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PREDICTING ACTIVATION OF EXPERIMENTS INSIDE THE ANNULAR CORE RESEARCH REACTOR

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B.S. CHEMICAL ENGINEERING, UNIVERSITY OF NEW MEXICO, 2008
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THESIS

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Dedication

I dedicate this paper to my wife, Lesley Greenberg, for constantly encouraging me, feeding me, cleaning up after me, and doing anything she could to help me keep a positive attitude and to never give up. She motivates me to do great work no matter what and I would not have been able complete this without her.

Acknowledgments

I would like to thank Dr. Gary Cooper, my advisor, for his guidance and support which made it possible for me to work on a topic that is of great interest to me.

I am grateful for Isaac McGarvey for his C# programming help and patience teaching me the language and taking time to make sure I understood exactly what was happening in my code.

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Abstract

The objective of this thesis is to create a program to quickly estimate the radioactivity and decay of experiments conducted inside of the Annular Core Research Reactor (ACRR) at Sandia National Laboratories and eliminate the need for users to write code. This estimation is achieved by using MCNP to model the neutron fluxes in the reactor's central cavity where experiments are conducted using one of the four possible neutron spectra available in the ACRR. The desired neutron spectrum, experiment material composition, and reactor power level are then input into CINDER2008 burnup code to obtain activation and decay information for every isotope generated. DREAD creates all of the files required for CINDER2008 through user selected inputs in a graphical user interface and executes the program for the user and displays the resulting estimation for dose rate at various distances. The DREAD program was validated by weighing and measuring various experiments in the different spectra and then collecting dose rate information after they were irradiated and comparing it with the dose rates that DREAD predicted. The program provides results with an average of 17% higher estimates than the actual values and takes seconds to execute.

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Preface

This thesis is written to complete a master's of science in nuclear engineering. I currently hold a bachelor's of science in chemical engineering from the University of New Mexico as well as a certificate of completion for the Advanced Nuclear Power Course from the Naval Nuclear Power Training Command. I was formerly a shielding engineer for Knolls Atomic Power Laboratory (KAPL). I then became a qualified Engineering Officer of the Watch (EOOW), an instructor, and drill coordinator at the Kesselring site for KAPL. For the past 5 years I have been a nuclear reactor engineer and operator at Sandia National Laboratories (SNL) at the Annular Core Research Reactor (ACRR).

My work experiences inspired me to attain higher education in nuclear engineering and presented me with a problem that had no easy solution, which has become the topic for this thesis. The goal is to provide myself and coworkers with a tool that is easy to learn and will run quickly on any computer for accurate and conservative results to aid in ALARA practices.

1. Introduction

Understanding the effects of radiation interactions with matter is an ongoing effort that has wide variety of applications. These applications include: radiation hardening, radiation damage, gamma and x-ray environment testing, neutron environment testing, space testing, reactor component testing, radiation therapy, and numerous others (Attix, 1986). The use of test reactors is an excellent method for conducting experiments for any of the aforementioned applications. However, the benefits of the radiation studies come with consequences that can be viewed as undesirable or adverse; particularly with respect to health of personnel. This paper focuses on a method to better control and reduce these detrimental effects of using nuclear reactors for radiation studies by providing an improved method for predicting both the radioactivity that will be induced in the experiments placed in the reactor and the dose rates that personnel will be exposed to in handling the activated experiment.

Figure 1 – Three Experimental Cavities at the Annular Core Research Reactor Facility (ACRRF) During a Pulse

Reactor operators and experimenters at the Annular Core Research Reactor (ACRR) are exposed to various sources of radiation on a daily basis. The facility is home to neutron and gamma sources, an open pool nuclear reactor with three dry experiment cavities, transuranic isotopes, reactor fuel, and various forms of radioactive materials (Figure 1). The sources of radiation that the operators are potentially exposed to are all necessary for carrying out the mission of Sandia National Laboratories (SNL). While exposure of personnel to radiation is unavoidable, it is essential that all work be planned and conducted in such a manner that all exposures are <u>A</u>s <u>L</u>ow <u>A</u>s <u>R</u>easonably <u>A</u>chievable (ALARA). By practicing ALARA, deleterious effects of radiation to personnel are minimized and the public and governing agencies will view the work as being conducted in a safe and responsible manner. Understanding the existing sources of radiation and the levels at which personnel are exposed is a relatively simple task and the radiation can be controlled accordingly. The radioactivity of experiments that are irradiated inside of one of the cavities at the ACRR, however, currently cannot be measured prior to removal from the reactor. Thus, the exposure rate generated by an experiment upon removal from the reactor is not accurately known and presents a potential health risk to personnel.

