77E+14
Same as above, Be next to A fuel plates	Boron in all but C arms	0.97955	7.55E+12	1.80E+14

5.3 Fuel in half of A ring

One possible configuration is that of using the half-sized fuel element arranged within the A-ring as shown in Figure 5.2. In this configuration, fuel is placed close to a centrally located ICSA, thus enhancing the fast flux. Orificed aluminum half-element dummies were placed adjacent to the ICSA to avoid the moderating effects of beryllium, which would soften the spectrum. In addition, a full spider with boron-stainless steel inserts was included in all cases using beryllium. Sufficient flexibility can be incorporated into this design to allow for multiple in-core experiments as can be seen in Section 5.5.

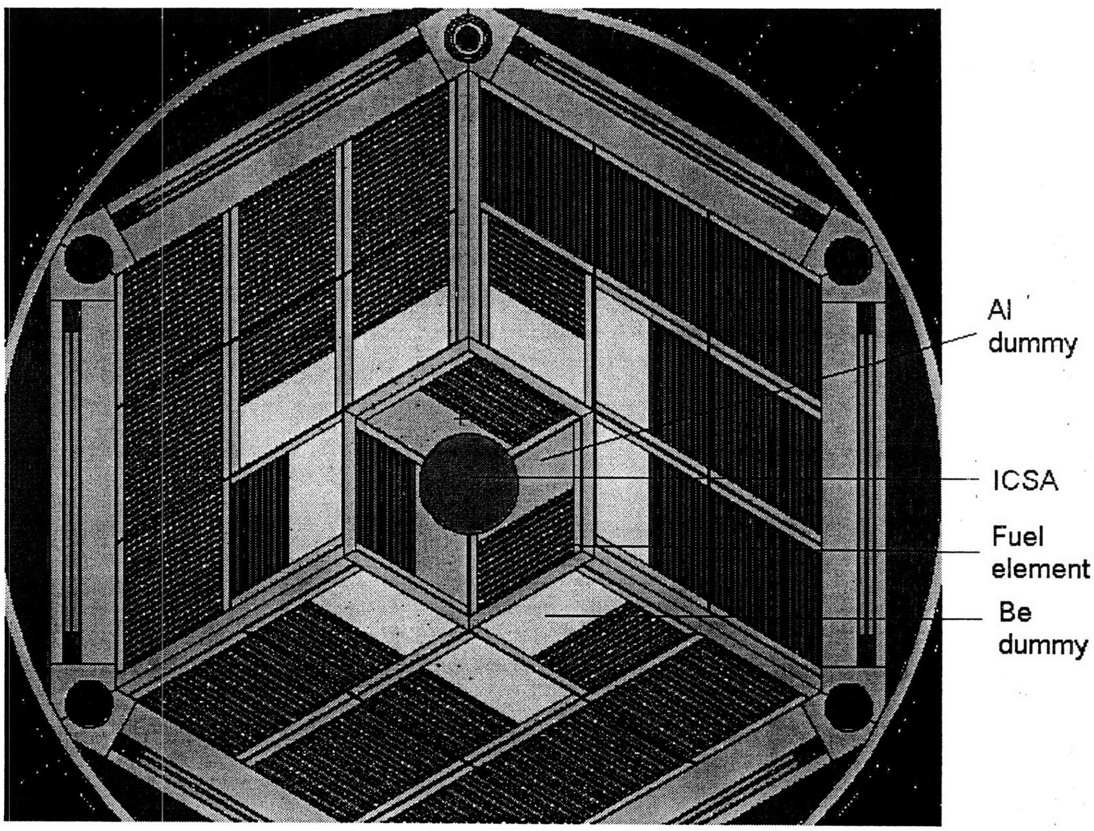

Figure 5.2 Half-element core with fuel in A ring.

The fast neutron flux and K_{eff} results of some material combinations in this design are shown in Table 5.3. The use of either aluminum or helium in the A-ring dummy positions made little difference in the ICSA fast flux, each case being about 10% below the HEU base case of 1.85 x 10^{14} n/cm^2 s. A lead-bismuth eutectic in the A-ring dummy positions was also modeled and showed little improvement in fast flux over aluminum.

The effect of using beryllium in place of A-ring fuel was also evaluated to explore the possibility of the use of a thermal neutron irradiation facility in-core. This showed a thermal flux increase of 20% over the HEU reference case.

Finally, two ICSAs were positioned in the A-1 and A-3 positions and showed slightly lower but identical fluxes. Of course, materials present inside the ICSA would have a significant effect on adjacent facilities. With the exception of the all-beryllium case, all K_{eff}s were at 0.99 or higher.

Table 5.3 Half-element A-ring K_{eff} and ICSA fast flux results

A ring	B ring	B corners	ICSA annulus	Notes	K_{eff}	ICSA fast flux (n/cm^{2}s) HEU=1.85E+14
Al/ fuel	1/2 Be	1/2 Be/Al	Al	Fuel in 1/2 A elems. Al 1/2 dummies in B3,6,9	0.997	1.68E+14
Al/ fuel	1/2 Be	1/2 Be	Al	Fuel in 1/2 A elems.	1.01255	1.70E+14
Al/ s. fuel	1/2 Be	1/2 Be	Al	Burned LEU fuel in A ring	0.99982	1.62E+14
Al/ fuel	1/2 Be	1/2 Be	He	fuel in 1/2 A, He annulus	1.01108	1.70E+14
He/ fuel	1/2 Be	1/2 Be	He	fuel in 1/2 A, He other 1/2 A	1.01097	1.70E+14
Pb-Bi/fuel	1/2 Be	1/2 Be	Pb-Bi	fuel in 1/2 A, Pb-Bi A dummies	1.01134	1.70E+14
Be	1/2 Be	1/2 Be	Be	All Be dummies	0.9856	7.98E+13
fuel/2ICSAs	Fuel/3 Be dummies	fuel	Al	A3, A1 ICSA	1.04139	1.54E+14 (each)

In order to try and increase the fast flux, the density of the beryllium in the B-ring was reduced to 75% of theoretical (1.3 g/cm^3). This density is fairly easily attainable through the use of beryllium spheres of different sizes placed within a dummy assembly. Results of selected cases with boron in the complete spider are shown in Table 5.4.

All cases had fast-to-thermal flux ratios exceeding that of the HEU base case. However, none of the cases showed a significant improvement of fast flux over the full density beryllium cases. In fact, no case was identified that would give a fast flux equivalent to the HEU core using beryllium in the inner regions. Thus, other options to reduce the moderation in the center of the core were explored.

Table 5.4 Reduced density beryllium K_{eff} and ICSA flux results

A ring	Annulus	Notes	K_{eff}	ICSA thermal flux (n/cm²s) HEU=4.31E+13	ICSA fast flux (n/cm²s) HEU=1.85E+14
Al/ fuel	He		0.99898	1.59E+13	1.70E+14
Pb-Bi/fuel	Pb-Bi	Pb-Bi other 1/2 of A	1.00142	1.61E+13	1.71E+14
Al/ fuel	He	full fuel in B1,4,7	1.01815	1.42E+13	1.71E+14

In order to reduce the moderation and thus harden the spectrum in the core center, the beryllium dummies in both the B ring and A ring were replaced with lead or lead-bismuth dummies. The results, given in Table 5.5, show a significant improvement in the ICSA fast flux, with values slightly exceeding the HEU case in both the lead and lead-bismuth cases where no spider was used. In these cases, K_{eff} values were also close to unity. However, the ex-core fluxes showed a reduction of about 8% when compared with the HEU case.

Table 5.5 K_{eff} and ICSA flux results for Pb-Bi in place of Be in A and B rings

A ring	spider	annulus	K_{eff}	Thermal flux (n/cm²s) HEU=4.31E+13	Fast flux (n/cm²s) HEU=1.85E+14
Pb-Bi/fuel	none	He	0.99582	2.35E+13	1.91E+14
Pb-Bi/fuel	inner B	He	0.97976	1.49E+13	1.73E+14
Pb/fuel	none	He	0.99468	2.34E+13	1.92E+14

Although the melting point of solid lead is fairly low (327 °C) as compared with other materials, the melting of lead produces no real chemical reactivity issues. The possible expansion and melting of lead will have to be addressed in the dummy design, particularly since gamma heating in core may be significant. However, this should not be difficult, since an appropriate void space for expansion can be made and cooling holes can be placed inside an encapsulated dummy with no significant spectral softening. The addition of bismuth in the dummy did not significantly change the spectrum and since a lead-bismuth mixture (particularly the eutectic form which melts at 125 °C) has a melting point much lower than solid lead, the lead dummy core was chosen to be the design basis for the LEU fueled core. Additional safety analyses are discussed in Chapters 6 and 7.

This core design is also more advantageous for in-core experiments in that the absorber spider is not used. Although the spider increases available fluxes at the bottom of the core for ex-core experiments at the expense of the upper core fluxes, the flux gradients in the core are more severe, which could make it more difficult to meet the in-core experiments' needs. However, the lack of fixed absorbers also make the loaded excess reactivity higher, being about 5% ΔK/K, as compared with about 3% ΔK/K for the HEU core configuration no. 2. A discussion of the resulting blade worths and shutdown margin is discussed in Section 7.5.

A possible disadvantage to using high density LEU fuel is the loss of gammas to in-core facilities. This could be important for those experiments which rely upon gamma heating to increase the experimental temperatures. MCNP runs show that the gamma flux to an in-core experiment using the lead dummy LEU core design results in a reduction of gamma flux to the central ICSA facility by almost a factor of five. Use of other materials in the dummies such as aluminum could increase the ICSA gamma flux somewhat, but will come at the expense of fast neutron flux. No combination of dummy material was found to approach the HEU ICSA gamma flux.

5.4 Spectrum comparisons

In order to show the neutron spectra for various facilities of interest, a constant lethargy (u=0.1) flux tally was made in the ICSA with varied choice of materials in the A-ring. Figure 5.3 shows a comparison of the spectra within the ICSA between the HEU core and LEU cores in both the HEU configuration and using the lead inner region as described above. The effect of resonances in the epithermal region can clearly be seen in all cases. In addition, all cases have a thermal peak at slightly less than 0.1 eV.

These results show that with both HEU and LEU cores being configured as in core configuration No. 2, the spectrum for the LEU core has significantly less flux than the HEU core at both fast and thermal energies. Only with the addition of a lead interior in the design can the LEU fast neutron flux reach that of the HEU. If desired, the flux can be softened to increase the thermal flux by the addition of a water annulus. This will, of course, come at the expense of the fast flux.

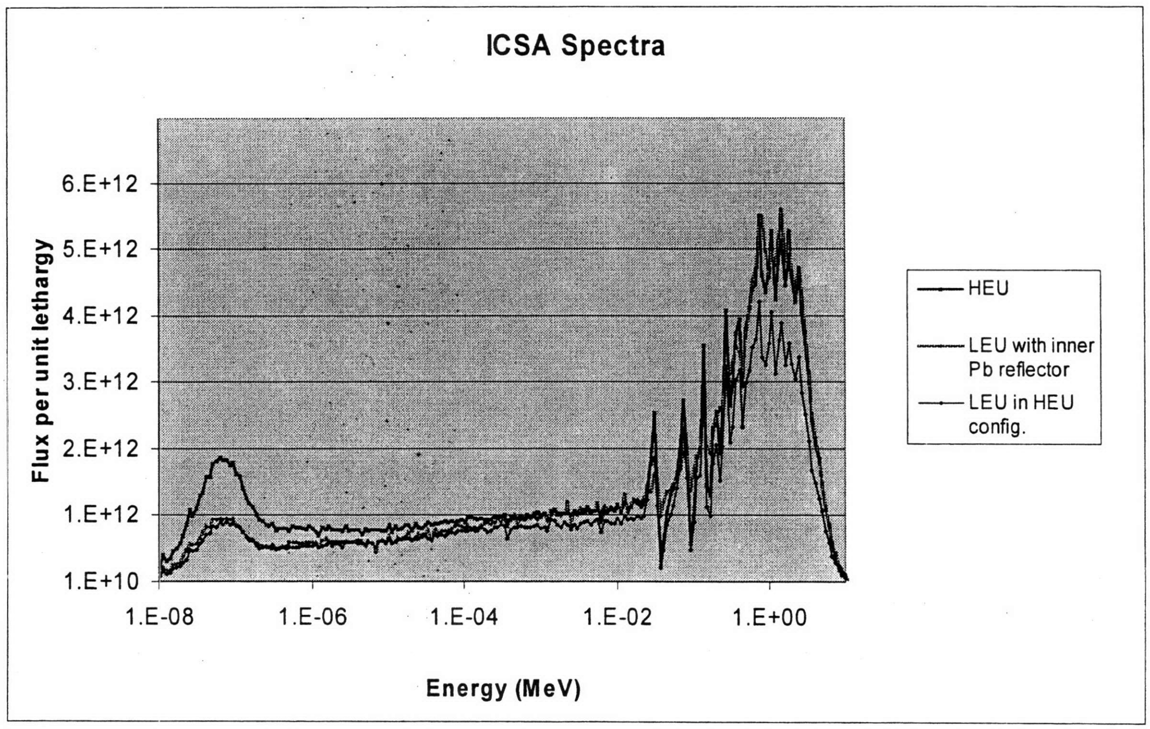

Figure 5.3 ICSA spectrum comparisons

Since experimental users of the in-core facilities would ideally like to match the spectra of power reactors of interest, the same tallies were used to compare with selected reactor designs. Figure 5.4 shows the spectral comparisons between the ICSA in the HEU reference core, the LEU half-element core with lead and fuel in the A-ring, and a 1250 MWe pressurized water reactor. To show the spectral effects, a water annulus was included in a second LEU case. With the exception of the water annulus case, the fast fluxes between the HEU, LEU and PWR cases were all very similar. The thermal flux was lower for the lead LEU case, but much higher when a water annulus is added. The

PWR thermal flux peak occurs at a slightly higher energy than the MITR cases because of the higher moderator temperature.

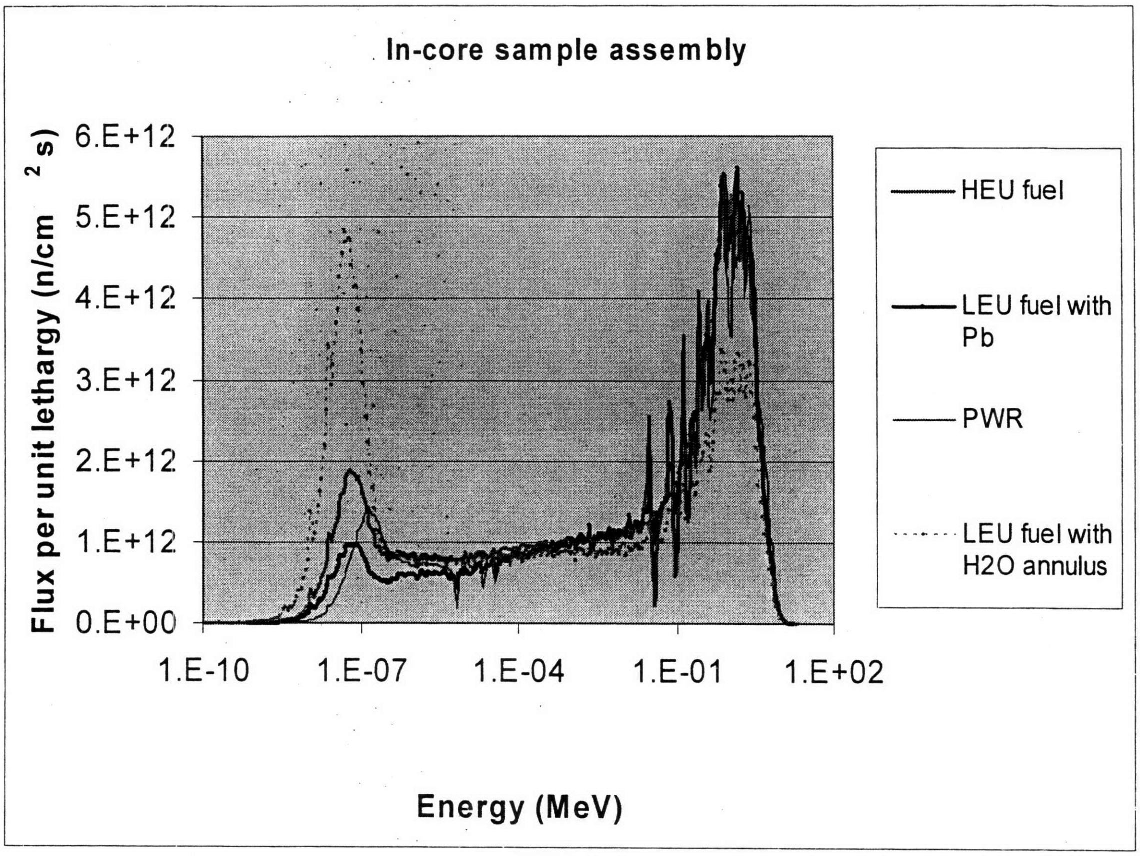

Figure 5.4 Comparison of spectra with thermal reactors

Figure 5.5 shows a comparison of spectra of the ICSA fluxes as compared with fast reactor designs, in this case the Superphenix fast reactor, modeled at a power level of 1200 MWe with both sodium and lead-bismuth eutectic coolants. Even though the shapes at energies above 1 MeV are fairly similar, the magnitude of the fluxes at any energy above about 1 keV could not be matched by the MITR ICSA, regardless of the choice of materials. However, it would be difficult for any research reactor at moderate power levels to match the fast neutron flux of a large fast reactor.

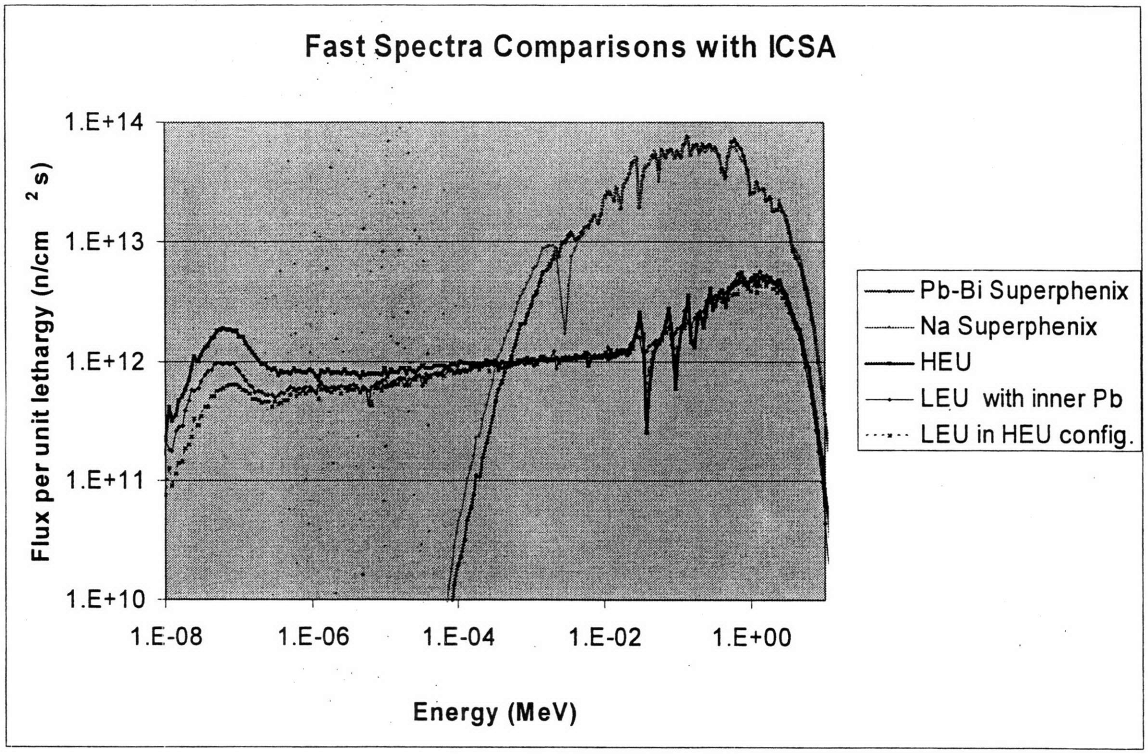

Figure 5.5 Comparison of fluxes and spectra with fast reactors

5.5 Configuration options

The above results show that an LEU U-7Mo core using half-sized elements, with lead in the B-ring and A-ring dummies as well as half-sized elements surrounding the ICSA, can provide equal fast flux to the HEU core. However, the core design should include enough flexibility to meet a variety of experimental needs. Several possible in-core configurations to meet some of these needs are summarized in Figure 5.6-5.9. The fuel configurations were chosen here to maintain approximate criticality as compared with the LEU design basis case. Of course, the actual configuration would depend on the reactivity worth of the experiment as well as fuel burnup.

Figure 5.6 shows a configuration with two fast neutron irradiation facilities. In order to make up for the reactivity loss with two of the A-ring elements, four B ring lead dummies were replaced with fuel. Fuel elements were placed adjacent to the irradiation facilities to enhance the experimental flux. Figure 5.7 shows a configuration where the two facilities have different spectral needs, with the facility in the A2 position being surrounded by fuel and lead for a fast spectrum and the facility in the A3 position having

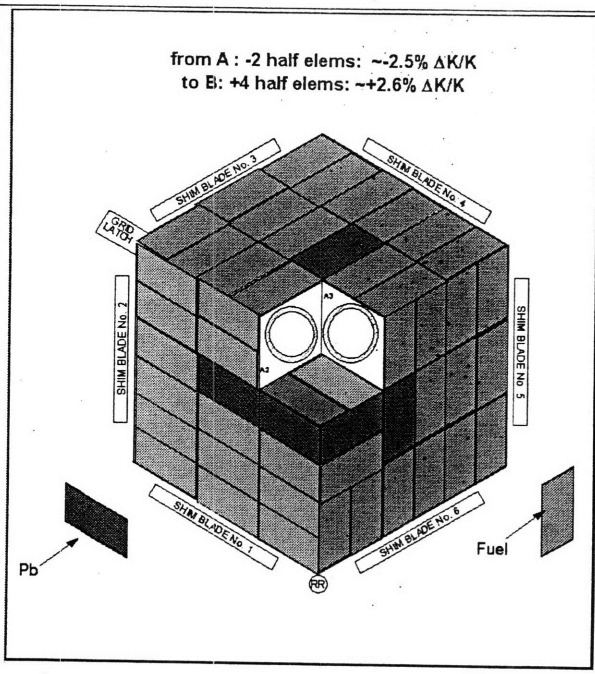

Figure 5.6 Configuration with two ICSAs

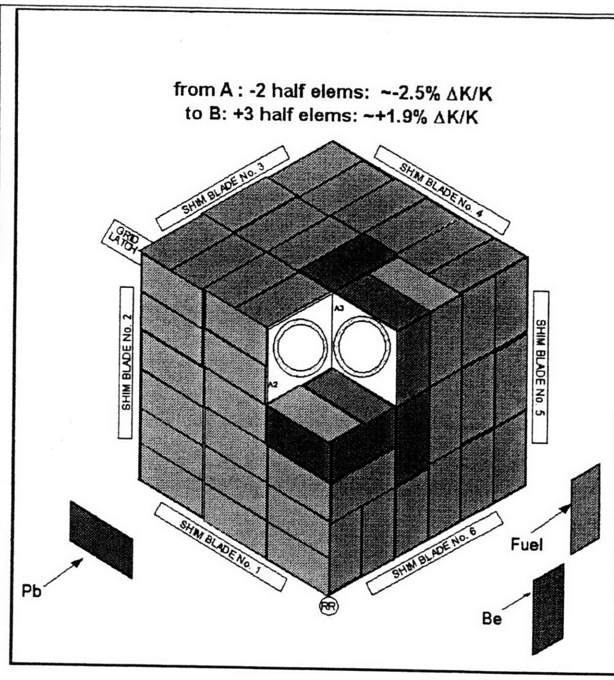

Figure 5.7 Configuration with a fast and thermal ICSA

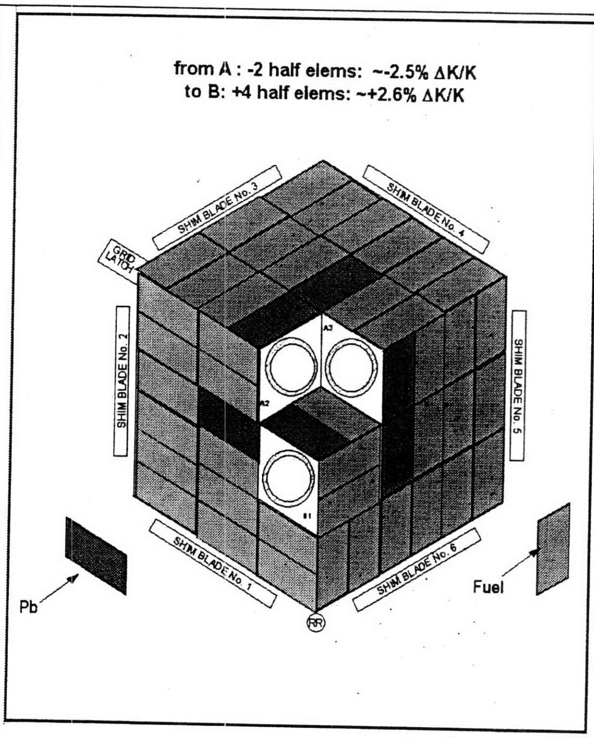

Figure 5.8 Configuration with three ICSAs

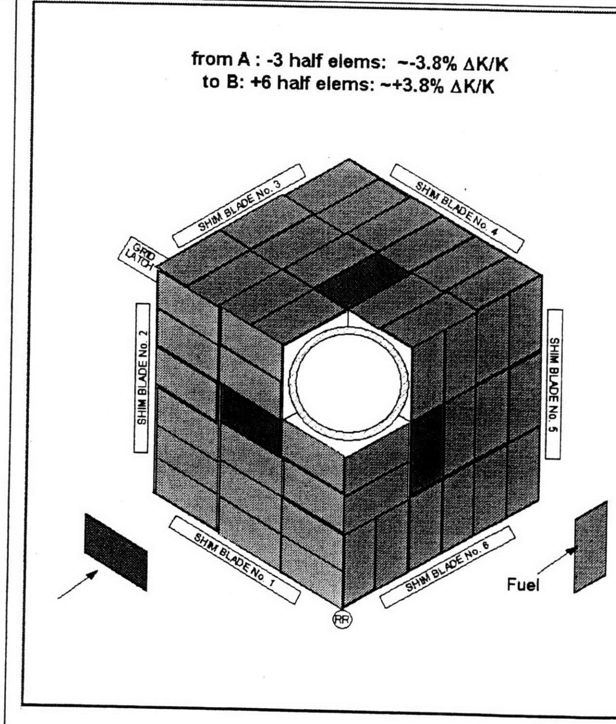

Figure 5.9 Configuration with large ICSA

adjacent beryllium dummies to approach a thermal spectrum. Figure 5.8 shows a configuration with three fast in-core facilities whereby four of the nine lead dummies had to be replaced with fuel to compensate for the loss of fuel in the A ring. Finally, Figure 5.9 shows a single large irradiation facility in the entire A-ring. This can accommodate experiments up to almost five inches in diameter, although reactivity issues will have to be carefully weighed against the loss of excess reactivity due to fuel loading.

5.6 Burnup Reactivity and Refueling

It is anticipated that there could be significant burnup reactivity gains with the LEU core as compared with the HEU core. This is due to two factors: spectral effects and higher actinide buildup. Because of the presence of large amounts of ^{238}U in the LEU fuel, the thermal flux in the fuel is roughly half that of the HEU fuel. In addition, the total ^{235}U loading in the LEU core is twice that of the HEU core, being 21 kg as compared with the 11 kg in the HEU core. The result is, that although the ^{235}U fission rate at 5 MW is approximately the same for either core, the larger absorption by ^{238}U causes the spectrum to be much harder. Thus, although the mass of fission products is about the same for both cores, thermal neutron absorption by fission products, particularly xenon and samarium (which account for about half of the neutron absorptions by fission products), is less for the LEU core, resulting in less negative reactivity from fission product absorption.

Figure 5.10 shows the MCODE K_{eff} results of the burnup of both HEU and LEU cores over time, at the current power level of 5 MW. Since the initial K_{eff}s are slightly different between the cores, the burnup reactivity changes as compared with the beginning of core life are shown in Figure 5.11. After 100 days (a typical HEU refueling interval), the HEU core has about 7% $\Delta K/K$ reactivity loss while the same loss for the LEU core takes over twice that long. Therefore, LEU refuelings should be less frequent and could, if necessary, begin with less excess reactivity (higher blade height). Thus, for a blade height modeled at 8.5 inches, a beginning-of-life K_{eff} as low as 0.95 could result in a 5 MW refueling interval similar to the current HEU interval.

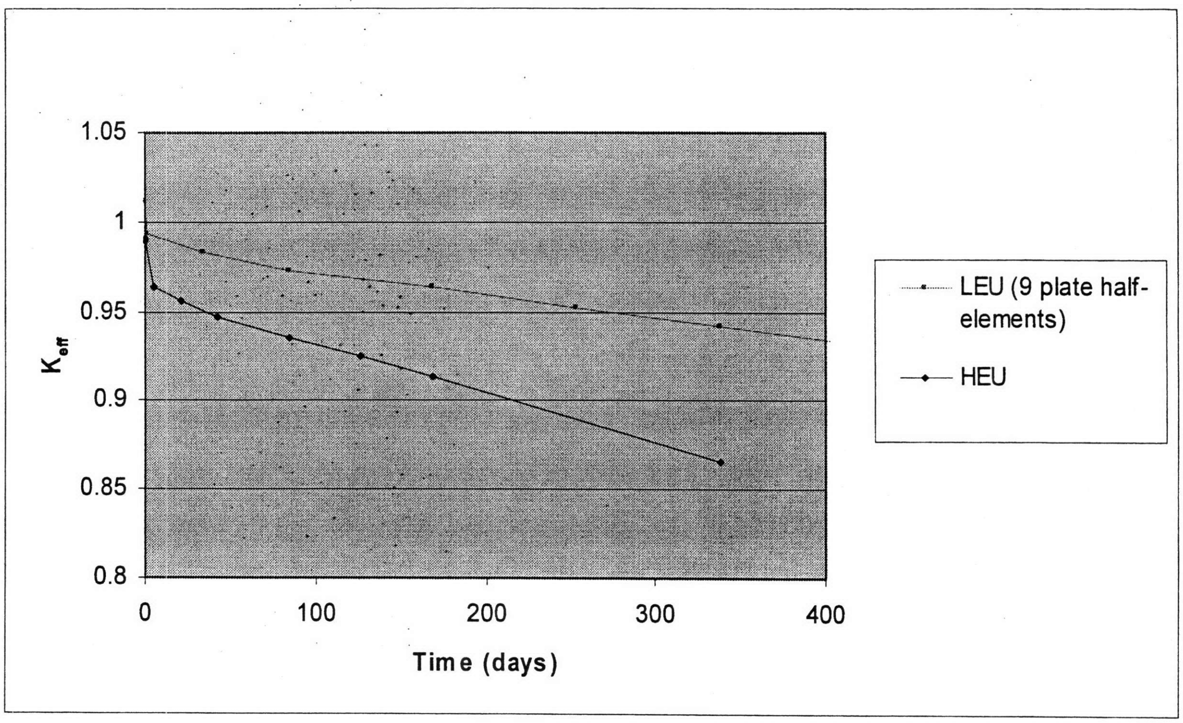

Figure 5.10 Burnup of HEU and LEU cores (at an MITR power level of 5 MW)

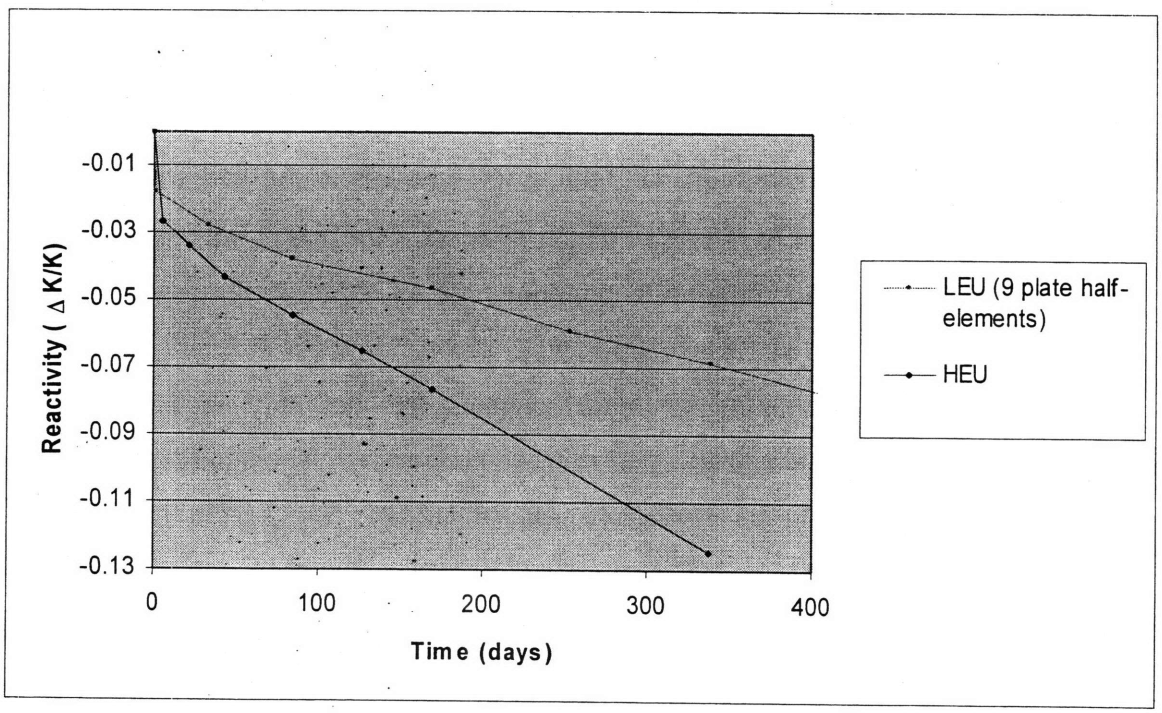

Figure 5.11 Reactivity change with burnup at 5 MW

On the other hand, if the reactor is allowed to operate at a higher power level, less time will be available for irradiation. In that case, the neutron flux level will increase proportionately to the reactor power.

Similarly, assuming adequate initial loading, in-core experiments with higher negative reactivity worth should not adversely affect the refueling interval. Any high worth experiments would still, of course, need to meet experimental reactivity limits such as that derived from the maximum allowed step reactivity insertion. A more detailed discussion of this is given in Section 7.3.

The other burnup reactivity difference between the LEU and HEU cores is the buildup of actinides, in particular ^{239}Pu. The ORIGEN output from MCODE indicates (with U-7Mo fuel burned to 50 MWd/kg, the anticipated approximate end of life) that about 7% of the fissions are caused by ^{239}Pu. The vast majority of the remainder is from ^{235}U fission, with about 2% of this resulting from fast fission of ^{238}U.

The buildup of actinides over time may also affect other reactor parameters. Because ^{239}Pu has a neutron emission (from thermal neutrons) of 2.89 per fission, as compared with 2.43 for ^{235}U [5.1], this will affect both available reactivity and neutron flux. MCNP results of the fuel burned to 50 MWd/kg above show a neutron emission of 2.49 per fission, as compared with 2.44 for a core with new fuel. Although slight, this increase at high burnup does have a positive effect on available reactivity.

In addition to neutron emission, the buildup of actinides in the fuel will change the delayed neutron fraction (β_{eff}) because of the presence of different amounts of delayed neutron precursors with the buildup of plutonium. This is further discussed in Section 7.3.

The actual burnup limitation for a fuel element will not only be from reactivity usefulness, but also from a materials performance perspective. The latter is derived from a concern of fuel swelling due to fission product buildup. The MITR-II HEU fuel is limited to a maximum of 1.8 x 10^{21} fissions/cm^3, a number based on materials studies in support of the Engineering Test Reactor [5.3]. However, later studies [5.4] suggest that this limit could be safely raised to 2.3 x 10^{21}. For LEU fuel this limit would equate to 50 MWd/kg. Although monolithic U-Mo LEU fuel is still undergoing testing and qualification, irradiation testing [5.5] suggests that the material can adequately withstand burnups as high as 3 x 10^{21} fissions/cm^3. This is roughly equivalent to 65 MWd/kg.

Because the LEU fuel will undergo higher burnup prior to discharge, a greater buildup of fission products (in addition to the actinides) will occur as compared to a conventional HEU fuel element. This will require a reevaluation of the source terms in accident analyses and in emergency planning. A preliminary investigation was conducted by Kennedy [5.6] and indicated that for equivalent burnups, the fission product source term was essentially the same for LEU and HEU fuels, but about 18 times more actinide activity exists in LEU fuel than in HEU fuel.

Because the fuel plates nearest the reflector regions have higher power peaking due to an increase in thermal flux, the fuel management strategy will be to load fresh fuel in the inner C-ring positions, as long as the plates are parallel to the core centerline, avoiding new plates to be positioned at the outer edge of the core. This will allow the more spent elements to be placed in the region of higher peaking, namely the inner B elements and outer C elements. A-ring fuel could be either new or partially spent fuel, depending on power peaking and experimental needs.

5.7 In-core vs. ex-core optimization

Since the enhancement of flux in the in-core facilities may come at the expense of the ex-core facilities, the management of fuel and placement of dummy element materials must be done with due consideration to the experimental needs at the time. Therefore, if no in-core experiment is present, the configuration should closely match that of the solid beryllium A-ring, as suggested in Section 4.7. If an in-core experiment is to be installed, the needs of all experiments should be evaluated and the flux and spectral needs of the in-core experiment should be met through the placement of beryllium or lead dummies and A-ring fuel as necessary.

5.8 Conclusions

Several options were considered to increase the LEU core ICSA fast flux levels to that of the HEU core. No single option resulted in a vast increase in ICSA fast flux. Rather, incremental changes in materials resulted in incremental increases in fast flux. The options considered included a fueled annulus, fuel plates positioned at the edge of the A-ring, and half width fuel elements in the A-ring. Manufacturing the annular fuel may not be feasible and both the annular fuel and the single plate cases had power peaking difficulties. The half-width elements showed promise in increasing the flux, particularly with the use of lead dummies in the inner core region. The most promising core configuration to enhance ICSA fast flux consisted of a combination of half-width elements and lead dummies in the A and B rings. However, any increase in in-core flux comes at the expense of ex-core experiment flux. Thus, flexibility should be designed into the LEU MITR core to meet the experimental needs both through placement of dummy materials and through fuel management designed to increase the experimental fluxes where needed.

Because of the hardness of the neutron spectrum in the LEU fuel, as well as the buildup of ^{239}Pu, the fuel lifetime, and thus the refueling interval, of the 5 MW LEU core is over twice that of the HEU core. This will allow significantly better reactor utilization and better accommodations of any forthcoming increase in reactor power level. The buildup of ^{239}Pu in the fuel will decrease the delayed neutron fraction over its lifetime, but since newer fuel will be added over time, the overall delayed neutron fraction change should be minimal. This effect should be carefully monitored when establishing a fuel management pattern so as to minimize any reactor dynamics or reactivity changes.

References

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Chapter 6
Thermal-Hydraulics

6.1 Average Channel Thermal-Hydraulic Performance

Heat transfer calculations were performed for both the HEU (15 plate) reference case and the LEU design basis (9 plate half-elements). Table 6.1 summarizes the parameters used in the calculations. As can be seen, the conductivity of the U-7Mo fuel is significantly less than that of the UAl_x used in the HEU fuel. Water properties were taken at 60 °C, the maximum allowed operating temperature of the coolant. Initially, the total minimum allowed operating primary flow rate of 0.114 m^3/s (1800 gal./min) was also assumed, as well as a reactor operating power of 5.5 MW, both of which are the limiting safety system settings in the current license.

Table 6.1. Heat transfer parameters

Fuel properties:

Area of plate (one side, including fins)	0.064	m^2
UAl_x fuel conductivity	42.5	W/m K
UMo fuel conductivity	17	W/m K
Al clad conductivity	180	W/m K

Coolant properties:

Channel length	584.2	mm
Water channel width	60.25	mm
Water density	983	kg/m^3
Viscosity	4.66E-04	kg/m s
Total volumetric flow rate	0.114	m^3/s
Total mass flow rate	112	kg/s
Gravity ΔP	5656	Pa
C_p	4184	J/kg K
Water conductivity	0.648	W/m K
Pr ($=C_p\mu/K$)	3.56	

Heat transfer calculations across an average fuel plate are shown in Table 6.2. The heat generation per plate is calculated by dividing the reactor power level (5.5 MW in this case) by the number of plates. Only 91% of the heat is actually generated in the fuel plates, since most gammas and some betas generated during fission deposit their energy outside the fuel. Thus, this number is multiplied by 0.91 to obtain the total heat generation per plate.

Because of the greater number of plates in the LEU core (378 vs. 330 for the HEU reference), the actual heat generated per plate is smaller. However, because of the thinness of the LEU plates, the volumetric heat generation rate, defined as

$$q''' = Q/V$$

is larger. The resulting heat flux to the coolant ($q'' = Q/A$) is slightly smaller for the LEU case. Because of the lower fuel conductivity, the temperature difference across the plate, defined as

$$\Delta T = q''(0.5 * t_{fuel}/K_{fuel} + t_{clad}/K_{clad})$$

where t is the thickness, is somewhat larger, although neither of the cases showed a ΔT of greater than $2^{o}C$. Thus, the fuel conductivity should not be a major factor in heat transfer under normal operating conditions. As described in Chapter 2, the fuel conductivity does not change significantly with burnup, although the buildup of oxide on the outer cladding can reduce the heat transfer to the coolant as well as reduce fin effectiveness over time. Parra [6.1] calculated that an oxide buildup of 0.025 mm in the worst case would reduce the fin effectiveness by about 15%, but would not significantly reduce the heat transfer to the coolant.

The flow and convective heat transfer calculations are shown in Table 6.3. The hydraulic diameter is calculated with 0.25 mm (0.01 inch) fins present. The channel flow rates are calculated assuming that the flow is proportional to the number of equivalent full-sized fuel elements present in the core. For flow channels with Reynold's numbers of less than 30,000, the Blasius equation:

$$f=0.316 * Re^{-0.25}$$

is used as was the case here. [6.2] Since the Reynold's numbers were very similar for all cases, the friction factors were essentially identical. In calculating the friction pressure drop, the entrance form loss was included, estimated from

$$\Delta p_{form} = K'(\rho v^2_{ref}/2),$$

where K' has been calculated by McGuire [6.3] to be 2.05, and v_{ref} is taken as the average velocity in a flow channel (2.52 m/s for HEU and 2.08 m/s for LEU)

Table 6.2 Heat transfer across the plates

No. of plates/element	15 (HEU)	18 (LEU)
Q (W/plate)	15,166	13,241
1/2 fuel thickness (mm)	0.381	0.2667
clad thickness (mm)	0.38	0.25
q''' (W/m^3)	6.22E+08	7.76E+08
q'' (W/m^2)	2.37E+05	2.07E+05
T_{max}-T_{co} (°C)	1.50	1.88

One of the most commonly used correlations in determining the coolant Nusselt number is the Dittus-Boelter equation, which is valid for 0.7<Pr<100, Re>10,000 and L/D>60, which cover the conditions within the fuel channels. For heated channels, this states that:

$$Nu=0.023*Re^{0.8}*Pr^{0.4}$$

$$\text{Where } Pr=C_p\mu/K$$

Because of the slightly smaller Reynold's number, the Nusselt number is smaller for the LEU case. This translates to a slightly smaller heat transfer coefficient, defined as

$$h=Nu\ K/D_{hyd}$$

Thus, the ΔT from plate surface to water, is calculated by:

$$T_w-T_m = q''/h$$

Where T_w is the clad outer temperature and T_m is the average coolant temperature across a channel, taken at the position of axial maximum, i.e. at the outlet. T_w-T_m is slightly smaller for the LEU case, thus allowing slightly higher peaking as compared with the

HEU case. In both cases, however, the T_w-T_m remains well below 20°C so that the coolant remains subcooled, even when a 50% peaking factor is assumed for the peak heat flux value. Since the inlet is assumed to be at 40 °C, the exit temperatures remain to be 42 or 43 °C.

Table 6.3 Forced convection heat transfer calculations

No. of plates/element	15 (HEU)	18 (LEU)
Water channel thickness (mm)	2.24	2.58
Hydraulic diameter (mm):	2.19	2.53
Avg. channel flow rate (g/s)	311	319
Velocity (m/s)	2.52	2.08
Reynold's number	11,692	11,455
friction factor (Blasius eqn.)	0.030	0.031
Friction pressure drop (Pa)	31895	19450
Nu (Dittus-Boelter)	64.2	63.2
h ($W/m^2 {}^oC$)	18,995	16,211
Tw-Tm (°C)	12.6	12.8
Clad wall temperature	52.6	52.8

6.2 Power peaking and hot plate performance

MCNP tallies of heat deposition in each of the fuel plates in the LEU design reference core using beryllium dummies in the B ring are shown in Figure 6.1. The results indicate that the maximum radial peaking occurs in the outer plates of the C-ring, when the plates are oriented facing the outer edge of the core. This is due to the large flux gradients at the outer edge of the core. When averaged across the element, the C-ring power peaking numbers are low, as is reflected in the element peaking numbers. There is also some peaking within a plate itself when oriented edge-on to the outer edge of the core. However, this is less of a concern since there is good conductivity across the plate.

The maximum radial power peaking factor in the C-ring is 1.76. Both the outer A-ring plates and the inner B-ring plates have similar peaking factors of 1.48 and 1.51, respectively. The peaking in the core with lead dummies is similar but a bit lower, being 1.48 for the A ring plates and 1.47 for the B ring plates. The LEU numbers are higher than the maximum HEU core no. 2 radial peaking of 1.39.

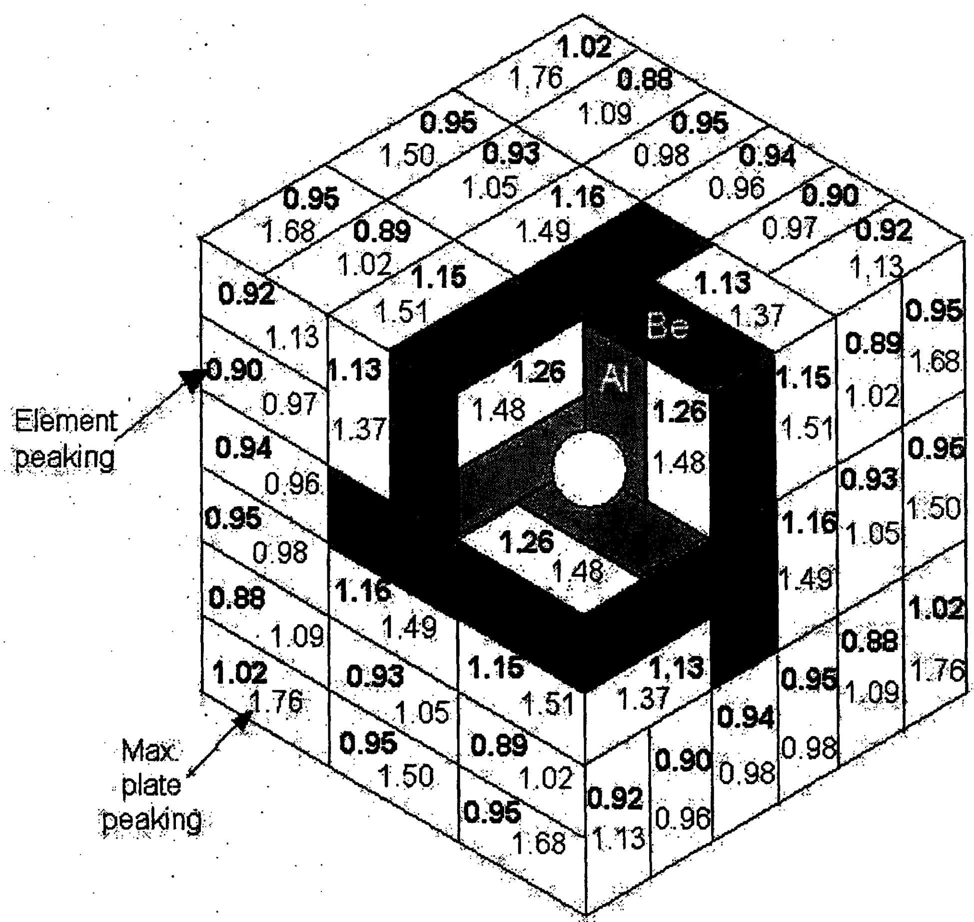

Figure 6.1 Power peaking in LEU core

Heat transfer calculations as presented above are shown in Table 6.4 using the hot channel. The heat generation here is calculated by multiplying the average plate heat generation by the maximum radial peaking factor. The results indicate that even the hottest plate in the LEU core will have a clad temperature well below saturation, i.e. the coolant at the clad remains subcooled.

It should be noted here that the above calculations are included for a comparative illustration, it being assumed that the hot channel power is generated evenly along the plate and the channel receives the average channel flow. In addition, although calculation of the plate surface area includes the fins, the actual heat transfer contribution from fins is not included. To assure that the onset of nucleate boiling is not reached, the axial peaking must be taken into account as well as any flow disparities and engineering factors, as well as fin effectiveness.

Table 6.4 Heat transfer of peak plates

Conduction across plates		
Radial Peaking Factor	1.39	1.76
No. of plates/element	15	18
	(HEU)	(LEU)
Q (W/plate)	21,080	23,304
1/2 fuel thickness (mm)	0.381	0.2667
q''' (W/m^3)	4.35E+08	6.87E+08
q'' (W/m^2)	3.32E+05	3.67E+05
$T_{max}-T_{co}$ (°C)	2.11	3.32
Convection		
Water channel thickness (mm)	2.24	2.58
Hydraulic diameter (mm):	2.20	2.53
Avg. channel flow rate (g/s)	311	319
Velocity (m/s)	2.52	2.08
Reynold's number	11,708	11,455
friction factor (Blasius eqn.)	0.030	0.031
Friction pressure drop (Pa)	31661	19450
Nu (Dittus-Boelter)	64.3	63.2
h (W/m^2 °C)	18,949	16,211
Tw-Tm (°C)	17.5	22.6
Clad wall temperature (°C)	67.5	72.6

6.3 MULCH-II whole core steady state analysis

The MULti-Channel Analysis Code (MULCH-II), developed by Hu and Bernard [6.4] was used to perform further heat transfer calculations for the LEU design core. This code uses the momentum and energy conservation equations to make the following two determinations for the MITR-II:

1) that the limiting safety system settings (LSSS) are not exceeded, thus ensuring that the limit of onset of nucleate boiling is not exceeded, and

2) that the reactor safety limits are not exceeded, which ensures that the onset of flow instabilities is not approached.

The inputs to the code, in addition to the dimensional differences with the HEU core, include a number of factors describing the core characteristics. As above, a radial peaking factor of 1.76 (as shown in Figure 6.1) was used, along with the axial flux distribution and peaking factors as calculated by MCNP for the LEU core. The flow disparity, which cannot be easily calculated because of the complexity of the shapes beneath the reactor, was assumed to be the same as for a 24 element HEU core. This is a reasonable (and possibly conservative) assumption, since the pressure drop across the core is smaller for the LEU case and the flow approaching the core is unchanged and thus the coolant flow factor (ratio of core coolant flow to the total flow) is unchanged. The flow distribution throughout the core should not significantly deviate from the minimum-to-average channel flow factor of 0.93 measured during the MITR-II startup. The flow distribution within an element (a "double" half-element such as used in the C ring) is also assumed to be the same as a 15 plate element, since the overall dimensions are the same. This distribution should be closer to unity for a half element such as used in the A or B rings, although the flow factor of 0.93 was again assumed.

Engineering factors are also assumed to be the same as the HEU 24 element core because the fuel dimensioning and density tolerances, although not yet known, should be the same (if not smaller) than for the current fuel. In addition, the plenum flow, power measurement, power density, and eccentricity tolerances should be unchanged.

For this case, the current minimum allowed core volumetric flow rate of 0.114 m^3/s (1800 gal/min) was assumed, along with a primary coolant entrance temperature of 40 °C and a reactor power level of 5.5 MW. The MULCH-II input file is shown in Appendix C.

The fuel, cladding, and plate wall axial temperature distributions for the average channel and hot channel are shown in Figure 6.2 and 6.3 respectively. The hot channel peak temperatures are shown to be generally about 20 °C above the average channel peak temperatures. Because the primary coolant remains in single phase (no subcooled boiling), the Dittus-Boelter relation is used to calculate heat transfer. Critical heat flux is calculated by the lowest result of two CHF relations by Gambill, described by McGuire. [6.3]

Both figures show that all temperatures are comfortably below those at the onset of nucleate boiling (ONB). The heat fluxes (and thus the fuel-clad temperature differences) are close to those calculated in Table 6.2. In addition, as shown in Figure 6.4, all heat fluxes are well below the critical heat flux, with the minimum critical heat flux ratio (CHFR -- ratio of critical heat flux to calculated heat flux) being 11.6 at the point of highest axial and radial peaking at about 11 cm from the core bottom. The CHFR closely follows the inverse of the heat flux profile. As can be seen, both the ONB and OFI limits are easily met.

There remains the possibility that the power distribution will shift more towards the C-ring with the raising of the blade height during operation. MCNP results from modeling at a higher (45 cm) blade height with unburned fuel indicate that the radial peaking factor will increase by about 20% in this case. However, the buildup of fission product poisons in a peaked area would limit this peaking. MULCH-II results using the larger peaking factor show that the temperatures will remain below ONB. Unfortunately, the LSSS conditions as currently defined are not met at three of the twelve axial nodes. Thus, power peaking should be reduced at the corner positions through fuel management prior to operation at high shim bank heights.