One method for predicting the activation of experiments is to rely on the experience of the operators. This approach is discussed below and is necessarily subject to several limitations. Computer simulations, on the other hand, probably represent the best method for predicting the activation of materials irradiated inside of the ACRR. Historically, experiments have been modeled using the neutron photon Monte Carlo transport code, MCNP (LANL). While MCNP will provide accurate predictions if the experiment and neutron source are accurately modeled, Using MCNP routinely presents several practical problems. MCNP is a complex code that requires experienced users for both modeling new experiments and to implement changes to pre-existing models as experiments are modified. The calculations take a considerable amount of time to run (upwards of a month on a PC) or, alternatively, must be placed in queues on the supercomputer. As a result of the long calculation times, modeling an ever-increasing number of experiments becomes less and less practical and essentially eliminates the modeling of any last minute changes. To solve these problems, this thesis created a graphical user interface (GUI) in C# that uses the flux profile from various MCNP reactor models and applies it to the experiments with the CINDER (Holloway) activation code to predict the activity induced in an experiment and to estimate the associated dose rate that operators and experimenters will be exposed to when removing irradiated experiments from the reactor core. This resulting program is titled “Dose Rate Estimator for Activation and Decay”: DREAD.

2. Background

The biological effects of radiation have been well studied in multiple groups of people: medical radiation recipients, radium-dial painters, uranium miners, nuclear accidents, and atomic bomb survivors (Turner, 2007). The effects can be grouped into two categories; acute and delayed. The acute effects are commonly referred to as radiation sickness, which is defined as, [“The complex of symptoms characterizing the disease known as radiation injury, resulting from excessive exposure (greater than 200 rads or 2 gray) of the whole body (or large part) to ionizing radiation. The earliest of these symptoms are nausea, fatigue, vomiting, and diarrhea, which may be followed by loss of hair (epilation), hemorrhage, inflammation of the mouth and throat, and general loss of energy. In severe cases, where the radiation exposure has been approximately 1000 rad (10 gray) or more, death may occur within two to four weeks. Those who survive six weeks after the receipt of a single large dose of radiation to the whole body may generally be expected to recover”] (NRC Glossary).

The delayed effects, also known as somatic or latent effects, may take a long time to manifest themselves. Some of these effects are cancer, cataracts, life-shortening, sterility, effects on the fetus, and multiple others. The likelihood of developing one of these effects is dependent on the amount of dose received and over what period of time it was received. The U.S. government regulates the amount of radiation a worker can receive in a year to 5 rem, and companies will typically make separate, more conservative policies on how they handle dose. For example, the maximum amount of dose a worker can receive in a year without needing an approval to increase their allowed level at Sandia National Laboratories is 250 millirem. Organizations within the labs further limit and regulate the dose rates that their personnel are allowed to be exposed to and monitor the staff daily to ensure that radiation level limits are not exceeded. The long term and short term effects on humans from excessive radiation exposure can be very serious and minimizing exposure is a very high priority. An accurate prediction of the doses workers can expect from irradiated packages at the ACRR can aid in reducing the exposure of the workers.

For the acute cases of radiation effects, the rad (radiation absorbed dose) unit is typically used. However, for delayed effects of radiation the units of dose received by the individual are measured in terms of rem (roentgen equivalent man) for a dose equivalent quantity (Shleien, 1984). The dose rates displayed in DREAD are in mrem/hr, which is the unit used in the documentation controlling work at the ACRR. Millirem is based on the radiation absorbed and is scaled by a quality factor which is a measure of how severely the body will react to a given type of radiation. Gamma and beta have the lowest quality factors and neutrons and alphas have the highest. Since the radiation of interest is primarily gamma radiation from irradiated materials, the quality factor used in this work is just "one". While, it is possible to use the program to solve transuranic experiments, it would require changes to the factors and programming. Since experiments of this type are infrequent and are planned far in advance, it would be better to fully model these experiments with MCNP rather than use the approach developed in this thesis.

The Annular Core Research Reactor is very unique. It utilizes a BeO-UO2 ceramic fuel to conduct pulsing operations. A pulse is generated when the reactivity insertion in the reactor is greater than the effective delayed neutron fraction for that particular reactor. This value is commonly referred to as $1 for pulse type reactors. This means that the fission chain reaction has enough neutrons from the fission events to continue a constant or increasing power level, which is referred to as prompt critical. There is no safety system fast enough to control a reactor of this type, and without a mechanism to shut down, the reactor will turn into a single use reactor (bomb). The ACRR is not highly enriched, and does have a mechanism to shut down. This mechanism is called Doppler broadening and is the result of the cross section resonances of U-238 expanding and absorbing neutrons as the fuel heats up. These neutrons do not cause fissions and are essentially eliminated from the neutron lifecycle. Once the absorption rate becomes fast enough to make the reactor subcritical, the reactor power will rapidly decrease. By the time the fuel cools off enough to reduce the negative reactivity induced by the Doppler broadening, the control rods have been dropped back into the core and the excursion is terminated. The rapid rise and fall of power occurs in about 7ms at Full Width at Half Maximum (FWHM) and is called a pulse.

Most experiments at the ACRRF are conducted inside the ACRR central cavity. The central cavity is a 9” diameter stainless steel cylinder that extends from above the upper bridge plate to the bottom of the reactor tank. It is equipped with a cavity purge system that creates a negative pressure inside of the cavity by drawing air through a series of filter banks and then releasing it through a stack above the facility. Typically, a 32-inch pedestal is placed at the bottom of the central cavity so that experiments can easily be placed at the flux centerline of the reactor, which is about 14 inches above the top of the pedestal. This is the location where DREAD is currently calibrated. There are other locations for experiments to take place at the facility including the neutron radiography tube, the FREC-II external core, and in-core test locations (Figure 2). DREAD currently only models the ACRR central cavity neutron activation, but in the future could be used for any of the locations or expanded for larger experiments where accuracy is more important than conservatism.