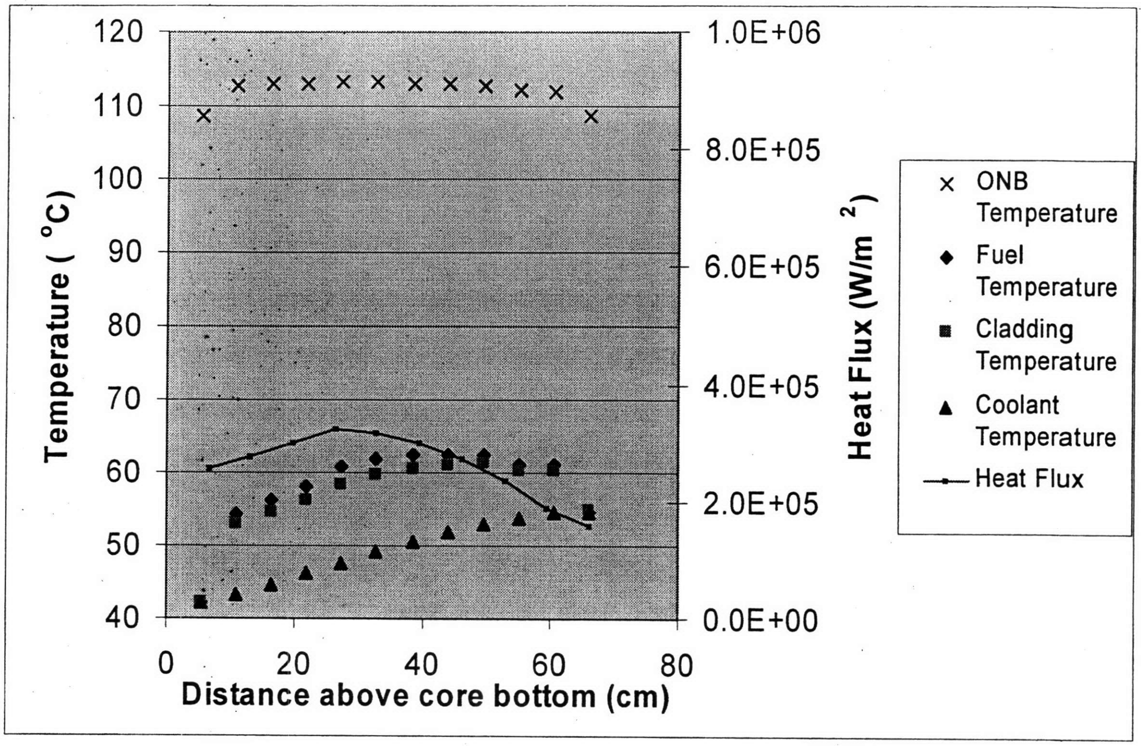

Figure 6.2 MULCH-II results for average channel at 5.5 MW

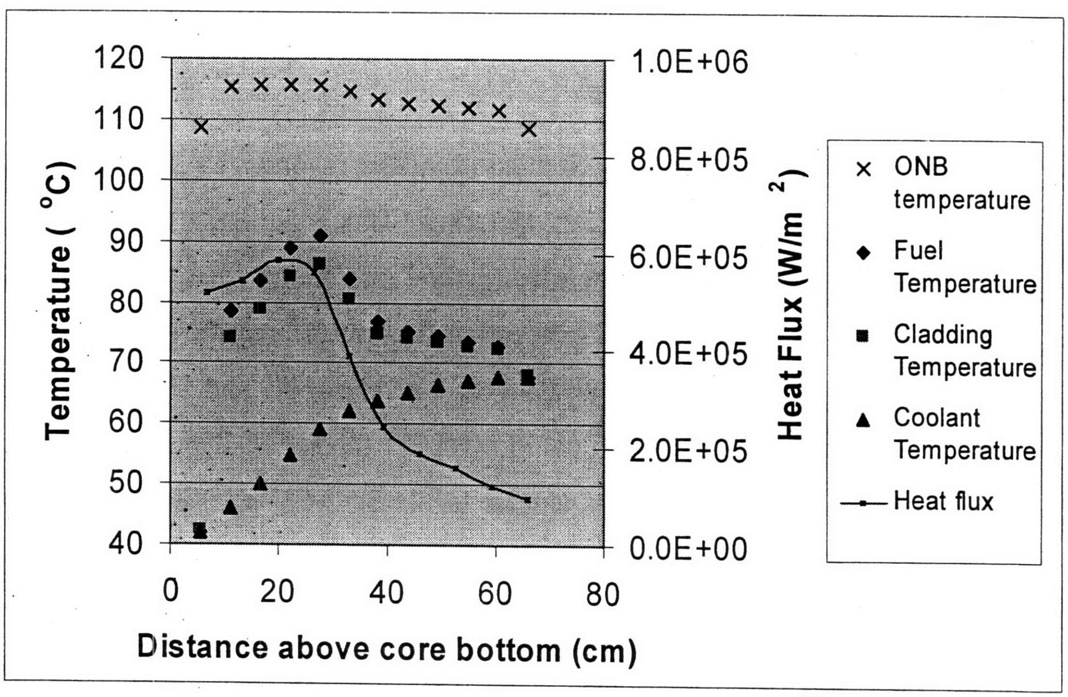

Figure 6.3 MULCH-II results for hot channel at 5.5 MW

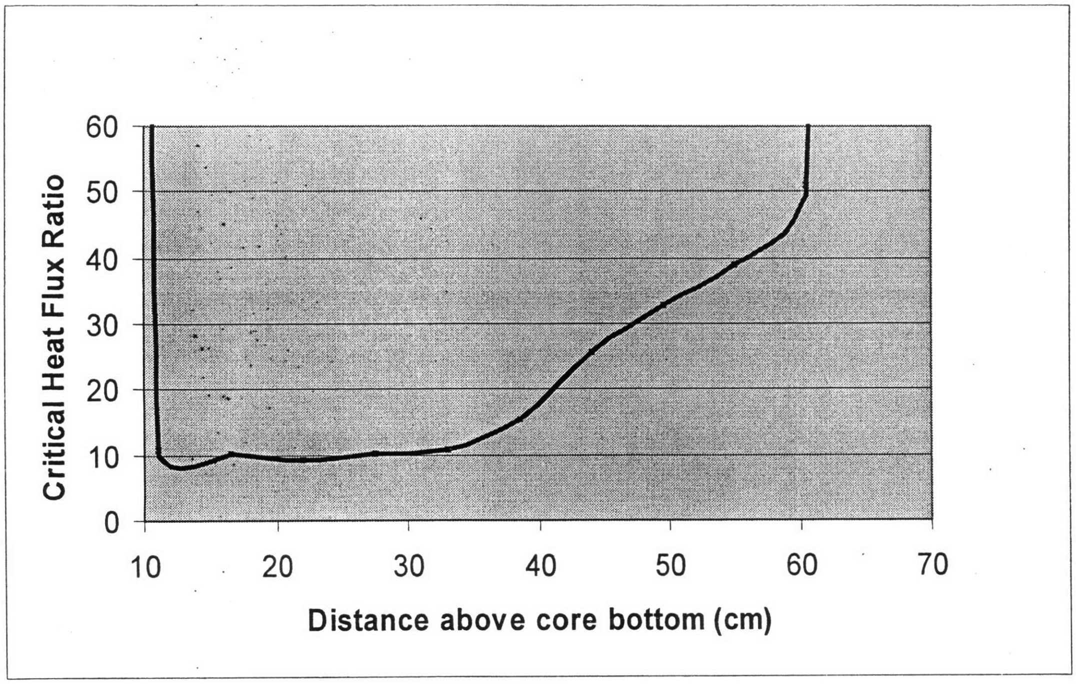

Figure 6.4 CHFR for hot channel at 5.5 MW

6.4 Natural convection upon loss of flow

The MITR is equipped with natural circulation valves in order to facilitate natural circulation when the primary pumps are not operating. This is particularly important for a loss of flow transient during operation, when natural circulation becomes the primary means of cooling the core. The natural convection flow in the reactor during a loss of flow transient was evaluated using MULCH-II for both the HEU and LEU cores. Just such a condition has been benchmarked using MULCH for MITR-II pump coastdown. [6.5] The MULCH-II model setup was similar to the 5.5 MW case above, with each case having the appropriate core and axial and radial peaking characteristics. The natural convection and anti-siphon valve characteristics as well as the pump coastdown curve were assumed to be the same for both the HEU and LEU cases, since no changes to these are anticipated.

A loss of flow transient, from pump coastdown to the establishment of steady state natural convection through the natural convection valves in the MITR-II is described in detail by McGuire [6.3]. The pump coastdown causes the forced flow to drop from its normal flow rate of 112 kg/s to essentially zero in about ten seconds. At this point, the natural convection flow through the valves begins to be established, reaching an equilibrium flow rate of about 2 kg/s in about 20 seconds. At this point, the flow through a channel is laminar, with a Reynold's number of about 350, causing the friction factor to be about 0.18 for the LEU core (the forced flow friction factor is 0.027). The heat transfer coefficient for the LEU core in laminar flow is over an order of magnitude lower than that at full flow (1230 W/m^2 °C vs 16,500 W/m^2 °C at full flow). However, because of a reactor scram occurring at about 2 seconds into the transient, and assuming only a prompt drop, the power produced is only about 7% of the initial power. Thus, cooling should be adequate.

A plot of the average channel exit coolant temperature is shown in Figure 6.5. Even though both channels begin the transient at approximately the same temperature, the slightly larger flow area for the LEU core results in a lower temperature after the initial loss of flow and subsequent pump coastdown, reaching equilibrium about 5 °C apart after 100 seconds or so.

The hot channel exit coolant temperatures are shown in Figure 6.6. In this case, because of the higher radial peaking in the LEU core, the initial temperature for the LEU peak channel is about 4 °C higher than the HEU peak channel. After the pump coastdown, the LEU peak channel temperature approaches the HEU temperature, but remains above it by two to three degrees. As equilibrium is established, the higher decay power in the LEU channel maintains its temperature about 4 °C higher than the HEU channel.

The above results indicate that natural circulation cooling after scram will be adequate in the LEU core, particularly since the flow area is larger, and thus the friction pressure loss is smaller, allowing a net increase in volumetric flow rate as compared with the HEU core.

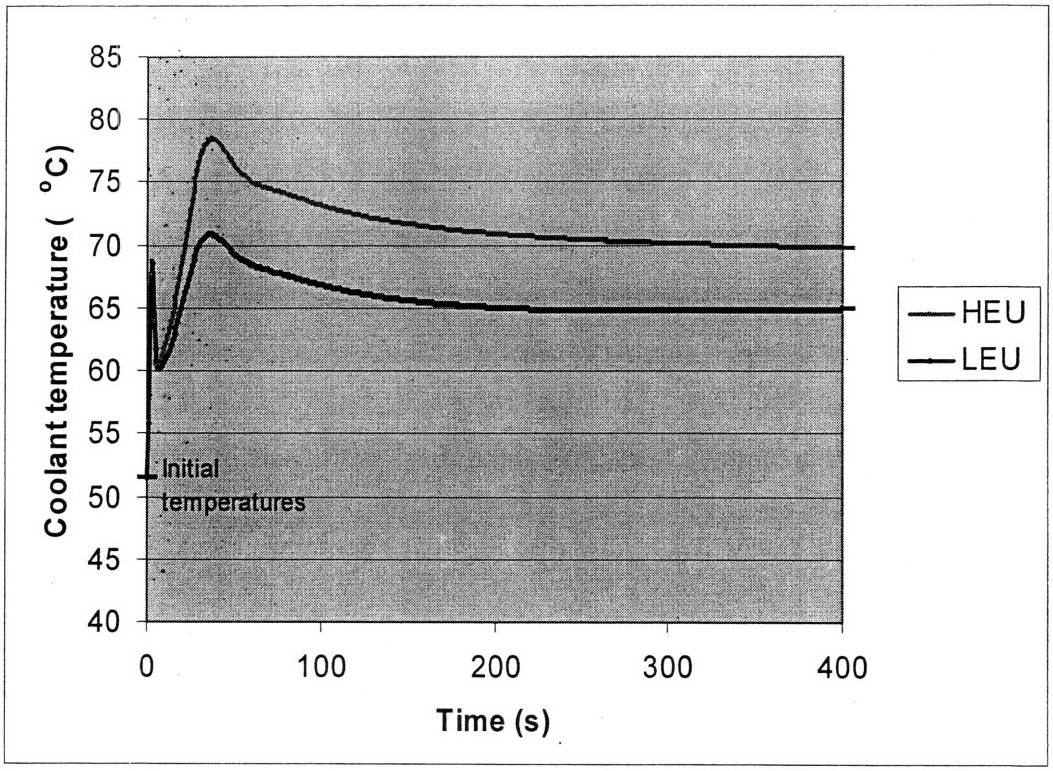

Figure 6.5 Loss of flow transient -- average channel

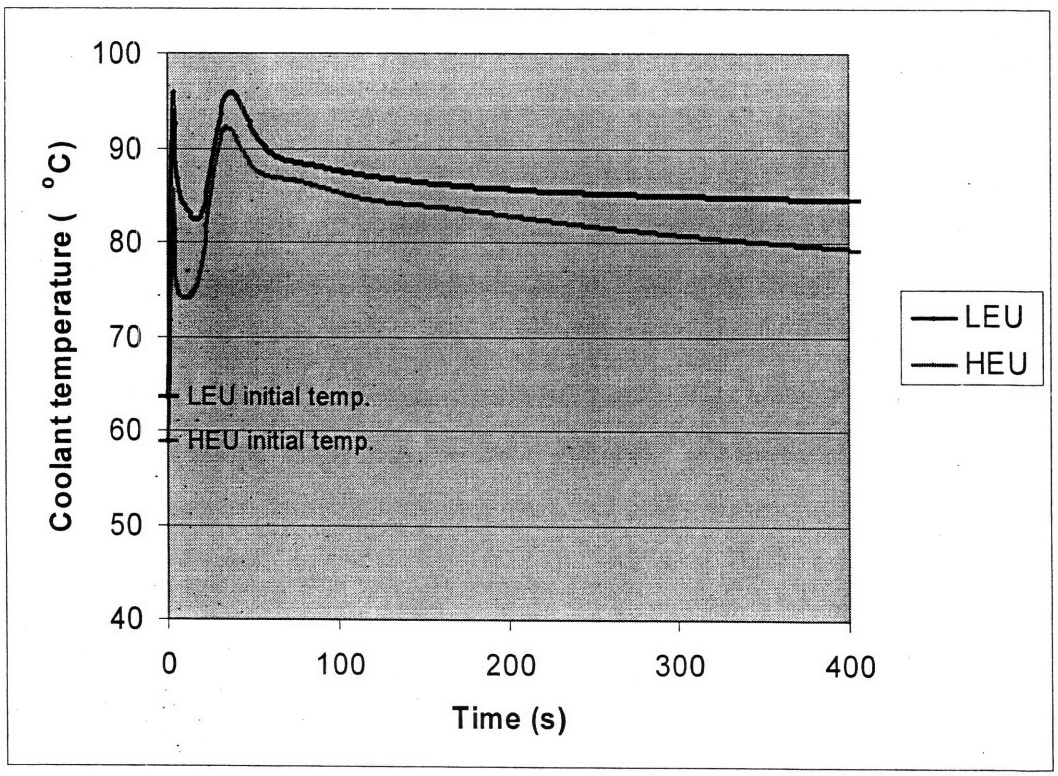

Figure 6.6 Loss of flow transient -- peak channel

6.5 Operation at 6 MW

In 1999, a safety analysis report [6.6] was prepared and submitted to the NRC in support of a power upgrade to 6 MW. At this power level, neutron fluxes can be assumed to scale linearly, that is, all fluxes given above as calculated for 5 MW can be increased by 20% to obtain a 6 MW value. The heat generation rate can also be scaled linearly and assuming that the heat exchange capability of the reactor systems can maintain the coolant properties unchanged (i.e. temperature, conductivity, specific heat and viscosity), the heat transfer parameters listed above also will change linearly, indicating that the hot channel wall temperature will get to 80 °C, which is still significantly below the boiling point. MULCH-II calculations were also performed at 6 MW and a nominal volumetric flow rate of 0.152 m^3/s (2000 gal/min), which are the values assumed in the safety analysis report [6.6].

The results show that all temperatures are well below the ONB temperatures as shown for the average channel in Figure 6.7 and the peak channel in Figure 6.8. The average channel is about 50 °C below the ONB temperature. The peak channel temperatures are about 20 °C greater than the average temperatures, but still well below ONB temperatures. The minimum CHFR, shown in Figure 6.9, is 9.1, indicating that 6 MW is well within the current capabilities of the MITR heat removal system with the LEU design core. A loss-of-flow analysis at 6 MW, similar to the 5 MW analysis above, showed that the maximum coolant temperature reached 99 °C, still below the point of ONB (about 107 °C).

It should be noted that at the higher power level, the burnup rate and buildup of fission products, in particular, ^{135}Xe, will be higher for both HEU and LEU cores. Thus, for comparable refueling intervals, a larger excess reactivity must be loaded into the core to compensate for this. However, care must be taken not to exceed power peaking or shutdown margin limits. In general, peaking factors should decrease with burnup since the overall volume of heat generation should increase with increasing shim bank height and any area of higher power production will have higher burnup rates and higher fission product buildup.

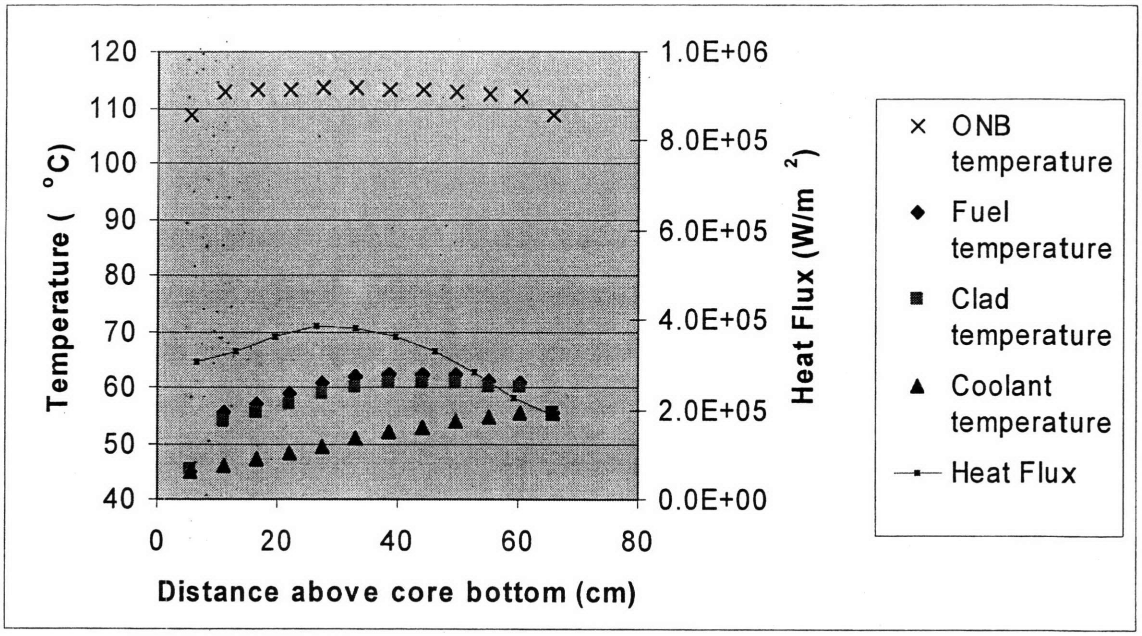

Figure 6.7 MULCH-II results for 6 MW average channel

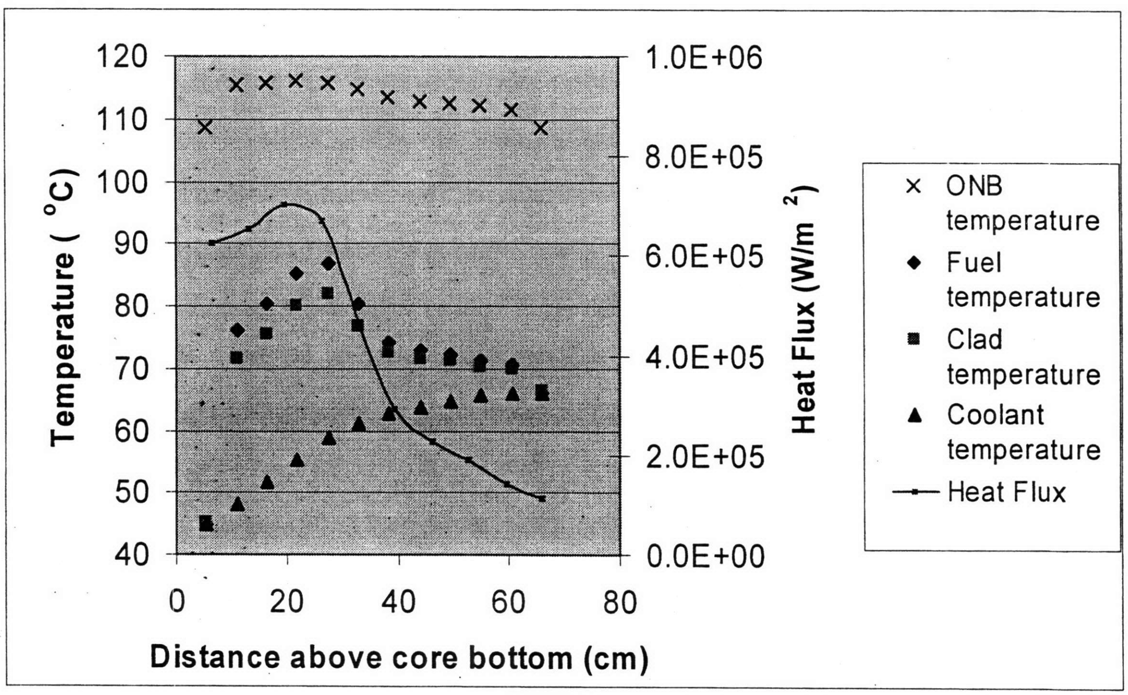

Figure 6.8 MULCH-II results for hot channel at 6 MW

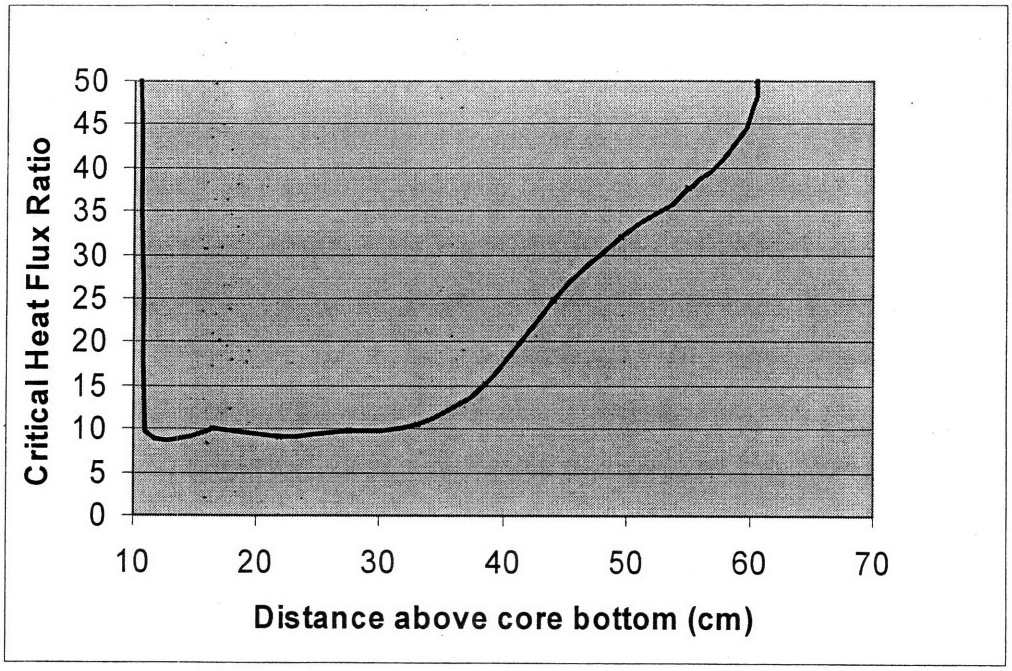

Figure 6.9 CHFR results for hot channel at 6 MW

6.6 Operation at 10 MW

There has been considerable interest in upgrading the power level of the MITR to 10 MW. Given the LEU design basis configuration parameters above and assuming that appropriate heat exchange equipment can be installed, MULCH-II was run using the 10 MW data as calculated above. In order to avoid the onset of nucleate boiling, it was found that the minimum flow necessary is 0.22 m^3/s (2900 gallons/minute), an increase of about 45% over the current nominal flow rate. The MULCH-II results for the average channel are shown in Figure 6.10. This shows a fairly comfortable margin of about 30 ^{o}C to the ONB temperatures. Figure 6.11 shows the peak channel temperatures. These temperatures are about 30 ^{o}C above the average channel temperatures, and are fairly close to the ONB temperatures. A plot of the peak CHFR, given in Figure 6.12, shows a minimum CHFR of 5.2 at the peak position near the core bottom.

The maximum allowable flow is mainly limited by the design pressure of the aluminum reactor core tank which is 165 kPa (24 psi). Calculations with a primary temperature of 50^{o}C and at the above flow rate of 0.22 m^3/s show that the pressure on the core tank is about 89 kPa (13 psi), well below the tank pressure limit. In fact, doubling the 5 MW minimum flow rate to 0.27 m^3/s (3600 gpm) will cause the pressure on the core tank to reach 103 kPa (15 psi). Similar calculations for the HEU core, since the flow area is smaller, show a tank pressure close to the limit at about 145 kPa (21 psi). However, it should be noted that the current primary system, including pumps and heat exchangers, is designed for a maximum flow of about 0.18 m^3/s (2400 gpm), so a redesign would be necessary for 10 MW operation.

The buildup of fission products, primarily xenon and samarium isotopes, at 10 MW will be twice that of 5 MW, and will result in a negative reactivity addition, as shown in Figure 6.13. This indicates that the refueling interval of the LEU core at 10 MW will be very close to that of the HEU core at 5 MW, although the buildup of ^{239}Pu will give some advantage over time.

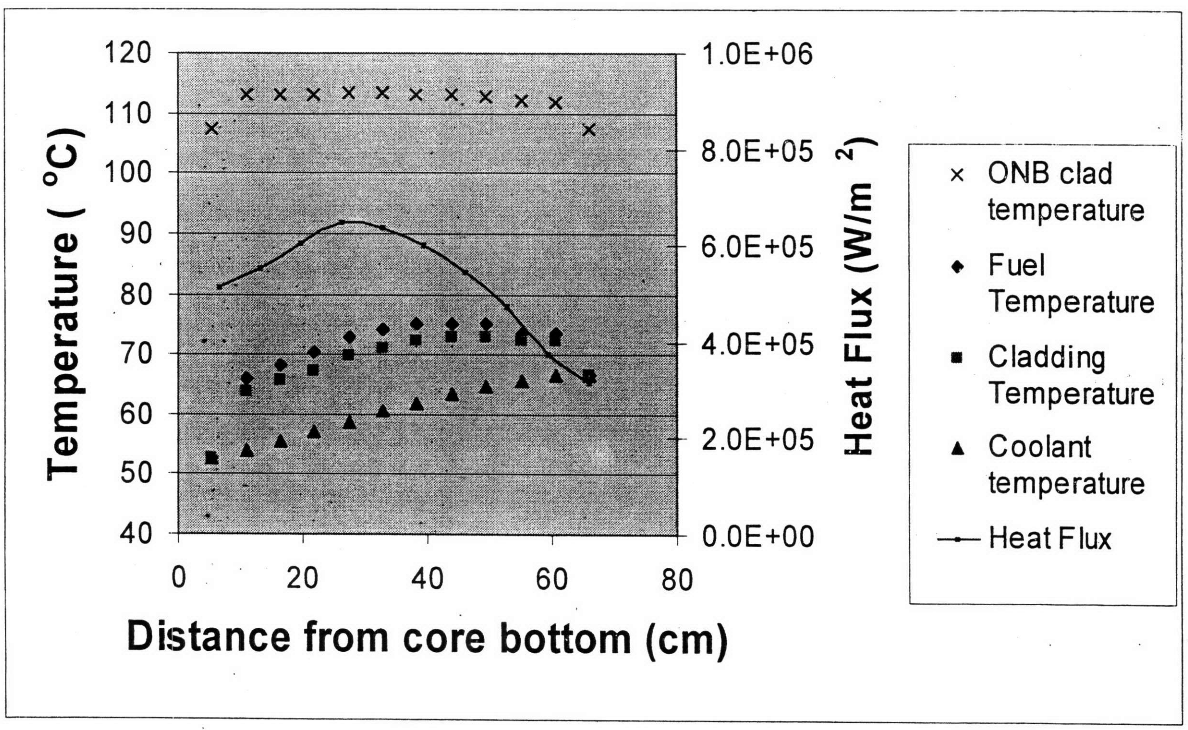

Figure 6.10 MULCH-II results 10 MW average channel

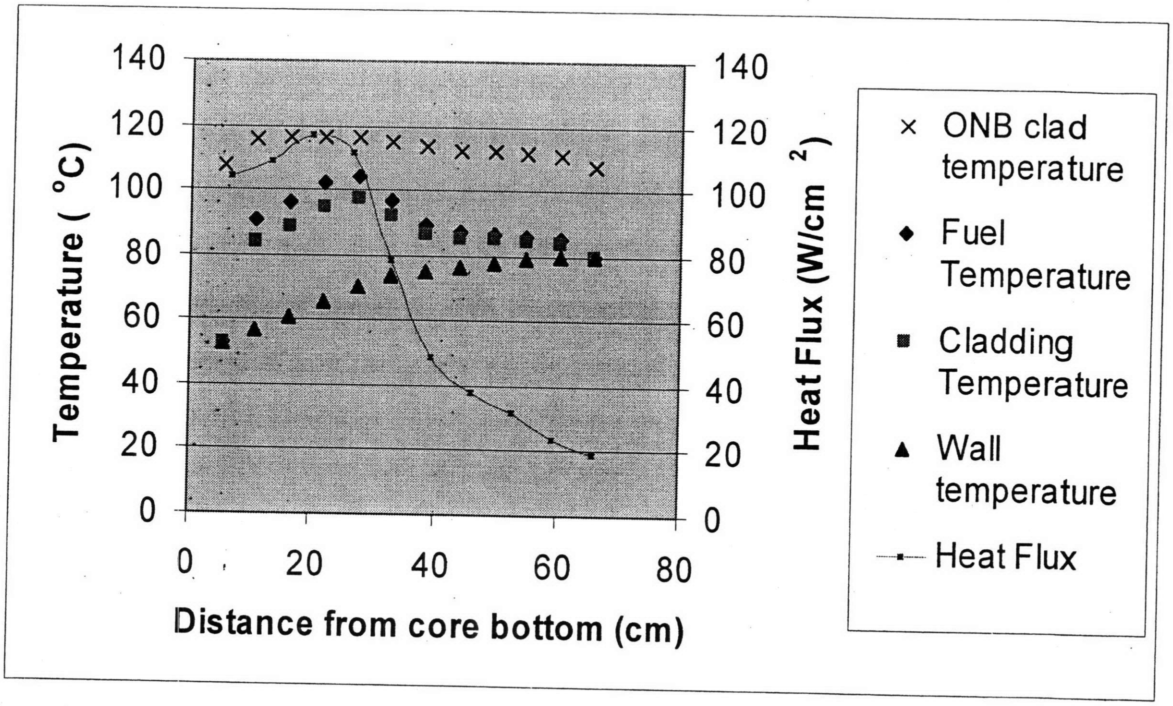

Figure 6.11 MULCH-II results 10 MW peak channel

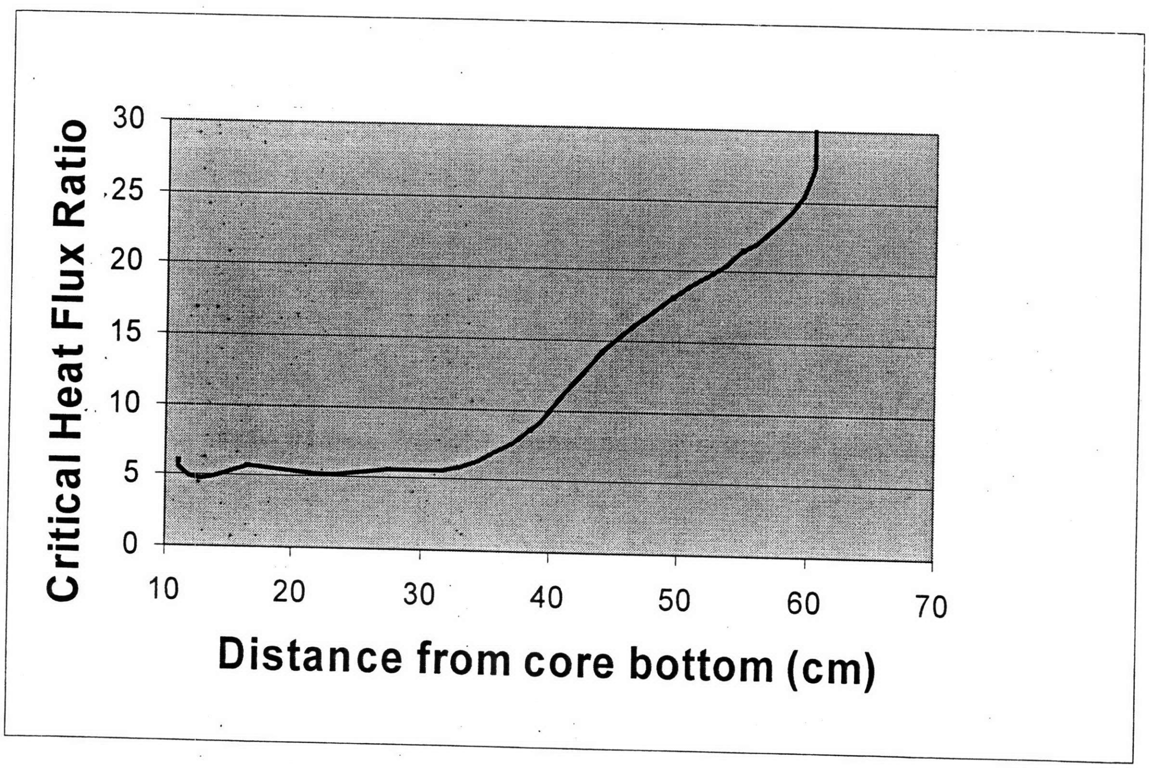

Figure 6.12 CHFR results for hot channel at 10 MW

Additionally, although the moderator temperature should not significantly change at higher power and higher flow rates, the fuel temperature will increase by about 8 degrees C. This will result in an additional negative reactivity for the LEU case of about 0.02% $\Delta K/K$. Although this is not significant from a fuel loading perspective, it will be noticeable by the reactor operator.

The above results indicate that operation at 10 MW is feasible with the LEU design core, but it is again suggested that in order to have a comfortable safety margin, the coolant flow rate be doubled, and/or the power peaking be reduced by fuel management or fixed absorbers.

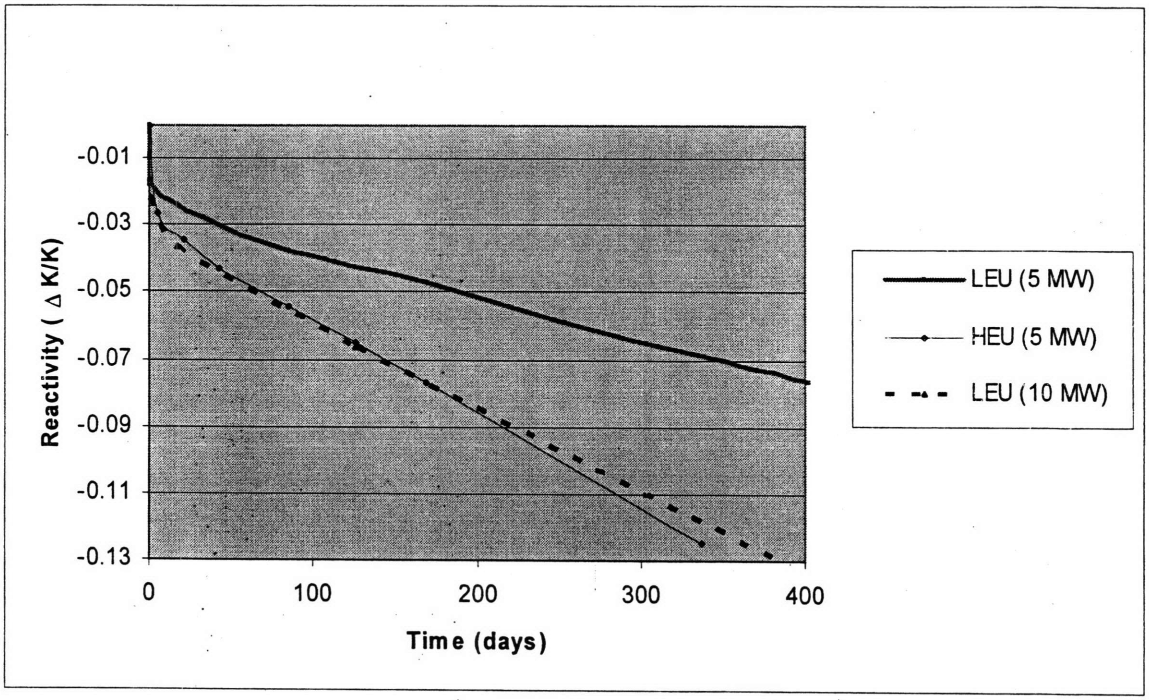

Figure 6.13 Burnup comparisons at 5 MW and 10 MW.

6.7 Storage

As mentioned in Section 5.5, for a given burnup period, the amount of fission products in the LEU fuel is approximately the same as that for the HEU fuel. Heat generation in a spent fuel element with a steady duty cycle at 5 MW and 100 days decay is about 100 W, which is easily cooled in water by natural convection. Of course, higher fission product loading in spent LEU fuel could increase the decay heat by perhaps a factor of two, but will remain easily cooled in water. Thus, short term storage at MIT would be mostly unaffected by conversion to LEU fuel. In addition, a full core's worth of spent LEU fuel contains less than 1 kg of ^{239}Pu, so proliferation concerns regarding separation of plutonium are minimized.

However, for long term waste storage, the larger amount of higher actinides in LEU fuel will increase the decay heat load of spent fuel. Figure 6.14 shows a comparison of decay heat of HEU and LEU fuels. Because of mass and configuration differences, the decay heat was normalized to be equivalent at end of irradiation to show the decay heat differences with time. After about 300 years, the heat load of actinides exceeds that of fission products. At this point, the decay heat is predominantly due to the presence of ^{241}Am, which (both from direct production and from decay of ^{241}Pu) is about a factor of four higher in LEU fuel. After about 5000 years, ^{239}Pu predominates, which is an order of magnitude higher in LEU fuel than in HEU fuel. Thus, conversion to LEU fuel will increase waste repository requirements, due to both decay heat and higher actinide activities.

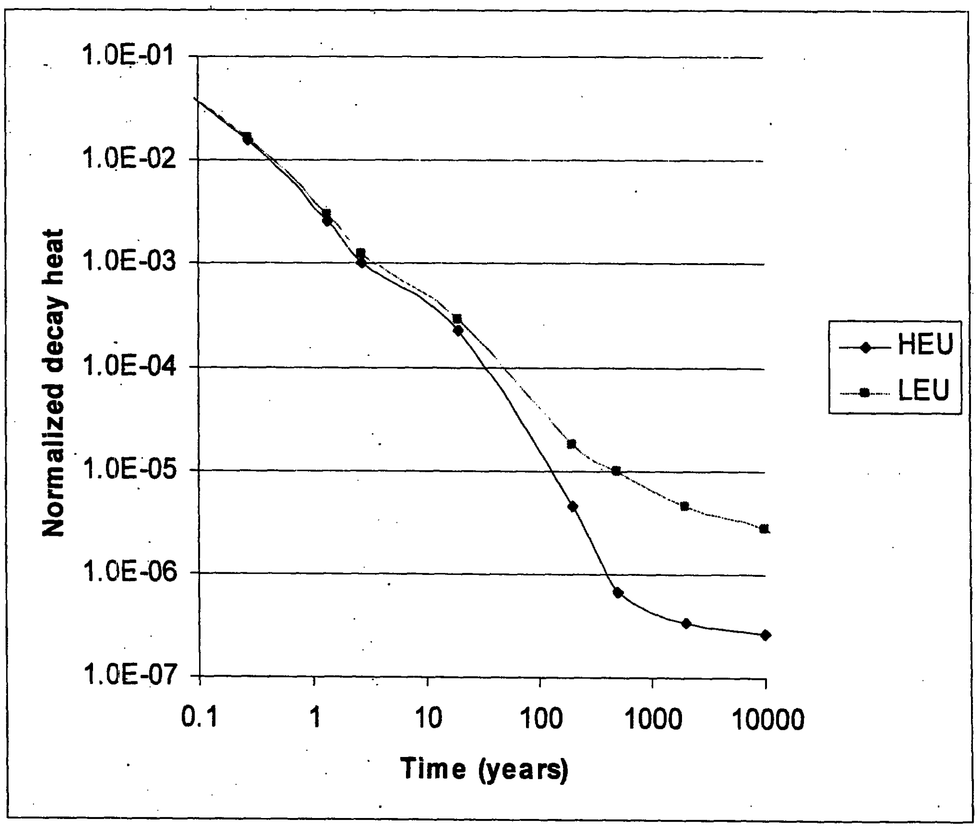

Figure 6.14 Comparison of HEU and LEU waste decay heat

6.8 Conclusions

Thermal-hydraulic calculations were performed for the design basis LEU core consisting of nine-plate half elements with a fuel thickness of 0.55 mm. These calculations were performed for both average and hot channels using a simple model with the Dittus-Boelter equation as well as using the MULCH-II thermal analysis code. In the MULCH-II analyses, operating characteristics (flow and water temperature) at the limiting safety system settings were used with the reactor power level at 5.5 MW, nominal operating characteristics at 6 MW, and with increased primary flow from 0.15 m^3/s (2000 gallons/minute) to 0.22 m^3/s (2900 gallons/minute) with enhanced heat exchange capability for a reactor power of 10 MW. The results showed that the LEU reactor core will remain below the onset of nucleate boiling and onset of flow instabilities under these circumstances.

Natural circulation calculations using MULCH-II for a loss of flow transient at 5 MW indicate that the LEU core will be adequately cooled, the average channel being about 5 ^{o}C cooler than an average HEU channel. Because of higher peaking in the LEU core, the peak channel temperature was slightly higher than the peak HEU channel.

As compared with the HEU core, it will generally be more feasible to operate the LEU design core at higher powers since the friction pressure drop is smaller, the fission product absorption in the fuel is smaller, and the core as designed has a higher loaded excess reactivity. However, higher reactor power may lead to lower margins of safety. In addition, the longer refueling times in the LEU core at 5 MW will improve reactor utilization, but shorter cycles will lead to a lesser impact on reactor utilization at higher reactor powers. However, care must be taken to reduce power peaking since it is somewhat higher than the HEU core. As with any power increase, a complete safety analysis including loss of coolant and loss of flow evaluations will need to be performed.

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Chapter 7
Reactor Safety Parameters and Limits

7.1. Moderator Reactivity Coefficients

How a reactor behaves under transient conditions is of primary importance in the assurance of safety. The controlling parameters of this behavior are the reactivity feedback coefficients, primarily the moderator temperature coefficient and the fuel temperature coefficient. For the LEU design core (the lead dummy half-element core discussed in Section 5.3), a number of MCNP runs were made by varying the water density to span the equivalent density at given temperatures and determining the effect on reactivity. Neutron cross-section libraries were chosen to represent the temperatures as close as possible. The reactivity results close to the reference value at 25 °C are shown in Figure 7.1. The slope of the curve is the moderator temperature coefficient (MTC). The curve shows that the overall moderator temperature coefficient is negative under all normal conditions of operation. In addition, as expected, the MTC becomes more negative with increasing temperature, indicating that the core becomes even further undermoderated.

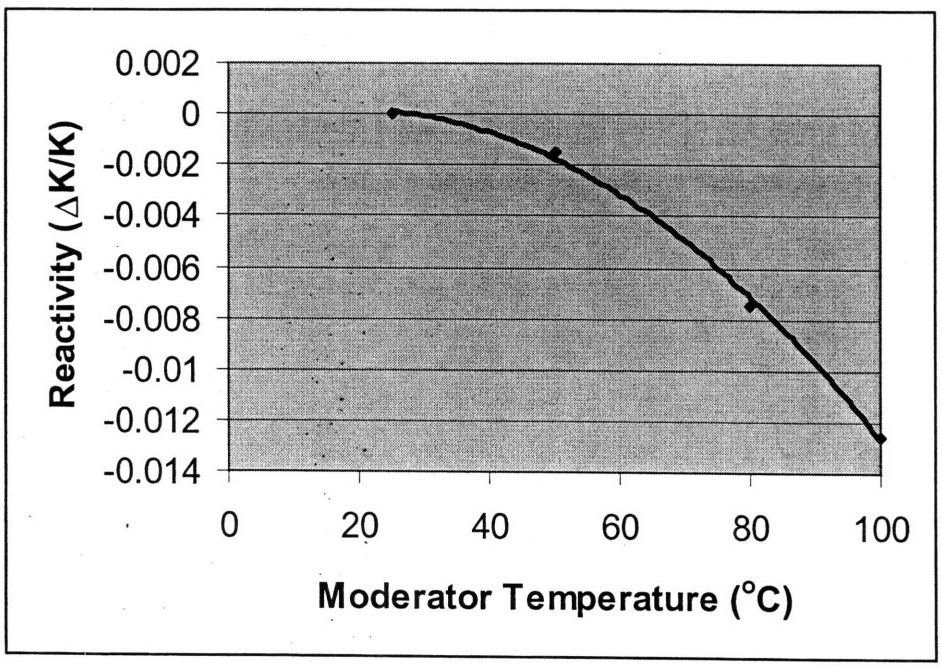

Figure 7.1 Moderator Temperature Coefficient

The value of the MTC in the normal operating region (25-50 °C) is -6 x 10^{-5} ΔK/K/°C. This increases to about -6 x 10^{-4} ΔK/K/°C when approaching 100 °C.

The effect of burnup on the MTC was also evaluated. MCNP results of a core burned to 50 MWd/kg indicated that the MTC became more negative, being -1.1 x 10^{-4} ΔK/K/°C in the 25-50 °C operating range. This is likely due to spectral hardening in the fuel because of the presence of fission products, making the moderator more reactive.

Because the presence of a beryllium moderator in the inner core could possibly result in a local positive moderator coefficient, the moderator temperature effect in the channels adjacent to the inner reflector in the LEU beryllium core was studied. Since the change in density of a single channel has such a slight effect on the overall core reactivity, determining the reactivity effect by looking at the K_{eff} output by MCNP would necessitate very long runs for statistical accuracy. Thus, the effect was determined by reducing the water density in a coolant channel and determining the effect on the neutron flux in the adjacent fuel plates. This was done for all fuel elements adjacent to the beryllium reflector, which, since the core is one-third symmetrical, would be reflected in the B-1, B-2 and B-3 inner plates, as well as any of the three A-ring outer plates. The results, given in Figure 7.2, show that, in all cases the thermal flux decreases slightly with decreasing water density. Although the fast flux is almost an order of magnitude larger in the fuel plates and shows very little variation with changing water density, fast fissions only account for about 3% of total fissions. Thus, the thermal flux results indicate that the local moderator temperature coefficient is indeed negative.

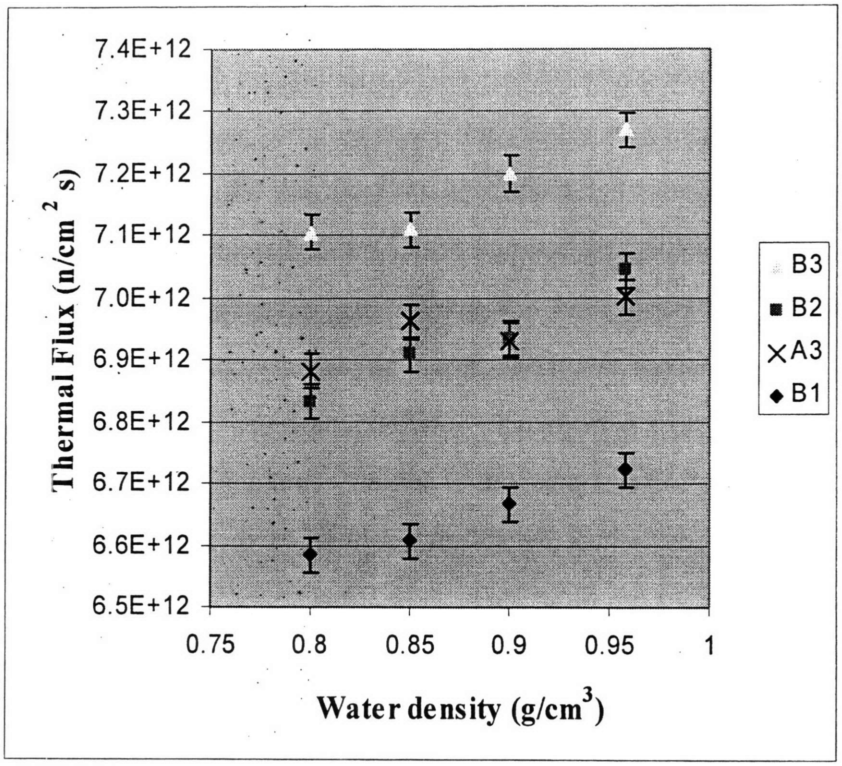

Figure 7.2 Thermal neutron fluxes in fuel plates adjacent to beryllium reflector

7.2. Fuel Reactivity Coefficients

Any reactivity changes due to fuel heating are primarily due to Doppler broadening of the ^{238}U resonance peaks. Because the HEU core has very little ^{238}U, the fuel temperature coefficient in the HEU core is negligible compared with other temperature related reactivity feedback mechanisms. However, the large amount of ^{238}U in the LEU core may result in significant fuel temperature reactivity effects.

To study this, the MCNP LEU model was used by changing only the fuel temperature and using Doppler-broadened cross-sections to determine the reactivity effects. Unfortunately, because of the manner in which cross-section libraries are generated, one must be careful to use Doppler-broadened cross-sections generated by the same group. The University of Texas ENDF B-VI libraries were used with cross section sets generated for 300 K (.62c), 600 K (.78c), and 900 K (.86c). [7.1] These were compared with the National Nuclear Data Center ENDF B-VI.2 libraries at 400 K (.12c) and 600 K(.14c). [7.2] The results of this are shown in Figure 7.3.

The differences between the two libraries can clearly be seen, with the NNDC library showing a larger K_{eff} than the University of Texas libraries. However, since the quantity of interest is the temperature effect, the slope of the curve is what determines the reactivity coefficient. Both of the libraries have almost the same slope at 400 K, with both of them yielding a fuel temperature reactivity coefficient of -2.5×10^{-5} ΔK/K/°C, with a statistical error of about 3%. Since the fuel temperature will vary almost 60 °C from shutdown to full power, this will result in a reactivity change of about 0.15 % ΔK/K or 190 mβ during startup of the reactor. When combined with the moderator density changes from shutdown to full power, the reactivity changes in the reactor will be about 400 mβ, considerably more than the 250 mβ currently experienced with reactor startup using HEU fuel.

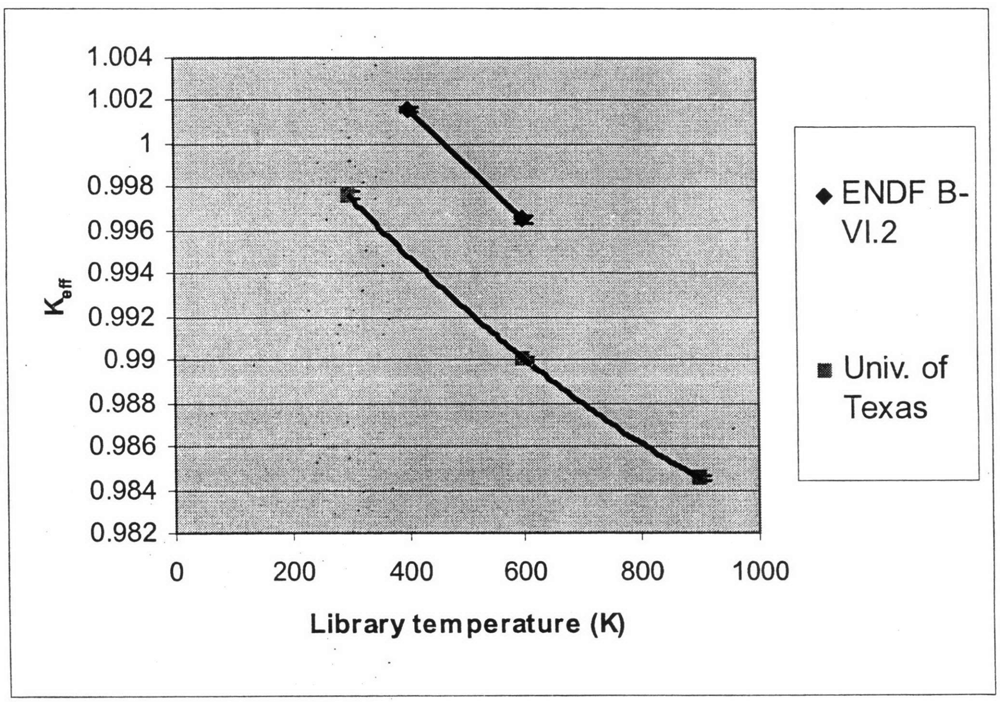

Figure 7.3. Doppler broadening MCNP results for various cross-section libraries

7.3 Burnup differences

As was discussed in Section 5.6, the delayed neutron fraction decreases with burnup due to the buildup of ^{239}Pu. The delayed neutron fraction (β_{eff}) can be calculated using MCNP by initially specifying (via the TOTNU card) calculations using prompt neutrons only followed by a subsequent calculation using total neutrons. The difference in the K_{eff} results of these two runs is the β_{eff}. MCNP results using fuel burned to 50 MWD/kg show the β_{eff} to be 0.0056 +/- 0.0002 as compared to a β_{eff} calculated for a new fuel element of 0.0067 +/- 0.00014. This is not surprising, since of the number of fissions occurring at this point, about 5% of them occur from ^{239}Pu, with most of the remainder occurring from ^{235}U, and the fact that the delayed neutron fraction for thermal fission for ^{239}Pu is 0.0021, as compared with 0.0065 for ^{235}U. [7.3] In addition, the neutron yield per fission is about 15% higher in ^{239}Pu. When coupled with the small amount (about 2%) of fast fissions from ^{238}U with a delayed neutron fraction of 0.0148, the delayed neutron fraction can be calculated to be very close to the 0.0056 MCNP value above.

It should be noted that MCNP does not model photoneutrons such as those produced in the D_2O reflector and thus the β_{eff} result does not include this effect in either case.. The net result of photoneutrons from D_2O is to increase the β_{eff}. However, since both the prompt and delayed gamma activities of irradiated LEU are very similar to that of HEU, no net change in β_{eff} is expected from photoneutrons with an LEU core. Thus, given that the β_{eff} for the HEU MITR-II including photoneutrons is taken to be 0.00786, the β_{eff} for a fully spent LEU core will be about 0.0069. However, any core consisting of fuel near the discharge limit will consist of newer and older fuel and so the β_{eff} for the core will actually be somewhat larger.

Similarly, the fuel temperature coefficient, initially at -2.5 x 10^{-4} $\Delta K/K/^{o}C$, becomes slightly less negative with burnup, becoming -2.4 x 10^{-5} $\Delta K/K/^{o}C$, at 50 MWD/kg, a reduction of about 6% over the life of the fuel. For a mixed fuel burnup in the core, a smaller change will materialize. Therefore, the burnup effect is negligible for both normal operations and for reactivity insertion accident analysis.

7.4 Step Reactivity

7.4.1. Reactivity Insertion of $2.3

The coupled thermal-hydraulic and point-kinetics code PARET was used to model the effects of reactivity change in the LEU core. This code is designed for the use of plate type reactors, such as the MITR. Single phase, two phase, and transition flow can be modeled using several correlations. For single phase heat transfer, the Dittus-Boelter relation,

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$$

was used, as discussed in Section 6.1. Although both this relation and the Sieder-Tate relation are available for use and are valid for similar flow regimes, the Dittus-Boelter relation is more universally used.

For two-phase heat transfer, the Bergles-Rohsenow correlation was used. This states that:

$$T_{clad\ wall} = q''_{ONB}/(15.6\ p^{1.156})^{p^{0.0234}/230} + T_{sat}$$

where T is in °F, q''_{ONB} is the heat flux at the onset of nucleate boiling in BTU/hr ft^2, and p is the pressure in psi. This correlation is recommended by the IAEA [7.4] for research reactor analyses.

Use of the Jens-Lottes correlation,

$$T_{clad\ wall} = 0.79q''^{0.25}/\ e^{P/0.62} + T_{sat}$$

where T is in °C, q" in W/m^2 and P in MPa, was investigated as well. The Jens-Lottes correlation yielded consistently lower temperatures under the conditions analyzed, so the Bergles-Rohsenow correlation was chosen for conservatism.

The Tong relation was used for transition boiling heat transfer. This relation is initially used in calculating the DNB heat flux:

$$q''_{DNB} = (0.23 \times 10^6 + 0.094G)[3.0 + 0.01(T_{sat} - T_{bulk})][0.435+1.23e^{-0.0093L/De}][1.7 - 1.4e^{-a}]$$

where

$$a = 0.532[(H_f\text{-}H_{inlet})/H_{fg}]^{0.75}\ (\rho_f/\rho_g)^{0.333}$$

and G is the mass flow rate, H_f is the enthalpy of saturated liquid, H_{inlet} is the enthalpy of coolant at core inlet, and ρ is the coolant density. The transition boiling heat flux (q''_{TB}) is then calculated by applying the following equation:

$$q''_{TB} = q''_{DNB} - K_{TB}\ (T_{clad} - T_{clad\ DNB})$$

where K_{TB} is a constant given in the PARET code. This equation is valid only for $q''_{TB} < q''_{DTB}$ and for $T_{clad} < T_{clad\ DTB}$, where DTB indicates the point of departure from transition boiling. Of the five transition relations available in PARET, this relation is stated by Woodruff [7.5] to most closely match the SPERT results, as discussed in Section 2.4.

For further discussion of heat transfer and flow correlations used in PARET, the reader is referred to the PARET manual. [7.6]

The MITR was modeled in PARET initially with a \$2.3 step reactivity addition, beginning at a power of 5 W, where fuel and moderator temperatures were modeled at 33 ^{o}C. This reactivity value was chosen because it is the current limit for the MITR-II HEU core, based on a calculation which showed that reactivity additions greater than this value resulted in an approach of the fuel temperature to the aluminum cladding softening point of 450 ^{o}C. [7.7] In addition, a reactor scram due to overpower was assumed to occur, tripping at 7 MW with a 0.1 second instrumentation delay prior to the blades beginning to drop. The blade bank reactivity worth curve was also input into PARET. A β_{eff} of 0.00786 was assumed for the HEU core, while 0.0074 was assumed for the LEU core. This LEU value was chosen since it will be the approximate β_{eff} with an equilibrium fuel loading combining newer and more burned fuel. Since the step reactivity input into PARET is given in dollars, a higher β_{eff} yields more conservative results.

There is considerable uncertainty as to the appropriate value to use for the prompt neutron lifetime. The MITR-II Safety Analysis Report (SAR) [7.8] lists a value of 8 x 10^{-5} seconds for the prompt neutron lifetime. Yarman [7.9], used the point kinetics code OZAN in the analysis of the MITR-II and suggested that a value of 1.2 x 10^{-4} seconds be used. MCNP results show a value for the HEU core of up to 7 x 10^{-4} seconds although MCNP weights all neutrons equally, so that neutrons outside the core have the same weight as those inside the core. Thus, the MCNP-generated lifetime could be skewed by the longer-lived neutrons present in the D_2O reflector. The MCNP value for the LEU core is somewhat smaller at 6 x 10^{-4} seconds. For conservatism, the SAR value of 8 x 10^{-5} seconds was used for the step reactivity analysis.

The fuel temperature coefficient was assumed to be -3.67 x 10^{-3} \$/^{o}C (-2.5 x 10^{-5} ΔK/K/^{o}C) for the LEU core and three orders of magnitude smaller for the HEU core (3.67 x 10^{-6} \$/^{o}C) since there is a small amount of ^{238}U present in the HEU core, although the actual value in this range makes no difference in the outcome. A linear fuel temperature coefficient was assumed, since this fits the curve fairly well and a quadratic fit makes very little difference for the temperature range in question.

The PARET results for the MITR will be conservative because the cooling effect of the fins was not able to be modeled and the axial peaking factors were taken from the MCNP values in the peak (outer C-ring) channel.

Although the moderator temperature coefficient is fairly non-linear with temperature, when plotted as a function of water density, the reactivity curve, shown in Figure 7.4 is much more linear. Thus, the moderator void coefficient input into PARET, based on the linear fit of the MCNP values of reactivity vs. water density for the LEU core is about 0.47 $/% void. Similar calculations for the HEU core show a slightly larger void coefficient of about 0.52 $/% void.