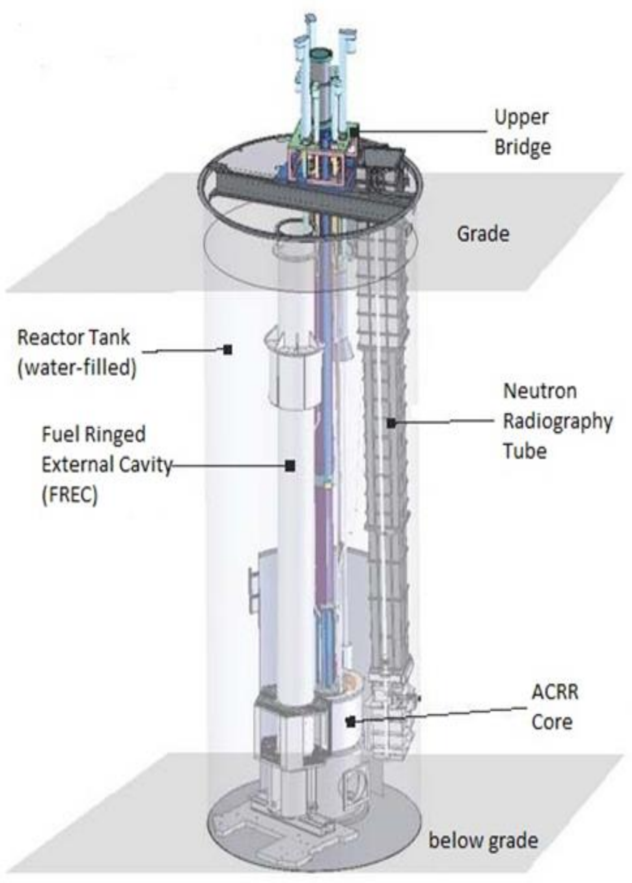

Upper Bridge
Grade
Reactor Tank (water-filled)
Neutron Radiography Tube
Fuel Ringed External Cavity (FREC)
ACRR Core
below grade

Figure 2- Experiment locations at ACRRF

The experiments at ACRR range from small dosimetry foils to large complex electronics assemblies. The neutrons in the core are mostly epithermal, about 10 keV on average, and, for many experiments, this is not the desired energy for the neutrons. For example, an experimenter may want to determine how their electronics will react to a nuclear weapon detonation in the atmosphere where the neutron spectrum is significantly harder than the spectrum in a water moderated reactor. In general, thermal neutrons are much more readily absorbed by materials versus fast neutrons. Many exhibit 1/v absorption characteristics, meaning that the lower the energy of the neutron, the more likely it is to be absorbed. To modify the energy of the neutrons that the experiment is subjected to, buckets composed of different materials are used. There are four different modifier regimes that the reactor currently utilizes: free field, a lead boron bucket for emphasis on fast neutron interaction, a lead poly bucket for thermal interaction, and a poly lead graphite bucket that serves as another thermal modifier. These spectrum modifiers are discussed and compared in more detail in the computer codes section.

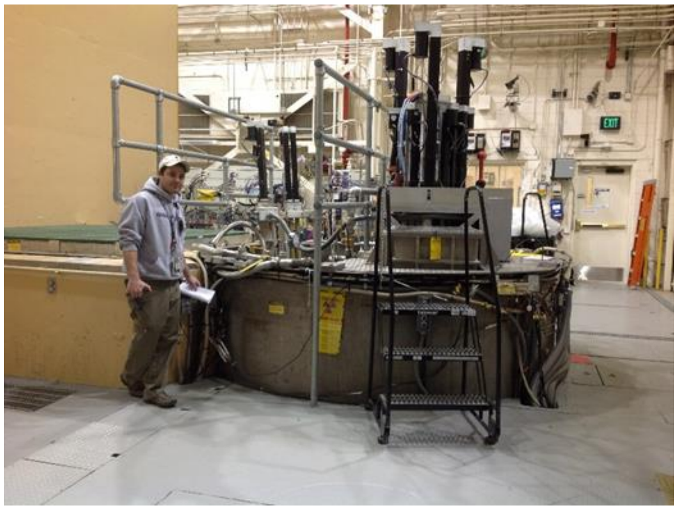


Figure 3 - View of the rod control drive motors (and me) surrounding the opening for the central cavity

After the target has been irradiated, the reactor operators must remove it from the central cavity using a 3-ton crane. Upon removal from the cavity, experimenters will climb a few steps, and standing on the upper bridge plate (Figure 3) will guide it to its next destination, which could be into a floor storage hole, onto a workbench, or into a shielded holding cell. This process involves the experimenter putting a plastic sleeve around the experiment and guiding it by hand to the proper area to make sure it does not come into contact with other structures or components. The typical work control allows experiments to be removed from the central cavity if the contact exposure rate is less than 30 R/hour. DREAD will give these experimenters and operators a better idea of how long to wait prior to removing an experiment, what exposure rates to expect, and how to prepare when pulling up an experiment. Minimizing exposure once the experiment package has been removed is still reliant on time, distance, and shielding; all of which are controlled by the operators and experimenters to some degree.

Currently, the expectations and wait times are all generally estimated from prior experiences with similar experiments. The reliance on experience falls short in a few areas. Aging staff members who retire and staff members who choose to change jobs have a lot of prior knowledge that leaves when they leave. New employees trying to determine wait times and expected radiation dose rates will lack this essential historical knowledge and may result in workers receiving more dose than "As Low As Reasonably Achievable". Further, new experiments and materials irradiated may not be fully understood by the senior staff and the best guess techniques would typically be used. Given the limited number of staff members, the low, allowable exposure limits for personnel, and the significant increase in the number of experiments that must be performed requires better anticipation of irradiate experiment dose rates. DREAD is a solution to these issues.

3. Computational Approach

Overview

DREAD utilizes three separate computer codes to function. The three codes are: MCNP 6.1, CINDER 2008, and Microsoft Visual Studio Professional 2013 © in C# language. MCNP is used to generate a model of the neutron flux in ACRR as a function of location and energy and this output is used as input to the energy group fluxes required for running CINDER. CINDER uses an algorithm to calculate the activation/transmutation of isotopes and outputs radiation, energies, curies, among other quantities for each isotope entered and created. The C# programming generates a GUI that anyone familiar with the reactor will be able to use. The user will be able to select from a list of a number of typical, reactor set-up configurations and from a number of commonly used materials that are to be irradiated. The GUI generates the four input decks required by CINDER based on the user's input and automatically will run CINDER. It then deciphers the output files from CINDER for the user and will display the mrem/hr they can expect to see after their selected irradiation and wait times.

MCNP

MCNP was chosen because the reactor models that have been validated for the ACRR have been created in MCNP and the code is available for use. The website description of MCNP states, "MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. Specific areas of application include, but are not limited to, radiation protection and dosimetry, radiation shielding, radiography, medical physics, nuclear criticality safety, Detector Design and analysis, nuclear oil well logging, Accelerator target design, Fission and fusion reactor design, decontamination and decommissioning. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori" (LANL).

Modifications were done to the MCNP model (Appendix A) to better represent the present structure of the reactor, narrow the scope of the model to look solely at neutron interactions vice photon and neutron interactions, and form energy groups consistent with the group numbers required by CINDER. Different models needed to be run for each of the different spectrum modifying buckets.

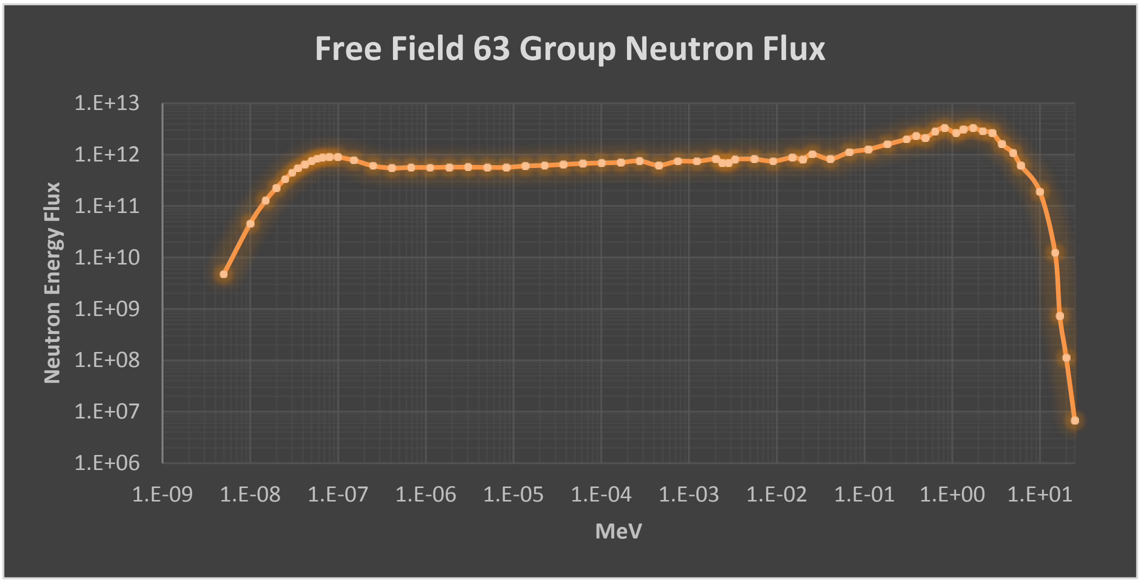


Figure 4 - Free Field Neutron Energy Flux per MW

Alterations of the code can be seen commented out in Appendix A. The most basic reactor model is the free field model (Figures 4 & 5). As the name states, there is not a spectrum modifier in the neutron field. Experimenters who are satisfied with the neutron spectrum of the reactor without modification will load their experiments into the central cavity on aluminum stands or in thin walled aluminum cans which have little effect on reactivity. Lines 1079 to 1115 in Appendix A are the f4 tally setup, with 1001 signifying a 6-cm sphere of interest at the centerline of the flux, number of particles to start with, and the mode for running the MCNP model. The number of starting particles was the number required to result in statistically smooth function graphs.