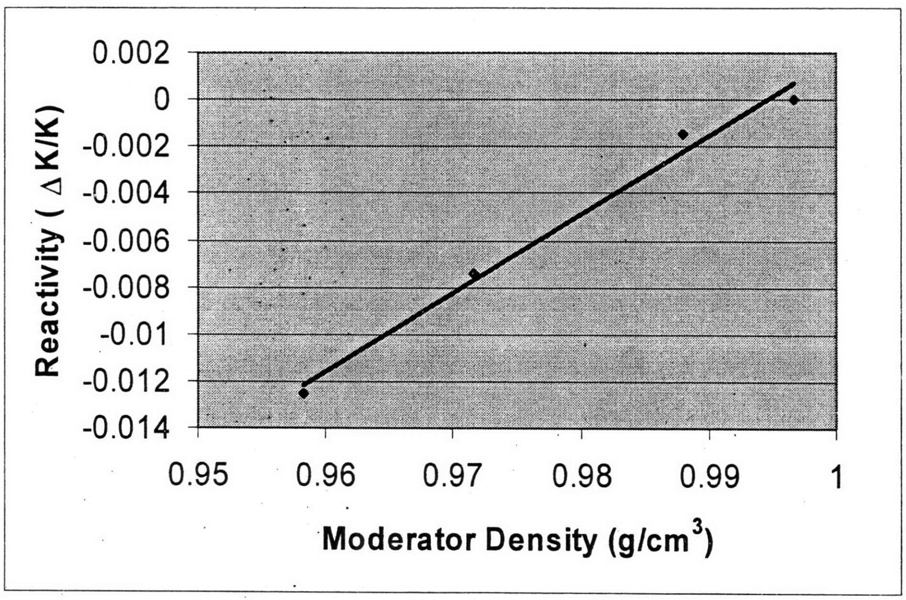

Figure 7.4 Reactivity variation with moderator density

The PARET results of the $2.3 step insertion are shown in Figures 7.5 and 7.6, with the reactivity values vs. time shown in Figure 7.5. In this case, the results for the LEU and HEU cores are fairly similar, with negative reactivity insertion due to voiding of the coolant occurring slightly earlier in the HEU core. This voiding occurs with the coolant quickly reaching transition boiling at about 0.15 seconds. In both cases, the coolant drops briefly to nucleate boiling before again reaching the liquid phase. A second positive reactivity insertion when the coolant drops from transition boiling to nucleate boiling occurs at about 0.18 seconds, although this effect is much more pronounced in the LEU case. The effect of the reactor scram beginning at about 0.25 seconds can clearly be seen in both cases.

The fuel temperature is shown in Figure 7.6. In this case, the differences in fuel temperature are more obvious, with the HEU rising to over 300 °C, while the LEU value does not exceed 250 °C. The HEU peak fuel temperature is significantly below the 450 °C result from that in the SAR, likely due to less conservative assumptions in the PARET input. The second temperature rise due to the drop in voiding can be seen occurring at about 0.23 seconds. Because of the relatively low fuel temperature for the LEU case, Doppler broadening has only a limited role in this case.

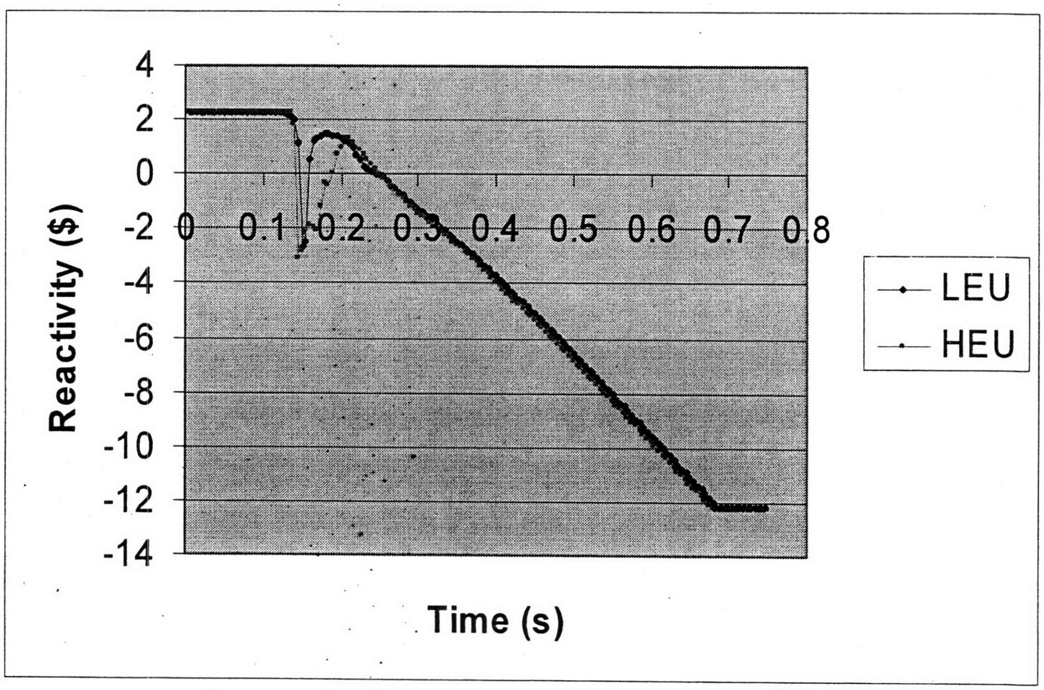

Figure 7.5 $2.3 step reactivity insertion

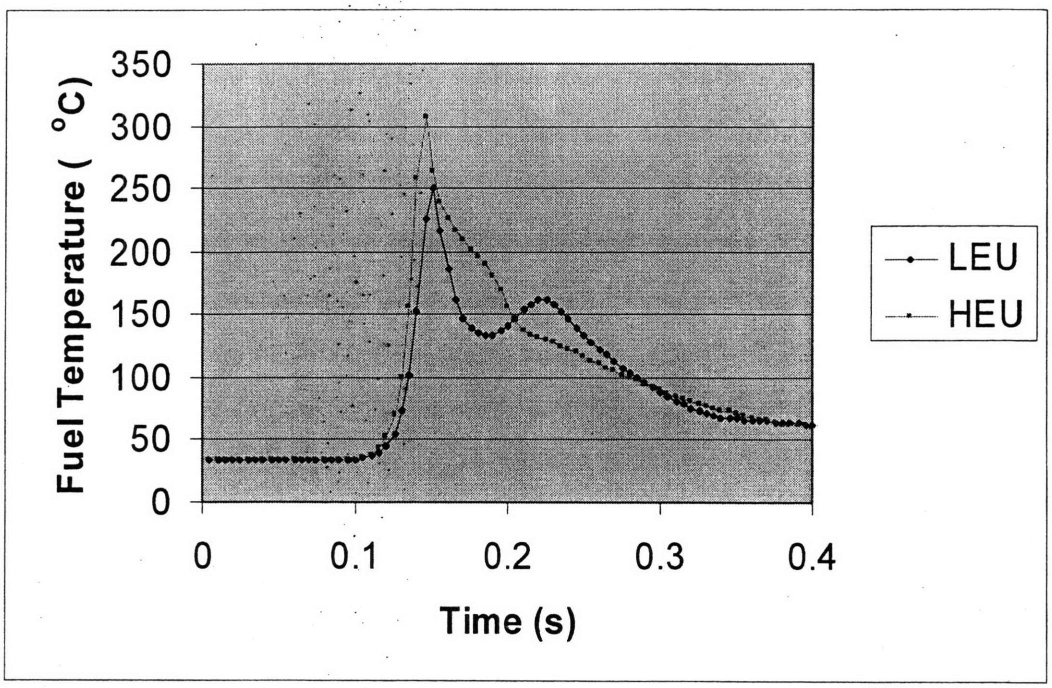

Figure 7.6 Fuel Temperature with $2.3 reactivity insertion

7.4.2. Step reactivity limit

PARET was used further to determine the maximum step reactivity insertion possible in the LEU core without exceeding the clad softening point of 450 °C. This value was determined to be $3.69. An attempt was made to compare this with HEU results at $3.69, but PARET became unstable because of the large temperatures reached. However, for comparative purposes, a $3.5 step reactivity for the HEU core was able to be run without encountering any instabilities.

The PARET results for both LEU and HEU cores are shown in Figures 7.7- 7.10. The reactivity change is shown in Figure 7.7. The reactivity in the LEU core, after the initial $3.69 step, drops rapidly due to Doppler broadening in the ^{238}U resonance peaks, with some reactivity oscillations occurring with a brief amount of water boiling, principally in the transition regime, prior to a second reactivity increase of about $1.8 due to the water changing boiling regimes, after a brief period of film boiling, as well as some cooling of the fuel. This is followed by further negative reactivity with the reactor scram, beginning at about 0.25 seconds. The HEU core, in contrast, has a slower negative reactivity response since there is no significant fuel temperature feedback. This occurs because of decreasing moderator density, followed by significant reactivity oscillations as the water moves from transition boiling (~0.08 s) to film boiling (~0.1 s) to bulk boiling (~0.28 s). It remains at bulk boiling throughout the transient.

It should be noted that the two-phase correlations used in PARET become less valid with significant voiding in the core. However, of all of the cases analyzed, only the $3.5 reactivity insertion in the HEU core results in significant voiding. It is included here only for comparative purposes.

The power is shown in Figure 7.8. While the Doppler feedback limits the LEU core power to about 470 MW, the HEU core reaches over 820 MW before the moderator temperature coefficient causes sufficient negative reactivity to limit the power. The boiling oscillations cause some secondary power increases after about 0.1 seconds.

The fuel temperature history is shown in Figure 7.9. After briefly reaching 400 °C, the LEU core fuel temperature drops back to the initial values of around 35 °C, as opposed to the HEU core that, because of the lack of Doppler feedback, exceeds the aluminum melting point of 660 °C, reaching and maintaining a temperature of 685 °C. The cladding temperature, shown in Figure 7.10, shows similar differences, with the HEU temperature increasing past the aluminum melting point after about 0.2 seconds. Neither the fuel nor the cladding reached the 450 °C aluminum softening point for the LEU case.

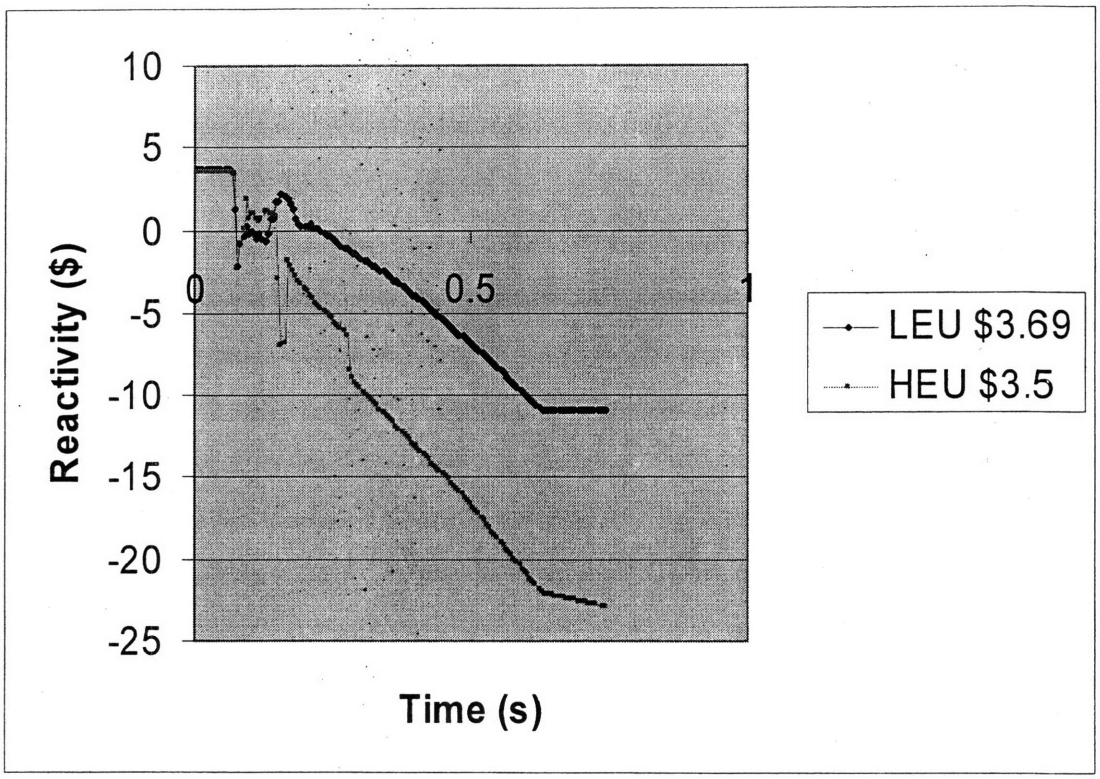

Figure 7.7 Reactivity history with $3.69 step reactivity increase beginning at 5 W and scram at 7 MW (0.1 s delay)

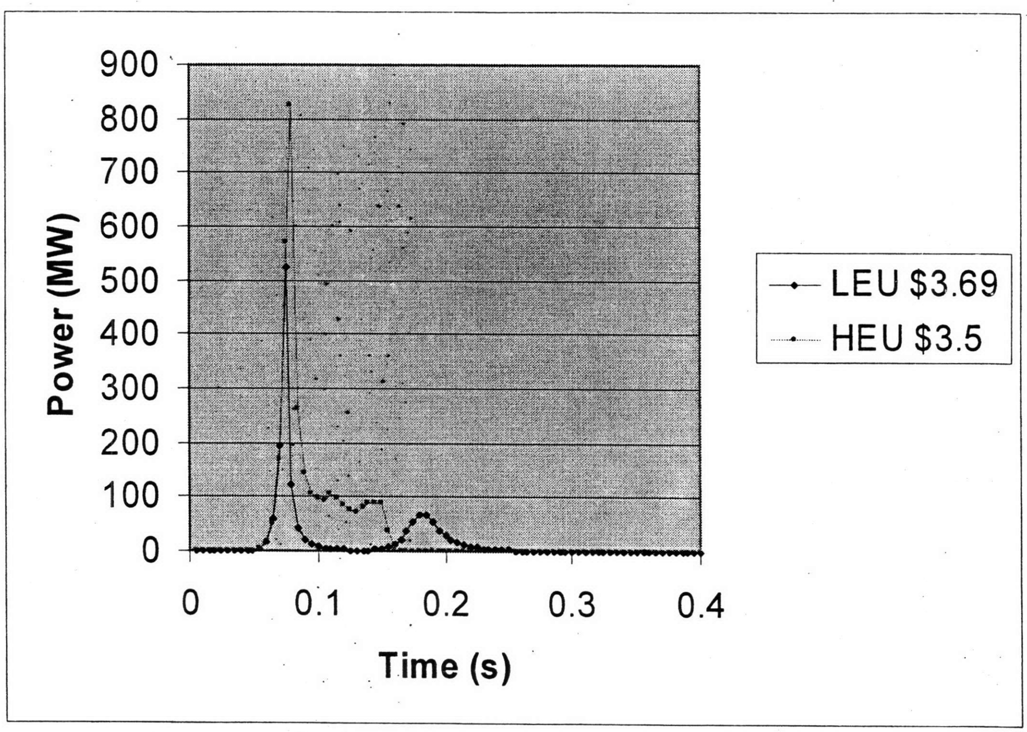

Figure 7.8 Power with $3.69 step reactivity increase

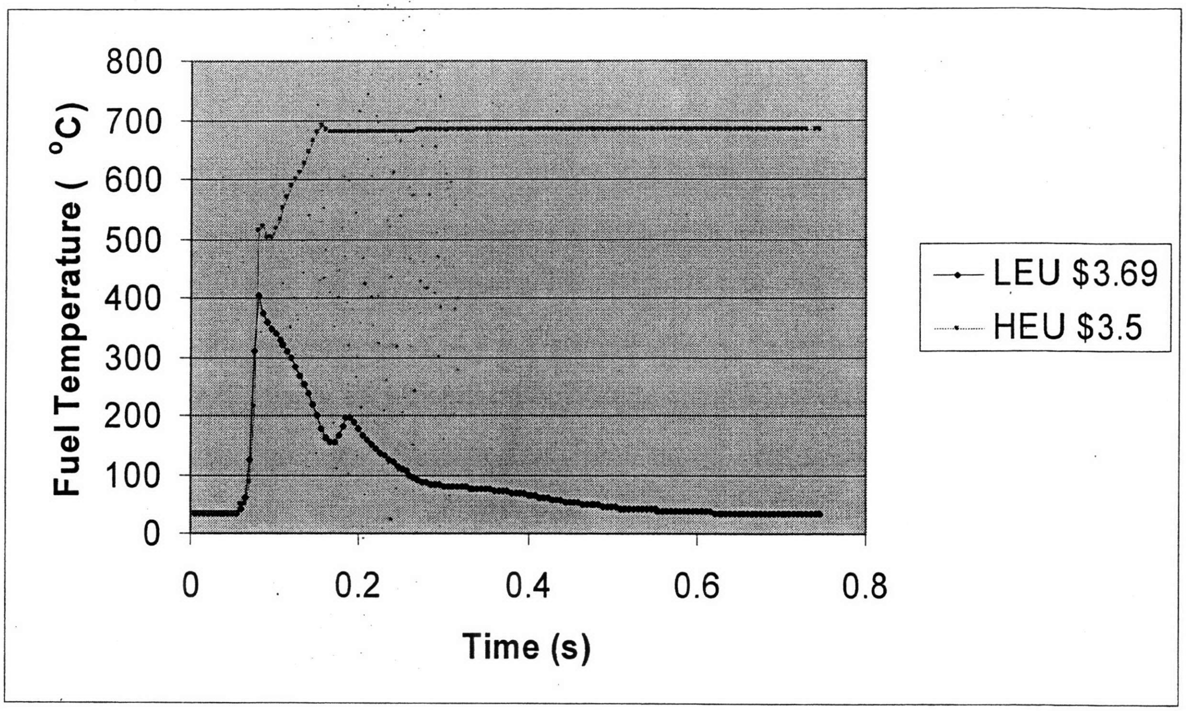

Figure 7.9. Fuel Temperature with $3.69 step reactivity increase

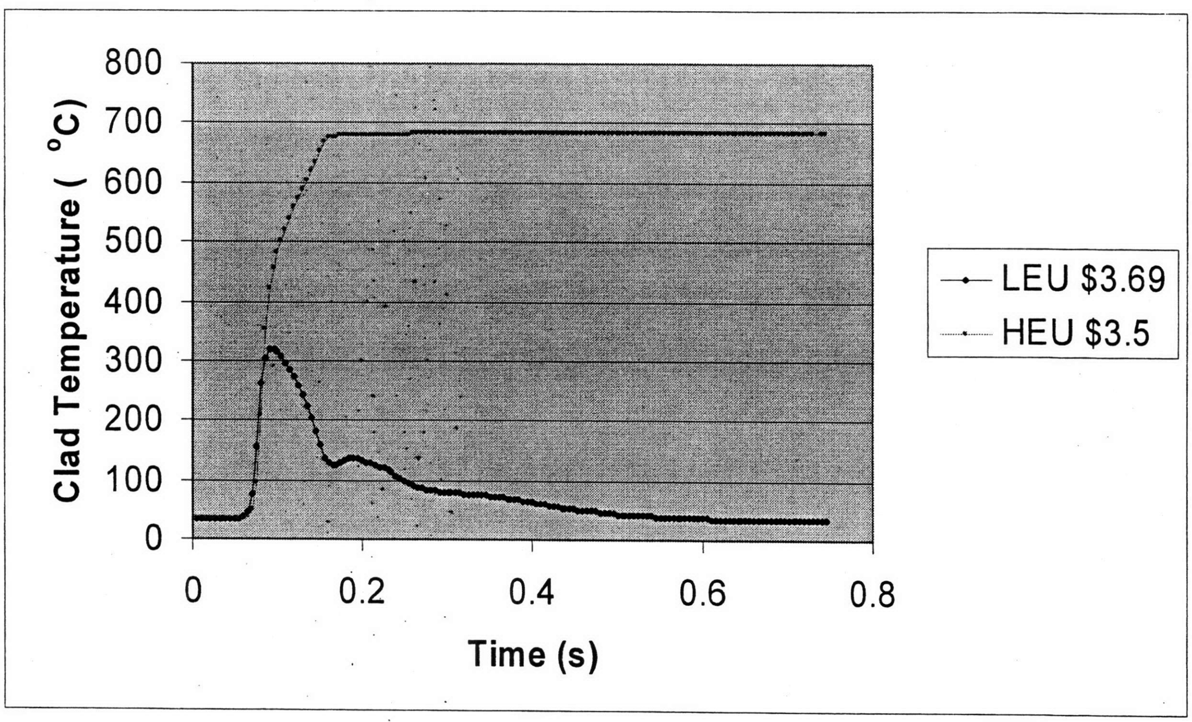

Figure 7.10 Clad temperature with $3.69 step reactivity increase

A PARET run at \$3.70 indicated that the LEU fuel temperature coefficient was not large enough to overcome the reactivity and resulted in fuel temperatures exceeding 450 ^{o}C.

The above results indicate that, mainly due to Doppler feedback, the LEU core is much better able to withstand a large positive reactivity increase than the current HEU design. Since the allowable reactivity limits for experiments are based on the maximum safe step reactivity, the limit for experiments for the LEU core should be \$3.69 or 2.6 % ΔK/K. It should be noted that when compared with the SPERT results, PARET has about a 30% uncertainty. However, because of the conservatisms listed above, the above reactivity step should still be within safe limits, despite any uncertainties in benchmarking and modeling. This approach was taken in relicensing the MITR-II [7.10]

7.5 Blade worths and shutdown margin

The MCNP generated blade worth curves for both the HEU and LEU cores are shown in Figure 7.11. These clearly show a larger reactivity worth at a given blade position for the LEU core, particularly at lower blade positions. This indicates that the total LEU blade worths are slightly less than in the HEU core, most likely because the spectrum is slightly harder in the LEU core, reducing the effectiveness of the boron absorber. The overall worth of the blades is about 11 % ΔK/K for the HEU core and 10% ΔK/K for the LEU core.

Because of this and a larger fuel loading in the LEU core, it must be assured that the required shutdown margin specification is met. This specification requires that the reactor must be subcritical by at least 1% ΔK/K, with the most reactive blade and the regulating rod out and the other five blades in, under cold, xenon-free conditions. [7.11] MCNP calculations of the LEU design core under these conditions show that the K_{eff} is 0.986, indicating that the reactor is shutdown by 1.4 % ΔK/K. As new fuel in the outer C ring is burnt and refueling strategy is as discussed in Section 5.6, the blade reactivity worth should be reduced, so that an individual blade being out would have less of a reactivity effect and the shutdown margin should be more easily met. As is the case currently, care must be taken to symmetrically load the fuel so that individual blades are not significantly more reactive.

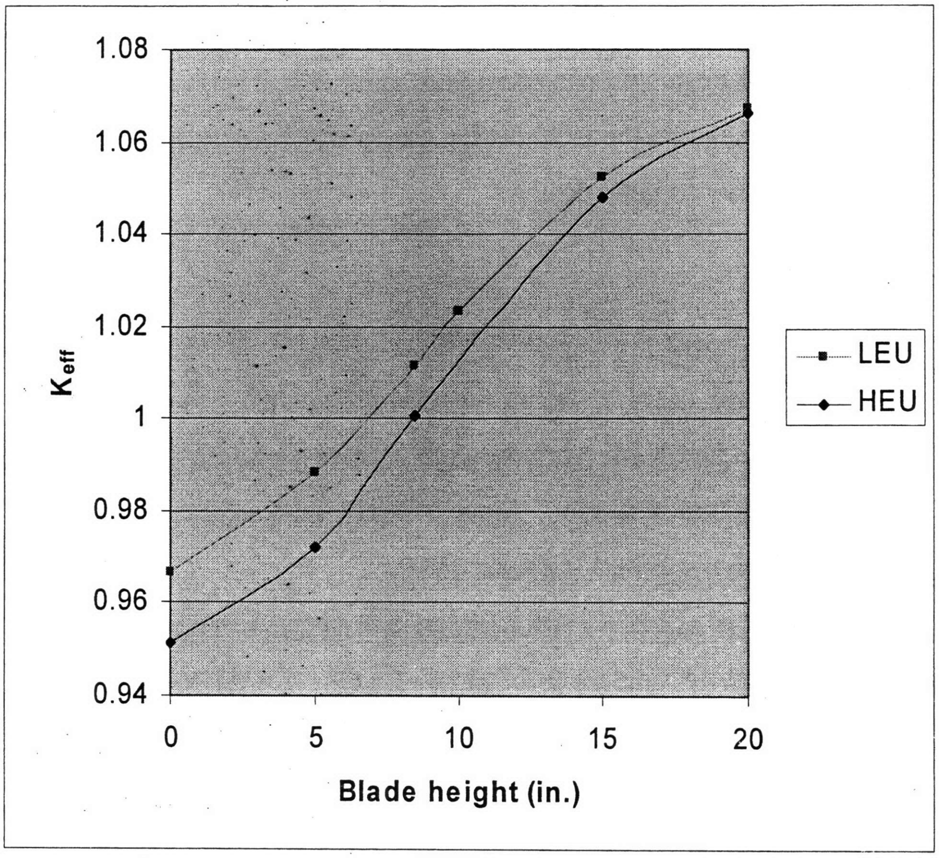

Figure 7.11 HEU and LEU blade worth curves

7.6 Conclusions

Safety parameters of moderator and fuel temperature reactivity coefficients were determined for the design basis LEU core. This evaluation showed that in all cases both the overall and local moderator temperature coefficients were negative. In addition, the fuel temperature coefficient is negative due to Doppler broadening in the ^{238}U cross-section resonances.

The coupled thermal-hydraulic and point kinetics code PARET was used to determine the effect of a step reactivity addition on the HEU and LEU MITR cores. This indicated that, primarily due to Doppler broadening, the LEU core is able to withstand a step reactivity addition of up to $3.69 before reaching cladding softening temperatures. This should allow inclusion of experiments in-core with reactivity worths of up to 2.6 % ΔK/K. Thus, the LEU core allows a higher value of reactivity associated with experiments than the 1.8% currently allowed.

MCNP analyses of blade worth and shutdown margin indicate that the overall blade worths for the LEU core is slightly less than the HEU core and that the shutdown margin requirement for the LEU design core is adequately met.

All of the above indicate that the LEU design core meets basic reactivity safety criteria, and thus should be a viable design.

References

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Chapter 8
Summary of Conclusions and Recommendations

8.1 Summary of design constraints

The design of an LEU-fueled MIT reactor was made assuming there are to be no changes beyond the existing core structure, since such changes might be expensive and are not likely to be funded under RERTR guidelines. Thus, the design was made under the constraint that the new fuel must fit within the existing core tank and grid. In addition, HEU core model benchmarking and HEU to LEU comparisons were made at a reactor power of 5 MW, since all measured data from the HEU core is at this power level. Similar control blade heights and other operating parameters such as temperatures were also assumed for HEU/LEU comparisons.

In order to compare various LEU core designs with the existing HEU core, fluxes were evaluated at four ex-core and one in-core experimental facilities. Similar energy groups were used in the evaluation for each, and identical neutron cross-section libraries were used when possible.

8.2 Summary of designs surveyed

Monolithic U-7Mo fuel with a density of 17.55 g/cm^3 and a uranium enrichment of 20% was used in a design of the MIT Nuclear Reactor core with the goal of avoiding reductions in neutron flux available to experiments due to the conversion to LEU fuel, as well as increasing the flexibility in meeting the needs of in-core experiments. Direct substitution of LEU fuel for the currently used UAl_x HEU fuel (with density of 3.7 g/cm^3 and 93% enrichment) resulted in a calculated reduction of experimental fluxes by at least 10% and a reactivity loss of about 1.2% ΔK/K. Such a reduction in flux is not surprising given the higher density of ^{235}U in the LEU fuel, and the constraint of fixed total core power. The configuration of fuel plates was then optimized by varying the plate number and fuel and cladding thicknesses and using MCNP to determine the effect on flux and reactivity. In addition, the use of different moderator and fuel dummy materials as well as fixed absorbers was evaluated to optimize the neutron fluxes, reactivity and neutron spectrum available for experiments.

8.3 Summary of optimum design

The optimum reactor design consisted of the use of half-sized fuel elements made up of nine U-7Mo LEU fuel plates of 0.55 mm thickness with 0.25 mm finned aluminum cladding. This design with solid beryllium dummies and boron fixed absorbers resulted in an ex-core experimental thermal flux increase of about 4% over that of the HEU fuel. Substitution of the beryllium dummies with lead dummies, elimination of the fixed absorbers, and use of half-elements in the three A-ring positions resulted in an in-core experimental fast flux increase of about 4% over that of the HEU core. Equivalent criticality (equal control blade heights) to the HEU core was maintained in both of these cases. However, in no case could fluxes equivalent to those of the HEU core be simultaneously delivered to ex-core and in-core experiments using LEU fuel.

8.4 Experimental capability of LEU core design

The LEU core of the MIT Reactor has been designed to best meet the needs of the experimental users of the reactor. Despite the necessary constraints of being placed within the existing core structure, this design was made flexible enough to meet the changing needs of experimenters over time. A summary of the main characteristics comparing the reference HEU core (MITR-II core configuration no. 2) with the design basis LEU core (42 half-sized U-7Mo fuel elements with lead dummy elements in twelve internal positions) is given in Table 8.1.

The number of plates in the LEU core is larger than that of the HEU core, which will decrease the average heat generation per plate. Although the plates used in the LEU core are thinner, the higher fuel density results in a much larger uranium loading. The fissile mass in the LEU core is twice that of the HEU core, resulting in an overall lower flux at a given power level. However, the core configuration was designed to optimize flux delivery to experimental positions.

Table 8.1 Comparison of HEU and LEU core characteristics

	HEU core no. 2	Proposed LEU core
Number of fuel elements/core	22	42
Number of fuel plates/element	15	9
Fuel material	UAl_x	Monolithic U-7Mo
Fuel material density (g/cm^3)	3.44	17.55
Fuel thickness (mm)	0.76	0.55
Cladding thickness (mm)	0.38	0.25
Uranium density (g U/cm^3)	1.54	16.32
Enrichment	93%	20%
Mass of uranium in reference core (kg)	11.5	107.9
Mass of ^{235}U in reference core (kg)	10.7	21.6

Thermal-hydraulic and heat transfer analyses were performed and indicate that the LEU core as designed has superior heat transfer characteristics than the HEU core, although the power peaking is somewhat higher. Reactivity transient analyses were performed and indicate that the LEU core can withstand a step reactivity insertion of up to $3.69, much higher than the $2.3 currently prescribed as a limit.

Although there may be a trade-off between ex-core and in-core experimental flux needs, the LEU core has some inherent experimental and utilization advantages over the current HEU core:

- Space for in-core facility to allow tests with up to over 10 cm in diameter.
- Secured in-core experiment reactivity limit of $3.69, a 60% increase over the current HEU limit.

- Refueling intervals of twice as long as that of the HEU fuel if the power remains at 5 MW. Combined with the results of the thermal-hydraulic analyses, this makes an upgrade to 10 MW much more easily accomplished.
- Wider coolant channels between plates, enhancing natural convection ability.
- Greater flexibility in fuel placement to both reduce power peaking and increase fluxes near experiments, as well as some ability to adjust the in-core experimental neutron spectrum.
- Core symmetry, simplifying future fuel management and experiment evaluations.
- Reduced enrichment which enhances the proliferation resistance aspects of the fuel.

Overall, the LEU core design has been shown to meet fundamental safety criteria and will meet current and future anticipated operational and experimental needs.

However, the use of LEU fuel will result in the production of a mass of ^{239}Pu an order of magnitude larger than that of using HEU fuel. This could result in larger exposure under accident conditions and prompts waste storage concerns because of the larger decay heat and long-lived activity.

8.5 Recommendations for future work

8.5.1 Future evaluations

Although the HEU core has been extensively benchmarked, validation of the effect of the addition of a significant amount of ^{238}U is needed. This will necessitate experimental measurements not currently possible at the MITR. However, partial validation could be made using experimental results at LEU reactors with similar design as the MITR.

In addition, there may be some interest in using U-7Mo fuel enriched in the heavier isotopes of molybdenum, since there is some resonance absorption in ^{96}Mo. This should be evaluated for the MITR.

8.5.2 Fuel management plan

Although a refueling strategy was outlined in Section 5.5, a detailed refueling plan should be developed, including the optimization of new and partially spent fuel placement for experimental needs. In addition, fuel management should include the reduction of power peaking, particularly in the C-ring at higher blade heights.

The codes currently in use for MITR neutronic analyses have some drawbacks for use as fuel management codes. It is unclear whether the diffusion theory code CITATION, currently being used for MITR-II fuel management, will be able to maintain its accuracy, particularly with the higher flux gradients within the high density LEU fuel plates. MCODE or other MCNP-based coupling point depletion codes depend on the ability of MCNP to tally the results of each node. Without homogenizing regions in the core, up to 3000 nodes would need to be tallied for long-term burnup accuracy. Thus, identification of a code for use in fuel management for the LEU core is needed.

8.5.3 Safety parameters and licensing

As was mentioned in Section 7.4, considerable uncertainties exist as to the appropriate value to use for the prompt neutron lifetime. This value should be determined using proper techniques and, if possible, experimentally verified.

In addition to the prompt neutron lifetime, an accurate estimate of the effect of photoneutrons on the delayed neutron fraction for both the HEU and LEU cores need to be determined.

A version of the PARET code using more updated heat transfer correlations is under evaluation at Argonne National Lab. When available, this should be used for further reactivity safety analyses.

In order for the LEU core to be licensed, the U-Mo fuel must first be qualified. This is in progress with the work of the RERTR program at ANL. After fuel qualification, a complete safety analysis report must be made, which includes not only those thermal-hydraulic and reactivity analyses made here, but also others such as loss of coolant, flow blockage, ramp reactivity insertion, fuel malfunction, and external events. In addition, radiological analyses must be made, including source term calculations and offsite dose calculations. Although activity levels at a given burnup should be comparable with the HEU analyses, the presence of higher amounts of actinides may affect radiation doses and as a result, emergency planning. Higher burnup in the LEU fuel will also result in higher fission product inventories which will also affect doses and emergency planning. Thus, the licensing of the LEU core will take considerable effort and, although DOE has set a goal of 2014 for conversion, care must be taken to assure an adequate safety analysis.

It is possible that the MITR will undergo an upgrade to 10 MW in the future. Although analyses here comparing the HEU and LEU cores show that the pressure drop is lower and the core lifetime is longer with the LEU core, the LEU fuel and core design should be further evaluated to optimize it for higher power if 10 MW operation is planned.

It is hoped that in any future work towards converting the MITR to LEU fuel, it is remembered that the *raison d'etre* of the MIT reactor is to meet the needs of the students and researchers. It is also hoped that the ideas presented here as well as any future work will further the goal of the MIT Nuclear Reactor Laboratory in performing world-class neutron research.

Appendix A
Calculation of U-Mo Fuel Conductivity

Unirradiated U-Mo fuel

Kim and Hoffman[1] determined a relation for the conductivity of U- Mo fuel to be

$$k^0_{U-Mo} = \left(1-\sqrt{1-x_{Mo}}\right)k_{Mo} + \sqrt{1-x_{Mo}}\,\left\{(1-x_{Mo})k_U + x_{Mo}k_{c,Mo}\right\} \qquad (1)$$

where k^0_{U-Mo} is in W/m-K, x_{Mo} is the Mo content in weight fraction. k_U is the conductivity of uranium metal, given by:

$$k_U(T) = 21.73 + 1.591\times10^{-2}\,\mathrm{T} + 5.907\times10^{-6}\,\mathrm{T}^2 \qquad (2)$$

and k_{Mo} by

$$k_{Mo}(T) = 150.0 - 4.0\times10^{-2}\,\mathrm{T}. \qquad (3)$$

. $k_{c,Mo}$ is a result of the regression analysis of the data to Eq.(1) and takes the form

$$k_{c,Mo} = -274.4 + 985.2\,x_{Mo} - 1.941\times10^3\,x_{Mo}^{\,2} + 3.640\times10^{-2}\,T + 7.365\times10^{-5}\,T^2 + 5.793\times10^{-2}\,x_{Mo}\,T \qquad (4)$$

where T is the fuel temperature in degrees K. The valid temperature range is $300 \le T \le 800\,\mathrm{K}$

For MITR U-7Mo fuel at 372 K, this would give a fuel conductivity of 17.56 W/m K.

Irradiated U-Mo fuel

For irradiated fuel, the conductivity becomes a function of the volume expansion of fission gas swelling, given by

$$\left(\frac{\Delta V}{V_0}\right)_G = \left[4.97\times10^{-6}\,T + (x_{Mo}-0.1)^2\exp\left\{-0.5\left(\frac{T-720}{84}\right)^2\right\}\right] \times 419\left(0.321B - 7.15\times10^{-3}B^2 + 1.99\times10^{-4}B^3\right) \qquad (5)$$

where $(\Delta V/V_0)_G$ is the volume expansion by fission gas swelling in percent, x_{Mo} the Mo content in weight fraction, B burnup in 10^{20} fissions/cm^3 and T temperature in K.

The conductivity can then be expressed by

$$k_{U-Mo} = \frac{1}{4}\left[A + \left(A^2 + 8k_{U-Mo}^0 k_g\right)^{\frac{1}{2}}\right] \quad (6)$$

where

$$A = (2-3P)k_{U-Mo}^0 + (3P-1)k_g, \quad (7)$$

And the porosity is given by $$P = \frac{1}{100}\left(\frac{\left(\frac{\Delta V}{V_0}\right)_G}{1+\left(\frac{\Delta V}{V_0}\right)_G}\right). \quad (8)$$

K_g, the pore thermal conductivity, given by

$$k_g = 0.1\left(8.247\times10^{-5}\,T^{0.8363}\right) + 0.9\left(4.351\times10^{-5}\,T^{0.8616}\right) \quad (9)$$

For MITR fuel at 10^{21} fissions/cm^3, the conductivity of U-7Mo is 17.4 W/m K.

References

1. Y. Kim and G. Hofman, "Thermal Conductivity of U-Mo During Irradiation," Intra-laboratory memo, Argonne National Lab, February 19, 2003.

Appendix B
MCNP LEU Input File

Because of fuel element orientation and geometry, each fuel element position series of cells (in a universe) are transformed according to the appropriate orientation in relation to the core centerline.

Lead dummies are modeled in this file, in half of all three A ring elements and half of all B ring elements. Empty ICSA (cell # 61047) with lead annulus is modeled in the center of the core.

U-7Mo fuel is modeled with a density of 17.55 g/cm^3, nine plates in A and B positions, eighteen plates in the C positions.

```
MITR-Shape/Peaking: 1 cm axial node, 18 plates, 8.5" Blade H
c
c    = Based on std427 MITR-II FULL REACTOR MODEL
c
c    message:   outp= spf.out   srctp= spf.src
c           runtpe= spf.tpe mctal= spf.tal
c
c
c     File's nameing convention is:
c       SPF = Shape/Peaking Factors Run
c
c     This run is to tally energy and flux for LEU core #2.
c       U7Mo monolithic fuel MCNP run 9/13/05.
c        18 plate fuel fuel thickness 0.021" thin clad
c       same water gap as HEU
c      fuel in half of A elems.(Pb other half) H2O in spider
c   B ring full, B3, B6, B9 rotated 90 degrees
c  Pb in inner half of all B ring
c  Pb surrounding ICSA in center of core
c
c     Initial model was made by Everett Redmond II, MIT '89
c      partial thermal column and fission converter added by
c      Stead Kiger
c     Core configuration modified by Tom Newton
c
c     the medical therapy beam is included and the
c     d20 blister and h20 tank are *full*
c
c
c
c     CELL DESCRIPTIONS
c
c     The cell numbers currently being used or reserved for further
c     development are:
c             100-127
c             1000-5999
c             9000-9999
c             11000-37999
c             50000-99999
c     For any item added please use another sequence of numbers and use the
c     same sequence for the surface cards as well.
c
c     Fuel element description cells used to fill the fuel element locations
c
```

```
c       Fuel element 1
c
c       The following fuel elements use the 51000 series of surfaces
c       A1, A2, A3, B1, B4, B7, C1, C2, C3, C6, C7, C8, C11, C12, C13
c
c       The picture shows the orientation of the element relative to the
c       axis system. The reason for having two elements oriented differently
c       and used in different fuel locations is because of the depleted core
c       models. The concentrations for these models are provided on a per element
c       basis in three radial regions and 14 axial regions. All of the radial
c       regions go from the inside of the reactor to the outside. The fuel
c       elements are oriented in such a way as to best represent the radial
c       effect on the concentrations for the depleted core. This orientation
c       results in the fuel plates for the fresh core going from the inside of
c       the reactor to the outside of the reactor in most locations.
c
c                y
c               /|\
c              |\ |
c              | \|
c              |  \
c              |  |\
c              |  | \
c              |  ---\---> x
c               \     |
c                \    |
c                 \   |
c                  \  |
c                   \ |
c                    \|
c
c
c          Dummy element Type A (normal end caps)
c
51035      1 -0.9967837    -51100  51130  51001  -51074   -79 85   u=-35
51036      30 9.07358e-02                                  79    u=35
51037      40 8.21151e-02                              -86       u=35
51038      1 -0.9967837   -51100  51130          51001  -80 85   u=35
51039      1 -0.9967837   -51100  51130  -51074         -80 85   u=35
51040      1 -0.9967837            51100                -80 85   u=35
51041      1 -0.9967837   -51130                        -80 85   u=35
35099      1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=35
35197      6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-35
35297      6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-35
35399      23 -17.55     -51112  51118  -51003  51004  -80  85  u=-35
35298      6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-35
35198      6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-35
35100      1 -0.9967837       -51110  51120  -51005  51006  -80  85  u=-35
35199      6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-35
35299      6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-35
35400      23 -17.55    -51112  51118  -51007  51008  -80  85  u=-35
35300      6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-35
35200      6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-35
35101      1 -0.9967837      -51110  51120  -51009  51010  -80  85  u=-35
35201      6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-35
35301      6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-35
35401      23 -17.55  -51112  51118  -51011  51012  -80  85  u=-35
35302      6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-35
35202      6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-35
35102      1 -0.9967837       -51110  51120  -51013  51014  -80  85  u=-35
35203      6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-35
35303      6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-35
35402      23 -17.55  -51112  51118  -51015  51016  -80  85  u=-35
35304      6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-35
```

```
35204    6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-35
35103    1 -0.9967837         -51110  51120  -51017  51018  -80  85  u=-35
35205    6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-35
35305    6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-35
35403    23 -17.55  -51112  51118  -51019  51020  -80  85  u=-35
35306    6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-35
35206    6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-35
35104    1 -0.9967837         -51110  51120  -51021  51022  -80  85  u=-35
35207    6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-35
35307    6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-35
35404    23 -17.55  -51112  51118  -51023  51024  -80  85  u=-35
35308    6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-35
35208    6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-35
35105    1 -0.9967837     -51110  51120  -51025  51026  -80  85  u=-35
35209    6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-35
35309    6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-35
35405    23 -17.55   -51112  51118  -51027  51028  -80  85  u=-35
35310    6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-35
35210    6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-35
35106    1 -0.9967837         -51110  51120  -51029  51030  -80  85  u=-35
35211    6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-35
35311    6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-35
35406    23 -17.55   -51112  51118  -51031  51032  -80  85  u=-35
35312    6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-35
35212    6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-35
35107    1 -0.9967837         -51110  51120  -51033  51034  -80  85  u=-35
35213    6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-35
35313    6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-35
35407    23 -17.55   -51112  51118  -51035  51036  -80  85  u=-35
35314    6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-35
35214    6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-35
35108    1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-35
35215    620 -10.364   -51110  51120  -51038  51074   -80  85  u=35
35600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-35
35610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=35
35620    30 9.07259-2                                   -79  80   u=35
35630    40 8.21151-2                                   -85  86     u=35
c 35640    620 -10.364      -51100  51130           51001  -80  85   u=-35
c 35645    620 -10.364      -51100  51130  -51074          -80  85   u=-35
c 35650    620 -10.364              51100                  -80  85   u=-35
c 35655    620 -10.364      -51130                         -80  85   u=-35
c
c  A2
c
52035    1 -0.9967837   -51100  51130  51001  -51074   -79 85    u=-37
52036    30 9.07358e-02                                 79    u=37
52037    40 8.21151e-02                             -86       u=37
52038    1 -0.9967837   -51100  51130         51001  -80 85   u=37
52039    1 -0.9967837   -51100  51130  -51074        -80 85   u=37
52040    1 -0.9967837           51100                -80 85   u=37
52041    1 -0.9967837   -51130                       -80 85   u=37
37099    1 -0.9967837         -51110  51120  -51001  51002  -80  85  u=37
37197    6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-37
37297    6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-37
37399    23 -17.55     -51112  51118  -51003  51004  -80  85  u=-37
37298    6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-37
37198    6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-37
37100    1 -0.9967837         -51110  51120  -51005  51006  -80  85  u=-37
37199    6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-37
37299    6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-37
37400    23 -17.55   -51112  51118  -51007  51008  -80  85  u=-37
37300    6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-37
37200    6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-37
37101    1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-37
```

```
37201     6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-37
37301     6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-37
37401     23 -17.55  -51112  51118  -51011  51012  -80  85  u=-37
37302     6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-37
37202     6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-37
37102     1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-37
37203     6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-37
37303     6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-37
37402     23 -17.55  -51112  51118  -51015  51016  -80  85  u=-37
37304     6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-37
37204     6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-37
37103     1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-37
37205     6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-37
37305     6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-37
37403     23 -17.55  -51112  51118  -51019  51020  -80  85  u=-37
37306     6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-37
37206     6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-37
37104     1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-37
37207     6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-37
37307     6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-37
37404     23 -17.55  -51112  51118  -51023  51024  -80  85  u=-37
37308     6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-37
37208     6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-37
37105     1 -0.9967837     -51110  51120  -51025  51026  -80  85  u=-37
37209     6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-37
37309     6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-37
37405     23 -17.55   -51112  51118  -51027  51028  -80  85  u=-37
37310     6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-37
37210     6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-37
37106     1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-37
37211     6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-37
37311     6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-37
37406     23 -17.55   -51112  51118  -51031  51032  -80  85  u=-37
37312     6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-37
37212     6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-37
37107     1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-37
37213     6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-37
37313     6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-37
37407     23 -17.55   -51112  51118  -51035  51036  -80  85  u=-37
37314     6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-37
37214     6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-37
37108     1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-37
37215     620 -10.364   -51110  51120  -51038  51074   -80  85  u=37
37600     6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-37
37610     6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=37
37620     30 9.07259-2                                  -79  80   u=37
37630     40 8.21151-2                                  -85  86    u=37
c
c  A3
c
53035     1 -0.9967837    -51100  51130  51001  -51074   -79 85   u=-38
53036     30 9.07358e-02                                    79    u=38
53037     40 8.21151e-02                                -86       u=38
53038     1 -0.9967837   -51100  51130          51001  -80 85   u=38
53039     1 -0.9967837   -51100  51130  -51074          -80 85   u=38
53040     1 -0.9967837          51100                   -80 85   u=38
53041     1 -0.9967837   -51130                         -80 85   u=38
38099     1 -0.9967838        -51110  51120  -51001  51002  -80  85  u=38
38197     6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-38
38297     6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-38
38399     23 -17.55     -51112  51118  -51003  51004  -80  85  u=-38
38298     6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-38
38198     6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-38
38100     1 -0.9967838        -51110  51120  -51005  51006  -80  85  u=-38
```

```
38199    6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-38
38299    6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-38
38400    23 -17.55    -51112  51118  -51007  51008  -80  85  u=-38
38300    6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-38
38200    6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-38
38101    1 -0.9967838        -51110  51120  -51009  51010  -80  85  u=-38
38201    6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-38
38301    6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-38
38401    23 -17.55  -51112  51118  -51011  51012  -80  85  u=-38
38302    6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-38
38202    6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-38
38102    1 -0.9967838         -51110  51120  -51013  51014  -80  85  u=-38
38203    6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-38
38303    6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-38
38402    23 -17.55  -51112  51118  -51015  51016  -80  85  u=-38
38304    6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-38
38204    6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-38
38103    1 -0.9967838         -51110  51120  -51017  51018  -80  85  u=-38
38205    6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-38
38305    6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-38
38403    23 -17.55  -51112  51118  -51019  51020  -80  85  u=-38
38306    6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-38
38206    6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-38
38104    1 -0.9967838         -51110  51120  -51021  51022  -80  85  u=-38
38207    6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-38
38307    6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-38
38404    23 -17.55  -51112  51118  -51023  51024  -80  85  u=-38
38308    6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-38
38208    6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-38
38105    1 -0.9967838      -51110  51120  -51025  51026  -80  85  u=-38
38209    6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-38
38309    6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-38
38405    23 -17.55   -51112  51118  -51027  51028  -80  85  u=-38
38310    6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-38
38210    6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-38
38106    1 -0.9967838         -51110  51120  -51029  51030  -80  85  u=-38
38211    6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-38
38311    6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-38
38406    23 -17.55   -51112  51118  -51031  51032  -80  85  u=-38
38312    6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-38
38212    6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-38
38107    1 -0.9967838         -51110  51120  -51033  51034  -80  85  u=-38
38213    6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-38
38313    6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-38
38407    23 -17.55   -51112  51118  -51035  51036  -80  85  u=-38
38314    6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-38
38214    6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-38
38108    1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-38
38215    620 -10.364   -51110  51120  -51038  51074   -80  85  u=38
38600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-38
38610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=38
38620    30 9.07259-2                                 -79  80   u=38
38630    40 8.21151-2                                 -85  86     u=38
c
c        ICSA
c
61035    6  6.0034-2   -51100  51130  -51009  51070  -79 86    u=36
61036    30 9.07358e-02                                  79    u=36
61033    40 8.21151e-02                                -86     u=36
61038    1 -0.9967837   -51100  51130          51009  -79 86   u=36
61034    1 -0.9967837   -51100  51130  -51070          -79 86   u=36
61040    1 -0.9967837          51100                   -79 86   u=36
61041    1 -0.9967837   -51130                         -79 86   u=36
c 61035    6  6.0034-2    u=34   $101
```

```
c 61036    1 -0.9967837       83 -101 102                          u=36 $fill vol
c 61038    6  6.0034-2   -51100  51130  -51001  51074 -83 86  102 u=36
c 61039    1 -0.9967837   -83 86 -102                              u=36 $fill vol
c 61040    40 8.21151e-02                               -86         u=36
c 61041    1 -0.9967837   -51100  51130          51001        86    u=36
c 61042    1 -0.9967837   -51100  51130  -51074               86    u=36
c 61043    1 -0.9967837           51100                       86    u=36
c 61044    1 -0.9967837   -51130                              86    u=36
c
c
c     Fuel element 2
c
c     The following fuel elements use the 71000 series of surfaces
c     B2, B3, B5, B6, B8, B9, C4, C5, C9, C10, C14, C15
c
c                          y
c                         /|\
c                          | /|
c                          |/ |
c                          /  |
c                         /|  |
c                        / |  |
c                       /  ---|--> x
c                      |      /
c                      |     /
c                      |    /
c                      |   /
c                      |  /
c                      | /
c                      |/
c
c
c        Dummy element  Type A (normal end caps)
c
c 71035    6  6.0034-2   -71100  71130  -71009  71070   -79 86  u=45
c 71036    30 9.07358e-02                                 79    u=45
c 71037    40 8.21151e-02                               -86     u=45
c 71038    1 -0.9967837   -71100  71130          71009    -79 86  u=45
c 71039    1 -0.9967837   -71100  71130  -71070           -79 86  u=45
c 71040    1 -0.9967837           71100                   -79 86  u=45
c 71041    1 -0.9967837   -71130                          -79 86  u=45
c
c        ICSA
c
81035    6  6.0034-2   -71100  71130  -71009  71070     83  101 u=46
81036    1 -0.9967837       83 -101 102                          u=46 $fill vol
81037    1 -0.9967837   -105 83 -102                             u=46 $fill vol
81038    6  6.0034-2   -71100  71130  -71009  71070 -83 86  102 u=46
81039    1 -0.9967837   -83 86 -102                              u=46 $fill vol
81040    40 8.21151e-02                               -86        u=46
81041    1 -0.9967837   -71100  71130          71009        86    u=46
81042    1 -0.9967837   -71100  71130  -71070               86    u=46
81043    1 -0.9967837           71100                       86    u=46
81044    1 -0.9967837   -71130                              86    u=46
81045    6  6.0034-2       105 -102 103                          u=46 $samp ass
81046    6  6.0034-2   -104 105 -103                             u=46 $samp ass
81047    3 -17.8-5          104  -103                            u=46 $samp area
c
c      100s water 200s cladding 300s extra al 400s fuel 600s top,bot,wat
c
c  fuel element B9
c
69099    1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-69
69197    6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-69
69297    6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-69
```

```
69399    23 -17.55     -51112  51118  -51003  51004  -80  85  u=-69
69298    6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-69
69198    6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-69
69100    1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-69
69199    6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-69
69299    6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-69
69400    23 -17.55   -51112  51118  -51007  51008  -80  85  u=-69
69300    6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-69
69200    6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-69
69101    1 -0.9967837       -51110  51120  -51009  51010  -80  85  u=-69
69201    6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-69
69301    6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-69
69401    23 -17.55  -51112  51118  -51011  51012  -80  85  u=-69
69302    6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-69
69202    6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-69
69102    1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-69
69203    6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-69
69303    6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-69
69402    23 -17.55  -51112  51118  -51015  51016  -80  85  u=-69
69304    6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-69
69204    6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-69
69103    1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-69
69205    6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-69
69305    6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-69
69403    23 -17.55  -51112  51118  -51019  51020  -80  85  u=-69
69306    6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-69
69206    6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-69
69104    1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-69
69207    6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-69
69307    6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-69
69404    23 -17.55  -51112  51118  -51023  51024  -80  85  u=-69
69308    6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-69
69208    6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-69
69105    1 -0.9967837     -51110  51120  -51025  51026  -80  85  u=-69
69209    6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-69
69309    6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-69
69405    23 -17.55   -51112  51118  -51027  51028  -80  85  u=-69
69310    6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-69
69210    6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-69
69106    1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-69
69211    6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-69
69311    6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-69
69406    23 -17.55   -51112  51118  -51031  51032  -80  85  u=-69
69312    6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-69
69212    6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-69
69107    1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-69
69213    6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-69
69313    6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-69
69407    23 -17.55   -51112  51118  -51035  51036  -80  85  u=-69
69314    6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-69
69214    6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-69
69108    1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-69
69215    620 -10.364  -51110  51120  -51038  51074  -80  85  u=-69
69600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-69
69610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-69
69620    30 9.07259-2                                      80   u=69
69630    40 8.21151-2                                 -85       u=69
69640    620 -10.364      -51100  51130           51001  -80  85   u=69
69645    620 -10.364      -51100  51130  -51074          -80  85   u=69
69650    620 -10.364              51100                  -80  85   u=69
69655    620 -10.364      -51130                         -80  85   u=69
c
c  fuel element B6
c
```

```
70099     620 -10.364      -51110  51120  -51001  51037  -80  85  u=-70
70108     1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-70
70215     6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-70
70315     6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-70
70408     23 -17.55   -51112  51118  -51039  51040  -80  85  u=-70
70316     6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-70
70216     6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-70
70109     1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-70
70217     6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-70
70317     6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-70
70409     23 -17.55    -51112  51118  -51043  51044  -80  85  u=-70
70318     6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-70
70218     6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-70
70110     1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-70
70219     6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-70
70319     6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-70
70410     23 -17.55    -51112  51118  -51047  51048  -80  85  u=-70
70320     6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-70
70220     6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-70
70111     1 -0.9967837      -51110  51120  -51049  51050  -80  85  u=-70
70221     6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-70
70321     6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-70
70411     23 -17.55     -51112  51118  -51051  51052  -80  85  u=-70
70322     6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-70
70222     6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-70
70112     1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-70
70223     6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-70
70323     6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-70
70412     23 -17.55     -51112  51118  -51055  51056  -80  85  u=-70
70324     6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-70
70224     6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-70
70113     1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-70
70225     6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-70
70325     6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-70
70413     23 -17.55     -51112  51118  -51059  51060  -80  85  u=-70
70326     6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-70
70226     6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-70
70114     1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-70
70227     6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-70
70327     6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-70
70414     23 -17.55     -51112  51118  -51063  51064  -80  85  u=-70
70328     6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-70
70228     6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-70
70115     1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-70
70229     6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-70
70329     6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-70
70415     23 -17.55    -51112  51118  -51067  51068  -80  85  u=-70
70330     6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-70
70230     6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-70
70116     1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-70
70231     6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-70
70331     6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-70
70416     23 -17.55     -51112  51118  -51071  51072  -80  85  u=-70
70332     6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-70
70232     6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-70
70117     1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-70
70600     6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-70
70610     6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-70
70620     30 9.07259-2                                       80    u=70
70630     40 8.21151-2                                  -85        u=70
70640     1 -0.9967837       -51100  51130            51001  -80  85    u=70
70645     1 -0.9967837       -51100  51130  -51074          -80  85    u=70
70650     1 -0.9967837               51100                  -80  85    u=70
70655     1 -0.9967837       -51130                         -80  85    u=70
```

```
c
c        Fuel Element #1 for tallying B-3
c
71099    620 -10.364      -51110  51120  -51001  51037  -80  85  u=-71
71108    1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-71
71215    6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-71
71315    6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-71
71408    23 -17.55   -51112  51118  -51039  51040  -80  85  u=-71
71316    6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-71
71216    6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-71
71109    1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-71
71217    6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-71
71317    6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-71
71409    23 -17.55    -51112  51118  -51043  51044  -80  85  u=-71
71318    6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-71
71218    6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-71
71110    1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-71
71219    6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-71
71319    6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-71
71410    23 -17.55    -51112  51118  -51047  51048  -80  85  u=-71
71320    6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-71
71220    6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-71
71111    1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-71
71221    6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-71
71321    6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-71
71411    23 -17.55     -51112  51118  -51051  51052  -80  85  u=-71
71322    6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-71
71222    6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-71
71112    1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-71
71223    6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-71
71323    6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-71
71412    23 -17.55     -51112  51118  -51055  51056  -80  85  u=-71
71324    6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-71
71224    6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-71
71113    1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-71
71225    6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-71
71325    6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-71
71413    23 -17.55     -51112  51118  -51059  51060  -80  85  u=-71
71326    6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-71
71226    6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-71
71114    1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-71
71227    6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-71
71327    6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-71
71414    23 -17.55     -51112  51118  -51063  51064  -80  85  u=-71
71328    6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-71
71228    6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-71
71115    1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-71
71229    6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-71
71329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-71
71415    23 -17.55    -51112  51118  -51067  51068  -80  85  u=-71
71330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-71
71230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-71
71116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-71
71231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-71
71331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-71
71416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-71
71332    6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-71
71232    6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-71
71117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-71
71600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-71
71610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-71
71620    30 9.07259-2                                    80    u=71
71630    40 8.21151-2                               -85       u=71
71640    1 -0.9967837       -51100  51130           51001  -80  85   u=71
```

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71645    1 -0.9967837      -51100  51130  -51074         -80  85   u=71
71650    1 -0.9967837              51100                 -80  85   u=71
71655    1 -0.9967837      -51130                        -80  85   u=71
c
c
c        Fuel Element #2 for tallying B-1
c
72099    620 -10.364      -51110  51120  -51001  51037  -80  85  u=-72
72108    1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-72
72215    6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-72
72315    6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-72
72408    23 -17.55      -51112  51118  -51039  51040  -80  85  u=-72
72316    6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-72
72216    6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-72
72109    1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-72
72217    6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-72
72317    6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-72
72409    23 -17.55      -51112  51118  -51043  51044  -80  85  u=-72
72318    6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-72
72218    6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-72
72110    1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-72
72219    6  6.0034-2    -51110  51120  -51046  51047  -80  85  u=-72
72319    6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-72
72410    23 -17.55      -51112  51118  -51047  51048  -80  85  u=-72
72320    6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-72
72220    6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-72
72111    1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-72
72221    6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-72
72321    6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-72
72411    23 -17.55      -51112  51118  -51051  51052  -80  85  u=-72
72322    6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-72
72222    6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-72
72112    1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-72
72223    6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-72
72323    6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-72
72412    23 -17.55      -51112  51118  -51055  51056  -80  85  u=-72
72324    6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-72
72224    6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-72
72113    1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-72
72225    6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-72
72325    6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-72
72413    23 -17.55      -51112  51118  -51059  51060  -80  85  u=-72
72326    6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-72
72226    6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-72
72114    1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-72
72227    6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-72
72327    6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-72
72414    23 -17.55      -51112  51118  -51063  51064  -80  85  u=-72
72328    6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-72
72228    6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-72
72115    1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-72
72229    6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-72
72329    6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-72
72415    23 -17.55      -51112  51118  -51067  51068  -80  85  u=-72
72330    6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-72
72230    6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-72
72116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-72
72231    6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-72
72331    6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-72
72416    23 -17.55      -51112  51118  -51071  51072  -80  85  u=-72
72332    6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-72
72232    6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-72
72117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-72
72600    6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-72
```

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72610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-72
72620    30 9.07259-2                                       80   u=72
72630    40 8.21151-2                                  -85       u=72
72640    1 -0.9967837       -51100  51130          51001  -80  85   u=72
72645    1 -0.9967837       -51100  51130  -51074         -80  85   u=72
72650    1 -0.9967837               51100                 -80  85   u=72
72655    1 -0.9967837       -51130                        -80  85   u=72
c
c
c        Fuel Element #3 for tallying B-2
c
73099    620 -10.364      -51110  51120  -51001  51037  -80  85  u=-73
73108    1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-73
73215    6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-73
73315    6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-73
73408    23 -17.55     -51112  51118  -51039  51040  -80  85  u=-73
73316    6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-73
73216    6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-73
73109    1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-73
73217    6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-73
73317    6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-73
73409    23 -17.55     -51112  51118  -51043  51044  -80  85  u=-73
73318    6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-73
73218    6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-73
73110    1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-73
73219    6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-73
73319    6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-73
73410    23 -17.55     -51112  51118  -51047  51048  -80  85  u=-73
73320    6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-73
73220    6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-73
73111    1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-73
73221    6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-73
73321    6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-73
73411    23 -17.55     -51112  51118  -51051  51052  -80  85  u=-73
73322    6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-73
73222    6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-73
73112    1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-73
73223    6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-73
73323    6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-73
73412    23 -17.55     -51112  51118  -51055  51056  -80  85  u=-73
73324    6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-73
73224    6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-73
73113    1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-73
73225    6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-73
73325    6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-73
73413    23 -17.55     -51112  51118  -51059  51060  -80  85  u=-73
73326    6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-73
73226    6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-73
73114    1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-73
73227    6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-73
73327    6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-73
73414    23 -17.55     -51112  51118  -51063  51064  -80  85  u=-73
73328    6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-73
73228    6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-73
73115    1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-73
73229    6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-73
73329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-73
73415    23 -17.55     -51112  51118  -51067  51068  -80  85  u=-73
73330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-73
73230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-73
73116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-73
73231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-73
73331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-73
73416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-73
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73332     6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-73
73232     6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-73
73117     1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-73
73600     6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-73
73610     6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-73
73620     30 9.07359-2                                      80   u=73
73630     40 8.21151-2                               -85         u=73
73640     1 -0.9967837       -51100  51130          51001   -80  85   u=73
73645     1 -0.9967837       -51100  51130  -51074          -80  85   u=73
73650     1 -0.9967837               51100                  -80  85   u=73
73655     1 -0.9967837       -51130                         -80  85   u=73
c
c
c         Fuel Element #4 for tallying B-4
c
74099     620 -10.364      -51110  51120  -51001  51037  -80  85  u=-74
74108     1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-74
74215     6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-74
74315     6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-74
74408     23 -17.55     -51112  51118  -51039  51040  -80  85  u=-74
74316     6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-74
74216     6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-74
74109     1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-74
74217     6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-74
74317     6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-74
74409     23 -17.55     -51112  51118  -51043  51044  -80  85  u=-74
74318     6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-74
74218     6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-74
74110     1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-74
74219     6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-74
74319     6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-74
74410     23 -17.55     -51112  51118  -51047  51048  -80  85  u=-74
74320     6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-74
74220     6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-74
74111     1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-74
74221     6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-74
74321     6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-74
74411     23 -17.55     -51112  51118  -51051  51052  -80  85  u=-74
74322     6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-74
74222     6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-74
74112     1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-74
74223     6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-74
74323     6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-74
74412     23 -17.55     -51112  51118  -51055  51056  -80  85  u=-74
74324     6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-74
74224     6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-74
74113     1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-74
74225     6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-74
74325     6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-74
74413     23 -17.55     -51112  51118  -51059  51060  -80  85  u=-74
74326     6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-74
74226     6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-74
74114     1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-74
74227     6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-74
74327     6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-74
74414     23 -17.55     -51112  51118  -51063  51064  -80  85  u=-74
74328     6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-74
74228     6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-74
74115     1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-74
74229     6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-74
74329     6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-74
74415     23 -17.55     -51112  51118  -51067  51068  -80  85  u=-74
74330     6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-74
74230     6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-74
```

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74116     1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-74
74231     6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-74
74331     6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-74
74416     23 -17.55      -51112  51118  -51071  51072  -80  85  u=-74
74332     6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-74
74232     6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-74
74117     1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-74
74600     6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-74
74610     6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-74
74620     30 9.07359-2                                       80   u=74
74630     40 8.21151-2                                 -85        u=74
74640     1 -0.9967837       -51100  51130          51001  -80  85   u=74
74645     1 -0.9967837       -51100  51130  -51074         -80  85   u=74
74650     1 -0.9967837               51100                 -80  85   u=74
74655     1 -0.9967837       -51130                        -80  85   u=74
c
c
c         Fuel Element #5 for tallying B-5
c
75099     620 -10.364      -51110  51120  -51001  51037  -80  85  u=-75
75108     1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-75
75215     6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-75
75315     6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-75
75408     23 -17.55      -51112  51118  -51039  51040  -80  85  u=-75
75316     6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-75
75216     6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-75
75109     1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-75
75217     6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-75
75317     6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-75
75409     23 -17.55      -51112  51118  -51043  51044  -80  85  u=-75
75318     6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-75
75218     6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-75
75110     1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-75
75219     6  6.0034-2    -51110  51120  -51046  51047  -80  85  u=-75
75319     6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-75
75410     23 -17.55      -51112  51118  -51047  51048  -80  85  u=-75
75320     6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-75
75220     6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-75
75111     1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-75
75221     6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-75
75321     6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-75
75411     23 -17.55      -51112  51118  -51051  51052  -80  85  u=-75
75322     6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-75
75222     6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-75
75112     1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-75
75223     6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-75
75323     6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-75
75412     23 -17.55      -51112  51118  -51055  51056  -80  85  u=-75
75324     6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-75
75224     6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-75
75113     1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-75
75225     6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-75
75325     6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-75
75413     23 -17.55      -51112  51118  -51059  51060  -80  85  u=-75
75326     6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-75
75226     6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-75
75114     1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-75
75227     6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-75
75327     6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-75
75414     23 -17.55      -51112  51118  -51063  51064  -80  85  u=-75
75328     6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-75
75228     6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-75
75115     1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-75
75229     6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-75
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75329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-75
75415    23 -17.55     -51112  51118  -51067  51068  -80  85  u=-75
75330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-75
75230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-75
75116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-75
75231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-75
75331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-75
75416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-75
75332    6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-75
75232    6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-75
75117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-75
75600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-75
75610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-75
75620    30 9.07359-2                                       80    u=75
75630    40 8.21151-2                                 -85        u=75
75640    1 -0.9967837       -51100  51130          51001 -80  85    u=75
75645    1 -0.9967837       -51100  51130  -51074         -80  85    u=75
75650    1 -0.9967837               51100                 -80  85    u=75
75655    1 -0.9967837       -51130                        -80  85    u=75
c
c
c        Fuel Element #6 for tallying B-7
c
76099    620 -10.364      -51110  51120  -51001  51037  -80  85  u=-76
76108    1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-76
76215    6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-76
76315    6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-76
76408    23 -17.55     -51112  51118  -51039  51040  -80  85  u=-76
76316    6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-76
76216    6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-76
76109    1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-76
76217    6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-76
76317    6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-76
76409    23 -17.55     -51112  51118  -51043  51044  -80  85  u=-76
76318    6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-76
76218    6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-76
76110    1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-76
76219    6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-76
76319    6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-76
76410    23 -17.55     -51112  51118  -51047  51048  -80  85  u=-76
76320    6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-76
76220    6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-76
76111    1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-76
76221    6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-76
76321    6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-76
76411    23 -17.55     -51112  51118  -51051  51052  -80  85  u=-76
76322    6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-76
76222    6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-76
76112    1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-76
76223    6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-76
76323    6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-76
76412    23 -17.55     -51112  51118  -51055  51056  -80  85  u=-76
76324    6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-76
76224    6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-76
76113    1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-76
76225    6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-76
76325    6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-76
76413    23 -17.55     -51112  51118  -51059  51060  -80  85  u=-76
76326    6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-76
76226    6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-76
76114    1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-76
76227    6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-76
76327    6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-76
76414    23 -17.55     -51112  51118  -51063  51064  -80  85  u=-76
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76328    6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-76
76228    6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-76
76115    1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-76
76229    6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-76
76329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-76
76415    23 -17.55     -51112  51118  -51067  51068  -80  85  u=-76
76330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-76
76230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-76
76116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-76
76231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-76
76331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-76
76416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-76
76332    6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-76
76232    6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-76
76117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-76
76600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-76
76610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-76
76620    30 9.07359-2                                     80   u=76
76630    40 8.21151-2                              -85         u=76
76640    1 -0.9967837       -51100  51130          51001  -80  85   u=76
76645    1 -0.9967837       -51100  51130  -51074         -80  85   u=76
76650    1 -0.9967837               51100                 -80  85   u=76
76655    1 -0.9967837       -51130                        -80  85   u=76
c
c
c        Fuel Element #7 for tallying B-8
c
77099    620 -10.364      -51110  51120  -51001  51037  -80  85  u=-77
77108    1 -0.9967837       -51110  51120  -51037  51038  -80  85  u=-77
77215    6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-77
77315    6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-77
77408    23 -17.55     -51112  51118  -51039  51040  -80  85  u=-77
77316    6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-77
77216    6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-77
77109    1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-77
77217    6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-77
77317    6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-77
77409    23 -17.55     -51112  51118  -51043  51044  -80  85  u=-77
77318    6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-77
77218    6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-77
77110    1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-77
77219    6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-77
77319    6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-77
77410    23 -17.55     -51112  51118  -51047  51048  -80  85  u=-77
77320    6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-77
77220    6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-77
77111    1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-77
77221    6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-77
77321    6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-77
77411    23 -17.55     -51112  51118  -51051  51052  -80  85  u=-77
77322    6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-77
77222    6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-77
77112    1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-77
77223    6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-77
77323    6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-77
77412    23 -17.55     -51112  51118  -51055  51056  -80  85  u=-77
77324    6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-77
77224    6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-77
77113    1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-77
77225    6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-77
77325    6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-77
77413    23 -17.55     -51112  51118  -51059  51060  -80  85  u=-77
77326    6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-77
77226    6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-77
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77114    1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-77
77227    6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-77
77327    6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-77
77414    23 -17.55     -51112  51118  -51063  51064  -80  85  u=-77
77328    6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-77
77228    6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-77
77115    1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-77
77229    6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-77
77329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-77
77415    23 -17.55     -51112  51118  -51067  51068  -80  85  u=-77
77330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-77
77230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-77
77116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-77
77231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-77
77331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-77
77416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-77
77332    6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-77
77232    6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-77
77117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-77
77600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-77
77610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-77
77620    30 9.07359-2                                    80     u=77
77630    40 8.21151-2                              -85          u=77
77640    1 -0.9967837      -51100  51130           51001   -80  85    u=77
77645    1 -0.9967837      -51100  51130  -51074           -80  85    u=77
77650    1 -0.9967837              51100                   -80  85    u=77
77655    1 -0.9967837      -51130                          -80  85    u=77
c
c
c        Fuel Element #8 for tallying C-1
c
78099    1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-78
78197    6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-78
78297    6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-78
78399    23 -17.55     -51112  51118  -51003  51004  -80  85  u=-78
78298    6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-78
78198    6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-78
78100    1 -0.9967837       -51110  51120  -51005  51006  -80  85  u=-78
78199    6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-78
78299    6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-78
78400    23 -17.55     -51112  51118  -51007  51008  -80  85  u=-78
78300    6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-78
78200    6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-78
78101    1 -0.9967837       -51110  51120  -51009  51010  -80  85  u=-78
78201    6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-78
78301    6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-78
78401    23 -17.55     -51112  51118  -51011  51012  -80  85  u=-78
78302    6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-78
78202    6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-78
78102    1 -0.9967837       -51110  51120  -51013  51014  -80  85  u=-78
78203    6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-78
78303    6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-78
78402    23 -17.55     -51112  51118  -51015  51016  -80  85  u=-78
78304    6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-78
78204    6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-78
78103    1 -0.9967837       -51110  51120  -51017  51018  -80  85  u=-78
78205    6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-78
78305    6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-78
78403    23 -17.55     -51112  51118  -51019  51020  -80  85  u=-78
78306    6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-78
78206    6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-78
78104    1 -0.9967837       -51110  51120  -51021  51022  -80  85  u=-78
78207    6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-78
78307    6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-78
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78404	23	-17.55	-51112	51118	-51023	51024	-80	85	u=-78
78308	6	6.0034-2	-51118	51120	-51023	51024	-80	85	u=-78
78208	6	6.0034-2	-51110	51120	-51024	51025	-80	85	u=-78
78105	1	-0.9967837	-51110	51120	-51025	51026	-80	85	u=-78
78209	6	6.0034-2	-51110	51120	-51026	51027	-80	85	u=-78
78309	6	6.0034-2	-51110	51112	-51027	51028	-80	85	u=-78
78405	23	-17.55	-51112	51118	-51027	51028	-80	85	u=-78
78310	6	6.0034-2	-51118	51120	-51027	51028	-80	85	u=-78
78210	6	6.0034-2	-51110	51120	-51028	51029	-80	85	u=-78
78106	1	-0.9967837	-51110	51120	-51029	51030	-80	85	u=-78
78211	6	6.0034-2	-51110	51120	-51030	51031	-80	85	u=-78
78311	6	6.0034-2	-51110	51112	-51031	51032	-80	85	u=-78
78406	23	-17.55	-51112	51118	-51031	51032	-80	85	u=-78
78312	6	6.0034-2	-51118	51120	-51031	51032	-80	85	u=-78
78212	6	6.0034-2	-51110	51120	-51032	51033	-80	85	u=-78
78107	1	-0.9967837	-51110	51120	-51033	51034	-80	85	u=-78
78213	6	6.0034-2	-51110	51120	-51034	51035	-80	85	u=-78
78313	6	6.0034-2	-51110	51112	-51035	51036	-80	85	u=-78
78407	23	-17.55	-51112	51118	-51035	51036	-80	85	u=-78
78314	6	6.0034-2	-51118	51120	-51035	51036	-80	85	u=-78
78214	6	6.0034-2	-51110	51120	-51036	51037	-80	85	u=-78
78108	1	-0.9967837	-51110	51120	-51037	51038	-80	85	u=-78
78215	6	6.0034-2	-51110	51120	-51038	51039	-80	85	u=-78
78315	6	6.0034-2	-51110	51112	-51039	51040	-80	85	u=-78
78408	23	-17.55	-51112	51118	-51039	51040	-80	85	u=-78
78316	6	6.0034-2	-51118	51120	-51039	51040	-80	85	u=-78
78216	6	6.0034-2	-51110	51120	-51040	51041	-80	85	u=-78
78109	1	-0.9967837	-51110	51120	-51041	51042	-80	85	u=-78
78217	6	6.0034-2	-51110	51120	-51042	51043	-80	85	u=-78
78317	6	6.0034-2	-51110	51112	-51043	51044	-80	85	u=-78
78409	23	-17.55	-51112	51118	-51043	51044	-80	85	u=-78
78318	6	6.0034-2	-51118	51120	-51043	51044	-80	85	u=-78
78218	6	6.0034-2	-51110	51120	-51044	51045	-80	85	u=-78
78110	1	-0.9967837	-51110	51120	-51045	51046	-80	85	u=-78
78219	6	6.0034-2	-51110	51120	-51046	51047	-80	85	u=-78
78319	6	6.0034-2	-51110	51112	-51047	51048	-80	85	u=-78
78410	23	-17.55	-51112	51118	-51047	51048	-80	85	u=-78
78320	6	6.0034-2	-51118	51120	-51047	51048	-80	85	u=-78
78220	6	6.0034-2	-51110	51120	-51048	51049	-80	85	u=-78
78111	1	-0.9967837	-51110	51120	-51049	51050	-80	85	u=-78
78221	6	6.0034-2	-51110	51120	-51050	51051	-80	85	u=-78
78321	6	6.0034-2	-51110	51112	-51051	51052	-80	85	u=-78
78411	23	-17.55	-51112	51118	-51051	51052	-80	85	u=-78
78322	6	6.0034-2	-51118	51120	-51051	51052	-80	85	u=-78
78222	6	6.0034-2	-51110	51120	-51052	51053	-80	85	u=-78
78112	1	-0.9967837	-51110	51120	-51053	51054	-80	85	u=-78
78223	6	6.0034-2	-51110	51120	-51054	51055	-80	85	u=-78
78323	6	6.0034-2	-51110	51112	-51055	51056	-80	85	u=-78
78412	23	-17.55	-51112	51118	-51055	51056	-80	85	u=-78
78324	6	6.0034-2	-51118	51120	-51055	51056	-80	85	u=-78
78224	6	6.0034-2	-51110	51120	-51056	51057	-80	85	u=-78
78113	1	-0.9967837	-51110	51120	-51057	51058	-80	85	u=-78
78225	6	6.0034-2	-51110	51120	-51058	51059	-80	85	u=-78
78325	6	6.0034-2	-51110	51112	-51059	51060	-80	85	u=-78
78413	23	-17.55	-51112	51118	-51059	51060	-80	85	u=-78
78326	6	6.0034-2	-51118	51120	-51059	51060	-80	85	u=-78
78226	6	6.0034-2	-51110	51120	-51060	51061	-80	85	u=-78
78114	1	-0.9967837	-51110	51120	-51061	51062	-80	85	u=-78
78227	6	6.0034-2	-51110	51120	-51062	51063	-80	85	u=-78
78327	6	6.0034-2	-51110	51112	-51063	51064	-80	85	u=-78
78414	23	-17.55	-51112	51118	-51063	51064	-80	85	u=-78
78328	6	6.0034-2	-51118	51120	-51063	51064	-80	85	u=-78
78228	6	6.0034-2	-51110	51120	-51064	51065	-80	85	u=-78
78115	1	-0.9967837	-51110	51120	-51065	51066	-80	85	u=-78

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78229    6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-78
78329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-78
78415    23 -17.55     -51112  51118  -51067  51068  -80  85  u=-78
78330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-78
78230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-78
78116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-78
78231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-78
78331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-78
78416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-78
78332    6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-78
78232    6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-78
78117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-78
78600    6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-78
78610    6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-78
78620    30 9.07359-2                                    80    u=78
78630    40 8.21151-2                               -85        u=78
78640    1 -0.9967837       -51100  51130          51001  -80  85    u=78
78645    1 -0.9967837       -51100  51130  -51074         -80  85    u=78
78650    1 -0.9967837               51100                 -80  85    u=78
78655    1 -0.9967837       -51130                        -80  85    u=78
c
c
c        Fuel Element #9 for tallying C-2
c
79099    1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-79
79197    6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-79
79297    6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-79
79399    23 -17.55     -51112  51118  -51003  51004  -80  85  u=-79
79298    6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-79
79198    6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-79
79100    1 -0.9967837       -51110  51120  -51005  51006  -80  85  u=-79
79199    6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-79
79299    6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-79
79400    23 -17.55     -51112  51118  -51007  51008  -80  85  u=-79
79300    6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-79
79200    6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-79
79101    1 -0.9967837       -51110  51120  -51009  51010  -80  85  u=-79
79201    6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-79
79301    6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-79
79401    23 -17.55     -51112  51118  -51011  51012  -80  85  u=-79
79302    6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-79
79202    6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-79
79102    1 -0.9967837       -51110  51120  -51013  51014  -80  85  u=-79
79203    6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-79
79303    6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-79
79402    23 -17.55     -51112  51118  -51015  51016  -80  85  u=-79
79304    6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-79
79204    6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-79
79103    1 -0.9967837       -51110  51120  -51017  51018  -80  85  u=-79
79205    6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-79
79305    6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-79
79403    23 -17.55     -51112  51118  -51019  51020  -80  85  u=-79
79306    6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-79
79206    6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-79
79104    1 -0.9967837       -51110  51120  -51021  51022  -80  85  u=-79
79207    6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-79
79307    6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-79
79404    23 -17.55     -51112  51118  -51023  51024  -80  85  u=-79
79308    6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-79
79208    6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-79
79105    1 -0.9967837       -51110  51120  -51025  51026  -80  85  u=-79
79209    6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-79
79309    6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-79
79405    23 -17.55     -51112  51118  -51027  51028  -80  85  u=-79
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79310     6  6.0034-2    -51118  51120  -51027  51028  -80  85  u=-79
79210     6  6.0034-2    -51110  51120  -51028  51029  -80  85  u=-79
79106     1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-79
79211     6  6.0034-2    -51110  51120  -51030  51031  -80  85  u=-79
79311     6  6.0034-2    -51110  51112  -51031  51032  -80  85  u=-79
79406     23 -17.55      -51112  51118  -51031  51032  -80  85  u=-79
79312     6  6.0034-2    -51118  51120  -51031  51032  -80  85  u=-79
79212     6  6.0034-2    -51110  51120  -51032  51033  -80  85  u=-79
79107     1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-79
79213     6  6.0034-2    -51110  51120  -51034  51035  -80  85  u=-79
79313     6  6.0034-2    -51110  51112  -51035  51036  -80  85  u=-79
79407     23 -17.55      -51112  51118  -51035  51036  -80  85  u=-79
79314     6  6.0034-2    -51118  51120  -51035  51036  -80  85  u=-79
79214     6  6.0034-2    -51110  51120  -51036  51037  -80  85  u=-79
79108     1 -0.9967837        -51110  51120  -51037  51038  -80  85  u=-79
79215     6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-79
79315     6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-79
79408     23 -17.55      -51112  51118  -51039  51040  -80  85  u=-79
79316     6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-79
79216     6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-79
79109     1 -0.9967837        -51110  51120  -51041  51042  -80  85  u=-79
79217     6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-79
79317     6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-79
79409     23 -17.55      -51112  51118  -51043  51044  -80  85  u=-79
79318     6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-79
79218     6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-79
79110     1 -0.9967837        -51110  51120  -51045  51046  -80  85  u=-79
79219     6  6.0034-2    -51110  51120  -51046  51047  -80  85  u=-79
79319     6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-79
79410     23 -17.55      -51112  51118  -51047  51048  -80  85  u=-79
79320     6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-79
79220     6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-79
79111     1 -0.9967837        -51110  51120  -51049  51050  -80  85  u=-79
79221     6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-79
79321     6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-79
79411     23 -17.55      -51112  51118  -51051  51052  -80  85  u=-79
79322     6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-79
79222     6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-79
79112     1 -0.9967837        -51110  51120  -51053  51054  -80  85  u=-79
79223     6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-79
79323     6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-79
79412     23 -17.55      -51112  51118  -51055  51056  -80  85  u=-79
79324     6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-79
79224     6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-79
79113     1 -0.9967837        -51110  51120  -51057  51058  -80  85  u=-79
79225     6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-79
79325     6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-79
79413     23 -17.55      -51112  51118  -51059  51060  -80  85  u=-79
79326     6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-79
79226     6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-79
79114     1 -0.9967837        -51110  51120  -51061  51062  -80  85  u=-79
79227     6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-79
79327     6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-79
79414     23 -17.55      -51112  51118  -51063  51064  -80  85  u=-79
79328     6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-79
79228     6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-79
79115     1 -0.9967837        -51110  51120  -51065  51066  -80  85  u=-79
79229     6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-79
79329     6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-79
79415     23 -17.55      -51112  51118  -51067  51068  -80  85  u=-79
79330     6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-79
79230     6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-79
79116     1 -0.9967837        -51110  51120  -51069  51070  -80  85  u=-79
79231     6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-79
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79331     6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-79
79416     23 -17.55     -51112  51118  -51071  51072  -80  85  u=-79
79332     6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-79
79232     6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-79
79117     1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-79
79600     6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-79
79610     6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-79
79620     30 9.07359-2                                        80   u=79
79630     40 8.21151-2                                   -85       u=79
79640     1 -0.9967837       -51100  51130          51001  -80  85   u=79
79645     1 -0.9967837       -51100  51130  -51074         -80  85   u=79
79650     1 -0.9967837               51100                 -80  85   u=79
79655     1 -0.9967837       -51130                        -80  85   u=79
c
c
c         Fuel Element #10 for tallying C-3
c
80099     1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-80
80197     6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-80
80297     6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-80
80399     23 -17.55     -51112  51118  -51003  51004  -80  85  u=-80
80298     6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-80
80198     6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-80
80100     1 -0.9967837       -51110  51120  -51005  51006  -80  85  u=-80
80199     6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-80
80299     6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-80
80400     23 -17.55     -51112  51118  -51007  51008  -80  85  u=-80
80300     6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-80
80200     6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-80
80101     1 -0.9967837       -51110  51120  -51009  51010  -80  85  u=-80
80201     6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-80
80301     6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-80
80401     23 -17.55     -51112  51118  -51011  51012  -80  85  u=-80
80302     6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-80
80202     6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-80
80102     1 -0.9967837       -51110  51120  -51013  51014  -80  85  u=-80
80203     6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-80
80303     6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-80
80402     23 -17.55     -51112  51118  -51015  51016  -80  85  u=-80
80304     6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-80
80204     6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-80
80103     1 -0.9967837       -51110  51120  -51017  51018  -80  85  u=-80
80205     6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-80
80305     6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-80
80403     23 -17.55     -51112  51118  -51019  51020  -80  85  u=-80
80306     6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-80
80206     6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-80
80104     1 -0.9967837       -51110  51120  -51021  51022  -80  85  u=-80
80207     6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-80
80307     6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-80
80404     23 -17.55     -51112  51118  -51023  51024  -80  85  u=-80
80308     6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-80
80208     6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-80
80105     1 -0.9967837       -51110  51120  -51025  51026  -80  85  u=-80
80209     6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-80
80309     6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-80
80405     23 -17.55     -51112  51118  -51027  51028  -80  85  u=-80
80310     6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-80
80210     6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-80
80106     1 -0.9967837       -51110  51120  -51029  51030  -80  85  u=-80
80211     6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-80
80311     6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-80
80406     23 -17.55     -51112  51118  -51031  51032  -80  85  u=-80
80312     6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-80
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80212    6  6.0034-2    -51110  51120  -51032  51033  -80  85  u=-80
80107    1 -0.9967837      -51110  51120  -51033  51034  -80  85  u=-80
80213    6  6.0034-2    -51110  51120  -51034  51035  -80  85  u=-80
80313    6  6.0034-2    -51110  51112  -51035  51036  -80  85  u=-80
80407    23 -17.55      -51112  51118  -51035  51036  -80  85  u=-80
80314    6  6.0034-2    -51118  51120  -51035  51036  -80  85  u=-80
80214    6  6.0034-2    -51110  51120  -51036  51037  -80  85  u=-80
80108    1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-80
80215    6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-80
80315    6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-80
80408    23 -17.55      -51112  51118  -51039  51040  -80  85  u=-80
80316    6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-80
80216    6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-80
80109    1 -0.9967837      -51110  51120  -51041  51042  -80  85  u=-80
80217    6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-80
80317    6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-80
80409    23 -17.55      -51112  51118  -51043  51044  -80  85  u=-80
80318    6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-80
80218    6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-80
80110    1 -0.9967837      -51110  51120  -51045  51046  -80  85  u=-80
80219    6  6.0034-2    -51110  51120  -51046  51047  -80  85  u=-80
80319    6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-80
80410    23 -17.55      -51112  51118  -51047  51048  -80  85  u=-80
80320    6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-80
80220    6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-80
80111    1 -0.9967837      -51110  51120  -51049  51050  -80  85  u=-80
80221    6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-80
80321    6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-80
80411    23 -17.55      -51112  51118  -51051  51052  -80  85  u=-80
80322    6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-80
80222    6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-80
80112    1 -0.9967837      -51110  51120  -51053  51054  -80  85  u=-80
80223    6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-80
80323    6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-80
80412    23 -17.55      -51112  51118  -51055  51056  -80  85  u=-80
80324    6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-80
80224    6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-80
80113    1 -0.9967837      -51110  51120  -51057  51058  -80  85  u=-80
80225    6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-80
80325    6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-80
80413    23 -17.55      -51112  51118  -51059  51060  -80  85  u=-80
80326    6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-80
80226    6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-80
80114    1 -0.9967837      -51110  51120  -51061  51062  -80  85  u=-80
80227    6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-80
80327    6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-80
80414    23 -17.55      -51112  51118  -51063  51064  -80  85  u=-80
80328    6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-80
80228    6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-80
80115    1 -0.9967837      -51110  51120  -51065  51066  -80  85  u=-80
80229    6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-80
80329    6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-80
80415    23 -17.55      -51112  51118  -51067  51068  -80  85  u=-80
80330    6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-80
80230    6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-80
80116    1 -0.9967837      -51110  51120  -51069  51070  -80  85  u=-80
80231    6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-80
80331    6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-80
80416    23 -17.55      -51112  51118  -51071  51072  -80  85  u=-80
80332    6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-80
80232    6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-80
80117    1 -0.9967837      -51110  51120  -51073  51074  -80  85  u=-80
80600    6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-80
80610    6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-80
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80620     30 9.07359-2                                               80    u=80
80630     40 8.21151-2                                         -85         u=80
80640     1 -0.9967837         -51100  51130           51001   -80  85    u=80
80645     1 -0.9967837         -51100  51130  -51074           -80  85    u=80
80650     1 -0.9967837                 51100                   -80  85    u=80
80655     1 -0.9967837         -51130                          -80  85    u=80
c
c
c         Fuel Element #11 for tallying C-4
c
81099     1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-81
81197     6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-81
81297     6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-81
81399     23 -17.55     -51112  51118  -51003  51004  -80  85  u=-81
81298     6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-81
81198     6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-81
81100     1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-81
81199     6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-81
81299     6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-81
81400     23 -17.55     -51112  51118  -51007  51008  -80  85  u=-81
81300     6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-81
81200     6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-81
81101     1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-81
81201     6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-81
81301     6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-81
81401     23 -17.55     -51112  51118  -51011  51012  -80  85  u=-81
81302     6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-81
81202     6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-81
81102     1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-81
81203     6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-81
81303     6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-81
81402     23 -17.55     -51112  51118  -51015  51016  -80  85  u=-81
81304     6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-81
81204     6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-81
81103     1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-81
81205     6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-81
81305     6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-81
81403     23 -17.55     -51112  51118  -51019  51020  -80  85  u=-81
81306     6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-81
81206     6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-81
81104     1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-81
81207     6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-81
81307     6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-81
81404     23 -17.55     -51112  51118  -51023  51024  -80  85  u=-81
81308     6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-81
81208     6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-81
81105     1 -0.9967837        -51110  51120  -51025  51026  -80  85  u=-81
81209     6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-81
81309     6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-81
81405     23 -17.55     -51112  51118  -51027  51028  -80  85  u=-81
81310     6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-81
81210     6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-81
81106     1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-81
81211     6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-81
81311     6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-81
81406     23 -17.55     -51112  51118  -51031  51032  -80  85  u=-81
81312     6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-81
81212     6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-81
81107     1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-81
81213     6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-81
81313     6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-81
81407     23 -17.55     -51112  51118  -51035  51036  -80  85  u=-81
81314     6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-81
81214     6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-81
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81108      1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-81
81215      6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-81
81315      6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-81
81408      23 -17.55     -51112  51118  -51039  51040  -80  85  u=-81
81316      6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-81
81216      6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-81
81109      1 -0.9967837      -51110  51120  -51041  51042  -80  85  u=-81
81217      6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-81
81317      6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-81
81409      23 -17.55     -51112  51118  -51043  51044  -80  85  u=-81
81318      6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-81
81218      6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-81
81110      1 -0.9967837      -51110  51120  -51045  51046  -80  85  u=-81
81219      6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-81
81319      6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-81
81410      23 -17.55     -51112  51118  -51047  51048  -80  85  u=-81
81320      6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-81
81220      6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-81
81111      1 -0.9967837      -51110  51120  -51049  51050  -80  85  u=-81
81221      6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-81
81321      6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-81
81411      23 -17.55     -51112  51118  -51051  51052  -80  85  u=-81
81322      6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-81
81222      6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-81
81112      1 -0.9967837      -51110  51120  -51053  51054  -80  85  u=-81
81223      6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-81
81323      6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-81
81412      23 -17.55     -51112  51118  -51055  51056  -80  85  u=-81
81324      6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-81
81224      6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-81
81113      1 -0.9967837      -51110  51120  -51057  51058  -80  85  u=-81
81225      6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-81
81325      6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-81
81413      23 -17.55     -51112  51118  -51059  51060  -80  85  u=-81
81326      6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-81
81226      6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-81
81114      1 -0.9967837      -51110  51120  -51061  51062  -80  85  u=-81
81227      6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-81
81327      6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-81
81414      23 -17.55     -51112  51118  -51063  51064  -80  85  u=-81
81328      6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-81
81228      6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-81
81115      1 -0.9967837      -51110  51120  -51065  51066  -80  85  u=-81
81229      6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-81
81329      6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-81
81415      23 -17.55     -51112  51118  -51067  51068  -80  85  u=-81
81330      6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-81
81230      6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-81
81116      1 -0.9967837      -51110  51120  -51069  51070  -80  85  u=-81
81231      6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-81
81331      6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-81
81416      23 -17.55     -51112  51118  -51071  51072  -80  85  u=-81
81332      6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-81
81232      6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-81
81117      1 -0.9967837      -51110  51120  -51073  51074  -80  85  u=-81
81600      6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-81
81610      6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-81
81620      30 9.07359-2                                   80    u=81
81630      40 8.21151-2                           -85           u=81
81640      1 -0.9967837      -51100  51130           51001  -80  85   u=81
81645      1 -0.9967837      -51100  51130  -51074          -80  85   u=81
81650      1 -0.9967837              51100                  -80  85   u=81
81655      1 -0.9967837      -51130                         -80  85   u=81
c
```

```
c
c         Fuel Element #12 for tallying C-5
c
82099     1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-82
82197     6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-82
82297     6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-82
82399     23 -17.55      -51112  51118  -51003  51004  -80  85  u=-82
82298     6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-82
82198     6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-82
82100     1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-82
82199     6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-82
82299     6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-82
82400     23 -17.55      -51112  51118  -51007  51008  -80  85  u=-82
82300     6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-82
82200     6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-82
82101     1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-82
82201     6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-82
82301     6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-82
82401     23 -17.55      -51112  51118  -51011  51012  -80  85  u=-82
82302     6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-82
82202     6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-82
82102     1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-82
82203     6  6.0034-2    -51110  51120  -51014  51015  -80  85  u=-82
82303     6  6.0034-2    -51110  51112  -51015  51016  -80  85  u=-82
82402     23 -17.55      -51112  51118  -51015  51016  -80  85  u=-82
82304     6  6.0034-2    -51118  51120  -51015  51016  -80  85  u=-82
82204     6  6.0034-2    -51110  51120  -51016  51017  -80  85  u=-82
82103     1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-82
82205     6  6.0034-2    -51110  51120  -51018  51019  -80  85  u=-82
82305     6  6.0034-2    -51110  51112  -51019  51020  -80  85  u=-82
82403     23 -17.55      -51112  51118  -51019  51020  -80  85  u=-82
82306     6  6.0034-2    -51118  51120  -51019  51020  -80  85  u=-82
82206     6  6.0034-2    -51110  51120  -51020  51021  -80  85  u=-82
82104     1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-82
82207     6  6.0034-2    -51110  51120  -51022  51023  -80  85  u=-82
82307     6  6.0034-2    -51110  51112  -51023  51024  -80  85  u=-82
82404     23 -17.55      -51112  51118  -51023  51024  -80  85  u=-82
82308     6  6.0034-2    -51118  51120  -51023  51024  -80  85  u=-82
82208     6  6.0034-2    -51110  51120  -51024  51025  -80  85  u=-82
82105     1 -0.9967837        -51110  51120  -51025  51026  -80  85  u=-82
82209     6  6.0034-2    -51110  51120  -51026  51027  -80  85  u=-82
82309     6  6.0034-2    -51110  51112  -51027  51028  -80  85  u=-82
82405     23 -17.55      -51112  51118  -51027  51028  -80  85  u=-82
82310     6  6.0034-2    -51118  51120  -51027  51028  -80  85  u=-82
82210     6  6.0034-2    -51110  51120  -51028  51029  -80  85  u=-82
82106     1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-82
82211     6  6.0034-2    -51110  51120  -51030  51031  -80  85  u=-82
82311     6  6.0034-2    -51110  51112  -51031  51032  -80  85  u=-82
82406     23 -17.55      -51112  51118  -51031  51032  -80  85  u=-82
82312     6  6.0034-2    -51118  51120  -51031  51032  -80  85  u=-82
82212     6  6.0034-2    -51110  51120  -51032  51033  -80  85  u=-82
82107     1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-82
82213     6  6.0034-2    -51110  51120  -51034  51035  -80  85  u=-82
82313     6  6.0034-2    -51110  51112  -51035  51036  -80  85  u=-82
82407     23 -17.55      -51112  51118  -51035  51036  -80  85  u=-82
82314     6  6.0034-2    -51118  51120  -51035  51036  -80  85  u=-82
82214     6  6.0034-2    -51110  51120  -51036  51037  -80  85  u=-82
82108     1 -0.9967837        -51110  51120  -51037  51038  -80  85  u=-82
82215     6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-82
82315     6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-82
82408     23 -17.55      -51112  51118  -51039  51040  -80  85  u=-82
82316     6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-82
82216     6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-82
82109     1 -0.9967837        -51110  51120  -51041  51042  -80  85  u=-82
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82217     6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-82
82317     6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-82
82409     23 -17.55      -51112  51118  -51043  51044  -80  85  u=-82
82318     6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-82
82218     6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-82
82110     1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-82
82219     6  6.0034-2    -51110  51120  -51046  51047  -80  85  u=-82
82319     6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-82
82410     23 -17.55      -51112  51118  -51047  51048  -80  85  u=-82
82320     6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-82
82220     6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-82
82111     1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-82
82221     6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-82
82321     6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-82
82411     23 -17.55      -51112  51118  -51051  51052  -80  85  u=-82
82322     6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-82
82222     6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-82
82112     1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-82
82223     6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-82
82323     6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-82
82412     23 -17.55      -51112  51118  -51055  51056  -80  85  u=-82
82324     6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-82
82224     6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-82
82113     1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-82
82225     6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-82
82325     6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-82
82413     23 -17.55      -51112  51118  -51059  51060  -80  85  u=-82
82326     6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-82
82226     6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-82
82114     1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-82
82227     6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-82
82327     6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-82
82414     23 -17.55      -51112  51118  -51063  51064  -80  85  u=-82
82328     6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-82
82228     6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-82
82115     1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-82
82229     6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-82
82329     6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-82
82415     23 -17.55      -51112  51118  -51067  51068  -80  85  u=-82
82330     6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-82
82230     6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-82
82116     1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-82
82231     6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-82
82331     6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-82
82416     23 -17.55      -51112  51118  -51071  51072  -80  85  u=-82
82332     6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-82
82232     6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-82
82117     1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-82
82600     6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-82
82610     6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-82
82620     30 9.07359-2                                     80   u=82
82630     40 8.21151-2                              -85         u=82
82640     1 -0.9967837       -51100  51130          51001  -80  85   u=82
82645     1 -0.9967837       -51100  51130  -51074         -80  85   u=82
82650     1 -0.9967837               51100                 -80  85   u=82
82655     1 -0.9967837       -51130                        -80  85   u=82
c
c
c         Fuel Element #13 for tallying C-6
c
83099     1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-83
83197     6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-83
83297     6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-83
83399     23 -17.55      -51112  51118  -51003  51004  -80  85  u=-83
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83298	6	6.0034-2	-51118	51120	-51003	51004	-80	85	u=-83
83198	6	6.0034-2	-51110	51120	-51004	51005	-80	85	u=-83
83100	1	-0.9967837	-51110	51120	-51005	51006	-80	85	u=-83
83199	6	6.0034-2	-51110	51120	-51006	51007	-80	85	u=-83
83299	6	6.0034-2	-51110	51112	-51007	51008	-80	85	u=-83
83400	23	-17.55	-51112	51118	-51007	51008	-80	85	u=-83
83300	6	6.0034-2	-51118	51120	-51007	51008	-80	85	u=-83
83200	6	6.0034-2	-51110	51120	-51008	51009	-80	85	u=-83
83101	1	-0.9967837	-51110	51120	-51009	51010	-80	85	u=-83
83201	6	6.0034-2	-51110	51120	-51010	51011	-80	85	u=-83
83301	6	6.0034-2	-51110	51112	-51011	51012	-80	85	u=-83
83401	23	-17.55	-51112	51118	-51011	51012	-80	85	u=-83
83302	6	6.0034-2	-51118	51120	-51011	51012	-80	85	u=-83
83202	6	6.0034-2	-51110	51120	-51012	51013	-80	85	u=-83
83102	1	-0.9967837	-51110	51120	-51013	51014	-80	85	u=-83
83203	6	6.0034-2	-51110	51120	-51014	51015	-80	85	u=-83
83303	6	6.0034-2	-51110	51112	-51015	51016	-80	85	u=-83
83402	23	-17.55	-51112	51118	-51015	51016	-80	85	u=-83
83304	6	6.0034-2	-51118	51120	-51015	51016	-80	85	u=-83
83204	6	6.0034-2	-51110	51120	-51016	51017	-80	85	u=-83
83103	1	-0.9967837	-51110	51120	-51017	51018	-80	85	u=-83
83205	6	6.0034-2	-51110	51120	-51018	51019	-80	85	u=-83
83305	6	6.0034-2	-51110	51112	-51019	51020	-80	85	u=-83
83403	23	-17.55	-51112	51118	-51019	51020	-80	85	u=-83
83306	6	6.0034-2	-51118	51120	-51019	51020	-80	85	u=-83
83206	6	6.0034-2	-51110	51120	-51020	51021	-80	85	u=-83
83104	1	-0.9967837	-51110	51120	-51021	51022	-80	85	u=-83
83207	6	6.0034-2	-51110	51120	-51022	51023	-80	85	u=-83
83307	6	6.0034-2	-51110	51112	-51023	51024	-80	85	u=-83
83404	23	-17.55	-51112	51118	-51023	51024	-80	85	u=-83
83308	6	6.0034-2	-51118	51120	-51023	51024	-80	85	u=-83
83208	6	6.0034-2	-51110	51120	-51024	51025	-80	85	u=-83
83105	1	-0.9967837	-51110	51120	-51025	51026	-80	85	u=-83
83209	6	6.0034-2	-51110	51120	-51026	51027	-80	85	u=-83
83309	6	6.0034-2	-51110	51112	-51027	51028	-80	85	u=-83
83405	23	-17.55	-51112	51118	-51027	51028	-80	85	u=-83
83310	6	6.0034-2	-51118	51120	-51027	51028	-80	85	u=-83
83210	6	6.0034-2	-51110	51120	-51028	51029	-80	85	u=-83
83106	1	-0.9967837	-51110	51120	-51029	51030	-80	85	u=-83
83211	6	6.0034-2	-51110	51120	-51030	51031	-80	85	u=-83
83311	6	6.0034-2	-51110	51112	-51031	51032	-80	85	u=-83
83406	23	-17.55	-51112	51118	-51031	51032	-80	85	u=-83
83312	6	6.0034-2	-51118	51120	-51031	51032	-80	85	u=-83
83212	6	6.0034-2	-51110	51120	-51032	51033	-80	85	u=-83
83107	1	-0.9967837	-51110	51120	-51033	51034	-80	85	u=-83
83213	6	6.0034-2	-51110	51120	-51034	51035	-80	85	u=-83
83313	6	6.0034-2	-51110	51112	-51035	51036	-80	85	u=-83
83407	23	-17.55	-51112	51118	-51035	51036	-80	85	u=-83
83314	6	6.0034-2	-51118	51120	-51035	51036	-80	85	u=-83
83214	6	6.0034-2	-51110	51120	-51036	51037	-80	85	u=-83
83108	1	-0.9967837	-51110	51120	-51037	51038	-80	85	u=-83
83215	6	6.0034-2	-51110	51120	-51038	51039	-80	85	u=-83
83315	6	6.0034-2	-51110	51112	-51039	51040	-80	85	u=-83
83408	23	-17.55	-51112	51118	-51039	51040	-80	85	u=-83
83316	6	6.0034-2	-51118	51120	-51039	51040	-80	85	u=-83
83216	6	6.0034-2	-51110	51120	-51040	51041	-80	85	u=-83
83109	1	-0.9967837	-51110	51120	-51041	51042	-80	85	u=-83
83217	6	6.0034-2	-51110	51120	-51042	51043	-80	85	u=-83
83317	6	6.0034-2	-51110	51112	-51043	51044	-80	85	u=-83
83409	23	-17.55	-51112	51118	-51043	51044	-80	85	u=-83
83318	6	6.0034-2	-51118	51120	-51043	51044	-80	85	u=-83
83218	6	6.0034-2	-51110	51120	-51044	51045	-80	85	u=-83
83110	1	-0.9967837	-51110	51120	-51045	51046	-80	85	u=-83
83219	6	6.0034-2	-51110	51120	-51046	51047	-80	85	u=-83