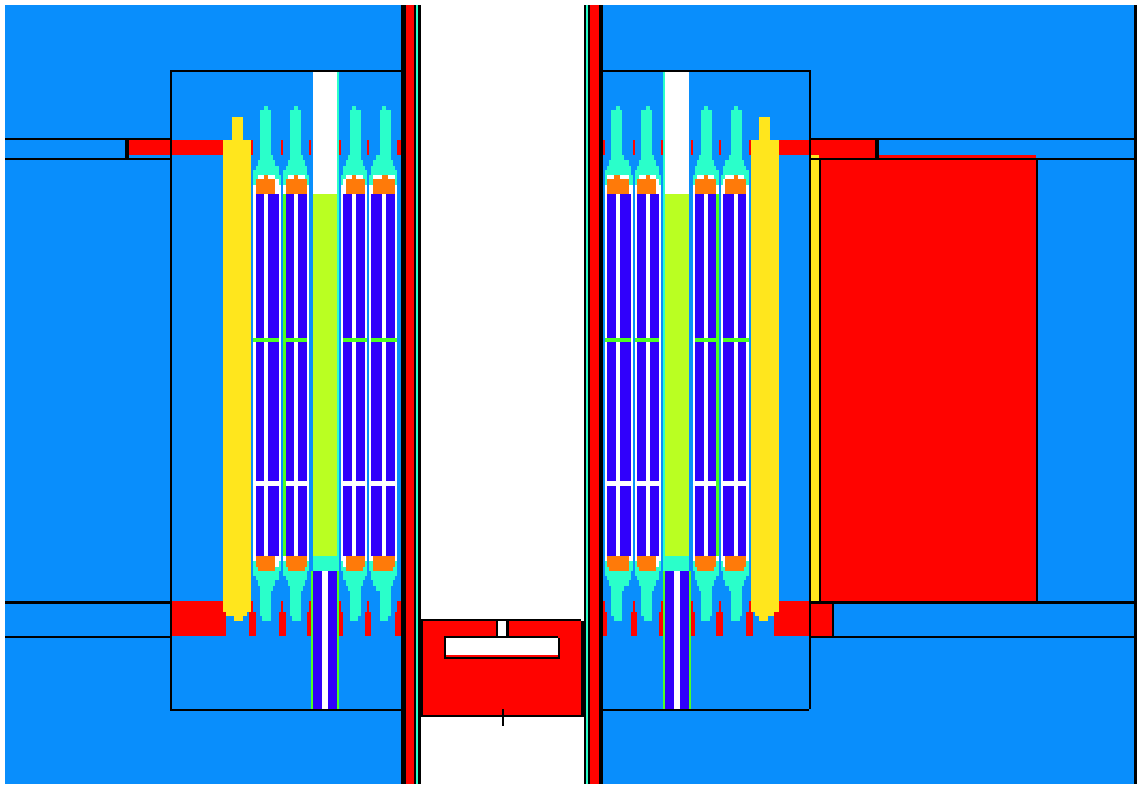


Figure 5 - Vised side cross section view of Free Field MCNP input model

Fewer particles resulted in energy band fluxes that appeared to jump orders of magnitude between adjacent energy bands, which is not indicative of actual neutron thermalization. These numbers stayed the same for all kcode runs. The variations in the code begin at line 265, where the commented sections were uncommented to add various spectrum modifiers to the code accordingly.

The 44 inch lead boron bucket (Figure 6) configuration exhibited the most sensitivity to the number of particle histories ran as shown in Figures 7 and 8. It is clear that from the 100,000 particle run that the thermal neutron energy flux was subject to unrealistic statistical fluctuations. The 10,000,000 particle k-code run, however, produced much better results.

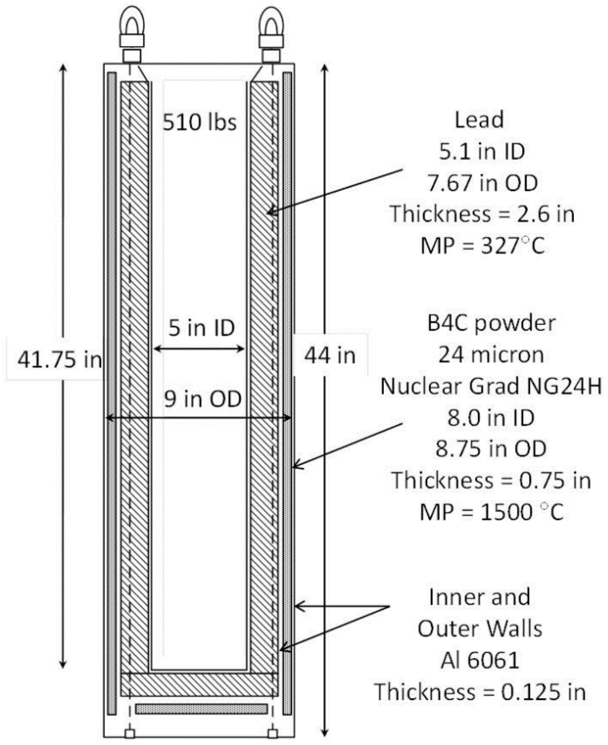


Figure 6 - 44 inch Lead Boron Bucket

However, it required using Sandia National Laboratories' super computer to finish within a reasonable amount of time versus a desktop PC which would have taken over a month of runtime.