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83319     6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-83
83410     23 -17.55      -51112  51118  -51047  51048  -80  85  u=-83
83320     6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-83
83220     6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-83
83111     1 -0.9967837        -51110  51120  -51049  51050  -80  85  u=-83
83221     6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-83
83321     6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-83
83411     23 -17.55      -51112  51118  -51051  51052  -80  85  u=-83
83322     6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-83
83222     6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-83
83112     1 -0.9967837        -51110  51120  -51053  51054  -80  85  u=-83
83223     6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-83
83323     6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-83
83412     23 -17.55      -51112  51118  -51055  51056  -80  85  u=-83
83324     6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-83
83224     6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-83
83113     1 -0.9967837        -51110  51120  -51057  51058  -80  85  u=-83
83225     6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-83
83325     6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-83
83413     23 -17.55      -51112  51118  -51059  51060  -80  85  u=-83
83326     6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-83
83226     6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-83
83114     1 -0.9967837        -51110  51120  -51061  51062  -80  85  u=-83
83227     6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-83
83327     6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-83
83414     23 -17.55      -51112  51118  -51063  51064  -80  85  u=-83
83328     6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-83
83228     6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-83
83115     1 -0.9967837        -51110  51120  -51065  51066  -80  85  u=-83
83229     6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-83
83329     6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-83
83415     23 -17.55      -51112  51118  -51067  51068  -80  85  u=-83
83330     6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-83
83230     6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-83
83116     1 -0.9967837        -51110  51120  -51069  51070  -80  85  u=-83
83231     6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-83
83331     6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-83
83416     23 -17.55      -51112  51118  -51071  51072  -80  85  u=-83
83332     6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-83
83232     6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-83
83117     1 -0.9967837        -51110  51120  -51073  51074  -80  85  u=-83
83600     6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-83
83610     6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-83
83620     30 9.07359-2                                      80    u=83
83630     40 8.21151-2                               -85         u=83
83640     1 -0.9967837        -51100  51130          51001  -80  85   u=83
83645     1 -0.9967837        -51100  51130  -51074         -80  85   u=83
83650     1 -0.9967837                51100                 -80  85   u=83
83655     1 -0.9967837        -51130                        -80  85   u=83
c
c
c         Fuel Element #14 for tallying C-7
c
84099     1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-84
84197     6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-84
84297     6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-84
84399     23 -17.55      -51112  51118  -51003  51004  -80  85  u=-84
84298     6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-84
84198     6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-84
84100     1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-84
84199     6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-84
84299     6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-84
84400     23 -17.55      -51112  51118  -51007  51008  -80  85  u=-84
84300     6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-84
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84200    6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-84
84101    1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-84
84201    6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-84
84301    6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-84
84401    23 -17.55      -51112  51118  -51011  51012  -80  85  u=-84
84302    6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-84
84202    6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-84
84102    1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-84
84203    6  6.0034-2    -51110  51120  -51014  51015  -80  85  u=-84
84303    6  6.0034-2    -51110  51112  -51015  51016  -80  85  u=-84
84402    23 -17.55      -51112  51118  -51015  51016  -80  85  u=-84
84304    6  6.0034-2    -51118  51120  -51015  51016  -80  85  u=-84
84204    6  6.0034-2    -51110  51120  -51016  51017  -80  85  u=-84
84103    1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-84
84205    6  6.0034-2    -51110  51120  -51018  51019  -80  85  u=-84
84305    6  6.0034-2    -51110  51112  -51019  51020  -80  85  u=-84
84403    23 -17.55      -51112  51118  -51019  51020  -80  85  u=-84
84306    6  6.0034-2    -51118  51120  -51019  51020  -80  85  u=-84
84206    6  6.0034-2    -51110  51120  -51020  51021  -80  85  u=-84
84104    1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-84
84207    6  6.0034-2    -51110  51120  -51022  51023  -80  85  u=-84
84307    6  6.0034-2    -51110  51112  -51023  51024  -80  85  u=-84
84404    23 -17.55      -51112  51118  -51023  51024  -80  85  u=-84
84308    6  6.0034-2    -51118  51120  -51023  51024  -80  85  u=-84
84208    6  6.0034-2    -51110  51120  -51024  51025  -80  85  u=-84
84105    1 -0.9967837        -51110  51120  -51025  51026  -80  85  u=-84
84209    6  6.0034-2    -51110  51120  -51026  51027  -80  85  u=-84
84309    6  6.0034-2    -51110  51112  -51027  51028  -80  85  u=-84
84405    23 -17.55      -51112  51118  -51027  51028  -80  85  u=-84
84310    6  6.0034-2    -51118  51120  -51027  51028  -80  85  u=-84
84210    6  6.0034-2    -51110  51120  -51028  51029  -80  85  u=-84
84106    1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-84
84211    6  6.0034-2    -51110  51120  -51030  51031  -80  85  u=-84
84311    6  6.0034-2    -51110  51112  -51031  51032  -80  85  u=-84
84406    23 -17.55      -51112  51118  -51031  51032  -80  85  u=-84
84312    6  6.0034-2    -51118  51120  -51031  51032  -80  85  u=-84
84212    6  6.0034-2    -51110  51120  -51032  51033  -80  85  u=-84
84107    1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-84
84213    6  6.0034-2    -51110  51120  -51034  51035  -80  85  u=-84
84313    6  6.0034-2    -51110  51112  -51035  51036  -80  85  u=-84
84407    23 -17.55      -51112  51118  -51035  51036  -80  85  u=-84
84314    6  6.0034-2    -51118  51120  -51035  51036  -80  85  u=-84
84214    6  6.0034-2    -51110  51120  -51036  51037  -80  85  u=-84
84108    1 -0.9967837        -51110  51120  -51037  51038  -80  85  u=-84
84215    6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-84
84315    6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-84
84408    23 -17.55      -51112  51118  -51039  51040  -80  85  u=-84
84316    6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-84
84216    6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-84
84109    1 -0.9967837        -51110  51120  -51041  51042  -80  85  u=-84
84217    6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-84
84317    6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-84
84409    23 -17.55      -51112  51118  -51043  51044  -80  85  u=-84
84318    6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-84
84218    6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-84
84110    1 -0.9967837        -51110  51120  -51045  51046  -80  85  u=-84
84219    6  6.0034-2    -51110  51120  -51046  51047  -80  85  u=-84
84319    6  6.0034-2    -51110  51112  -51047  51048  -80  85  u=-84
84410    23 -17.55      -51112  51118  -51047  51048  -80  85  u=-84
84320    6  6.0034-2    -51118  51120  -51047  51048  -80  85  u=-84
84220    6  6.0034-2    -51110  51120  -51048  51049  -80  85  u=-84
84111    1 -0.9967837        -51110  51120  -51049  51050  -80  85  u=-84
84221    6  6.0034-2    -51110  51120  -51050  51051  -80  85  u=-84
84321    6  6.0034-2    -51110  51112  -51051  51052  -80  85  u=-84
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84411    23 -17.55      -51112  51118  -51051  51052  -80  85  u=-84
84322    6  6.0034-2    -51118  51120  -51051  51052  -80  85  u=-84
84222    6  6.0034-2    -51110  51120  -51052  51053  -80  85  u=-84
84112    1 -0.9967837        -51110  51120  -51053  51054  -80  85  u=-84
84223    6  6.0034-2    -51110  51120  -51054  51055  -80  85  u=-84
84323    6  6.0034-2    -51110  51112  -51055  51056  -80  85  u=-84
84412    23 -17.55      -51112  51118  -51055  51056  -80  85  u=-84
84324    6  6.0034-2    -51118  51120  -51055  51056  -80  85  u=-84
84224    6  6.0034-2    -51110  51120  -51056  51057  -80  85  u=-84
84113    1 -0.9967837        -51110  51120  -51057  51058  -80  85  u=-84
84225    6  6.0034-2    -51110  51120  -51058  51059  -80  85  u=-84
84325    6  6.0034-2    -51110  51112  -51059  51060  -80  85  u=-84
84413    23 -17.55      -51112  51118  -51059  51060  -80  85  u=-84
84326    6  6.0034-2    -51118  51120  -51059  51060  -80  85  u=-84
84226    6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-84
84114    1 -0.9967837        -51110  51120  -51061  51062  -80  85  u=-84
84227    6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-84
84327    6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-84
84414    23 -17.55      -51112  51118  -51063  51064  -80  85  u=-84
84328    6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-84
84228    6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-84
84115    1 -0.9967837        -51110  51120  -51065  51066  -80  85  u=-84
84229    6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-84
84329    6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-84
84415    23 -17.55      -51112  51118  -51067  51068  -80  85  u=-84
84330    6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-84
84230    6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-84
84116    1 -0.9967837        -51110  51120  -51069  51070  -80  85  u=-84
84231    6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-84
84331    6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-84
84416    23 -17.55      -51112  51118  -51071  51072  -80  85  u=-84
84332    6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-84
84232    6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-84
84117    1 -0.9967837        -51110  51120  -51073  51074  -80  85  u=-84
84600    6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-84
84610    6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-84
84620    30 9.07359-2                                      80    u=84
84630    40 8.21151-2                                -85         u=84
84640    1 -0.9967837        -51100  51130          51001  -80  85   u=84
84645    1 -0.9967837        -51100  51130  -51074         -80  85   u=84
84650    1 -0.9967837                51100                 -80  85   u=84
84655    1 -0.9967837        -51130                        -80  85   u=84
c
c
c        Fuel Element #15 for tallying C-8
c
85099    1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-85
85197    6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-85
85297    6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-85
85399    23 -17.55      -51112  51118  -51003  51004  -80  85  u=-85
85298    6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-85
85198    6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-85
85100    1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-85
85199    6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-85
85299    6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-85
85400    23 -17.55      -51112  51118  -51007  51008  -80  85  u=-85
85300    6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-85
85200    6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-85
85101    1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-85
85201    6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-85
85301    6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-85
85401    23 -17.55      -51112  51118  -51011  51012  -80  85  u=-85
85302    6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-85
85202    6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-85
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85102    1 -0.9967837      -51110  51120  -51013  51014  -80  85  u=-85
85203    6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-85
85303    6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-85
85402    23 -17.55     -51112  51118  -51015  51016  -80  85  u=-85
85304    6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-85
85204    6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-85
85103    1 -0.9967837      -51110  51120  -51017  51018  -80  85  u=-85
85205    6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-85
85305    6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-85
85403    23 -17.55     -51112  51118  -51019  51020  -80  85  u=-85
85306    6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-85
85206    6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-85
85104    1 -0.9967837      -51110  51120  -51021  51022  -80  85  u=-85
85207    6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-85
85307    6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-85
85404    23 -17.55     -51112  51118  -51023  51024  -80  85  u=-85
85308    6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-85
85208    6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-85
85105    1 -0.9967837      -51110  51120  -51025  51026  -80  85  u=-85
85209    6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-85
85309    6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-85
85405    23 -17.55     -51112  51118  -51027  51028  -80  85  u=-85
85310    6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-85
85210    6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-85
85106    1 -0.9967837      -51110  51120  -51029  51030  -80  85  u=-85
85211    6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-85
85311    6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-85
85406    23 -17.55     -51112  51118  -51031  51032  -80  85  u=-85
85312    6  6.0034-2   -51118  51120  -51031  51032  -80  85  u=-85
85212    6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-85
85107    1 -0.9967837      -51110  51120  -51033  51034  -80  85  u=-85
85213    6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-85
85313    6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-85
85407    23 -17.55     -51112  51118  -51035  51036  -80  85  u=-85
85314    6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-85
85214    6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-85
85108    1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-85
85215    6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-85
85315    6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-85
85408    23 -17.55     -51112  51118  -51039  51040  -80  85  u=-85
85316    6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-85
85216    6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-85
85109    1 -0.9967837      -51110  51120  -51041  51042  -80  85  u=-85
85217    6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-85
85317    6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-85
85409    23 -17.55     -51112  51118  -51043  51044  -80  85  u=-85
85318    6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-85
85218    6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-85
85110    1 -0.9967837      -51110  51120  -51045  51046  -80  85  u=-85
85219    6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-85
85319    6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-85
85410    23 -17.55     -51112  51118  -51047  51048  -80  85  u=-85
85320    6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-85
85220    6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-85
85111    1 -0.9967837      -51110  51120  -51049  51050  -80  85  u=-85
85221    6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-85
85321    6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-85
85411    23 -17.55     -51112  51118  -51051  51052  -80  85  u=-85
85322    6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-85
85222    6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-85
85112    1 -0.9967837      -51110  51120  -51053  51054  -80  85  u=-85
85223    6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-85
85323    6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-85
85412    23 -17.55     -51112  51118  -51055  51056  -80  85  u=-85
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85324     6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-85
85224     6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-85
85113     1 -0.9967837        -51110  51120  -51057  51058  -80  85  u=-85
85225     6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-85
85325     6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-85
85413     23 -17.55     -51112  51118  -51059  51060  -80  85  u=-85
85326     6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-85
85226     6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-85
85114     1 -0.9967837        -51110  51120  -51061  51062  -80  85  u=-85
85227     6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-85
85327     6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-85
85414     23 -17.55     -51112  51118  -51063  51064  -80  85  u=-85
85328     6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-85
85228     6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-85
85115     1 -0.9967837        -51110  51120  -51065  51066  -80  85  u=-85
85229     6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-85
85329     6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-85
85415     23 -17.55     -51112  51118  -51067  51068  -80  85  u=-85
85330     6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-85
85230     6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-85
85116     1 -0.9967837        -51110  51120  -51069  51070  -80  85  u=-85
85231     6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-85
85331     6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-85
85416     23 -17.55     -51112  51118  -51071  51072  -80  85  u=-85
85332     6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-85
85232     6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-85
85117     1 -0.9967837        -51110  51120  -51073  51074  -80  85  u=-85
85600     6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-85
85610     6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-85
85620     30 9.07359-2                                   80   u=85
85630     40 8.21151-2                              -85       u=85
85640     1 -0.9967837        -51100  51130         51001 -80  85   u=85
85645     1 -0.9967837        -51100  51130  -51074        -80  85   u=85
85650     1 -0.9967837                51100                -80  85   u=85
85655     1 -0.9967837        -51130                       -80  85   u=85
c
c
c         Fuel Element #16 for tallying C-9
c
86099     1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-86
86197     6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-86
86297     6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-86
86399     23 -17.55     -51112  51118  -51003  51004  -80  85  u=-86
86298     6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-86
86198     6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-86
86100     1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-86
86199     6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-86
86299     6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-86
86400     23 -17.55     -51112  51118  -51007  51008  -80  85  u=-86
86300     6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-86
86200     6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-86
86101     1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-86
86201     6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-86
86301     6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-86
86401     23 -17.55     -51112  51118  -51011  51012  -80  85  u=-86
86302     6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-86
86202     6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-86
86102     1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-86
86203     6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-86
86303     6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-86
86402     23 -17.55     -51112  51118  -51015  51016  -80  85  u=-86
86304     6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-86
86204     6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-86
86103     1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-86
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86205	6	6.0034-2	-51110	51120	-51018	51019	-80	85	u=-86
86305	6	6.0034-2	-51110	51112	-51019	51020	-80	85	u=-86
86403	23	-17.55	-51112	51118	-51019	51020	-80	85	u=-86
86306	6	6.0034-2	-51118	51120	-51019	51020	-80	85	u=-86
86206	6	6.0034-2	-51110	51120	-51020	51021	-80	85	u=-86
86104	1	-0.9967837	-51110	51120	-51021	51022	-80	85	u=-86
86207	6	6.0034-2	-51110	51120	-51022	51023	-80	85	u=-86
86307	6	6.0034-2	-51110	51112	-51023	51024	-80	85	u=-86
86404	23	-17.55	-51112	51118	-51023	51024	-80	85	u=-86
86308	6	6.0034-2	-51118	51120	-51023	51024	-80	85	u=-86
86208	6	6.0034-2	-51110	51120	-51024	51025	-80	85	u=-86
86105	1	-0.9967837	-51110	51120	-51025	51026	-80	85	u=-86
86209	6	6.0034-2	-51110	51120	-51026	51027	-80	85	u=-86
86309	6	6.0034-2	-51110	51112	-51027	51028	-80	85	u=-86
86405	23	-17.55	-51112	51118	-51027	51028	-80	85	u=-86
86310	6	6.0034-2	-51118	51120	-51027	51028	-80	85	u=-86
86210	6	6.0034-2	-51110	51120	-51028	51029	-80	85	u=-86
86106	1	-0.9967837	-51110	51120	-51029	51030	-80	85	u=-86
86211	6	6.0034-2	-51110	51120	-51030	51031	-80	85	u=-86
86311	6	6.0034-2	-51110	51112	-51031	51032	-80	85	u=-86
86406	23	-17.55	-51112	51118	-51031	51032	-80	85	u=-86
86312	6	6.0034-2	-51118	51120	-51031	51032	-80	85	u=-86
86212	6	6.0034-2	-51110	51120	-51032	51033	-80	85	u=-86
86107	1	-0.9967837	-51110	51120	-51033	51034	-80	85	u=-86
86213	6	6.0034-2	-51110	51120	-51034	51035	-80	85	u=-86
86313	6	6.0034-2	-51110	51112	-51035	51036	-80	85	u=-86
86407	23	-17.55	-51112	51118	-51035	51036	-80	85	u=-86
86314	6	6.0034-2	-51118	51120	-51035	51036	-80	85	u=-86
86214	6	6.0034-2	-51110	51120	-51036	51037	-80	85	u=-86
86108	1	-0.9967837	-51110	51120	-51037	51038	-80	85	u=-86
86215	6	6.0034-2	-51110	51120	-51038	51039	-80	85	u=-86
86315	6	6.0034-2	-51110	51112	-51039	51040	-80	85	u=-86
86408	23	-17.55	-51112	51118	-51039	51040	-80	85	u=-86
86316	6	6.0034-2	-51118	51120	-51039	51040	-80	85	u=-86
86216	6	6.0034-2	-51110	51120	-51040	51041	-80	85	u=-86
86109	1	-0.9967837	-51110	51120	-51041	51042	-80	85	u=-86
86217	6	6.0034-2	-51110	51120	-51042	51043	-80	85	u=-86
86317	6	6.0034-2	-51110	51112	-51043	51044	-80	85	u=-86
86409	23	-17.55	-51112	51118	-51043	51044	-80	85	u=-86
86318	6	6.0034-2	-51118	51120	-51043	51044	-80	85	u=-86
86218	6	6.0034-2	-51110	51120	-51044	51045	-80	85	u=-86
86110	1	-0.9967837	-51110	51120	-51045	51046	-80	85	u=-86
86219	6	6.0034-2	-51110	51120	-51046	51047	-80	85	u=-86
86319	6	6.0034-2	-51110	51112	-51047	51048	-80	85	u=-86
86410	23	-17.55	-51112	51118	-51047	51048	-80	85	u=-86
86320	6	6.0034-2	-51118	51120	-51047	51048	-80	85	u=-86
86220	6	6.0034-2	-51110	51120	-51048	51049	-80	85	u=-86
86111	1	-0.9967837	-51110	51120	-51049	51050	-80	85	u=-86
86221	6	6.0034-2	-51110	51120	-51050	51051	-80	85	u=-86
86321	6	6.0034-2	-51110	51112	-51051	51052	-80	85	u=-86
86411	23	-17.55	-51112	51118	-51051	51052	-80	85	u=-86
86322	6	6.0034-2	-51118	51120	-51051	51052	-80	85	u=-86
86222	6	6.0034-2	-51110	51120	-51052	51053	-80	85	u=-86
86112	1	-0.9967837	-51110	51120	-51053	51054	-80	85	u=-86
86223	6	6.0034-2	-51110	51120	-51054	51055	-80	85	u=-86
86323	6	6.0034-2	-51110	51112	-51055	51056	-80	85	u=-86
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86324	6	6.0034-2	-51118	51120	-51055	51056	-80	85	u=-86
86224	6	6.0034-2	-51110	51120	-51056	51057	-80	85	u=-86
86113	1	-0.9967837	-51110	51120	-51057	51058	-80	85	u=-86
86225	6	6.0034-2	-51110	51120	-51058	51059	-80	85	u=-86
86325	6	6.0034-2	-51110	51112	-51059	51060	-80	85	u=-86
86413	23	-17.55	-51112	51118	-51059	51060	-80	85	u=-86
86326	6	6.0034-2	-51118	51120	-51059	51060	-80	85	u=-86

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86226    6  6.0034-2    -51110  51120  -51060  51061  -80  85  u=-86
86114    1 -0.9967837        -51110  51120  -51061  51062  -80  85  u=-86
86227    6  6.0034-2    -51110  51120  -51062  51063  -80  85  u=-86
86327    6  6.0034-2    -51110  51112  -51063  51064  -80  85  u=-86
86414    23 -17.55      -51112  51118  -51063  51064  -80  85  u=-86
86328    6  6.0034-2    -51118  51120  -51063  51064  -80  85  u=-86
86228    6  6.0034-2    -51110  51120  -51064  51065  -80  85  u=-86
86115    1 -0.9967837        -51110  51120  -51065  51066  -80  85  u=-86
86229    6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-86
86329    6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-86
86415    23 -17.55      -51112  51118  -51067  51068  -80  85  u=-86
86330    6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-86
86230    6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-86
86116    1 -0.9967837        -51110  51120  -51069  51070  -80  85  u=-86
86231    6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-86
86331    6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-86
86416    23 -17.55      -51112  51118  -51071  51072  -80  85  u=-86
86332    6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-86
86232    6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-86
86117    1 -0.9967837        -51110  51120  -51073  51074  -80  85  u=-86
86600    6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-86
86610    6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-86
86620    30 9.07359-2                                    80   u=86
86630    40 8.21151-2                             -85         u=86
86640    1 -0.9967837        -51100  51130         51001  -80  85    u=86
86645    1 -0.9967837        -51100  51130  -51074         -80  85    u=86
86650    1 -0.9967837                51100                 -80  85    u=86
86655    1 -0.9967837        -51130                        -80  85    u=86
c
c
c        Fuel Element #17 for tallying C-10
c
87099    1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-87
87197    6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-87
87297    6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-87
87399    23 -17.55      -51112  51118  -51003  51004  -80  85  u=-87
87298    6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-87
87198    6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-87
87100    1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-87
87199    6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-87
87299    6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-87
87400    23 -17.55      -51112  51118  -51007  51008  -80  85  u=-87
87300    6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-87
87200    6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-87
87101    1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-87
87201    6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-87
87301    6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-87
87401    23 -17.55      -51112  51118  -51011  51012  -80  85  u=-87
87302    6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-87
87202    6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-87
87102    1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-87
87203    6  6.0034-2    -51110  51120  -51014  51015  -80  85  u=-87
87303    6  6.0034-2    -51110  51112  -51015  51016  -80  85  u=-87
87402    23 -17.55      -51112  51118  -51015  51016  -80  85  u=-87
87304    6  6.0034-2    -51118  51120  -51015  51016  -80  85  u=-87
87204    6  6.0034-2    -51110  51120  -51016  51017  -80  85  u=-87
87103    1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-87
87205    6  6.0034-2    -51110  51120  -51018  51019  -80  85  u=-87
87305    6  6.0034-2    -51110  51112  -51019  51020  -80  85  u=-87
87403    23 -17.55      -51112  51118  -51019  51020  -80  85  u=-87
87306    6  6.0034-2    -51118  51120  -51019  51020  -80  85  u=-87
87206    6  6.0034-2    -51110  51120  -51020  51021  -80  85  u=-87
87104    1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-87
87207    6  6.0034-2    -51110  51120  -51022  51023  -80  85  u=-87
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87307	6	6.0034-2	-51110	51112	-51023	51024	-80	85	u=-87
87404	23	-17.55	-51112	51118	-51023	51024	-80	85	u=-87
87308	6	6.0034-2	-51118	51120	-51023	51024	-80	85	u=-87
87208	6	6.0034-2	-51110	51120	-51024	51025	-80	85	u=-87
87105	1	-0.9967837	-51110	51120	-51025	51026	-80	85	u=-87
87209	6	6.0034-2	-51110	51120	-51026	51027	-80	85	u=-87
87309	6	6.0034-2	-51110	51112	-51027	51028	-80	85	u=-87
87405	23	-17.55	-51112	51118	-51027	51028	-80	85	u=-87
87310	6	6.0034-2	-51118	51120	-51027	51028	-80	85	u=-87
87210	6	6.0034-2	-51110	51120	-51028	51029	-80	85	u=-87
87106	1	-0.9967837	-51110	51120	-51029	51030	-80	85	u=-87
87211	6	6.0034-2	-51110	51120	-51030	51031	-80	85	u=-87
87311	6	6.0034-2	-51110	51112	-51031	51032	-80	85	u=-87
87406	23	-17.55	-51112	51118	-51031	51032	-80	85	u=-87
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87212	6	6.0034-2	-51110	51120	-51032	51033	-80	85	u=-87
87107	1	-0.9967837	-51110	51120	-51033	51034	-80	85	u=-87
87213	6	6.0034-2	-51110	51120	-51034	51035	-80	85	u=-87
87313	6	6.0034-2	-51110	51112	-51035	51036	-80	85	u=-87
87407	23	-17.55	-51112	51118	-51035	51036	-80	85	u=-87
87314	6	6.0034-2	-51118	51120	-51035	51036	-80	85	u=-87
87214	6	6.0034-2	-51110	51120	-51036	51037	-80	85	u=-87
87108	1	-0.9967837	-51110	51120	-51037	51038	-80	85	u=-87
87215	6	6.0034-2	-51110	51120	-51038	51039	-80	85	u=-87
87315	6	6.0034-2	-51110	51112	-51039	51040	-80	85	u=-87
87408	23	-17.55	-51112	51118	-51039	51040	-80	85	u=-87
87316	6	6.0034-2	-51118	51120	-51039	51040	-80	85	u=-87
87216	6	6.0034-2	-51110	51120	-51040	51041	-80	85	u=-87
87109	1	-0.9967837	-51110	51120	-51041	51042	-80	85	u=-87
87217	6	6.0034-2	-51110	51120	-51042	51043	-80	85	u=-87
87317	6	6.0034-2	-51110	51112	-51043	51044	-80	85	u=-87
87409	23	-17.55	-51112	51118	-51043	51044	-80	85	u=-87
87318	6	6.0034-2	-51118	51120	-51043	51044	-80	85	u=-87
87218	6	6.0034-2	-51110	51120	-51044	51045	-80	85	u=-87
87110	1	-0.9967837	-51110	51120	-51045	51046	-80	85	u=-87
87219	6	6.0034-2	-51110	51120	-51046	51047	-80	85	u=-87
87319	6	6.0034-2	-51110	51112	-51047	51048	-80	85	u=-87
87410	23	-17.55	-51112	51118	-51047	51048	-80	85	u=-87
87320	6	6.0034-2	-51118	51120	-51047	51048	-80	85	u=-87
87220	6	6.0034-2	-51110	51120	-51048	51049	-80	85	u=-87
87111	1	-0.9967837	-51110	51120	-51049	51050	-80	85	u=-87
87221	6	6.0034-2	-51110	51120	-51050	51051	-80	85	u=-87
87321	6	6.0034-2	-51110	51112	-51051	51052	-80	85	u=-87
87411	23	-17.55	-51112	51118	-51051	51052	-80	85	u=-87
87322	6	6.0034-2	-51118	51120	-51051	51052	-80	85	u=-87
87222	6	6.0034-2	-51110	51120	-51052	51053	-80	85	u=-87
87112	1	-0.9967837	-51110	51120	-51053	51054	-80	85	u=-87
87223	6	6.0034-2	-51110	51120	-51054	51055	-80	85	u=-87
87323	6	6.0034-2	-51110	51112	-51055	51056	-80	85	u=-87
87412	23	-17.55	-51112	51118	-51055	51056	-80	85	u=-87
87324	6	6.0034-2	-51118	51120	-51055	51056	-80	85	u=-87
87224	6	6.0034-2	-51110	51120	-51056	51057	-80	85	u=-87
87113	1	-0.9967837	-51110	51120	-51057	51058	-80	85	u=-87
87225	6	6.0034-2	-51110	51120	-51058	51059	-80	85	u=-87
87325	6	6.0034-2	-51110	51112	-51059	51060	-80	85	u=-87
87413	23	-17.55	-51112	51118	-51059	51060	-80	85	u=-87
87326	6	6.0034-2	-51118	51120	-51059	51060	-80	85	u=-87
87226	6	6.0034-2	-51110	51120	-51060	51061	-80	85	u=-87
87114	1	-0.9967837	-51110	51120	-51061	51062	-80	85	u=-87
87227	6	6.0034-2	-51110	51120	-51062	51063	-80	85	u=-87
87327	6	6.0034-2	-51110	51112	-51063	51064	-80	85	u=-87
87414	23	-17.55	-51112	51118	-51063	51064	-80	85	u=-87
87328	6	6.0034-2	-51118	51120	-51063	51064	-80	85	u=-87
87228	6	6.0034-2	-51110	51120	-51064	51065	-80	85	u=-87

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87115     1 -0.9967837        -51110  51120  -51065  51066  -80  85  u=-87
87229     6  6.0034-2    -51110  51120  -51066  51067  -80  85  u=-87
87329     6  6.0034-2    -51110  51112  -51067  51068  -80  85  u=-87
87415     23 -17.55      -51112  51118  -51067  51068  -80  85  u=-87
87330     6  6.0034-2    -51118  51120  -51067  51068  -80  85  u=-87
87230     6  6.0034-2    -51110  51120  -51068  51069  -80  85  u=-87
87116     1 -0.9967837        -51110  51120  -51069  51070  -80  85  u=-87
87231     6  6.0034-2    -51110  51120  -51070  51071  -80  85  u=-87
87331     6  6.0034-2    -51110  51112  -51071  51072  -80  85  u=-87
87416     23 -17.55      -51112  51118  -51071  51072  -80  85  u=-87
87332     6  6.0034-2    -51118  51120  -51071  51072  -80  85  u=-87
87232     6  6.0034-2    -51110  51120  -51072  51073  -80  85  u=-87
87117     1 -0.9967837        -51110  51120  -51073  51074  -80  85  u=-87
87600     6  6.0034-2    -51100  51110  -51001  51074  -80  85  u=-87
87610     6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-87
87620     30 9.07359-2                                        80    u=87
87630     40 8.21151-2                                   -85        u=87
87640     1 -0.9967837        -51100  51130          51001  -80  85   u=87
87645     1 -0.9967837        -51100  51130  -51074         -80  85   u=87
87650     1 -0.9967837                51100                 -80  85   u=87
87655     1 -0.9967837        -51130                        -80  85   u=87
c
c
c         Fuel Element #18 for tallying C-11
c
88099     1 -0.9967837        -51110  51120  -51001  51002  -80  85  u=-88
88197     6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-88
88297     6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-88
88399     23 -17.55      -51112  51118  -51003  51004  -80  85  u=-88
88298     6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-88
88198     6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-88
88100     1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-88
88199     6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-88
88299     6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-88
88400     23 -17.55      -51112  51118  -51007  51008  -80  85  u=-88
88300     6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-88
88200     6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-88
88101     1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-88
88201     6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-88
88301     6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-88
88401     23 -17.55      -51112  51118  -51011  51012  -80  85  u=-88
88302     6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-88
88202     6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-88
88102     1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-88
88203     6  6.0034-2    -51110  51120  -51014  51015  -80  85  u=-88
88303     6  6.0034-2    -51110  51112  -51015  51016  -80  85  u=-88
88402     23 -17.55      -51112  51118  -51015  51016  -80  85  u=-88
88304     6  6.0034-2    -51118  51120  -51015  51016  -80  85  u=-88
88204     6  6.0034-2    -51110  51120  -51016  51017  -80  85  u=-88
88103     1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-88
88205     6  6.0034-2    -51110  51120  -51018  51019  -80  85  u=-88
88305     6  6.0034-2    -51110  51112  -51019  51020  -80  85  u=-88
88403     23 -17.55      -51112  51118  -51019  51020  -80  85  u=-88
88306     6  6.0034-2    -51118  51120  -51019  51020  -80  85  u=-88
88206     6  6.0034-2    -51110  51120  -51020  51021  -80  85  u=-88
88104     1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-88
88207     6  6.0034-2    -51110  51120  -51022  51023  -80  85  u=-88
88307     6  6.0034-2    -51110  51112  -51023  51024  -80  85  u=-88
88404     23 -17.55      -51112  51118  -51023  51024  -80  85  u=-88
88308     6  6.0034-2    -51118  51120  -51023  51024  -80  85  u=-88
88208     6  6.0034-2    -51110  51120  -51024  51025  -80  85  u=-88
88105     1 -0.9967837        -51110  51120  -51025  51026  -80  85  u=-88
88209     6  6.0034-2    -51110  51120  -51026  51027  -80  85  u=-88
88309     6  6.0034-2    -51110  51112  -51027  51028  -80  85  u=-88
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88405    23 -17.55       -51112  51118  -51027  51028  -80  85  u=-88
88310    6  6.0034-2     -51118  51120  -51027  51028  -80  85  u=-88
88210    6  6.0034-2     -51110  51120  -51028  51029  -80  85  u=-88
88106    1 -0.9967837         -51110  51120  -51029  51030  -80  85  u=-88
88211    6  6.0034-2     -51110  51120  -51030  51031  -80  85  u=-88
88311    6  6.0034-2     -51110  51112  -51031  51032  -80  85  u=-88
88406    23 -17.55       -51112  51118  -51031  51032  -80  85  u=-88
88312    6  6.0034-2     -51118  51120  -51031  51032  -80  85  u=-88
88212    6  6.0034-2     -51110  51120  -51032  51033  -80  85  u=-88
88107    1 -0.9967837         -51110  51120  -51033  51034  -80  85  u=-88
88213    6  6.0034-2     -51110  51120  -51034  51035  -80  85  u=-88
88313    6  6.0034-2     -51110  51112  -51035  51036  -80  85  u=-88
88407    23 -17.55       -51112  51118  -51035  51036  -80  85  u=-88
88314    6  6.0034-2     -51118  51120  -51035  51036  -80  85  u=-88
88214    6  6.0034-2     -51110  51120  -51036  51037  -80  85  u=-88
88108    1 -0.9967837         -51110  51120  -51037  51038  -80  85  u=-88
88215    6  6.0034-2     -51110  51120  -51038  51039  -80  85  u=-88
88315    6  6.0034-2     -51110  51112  -51039  51040  -80  85  u=-88
88408    23 -17.55       -51112  51118  -51039  51040  -80  85  u=-88
88316    6  6.0034-2     -51118  51120  -51039  51040  -80  85  u=-88
88216    6  6.0034-2     -51110  51120  -51040  51041  -80  85  u=-88
88109    1 -0.9967837         -51110  51120  -51041  51042  -80  85  u=-88
88217    6  6.0034-2     -51110  51120  -51042  51043  -80  85  u=-88
88317    6  6.0034-2     -51110  51112  -51043  51044  -80  85  u=-88
88409    23 -17.55       -51112  51118  -51043  51044  -80  85  u=-88
88318    6  6.0034-2     -51118  51120  -51043  51044  -80  85  u=-88
88218    6  6.0034-2     -51110  51120  -51044  51045  -80  85  u=-88
88110    1 -0.9967837         -51110  51120  -51045  51046  -80  85  u=-88
88219    6  6.0034-2     -51110  51120  -51046  51047  -80  85  u=-88
88319    6  6.0034-2     -51110  51112  -51047  51048  -80  85  u=-88
88410    23 -17.55       -51112  51118  -51047  51048  -80  85  u=-88
88320    6  6.0034-2     -51118  51120  -51047  51048  -80  85  u=-88
88220    6  6.0034-2     -51110  51120  -51048  51049  -80  85  u=-88
88111    1 -0.9967837         -51110  51120  -51049  51050  -80  85  u=-88
88221    6  6.0034-2     -51110  51120  -51050  51051  -80  85  u=-88
88321    6  6.0034-2     -51110  51112  -51051  51052  -80  85  u=-88
88411    23 -17.55       -51112  51118  -51051  51052  -80  85  u=-88
88322    6  6.0034-2     -51118  51120  -51051  51052  -80  85  u=-88
88222    6  6.0034-2     -51110  51120  -51052  51053  -80  85  u=-88
88112    1 -0.9967837         -51110  51120  -51053  51054  -80  85  u=-88
88223    6  6.0034-2     -51110  51120  -51054  51055  -80  85  u=-88
88323    6  6.0034-2     -51110  51112  -51055  51056  -80  85  u=-88
88412    23 -17.55       -51112  51118  -51055  51056  -80  85  u=-88
88324    6  6.0034-2     -51118  51120  -51055  51056  -80  85  u=-88
88224    6  6.0034-2     -51110  51120  -51056  51057  -80  85  u=-88
88113    1 -0.9967837         -51110  51120  -51057  51058  -80  85  u=-88
88225    6  6.0034-2     -51110  51120  -51058  51059  -80  85  u=-88
88325    6  6.0034-2     -51110  51112  -51059  51060  -80  85  u=-88
88413    23 -17.55       -51112  51118  -51059  51060  -80  85  u=-88
88326    6  6.0034-2     -51118  51120  -51059  51060  -80  85  u=-88
88226    6  6.0034-2     -51110  51120  -51060  51061  -80  85  u=-88
88114    1 -0.9967837         -51110  51120  -51061  51062  -80  85  u=-88
88227    6  6.0034-2     -51110  51120  -51062  51063  -80  85  u=-88
88327    6  6.0034-2     -51110  51112  -51063  51064  -80  85  u=-88
88414    23 -17.55       -51112  51118  -51063  51064  -80  85  u=-88
88328    6  6.0034-2     -51118  51120  -51063  51064  -80  85  u=-88
88228    6  6.0034-2     -51110  51120  -51064  51065  -80  85  u=-88
88115    1 -0.9967837         -51110  51120  -51065  51066  -80  85  u=-88
88229    6  6.0034-2     -51110  51120  -51066  51067  -80  85  u=-88
88329    6  6.0034-2     -51110  51112  -51067  51068  -80  85  u=-88
88415    23 -17.55       -51112  51118  -51067  51068  -80  85  u=-88
88330    6  6.0034-2     -51118  51120  -51067  51068  -80  85  u=-88
88230    6  6.0034-2     -51110  51120  -51068  51069  -80  85  u=-88
88116    1 -0.9967837         -51110  51120  -51069  51070  -80  85  u=-88
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88231     6  6.0034-2   -51110  51120  -51070  51071  -80   85  u=-88
88331     6  6.0034-2   -51110  51112  -51071  51072  -80   85  u=-88
88416     23 -17.55     -51112  51118  -51071  51072  -80   85  u=-88
88332     6  6.0034-2   -51118  51120  -51071  51072  -80   85  u=-88
88232     6  6.0034-2   -51110  51120  -51072  51073  -80   85  u=-88
88117     1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-88
88600     6  6.0034-2   -51100  51110  -51001  51074  -80   85  u=-88
88610     6  6.0034-2   -51120  51130  -51001  51074  -80   85  u=-88
88620     30 9.07359-2                                    80    u=88
88630     40 8.21151-2                              -85         u=88
88640     1 -0.9967837       -51100  51130          51001  -80  85    u=88
88645     1 -0.9967837       -51100  51130  -51074         -80  85    u=88
88650     1 -0.9967837               51100                 -80  85    u=88
88655     1 -0.9967837       -51130                        -80  85    u=88
c
c
c         Fuel Element #19 for tallying C-12
c
89099     1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-89
89197     6  6.0034-2   -51110  51120  -51002  51003  -80   85  u=-89
89297     6  6.0034-2   -51110  51112  -51003  51004  -80   85  u=-89
89399     23 -17.55     -51112  51118  -51003  51004  -80   85  u=-89
89298     6  6.0034-2   -51118  51120  -51003  51004  -80   85  u=-89
89198     6  6.0034-2   -51110  51120  -51004  51005  -80   85  u=-89
89100     1 -0.9967837       -51110  51120  -51005  51006  -80  85  u=-89
89199     6  6.0034-2   -51110  51120  -51006  51007  -80   85  u=-89
89299     6  6.0034-2   -51110  51112  -51007  51008  -80   85  u=-89
89400     23 -17.55     -51112  51118  -51007  51008  -80   85  u=-89
89300     6  6.0034-2   -51118  51120  -51007  51008  -80   85  u=-89
89200     6  6.0034-2   -51110  51120  -51008  51009  -80   85  u=-89
89101     1 -0.9967837       -51110  51120  -51009  51010  -80  85  u=-89
89201     6  6.0034-2   -51110  51120  -51010  51011  -80   85  u=-89
89301     6  6.0034-2   -51110  51112  -51011  51012  -80   85  u=-89
89401     23 -17.55     -51112  51118  -51011  51012  -80   85  u=-89
89302     6  6.0034-2   -51118  51120  -51011  51012  -80   85  u=-89
89202     6  6.0034-2   -51110  51120  -51012  51013  -80   85  u=-89
89102     1 -0.9967837       -51110  51120  -51013  51014  -80  85  u=-89
89203     6  6.0034-2   -51110  51120  -51014  51015  -80   85  u=-89
89303     6  6.0034-2   -51110  51112  -51015  51016  -80   85  u=-89
89402     23 -17.55     -51112  51118  -51015  51016  -80   85  u=-89
89304     6  6.0034-2   -51118  51120  -51015  51016  -80   85  u=-89
89204     6  6.0034-2   -51110  51120  -51016  51017  -80   85  u=-89
89103     1 -0.9967837       -51110  51120  -51017  51018  -80  85  u=-89
89205     6  6.0034-2   -51110  51120  -51018  51019  -80   85  u=-89
89305     6  6.0034-2   -51110  51112  -51019  51020  -80   85  u=-89
89403     23 -17.55     -51112  51118  -51019  51020  -80   85  u=-89
89306     6  6.0034-2   -51118  51120  -51019  51020  -80   85  u=-89
89206     6  6.0034-2   -51110  51120  -51020  51021  -80   85  u=-89
89104     1 -0.9967837       -51110  51120  -51021  51022  -80  85  u=-89
89207     6  6.0034-2   -51110  51120  -51022  51023  -80   85  u=-89
89307     6  6.0034-2   -51110  51112  -51023  51024  -80   85  u=-89
89404     23 -17.55     -51112  51118  -51023  51024  -80   85  u=-89
89308     6  6.0034-2   -51118  51120  -51023  51024  -80   85  u=-89
89208     6  6.0034-2   -51110  51120  -51024  51025  -80   85  u=-89
89105     1 -0.9967837       -51110  51120  -51025  51026  -80  85  u=-89
89209     6  6.0034-2   -51110  51120  -51026  51027  -80   85  u=-89
89309     6  6.0034-2   -51110  51112  -51027  51028  -80   85  u=-89
89405     23 -17.55     -51112  51118  -51027  51028  -80   85  u=-89
89310     6  6.0034-2   -51118  51120  -51027  51028  -80   85  u=-89
89210     6  6.0034-2   -51110  51120  -51028  51029  -80   85  u=-89
89106     1 -0.9967837       -51110  51120  -51029  51030  -80  85  u=-89
89211     6  6.0034-2   -51110  51120  -51030  51031  -80   85  u=-89
89311     6  6.0034-2   -51110  51112  -51031  51032  -80   85  u=-89
89406     23 -17.55     -51112  51118  -51031  51032  -80   85  u=-89
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89312	6	6.0034-2	-51118	51120	-51031	51032	-80	85	u=-89
89212	6	6.0034-2	-51110	51120	-51032	51033	-80	85	u=-89
89107	1	-0.9967837	-51110	51120	-51033	51034	-80	85	u=-89
89213	6	6.0034-2	-51110	51120	-51034	51035	-80	85	u=-89
89313	6	6.0034-2	-51110	51112	-51035	51036	-80	85	u=-89
89407	23	-17.55	-51112	51118	-51035	51036	-80	85	u=-89
89314	6	6.0034-2	-51118	51120	-51035	51036	-80	85	u=-89
89214	6	6.0034-2	-51110	51120	-51036	51037	-80	85	u=-89
89108	1	-0.9967837	-51110	51120	-51037	51038	-80	85	u=-89
89215	6	6.0034-2	-51110	51120	-51038	51039	-80	85	u=-89
89315	6	6.0034-2	-51110	51112	-51039	51040	-80	85	u=-89
89408	23	-17.55	-51112	51118	-51039	51040	-80	85	u=-89
89316	6	6.0034-2	-51118	51120	-51039	51040	-80	85	u=-89
89216	6	6.0034-2	-51110	51120	-51040	51041	-80	85	u=-89
89109	1	-0.9967837	-51110	51120	-51041	51042	-80	85	u=-89
89217	6	6.0034-2	-51110	51120	-51042	51043	-80	85	u=-89
89317	6	6.0034-2	-51110	51112	-51043	51044	-80	85	u=-89
89409	23	-17.55	-51112	51118	-51043	51044	-80	85	u=-89
89318	6	6.0034-2	-51118	51120	-51043	51044	-80	85	u=-89
89218	6	6.0034-2	-51110	51120	-51044	51045	-80	85	u=-89
89110	1	-0.9967837	-51110	51120	-51045	51046	-80	85	u=-89
89219	6	6.0034-2	-51110	51120	-51046	51047	-80	85	u=-89
89319	6	6.0034-2	-51110	51112	-51047	51048	-80	85	u=-89
89410	23	-17.55	-51112	51118	-51047	51048	-80	85	u=-89
89320	6	6.0034-2	-51118	51120	-51047	51048	-80	85	u=-89
89220	6	6.0034-2	-51110	51120	-51048	51049	-80	85	u=-89
89111	1	-0.9967837	-51110	51120	-51049	51050	-80	85	u=-89
89221	6	6.0034-2	-51110	51120	-51050	51051	-80	85	u=-89
89321	6	6.0034-2	-51110	51112	-51051	51052	-80	85	u=-89
89411	23	-17.55	-51112	51118	-51051	51052	-80	85	u=-89
89322	6	6.0034-2	-51118	51120	-51051	51052	-80	85	u=-89
89222	6	6.0034-2	-51110	51120	-51052	51053	-80	85	u=-89
89112	1	-0.9967837	-51110	51120	-51053	51054	-80	85	u=-89
89223	6	6.0034-2	-51110	51120	-51054	51055	-80	85	u=-89
89323	6	6.0034-2	-51110	51112	-51055	51056	-80	85	u=-89
89412	23	-17.55	-51112	51118	-51055	51056	-80	85	u=-89
89324	6	6.0034-2	-51118	51120	-51055	51056	-80	85	u=-89
89224	6	6.0034-2	-51110	51120	-51056	51057	-80	85	u=-89
89113	1	-0.9967837	-51110	51120	-51057	51058	-80	85	u=-89
89225	6	6.0034-2	-51110	51120	-51058	51059	-80	85	u=-89
89325	6	6.0034-2	-51110	51112	-51059	51060	-80	85	u=-89
89413	23	-17.55	-51112	51118	-51059	51060	-80	85	u=-89
89326	6	6.0034-2	-51118	51120	-51059	51060	-80	85	u=-89
89226	6	6.0034-2	-51110	51120	-51060	51061	-80	85	u=-89
89114	1	-0.9967837	-51110	51120	-51061	51062	-80	85	u=-89
89227	6	6.0034-2	-51110	51120	-51062	51063	-80	85	u=-89
89327	6	6.0034-2	-51110	51112	-51063	51064	-80	85	u=-89
89414	23	-17.55	-51112	51118	-51063	51064	-80	85	u=-89
89328	6	6.0034-2	-51118	51120	-51063	51064	-80	85	u=-89
89228	6	6.0034-2	-51110	51120	-51064	51065	-80	85	u=-89
89115	1	-0.9967837	-51110	51120	-51065	51066	-80	85	u=-89
89229	6	6.0034-2	-51110	51120	-51066	51067	-80	85	u=-89
89329	6	6.0034-2	-51110	51112	-51067	51068	-80	85	u=-89
89415	23	-17.55	-51112	51118	-51067	51068	-80	85	u=-89
89330	6	6.0034-2	-51118	51120	-51067	51068	-80	85	u=-89
89230	6	6.0034-2	-51110	51120	-51068	51069	-80	85	u=-89
89116	1	-0.9967837	-51110	51120	-51069	51070	-80	85	u=-89
89231	6	6.0034-2	-51110	51120	-51070	51071	-80	85	u=-89
89331	6	6.0034-2	-51110	51112	-51071	51072	-80	85	u=-89
89416	23	-17.55	-51112	51118	-51071	51072	-80	85	u=-89
89332	6	6.0034-2	-51118	51120	-51071	51072	-80	85	u=-89
89232	6	6.0034-2	-51110	51120	-51072	51073	-80	85	u=-89
89117	1	-0.9967837	-51110	51120	-51073	51074	-80	85	u=-89
89600	6	6.0034-2	-51100	51110	-51001	51074	-80	85	u=-89

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89610     6  6.0034-2    -51120  51130  -51001  51074  -80  85  u=-89
89620     30 9.07359-2                                          80   u=89
89630     40 8.21151-2                                     -85       u=89
89640     1 -0.9967837       -51100  51130          51001 -80  85    u=89
89645     1 -0.9967837       -51100  51130  -51074          -80  85   u=89
89650     1 -0.9967837               51100                  -80  85   u=89
89655     1 -0.9967837       -51130                         -80  85   u=89
c
c
c         Fuel Element #20 for tallying C-13
c
90099     1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-90
90197     6  6.0034-2    -51110  51120  -51002  51003  -80  85  u=-90
90297     6  6.0034-2    -51110  51112  -51003  51004  -80  85  u=-90
90399     23 -17.55      -51112  51118  -51003  51004  -80  85  u=-90
90298     6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-90
90198     6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-90
90100     1 -0.9967837       -51110  51120  -51005  51006  -80  85  u=-90
90199     6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-90
90299     6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-90
90400     23 -17.55      -51112  51118  -51007  51008  -80  85  u=-90
90300     6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-90
90200     6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-90
90101     1 -0.9967837       -51110  51120  -51009  51010  -80  85  u=-90
90201     6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-90
90301     6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-90
90401     23 -17.55      -51112  51118  -51011  51012  -80  85  u=-90
90302     6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-90
90202     6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-90
90102     1 -0.9967837       -51110  51120  -51013  51014  -80  85  u=-90
90203     6  6.0034-2    -51110  51120  -51014  51015  -80  85  u=-90
90303     6  6.0034-2    -51110  51112  -51015  51016  -80  85  u=-90
90402     23 -17.55      -51112  51118  -51015  51016  -80  85  u=-90
90304     6  6.0034-2    -51118  51120  -51015  51016  -80  85  u=-90
90204     6  6.0034-2    -51110  51120  -51016  51017  -80  85  u=-90
90103     1 -0.9967837       -51110  51120  -51017  51018  -80  85  u=-90
90205     6  6.0034-2    -51110  51120  -51018  51019  -80  85  u=-90
90305     6  6.0034-2    -51110  51112  -51019  51020  -80  85  u=-90
90403     23 -17.55      -51112  51118  -51019  51020  -80  85  u=-90
90306     6  6.0034-2    -51118  51120  -51019  51020  -80  85  u=-90
90206     6  6.0034-2    -51110  51120  -51020  51021  -80  85  u=-90
90104     1 -0.9967837       -51110  51120  -51021  51022  -80  85  u=-90
90207     6  6.0034-2    -51110  51120  -51022  51023  -80  85  u=-90
90307     6  6.0034-2    -51110  51112  -51023  51024  -80  85  u=-90
90404     23 -17.55      -51112  51118  -51023  51024  -80  85  u=-90
90308     6  6.0034-2    -51118  51120  -51023  51024  -80  85  u=-90
90208     6  6.0034-2    -51110  51120  -51024  51025  -80  85  u=-90
90105     1 -0.9967837       -51110  51120  -51025  51026  -80  85  u=-90
90209     6  6.0034-2    -51110  51120  -51026  51027  -80  85  u=-90
90309     6  6.0034-2    -51110  51112  -51027  51028  -80  85  u=-90
90405     23 -17.55      -51112  51118  -51027  51028  -80  85  u=-90
90310     6  6.0034-2    -51118  51120  -51027  51028  -80  85  u=-90
90210     6  6.0034-2    -51110  51120  -51028  51029  -80  85  u=-90
90106     1 -0.9967837       -51110  51120  -51029  51030  -80  85  u=-90
90211     6  6.0034-2    -51110  51120  -51030  51031  -80  85  u=-90
90311     6  6.0034-2    -51110  51112  -51031  51032  -80  85  u=-90
90406     23 -17.55      -51112  51118  -51031  51032  -80  85  u=-90
90312     6  6.0034-2    -51118  51120  -51031  51032  -80  85  u=-90
90212     6  6.0034-2    -51110  51120  -51032  51033  -80  85  u=-90
90107     1 -0.9967837       -51110  51120  -51033  51034  -80  85  u=-90
90213     6  6.0034-2    -51110  51120  -51034  51035  -80  85  u=-90
90313     6  6.0034-2    -51110  51112  -51035  51036  -80  85  u=-90
90407     23 -17.55      -51112  51118  -51035  51036  -80  85  u=-90
90314     6  6.0034-2    -51118  51120  -51035  51036  -80  85  u=-90
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90214	6	6.0034-2	-51110	51120	-51036	51037	-80	85	u=-90
90108	1	-0.9967837	-51110	51120	-51037	51038	-80	85	u=-90
90215	6	6.0034-2	-51110	51120	-51038	51039	-80	85	u=-90
90315	6	6.0034-2	-51110	51112	-51039	51040	-80	85	u=-90
90408	23	-17.55	-51112	51118	-51039	51040	-80	85	u=-90
90316	6	6.0034-2	-51118	51120	-51039	51040	-80	85	u=-90
90216	6	6.0034-2	-51110	51120	-51040	51041	-80	85	u=-90
90109	1	-0.9967837	-51110	51120	-51041	51042	-80	85	u=-90
90217	6	6.0034-2	-51110	51120	-51042	51043	-80	85	u=-90
90317	6	6.0034-2	-51110	51112	-51043	51044	-80	85	u=-90
90409	23	-17.55	-51112	51118	-51043	51044	-80	85	u=-90
90318	6	6.0034-2	-51118	51120	-51043	51044	-80	85	u=-90
90218	6	6.0034-2	-51110	51120	-51044	51045	-80	85	u=-90
90110	1	-0.9967837	-51110	51120	-51045	51046	-80	85	u=-90
90219	6	6.0034-2	-51110	51120	-51046	51047	-80	85	u=-90
90319	6	6.0034-2	-51110	51112	-51047	51048	-80	85	u=-90
90410	23	-17.55	-51112	51118	-51047	51048	-80	85	u=-90
90320	6	6.0034-2	-51118	51120	-51047	51048	-80	85	u=-90
90220	6	6.0034-2	-51110	51120	-51048	51049	-80	85	u=-90
90111	1	-0.9967837	-51110	51120	-51049	51050	-80	85	u=-90
90221	6	6.0034-2	-51110	51120	-51050	51051	-80	85	u=-90
90321	6	6.0034-2	-51110	51112	-51051	51052	-80	85	u=-90
90411	23	-17.55	-51112	51118	-51051	51052	-80	85	u=-90
90322	6	6.0034-2	-51118	51120	-51051	51052	-80	85	u=-90
90222	6	6.0034-2	-51110	51120	-51052	51053	-80	85	u=-90
90112	1	-0.9967837	-51110	51120	-51053	51054	-80	85	u=-90
90223	6	6.0034-2	-51110	51120	-51054	51055	-80	85	u=-90
90323	6	6.0034-2	-51110	51112	-51055	51056	-80	85	u=-90
90412	23	-17.55	-51112	51118	-51055	51056	-80	85	u=-90
90324	6	6.0034-2	-51118	51120	-51055	51056	-80	85	u=-90
90224	6	6.0034-2	-51110	51120	-51056	51057	-80	85	u=-90
90113	1	-0.9967837	-51110	51120	-51057	51058	-80	85	u=-90
90225	6	6.0034-2	-51110	51120	-51058	51059	-80	85	u=-90
90325	6	6.0034-2	-51110	51112	-51059	51060	-80	85	u=-90
90413	23	-17.55	-51112	51118	-51059	51060	-80	85	u=-90
90326	6	6.0034-2	-51118	51120	-51059	51060	-80	85	u=-90
90226	6	6.0034-2	-51110	51120	-51060	51061	-80	85	u=-90
90114	1	-0.9967837	-51110	51120	-51061	51062	-80	85	u=-90
90227	6	6.0034-2	-51110	51120	-51062	51063	-80	85	u=-90
90327	6	6.0034-2	-51110	51112	-51063	51064	-80	85	u=-90
90414	23	-17.55	-51112	51118	-51063	51064	-80	85	u=-90
90328	6	6.0034-2	-51118	51120	-51063	51064	-80	85	u=-90
90228	6	6.0034-2	-51110	51120	-51064	51065	-80	85	u=-90
90115	1	-0.9967837	-51110	51120	-51065	51066	-80	85	u=-90
90229	6	6.0034-2	-51110	51120	-51066	51067	-80	85	u=-90
90329	6	6.0034-2	-51110	51112	-51067	51068	-80	85	u=-90
90415	23	-17.55	-51112	51118	-51067	51068	-80	85	u=-90
90330	6	6.0034-2	-51118	51120	-51067	51068	-80	85	u=-90
90230	6	6.0034-2	-51110	51120	-51068	51069	-80	85	u=-90
90116	1	-0.9967837	-51110	51120	-51069	51070	-80	85	u=-90
90231	6	6.0034-2	-51110	51120	-51070	51071	-80	85	u=-90
90331	6	6.0034-2	-51110	51112	-51071	51072	-80	85	u=-90
90416	23	-17.55	-51112	51118	-51071	51072	-80	85	u=-90
90332	6	6.0034-2	-51118	51120	-51071	51072	-80	85	u=-90
90232	6	6.0034-2	-51110	51120	-51072	51073	-80	85	u=-90
90117	1	-0.9967837	-51110	51120	-51073	51074	-80	85	u=-90
90600	6	6.0034-2	-51100	51110	-51001	51074	-80	85	u=-90
90610	6	6.0034-2	-51120	51130	-51001	51074	-80	85	u=-90
90620	30	9.07359-2					80		u=90
90630	40	8.21151-2				-85			u=90
90640	1	-0.9967837	-51100	51130		51001	-80	85	u=90
90645	1	-0.9967837	-51100	51130	-51074		-80	85	u=90
90650	1	-0.9967837		51100			-80	85	u=90
90655	1	-0.9967837	-51130				-80	85	u=90

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c
c
c       Fuel Element #21 for tallying C-14
c
91099   1 -0.9967837      -51110  51120  -51001  51002  -80  85  u=-91
91197   6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-91
91297   6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-91
91399   23 -17.55     -51112  51118  -51003  51004  -80  85  u=-91
91298   6  6.0034-2   -51118  51120  -51003  51004  -80  85  u=-91
91198   6  6.0034-2   -51110  51120  -51004  51005  -80  85  u=-91
91100   1 -0.9967837      -51110  51120  -51005  51006  -80  85  u=-91
91199   6  6.0034-2   -51110  51120  -51006  51007  -80  85  u=-91
91299   6  6.0034-2   -51110  51112  -51007  51008  -80  85  u=-91
91400   23 -17.55     -51112  51118  -51007  51008  -80  85  u=-91
91300   6  6.0034-2   -51118  51120  -51007  51008  -80  85  u=-91
91200   6  6.0034-2   -51110  51120  -51008  51009  -80  85  u=-91
91101   1 -0.9967837      -51110  51120  -51009  51010  -80  85  u=-91
91201   6  6.0034-2   -51110  51120  -51010  51011  -80  85  u=-91
91301   6  6.0034-2   -51110  51112  -51011  51012  -80  85  u=-91
91401   23 -17.55     -51112  51118  -51011  51012  -80  85  u=-91
91302   6  6.0034-2   -51118  51120  -51011  51012  -80  85  u=-91
91202   6  6.0034-2   -51110  51120  -51012  51013  -80  85  u=-91
91102   1 -0.9967837      -51110  51120  -51013  51014  -80  85  u=-91
91203   6  6.0034-2   -51110  51120  -51014  51015  -80  85  u=-91
91303   6  6.0034-2   -51110  51112  -51015  51016  -80  85  u=-91
91402   23 -17.55     -51112  51118  -51015  51016  -80  85  u=-91
91304   6  6.0034-2   -51118  51120  -51015  51016  -80  85  u=-91
91204   6  6.0034-2   -51110  51120  -51016  51017  -80  85  u=-91
91103   1 -0.9967837      -51110  51120  -51017  51018  -80  85  u=-91
91205   6  6.0034-2   -51110  51120  -51018  51019  -80  85  u=-91
91305   6  6.0034-2   -51110  51112  -51019  51020  -80  85  u=-91
91403   23 -17.55     -51112  51118  -51019  51020  -80  85  u=-91
91306   6  6.0034-2   -51118  51120  -51019  51020  -80  85  u=-91
91206   6  6.0034-2   -51110  51120  -51020  51021  -80  85  u=-91
91104   1 -0.9967837      -51110  51120  -51021  51022  -80  85  u=-91
91207   6  6.0034-2   -51110  51120  -51022  51023  -80  85  u=-91
91307   6  6.0034-2   -51110  51112  -51023  51024  -80  85  u=-91
91404   23 -17.55     -51112  51118  -51023  51024  -80  85  u=-91
91308   6  6.0034-2   -51118  51120  -51023  51024  -80  85  u=-91
91208   6  6.0034-2   -51110  51120  -51024  51025  -80  85  u=-91
91105   1 -0.9967837      -51110  51120  -51025  51026  -80  85  u=-91
91209   6  6.0034-2   -51110  51120  -51026  51027  -80  85  u=-91
91309   6  6.0034-2   -51110  51112  -51027  51028  -80  85  u=-91
91405   23 -17.55     -51112  51118  -51027  51028  -80  85  u=-91
91310   6  6.0034-2   -51118  51120  -51027  51028  -80  85  u=-91
91210   6  6.0034-2   -51110  51120  -51028  51029  -80  85  u=-91
91106   1 -0.9967837      -51110  51120  -51029  51030  -80  85  u=-91
91211   6  6.0034-2   -51110  51120  -51030  51031  -80  85  u=-91
91311   6  6.0034-2   -51110  51112  -51031  51032  -80  85  u=-91
91406   23 -17.55     -51112  51118  -51031  51032  -80  85  u=-91
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91212   6  6.0034-2   -51110  51120  -51032  51033  -80  85  u=-91
91107   1 -0.9967837      -51110  51120  -51033  51034  -80  85  u=-91
91213   6  6.0034-2   -51110  51120  -51034  51035  -80  85  u=-91
91313   6  6.0034-2   -51110  51112  -51035  51036  -80  85  u=-91
91407   23 -17.55     -51112  51118  -51035  51036  -80  85  u=-91
91314   6  6.0034-2   -51118  51120  -51035  51036  -80  85  u=-91
91214   6  6.0034-2   -51110  51120  -51036  51037  -80  85  u=-91
91108   1 -0.9967837      -51110  51120  -51037  51038  -80  85  u=-91
91215   6  6.0034-2   -51110  51120  -51038  51039  -80  85  u=-91
91315   6  6.0034-2   -51110  51112  -51039  51040  -80  85  u=-91
91408   23 -17.55     -51112  51118  -51039  51040  -80  85  u=-91
91316   6  6.0034-2   -51118  51120  -51039  51040  -80  85  u=-91
91216   6  6.0034-2   -51110  51120  -51040  51041  -80  85  u=-91
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91109    1 -0.9967837       -51110  51120  -51041  51042  -80  85  u=-91
91217    6  6.0034-2   -51110  51120  -51042  51043  -80  85  u=-91
91317    6  6.0034-2   -51110  51112  -51043  51044  -80  85  u=-91
91409    23 -17.55     -51112  51118  -51043  51044  -80  85  u=-91
91318    6  6.0034-2   -51118  51120  -51043  51044  -80  85  u=-91
91218    6  6.0034-2   -51110  51120  -51044  51045  -80  85  u=-91
91110    1 -0.9967837       -51110  51120  -51045  51046  -80  85  u=-91
91219    6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-91
91319    6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-91
91410    23 -17.55     -51112  51118  -51047  51048  -80  85  u=-91
91320    6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-91
91220    6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-91
91111    1 -0.9967837       -51110  51120  -51049  51050  -80  85  u=-91
91221    6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-91
91321    6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-91
91411    23 -17.55     -51112  51118  -51051  51052  -80  85  u=-91
91322    6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-91
91222    6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-91
91112    1 -0.9967837       -51110  51120  -51053  51054  -80  85  u=-91
91223    6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-91
91323    6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-91
91412    23 -17.55     -51112  51118  -51055  51056  -80  85  u=-91
91324    6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-91
91224    6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-91
91113    1 -0.9967837       -51110  51120  -51057  51058  -80  85  u=-91
91225    6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-91
91325    6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-91
91413    23 -17.55     -51112  51118  -51059  51060  -80  85  u=-91
91326    6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-91
91226    6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-91
91114    1 -0.9967837       -51110  51120  -51061  51062  -80  85  u=-91
91227    6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-91
91327    6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-91
91414    23 -17.55     -51112  51118  -51063  51064  -80  85  u=-91
91328    6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-91
91228    6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-91
91115    1 -0.9967837       -51110  51120  -51065  51066  -80  85  u=-91
91229    6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-91
91329    6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-91
91415    23 -17.55     -51112  51118  -51067  51068  -80  85  u=-91
91330    6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-91
91230    6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-91
91116    1 -0.9967837       -51110  51120  -51069  51070  -80  85  u=-91
91231    6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-91
91331    6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-91
91416    23 -17.55     -51112  51118  -51071  51072  -80  85  u=-91
91332    6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-91
91232    6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-91
91117    1 -0.9967837       -51110  51120  -51073  51074  -80  85  u=-91
91600    6  6.0034-2   -51100  51110  -51001 51074  -80  85  u=-91
91610    6  6.0034-2   -51120  51130  -51001 51074  -80  85  u=-91
91620    30 9.07359-2                                80   u=91
91630    40 8.21151-2                         -85        u=91
91640    1 -0.9967837      -51100  51130          51001 -80  85   u=91
91645    1 -0.9967837      -51100  51130  -51074          -80  85   u=91
91650    1 -0.9967837              51100                  -80  85   u=91
91655    1 -0.9967837      -51130                         -80  85   u=91
c
c
c        Fuel Element #22 for tallying C-15
c
92099    1 -0.9967837       -51110  51120  -51001  51002  -80  85  u=-92
92197    6  6.0034-2   -51110  51120  -51002  51003  -80  85  u=-92
92297    6  6.0034-2   -51110  51112  -51003  51004  -80  85  u=-92
```

```
92399    23 -17.55      -51112  51118  -51003  51004  -80  85  u=-92
92298    6  6.0034-2    -51118  51120  -51003  51004  -80  85  u=-92
92198    6  6.0034-2    -51110  51120  -51004  51005  -80  85  u=-92
92100    1 -0.9967837        -51110  51120  -51005  51006  -80  85  u=-92
92199    6  6.0034-2    -51110  51120  -51006  51007  -80  85  u=-92
92299    6  6.0034-2    -51110  51112  -51007  51008  -80  85  u=-92
92400    23 -17.55      -51112  51118  -51007  51008  -80  85  u=-92
92300    6  6.0034-2    -51118  51120  -51007  51008  -80  85  u=-92
92200    6  6.0034-2    -51110  51120  -51008  51009  -80  85  u=-92
92101    1 -0.9967837        -51110  51120  -51009  51010  -80  85  u=-92
92201    6  6.0034-2    -51110  51120  -51010  51011  -80  85  u=-92
92301    6  6.0034-2    -51110  51112  -51011  51012  -80  85  u=-92
92401    23 -17.55      -51112  51118  -51011  51012  -80  85  u=-92
92302    6  6.0034-2    -51118  51120  -51011  51012  -80  85  u=-92
92202    6  6.0034-2    -51110  51120  -51012  51013  -80  85  u=-92
92102    1 -0.9967837        -51110  51120  -51013  51014  -80  85  u=-92
92203    6  6.0034-2    -51110  51120  -51014  51015  -80  85  u=-92
92303    6  6.0034-2    -51110  51112  -51015  51016  -80  85  u=-92
92402    23 -17.55      -51112  51118  -51015  51016  -80  85  u=-92
92304    6  6.0034-2    -51118  51120  -51015  51016  -80  85  u=-92
92204    6  6.0034-2    -51110  51120  -51016  51017  -80  85  u=-92
92103    1 -0.9967837        -51110  51120  -51017  51018  -80  85  u=-92
92205    6  6.0034-2    -51110  51120  -51018  51019  -80  85  u=-92
92305    6  6.0034-2    -51110  51112  -51019  51020  -80  85  u=-92
92403    23 -17.55      -51112  51118  -51019  51020  -80  85  u=-92
92306    6  6.0034-2    -51118  51120  -51019  51020  -80  85  u=-92
92206    6  6.0034-2    -51110  51120  -51020  51021  -80  85  u=-92
92104    1 -0.9967837        -51110  51120  -51021  51022  -80  85  u=-92
92207    6  6.0034-2    -51110  51120  -51022  51023  -80  85  u=-92
92307    6  6.0034-2    -51110  51112  -51023  51024  -80  85  u=-92
92404    23 -17.55      -51112  51118  -51023  51024  -80  85  u=-92
92308    6  6.0034-2    -51118  51120  -51023  51024  -80  85  u=-92
92208    6  6.0034-2    -51110  51120  -51024  51025  -80  85  u=-92
92105    1 -0.9967837        -51110  51120  -51025  51026  -80  85  u=-92
92209    6  6.0034-2    -51110  51120  -51026  51027  -80  85  u=-92
92309    6  6.0034-2    -51110  51112  -51027  51028  -80  85  u=-92
92405    23 -17.55      -51112  51118  -51027  51028  -80  85  u=-92
92310    6  6.0034-2    -51118  51120  -51027  51028  -80  85  u=-92
92210    6  6.0034-2    -51110  51120  -51028  51029  -80  85  u=-92
92106    1 -0.9967837        -51110  51120  -51029  51030  -80  85  u=-92
92211    6  6.0034-2    -51110  51120  -51030  51031  -80  85  u=-92
92311    6  6.0034-2    -51110  51112  -51031  51032  -80  85  u=-92
92406    23 -17.55      -51112  51118  -51031  51032  -80  85  u=-92
92312    6  6.0034-2    -51118  51120  -51031  51032  -80  85  u=-92
92212    6  6.0034-2    -51110  51120  -51032  51033  -80  85  u=-92
92107    1 -0.9967837        -51110  51120  -51033  51034  -80  85  u=-92
92213    6  6.0034-2    -51110  51120  -51034  51035  -80  85  u=-92
92313    6  6.0034-2    -51110  51112  -51035  51036  -80  85  u=-92
92407    23 -17.55      -51112  51118  -51035  51036  -80  85  u=-92
92314    6  6.0034-2    -51118  51120  -51035  51036  -80  85  u=-92
92214    6  6.0034-2    -51110  51120  -51036  51037  -80  85  u=-92
92108    1 -0.9967837        -51110  51120  -51037  51038  -80  85  u=-92
92215    6  6.0034-2    -51110  51120  -51038  51039  -80  85  u=-92
92315    6  6.0034-2    -51110  51112  -51039  51040  -80  85  u=-92
92408    23 -17.55      -51112  51118  -51039  51040  -80  85  u=-92
92316    6  6.0034-2    -51118  51120  -51039  51040  -80  85  u=-92
92216    6  6.0034-2    -51110  51120  -51040  51041  -80  85  u=-92
92109    1 -0.9967837        -51110  51120  -51041  51042  -80  85  u=-92
92217    6  6.0034-2    -51110  51120  -51042  51043  -80  85  u=-92
92317    6  6.0034-2    -51110  51112  -51043  51044  -80  85  u=-92
92409    23 -17.55      -51112  51118  -51043  51044  -80  85  u=-92
92318    6  6.0034-2    -51118  51120  -51043  51044  -80  85  u=-92
92218    6  6.0034-2    -51110  51120  -51044  51045  -80  85  u=-92
92110    1 -0.9967837        -51110  51120  -51045  51046  -80  85  u=-92
```

```
92219     6  6.0034-2   -51110  51120  -51046  51047  -80  85  u=-92
92319     6  6.0034-2   -51110  51112  -51047  51048  -80  85  u=-92
92410     23 -17.55     -51112  51118  -51047  51048  -80  85  u=-92
92320     6  6.0034-2   -51118  51120  -51047  51048  -80  85  u=-92
92220     6  6.0034-2   -51110  51120  -51048  51049  -80  85  u=-92
92111     1 -0.9967837      -51110  51120  -51049  51050  -80  85  u=-92
92221     6  6.0034-2   -51110  51120  -51050  51051  -80  85  u=-92
92321     6  6.0034-2   -51110  51112  -51051  51052  -80  85  u=-92
92411     23 -17.55     -51112  51118  -51051  51052  -80  85  u=-92
92322     6  6.0034-2   -51118  51120  -51051  51052  -80  85  u=-92
92222     6  6.0034-2   -51110  51120  -51052  51053  -80  85  u=-92
92112     1 -0.9967837      -51110  51120  -51053  51054  -80  85  u=-92
92223     6  6.0034-2   -51110  51120  -51054  51055  -80  85  u=-92
92323     6  6.0034-2   -51110  51112  -51055  51056  -80  85  u=-92
92412     23 -17.55     -51112  51118  -51055  51056  -80  85  u=-92
92324     6  6.0034-2   -51118  51120  -51055  51056  -80  85  u=-92
92224     6  6.0034-2   -51110  51120  -51056  51057  -80  85  u=-92
92113     1 -0.9967837      -51110  51120  -51057  51058  -80  85  u=-92
92225     6  6.0034-2   -51110  51120  -51058  51059  -80  85  u=-92
92325     6  6.0034-2   -51110  51112  -51059  51060  -80  85  u=-92
92413     23 -17.55     -51112  51118  -51059  51060  -80  85  u=-92
92326     6  6.0034-2   -51118  51120  -51059  51060  -80  85  u=-92
92226     6  6.0034-2   -51110  51120  -51060  51061  -80  85  u=-92
92114     1 -0.9967837      -51110  51120  -51061  51062  -80  85  u=-92
92227     6  6.0034-2   -51110  51120  -51062  51063  -80  85  u=-92
92327     6  6.0034-2   -51110  51112  -51063  51064  -80  85  u=-92
92414     23 -17.55     -51112  51118  -51063  51064  -80  85  u=-92
92328     6  6.0034-2   -51118  51120  -51063  51064  -80  85  u=-92
92228     6  6.0034-2   -51110  51120  -51064  51065  -80  85  u=-92
92115     1 -0.9967837      -51110  51120  -51065  51066  -80  85  u=-92
92229     6  6.0034-2   -51110  51120  -51066  51067  -80  85  u=-92
92329     6  6.0034-2   -51110  51112  -51067  51068  -80  85  u=-92
92415     23 -17.55     -51112  51118  -51067  51068  -80  85  u=-92
92330     6  6.0034-2   -51118  51120  -51067  51068  -80  85  u=-92
92230     6  6.0034-2   -51110  51120  -51068  51069  -80  85  u=-92
92116     1 -0.9967837      -51110  51120  -51069  51070  -80  85  u=-92
92231     6  6.0034-2   -51110  51120  -51070  51071  -80  85  u=-92
92331     6  6.0034-2   -51110  51112  -51071  51072  -80  85  u=-92
92416     23 -17.55     -51112  51118  -51071  51072  -80  85  u=-92
92332     6  6.0034-2   -51118  51120  -51071  51072  -80  85  u=-92
92232     6  6.0034-2   -51110  51120  -51072  51073  -80  85  u=-92
92117     1 -0.9967837      -51110  51120  -51073  51074  -80  85  u=-92
92600     6  6.0034-2   -51100  51110  -51001  51074  -80  85  u=-92
92610     6  6.0034-2   -51120  51130  -51001  51074  -80  85  u=-92
92620     30 9.07359-2                                     80    u=92
92630     40 8.21151-2                               -85         u=92
92640     1 -0.9967837      -51100  51130          51001  -80  85    u=92
92645     1 -0.9967837      -51100  51130  -51074         -80  85    u=92
92650     1 -0.9967837              51100                 -80  85    u=92
92655     1 -0.9967837      -51130                        -80  85    u=92
c
c
c
c
c
c
c      FUEL LOCATIONS
c
c      A-1
c
101    0  -740   750  -650   660   -65   100 101
       *fill=35 (3.54592 0 0 30 120 90 60 30 90 90 90 0)
c
c      A-2
```

```
c
102   0 -550   560 -750   760   -65   100  101
      *fill=37 (-1.7729619 -3.07086 0 210 120 90 -60 150 90 90 90 0)
c     *fill=35 (-1.7729619 -3.07086 0 30 -60 90 120 30 90 90 90 0)
c
c     A-3
c
103   0 -540   550 -640   650   -65   100  101
      fill=38 (-1.7729619 3.07086 0 0 1 0 -1 0 0 0 0 1)
c
c     B-1
c
104   0 -555   565 -665   670   -65   100
      fill=72 (9.22409 -3.69316 0 0 1 0 -1 0 0 0 0 1)
c
c     B-2
c
105   0 -565   570 -665   670   -65   100
      fill=73 (5.67817 -9.83488 0 0 1 0 -1 0 0 0 0 1)
c      *fill=62 (5.67817 -9.83488 0 -30 240 90 60 -30 90 90 90 0)
c
c     B-3
c
106   0 -565   570 -655   665   -65   100
      *fill=71 (-1.413678 -9.83488 0 210 120 90 300 30 90 90 90 0)
c      fill=71 (-1.413678 -9.83488 0 -30 240 90 60 -30 90 90 90 0)
c      *fill=62 (-1.413678 -9.83488 0 -30 240 90 60 -30 90 90 90 0)
c
c     B-4
c
107    0 -635   645 -765   770   -65   100
      *fill=74 (-7.810416 -6.14172 0 -30 240 90 60 -30 90 90 90 0)
c
c     B-5
c
108    0 -630   635 -765   770   -65   100
      *fill=75 (-11.35634 0 0 -30 240 90 60 -30 90 90 90 0)
c      *fill=62 (-11.35634 0 0 210 120 90 300 210 90 90 90 0)
c
c     B-6
c
109   0 -630   635 -755   765   -65   100
       *fill=70 (-7.810416 6.14172 0 -30 240 90 60 150 90 90 90 0)
c      *fill=70 (-7.810416 6.14172 0 -30 240 90 60 -30 90 90 90 0)
c      *fill=62 (-7.810416 6.14172 0 210 120 90 300 210 90 90 90 0)
c
c     B-7
c
110   0 -735   745 -530   535   -65   100
      *fill=76 (-1.413678 9.83488 0 210 120 90 300 210 90 90 90 0)
c
c     B-8
c
111   0 -730   735 -530   535   -65   100
      *fill=77 (5.67817 9.83488 0 210 120 90 300 210 90 90 90 0)
c      fill=62 (5.67817 9.83488 0 0 1 0 -1 0 0 0 0 1)
c
c     B-9
c
112   0 -730   735 -535   545   -65   100
      fill=69 (9.22409 3.69316 0 0 1 0 1 0 0 0 0 1 0)
c     *fill=69 (9.22409 3.69316 0 210 120 90 300 210 90 90 90 0)
c      fill=62 (9.22409 3.69316 0 0 1 0 -1 0 0 0 0 1)
c
```

```
c      C-1
c
113    0  -555    565  -670    675    -65    100
       fill=78 (16.315941 -3.69316 0 0 1 0 -1 0 0 0 0 1)
c
c      C-2
c
114    0  -565    570  -670    675    -65    100
       fill=79 (12.770018 -9.83488 0 0 1 0 -1 0 0 0 0 1)
c
c      C-3
c
115    0  -570    575  -670    675    -65    100
       fill=80 (9.22409 -15.9766 0 0 1 0 -1 0 0 0 0 1)
c
c      C-4
c
116    0  -570    575  -665    670    -65    100
       fill=81 (2.132246 -15.9766 0 0 1 0 -1 0 0 0 0 1)
c        *fill=62 (2.132246 -15.9766 0 -30 240 90 60 -30 90 90 90 0)
c
c      C-5
c
117    0  -570    575  -655    665    -65    100
       fill=82 (-4.959601 -15.9766 0 0 1 0 -1 0 0 0 0 1)
c        *fill=62 (-4.959601 -15.9766 0 -30 240 90 60 -30 90 90 90 0)
c
c      C-6
c
118    0  -770    775  -635    645    -65    100
       *fill=83 (-11.35634 -12.28344 0 -30 240 90 60 -30 90 90 90 0)
c
c      C-7
c
119    0  -770    775  -630    635    -65    100
       *fill=84 (-14.902264 -6.14172 0 -30 240 90 60 -30 90 90 90 0)
c
c      C-8
c
120    0  -770    775  -625    630    -65    100
       *fill=85 (-18.448188 0 0 -30 240 90 60 -30 90 90 90 0)
c
c      C-9
c
121    0 -765    770  -625    630    -65    100
       *fill=86 (-14.902264 6.14172 0 -30 240 90 60 -30 90 90 90 0)
c        *fill=62 (-14.902264 6.14172 0 210 120 90 300 210 90 90 90 0)
c
c      C-10
c
122    0  -755    765  -625    630    -65    100
       *fill=87 (-11.35634 12.28344 0 -30 240 90 60 -30 90 90 90 0)
c        *fill=62 (-11.35634 12.28344 0 210 120 90 300 210 90 90 90 0)
c
c      C-11
c
123     0 -735    745  -525    530    -65    100
       *fill=88 (-4.959601 15.9766 0 210 120 90 300 210 90 90 90 0)
c
c      C-12
c
124    0  -730    735  -525    530    -65    100
       *fill=89 (2.132246 15.9766 0 210 120 90 300 210 90 90 90 0)
c
```

```
c      C-13
c
125    0  -725   730  -525   530   -65   100
       *fill=90 (9.22409 15.9766 0 210 120 90 300 210 90 90 90 0)
c
c      C-14
c
126    0  -725   730  -530   535   -65   100
       *fill=91 (12.770018 9.83488 0 210 120 90 300 210 90 90 90 0)
c       fill=62 (12.770018 9.83488 0 0 1 0 -1 0 0 0 0 1)
c
c      C-15
c
127    0  -725   730  -535   545   -65   100
       *fill=92 (16.315941 3.69316 0 210 120 90 300 210 90 90 90 0)
c       fill=62 (16.315941 3.69316 0 0 1 0 -1 0 0 0 0 1)
c  ICSA
61037    6  6.0034-2   -105 100 -102              $u=36 lower Al fill
61045   620 -10.364       -65 105 -102 103            $u=36 samp annulus He
61046    3 -17.8-5   -104 105 -103                        $u=36 samp ass
61047    3 -17.8-5        -65   104  -103                   $u=36 samp area
61039    3 -17.8-5    -65 100  102  -101                  $u=36 Al annulus
c      SPIDER
c
c      Inner Hex
c
1010  6    6.0034-2  -550   750  -660   665   -82   100
1011  6    6.0034-2  -550   750  -660   661   -65   82
1012  6    6.0034-2  -550   831  -661   665   -65   82
1013  1 -0.9967837   -831   832  -661   665   -65   82  $ Insert
1014  6    6.0034-2  -832   750  -661   665   -65   82
c
1020  6    6.0034-2  -750  -650  -560   565   -82   100
1021  6    6.0034-2  -750  -650  -560   561   -65   82
1022  6    6.0034-2  -750   811  -561   565   -65   82
1023  1 -0.9967837   -811   812  -561   565   -65   82  $ Insert
1024  6    6.0034-2  -812  -650  -561   565   -65   82
c
1030  6    6.0034-2   650  -550  -760   765   -82   100
1031  6    6.0034-2   650  -550  -760   761   -65   82
1032  6    6.0034-2   650   851  -761   765   -65   82
1033  1 -0.9967837   -851   852  -761   765   -65   82  $ Insert
1034  6    6.0034-2  -852  -550  -761   765   -65   82
c
1040  6    6.0034-2   550  -750  -635   640   -82   100
1041  6    6.0034-2   550  -750  -636   640   -65   82
1042  6    6.0034-2   550  -832  -635   636   -65   82
1043  1 -0.9967837    832  -831  -635   636   -65   82  $ Insert
1044  6    6.0034-2   831  -750  -635   636   -65   82
c
1050  6    6.0034-2   650   750  -535   540   -82   100
1051  6    6.0034-2   650   750  -536   540   -65   82
1052  6    6.0034-2   750  -812  -535   536   -65   82
1053  1 -0.9967837    812  -811  -535   536   -65   82  $ Insert
1054  6    6.0034-2   811   650  -535   536   -65   82
c
1060  6    6.0034-2   550  -650  -735   740   -82   100
1061  6    6.0034-2   550  -650  -736   740   -65   82
1062  6    6.0034-2  -650  -852  -735   736   -65   82
1063  1 -0.9967837    852  -851  -735   736   -65   82  $ Insert
1064  6    6.0034-2   851   550  -735   736   -65   82
c
c      Arms
c
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1070  6   6.0034-2  -545   550  -725   735   -82   100 -1145
1071  6   6.0034-2  -550   555  -665   675   -65   100 -1145
1072  1 -0.9967837    -545   550  -725   735   -65   100  1145
1073  1 -0.9967837    -550   555  -665   675   -65   100  1145
1074  6   6.0034-2  -545   547  -725   726   -65   82
1075  1 -0.9967837    -545   547  -726   727   -65   81  $ C ring Insert
1057  1 -0.9967837   -545   547  -726   727   -81   82  $ C ring Insert
1076  6   6.0034-2  -545   547  -727   731   -65   82
1077  1 -0.9967837    -545   547  -731   732   -65   81  $ B ring Insert
1067  1 -0.9967837    -545   547  -731   732   -81   82  $ B ring Insert
1078  6   6.0034-2  -545   547  -732   735   -65   82
1079  6   6.0034-2  -547   550  -725   735   -65   82
c
1080  6   6.0034-2  -645   650  -765   775   -65   100 -1145
1081  6   6.0034-2  -650   655  -565   575   -82   100 -1145
1082  1 -0.9967837    -645   650  -765   775   -65   100  1145
1083  1 -0.9967837    -650   655  -565   575   -65   100  1145
1084  6   6.0034-2  -652   655  -565   566   -65   82
1085  1 -0.9967837    -652   655  -566   567   -65   81  $ B ring Insert
1068  1 -0.9967837    -652   655  -566   567   -81   82  $ B ring Insert
1086  6   6.0034-2  -652   655  -567   571   -65   82
1087  1 -0.9967837     -652   655  -571   572   -65   81  $ C ring Insert
1058  1 -0.9967837    -652   655  -571   572   -81   82  $ C ring Insert
1088  6   6.0034-2  -652   655  -572   575   -65   82
1089  6   6.0034-2  -650   652  -565   575   -65   82
c
1090  6   6.0034-2  -745   750  -525   535   -65   100 -1145
1091  6   6.0034-2  -750   755  -625   635   -82   100 -1145
1092  1 -0.9967837    -745   750  -525   535   -65   100  1145
1093  1 -0.9967837    -750   755  -625   635   -65   100  1145
1094  6   6.0034-2  -752   755  -625   626   -65   82
1095  1 -0.9967837     -752   755  -626   627   -65   81  $ C ring Insert
1059  1 -0.9967837    -752   755  -626   627   -81   82  $ C ring Insert
1096  6   6.0034-2  -752   755  -627   631   -65   82
1097  1 -0.9967837    -752   755  -631   632   -65   81  $ B ring Insert
1069  1 -0.9967837    -752   755  -631   632   -81   82  $ B ring Insert
1098  6   6.0034-2  -752   755  -632   635   -65   82
1099  6   6.0034-2  -750   752  -625   635   -65   82
c
c     OUTER HEX
c
c     HEX REGION 1
c
1101  6   6.0034-2  -550   820  -675   690  -65    1147  -1050   1000
1102  6   6.0034-2  -550   820  -675   690  -1147  1150  -1050
1103  6   6.0034-2  -550   820  -675   690  -1150  1125  -1050  -1145
1104  1 -0.9967837  -550   820  -675   690  -1150  1125  -1050   1145
1105  6   6.0034-2  -550   820  -675   690  -1125  100           -1145
1106  1 -0.9967837  -550   820  -675   690  -1125  100   -1080   1145
c
1107  6   6.0034-2  -820   830  -675   680  -65    1150
1108  6   6.0034-2  -820   830  -675   680  -1150  1125  -1145
1109  1 -0.9967837  -820   830  -675   680  -1150  1125   1145
1110  6   6.0034-2  -820   830  -675   680  -1125  100   -1145
1111  1 -0.9967837  -820   830  -675   680  -1125  100    1145  -1080
c
1170  1 -0.9967837  -820   830  -680   681  -1105   1153        $ Control blade
1172  1 -0.9967837  -820   830  -684   685  -1105   1153        $ Control blade
1174  1 -0.9967837  -820   822  -681   684  -1105   1153        $ Control blade
1176  1 -0.9967837  -825   830  -681   684  -1105   1153        $ Control blade
1178  1 -0.9967837  -822   825  -681   684  -1105   876         $ Control blade
1179  1 -0.9967837  -822   825  -682   683  -876    872         $ Control blade
1180  1 -0.9967837  -822   825  -681   684  -872    1153  864   $ Control blade
1181  1 -0.9967837  -822   825  -682   683  -872   -864         $ Control blade
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1185  8  -8.027173  -822   825  -681   682  -876    872        $ Control blade
1190  8  -8.027173  -822   825  -681   682  -872   -864        $ Control blade
1192  8  -8.027173  -822   825  -683   684  -876    872        $ Control blade
1194  8  -8.027173  -822   825  -683   684  -872   -864        $ Control blade
c
1113  6   6.0034-2  -820   830  -680   685  -1153  1125  -1145
1114  1 -0.9967837  -820   830  -680   685  -1153  1125   1145
1115  6   6.0034-2  -820   830  -680   685  -1125  100   -1145
1116  1 -0.9967837  -820   830  -680   685  -1125  100    1145  -1080
c
1117  6   6.0034-2  -820   830  -685   690  -65    1150
1118  6   6.0034-2  -820   830  -685   690  -1150  1125  -1145
1119  1 -0.9967837  -820   830  -685   690  -1150  1125   1145
1120  6   6.0034-2  -820   830  -685   690  -1125  100   -1145
1121  1 -0.9967837  -820   830  -685   690  -1125  100    1145  -1080
c
1122  6   6.0034-2  -830   750  -675   690  -65    1147  -1050   1020
1123  6   6.0034-2  -830   750  -675   690  -1147  1150  -1050
1124  6   6.0034-2  -830   750  -675   690  -1150  1125  -1050  -1145
1125  1 -0.9967837  -830   750  -675   690  -1150  1125  -1050   1145
1126  6   6.0034-2  -830   750  -675   690  -1125  100          -1145
1127  1 -0.9967837  -830   750  -675   690  -1125  100   -1080   1145
c
c     Water Hole 1 and Regulating rod
c
1128  1 -0.9967837  -1000  -1105  896
1129  1 -0.9967837  -1000   1001  -896  890
1130  1 -0.9967837  -1000  -890   1147
1131  6   6.0034-2  -1001   1002  -896  890
1132  6   6.0034-2  -1002   1003  -896  894
1133  10  -8.65     -1002   1003  -894  892
1134  6   6.0034-2  -1002   1003  -892  890
1135  6   6.0034-2  -1003   1004  -896  890
1136  1 -0.9967837  -1004   -896   890
c
c     HEX REGION 2
c
1201  6   6.0034-2  -750   800  -575   590  -65    1147  -1050   1020
1202  6   6.0034-2  -750   800  -575   590  -1147  1150  -1050
1203  6   6.0034-2  -750   800  -575   590  -1150  1125  -1050  -1145
1204  1 -0.9967837  -750   800  -575   590  -1150  1125  -1050   1145
1205  6   6.0034-2  -750   800  -575   590  -1125  100          -1145
1206  1 -0.9967837  -750   800  -575   590  -1125  100   -1080   1145
c
1207  6   6.0034-2  -800   810  -575   580  -65    1150
1208  6   6.0034-2  -800   810  -575   580  -1150  1125  -1145
1209  1 -0.9967837  -800   810  -575   580  -1150  1125   1145
1210  6   6.0034-2  -800   810  -575   580  -1125  100   -1145
1211  1 -0.9967837  -800   810  -575   580  -1125  100    1145  -1080
c
1270  1 -0.9967837  -800   810  -580   581  -1105   1153        $ Control blade
1272  1 -0.9967837  -800   810  -584   585  -1105   1153        $ Control blade
1274  1 -0.9967837  -800   802  -581   584  -1105   1153        $ Control blade
1276  1 -0.9967837  -805   810  -581   584  -1105   1153        $ Control blade
1278  1 -0.9967837  -802   805  -581   584  -1105   876         $ Control blade
1279  1 -0.9967837  -802   805  -582   583  -876    872         $ Control blade
1280  1 -0.9967837  -802   805  -581   584  -872    1153  860   $ Control blade
1281  1 -0.9967837  -802   805  -582   583  -872   -860         $ Control blade
1285  8  -8.027173  -802   805  -581   582  -876    872         $ Control blade
1290  8  -8.027173  -802   805  -581   582  -872   -860         $ Control blade
1292  8  -8.027173  -802   805  -583   584  -876    872         $ Control blade
1294  8  -8.027173  -802   805  -583   584  -872   -860         $ Control blade
c
1213  6   6.0034-2  -800   810  -580   585  -1153  1125  -1145
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1214  1 -0.9967837  -800   810  -580   585  -1153  1125   1145
1215  6   6.0034-2  -800   810  -580   585  -1125  100   -1145
1216  1 -0.9967837  -800   810  -580   585  -1125  100    1145  -1080
c
1217  6   6.0034-2  -800   810  -585   590  -65    1150
1218  6   6.0034-2  -800   810  -585   590  -1150  1125  -1145
1219  1 -0.9967837  -800   810  -585   590  -1150  1125   1145
1220  6   6.0034-2  -800   810  -585   590  -1125  100   -1145
1221  1 -0.9967837  -800   810  -585   590  -1125  100    1145  -1080
c
1222  6   6.0034-2  -810  -650  -575   590  -65    1147  -1050   1015
1223  6   6.0034-2  -810  -650  -575   590  -1147  1150  -1050
1224  6   6.0034-2  -810  -650  -575   590  -1150  1125  -1050  -1145
1225  1 -0.9967837  -810  -650  -575   590  -1150  1125  -1050   1145
1226  6   6.0034-2  -810  -650  -575   590  -1125  100          -1145
1227  1 -0.9967837  -810  -650  -575   590  -1125  100   -1080   1145
c
c     Water Hole 2
c
1228  1 -0.9967837  -1020   -1105  1147
c
c     HEX REGION 3
c
1301  6   6.0034-2   650   840  -775   790  -65    1147  -1050   1015
1302  6   6.0034-2   650   840  -775   790  -1147  1150  -1050
1303  6   6.0034-2   650   840  -775   790  -1150  1125  -1050  -1145
1304  1 -0.9967837   650   840  -775   790  -1150  1125  -1050   1145
1305  6   6.0034-2   650   840  -775   790  -1125  100          -1145
1306  1 -0.9967837   650   840  -775   790  -1125  100   -1080   1145
c
1307  6   6.0034-2  -840   850  -775   780  -65    1150
1308  6   6.0034-2  -840   850  -775   780  -1150  1125  -1145
1309  1 -0.9967837  -840   850  -775   780  -1150  1125   1145
1310  6   6.0034-2  -840   850  -775   780  -1125  100   -1145
1311  1 -0.9967837  -840   850  -775   780  -1125  100    1145  -1080
c
1370  1 -0.9967837  -840   850  -780   781  -1105   1153        $ Control blade
1372  1 -0.9967837  -840   850  -784   785  -1105   1153        $ Control blade
1374  1 -0.9967837  -840   842  -781   784  -1105   1153        $ Control blade
1376  1 -0.9967837  -845   850  -781   784  -1105   1153        $ Control blade
1378  1 -0.9967837  -842   845  -781   784  -1105   876         $ Control blade
1379  1 -0.9967837  -842   845  -782   783  -876    872         $ Control blade
1380  1 -0.9967837  -842   845  -781   784  -872    1153  868   $ Control blade
1381  1 -0.9967837  -842   845  -782   783  -872   -868         $ Control blade
1385  8   -8.027173 -842   845  -781   782  -876    872         $ Control blade
1390  8   -8.027173 -842   845  -781   782  -872   -868         $ Control blade
1392  8   -8.027173 -842   845  -783   784  -876    872         $ Control blade
1394  8   -8.027173 -842   845  -783   784  -872   -868         $ Control blade
c
1313  6   6.0034-2  -840   850  -780   785  -1153  1125  -1145
1314  1 -0.9967837  -840   850  -780   785  -1153  1125   1145
1315  6   6.0034-2  -840   850  -780   785  -1125  100   -1145
1316  1 -0.9967837  -840   850  -780   785  -1125  100    1145  -1080
c
1317  6   6.0034-2  -840   850  -785   790  -65    1150
1318  6   6.0034-2  -840   850  -785   790  -1150  1125  -1145
1319  1 -0.9967837  -840   850  -785   790  -1150  1125   1145
1320  6   6.0034-2  -840   850  -785   790  -1125  100   -1145
1321  1 -0.9967837  -840   850  -785   790  -1125  100    1145  -1080
c
1322  6   6.0034-2  -850  -550  -775   790  -65    1147  -1050   1005
1323  6   6.0034-2  -850  -550  -775   790  -1147  1150  -1050
1324  6   6.0034-2  -850  -550  -775   790  -1150  1125  -1050  -1145
1325  1 -0.9967837  -850  -550  -775   790  -1150  1125  -1050   1145
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1326  6   6.0034-2  -850  -550  -775   790  -1125  100          -1145
1327  1 -0.9967837  -850  -550  -775   790  -1125  100   -1080   1145
c
c     Water Hole 3
c
1328  1 -0.9967837  -1015  -1105  1147
c
c     HEX REGION 4
c
1401  6   6.0034-2   550  -830  -610   625  -65    1147  -1050   1005
1402  6   6.0034-2   550  -830  -610   625  -1147  1150  -1050
1403  6   6.0034-2   550  -830  -610   625  -1150  1125  -1050  -1145
1404  1 -0.9967837   550  -830  -610   625  -1150  1125  -1050   1145
1405  6   6.0034-2   550  -830  -610   625  -1125  100          -1145
1406  1 -0.9967837   550  -830  -610   625  -1125  100   -1080   1145
c
1407  6   6.0034-2  -820   830  -620   625  -65    1150
1408  6   6.0034-2  -820   830  -620   625  -1150  1125  -1145
1409  1 -0.9967837  -820   830  -620   625  -1150  1125   1145
1410  6   6.0034-2  -820   830  -620   625  -1125  100   -1145
1411  1 -0.9967837  -820   830  -620   625  -1125  100    1145  -1080
c
1470  1 -0.9967837  -820   830   -619  620  -1105   1153        $ Control blade
1472  1 -0.9967837  -820   830   -615  616  -1105   1153        $ Control blade
1474  1 -0.9967837  -820   822   -616  619  -1105   1153        $ Control blade
1476  1 -0.9967837  -825   830   -616  619  -1105   1153        $ Control blade
1478  1 -0.9967837  -822   825   -616  619  -1105   876         $ Control blade
1479  1 -0.9967837  -822   825   -617  618  -876    872         $ Control blade
1480  1 -0.9967837  -822   825   -616  619  -872    1153  864   $ Control blade
1481  1 -0.9967837  -822   825   -617  618  -872   -864         $ Control blade
1485  8   -8.027173 -822   825   -616  617  -876    872         $ Control blade
1490  8   -8.027173 -822   825   -616  617  -872   -864         $ Control blade
1492  8   -8.027173 -822   825   -618  619  -876    872         $ Control blade
1494  8   -8.027173 -822   825   -618  619  -872   -864         $ Control blade
c
1413  6   6.0034-2  -820   830  -615   620  -1153  1125  -1145
1414  1 -0.9967837  -820   830  -615   620  -1153  1125   1145
1415  6   6.0034-2  -820   830  -615   620  -1125  100   -1145
1416  1 -0.9967837  -820   830  -615   620  -1125  100    1145  -1080
c
1417  6   6.0034-2  -820   830  -610   615  -65    1150
1418  6   6.0034-2  -820   830  -610   615  -1150  1125  -1145
1419  1 -0.9967837  -820   830  -610   615  -1150  1125   1145
1420  6   6.0034-2  -820   830  -610   615  -1125  100   -1145
1421  1 -0.9967837  -820   830  -610   615  -1125  100    1145  -1080
c
1422  6   6.0034-2   820  -750  -610   625  -65    1147  -1050   1025
1423  6   6.0034-2   820  -750  -610   625  -1147  1150  -1050
1424  6   6.0034-2   820  -750  -610   625  -1150  1125  -1050  -1145
1425  1 -0.9967837   820  -750  -610   625  -1150  1125  -1050   1145
1426  6   6.0034-2   820  -750  -610   625  -1125  100          -1145
1427  1 -0.9967837   820  -750  -610   625  -1125  100   -1080   1145
c
c     Water Hole 4
c
1428  1 -0.9967837  -1005  -1105  1147
c
c     HEX REGION 5
c
1501  6   6.0034-2  -810   750  -510   525  -65    1147  -1050   1025
1502  6   6.0034-2  -810   750  -510   525  -1147  1150  -1050
1503  6   6.0034-2  -810   750  -510   525  -1150  1125  -1050  -1145
1504  1 -0.9967837  -810   750  -510   525  -1150  1125  -1050   1145
1505  6   6.0034-2  -810   750  -510   525  -1125  100          -1145
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1506  1 -0.9967837  -810    750   -510    525  -1125  100    -1080   1145
c
1507  6    6.0034-2  -800    810   -520    525  -65     1150
1508  6    6.0034-2  -800    810   -520    525  -1150   1125   -1145
1509  1 -0.9967837  -800    810   -520    525  -1150   1125    1145
1510  6    6.0034-2  -800    810   -520    525  -1125   100    -1145
1511  1 -0.9967837  -800    810   -520    525  -1125   100     1145   -1080
c
1570  1 -0.9967837  -800    810    -519   520  -1105    1153         $ Control blade
1572  1 -0.9967837  -800    810    -515   516  -1105    1153         $ Control blade
1574  1 -0.9967837  -800    802    -516   519  -1105    1153         $ Control blade
1576  1 -0.9967837  -805    810    -516   519  -1105    1153         $ Control blade
1578  1 -0.9967837  -802    805    -516   519  -1105    876          $ Control blade
1579  1 -0.9967837  -802    805    -517   518  -876     872          $ Control blade
1580  1 -0.9967837  -802    805    -516   519  -872     1153   860   $ Control blade
1581  1 -0.9967837  -802    805    -517   518  -872    -860          $ Control blade
1585  8   -8.027173  -802    805    -516   517  -876     872          $ Control blade
1590  8   -8.027173  -802    805    -516   517  -872    -860          $ Control blade
1592  8   -8.027173  -802    805    -518   519  -876     872          $ Control blade
1594  8   -8.027173  -802    805    -518   519  -872    -860          $ Control blade
c
1513  6    6.0034-2  -800    810   -515    520  -1153   1125   -1145
1514  1 -0.9967837  -800    810   -515    520  -1153   1125    1145
1515  6    6.0034-2  -800    810   -515    520  -1125   100    -1145
1516  1 -0.9967837  -800    810   -515    520  -1125   100     1145   -1080
c
1517  6    6.0034-2  -800    810   -510    515  -65     1150
1518  6    6.0034-2  -800    810   -510    515  -1150   1125   -1145
1519  1 -0.9967837  -800    810   -510    515  -1150   1125    1145
1520  6    6.0034-2  -800    810   -510    515  -1125   100    -1145
1521  1 -0.9967837  -800    810   -510    515  -1125   100     1145   -1080
c
1522  6    6.0034-2   650    800   -510    525  -65     1147   -1050   1010
1523  6    6.0034-2   650    800   -510    525  -1147   1150   -1050
1524  6    6.0034-2   650    800   -510    525  -1150   1125   -1050  -1145
1525  1 -0.9967837   650    800   -510    525  -1150   1125   -1050   1145
1526  6    6.0034-2   650    800   -510    525  -1125   100           -1145
1527  1 -0.9967837   650    800   -510    525  -1125   100    -1080   1145
c
c     Water Hole 5
c
1528  1 -0.9967837  -1025  -1105  1147
c
c     HEX REGION 6
c
1601  6    6.0034-2  -850   -650   -710    725  -65     1147   -1050   1010
1602  6    6.0034-2  -850   -650   -710    725  -1147   1150   -1050
1603  6    6.0034-2  -850   -650   -710    725  -1150   1125   -1050  -1145
1604  1 -0.9967837  -850   -650   -710    725  -1150   1125   -1050   1145
1605  6    6.0034-2  -850   -650   -710    725  -1125   100           -1145
1606  1 -0.9967837  -850   -650   -710    725  -1125   100    -1080   1145
c
1607  6    6.0034-2  -840    850   -720    725  -65     1150
1608  6    6.0034-2  -840    850   -720    725  -1150   1125   -1145
1609  1 -0.9967837  -840    850   -720    725  -1150   1125    1145
1610  6    6.0034-2  -840    850   -720    725  -1125   100    -1145
1611  1 -0.9967837  -840    850   -720    725  -1125   100     1145   -1080
c
1670  1 -0.9967837  -840    850    -719   720  -1105    1153         $ Control blade
1672  1 -0.9967837  -840    850    -715   716  -1105    1153         $ Control blade
1674  1 -0.9967837  -840    842    -716   719  -1105    1153         $ Control blade
1676  1 -0.9967837  -845    850    -716   719  -1105    1153         $ Control blade
1678  1 -0.9967837  -842    845    -716   719  -1105    876          $ Control blade
1679  1 -0.9967837  -842    845    -717   718  -876     872          $ Control blade
```

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1680  1 -0.9967837  -842   845   -716  719  -872    1153  868  $ Control blade
1681  1 -0.9967837  -842   845   -717  718  -872   -868        $ Control blade
1685  8  -8.027173  -842   845   -716  717  -876    872        $ Control blade
1690  8  -8.027173  -842   845   -716  717  -872   -868        $ Control blade
1692  8  -8.027173  -842   845   -718  719  -876    872        $ Control blade
1694  8  -8.027173  -842   845   -718  719  -872   -868        $ Control blade
c
1613  6   6.0034-2  -840   850  -715   720  -1153  1125  -1145
1614  1 -0.9967837  -840   850  -715   720  -1153  1125   1145
1615  6   6.0034-2  -840   850  -715   720  -1125  100   -1145
1616  1 -0.9967837  -840   850  -715   720  -1125  100    1145  -1080
c
1617  6   6.0034-2  -840   850  -710   715  -65    1150
1618  6   6.0034-2  -840   850  -710   715  -1150  1125  -1145
1619  1 -0.9967837  -840   850  -710   715  -1150  1125   1145
1620  6   6.0034-2  -840   850  -710   715  -1125  100   -1145
1621  1 -0.9967837  -840   850  -710   715  -1125  100    1145  -1080
c
1622  6   6.0034-2   550   840  -710   725  -65    1147  -1050   1000
1623  6   6.0034-2   550   840  -710   725  -1147  1150  -1050
1624  6   6.0034-2   550   840  -710   725  -1150  1125  -1050  -1145
1625  1 -0.9967837   550   840  -710   725  -1150  1125  -1050   1145
1626  6   6.0034-2   550   840  -710   725  -1125  100          -1145
1627  1 -0.9967837   550   840  -710   725  -1125  100   -1080   1145
c
c     Water Hole 6
c
1628  1 -0.9967837  -1010  -1105  1147
c
c     Core Tank
c
2000  6 6.0034-2  -1070   1065  -1105   1110
2002  6 6.0034-2  -1070   1065  -1110  -1085
2004  6 6.0034-2  -1090   1085   1050  -1055 -1110
2005  6 6.0034-2  -1090   1085   1055  -1060 -1110
2006  6 6.0034-2  -1090   1085  -1070   1060  -1110
2007  6 6.0034-2  -1055   1050   1090   1115   -1110
2008  6 6.0034-2  -1060   1055   1090   1115   -1110
2010  6 6.0034-2  -1055   1050  -1115   1120
2011  6 6.0034-2  -1060   1055  -1115   1120
2015  6 6.0034-2  -1055   1050  -1120   1125
c     2020  6 6.0034-2  -1075   1080  -1125   1140  1095
2020  6 6.0034-2  -1075   1080  -1125   1140  1095 -1055
2025  6 6.0034-2  -1130   1135  -1140   1095
2030  6 6.0034-2  -1095   1100   1135
c
c     Core housing support
c
c     2035  6 6.0034-2  -1110   1112  -1062 (-690:-590:-790:610:510:710:1050)
2035  6 6.0034-2  -1110   1112  -1055 (-690:-590:-790:610:510:710:1050)
2036  6 6.0034-2  -1110   1112  -1060 1055
2037  6 6.0034-2  -1110   1112  -1062 1060
2040  6 6.0034-2  -1110   1113   1062  -1065  -1085
c
c     Water Inside Core Tank
c
c     Outside the core housing and inside the core tank
c
2101  1 -0.9967837    -1105     1110    -690  -1050
2102  1 -0.9967837    -1105     1110    -590  -1050
2103  1 -0.9967837    -1105     1110    -790  -1050
2104  1 -0.9967837    -1105     1110     610  -1050
2105  1 -0.9967837    -1105     1110     510  -1050
2106  1 -0.9967837    -1105     1110     710  -1050
```

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c
2111  1 -0.9967837      -1112   1125   -690  -1050
2112  1 -0.9967837      -1112   1125   -590  -1050
2113  1 -0.9967837      -1112   1125   -790  -1050
2114  1 -0.9967837      -1112   1125    610  -1050
2115  1 -0.9967837      -1112   1125    510  -1050
2116  1 -0.9967837      -1112   1125    710  -1050
c
2121  1 -0.9967837    -1125    100   -690  -1080
2122  1 -0.9967837    -1125    100   -590  -1080
2123  1 -0.9967837    -1125    100   -790  -1080
2124  1 -0.9967837    -1125    100    610  -1080
2125  1 -0.9967837    -1125    100    510  -1080
2126  1 -0.9967837    -1125    100    710  -1080
c
2141  1 -0.9967837     -100   1140  -1080
c
2151  1 -0.9967837     -100   1130  -1140   1095
c
c     Water from top of model to top of cone - outside of core tank inner surf
c
2200  1 -0.9967837     -1105  1110  -1055   1050
2291  1 -0.9967837     -1105  1110  -1060   1055
2292  1 -0.9967837     -1105  1110  -1065   1060
c
c     Water next to upper core tank - outside of core tank inner surf
c
2201  60 9.80159-2     -1113  -1085  -1055  1050
2202  60 9.80159-2     -1113  -1085  -1060  1055
2203  60 9.80159-2     -1113  -1085   1060
2204  60 9.80159-2     -1112   1113  -1055  1050
2205  60 9.80159-2     -1112   1113  -1060  1055
2206  60 9.80159-2     -1112   1113  -1062  1060
c
c     Upper grid plate
c
2211  61 8.00245-2  -550   820  -675   690   -1155  65   1000  -1050
2212  61 8.00245-2  -820   830  -675   680   -1155  65
2214  61 8.00245-2  -820   830  -685   690   -1155  65
2215  61 8.00245-2  -830   750  -675   690   -1155  65   1020  -1050
2216  61 8.00245-2   675   575   775  -625   -525  -725 -1155  65
c
2221  61 8.00245-2  -750   800  -575   590   -1155  65   1020  -1050
2222  61 8.00245-2  -800   810  -575   580   -1155  65
2224  61 8.00245-2  -800   810  -585   590   -1155  65
2225  61 8.00245-2  -810  -650  -575   590   -1155  65   1015  -1050
c
2231  61 8.00245-2   650   840  -775   790   -1155  65   1015  -1050
2232  61 8.00245-2  -840   850  -775   780   -1155  65
2234  61 8.00245-2  -840   850  -785   790   -1155  65
2235  61 8.00245-2  -850  -550  -775   790   -1155  65   1005  -1050
c
2241  61 8.00245-2   550  -830  -610   625   -1155  65   1005  -1050
2242  61 8.00245-2  -820   830  -620   625   -1155  65
2244  61 8.00245-2  -820   830  -610   615   -1155  65
2245  61 8.00245-2   820  -750  -610   625   -1155  65   1025  -1050
c
2251  61 8.00245-2  -810   750  -510   525   -1155  65   1025  -1050
2252  61 8.00245-2  -800   810  -520   525   -1155  65
2254  61 8.00245-2  -800   810  -510   515   -1155  65
2255  61 8.00245-2   650   800  -510   525   -1155  65   1010  -1050
c
2261  61 8.00245-2  -850  -650  -710   725   -1155  65   1010  -1050
2262  61 8.00245-2  -840   850  -720   725   -1155  65
```

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2264  61 8.00245-2  -840   850  -710   715   -1155  65
2265  61 8.00245-2   550   840  -710   725   -1155  65   1000  -1050
c
c     Flow Shroud - above grid plate
c
2301  6 6.0034-2  -550   750  1000   1020  -675   680  -1105  1155
2302  6 6.0034-2  -750  -650   1020  1015  -575   580  -1105  1155
2303  6 6.0034-2   650  -550  1015  1005  -775   780  -1105  1155
2304  6 6.0034-2   550  -750  1005  1025  -620   625  -1105  1155
2305  6 6.0034-2   750   650  1025  1010  -520   525  -1105  1155
2306  6 6.0034-2  -650   550  1010  1000  -720   725  -1105  1155
c
c     Water outside flow shroud inside core housing hex
c
2311  1 -0.9967837    -550   820  -680   690  1000  -1050  -1105  1155
2312  1 -0.9967837    -820   830  -685   690  -1105  1155
2313  1 -0.9967837    -830   750  -680   690  1020   -1050  -1105  1155
c
2321  1 -0.9967837    -750   800  -580   590  1020   -1050  -1105  1155
2322  1 -0.9967837    -800   810  -585   590  -1105  1155
2323  1 -0.9967837    -810  -650  -580   590  1015  -1050  -1105  1155
c
2331  1 -0.9967837     650   840  -780   790  1015  -1050  -1105  1155
2332  1 -0.9967837    -840   850  -785   790  -1105  1155
2333  1 -0.9967837    -850  -550  -780   790  1005  -1050  -1105  1155
c
2341  1 -0.9967837     550  -830  -610   620  1005  -1050  -1105  1155
2342  1 -0.9967837    -820   830  -610   615  -1105  1155
2343  1 -0.9967837     820  -750  -610   620  1025  -1050  -1105  1155
c
2351  1 -0.9967837    -810   750  -510   520  1025  -1050  -1105  1155
2352  1 -0.9967837    -800   810  -510   515  -1105  1155
2353  1 -0.9967837     650   800  -510   520  1010  -1050  -1105  1155
c
2361  1 -0.9967837    -850  -650  -710   720  1010  -1050  -1105  1155
2362  1 -0.9967837    -840   850  -710   715  -1105  1155
2363  1 -0.9967837     550   840  -710   720  1000  -1050  -1105  1155
c
c     Water inside flow shroud
c
2371  1 -0.9967837     675  575  775  -625  -525  -725  -1105  1155
c
c     Reflector Tank
c
3000  6 6.0034-2  -1105 2070 -2005 2000 2030 -4200 -4205  4015  4030 4055
                   5340 5360
3001  6 6.0034-2  -1105 2070 -2005 2000 2030 -4200  4205  4055  4080 4385
3002  6 6.0034-2  -1105 2070 -2005 2000 2030  4200  4205  4040  4065 4395
3003  6 6.0034-2  -1105 2070 -2005 2000 2030  4200 -4205  4065  4090 4105
                   5350 5330
3005  6 6.0034-2  -2070   2033  -2060   2055 2030
3010  6 6.0034-2  -2033  -2040   2035   2030
c
c     D2O bubble
c
3020  6 6.0034-2  -2035  -2070  -2020   2010
3025  6 6.0034-2  -2065   2070  -2020   2015
3030  6 6.0034-2   2065  -2050   2045
c
c     D2O pipe
c
3035  6 6.0034-2  -2075    3015  -2030   2025
c
c     D2O pipe volume
```

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c
3040  2 -1.10445  -2075   3015  -2025
c
c     Reflector volume
c
3110  3  -17.8-5    -1105   1110   1070  -2000
3115  2 -1.10445  -1110   1115   1070  -2000
3120  2 -1.10445  -1070  1060   1090  1115  -1110
3130  2 -1.10445  -1115   1120   1060  -2000
3131  2 -1.10445  -1120   1125   1055  -1060
c     3140  2 -1.10445  -1120   1125   1060  -2000
c                       -4200  -4420   4405sx
c     3141  2 -1.10445  -1120   1125   1060  -2000
c                        4200  -4425   4415sx
c     3142  2 -1.10445  -1120   1125   1060  -2000
c                       -4200   4420px   4385cx
c     3143  2 -1.10445  -1120   1125   1060  -2000
c                        4200   4425pl   4395cx
3144  2 -1.10445  -1125   1135   1140   1075  -1055 1095
3145  2 -1.10445  -1125   1135   1055  -1060
c     3146  2 -1.10445  -1125   1135   1060  -2000
c                    4015 4030 4055 4080 4040 4065 4090 4105
c                   -4200
c     3147  2 -1.10445  -1125   1135   1060  -2000
c                    4015 4030 4055 4080 4040 4065 4090 4105
c                    4200
c
3401  2 -1.10445  -1120   1121   1060  -2000 4123 -4122
3402  2 -1.10445  -1120   1121   1060  -2000 4122 -4121
3403  2 -1.10445  -1120   1121   1060  -2000 4121 -4120
3404  2 -1.10445  -1120   1121   1060  -2000 4120  4045
3405  2 -1.10445  -1120   1121   1060  -2000 -4045 4070
3406  2 -1.10445  -1120   1121   1060  -2000 -4070 4095
3407  2 -1.10445  -1120   1121   1060  -2000 -4095 5370
3408  2 -1.10445  -1120   1121   1060  -2000 -5370 5375
3409  2 -1.10445  -1120   1121   1060  -2000 -5375 -4020
3410  2 -1.10445  -1120   1121   1060  -2000 4020  -4045
3411  2 -1.10445  -1120   1121   1060  -2000 4045  -4070
3412  2 -1.10445  -1120   1121   1060  -2000 4070  -4125
3413  2 -1.10445  -1120   1121   1060  -2000 4125  -4124
3414  2 -1.10445  -1120   1121   1060  -2000 4124  -4123
c
3421  2 -1.10445  -1121   3084   1060  -2000 4123 -4122
3422  2 -1.10445  -1121   3084   1060  -2000 4122 -4121
3423  2 -1.10445  -1121   3084   1060  -2000 4121 -4120
3424  2 -1.10445  -1121   3084  -2000   4120  4045
            4425   4395
3425  2 -1.10445  -1121   3084   1060   4120  4045
           -4425   4415
3426  2 -1.10445  -1121   3084   1060  -2000 -4045 4070
3427  2 -1.10445  -1121   3084   1060  -2000 -4070 4095
3428  2 -1.10445  -1121   3084   1060  -2000 -4095 5370
3429  2 -1.10445  -1121   3084   1060  -2000 -5370 5375
3430  2 -1.10445  -1121   3084   1060  -2000 -5375 -4020
3431  2 -1.10445  -1121   3084   1060  -2000 4020  -4045
3432  2 -1.10445  -1121   3084   1060  -2000 4045  -4070
3433  2 -1.10445  -1121   3084  -2000   4070  -4125
            4420   4385
3434  2 -1.10445  -1121   3084   1060   4070  -4125
           -4420   4405
3435  2 -1.10445  -1121   3084   1060  -2000 4125  -4124
3436  2 -1.10445  -1121   3084   1060  -2000 4124  -4123
c
3441  2 -1.10445  -3084   1135   1060  -2000 4123 -4122
```

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3442  2 -1.10445  -3084   1135   1060  -2000 4122 -4121
3443  2 -1.10445  -3084   1135   1060  -2000 4121 -4120
3444  2 -1.10445  -3084   1135   1060  -2000 4120  4045 4040
3445  2 -1.10445  -3084   1135   1060  -2000 -4045 4070 4065
3446  2 -1.10445  -3084   1135   1060  -2000 -4070 4095 4090
3447  2 -1.10445  -3084   1135   1060  -2000 -4095 5370 4105
3448  2 -1.10445  -3084   1135   1060  -2000 -5370 5375
3449  2 -1.10445  -3084   1135   1060  -2000 -5375 -4020 4015
3450  2 -1.10445  -3084   1135   1060  -2000 4020  -4045 4030
3451  2 -1.10445  -3084   1135   1060  -2000 4045  -4070 4055
3452  2 -1.10445  -3084   1135   1060  -2000 4070  -4125 4080
3453  2 -1.10445  -3084   1135   1060  -2000 4125  -4124
3454  2 -1.10445  -3084   1135   1060  -2000 4124  -4123
c
c               D2O below bubble
3151  2 -1.10445   1135  -1100
c               D2O inside beam tubes
3301  2 -1.10445  -1135   1136  -4000
c               Small D2O regions to left of center
3302  2 -1.10445  -1135   1136  -4200   4000  -4020   4015   5405
3303  2 -1.10445  -1135   1136  -4095   4200   4000   4105  -5400
c               Azmuthal D2O regions
3304  2 -1.10445  -1135   1136  -4200  -2000  -5405   5375   5340
3305  2 -1.10445  -1135   1136  -2000  -4020   4015  -5405
                   -5375  (5360:-5385)
3306  2 -1.10445  -1135   1136   4020  -4045   4000  -2000   4030
3307  2 -1.10445  -1135   1136   4045  -4070   4000  -2000   4055
3308  2 -1.10445  -1135   1136   4070  -4125   4000  -2000   4080
3309  2 -1.10445  -1135   1136   4125  -4124   4000  -2000
3310  2 -1.10445  -1135   1136   4124  -4123   4000  -2000
3311  2 -1.10445  -1135   1136  -4122   4123   4000  -2000
3312  2 -1.10445  -1135   1136  -4121   4122   4000  -2000
3313  2 -1.10445  -1135   1136  -4120   4121   4000  -2000
3314  2 -1.10445  -1135   1136   4045   4120   4000  -2000   4040
3315  2 -1.10445  -1135   1136   4070  -4045   4000  -2000   4065
3316  2 -1.10445  -1135   1136  -4070   4095   4000  -2000   4090
3317  2 -1.10445  -1135   1136  -4095  -2000   4105   5400
                    5370  (5350:5380)
3318  2 -1.10445  -1135   1136   4200  -2000   5400  -5370   5330
c
3320  2 -1.10445  -1136   2062  -4000
3321  2 -1.10445  -1136   2062  -4200   4000  -4020   5405 $ 4015
3322  2 -1.10445  -1136   2062  -4095   4200   4000  -5400 $ 4105
3323  2 -1.10445  -1136   2062  -4200  -2000  -5405   5375 $ 5340
3324  2 -1.10445  -1136   2062  -2000  -4020  -5405  -5375
c                     4015 (5360:-5385)
3325  2 -1.10445  -1136   2062   4020  -4045   4000  -2000 $   4030
3326  2 -1.10445  -1136   2062   4045  -4070   4000  -2000 $   4055
3327  2 -1.10445  -1136   2062   4070  -4125   4000  -2000 $   4080
3328  2 -1.10445  -1136   2062   4125  -4124   4000  -2000
3329  2 -1.10445  -1136   2062   4124  -4123   4000  -2000
3330  2 -1.10445  -1136   2062  -4122   4123   4000  -2000
3331  2 -1.10445  -1136   2062  -4121   4122   4000  -2000
3332  2 -1.10445  -1136   2062  -4120   4121   4000  -2000
3333  2 -1.10445  -1136   2062   4045   4120   4000  -2000 $   4040
3334  2 -1.10445  -1136   2062   4070  -4045   4000  -2000 $   4065
3335  2 -1.10445  -1136   2062  -4070   4095   4000  -2000 $   4090
3336  2 -1.10445  -1136   2062  -4095  -2000   5400   5370
c                     4105   (5350:5380)
3337  2 -1.10445  -1136   2062   4200  -2000   5400  -5370 $  5330
c              D2O regions around blister tank
3178  2 -1.10445  -2062   2063  -4000   2050
3179  2 -1.10445  -2063   2065  -4000   2050
c
```