The portion of the spectrum that is non-physical in the 100,000 particle run is similar in shape but not magnitude to that of the 10,000,000 particle run. Since the thermal region for neutrons is where the majority of absorptions take place, however, it needs to be as accurate as possible to get accurate, useful results from CINDER. While the calculated spectra from the other geometries did not display the same degree of sensitivity, they were rerun on the supercomputer with 10,000,000 particles for consistency and the all the resulting calculated spectra were smoothed to give a better representation of the actual neutron energy flux in the 6-cm sphere.

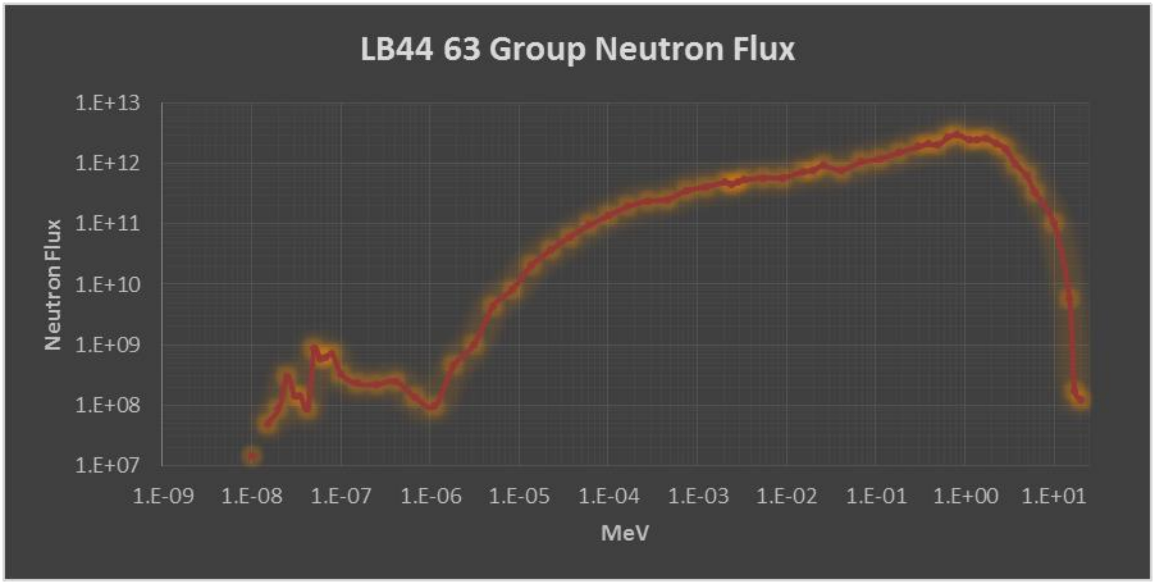


Figure 7 - 44 inch lead boron bucket with 100,000 particles energy flux per MW

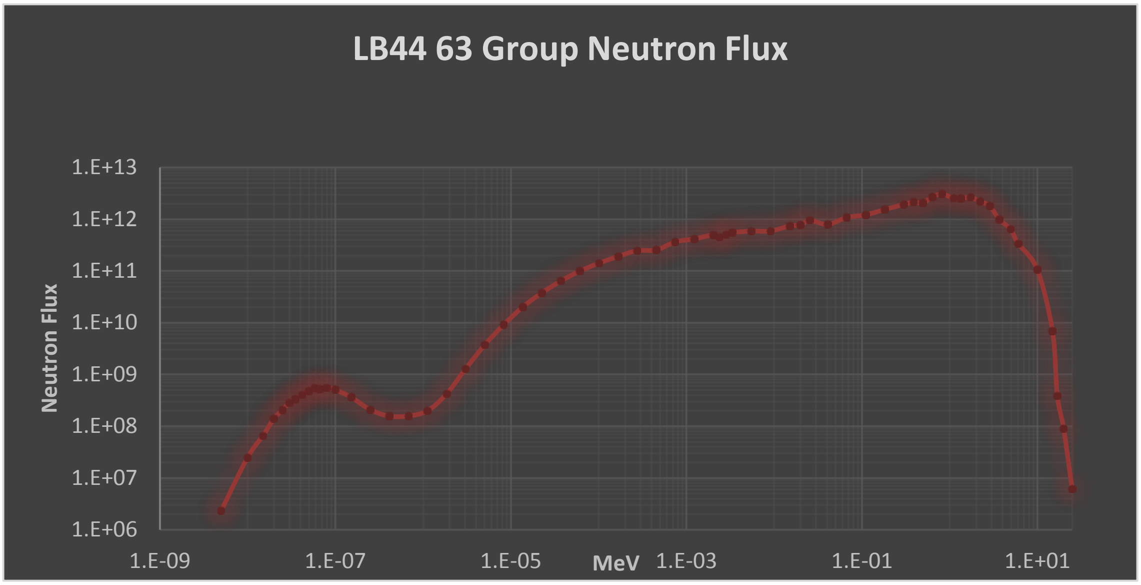


Figure 8 - 44 inch lead boron bucket with 10,000,000 particles energy flux per MW