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3502  2 -1.10445  -2062   2063  -2000   4000  4122  -4121
3503  2 -1.10445  -2062   2063  -2000   4000  4121  -4120
3504  2 -1.10445  -2062   2063  -2000   4000  2050   4120   4045
3505  2 -1.10445  -2062   2063  -2000   4000  2050  -4045   4070
3506  2 -1.10445  -2062   2063  -2000   4000  2050  -4070   4095
3507  2 -1.10445  -2062   2063  -2000   4000  2050  -4095   5370
3508  2 -1.10445  -2062   2063  -2000   4000  2050  -5370   5375  -4205
3509  2 -1.10445  -2062   2063  -2000   4000  2050  -5375  -4020
3510  2 -1.10445  -2062   2063  -2000   4000  2050   4020  -4045
3511  2 -1.10445  -2062   2063  -2000   4000  2050   4045  -4070
3512  2 -1.10445  -2062   2063  -2000   4000  2050   4070  -4125
3513  2 -1.10445  -2062   2063  -2000   4000  4125  -4124
3514  2 -1.10445  -2062   2063  -2000   4000  4124  -4123
c
3521  2 -1.10445  -2063   2065  -2000   4000  4123  -4122
3522  2 -1.10445  -2063   2065  -2000   4000  2050   4122  -4121
3523  2 -1.10445  -2063   2065  -2000   4000  2050   4121  -4120
3524  2 -1.10445  -2063   2065  -2000   4000  2050   4120   4045
3525  2 -1.10445  -2063   2065  -2000   4000  2050  -4045   4070
3526  2 -1.10445  -2063   2065  -2000   4000  2050  -4070   4095
3527  2 -1.10445  -2063   2065  -2000   4000  2050  -4095   5370
3528  2 -1.10445  -2063   2065  -2000   4000  2050  -5370   5375  -4205
3529  2 -1.10445  -2063   2065  -2000   4000  2050  -5375  -4020
3530  2 -1.10445  -2063   2065  -2000   4000  2050   4020  -4045
3531  2 -1.10445  -2063   2065  -2000   4000  2050   4045  -4070
3532  2 -1.10445  -2063   2065  -2000   4000  2050   4070  -4125
3533  2 -1.10445  -2063   2065  -2000   4000  2050   4125  -4124
3534  2 -1.10445  -2063   2065  -2000   4000  2050   4124  -4123
c
c              D2O regions around blister tank
3180  2 -1.10445  -2065   2070  -2000   2020
3190  2 -1.10445  -2070  -2055   2033   (2075:2030)
3200  2 -1.10445  -2070  -2035  -2033   2020  (2075:2030)
c
c      D2O bubble volume
c
3210  2 -1.10445    2065  -2045
3220  2 -1.10445   -2065   2070  -2015
3230  2 -1.10445   -2070  -2035  -2010
c
c      Graphite with Beam Tubes
c
4400  4  -1.75     -3075   1120    3002  -3010       4123  -4122
4401  4  -1.75     -3075   1120  -3005 3002   -3010 4122  -4121
4402  4  -1.75     -3075   1120  -3005 3002   -3010 4121  -4120
4403  4  -1.75     -3075   1120  -3005 3002   -3010 4120   4045   3131
4404  4  -1.75     -3075   1120  -3005 3002        -4045   4070
4405  4  -1.75     -3075   1120  -3005 3002        -4070   4095
4406  4  -1.75     -3075   1120  -3005 3002        -4095   5370
4407  4  -1.75     -3075   1120  -3005 3002        -5370   5375
4408  4  -1.75     -3075   1120  -3005 3002        -5375  -4020
4409  4  -1.75     -3075   1120  -3005 3002         4020  -4045
4410  4  -1.75     -3075   1120  -3005 3002         4045  -4070
4411  4  -1.75     -3075   1120  -3005 3002         4070  -4125   3126
4412  4  -1.75     -3075   1120  -3005 3002   -3010 4125  -4124
4413  4  -1.75     -3075   1120  -3005 3002   -3010 4124  -4123
c
4420  4  -1.75     -1120   1121    3002  -3010       4123  -4122
4421  4  -1.75     -1120   1121  -3005 3002   -3010 4122  -4121
4422  4  -1.75     -1120   1121  -3005 3002   -3010 4121  -4120
4423  4  -1.75     -1120   1121  -3005 3002   -3010 4120   4045
4424  4  -1.75     -1120   1121  -3005 3002        -4045   4070
4425  4  -1.75     -1120   1121  -3005 3002        -4070   4095
```

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4427  4  -1.75     -1120   1121  -3005 3002        -5370   5375
4428  4  -1.75     -1120   1121  -3005 3002        -5375  -4020
4429  4  -1.75     -1120   1121  -3005 3002         4020  -4045
4430  4  -1.75     -1120   1121  -3005 3002         4045  -4070
4431  4  -1.75     -1120   1121  -3005 3002         4070  -4125
4432  4  -1.75     -1120   1121  -3005 3002  -3010 4125  -4124
4433  4  -1.75     -1120   1121  -3005 3002  -3010 4124  -4123
c
4500  4  -1.75     -1121   3085   3002  -3010       4123  -4122
4501  4  -1.75     -1121   3084  -3005 3002  -3010 4122  -4121
4502  4  -1.75     -1121   3084  -3005 3002  -3010 4121  -4120
4503  4  -1.75     -1121   3084  -3005 3002  -3010 4120   4045   3131
4504  4  -1.75     -1121   3084  -3005 3002        -4045   4070
4505  4  -1.75     -1121   3084  -3005 3002        -4070   4095
4506  4  -1.75     -1121   3084  -3005 3002        -4095   5370
4507  4  -1.75     -1121   3084  -3005 3002        -5370   5375
4508  4  -1.75     -1121   3084  -3005 3002        -5375  -4020
4509  4  -1.75     -1121   3084  -3005 3002         4020  -4045
4510  4  -1.75     -1121   3084  -3005 3002         4045  -4070
4511  4  -1.75     -1121   3084  -3005 3002         4070  -4125   3126
4512  4  -1.75     -1121   3084  -3005 3002  -3010 4125  -4124
4513  4  -1.75     -1121   3084  -3005 3002  -3010 4124  -4123
4514  4  -1.75     -3085   3084   3002  -3010       4123  -3088
4515  4  -1.75     -3085   3084   3002  -3010       3087  -4122
c
4520  4  -1.75     -3084   1135   3002  -3010       3087  -4122
4521  4  -1.75     -3084   1135  -3005 3002  -3010 4122  -4121
4522  4  -1.75     -3084   1135  -3005 3002  -3010 4121  -4120
4523  4  -1.75     -3084   1135  -3005 3002  -3010 4120   4045   3101 3131
4524  4  -1.75     -3084   1135  -3005 3002        -4045   4070   3106
4525  4  -1.75     -3084   1135  -3005 3002        -4070   4095   3111
4526  4  -1.75     -3084   1135  -3005 3002        -4095   5370   3116 3141
4527  4  -1.75     -3084   1135  -3005 3002        -5370   5375   3081
4528  4  -1.75     -3084   1135  -3005 3002        -5375  -4020   3146 3096
4529  4  -1.75     -3084   1135  -3005 3002         4020  -4045   3101
4530  4  -1.75     -3084   1135  -3005 3002         4045  -4070   3106
4531  4  -1.75     -3084   1135  -3005 3002         4070  -4125   3111 3126
4532  4  -1.75     -3084   1135  -3005 3002  -3010 4125  -4124
4533  4  -1.75     -3084   1135  -3005 3002  -3010 4124  -4123
4534  4  -1.75     -3084   1135   3002  -3010       4123  -3088
c
4540  4  -1.75     -1135   1136   3002  -3010       3087  -4122
4541  4  -1.75     -1135   1136  -3005 3002  -3010 4122  -4121
4542  4  -1.75     -1135   1136  -3005 3002  -3010 4121  -4120
4543  4  -1.75     -1135   1136  -3005 3002  -3010 4120   4045   3101 3131
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4545  4  -1.75     -1135   1136  -3005 3002        -4070   4095   3111
4546  4  -1.75     -1135   1136  -3005 3002        -4095   5370   3116 3141
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4548  4  -1.75     -1135   1136  -3005 3002        -5375  -4020   3146 3096
4549  4  -1.75     -1135   1136  -3005 3002         4020  -4045   3101
4550  4  -1.75     -1135   1136  -3005 3002         4045  -4070   3106
4551  4  -1.75     -1135   1136  -3005 3002         4070  -4125   3111 3126
4552  4  -1.75     -1135   1136  -3005 3002  -3010 4125  -4124
4553  4  -1.75     -1135   1136  -3005 3002  -3010 4124  -4123
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c
4560  4  -1.75     -1136   3086   3002  -3010       3087  -4122
4561  4  -1.75     -1136   3086  -3005 3002  -3010 4122  -4121
4562  4  -1.75     -1136   3086  -3005 3002  -3010 4121  -4120
4563  4  -1.75     -1136   3086  -3005 3002  -3010 4120   4045    $ 3101 3131
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```

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4571  4  -1.75     -1136    3086  -3005 3002         4070  -4125    $ 3111 3126
4572  4  -1.75     -1136    3086  -3005 3002  -3010 4125  -4124
4573  4  -1.75     -1136    3086  -3005 3002  -3010 4124  -4123
4574  4  -1.75     -1136    3086   3002  -3010       4123  -3088
4575  4  -1.75     -3082    3086   3002  -3010       3088  -3087 4205
c
4580  4  -1.75     -3086    2063   3002  -3010       4123  -4122
4581  4  -1.75     -3086    2063  -3005 3002  -3010 4122  -4121 4110
4582  4  -1.75     -3086    2063  -3005 3002  -3010 4121  -4120 4110
4583  4  -1.75     -3086    2063  -3005 3002  -3010 4120   4045 4110
4584  4  -1.75     -3086    2063  -3005 3002        -4045   4070
4585  4  -1.75     -3086    2063  -3005 3002        -4070   4095
4586  4  -1.75     -3086    2063  -3005 3002        -4095   5370
4587  4  -1.75     -3086    2063  -3005 3002        -5370   5375
4588  4  -1.75     -3086    2063  -3005 3002        -5375  -4020
4589  4  -1.75     -3086    2063  -3005 3002         4020  -4045
4590  4  -1.75     -3086    2063  -3005 3002         4045  -4070
4591  4  -1.75     -3086    2063  -3005 3002         4070  -4125 4110
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c
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4448  4  -1.75     -2063    2065  -3005 3002        -5375  -4020
4449  4  -1.75     -2063    2065  -3005 3002         4020  -4045
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4453  4  -1.75     -2063    2065  -3005 3002  -3010 4124  -4123 4110
c
4460  4  -1.75     -2065    2066   3002  -3010       4123  -4122
4461  4  -1.75     -2065    2066  -3005 3002  -3010 4122  -4121
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4463  4  -1.75     -2065    2066  -3005 3002  -3010 4120   4045
4464  4  -1.75     -2065    2066  -3005 3002        -4045   4070
4465  4  -1.75     -2065    2066  -3005 3002        -4070   4095
4466  4  -1.75     -2065    2066  -3005 3002        -4095   5370
4467  4  -1.75     -2065    2066  -3005 3002        -5370   5375
4468  4  -1.75     -2065    2066  -3005 3002        -5375  -4020
4469  4  -1.75     -2065    2066  -3005 3002         4020  -4045
4470  4  -1.75     -2065    2066  -3005 3002         4045  -4070
4471  4  -1.75     -2065    2066  -3005 3002         4070  -4125
4472  4  -1.75     -2065    2066  -3005 3002  -3010 4125  -4124
4473  4  -1.75     -2065    2066  -3005 3002  -3010 4124  -4123
c
4480  4  -1.75     -2066    3020   3002  -3010       4123  -4122
4481  4  -1.75     -2066    3020  -3005 3002  -3010 4122  -4121 4115
4482  4  -1.75     -2066    3020  -3005 3002  -3010 4121  -4120 4115
4483  4  -1.75     -2066    3020  -3005 3002  -3010 4120   4045 4115
4484  4  -1.75     -2066    3020  -3005 3002        -4045   4070
4485  4  -1.75     -2066    3020  -3005 3002        -4070   4095
4486  4  -1.75     -2066    3020  -3005 3002        -4095   5370
4487  4  -1.75     -2066    3020  -3005 3002        -5370   5375
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c
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c
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5393  4  -1.75     -3017   3015  -3005 3002  -3010 4124  -4123
c
4700  5 -1.575     -3075   1120  3000 -3002         4123  -4122
4701  5 -1.575     -3075   1120  3000 -3002         4122  -4121
4702  5 -1.575     -3075   1120  3000 -3002         4121  -4120
4703  5 -1.575     -3075   1120  3000 -3002         4120   4045    3131
4704  5 -1.575     -3075   1120  3000 -3002        -4045   4070
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4707  5 -1.575     -3075   1120  3000 -3002        -5370   5375
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4712  5 -1.575     -3075   1120  3000 -3002         4125  -4124
4713  5 -1.575     -3075   1120  3000 -3002         4124  -4123
c
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4721  5 -1.575     -1120   1121  3000 -3002         4122  -4121
4722  5 -1.575     -1120   1121  3000 -3002         4121  -4120
4723  5 -1.575     -1120   1121  3000 -3002         4120   4045
4724  5 -1.575     -1120   1121  3000 -3002        -4045   4070
4725  5 -1.575     -1120   1121  3000 -3002        -4070   4095
4726  5 -1.575     -1120   1121  3000 -3002        -4095   5370
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4728  5 -1.575     -1120   1121  3000 -3002        -5375  -4020
4729  5 -1.575     -1120   1121  3000 -3002         4020  -4045
4730  5 -1.575     -1120   1121  3000 -3002         4045  -4070
4731  5 -1.575     -1120   1121  3000 -3002         4070  -4125
```

```
4732  5 -1.575     -1120   1121  3000 -3002        4125  -4124
4733  5 -1.575     -1120   1121  3000 -3002        4124  -4123
c
4600  5 -1.575     -1121   3085  3000 -3002        4123  -4122
4601  5 -1.575     -1121   3084  3000 -3002        4122  -4121
4602  5 -1.575     -1121   3084  3000 -3002        4121  -4120
4603  5 -1.575     -1121   3084  3000 -3002        4120   4045   3131
4604  5 -1.575     -1121   3084  3000 -3002       -4045   4070
4605  5 -1.575     -1121   3084  3000 -3002       -4070   4095
4606  5 -1.575     -1121   3084  3000 -3002       -4095   5370
4607  5 -1.575     -1121   3084  3000 -3002       -5370   5375
4608  5 -1.575     -1121   3084  3000 -3002       -5375  -4020
4609  5 -1.575     -1121   3084  3000 -3002        4020  -4045
4610  5 -1.575     -1121   3084  3000 -3002        4045  -4070
4611  5 -1.575     -1121   3084  3000 -3002        4070  -4125   3126
4612  5 -1.575     -1121   3084  3000 -3002        4125  -4124
4613  5 -1.575     -1121   3084  3000 -3002        4124  -4123
4614  5 -1.575     -3085   3084  3000 -3002        4123  -3088
4615  5 -1.575     -3085   3084  3000 -3002        3087  -4122
c
4620  5 -1.575     -3084   1135  3000 -3002        3087  -4122
4621  5 -1.575     -3084   1135  3000 -3002        4122  -4121
4622  5 -1.575     -3084   1135  3000 -3002        4121  -4120
4623  5 -1.575     -3084   1135  3000 -3002        4120   4045   3101 3131
4624  5 -1.575     -3084   1135  3000 -3002       -4045   4070   3106
4625  5 -1.575     -3084   1135  3000 -3002       -4070   4095   3111
4626  5 -1.575     -3084   1135  3000 -3002       -4095   5370   3116 3141
4627  5 -1.575     -3084   1135  3000 -3002       -5370   5375   3081
4628  5 -1.575     -3084   1135  3000 -3002       -5375  -4020   3146 3096
4629  5 -1.575     -3084   1135  3000 -3002        4020  -4045   3101
4630  5 -1.575     -3084   1135  3000 -3002        4045  -4070   3106
4631  5 -1.575     -3084   1135  3000 -3002        4070  -4125   3111 3126
4632  5 -1.575     -3084   1135  3000 -3002        4125  -4124
4633  5 -1.575     -3084   1135  3000 -3002        4124  -4123
4634  5 -1.575     -3084   1135  3000 -3002        4123  -3088
c
4640  5 -1.575     -1135   1136  3000 -3002        3087  -4122
4641  5 -1.575     -1135   1136  3000 -3002        4122  -4121
4642  5 -1.575     -1135   1136  3000 -3002        4121  -4120
4643  5 -1.575     -1135   1136  3000 -3002        4120   4045   3101 3131
4644  5 -1.575     -1135   1136  3000 -3002       -4045   4070   3106
4645  5 -1.575     -1135   1136  3000 -3002       -4070   4095   3111
4646  5 -1.575     -1135   1136  3000 -3002       -4095   5370   3116 3141
4647  5 -1.575     -1135   1136  3000 -3002       -5370   5375   3081
4648  5 -1.575     -1135   1136  3000 -3002       -5375  -4020   3146 3096
4649  5 -1.575     -1135   1136  3000 -3002        4020  -4045   3101
4650  5 -1.575     -1135   1136  3000 -3002        4045  -4070   3106
4651  5 -1.575     -1135   1136  3000 -3002        4070  -4125   3111 3126
4652  5 -1.575     -1135   1136  3000 -3002        4125  -4124
4653  5 -1.575     -1135   1136  3000 -3002        4124  -4123
4654  5 -1.575     -1135   1136  3000 -3002        4123  -3088
c
4660  5 -1.575     -1136   3086  3000 -3002        3087  -4122
4661  5 -1.575     -1136   3086  3000 -3002        4122  -4121
4662  5 -1.575     -1136   3086  3000 -3002        4121  -4120
4663  5 -1.575     -1136   3086  3000 -3002        4120   4045    $ 3101 3131
4664  5 -1.575     -1136   3086  3000 -3002       -4045   4070   3106
4665  5 -1.575     -1136   3086  3000 -3002       -4070   4095    $ 3111
4666  5 -1.575     -1136   3086  3000 -3002       -4095   5370   3116  $ 3141
4667  5 -1.575     -1136   3086  3000 -3002       -5370   5375   3081
4668  5 -1.575     -1136   3086  3000 -3002       -5375  -4020   3096  $ 3146
4669  5 -1.575     -1136   3086  3000 -3002        4020  -4045    $ 3101
4670  5 -1.575     -1136   3086  3000 -3002        4045  -4070   3106
4671  5 -1.575     -1136   3086  3000 -3002        4070  -4125    $ 3111 3126
```

```
4672  5 -1.575     -1136   3086  3000 -3002      4125  -4124
4673  5 -1.575     -1136   3086  3000 -3002      4124  -4123
4674  5 -1.575     -1136   3086  3000 -3002      4123  -3088
4675  5 -1.575     -3082   3086  3000 -3002      3088  -3087 4205
c
4680  5 -1.575     -3086   2063  3000 -3002      4123  -4122 4110
4681  5 -1.575     -3086   2063  3000 -3002      4122  -4121 4110
4682  5 -1.575     -3086   2063  3000 -3002      4121  -4120 4110
4683  5 -1.575     -3086   2063  3000 -3002      4120   4045
4684  5 -1.575     -3086   2063  3000 -3002     -4045   4070
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4690  5 -1.575     -3086   2063  3000 -3002      4045  -4070
4691  5 -1.575     -3086   2063  3000 -3002      4070  -4125
4692  5 -1.575     -3086   2063  3000 -3002      4125  -4124 4110
4693  5 -1.575     -3086   2063  3000 -3002      4124  -4123 4110
c
4740  5 -1.575     -2063   2065  3000 -3002      4123  -4122 4110
4741  5 -1.575     -2063   2065  3000 -3002      4122  -4121 4110
4742  5 -1.575     -2063   2065  3000 -3002      4121  -4120 4110
4743  5 -1.575     -2063   2065  3000 -3002      4120   4045
4744  5 -1.575     -2063   2065  3000 -3002     -4045   4070
4745  5 -1.575     -2063   2065  3000 -3002     -4070   4095
4746  5 -1.575     -2063   2065  3000 -3002     -4095   5370
4747  5 -1.575     -2063   2065  3000 -3002     -5370   5375
4748  5 -1.575     -2063   2065  3000 -3002     -5375  -4020
4749  5 -1.575     -2063   2065  3000 -3002      4020  -4045
4750  5 -1.575     -2063   2065  3000 -3002      4045  -4070
4751  5 -1.575     -2063   2065  3000 -3002      4070  -4125
4752  5 -1.575     -2063   2065  3000 -3002      4125  -4124 4110
4753  5 -1.575     -2063   2065  3000 -3002      4124  -4123 4110
c
4760  5 -1.575     -2065   2066  3000 -3002      4123  -4122
4761  5 -1.575     -2065   2066  3000 -3002      4122  -4121
4762  5 -1.575     -2065   2066  3000 -3002      4121  -4120
4763  5 -1.575     -2065   2066  3000 -3002      4120   4045
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4766  5 -1.575     -2065   2066  3000 -3002     -4095   5370
4767  5 -1.575     -2065   2066  3000 -3002     -5370   5375
4768  5 -1.575     -2065   2066  3000 -3002     -5375  -4020
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4770  5 -1.575     -2065   2066  3000 -3002      4045  -4070
4771  5 -1.575     -2065   2066  3000 -3002      4070  -4125
4772  5 -1.575     -2065   2066  3000 -3002      4125  -4124
4773  5 -1.575     -2065   2066  3000 -3002      4124  -4123
c
5301  5 -1.575     -2066   3020  3000 -3002      4123  -4122 4115
5302  5 -1.575     -2066   3020  3000 -3002      4122  -4121 4115
5303  5 -1.575     -2066   3020  3000 -3002      4121  -4120 4115
5304  5 -1.575     -2066   3020  3000 -3002      4120   4045
5305  5 -1.575     -2066   3020  3000 -3002     -4045   4070
5306  5 -1.575     -2066   3020  3000 -3002     -4070   4095
5307  5 -1.575     -2066   3020  3000 -3002     -4095   5370
5308  5 -1.575     -2066   3020  3000 -3002     -5370   5375
5309  5 -1.575     -2066   3020  3000 -3002     -5375  -4020
5310  5 -1.575     -2066   3020  3000 -3002      4020  -4045
5311  5 -1.575     -2066   3020  3000 -3002      4045  -4070
5312  5 -1.575     -2066   3020  3000 -3002      4070  -4125
5313  5 -1.575     -2066   3020  3000 -3002      4125  -4124 4115
5314  5 -1.575     -2066   3020  3000 -3002      4124  -4123 4115
```

```
c
5320  5 -1.575     -3020   3017  3000 -3002        4123   -4122 4115
5321  5 -1.575     -3020   3017  3000 -3002        4122   -4121 4115
5322  5 -1.575     -3020   3017  3000 -3002        4121   -4120
5323  5 -1.575     -3020   3017  3000 -3002        4120    4045
5324  5 -1.575     -3020   3017  3000 -3002       -4045    4070
5325  5 -1.575     -3020   3017  3000 -3002       -4070    4095
5326  5 -1.575     -3020   3017  3000 -3002       -4095    5370
5327  5 -1.575     -3020   3017  3000 -3002       -5370    5375
5328  5 -1.575     -3020   3017  3000 -3002       -5375   -4020
5329  5 -1.575     -3020   3017  3000 -3002        4020   -4045
5330  5 -1.575     -3020   3017  3000 -3002        4045   -4070
5331  5 -1.575     -3020   3017  3000 -3002        4070   -4125
5332  5 -1.575     -3020   3017  3000 -3002        4125   -4124
5333  5 -1.575     -3020   3017  3000 -3002        4124   -4123 4115
c
5340  5 -1.575     -3017   3015  3000 -3002        4123   -4122
5341  5 -1.575     -3017   3015  3000 -3002        4122   -4121
5342  5 -1.575     -3017   3015  3000 -3002        4121   -4120
5343  5 -1.575     -3017   3015  3000 -3002        4120    4045
5344  5 -1.575     -3017   3015  3000 -3002       -4045    4070
5345  5 -1.575     -3017   3015  3000 -3002       -4070    4095
5346  5 -1.575     -3017   3015  3000 -3002       -4095    5370
5347  5 -1.575     -3017   3015  3000 -3002       -5370    5375
5348  5 -1.575     -3017   3015  3000 -3002       -5375   -4020
5349  5 -1.575     -3017   3015  3000 -3002        4020   -4045
5350  5 -1.575     -3017   3015  3000 -3002        4045   -4070
5351  5 -1.575     -3017   3015  3000 -3002        4070   -4125
5352  5 -1.575     -3017   3015  3000 -3002        4125   -4124
5353  5 -1.575     -3017   3015  3000 -3002        4124   -4123
c
c     4917  4  -1.75      -3020   3015  -3005   3002  -3010       4205
c     4918  4  -1.75      -3020   3015  -3005   3002  -3010      -4205
c     4919  5  -1.575     -3020   3015  -3002   3000              4205
c     4924  5  -1.575     -3020   3015  -3002   3000  -3010      -4205
4921  3  -17.8-5   -3020   3017  -3000   3030   3025 -2065 2030
c
c     Graphite surrounding the h2o tank
c
4150  4  -1.75     -3017   3015  -3000   3030   3174
4152  4  -1.75     -3017   3015  -3000   2030  -3176
4154  4  -1.75     -3017   3015  -3000   3030   2030
                    3170  -3174   3176
4156  3  -17.8-5   -3017   3015   3030   2030  -3170
                    3172  -3174   3176
4158  4  -1.75     -3017   3015  -3000   3030   2030
                   -3172  -3174   3176
c
c     12 SH 1
c
4015  6  6.0034-2  -4205  -3001   3000  -3080
4016  3 -17.8-5    -4205  -3005   3001  -3080
4017  6  6.0034-2  -4205  -3005   3000   3080  -3081
c
c     6 SH 2
c
4025  6  6.0034-2  -4200  -3001   3000  -3095
4026  3 -17.8-5    -4200   3097   3001  -3095
4027  3 -17.8-5           -3097   3098  -3095
4028  3 -17.8-5    -4200  -3005  -3098  -3095
4029  6  6.0034-2  -4200  -3005   3000   3095  -3096
c
c     4 DH 2
c
```

```
4030  6  6.0034-2  -4200  -3001   3000  -3100
4031  3 -17.8-5    -4200   3102   3001  -3100
4032  3 -17.8-5           -3102   3103  -3100
4033  3 -17.8-5    -4200  -3005  -3103  -3100
4034  6  6.0034-2  -4200  -3005   3000   3100  -3101
c
c     6 SH 1
c
4035  6  6.0034-2  -4200  -3001   3000  -3105
4036  3 -17.8-5    -4200   3107   3001  -3105
4037  3 -17.8-5           -3107   3108  -3105
4038  3 -17.8-5    -4200  -3005  -3108  -3105
4039  6  6.0034-2  -4200  -3005   3000   3105  -3106
c
c     4 DH 1
c
4040  6  6.0034-2  -4200  -3001   3000  -3110
4041  3 -17.8-5    -4200   3112   3001  -3110
4042  3 -17.8-5           -3112   3113  -3110
4043  3 -17.8-5    -4200  -3005  -3113  -3110
4044  6  6.0034-2  -4200  -3005   3000   3110  -3111
c
c     6 RH 1
c
4045  6  6.0034-2  -4200  -3001   3000  -3125
4046  3 -17.8-5    -4200  -3005   3001  -3125
4047  6  6.0034-2  -4200  -3005   3000   3125  -3126
c
c     Thermal Column Reentrant Thimble (14 inch window)
c
4348  3 -17.8-5    4205 -3004 3000 3082 -3085 3088 -3087 -4200
4349  3 -17.8-5    4205 -3004 3000 3082 -3085 3088 -3087  4200
4049  6  6.0034-2  4205 -3003 3004 3082 -3085 3088 -3087
4350  3 -17.8-5    4205 -3011 3002 1135 -3089 3092 -3091
4351  3 -17.8-5    4205 -3011 3002 1136 -1135 3092 -3091
4352  3 -17.8-5    4205 -3011 3002 3090 -1136 3092 -3091
4353  3 -17.8-5    4205 -3002 3003 1135 -3089 3092 -3091
4354  3 -17.8-5    4205 -3002 3003 1136 -1135 3092 -3091
4355  3 -17.8-5    4205 -3002 3003 3090 -1136 3092 -3091
4356  3 -17.8-5    4205 -3010 3011 3090 -3089 3092 -3091
4050  6  6.0034-2  4205 -3010 3002 3090 -3089 3091 -3087
4051  6  6.0034-2  4205 -3002 3003 3090 -3089 3091 -3087
4052  6  6.0034-2  4205 -3010 3003 3090 -3089 3088 -3092
4053  6  6.0034-2  4205 -3010 3003 3088 -3087 3089 -3085
4054  6  6.0034-2  4205 -3010 3003 3088 -3087 3082 -3090
c
c     4 DH 6
c
4055  6  6.0034-2   4200  -3001   3000  -3100
4056  3 -17.8-5     4200  -3005   3001  -3100
4057  6  6.0034-2   4200  -3005   3000   3100  -3101
c
c     6 SH 4
c
4060  6  6.0034-2   4200  -3001   3000  -3105
4061  3 -17.8-5     4200  -3005   3001  -3105
4062  6  6.0034-2   4200  -3005   3000   3105  -3106
c
c     4 DH 5
c
4065  6  6.0034-2   4200  -3001   3000  -3110
4066  3 -17.8-5     4200  -3005   3001  -3110
4067  6  6.0034-2   4200  -3005   3000   3110  -3111
c
```

```
c       6 SH 3
c
4068  6  6.0034-2   4200  -3001   3000  -3115
4069  3 -17.8-5     4200  -3005   3001  -3115
4070  6  6.0034-2   4200  -3005   3000   3115  -3116
c
c       6 RH 2
c
4071  6  6.0034-2   4200  -3001   3000  -3130
4072  3 -17.8-5     4200  -4440   3001  -3130
4172  3 -17.8-5           -4445   4440  -3130
4173  3 -17.8-5     4200  -3005   4445  -3130
4073  6  6.0034-2   4200  -3005   3000   3130  -3131
c
c       4 DH 4
c
4074  6  6.0034-2   4200  -3001   3000  -3140
4075  3 -17.8-5     4200  -3005   3001  -3140
4076  6  6.0034-2   4200  -3005   3000   3140  -3141
c
c       4 DH 3
c
4077  6  6.0034-2  -4200  -3001   3000  -3145
4078  3 -17.8-5    -4200  -3005   3001  -3145
4079  6  6.0034-2  -4200  -3005   3000   3145  -3146
c
c       H2O tank
c
4080  6 6.0034-2   -3065   3015  -3035   3040
4085  6 6.0034-2    3065   3070  -3055   3060
4090  6 6.0034-2   -3070  -3045   3050
c
c       H2O fill
c
4100  1 -0.99678   -3065   3015  -3040
4105  1 -0.99678    3065   3070  -3060
4110  1 -0.99678    3065  -3070  -3050
c
c       Helium gap
c
4200  3 -17.8-5    -3075   2070  -3000   2005  4200
4201  3 -17.8-5    -3075   2070  -3000   2005 -4200
4205  3 -17.8-5    -2070   2033   2060  -3000  -3025   2030
4210  3 -17.8-5    -2033  -3000  -3025   2040   2030  -2065
4215  3 -17.8-5    -3000   3025   3020   2030  -2065
4220  3 -17.8-5    -3065   3015  -3030   3035
4225  3 -17.8-5     3065   3070  -3030   3055
4230  3 -17.8-5    -3070  -3030   3045   3025 3015 -2065
c
c       Beam Tubes
c
c       6 SH 2
c
5000  3 -17.8-5    -4010   4005  -4020  -4200   4012
5001  3 -17.8-5    -4010  -4200  -4012   4013   4011
5002  3 -17.8-5    -4010  -2005  -4200  -4013
5003  3 -17.8-5    -4011  -4012   4013
5005  6 6.0034-2   -4015   4010  -2005   4005  -4020  -4200
5010  6 6.0034-2   -4015  -4005   4000  -4020  -4200
c
c       4 DH 2
c
5015  3 -17.8-5    -4025   4005  -4045   4020  -4200   4027
5016  3 -17.8-5    -4025  -4200  -4027   4028   4026
```

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5017  3 -17.8-5    -4025  -2005  -4200  -4028
5018  3 -17.8-5    -4026  -4027   4028
5020  6 6.0034-2   -4030   4025   4005  -2005  -4045   4020
5025  6 6.0034-2   -4030  -4005   4000  -4045   4020  -4200
c
c     6 SH 1
c
5030  3 -17.8-5    -4050   4005  -4070   4045  -4200  4052
5031  3 -17.8-5    -4050  -4200  -4052   4053   4051
5032  3 -17.8-5    -4050  -2005  -4200  -4053
5033  3 -17.8-5    -4051  -4052   4053
5035  6 6.0034-2   -4055   4050   4005  -2005  -4070   4045  -4200
5040  6 6.0034-2   -4055  -4005   4000  -4070   4045  -4200
c
c     4 DH 1
c
5045  3 -17.8-5    -4075   4005   4070  -4200   4077
5046  3 -17.8-5    -4075  -4200  -4077   4078   4076
5047  3 -17.8-5    -4075  -2005  -4200  -4078
5048  3 -17.8-5    -4076  -4077   4078
5050  6 6.0034-2   -4080   4075   4005  -2005   4070  -4200
5055  6 6.0034-2   -4080  -4005   4000   4070  -4200
c
c     4 DH 6
c
5060  3 -17.8-5    -4035   4005  -2005   4045   4200
5065  6 6.0034-2   -4040   4035   4005  -2005   4045   4200
5070  6 6.0034-2   -4040  -4005   4000   4045   4200
c
c     6 SH 4
c
5075  3 -17.8-5    -4060   4005  -2005  -4045   4070   4200
5080  6 6.0034-2   -4065   4060   4005  -2005  -4045   4070   4200
5085  6 6.0034-2   -4065  -4005   4000  -4045   4070   4200
c
c     4 DH 5
c
5090  3 -17.8-5    -4085   4005  -2005  -4070   4095   4200
5095  6 6.0034-2   -4090   4085   4005  -2005  -4070   4095   4200
5100  6 6.0034-2   -4090  -4005   4000  -4070   4095   4200
c
c     6 SH 3
c
5105  3 -17.8-5    -4100   4005  -2005  -4095   4200
5110  6 6.0034-2   -4105   4100   4005  -2005  -4095   4200
5115  6 6.0034-2   -4105  -4005   4000  -4095   4200
c
c     4 DH 4 and 12 SH 1 and 4 DH 3
c
5120  6 6.0034-2   -2005  -5330   5335  -5370   5410 -5390
5122  6 6.0034-2   -2005  -5350   5355   5370  -5390 5410
5124  6 6.0034-2   -5380   5390  -5350   5410  -5330
5126  6 6.0034-2   -5410   5400  -5330  -5350  -5380
c
c     4 DH 4 and 12 SH 1 and 4 DH 3
c
5130  6 6.0034-2   -2005  -5340   5345   5375  -5415   5395
5132  6 6.0034-2   -2005  -5360   5365  -5375   5395  -5415
5134  6 6.0034-2    5385  -5395  -5360  -5415  -5340
5136  6 6.0034-2    5415  -5405  -5340  -5360   5385
c
c     4 DH 4 and 12 SH 1 and 4 DH 3
c
5150  3 -17.8-5    -2005  -5335  -5370   5410  -5390
```

```
5152  3 -17.8-5    -2005  -5355   5370  -5390
5154  3 -17.8-5    -2005  -5345   5375   5395  -5415
5156  3 -17.8-5    -2005  -5365  -5375   5395
c
c     6 RH 1
c
5200  3 -17.8-5    -4400  -4420
5205  3 -17.8-5     4420  -2005  -4380
5210  6 6.0034-2    4420  -2005  -4385   4380
5215  6 6.0034-2   -4420  -4405   4400
c
c     6 RH 2
c
5220  3 -17.8-5    -4425  -4410
5225  3 -17.8-5     4425  -4430  -4390
5226  3 -17.8-5     4425   4430  -4390  -2005
5230  6 6.0034-2    4425  -2005  -4395   4390
5235  6 6.0034-2   -4425  -4415   4410
c
c     4 TH 1 - 3
c
5250  6 6.0034-2    4111  -4110   -3005
5260  3 -17.8-5           -4111   -3005
c
c     4 TH 2 - 4
c
5270  6 6.0034-2    4116  -4115   -3005
5280  3 -17.8-5           -4116   -3005
c
c     -----------------------------------------------------------
c
c      Cell Definitions for flux tally at graphite edge
c
c
c     40050   0   3010  -40500   40330 -40230   40050 -40060
c     40040   0   3010  -40500   40330 -40230   40040 -40050
c     40030   0   3010  -40500   40330 -40230   40030 -40040
c     40020   0   3010  -40500   40330 -40230   40020 -40030
c     40010   0   3010  -40500   40330 -40230   40010 -40020
c     40000   0   3010  -40500   40330 -40230   40000 -40010
c     40100   0   3010  -40500   40330 -40230   40110 -40000
c     40110   0   3010  -40500   40330 -40230   40120 -40110
c     40120   0   3010  -40500   40330 -40230   40130 -40120
c     40130   0   3010  -40500   40330 -40230   40140 -40130
c     40140   0   3010  -40500   40330 -40230   40150 -40140
c     40150   0   3010  -40500   40330 -40230   40160 -40150
c     40160   0   3010  -40500   40330 -40230   40170 -40160
c     40170   0   3010  -40500   40330 -40230   40180 -40170
c     40180   0   3010  -40500   40330 -40230   40190 -40180
c     40190   0   3010  -40500   40330 -40230   40100 -40190
c
c      ** Not tally cells **
c     40300   0   3010  -40500  -40330 -3005    40100 -40060
c     40301   0   3010  -40500   40230 -3005    40100 -40060
c     40310   0   3010  -40500     -3005        40060  -3075
c     40311   0   3010  -40500     -3005         3015 -40100
c
c
c
c     External world
c
c      99999 0  (3075 2005):1105:(3005 -4205):-9181:(-9147 9181 9146 -3005 -
40500):
c              (3005  38101 4205) : (38120  43300) : ( 45300 40500) :
```

```
c               (3005 -38100 4205) : (38120 -43310) : (-45310 40500) :
c               -48095
c          (3010 40230):(3010 -40330):(3010 40060):(3010 -40100):
c       99999  0  (-3015:3005:3010) -45310
c       99998  0  (42000:(-43310 38120):(43300 38120):(38101 3005 4205):
c                 (-38100 3005 4205):(3005 -4205)) -45300 45310
c       99997  0  1105:(2005 3075):((3005:3010) 45300)
c
99999  0   3005 :3010:-3015:1105:(2005 3075)
c
c       99999  0 (42000:(-43310 38120):(43300 38120):(38101 3005 4205):
c          (-38100 3005 4205):(3005 -4205)):-3015:1105:(2005 3075):
c          ((3005:3010) 45300):((3005:3010) -45310)
c
c     Geometry Debugging
c       add these cards and remove previous cell 99999
c
c     99998 0  ((3075 2005):1105:3005:3010:-3015) -9999
c     99999 0  9999
c
c      BLANK LINE

c      BLANK LINE
c
c      SURFACE SPECIFICATIONS
c
c      Surface numbers currently being used
c              0-399
c              500-5999
c              9000-9999
c              50000-99999
c      Not all of these are used but they are reserved for further development
c      Any item added (incore experiment) should use a separate sequence
c      corresponding to the cell numbers chosen.
c
c      Fuel plate descriptions
c
65      pz                  33.33755        $ Top of element
79      pz                  29.21           $ Top of 23 in plate
80      pz                  28.41625        $ Top of fuel
81      pz                  23.17755        $ Bottom of 4 in sstl insert
82      pz                  2.0638          $ Bottom of insert 12 5/16 in
83      pz                 -9.84245         $ Bottom of 2 inch ICSA
85      pz                 -28.41625        $ Bottom of fuel
86      pz                 -29.21           $ Bottom of 23 in plate
100     pz                 -33.33755        $ Bottom of element
101     cz                  2.667           $ IR of upper ICSA
102     cz                  1.5875          $ IR of lower ICSA
103     cz                  1.42875         $ IR of sample assembly
104     pz                 -9.52495         $ Bottom of ICSA sample assem
105     pz                 -9.6837          $ Bottom of ICSA sample assem
c
c      Fuel element 1 surfaces
c
c              y
c             /|\
c          |\  |
c          | \|
c          |   \
c          |   |\
c          |   | \
c          |   ---\---> x
c           \       |
c            \      |
```

```
c                \   |
c                 \  |
c                  \ |
c                   \|
c
51121   p   0.57735  1  0  2.09763  $ For depleted 3 region model
51157   p   0.57735  1  0  -2.09763  $ For depleted 3 region model
c
51001    p    0.57735    1    0 3.49605
51002    p    0.57735    1    0 3.3465897
51003    p    0.57735    1    0 3.3089977
51004    p    0.57735    1    0 3.2556577
51005    p    0.57735    1    0 3.2180657
51006    p    0.57735    1    0 2.9604335
51007    p    0.57735    1    0 2.9228415
51008    p    0.57735    1    0 2.8695015
51009    p    0.57735    1    0 2.8319095
51010    p    0.57735    1    0 2.5742773
51011    p    0.57735    1    0 2.5366853
51012    p    0.57735    1    0 2.4833453
51013    p    0.57735    1    0 2.4457533
51014    p    0.57735    1    0 2.1881211
51015    p    0.57735    1    0 2.1505291
51016    p    0.57735    1    0 2.0971891
51017    p    0.57735    1    0 2.0595971
51018    p    0.57735    1    0 1.8019649
51019    p    0.57735    1    0 1.7643729
51020    p    0.57735    1    0 1.7110329
51021    p    0.57735    1    0 1.6734409
51022    p    0.57735    1    0 1.4158087
51023    p    0.57735    1    0 1.3782167
51024    p    0.57735    1    0 1.3248767
51025    p    0.57735    1    0 1.2872847
51026    p    0.57735    1    0 1.0296525
51027    p    0.57735    1    0 0.9920605
51028    p    0.57735    1    0 0.9387205
51029    p    0.57735    1    0 0.9011285
51030    p    0.57735    1    0 0.6434963
51031    p    0.57735    1    0 0.6059043
51032    p    0.57735    1    0 0.5525643
51033    p    0.57735    1    0 0.5149723
51034    p    0.57735    1    0 0.2573401
51035    p    0.57735    1    0 0.2197481
51036    p    0.57735    1    0 0.1664081
51037    p    0.57735    1    0 0.1288161
51038    p    0.57735    1    0 -0.1288161
51039    p    0.57735    1    0 -0.1664081
51040    p    0.57735    1    0 -0.2197481
51041    p    0.57735    1    0 -0.2573401
51042    p    0.57735    1    0 -0.5149723
51043    p    0.57735    1    0 -0.5525643
51044    p    0.57735    1    0 -0.6059043
51045    p    0.57735    1    0 -0.6434963
51046    p    0.57735    1    0 -0.9011285
51047    p    0.57735    1    0 -0.9387205
51048    p    0.57735    1    0 -0.9920605
51049    p    0.57735    1    0 -1.0296525
51050    p    0.57735    1    0 -1.2872847
51051    p    0.57735    1    0 -1.3248767
51052    p    0.57735    1    0 -1.3782167
51053    p    0.57735    1    0 -1.4158087
51054    p    0.57735    1    0 -1.6734409
51055    p    0.57735    1    0 -1.7110329
51056    p    0.57735    1    0 -1.7643729
```

```
51057    p    0.57735    1    0 -1.8019649
51058    p    0.57735    1    0 -2.0595971
51059    p    0.57735    1    0 -2.0971891
51060    p    0.57735    1    0 -2.1505291
51061    p    0.57735    1    0 -2.1881211
51062    p    0.57735    1    0 -2.4457533
51063    p    0.57735    1    0 -2.4833453
51064    p    0.57735    1    0 -2.5366853
51065    p    0.57735    1    0 -2.5742773
51066    p    0.57735    1    0 -2.8319095
51067    p    0.57735    1    0 -2.8695015
51068    p    0.57735    1    0 -2.9228415
51069    p    0.57735    1    0 -2.9604335
51070    p    0.57735    1    0 -3.2180657
51071    p    0.57735    1    0 -3.2556577
51072    p    0.57735    1    0 -3.3089977
51073    p    0.57735    1    0 -3.3465897
51074    p    0.57735    1    0 -3.49605
51100   px                  3.02260
51110   px                  2.6090747
51112   px                  2.2616253
51118   px                  -2.2616253
51120   px                  -2.6090747
51130   px                  -3.02260
c
c     Fuel element 2 surfaces
c                               y
c                              /|\
c                               | /|
c                               |/ |
c                               /  |
c                              /|  |
c                             / |  |
c                            /  ---|--> x
c                           |     /
c                           |    /
c                           |   /
c                           |  /
c                           | /
c                           |/
71121   p   -0.57735  1  0  2.09763  $ For depleted 3 region model
71157   p   -0.57735  1  0  -2.09763  $ For depleted 3 region model
c
71009   p   -0.57735  1  0  3.49605
71010   p   -0.57735  1  0  3.347610235
71011   p   -0.57735  1  0  3.287825108
71012   p   -0.57735  1  0  3.199836731
71013   p   -0.57735  1  0  3.140051603
71014   p   -0.57735  1  0  2.884205818
71015   p   -0.57735  1  0  2.824420691
71016   p   -0.57735  1  0  2.736432314
71017   p   -0.57735  1  0  2.676647186
71018   p   -0.57735  1  0  2.420801401
71019   p   -0.57735  1  0  2.361016273
71020   p   -0.57735  1  0  2.273027897
71021   p   -0.57735  1  0  2.213242769
71022   p   -0.57735  1  0  1.957396984
71023   p   -0.57735  1  0  1.897611737
71024   p   -0.57735  1  0  1.809623599
71025   p   -0.57735  1  0  1.749838352
71026   p   -0.57735  1  0  1.493992567
71027   p   -0.57735  1  0  1.434207320
71028   p   -0.57735  1  0  1.346219182
71029   p   -0.57735  1  0  1.286433935
```

```
71030   p    -0.57735  1  0  1.030588031
71031   p    -0.57735  1  0  0.970802844
71032   p    -0.57735  1  0  0.882814705
71033   p    -0.57735  1  0  0.823029518
71034   p    -0.57735  1  0  0.567183673
71035   p    -0.57735  1  0  0.507398486
71036   p    -0.57735  1  0  0.419410318
71037   p    -0.57735  1  0  0.359625131
71038   p    -0.57735  1  0  0.103779286
71039   p    -0.57735  1  0  0.043994091
71040   p    -0.57735  1  0  -0.043994091
71041   p    -0.57735  1  0  -0.103779286
71042   p    -0.57735  1  0  -0.359625131
71043   p    -0.57735  1  0  -0.419410318
71044   p    -0.57735  1  0  -0.507398486
71045   p    -0.57735  1  0  -0.567183673
71046   p    -0.57735  1  0  -0.823029518
71047   p    -0.57735  1  0  -0.882814705
71048   p    -0.57735  1  0  -0.970802844
71049   p    -0.57735  1  0  -1.030588031
71050   p    -0.57735  1  0  -1.286433935
71051   p    -0.57735  1  0  -1.346219182
71052   p    -0.57735  1  0  -1.434207320
71053   p    -0.57735  1  0  -1.493992567
71054   p    -0.57735  1  0  -1.749838352
71055   p    -0.57735  1  0  -1.809623599
71056   p    -0.57735  1  0  -1.897611737
71057   p    -0.57735  1  0  -1.957396984
71058   p    -0.57735  1  0  -2.213242769
71059   p    -0.57735  1  0  -2.273027897
71060   p    -0.57735  1  0  -2.361016273
71061   p    -0.57735  1  0  -2.420801401
71062   p    -0.57735  1  0  -2.676647186
71063   p    -0.57735  1  0  -2.736432314
71064   p    -0.57735  1  0  -2.824420691
71065   p    -0.57735  1  0  -2.884205818
71066   p    -0.57735  1  0  -3.140051603
71067   p    -0.57735  1  0  -3.199836731
71068   p    -0.57735  1  0  -3.287825108
71069   p    -0.57735  1  0  -3.347610235
71070   p    -0.57735  1  0  -3.49605
71100   px                   3.02260
71110   px                   2.6090747
71112   px                   2.2616253
71118   px                   -2.2616253
71120   px                   -2.6090747
71130   px                   -3.02260
c
c       Fuel segmentation
c
201      pz      27.2322396
202      pz      26.0482292
203      pz      24.8642188
204      pz      23.6802084
205      pz      22.496198
206      pz      21.3121876
207      pz      20.1281772
208      pz      18.9441668
209      pz      17.7601564
210      pz      16.576146
211      pz      15.3921356
212      pz      14.2081252
213      pz      13.0241148
214      pz      11.8401044
```

```
215     pz     10.656094
216     pz     9.4720836
217     pz     8.2880732
218     pz     7.1040628
219     pz     5.9200524
220     pz     4.736042
221     pz     3.5520316
222     pz     2.3680212
223     pz     1.1840106
224     pz     0.0
225     pz    -1.1840106
226     pz    -2.3680212
227     pz    -3.5520316
228     pz    -4.736042
229     pz    -5.9200524
230     pz    -7.1040628
231     pz    -8.2880732
232     pz    -9.4720836
233     pz    -10.656094
234     pz    -11.8401044
235     pz    -13.0241148
236     pz    -14.2081252
237     pz    -15.3921356
238     pz    -16.576146
239     pz    -17.7601564
240     pz    -18.9441668
241     pz    -20.1281772
242     pz    -21.3121876
243     pz    -22.496198
244     pz    -23.6802084
245     pz    -24.8642188
246     pz    -26.0482292
247     pz    -27.2322396
c
c      Spider definitions
c
510     py 22.5425
515     py 21.9075
516     py 21.81225     $ Control blade
517     py 21.49475     $ Control blade
518     py 21.36775     $ Control blade
519     py 21.05025     $ Control blade
520     py 20.955
525     py 19.05
530     py 12.90574
535     py 6.75132
536     py 6.43382      $ Insert in hex 535,536
540     py 6.15442
545     py 0.6223
547     py 0.3048       $ Insert 0.125 instead of 0.165 in 545,547
550     py 0.0
555     py -0.6223
560     py -6.15442
561     py -6.43382      $ Insert in hex 0.125 in 561,565
565     py -6.75132
566     py -7.36085      $ Insert
567     py -12.31018     $ Insert width 2.25 in
570     py -12.90574
571     py -13.50304     $ Insert
572     py -18.45237     $ Insert width 2.25 in
575     py -19.05
580     py -20.955
581     py -21.05025     $ Control blade
582     py -21.36775     $ Control blade
```

```
583     py -21.49475    $ Control blade
584     py -21.81225    $ Control blade
585     py -21.9075
590     py -22.5425
c
610    1   py 22.5425
615    1   py 21.9075
616    1   py 21.81225    $ Control blade
617    1   py 21.49475    $ Control blade
618    1   py 21.36775    $ Control blade
619    1   py 21.05025    $ Control blade
620    1   py 20.955
625    1   py 19.05
626    1   py 18.45237    $ Insert width 2.25 in
627    1   py 13.50304    $ Insert
630    1   py 12.90574
631    1   py 12.31018    $ Insert width 2.25 in
632    1   py 7.36085     $ Insert
635    1   py 6.75132
636    1   py 6.43382     $ Insert in hex 0.125 in 635,636
640    1   py 6.15442
645    1   py 0.6223
650    1   py 0.0
652    1   py -0.3048      $ Insert 0.165 in 652,655
655    1   py -0.6223
660    1   py -6.15442
661    1   py -6.43382     $ Insert in hex 661,665
665    1   py -6.75132
670    1   py -12.90574
675    1   py -19.05
680    1   py -20.955
681    1   py -21.05025    $ Control blade
682    1   py -21.36775    $ Control blade
683    1   py -21.49475    $ Control blade
684    1   py -21.81225    $ Control blade
685    1   py -21.9075
690    1   py -22.5425
c
710    2   py 22.5425
715    2   py 21.9075
716    2   py 21.81225    $ Control blade
717    2   py 21.49475    $ Control blade
718    2   py 21.36775    $ Control blade
719    2   py 21.05025    $ Control blade
720    2   py 20.955
725    2   py 19.05
726    2   py 18.45237    $ Insert width 2.25 in
727    2   py 13.50304    $ Insert
730    2   py 12.90574
731    2   py 12.31018    $ Insert width 2.25 in
732    2   py 7.36085     $ Insert
735    2   py 6.75132
736    2   py 6.43382     $ Insert in hex 735,736
740    2   py 6.15442
745    2   py 0.6223
750    2   py 0.0
752    2   py -0.3048      $ Insert 0.165 in 752,755
755    2   py -0.6223
760    2   py -6.15442
761    2   py -6.43382     $ Insert in hex 761,765
765    2   py -6.75132
770    2   py -12.90574
775    2   py -19.05
780    2   py -20.955
```

```
781    2   py -21.05025    $ Control blade
782    2   py -21.36775    $ Control blade
783    2   py -21.49475    $ Control blade
784    2   py -21.81225    $ Control blade
785    2   py -21.9075
790    2   py -22.5425
c
800    px 9.68375
802    px 8.89         $ Control blade
805    px -8.89        $ Control blade
810    px -9.68375
811    px 2.8575       $ Insert in Hex
812    px -2.8575      $ Insert in Hex
c
820    1   px 9.68375
822    1   px 8.89         $ Control blade
825    1   px -8.89        $ Control blade
830    1   px -9.68375
831    1   px 2.8575       $ Insert in Hex
832    1   px -2.8575      $ Insert in Hex
c
840    2   px 9.68375
842    2   px 8.89         $ Control blade
845    2   px -8.89        $ Control blade
850    2   px -9.68375
851    2   px 2.8575       $ Insert in Hex
852    2   px -2.8575      $ Insert in Hex
c
c      Control Blades
c
c      The following definitions will move the control blades as a bank.
c      Simply change the z value to the position of the blades as recorded in
c      the control room. Follow same procedure for the regulating rods.
c
860    3   c/y  0  21.59  8.89
864    4   c/y  0  21.59  8.89
868    5   c/y  0  21.59  8.89
872    3   pz  21.59
874    6   pz  21.59
876    7   pz  21.59
c
c      Regulating Rods
c
890    8   pz  5.0038
892    9   pz  5.0038
894    10  pz  5.0038
896    11  pz  5.0038
c
c      Water holes in the Outer Hex
c
1000   c/z   23.65375  0  1.27
1001   c/z   23.65375  0  1.11125   $ Regulating rod
1002   c/z   23.65375  0  0.98679   $ Regulating rod
1003   c/z   23.65375  0  0.88519   $ Regulating rod
1004   c/z   23.65375  0  0.635     $ Regulating rod
1005   c/z  -23.65375  0  1.27
1010   1  c/z   23.65375  0  1.27
1015   1  c/z  -23.65375  0  1.27
1020   2  c/z   23.65375  0  1.27
1025   2  c/z  -23.65375  0  1.27
c
c      Core tank
c
1050   cz   25.4
```

```
1055   cz   26.035
1060   cz   26.67
1062   cz   34.925
1065   cz   57.070625
1070   cz   58.340625
1075   tz   0  0  -28.10745  16.906875  8.255  9.128125
1080   tz   0  0  -28.10745  16.906875  7.62   8.493125
1085   sz   100.48005  86.36
1090   sz   100.48005  87.9475
1095   sz   -95.41745  61.595
1100   sz   -95.41745  60.96
1105   pz   105
1110   pz   36.98005
1112   pz   32.53505
1113   pz   28.09005
1115   pz    9.67505
1120   pz   9.04005
1121   pz   -7.30495  $ for segementing the graphite and d2o
1125   pz   -28.10745
1130   pz   -35.72745
1135   pz   -36.36245
1136   pz   -48.4      $ for splitting up reflector for weight windows
1140   cz   16.906875
1145   kz   -111.542 0.07179677  +1
1147   pz   -14.208075 $ bottom of flow holes
1150   pz   -16.748075 $ begin 15 degree cut
1153   pz   -27.225575 $ bottom of control blades
1155   pz   37.14755
c
c      Reflector tank
c
2000   cz   60.0075
2005   cz   60.96
2010   c/z   -15.24  0  22.5425
2015   c/z   -15.24  0  22.86
2020   c/z   -15.24  0  23.1775
2025   c/z   30.532871  -30.532871  10.16
2030   c/z   30.532871  -30.532871  11.1125
2033   kz    62.4369403  0.11773044  -1
2035   sz    13.49755   121.92
2040   sz    13.49755   122.8725
2045   s     -15.24  0  -83.65745  22.86
2050   s     -15.24  0  -83.65745  23.1775
2055   tz    0  0  -87.46745  51.435  8.5725  8.5725
2060   tz    0  0  -87.46745  51.435  9.525   9.525
2062   pz    -60.4
2063   pz    -71.4   $ for segementing of graphite and d2o
2065   pz    -83.65745
2066   pz    -94.65  $ for segmenting of graphite
2070   pz    -87.46745
2075   pz    -95.52245    $ should be according to blue prints  -95.72245
c
c      Graphite reflector and H2O shutter
c
3000   cz    63.5
3004   px    63.5
3001   cz    63.8175
3003   px    63.65875
3002   cz    82.55
3005   cz    120.396
3010   px    100.0125
3011   px    100.0     $ for tallying
3015   pz    -157.84995
3017   pz    -127.36995
```

```
3020   pz    -107.50245
3025   sz    13.49755  130.4925
3030   c/z   -15.24  0  31.75
3035   c/z   -15.24  0  30.48
3040   c/z   -15.24  0  30.1625
3045   s     -15.24  0  -196.8462  61.2775
3050   s     -15.24  0  -196.8462  60.96
3055   tz    -15.24  0  -146.9987  25.4  5.08  5.08
3060   tz    -15.24  0  -146.9987  25.4  4.7625  4.7625
3065   pz    -146.9987
3070   k/z   -15.24  0  -241.878742  0.07166675  +1
3075   pz    62.2338  $ top of graphite
3080   16   cx   15.24
3081   16   cx   15.5575
c      3085   16   cx   17.145
c      3086   16   cx   17.4625
3082   39   pz   -17.78
3084   16   pz    17.78
3085   39   pz    17.78
3086   16   pz   -17.78
3087   39   py    17.78
3088   39   py   -17.78
3089   39   pz    17.62125
3090   39   pz   -17.62125
3091   39   py    17.62125
3092   39   py   -17.62125
3095   12   cy   7.62
3096   12   cy   7.9375
3097   12   py   -65.0
3098   12   py   -115.0
3100   14   cy   5.08
3101   14   cy   5.3975
3102   14   py   -65.0
3103   14   py   -115.0
3105   16   cy   7.62
3106   16   cy   7.9375
3107   16   py   -65.0
3108   16   py   -115.0
3110   18   cy   5.08
3111   18   cy   5.3975
3112   18   py   -65.0
3113   18   py   -115.0
3115   20   cy   7.62
3116   20   cy   7.9375
3125   25   cx   7.62
3126   25   cx   7.9375
3130   26   cx   7.62
3131   26   cx   7.9375
3140   14   cx   5.08
3141   14   cx   5.3975
3145   18   cx   5.08
3146   18   cx   5.3975
3170   p     0.66705  1.0  0.0  -0.14735
3172   p     0.66705  1.0  0.0  -20.18433
3174   p    -1.49914  1.0  0.0   22.84689
3176   p    -1.49914  1.0  0.0  -76.30586
c
c      planes used for segmenting beam tubes
c
3501   12   py  -35.0          $  -----------
3502   12   py  -40.0          $
3503   12   py  -45.0          $  cell 5003
3504   12   py  -50.0          $
3505   12   py  -55.0          $  -----------
```

```
3506   12   py  -70.0          $  -----------
3507   12   py  -75.0          $
3508   12   py  -80.0          $
3509   12   py  -85.0          $
3510   12   py  -90.0          $  cell 4027
3511   12   py  -95.0          $
3512   12   py  -100.0         $
3513   12   py  -105.0         $
3514   12   py  -110.0         $  -----------
c
3521   14   py  -35.0          $  -----------
3522   14   py  -40.0          $
3523   14   py  -45.0          $  cell 5018
3524   14   py  -50.0          $
3525   14   py  -55.0          $  -----------
3526   14   py  -70.0          $  -----------
3527   14   py  -75.0          $
3528   14   py  -80.0          $
3529   14   py  -85.0          $
3530   14   py  -90.0          $  cell 4032
3531   14   py  -95.0          $
3532   14   py  -100.0         $
3533   14   py  -105.0         $
3534   14   py  -110.0         $  -----------
c
3541   16   py  -35.0          $  -----------
3542   16   py  -40.0          $
3543   16   py  -45.0          $  cell 5033
3544   16   py  -50.0          $
3545   16   py  -55.0          $  -----------
3546   16   py  -70.0          $  -----------
3547   16   py  -75.0          $
3548   16   py  -80.0          $
3549   16   py  -85.0          $
3550   16   py  -90.0          $  cell 4037
3551   16   py  -95.0          $
3552   16   py  -100.0         $
3553   16   py  -105.0         $
3554   16   py  -110.0         $  -----------
c
3561   18   py  -35.0          $  -----------
3562   18   py  -40.0          $
3563   18   py  -45.0          $  cell 5048
3564   18   py  -50.0          $
3565   18   py  -55.0          $  -----------
3566   18   py  -70.0          $  -----------
3567   18   py  -75.0          $
3568   18   py  -80.0          $
3569   18   py  -85.0          $
3570   18   py  -90.0          $  cell 4042
3571   18   py  -95.0          $
3572   18   py  -100.0         $
3573   18   py  -105.0         $
3574   18   py  -110.0         $  -----------
c
3581   pz   -37.36245          $  -----------
3582   pz   -38.36245          $
3583   pz   -39.36245          $
3584   pz   -40.36245          $
3585   pz   -41.36245          $
3586   pz   -42.36245          $
3587   pz   -43.36245          $
3588   pz   -44.36245          $
3589   pz   -45.36245          $
```

```
3590   pz   -46.36245        $
3591   pz   -47.36245        $
3592   pz   -48.36245        $
3593   pz   -49.36245        $  cell 3152
3594   pz   -50.36245        $
3595   pz   -51.36245        $
3596   pz   -52.36245        $
3597   pz   -53.36245        $
3598   pz   -54.36245        $
3599   pz   -55.36245        $
3600   pz   -56.36245        $
3601   pz   -57.36245        $
3602   pz   -58.36245        $
3603   pz   -59.36245        $
3604   pz   -60.36245        $  -----------
c
3611   26  px     24.20875   $  -----------
3612   26  px     29.20875   $  cell 5225
3613   26  px     34.20875   $
3614   26  px     39.20875   $  -----------
c
3615   26  px     55.20875   $  -----------
3616   26  px     60.20875   $
3617   26  px     65.20875   $
3618   26  px     70.20875   $
3619   26  px     75.20875   $  cell 4172
3620   26  px     80.20875   $
3621   26  px     85.20875   $
3622   26  px     90.20875   $
3623   26  px     95.20875   $  -----------
c
c      Beam Tubes
c
4000   cz  10.16
4005   cz  10.4775
c
4010   12   ky  74.5066666  0.00140625
4011   12   cy  3.81
4012   12   py  -30.0
4013   12   py  -60.0
4015   12   ky  82.979284   0.00140625
4020   13   px  0
4025   14   ky  74.5066666  0.00140625
4026   14   cy  3.81
4027   14   py  -30.0
4028   14   py  -60.0
4030   14   ky  82.979284   0.00140625
4035   14   ky  -74.5066666  0.00140625
4040   14   ky  -82.979284   0.00140625
4045   15   px  0
4050   16   ky  74.5066666  0.00140625
4051   16   cy  3.81
4052   16   py  -30.0
4053   16   py  -60.0
4055   16   ky  82.979284   0.00140625
4060   16   ky  -74.5066666  0.00140625
4065   16   ky  -82.979284   0.00140625
4070   17   px  0
4075   18   ky  74.5066666  0.00140625
4076   18   cy  3.81
4077   18   py  -30.0
4078   18   py  -60.0
4080   18   ky  82.979284   0.00140625
4085   18   ky  -74.5066666  0.00140625
```

```
4090    18   ky  -82.979284    0.00140625
4095    19   px  0
4100    20   ky  -74.5066666   0.00140625
4105    20   ky  -82.979284    0.00140625
c
c
c       4TH1 - 3
4110    c/y  70.088125   -76.20   5.95376
4111    c/y  70.088125   -76.20   5.715
c
c       4TH2 - 4
4115    c/y  70.088125  -101.60   5.95376
4116    c/y  70.088125  -101.60   5.715
c
c
c       for segementing the D2O  2/4/94
c
4120    20  py 0
4121    19  py 0
4122    30  py 0
4123    31  py 0
4124    13  py 0
4125    12  py 0
c
c       Not for segmenting D2O
4200    py  0
4205    px  0
c
4380    25   cx    3.81
4385    25   cx    4.1275
4390    26   cx    3.81
4395    26   cx    4.1275
4400    25   sx    20.955     3.81
4405    25   sx    20.955     4.1275
4410    26   sx    19.20875   3.81
4415    26   sx    19.20875   4.1275
4420    25   px    20.955
4425    26   px    19.20875
4430    26   px    44.20875
4440    26   px    50.20875
4445    26   px    100.20875
c
5330    16   c/x   10.16    0.0    4.1275
5335    16   c/x   10.16    0.0    3.81
5340    16   c/x  -10.16    0.0    4.1275
5345    16   c/x  -10.16    0.0    3.81
5350    14   cx      4.1275
5355    14   cx      3.81
5360    18   cx      4.1275
5365    18   cx      3.81
5370    16   p       0.198912   1.0    0.0     5.280996
5375    16   p      -0.198912   1.0    0.0    -5.280996
5380    16   p       0.713293   1.0    0.0    -1.990651
5385    16   p      -0.713293   1.0    0.0     1.990651
5390    16   p       0.713293   1.0    0.0    -2.575644
5395    16   p      -0.713293   1.0    0.0     2.575644
5400    16   p      -5.027339   1.0    0.0    83.021655
5405    16   p       5.027339   1.0    0.0   -83.021655
5410    16   p      -5.027339   1.0    0.0    84.649103
5415    16   p       5.027339   1.0    0.0   -84.649103
c
c      Medical therapy beam surfaces
c      _________________________
c      define surface cards
```

```
c     --------------------
c
c       graphite reflector
c
c         9035       cy  124.5   changed to 3005
9036    27  cy  63.5
c         9037    27   py  183.05
c         9038       py  134.6   changed to 3015
9039    27  py  133.965
c         9040       pz -105.41  changed to -3010
c
c       medical shield plug
c
9045    27  py  128.885
9046    27  py  125.075
9047    27  py  119.995
9049    27  c/y 0.0  12.7  34.925
9050    27  c/y 0.0  12.7  34.3
9052    27  py  106.635
9060    27  k/y 0.0  -35.265 8.89  0.02509  1
9061    27  c/y 0.0  8.89  31.75
9062    27  c/y 0.0  8.89  31.115
9063    27  py  71.39
9064    27  py  70.755
9065    27  c/y 0.0  8.89  22.86
9066    27  c/y 0.0  8.89  22.225
9067    27  py  99.965
9068    27  py  40.275
9069    27  c/y 0.0  8.89  33.02
9070    27  c/y 0.0  8.89  24.13
9071    27  py  68.85
9072    27  c/y 0.0 14.605 42.228
9073    27  c/y 0.0 14.605 40.323
9074    27  py  96.79
9075    27  py  36.465
9076    27  c/y 0.0  8.89  17.78
9077    27  py  40.91
9078    27  pz  8.89
c
c       medical shutter
c
9080    27  s   0.0  44.72  8.89  60.96
9081    27  s   0.0  44.72  8.89  61.28
9082    27  c/y 0.0   8.89  30.1625
9083    27  c/y 0.0   8.89  30.48
9084    27  s   0.0  96.47  8.89  60.96
9085    27  s   0.0  96.47  8.89  61.28
9086    27  py  100.6
9087    27  py  100.92
9089    27  py  139.65
9090    27  py  106.0
c
c       medical system shutters
c
9120    27  py  35.225
9121    27  c/y  0.0  14.605  49.848
9122    27  py  33.955
9123    27  c/y  0.0  14.605  29.845
9124    27  c/y  0.0  14.605  31.115
9125    27  py  23.478
9126    27  py  22.208
9127    27  pz  45.72
9128    27  pz -16.51
9129    27  c/y  0.0  14.605  24.445
```

```
9131    27   c/y  0.0  14.605  47.94
9132    27   py  -5.415
9133    27   py  21.255
9134    27   py  19.45
9135    27   pz  39.05
9136    27   pz  -9.845
9137    27   pz  40.32
9138    27   pz -11.115
9139    27   py  4.428
9140    27   py  3.158
9141    27   pz  44.45
9142    27   pz -15.24
9143    27   pz  47.625
9144    27   pz -18.415
9145    27   py  -2.875
9146    27   c/y  0.0  14.605  57.15
9147    27   py  -9.225
9148    27   py  19.432
9149    27   pz  37.78
9150    27   pz  -8.575
9151    27   py  -3.827
9152    27   py  -7.955
9153    27   c/y  0.0  14.605  19.05
9154    27   c/y  0.0  14.605  17.78
9155    27   c/y  0.0  14.605  10.795
9156    27   c/y  0.0  14.605  14.288
c            160      k/y  0.0 -29.71 14.605  0.08774  1
9160    27   c/y  0.0   8.89    8.89
9166    27   py   -7.905
9167    27   py  -6.685
c
c        poly head phantom
c
9170    27   c/y  0.0  14.605  8.89
9171    27   py   -10.473
9172    27   py   -11.108
9173    27   py   -11.743
9174    27   py   -12.378
9175    27   py   -14.918
9176    27   py   -17.458
9177    27   py   -19.998
9178    27   py   -22.538
9179    27   py   -25.078
9180    27   py   -27.618
9181    27   py   -30.158
c
9185    27   py   -9.788
9186    27   c/y  0.0  8.89  3.0
c
c        neutron filter
c
9199    27   py   89.293
9200    27   py   88.976
9201    27   py   88.958
9202    27   py   40.71
9203    27   py   55.91
9204    27   c/y  0.0  8.89   8.89
9205    27   c/y  0.0  14.605  17.78
9206    27   c/y  0.0  8.89    8.255
9207    27   c/y  0.0  8.89    7.620
9208    27   py   22.526
9209    27   py   -9.828
c
c        bi filter region
```

```
c
9300    27   py  6.015
9301    27   py  11.95
9302    27   py  14.35
9303    27   py  19.412
c
c         slabs
c
9310    27   py  27.288
9311    27   py  31.098
9312    27   py  33.478
9313    27   py  38.718
9314    27   py  43.558
9315    27   py  46.338
9316    27   py  51.458
9317    27   py  53.958
9318    27   py  57.88
9319    27   py  57.90
9320    27   py  63.982
9321    27   py  68.478
9322    27   py  68.498
9323    27   py  76.818
9324    27   py  84.438
9325    27   py  46.78
c
c
c        Segmenting surfaces for fission heating tally in u=72 Fuel element
c
7201    pz    28.0
7202    pz    27.0
7203    pz    26.0
7204    pz    25.0
7205    pz    24.0
7206    pz    23.0
7207    pz    22.0
7208    pz    21.0
7209    pz    20.0
7210    pz    19.0
7211    pz    18.0
7212    pz    17.0
7213    pz    16.0
7214    pz    15.0
7215    pz    14.0
7216    pz    13.0
7217    pz    12.0
7218    pz    11.0
7219    pz    10.0
7220    pz     9.0
7221    pz     8.0
7222    pz     7.0
7223    pz     6.0
7224    pz     5.0
7225    pz     4.0
7226    pz     3.0
7227    pz     2.0
7228    pz     1.0
7229    pz     0.0
7230    pz    -1.0
7231    pz    -2.0
7232    pz    -3.0
7233    pz    -4.0
7234    pz    -5.0
7235    pz    -6.0
7236    pz    -7.0
```

```
7237    pz    -8.0
7238    pz    -9.0
7239    pz   -10.0
7240    pz   -11.0
7241    pz   -12.0
7242    pz   -13.0
7243    pz   -14.0
7244    pz   -15.0
7245    pz   -16.0
7246    pz   -17.0
7247    pz   -18.0
7248    pz   -19.0
7249    pz   -20.0
7250    pz   -21.0
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7255    pz   -26.0
7256    pz   -27.0
7257    pz   -28.0
c
c
c       Geometry debugging
c
9999    so  500
c
c       BLANK LINE

c       BLANK LINE
c
c       Cell Temperatures & Importances
c
c       Temperatures are according to materials
c         m1    H2O      55 C   2.8277e-8 MeV
c         m2    D2O      50 C   2.7846e-8
c         m3    He       RT     2.53e-8
c         m4,5 Graphite  200 C  4.0771e-8
c         m6   Al        100 C  3.2154e-8
c         m8   Borated   RT     2.53e-8
c                304 SS
c         m9   Boron SS  RT     2.53e-8
c         m10  Cadmium   RT     2.53e-8
c         m23  Fuel      100 C  3.2154e-8
c         m30  End Cap   RT     2.53e-8
c              on Element
c         m40  End Cap @ RT     2.53e-8
c              bt grid plt
c         m60  5/95%     RT     2.5e-8
c              Al/H2O
c         m61  50/50%    RT     2.5e-8
c              Al/H2O
c
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51041   2.8277e-8      1
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5308	4.0771e-8	1
5309	4.0771e-8	1

5310	4.0771e-8	1
5311	4.0771e-8	1
5312	4.0771e-8	1
5313	4.0771e-8	1
5314	4.0771e-8	1
5320	4.0771e-8	1
5321	4.0771e-8	1
5322	4.0771e-8	1
5323	4.0771e-8	1
5324	4.0771e-8	1
5325	4.0771e-8	1
5326	4.0771e-8	1
5327	4.0771e-8	1
5328	4.0771e-8	1
5329	4.0771e-8	1
5330	4.0771e-8	1
5331	4.0771e-8	1
5332	4.0771e-8	1
5333	4.0771e-8	1
5340	4.0771e-8	1
5341	4.0771e-8	1
5342	4.0771e-8	1
5343	4.0771e-8	1
5344	4.0771e-8	1
5345	4.0771e-8	1
5346	4.0771e-8	1
5347	4.0771e-8	1
5348	4.0771e-8	1
5349	4.0771e-8	1
5350	4.0771e-8	1
5351	4.0771e-8	1
5352	4.0771e-8	1
5353	4.0771e-8	1
4921	2.5300e-8	1
4150	4.0771e-8	1
4152	4.0771e-8	1
4154	4.0771e-8	1
4156	2.5300e-8	1
4158	4.0771e-8	1
4015	3.2154e-8	1
4016	2.5300e-8	1
4017	3.2154e-8	1
4025	3.2154e-8	1
4026	2.5300e-8	1
4027	2.5300e-8	1
4028	2.5300e-8	1
4029	3.2154e-8	1
4030	3.2154e-8	1
4031	2.5300e-8	1
4032	2.5300e-8	1
4033	2.5300e-8	1
4034	3.2154e-8	1
4035	3.2154e-8	1
4036	2.5300e-8	1
4037	2.5300e-8	1
4038	2.5300e-8	1
4039	3.2154e-8	1
4040	3.2154e-8	1
4041	2.5300e-8	1
4042	2.5300e-8	1
4043	2.5300e-8	1
4044	3.2154e-8	1
4045	3.2154e-8	1
4046	2.5300e-8	1

4047	3.2154e-8	1
4348	2.5300e-8	1
4349	2.5300e-8	1
4049	3.2154e-8	1
4350	2.5300e-8	1
4351	2.5300e-8	1
4352	2.5300e-8	1
4353	2.5300e-8	1
4354	2.5300e-8	1
4355	2.5300e-8	1
4356	2.5300e-8	1
4050	3.2154e-8	1
4051	3.2154e-8	1
4052	3.2154e-8	1
4053	3.2154e-8	1
4054	3.2154e-8	1
4055	3.2154e-8	1
4056	2.5300e-8	1
4057	3.2154e-8	1
4060	3.2154e-8	1
4061	2.5300e-8	1
4062	3.2154e-8	1
4065	3.2154e-8	1
4066	2.5300e-8	1
4067	3.2154e-8	1
4068	3.2154e-8	1
4069	2.5300e-8	1
4070	3.2154e-8	1
4071	3.2154e-8	1
4072	2.5300e-8	1
4172	2.5300e-8	1
4173	2.5300e-8	1
4073	3.2154e-8	1
4074	3.2154e-8	1
4075	2.5300e-8	1
4076	3.2154e-8	1
4077	3.2154e-8	1
4078	2.5300e-8	1
4079	3.2154e-8	1
4080	3.2154e-8	1
4085	3.2154e-8	1
4090	3.2154e-8	1
4100	2.8277e-8	1
4105	2.8277e-8	1
4110	2.8277e-8	1
4200	2.5300e-8	1
4201	2.5300e-8	1
4205	2.5300e-8	1
4210	2.5300e-8	1
4215	2.5300e-8	1
4220	2.5300e-8	1
4225	2.5300e-8	1
4230	2.5300e-8	1
5000	2.5300e-8	1
5001	2.5300e-8	1
5002	2.5300e-8	1
5003	2.5300e-8	1
5005	3.2154e-8	1
5010	3.2154e-8	1
5015	2.5300e-8	1
5016	2.5300e-8	1
5017	2.5300e-8	1
5018	2.5300e-8	1
5020	3.2154e-8	1

```
 5025   3.2154e-8      1
 5030   2.5300e-8      1
 5031   2.5300e-8      1
 5032   2.5300e-8      1
 5033   2.5300e-8      1
 5035   3.2154e-8      1
 5040   3.2154e-8      1
 5045   2.5300e-8      1
 5046   2.5300e-8      1
 5047   2.5300e-8      1
 5048   2.5300e-8      1
 5050   3.2154e-8      1
 5055   3.2154e-8      1
 5060   2.5300e-8      1
 5065   3.2154e-8      1
 5070   3.2154e-8      1
 5075   2.5300e-8      1
 5080   3.2154e-8      1
 5085   3.2154e-8      1
 5090   2.5300e-8      1
 5095   3.2154e-8      1
 5100   3.2154e-8      1
 5105   2.5300e-8      1
 5110   3.2154e-8      1
 5115   3.2154e-8      1
 5120   3.2154e-8      1
 5122   3.2154e-8      1
 5124   3.2154e-8      1
 5126   3.2154e-8      1
 5130   3.2154e-8      1
 5132   3.2154e-8      1
 5134   3.2154e-8      1
 5136   3.2154e-8      1
 5150   2.5300e-8      1
 5152   2.5300e-8      1
 5154   2.5300e-8      1
 5156   2.5300e-8      1
 5200   2.5300e-8      1
 5205   2.5300e-8      1
 5210   3.2154e-8      1
 5215   3.2154e-8      1
 5220   2.5300e-8      1
 5225   2.5300e-8      1
 5226   2.5300e-8      1
 5230   3.2154e-8      1
 5235   3.2154e-8      1
 5250   3.2154e-8      1
 5260   2.5300e-8      1
 5270   3.2154e-8      1
 5280   2.5300e-8      1
99999   2.53e-8        0
c
c
c       TRANSFORMATIONS
c
c       Spider transformations
c
*tr1     0  0  0  60 30 90 150 60 90   90 90 0
*tr2     0  0  0  60 150 90 30 60 90   90 90 0
c
c       Control blade transformations
c
tr3     0  0  -17.78
*tr4     0  0  -17.78  60 30 90 150 60 90  90 90 0
```

```
*tr5     0  0  -17.78   60 150 90 30 60 90   90 90 0
tr6     0  0  29.68625
tr7     0  0  47.205
c
c       Regulating rod transformations
c
tr8     0  0  -13.97
tr9     0  0  -12.7
tr10    0  0  31.115
tr11    0  0  49.2125
c
c       Beam tube transformations
c
*tr12  0  0  -41.42995  -45  -135  90  45  -45  90  90  90  0
*tr13  0  0  -41.42995  -33.75  -123.75  90  56.25  -33.75  90  90  90  0
*tr14  0  0  -41.42995  -22.5   -112.5   90  67.5  -22.5  90  90  90  0
*tr15  0  0  -41.42995  -11.25  -101.25  90  78.75  -11.25  90  90  90  0
*tr16  0  0  -41.42995
*tr17  0  0  -41.42995  11.25  -78.75  90  101.25  11.25  90  90  90  0
*tr18  0  0  -41.42995  22.5  -67.5  90  112.5  22.5  90  90  90  0
*tr19  0  0  -41.42995  33.75  -56.25  90  123.75  33.75  90  90  90  0
*tr20  0  0  -41.42995  45  -45  90  135  45  90  90  90  0
*tr25   0  -20.32   -18.56995  -42  -132  90  48  -42  90  90  90  0
*tr26   0   20.32   -18.56995   42  -48   90  132  42  90  90  90  0
c
c       surfaces for segementing for weight windows
c
*tr30  0 0 0 16.5 -73.5 90 106.5 16.5 90 90 90 0
*tr31  0 0 0 -16.5 -106.5 90 73.5 -16.5 90 90 90 0
c
c       Medical therapy room transformation
c
c            reac sys                           med sys
c
c            z    y                             y     x
c            |   /                              |    /
c            |  /                               |   /
c            | /                                |  /
c            | /                                | /
c            |/-------> x               z<-------|/
c
c
tr27    -6.35 0.0  -292.44995 0 1 0 0 0 1 -1 0 0
c
c
c       Fission Converter Transformations
c
tr28     105.0926  0.0  -41.42995
tr39       0.0     0.0  -36.6                   $ 14 inch reentrant thimble
transform
tr40     293.0926  0.0  -41.42995   -1 0 0   0 1 0   0 0 -1
c        tr28    x   0   z
c        tr40     188.0+x  0  0+z   -1 0 0   0 1 0   0 0 -1
c
c
c        MATERIAL SPECIFICATIONS
c
c        Material 1 - H2O pool total conc = -0.99707 gm/cc (25 C)
c
m1       1001.50c  0.66667  8016.50c  0.33333
c
c        Material 2 - D2O reflector total conc = -1.10445 gm/cc (25 C)
c
m2       1001.50c  1.6671-3  1002.55c  6.6502-1  8016.50c  3.3332-1
```

```
c
c       Material 3 - He density of 0.031756-2 g/cc
c
m3      2004.50c 1.0
c
c       Material 4 - graphite 1.75 g/cc
c
m4      6012.50c 1.0
c
c       Material 5 - graphite 1.575 g/cc
c
m5      6012.50c 1.0
c
c       Material 6 - Al 6061 total conc = 6.0034-2
c
m6       13027.50c 0.975492    14000.50c 5.81337-3  26000.55c 3.4114-3
         29000.50c 1.17767-3   25055.50c 7.43079-4  12000.50c 1.1197-2
         24000.50c 1.31342-3   22000.50c 8.52184-4
c
c
c       Material 8 - Borated 304 Stainless Steel conc = 8.0271729 g/cc
c
c
m8      6000.50c  -0.0004   25055.50c -0.0162  16032.50c -0.00004
        14000.50c -0.0064   24000.50c -0.1851  28000.50c -0.1377
        15031.50c -0.00011  26000.55c -0.64345 5010.50c  -0.001954
        5011.55c  -0.008646
c
c
c       Material 10 - Cadmium 8.65 g/cc
c
m10     48000.50c 1.0
c
c       Material 11 -  Be
c
m11     4009.50c 1.0
c
c
c
c
c       Material 23 - LEU FUEL U6Mo total conc= 17.55 g/cc
c
c
m23     92238.50c  -0.744  92235.50c -0.186
        42000.50c  -0.07
c
c
c       Material 30 - END CAPS ON FUEL ELEMENTS total conc = 9.07359E-02
c
m30   13027.50c 1.49793e-01 14000.50c 8.92683e-04 26000.55c 5.23844e-04
      29000.50c 1.80839e-04 25055.50c 1.14105e-04 12000.50c 1.71938e-03
      24000.50c 2.01685e-04 22000.50c 1.30859e-04 1001.50c 5.64298e-01
      8016.50c 2.82145e-01
c       Total Concentration = 9.07359E-02
c
c       Material 40 - fuel end cap at bottom grid plate
c                     total conc = 8.21151E-02
c
m40   13027.50c 3.19298e-01 14000.50c 1.90283e-03 26000.55c 1.11662e-03
      29000.50c 3.85475e-04 25055.50c 2.43225e-04 12000.50c 3.66500e-03
      24000.50c 4.29909e-04 22000.50c 2.78937e-04 1001.50c 4.48455e-01
      8016.50c 2.24224e-01
c       Total Concentration = 8.21151E-02
c
```

```
c        Material 60 - 05/95 Al6061 H2O total conc =  9.80159-2
c
m60    13027.50c 2.98741e-02 14000.50c 1.78032e-04 26000.55c 1.04473e-04
       29000.50c 3.60657e-05 25055.50c 2.27565e-05 12000.50c 3.42904e-04
       24000.50c 4.02230e-05 22000.50c 2.60978e-05 1001.50c 6.46254e-01
       8016.50c 3.23122e-01
c       Total Concentration = 9.80159E-02
c
c        Material 61 - 50/50 Al6061 H2O total conc = 8.00245-2
c
m61    13027.50c 3.65905e-01 14000.50c 2.18058e-03 26000.55c 1.27961e-03
       29000.50c 4.41741e-04 25055.50c 2.78727e-04 12000.50c 4.19997e-03
       24000.50c 4.92661e-04 22000.50c 3.19652e-04 1001.50c 4.16604e-01
       8016.50c 2.08299e-01
c       Total Concentration = 8.00245E-02
c
mt1      lwtr.01t
mt2      hwtr.01t
mt4      grph.01t
mt5      grph.01t
mt30     lwtr.01t
mt40     lwtr.01t
mt60     lwtr.01t
mt61     lwtr.01t
c
c
c
c
c
c       Material 620 - Lead density = -10.364 g/cc
m620      82000.50c  1
c
print
c         10 60 50 40 110 170 90
prdmp    2j 1 1
c
c
c
c
totnu
c        ctme    360
c
c
c        CRITICALITY SOURCE DEFINITION
c
kcode    5000 1.000 5 3000
c
c
c        the ksrc entries can be generated with the program ksrc.f
c
c       kcode source from file
c
c
c       TALLY SPECIFICATION
c
c
c          Fission Heating Tally for individual fuel Plates in Fuel Element u=87
c         Results are in MeV/g. Multiply by J/MeV*g/cm^3 in order to get in
c         result in J/cm^3.
c
c
c
fc17       heating Profile - A2 1
f17:n      37399
```

```
fc27        heating Profile - A2 2
f27:n       37400
fc37        heating Profile - A2 3
f37:n       37401
fc47        heating Profile - A2 4
f47:n       37402
fc57        heating Profile - A2 5
f57:n       37403
fc67        heating Profile - A2 6
f67:n       37404
fc77        heating Profile - A2 7
f77:n       37405
fc87        heating Profile - A2 8
f87:n       37406
fc97        heating Profile - A2 9
f97:n       37407
fc107        heating Profile - B4 1
f107:n       74408
fc117        heating Profile - B4 2
f117:n       74409
fc127        heating Profile - B4 3
f127:n       74410
fc137        heating Profile - B4 4
f137:n       74411
fc147        heating Profile - B4 5
f147:n       74412
fc157        heating Profile - B4 6
f157:n       74413
fc167        heating Profile - B4 7
f167:n       74414
fc177        heating Profile - B4 8
f177:n       74415
fc187        heating Profile - B4 9
f187:n       74416
c     THE END
```

Appendix C MULCH-II Input Files

Below is a listing of a representative LEU core input file data used for analysis with MULCH-II. The majority of systems information outside the core is taken from McGuire [6.3].

Title=SL AND LSSS PREDICTION FOR 5 MW with LEU

Initial Conditions
5e6=init. Power (W)
18.9=Cooling Tower Outlet Temperature (°C)
112.2=Primary Flow (kg/s)
103.8 =Secondary Flow (kg/s)
0.8=Cooling Tower Efficiency
50.0=Reference cooling temperature (°C)
2.968=height from water/air interface to top of flow guide (m)

1=Loss of Flow transient
1000=hours of steady state operation

0.1=time step (s)
0.1=total simulation time (s)
Scram Setpoints
7.5E6=Reactor Power setpoint (W)
100.0=Primary Flow setpoint (kg/s)
50=Secondary flow setpoint (kg/s)
40=Core inlet temperature setpoint (°C)
55=core outlet temperature setpoint (°C)
50=secondary inlet temperature setpoint (°C)
50=secondary outlet temperature setopint (°C)

1.0=instrument delay time (s)
1.0=80% blade drop time (s)

Pump coastdown curve coefficients
-1.87
0.41
2.95
-0.68
0.5136
1.492

Hot Leg Primary
0.032=flow area (m^3)
0.427=volume (m^3)
0.203=hydraulic diameter (m)

-7.08=elevation (m)
4.58=K factor
1=number of channels

Heat exchanger, primary side
3.887E-5=flow area (m^3)
1.679E-4=volume (m^3)
7.04e-3=hydraulic diameter (m)
0.0=elevation (m)
7.30=K factor
1=number of channels

Cold Leg Primary
0.032=flow area (m^3)
0.468=volume (m^3)
0.203=hydraulic diameter (m)
6.97=elevation (m)
2.17=K factor
1=number of channels

Downcomer #1
0.339=flow area (m^3)
0.413=volume (m^3)
0.180=hydraulic diameter (m)
-1.22=elevation (m)
0=K factor
1=number of channels

Downcomer #2
0.111=flow area (m^3)
0.076=volume (m^3)
0.063=hydraulic diameter (m)
-0.69=elevation (m)
0.3=K factor
1=number of channels

Downcomer #3
0.0044=flow area (m^3)
0.016=volume (m^3)
0.022=hydraulic diameter (m)
-0.01=elevation (m)
0.18=K factor
1=number of channels

Downcomer #4
0.029=flow area (m^3)
0.018=volume (m^3)
0.04=hydraulic diameter (m)
-0.61=elevation (m)
0.0=K factor

1=number of channels

Core
1.5545e-4=flow area (m^3)
1.0259e-4=volume (m^3)
2.526e-4=hydraulic diameter (m)
0.66=elevation (m)
2.05=K factor
387=number of channels

Flow guide
0.13=flow area (m^3)
0.099=volume (m^3)
0.387=hydraulic diameter (m)
0.76=elevation (m)
0.0=K factor
1=number of channels

Mixing area
0.923=flow area (m^3)
1.92=volume (m^3)
1.084=hydraulic diameter (m)
1.22=elevation (m)
0.0=K factor
387=number of channels

Cold leg secondary
0.032=flow area (m^3)
0.427=volume (m^3)
0.203=hydraulic diameter (m)
6.97=elevation (m)
2.17=K factor
1=number of channels

Heat exchanger secondary side
9.00e-5=flow area (m^3)
3.89=volume (m^3)
3.01e-3=hydraulic diameter (m)
0.0=elevation (m)
7.3=K factor
1770=number of channels

Hot leg secondary
0.032=flow area (m^3)
0.468=volume (m^3)
0.203=hydraulic diameter (m)
6.97=elevation (m)
2.17=K factor
1=number of channels

Anti-siphon valves
1.78e-3=float contact area (m2)
3.837e-3=reference area for loss coefficient (m2)
1.059e-4=float volume (m3)
2715.0=length
7.9=Kfactor (upflow)
6.9=K factor (downflow)
2=no. of valves

Natural convection valves
2.71e-3=float contact area (m2)

8.107e-3=reference area for loss coefficient (m2)
2.04e-4=float volume (m3)
2715.0=length
46.3=Kfactor (upflow)
52.0=K factor (downflow)
4=no. of valves

Fuel
23=number of fuel elements (not used)
5.33e-4=fuel meat thickness (m)
3.77e-4=fuel clad thickness (m)
2.54e-5=crud thickness (m)
0.05588=fuel width(m)
0.5683=fuel length (m)
1.9=fin effectiveness

bypass flow
0.9205=ratio of forced flow through fueled core region

Heat exchanger fouling factor
3.50e-4=fouling factor

power distribution
1.0=power in fuel
0.0=power in coolant
0.0=power in D2O
0.0=power in graphite

1.76=Hot channel factor

neutron flux distribution for average channel
0.998,1.049,1.125,1.222,1.199,1.140,1.028,0.912,0.707,0.62

neutron flux distribution for hot channel
1.537,1.626,1.735,1.660,1.146,0.700,0.537,0.446,0.341,0.271

Local axial peaking factor for each node in average channel
1.080,1.078,1.090,1.075,1.021,1.054,1.101,1.156,1.261,1.193

Local axial peaking factor for each node in hot channel
1.049,1.049,1.074,1.048,1.430,1.612,1.276,1.197,1.325,1.269

Flow disparity for the hot channel
0.864

Engineering factors
1.395=power
1.536=flow rate
1.241=heat transfer coefficient
1.0=heat flux at hot spot

1.5=minimum heat flux ratio
1.5=minimum DNB ratio

<u>Listing of input file</u>:

```
SL AND LSSS PREDICTION FOR 5 MW with LEU
--------------------------------------------
5.0e6,18.9,112.2,103.0,0.8,50.0,2.968   ! 112.2 kg/s is 1800gpm @ 50C
1,1.e3                                  ! 4" below overflow
1.0,500
7.5e6,100.0,50,40.,55.,50.,50.
1.0,1.0
--------------------------------------------
-1.87,0.41,2.95,-0.68,0.5136,1.492     ! pump coast down curve
0.032,0.427,0.203,-7.08,4.58,1
3.8870e-5,1.6792e-4,7.04e-3,0.0,7.30,1770
0.032,0.468,0.203,6.97,2.17,1
0.339,0.413,0.180,-1.22,0.0,1
0.111,0.076,0.063,-0.69,0.3,1
0.0044,0.016,0.22,-0.01,0.18,1
0.029,0.018,0.04,-0.61,0.0,1
1.5545e-4,1.0259e-4,2.5259e-3,0.66,2.05,387 !core
0.13,0.099,0.387,0.76,0.0,1
0.923,1.92,1.084,1.22,0.0,1
0.032,0.427,0.203,-7.08,4.58,1
9.003e-5,3.8895e-4,3.010e-3,0.0,7.3,1770
0.032,0.468,0.203,6.97,2.17,1
1.78e-3,3.837e-3,1.059e-4,2715.0,7.9,6.9,2
2.71e-3,8.107e-3,2.04e-4,2715.0,46.3,52.0,4
--------------------------------------------------
23,5.33e-4,3.77e-4,2.54e-5,0.05588,0.5683,1.9   !min 23 elements
0.9205
3.5E-4
-----------------------------------------------------
```

```
1.0,0.0,0.0,0.0
1.76                    ! hcf
0.998,1.049,1.125,1.222,1.199,1.140,1.028,0.912,0.707,0.62
1.537,1.626,1.735,1.660,1.146,0.700,0.537,0.446,0.341,0.271
1.080,1.078,1.090,1.075,1.021,1.054,1.101,1.156,1.261,1.193
1.049,1.049,1.074,1.048,1.430,1.612,1.276,1.197,1.325,1.269
0.864
1.395,1.536,1.241,1.0          ! MITR-II e-factors
1.5,1.5
0,0
---------------------------------------------------------


1.173,1.275,1.123,1.0          ! new e-factors 1/26/99
95.0e-2,5.0e-2,0.0e-2,0.0e-2

1.0,1.0,1.0,1.0
```

Appendix D
PARET input files

D.1 HEU PARET input files

Below is a listing of parameters used in PARET for the input file for the HEU core.

General Information (1000 series cards)
1= No. of channels (SI)
20=no. of axial nodes
7=no. of radial nodes
0=slab geometry
1=reactivity specified
1=vapor fraction and quality calc. In both subcooled and saturation regions

1=outlet pressure specified
1=time step reduced when necessary
6=no. of delayed groups
-1= printout option
0=no avg. T printout
10=max. heat transfer iterations

5e-6=init. Power (MW)
.00824=total vol. Of fuel in core (m^3)
1.18e5=op. pressure (Pa)
-33=moderator inlet T (^oC)
8.89e-4=plate half thickness incl. Clad (m)

3.81e-4=fuel half thickness(m)
3.81e-4=distance to inner surf of clad (m)
0.0586=plate width (m)
0.0529=fuel width (m)
0.5683=active fuel height (m)
.00794=inlet non-fueled length (m)

.00794=outlet non-fueled length (m)
.00786=β_{eff}
8.00E-5=prompt n generation time (s)
9.80664=g (m/s^2)
0.01367=heat source description for moderator

0.75=transient time (s)
0.8=const. In void generation equation
1=exponent in void generation equation
992=moderator refernce density (kg/m^3)
0=const. Coeff. In fuel temp. feedback eqn.

3.6E-6=linear coeff in fuelT feedback eqn.
0=quad. Coeff in fuel T feedback eqn.

0=cubic coeff in fuel T feedback eqn.
0=-temp. offset coeff in fuel temp. feedback eqn.
1=exponent in fuel T feedback eqn.
0.001=upper limit on kinetics timestep

0=steady-state DNB heat fluxes calculated
0.0005=nucleate boiling collapse time (s)
0.001=transition boiling bubble collapse time (s)
0.03=fraction of clad surf. Heat transfer in subcooled nucleate boiling
0.05=fraction of clad surf. Heat transfer in subcooled transition boiling
0.05=fraction of clad surf. Heat transfer in subcooled film boiling

1.4=natural convection heat transfer constant
0.33=natural convection heat transfer constant.

Additional General Information (1111 Series cards)
1111
0.04748=total cross-sect. Flow area of all flow channels (m^3)
1=flux weighting factor
1112
1=Seider-Tate single phase correleation
2=Bergles-Rohsenow two-phase correlation
1=transition model two phase transient scheme
0=original (Tang) DNB correleation
0=original single phase heat transfer subroutine
2.26e+5=Avg. core heat flux (W/m^2) (not used)
25=bubble detachment parameter (not used)
4227=Cp (not used)
1113
1.2=rate of control blade movement (m/s)
0.1=delay time on blade move (s)
7.4=overpower trip point (MW)
0=low flow trip point (%)
1114
1.92=height above reactor for natural circulation (m)
0.0062=height below reactor for natural circulation (m)

Thermal Properties of Fuel element materials (2000 series cards)
<u>Fuel</u>
$k=\alpha_1 T^2+\alpha_2 T+\alpha_3+\alpha_4/T$ $\quad T=(u_n+u_{n+1})/2+\alpha_5$
$g=\beta_1 T^2+\beta_2 T+\beta_3+\beta_4/T$ $\quad T=(u_n+u_{n+1})/2+\beta_5$
2001
$0=\alpha_1$
$0=\alpha_2$
$42.5=\alpha_3$ (W/m K)
$0=\alpha_4$
$0=\alpha_5$
2002
$0=\beta_1$

1100=β_2 (J/m^{3}K^2)
1.93E+6=β_3 (J/m^3 K)
0=β_4
0=β_5

Clad
2003
0=α_1
0.12=α_2
131=α_3 (W/m K)
0=α_4
0=α_5
2004
0=β_1
1134=β_2 (J/m^{3}K^2)
2.10E+6=β_3 (J/m^3 K)
0=β_4
0=β_5

Radial or Half-Plate description (3000 series cards)

3001
9.52e-5=radial increment length (m)
5=radial node to which increment applies
1=composition (1=fuel)
0.967=radial source (fraction of heat generated in fuel)
3002
2.54e-4=radial increment length (m)
7=radial node to which increment applies
2=composition (2=clad)
0=radial source (fraction of heat generated in clad)

Axial Description (4000 series cards)

4001
2.8415E-2=radial increment length (m)
20=node u=number up to which increment applies

Individual Channel Information (5000 series cards)

1=flow-forced channel
0=pressure drop (Pa)(zero for flow-forced)
2.39E-3=radial distance from center of slab to center of channel (m)
1=reactivity feedback weight factor of channel
0.55=loss coeff. For inlet of channel
0.65=loss coeff for outlet of channel

0.9=inlet area ratio
0.9=outlet area ratio
0.52=overall density/void coeff.($/% of core)
2.1070E-2=overall coolant temperature coeff ($/C)

0.0651=length of inlet plenum(m)

1.9193=length of outlet plenum (m)
0.3875=inlet plenum equiv. Diameter (m)
0.3875=outlet plenum equiv. Diameter (m)

1.980=axial flux peaking factors (one for each axial node)
1=moderator density feedback weighting factor
1=fuel density feedback weighting factor
1=coolant density feedback weighting factor

Delayed Neutron Information (6000 series cards)

group delayed neutron fraction	decay const.
3.30700-2	1.24000-2
2.19010-1	3.05000-2
1.95940-1	1.11000-1
3.94950-1	3.01000-1
1.15040-1	1.14
4.19900-2	3.01

Power or reactivity vs. Time (9000 series cards)

3=number of pairs of entries in table

reactivity ($)	time (s)
0	0
2.9	1.00-3
2.9	10

Moderator Inlet mass velocity vs. Time (10000 series cards)

2=number of pairs of entries in table

mass velocity	time (s)
3000	0
3000	10

Percent Linear Thermal Expansion of the Clad vs. Temperature (11000 series cards)

2=number of pairs of entries in table

% expansion	Temp (K)
0	58
0	4000

Total Pressure Drop vs. Time (12000 series cards)

Total pressure drop across channel	Time (s)
0	0
0	10

Time Increment vs. time (14000 series cards)

4=number of pairs of entries in table

time increment	as of time (s)
1.00-5	0
1.00-5	0.4
3.00-5	1.2
3.00-5	2

Print frquency vs. time (16000 series cards)

2=number of pairs of entries in table

Print time increment	Freq. Of input	as of time (s)
1	100	0
1	100	10

Pump mass velocity fraction vs. time (17000 series cards)

3=number of pairs of entries in table

coolant mass vel. Fraction	time(s)
1	0
1	0
0	10

Blade worth vs. blade location (18000 series cards)

2=number of pairs of entries in table

Reactivity of blade bank ($)	blade position (m)
0	0
-14.5	0.5683

HEU PARET input file:

```
     0
* PARET:  MITR HEU calc  $2.30 Step (w/ fins, 5 W, FC 1800 gpm HEU
cond.)
1001,     -1            20      7      0      1      1
1002,             1      1      6     -1      0     10
1003,    5.000-6    0.008240   1.18000+5   -33.0       8.80800-4
1004,    3.81000-4  3.81000-4   5.86000-2    5.28830-2  0.5683
0.00794
1005,    0.00794      0.00786     8.00-5      9.80664       0.01367
1006,    0.75        0.8000       1.0         992.00        0.0
1007,    3.674-6      0.0        0.0          0.0          1.0
0.001
1008,   0.0           0.0005       0.001        0.03          0.05
0.05
1009,   1.4           0.33
1111,   0.04748       1.00
1112,      1      2      1      0      0        2.260000+5   25.000
4227.0
1113,   1.20        0.1           7.4000         0.0
1114,   1.92        0.062
2001,   0.0         0.0           42.5          0.0         0.0
2002,   0.0          1100.0       1.92600+6    0.0         0.0
2003,   0.0        0.12           131.0         0.0         0.0
2004,   0.0          1134.0       2.10165+6    0.0         0.0
3001,    9.520-5     5     1      0.967
3002,    2.500-4     7     2.     0.0
4001,    2.84150-2    20
5100,      1             0.       2.39000-3  1.00         0.55
0.65
5100,  0.9          0.9          0.5200          2.1070-2
5101,   0.0651       1.9193       0.3875       0.3875
5102,   1.98         1.0          1.0          1.0
5103,   2.0250       1.0          1.0          1.0
5104,   2.0700       1.0          1.0          1.0
5105,   2.1500       1.0          1.0          1.0
5106,   2.2300       1.0          1.0          1.0
5107,   2.1800       1.0          1.0          1.0
5108,   2.1200       1.0          1.0          1.0
```

```
5109,   1.8000     1.0        1.0        1.0
5110,   1.4900     1.0        1.0        1.0
5111,   1.2000     1.0        1.0        1.0
5112,   0.9200     1.0        1.0        1.0
5113,   0.8200     1.0        1.0        1.0
5114,   0.7200     1.0        1.0        1.0
5115,   0.6600     1.0        1.0        1.0
5116,   0.6000     1.0        1.0        1.0
5117,   0.5300     1.0        1.0        1.0
5118,   0.4600     1.0        1.0        1.0
5119,   0.4070     1.0        1.0        1.0
5120,   0.3600     1.0        1.0        1.0
5121,   0.3600     1.0        1.0        1.0
6001,    3.30700-2   1.24000-2   2.19010-1   3.05000-2   1.95940-1
1.11000-1
6002,    3.94950-1   3.01000-1   1.15040-1   1.1400      4.19900-2
3.0100
9000,      3
9001,     0.0        0.0         2.30       1.00-3           2.30
10.0
10000,     2
10001,   3000.       0.0         3000.       10.0
11000,     2
11001,   0.0         58.0        0.0         4000.0
12000,     2
12001,    0.0         0.0         0.0        10.0
14000,     4
14001,   1.00-5        0.0        1.00-5       0.40      3.00-5
1.20
14002,   3.00-4        2.0
16000,     2
16001,     1.00        500       0.0         1.0          500        10.0
17000,     3
17001,     1.00        0.0        1.0000     1.0          0.0         10.0
18000,     2
18001,     0.0        0.0        -14.50      0.5683
```

D.2 LEU PARET input files

Below is a listing of parameters used in PARET for the input file for the LEU core.

General Information (1000 series cards)
1= No. of channels (SI)
20=no. of axial nodes
7=no. of radial nodes
0=slab geometry
1=reactivity specified
1=vapor fraction and quality calc. In both subcooled and saturation regions

1=outlet pressure specified
1=time step reduced when necessary
6=no. of delayed groups
"-1= printout option
0=no avg. T printout
10=max. heat transfer iterations

5e-6=init. Power (MW)
.0067=total vol. Of fuel in core (m^3)
1.18e5=op. pressure (Pa)
-33=moderator inlet T (^oC)
5.06e-4=plate half thickness incl. Clad (m)

3.18e-4=fuel half thickness(m)
3.18e-4=distance to inner surf of clad (m)
0.0586=plate width (m)
0.0529=fuel width (m)
0.5683=active fuel height (m)
.00794=inlet non-fueled length (m)

.00794=outlet non-fueled length (m)
.0075=β_{eff}
8.00E-5=prompt n generation time (s)
9.80664=g (m/s^2)
0.01367=heat source description for moderator

0.75=transient time (s)
0.8=const. In void generation equation
1=exponent in void generation equation
992=moderator refernce density (kg/m^3)
0=const. Coeff. In fuel temp. feedback eqn.

3.6E-3=linear coeff in fuelT feedback eqn.
0=quad. Coeff in fuel T feedback eqn.
0=cubic coeff in fuel T feedback eqn.
0=-temp. offset coeff in fuel temp. feedback eqn.
1=exponent in fuel T feedback eqn.

0.001=upper limit on kinetics timestep

0=steady-state DNB heat fluxes calculated
0.0005=nucleate boiling collapse time (s)
0.001=transition boiling bubble collapse time (s)
0.03=fraction of clad surf. Heat transfer in subcooled nucleate boiling
0.05=fraction of clad surf. Heat transfer in subcooled transition boiling
0.05=fraction of clad surf. Heat transfer in subcooled film boiling

1.4=natural convection heat transfer constant
0.33=natural convection heat transfer constant.

Additional General Information (1111 Series cards)
1111
0.051225=total cross-sect. Flow area of all flow channels (m^3)
1=flux weighting factor
1112
1=Seider-Tate single phase correleation
2=Bergles-Rohsenow two-phase correlation
1=transition model two phase transient scheme
0=original (Tang) DNB correleation
0=original single phase heat transfer subroutine
2.26e+5=Avg. core heat flux (W/m^2) (not used)
25=bubble detachment parameter (not used)
4227=Cp (not used)
1113
1.2=rate of control blade movement (m/s)
0.1=delay time on blade move (s)
7.4=overpower trip point (MW)
0=low flow trip point (%)
1114
1.92=height above reactor for natural circulation (m)
0.0062=height below reactor for natural circulation (m)

Thermal Properties of Fuel element materials (2000 series cards)
Fuel
$k=\alpha_1T^2+\alpha_2T+\alpha_3+\alpha_4/T$ $T=(u_n+u_{n+1})/2+\alpha_5$
$g=\beta_1T^2+\beta_2T+\beta_3+\beta_4/T$ $T=(u_n+u_{n+1})/2+\beta_5$
2001
$0=\alpha_1$
$0=\alpha_2$
$17=\alpha_3$ (W/m K)
$0=\alpha_4$
$0=\alpha_5$
2002
$0=\beta_1$
$1100=\beta_2$ (J/m^3K^2)
1.93E+6=β_3 (J/m^3 K)

$0=\beta_4$
$0=\beta_5$

Clad
2003
$0=\alpha_1$
$0.12=\alpha_2$
$131=\alpha_3$ (W/m K)
$0=\alpha_4$
$0=\alpha_5$
2004
$0=\beta_1$
$1134=\beta_2$ (J/m^3K^2)
$2.10E+6=\beta_3$ (J/m^3 K)
$0=\beta_4$
$0=\beta_5$

Radial or Half-Plate description (3000 series cards)

3001
7.950E-5=radial increment length (m)
5=radial node to which increment applies
1=composition (1=fuel)
0.967=radial source (fraction of heat generated in fuel)
3002
9.4e-5=radial increment length (m)
7=radial node to which increment applies
2=composition (2=clad)
0=radial source (fraction of heat generated in clad)

Axial Description (4000 series cards)

4001
2.8415E-2=radial increment length (m)
20=node u=number up to which increment applies

Individual Channel Information (5000 series cards)

1=flow-forced channel
0=pressure drop (Pa)(zero for flow-forced)
2.06E-3=radial distance from center of slab to center of channel (m)
1=reactivity feedback weight factor of channel
0.55=loss coeff. For inlet of channel
0.65=loss coeff for outlet of channel

0.9=inlet area ratio
0.9=outlet area ratio
0.473=overall density/void coeff.($/% of core)
2.1070E-2=overall coolant temperature coeff ($/C)

0.0651=length of inlet plenum(m)
1.9193=length of outlet plenum (m)
0.3875=inlet plenum equiv. Diameter (m)

0.3875=outlet plenum equiv. Diameter (m)

1.980=axial flux peaking factors (one for each axial node)
1=moderator density feedback weighting factor
1=fuel density feedback weighting factor
1=coolant density feedback weighting factor

Delayed Neutron Information (6000 series cards)

group delayed neutron fraction	decay const.
3.30700-2	1.24000-2
2.19010-1	3.05000-2
1.95940-1	1.11000-1
3.94950-1	3.01000-1
1.15040-1	1.14
4.19900-2	3.01

Power or reactivity vs. Time (9000 series cards)

3=number of pairs of entries in table

reactivity ($)	time (s)
0	0
2.9	1.00-3
2.9	10

Moderator Inlet mass velocity vs. Time (10000 series cards)

2=number of pairs of entries in table

mass velocity	time (s)
3000	0
3000	10

Percent Linear Thermal Expansion of the Clad vs. Temperature (11000 series cards)

2=number of pairs of entries in table

% expansion	Temp (K)
0	58
0	4000

Total Pressure Drop vs. Time (12000 series cards)

Total pressure drop across channel	Time (s)
0	0
0	10

Time Increment vs. time (14000 series cards)

4=number of pairs of entries in table

time increment	as of time (s)
1.00-5	0
1.00-5	0.4
3.00-5	1.2
3.00-5	2

Print frquency vs. time (16000 series cards)

2=number of pairs of entries in table

Print time increment	Freq. Of input	as of time (s)
1	100	0
1	100	10

Pump mass velocity fraction vs. time (17000 series cards)

3=number of pairs of entries in table

coolant mass vel. Fraction	time(s)
1	0
1	0
0	10

Blade worth vs. blade location (18000 series cards)

2=number of pairs of entries in table

Reactivity of blade bank ($)	blade position (m)
0	0
-8.4	0.5683

LEU PARET input file:

```
    0
* PARET:  MITR LEU calc  $2.30 Step (w/ fins, 5 W, FC 1800 gpm HEU
cond.)
1001,     -1           20      7      0      1      1
1002,            1      1      6     -1      0     10
1003,     5.000-6    0.006700   1.18000+5   -33.0       5.06000-4
1004,     3.18000-4  3.18000-4   5.86000-2    5.28830-2  0.5683
0.00794
1005,     0.00794       0.0069      8.00-5       9.80664       0.01367
1006,     0.75         0.8000       1.0          992.00        0.0
1007,     3.674-3       0.0         0.0          0.0          1.0
0.001
1008,   0.0             0.0005        0.001        0.03          0.05
0.05
1009,   1.4             0.33
1111,   0.051225        1.00
1112,      1      2      1      0      0         2.260000+5   25.000
4227.0
1113,   1.20          0.1           7.4000         0.0
1114,   1.92          0.062
2001,   0.0           0.0           17.0          0.0          0.0
2002,   0.0            1100.0       1.92600+6    0.0          0.0
2003,   0.0          0.12           131.0         0.0          0.0
2004,   0.0            1134.0       2.10165+6    0.0          0.0
3001,    7.950-5      5      1      0.967
3002,    9.400-5      7      2      0.0
4001,    2.84150-2     20
5100,      1               0.       2.06000-3  1.00         0.55
0.65
5100,  0.9            0.9          0.4730         2.1070-2
5101,   0.0651        1.9193       0.3875       0.3875
5102,   1.98          1.0          1.0          1.0
5103,   2.0250        1.0          1.0          1.0
5104,   2.0700        1.0          1.0          1.0
5105,   2.1500        1.0          1.0          1.0
5106,   2.2300        1.0          1.0          1.0
5107,   2.1800        1.0          1.0          1.0
5108,   2.1200        1.0          1.0          1.0
5109,   1.8000        1.0          1.0          1.0
5110,   1.4900        1.0          1.0          1.0
5111,   1.2000        1.0          1.0          1.0
5112,   0.9200        1.0          1.0          1.0
```

```
5113,    0.8200      1.0        1.0        1.0
5114,    0.7200      1.0        1.0        1.0
5115,    0.6600      1.0        1.0        1.0
5116,    0.6000      1.0        1.0        1.0
5117,    0.5300      1.0        1.0        1.0
5118,    0.4600      1.0        1.0        1.0
5119,    0.4070      1.0        1.0        1.0
5120,    0.3600      1.0        1.0        1.0
5121,    0.3600      1.0        1.0        1.0
6001,     3.30700-2   1.24000-2   2.19010-1   3.05000-2   1.95940-1
1.11000-1
6002,     3.94950-1   3.01000-1   1.15040-1   1.1400      4.19900-2
3.0100
9000,      3
9001,      0.0        0.0          2.30       1.00-3           2.30
10.0
10000,     2
10001,    3000.       0.0         3000.       10.0
11000,     2
11001,    0.0         58.0       0.0         4000.0
12000,     2
12001,     0.0         0.0        0.0         10.0
14000,     4
14001,    1.00-5        0.0        1.00-5       0.40     3.00-5
1.20
14002,    3.00-4        2.0
16000,     2
16001,     1.00        500      0.0         1.0         500        10.0
17000,     3
17001,     1.00        0.0        1.0000      1.0         0.0         10.0
18000,     2
18001,     0.0        0.0        -14.50      0.5683
```