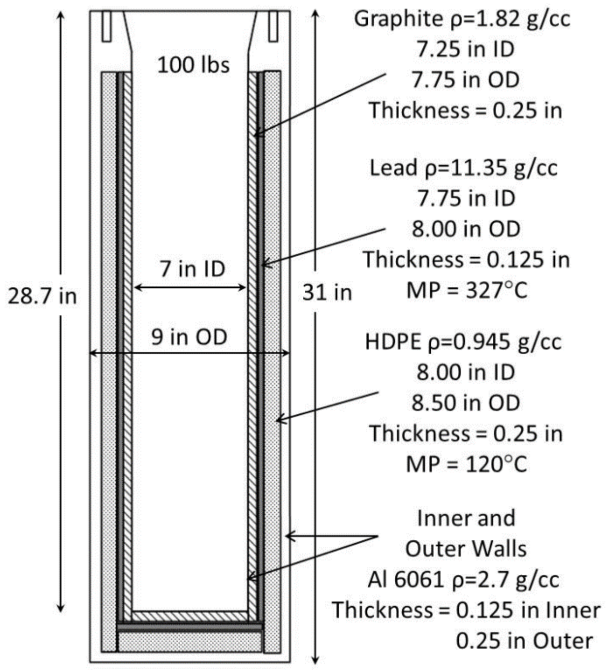


Figure 9 - Poly-Lead-Graphite bucket cross section

Plots for the poly-lead-graphite (Figure 9) and lead-poly buckets were also generated. All of the plots were compared on a single graph to better visualize their effects on the neutron energy inside of each bucket (Figure 10). This graph is on a log-log scale to fit all of the information in one view. To the eye this log-log view tends to underemphasize the significant differences between the spectra, but several large differences can be noted. The most obvious difference is between

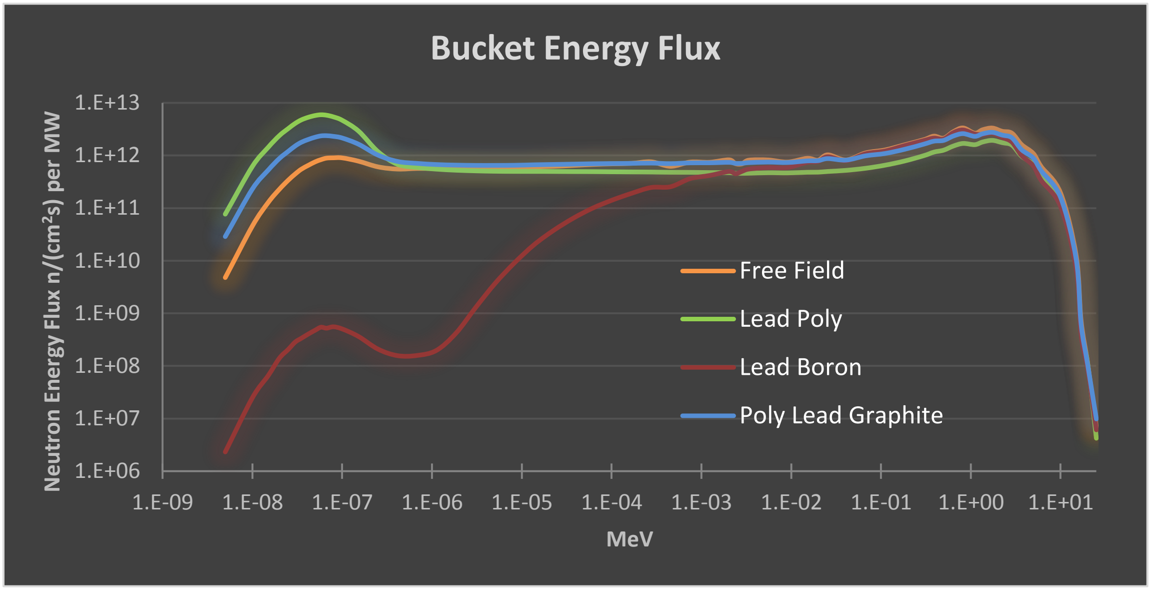


Figure 10 - Bucket energy flux per MW comparison

the lead boron bucket and the rest of the buckets. The thermal neutron flux reaching the 6 cm sphere of interest is many orders-of-magnitude lower than the next lowest thermal neutron flux: free field. This information is useful to experimenters who desire to remove or generate thermal neutrons for their experiments. An experimenter who is not familiar with nuclear reactors may make requests that do not suit his/her needs and it is the duty of the reactor operations staff to help interpret their goals. Neutron damage to electronic parts is often related to 1-MeV, silicone-equivalent neutrons (Williams, 2007). An experimenter who wants thermal neutron absorption would be advised to use the poly lead graphite bucket. These buckets require about 1,000 to 10,000 times less energy from the reactor to achieve the same number of thermal neutrons interacting with the target as in a lead boron bucket operation and 10 times less energy than a free field operation. Experimenters only interested in fast neutron interaction might consider using the lead boron bucket, which filters out a factor of 1,000 thermal neutrons from interacting with the experiment.

The plots (Figures 4, 8, and 10) were created from the 63 group neutron tally calculated from MCNP. To convert the output of MCNP into useful information,

$$\Phi\left[\frac{\text{neutron}}{\text{cm}^2\text{s}}\right]=\frac{P[\text{W}]\bar{\nu}\left[\frac{\text{neutron}}{\text{fission}}\right]}{\left(1.6022\cdot10^{-13}\frac{\text{J}}{\text{MeV}}\right)w_f\left[\frac{\text{MeV}}{\text{fission}}\right]}\frac{1}{k_{eff}}\Phi_{F4}\left[\frac{1}{\text{cm}^2}\right]$$

Equation 1- Total Neutron Flux Scaling Factor for MCNP F4 Tally

P – Power of the reactor in watts
v – Average neutrons per fission 2.44
w_f – energy released per fission 192.4 MeV
ϕ – neutron flux in energy band
ϕ_{f4} – f4 tally result from MCNP
k_{eff} – MCNP effective multiplication factor

several transformations of the data were required. The output from MCNP for these runs is per source neutron. To convert the fission source neutrons into neutron flux at different energy levels, a scaling factor was used to convert source fission neutron flux into flux per MW. This scaling factor was then multiplied by the f4 tally flux and divided by the keff of the kcode run in order to determine the flux inside each energy band. Equation 1 (Snoj, 2006) represents the calculation to determine each energy group flux. Once the flux in each energy group was determined, it was averaged over the energy group width to display on a point on the graph per average MeV in the band rather than per energy band used, which would form a step function graph. All of the MCNP computations were completed once all four plots were generated and fluxes were determined for each energy group for each of the four spectrum modifiers.

CINDER

CINDER2008 is a code used to calculate the inventory of nuclides in an irradiated material (England, 1964). This is also referred to as activation/depletion, burn-up, transmutation, etc. CINDER was chosen because of its extremely fast run time and it uses nuclide data libraries that have already been established, such as ENDF-7. It requires a very specific set of inputs consisting of at least four different files and many variables that have stringent numbers of characters. Creating the input files for CINDER is a very tedious and time consuming process. The four different file types required for CINDER to run are: input, fluxes, locate, and material.

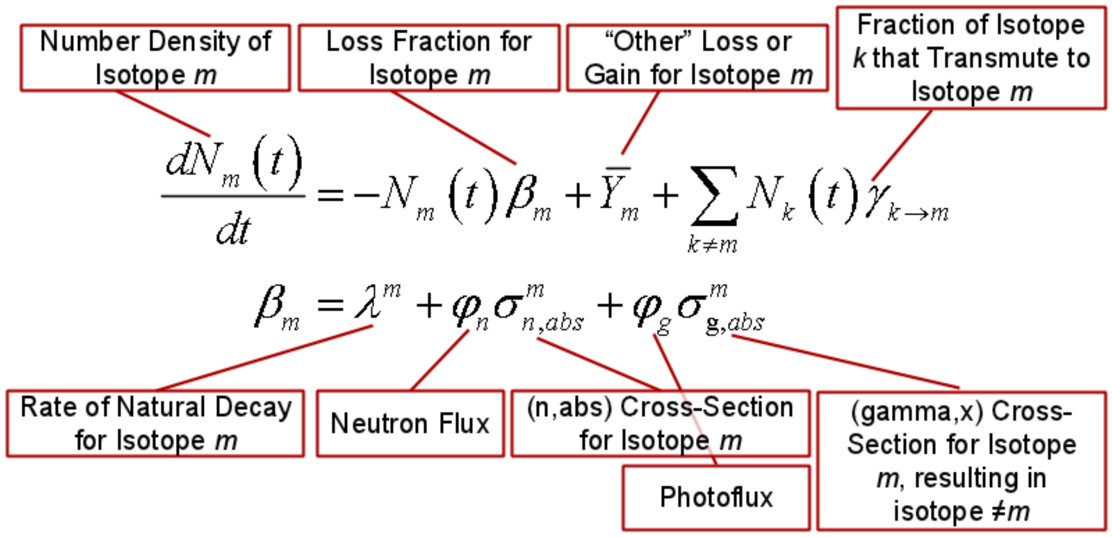
The input file includes a calculation name, a free form comma separated string which includes the volume of material and the flux multiplier, a description, the flux file's name, the material file name, the flux on time and multiplier, and the wait time. This file tells CINDER what files to use for data generation, how much to multiply the basic flux of 1 MW to achieve the user desired flux, how long to run the reactor, and how long to wait before removing the sample. The way input is created results in two sets of output, the isotope information at the time the reactor was shut down and the information when the experiment is going to be removed (See Input in Appendix B).

The Fluxes file is what CINDER uses as the base flux for the input file. It consists of a title, the number of neutron energy groups, the flux name, the total neutron flux, and the neutron flux in each energy group. The fluxes entered in the total and individual energy group fluxes are reliant on the type of spectrum that the user wants to input. These values were calculated in Microsoft Excel 2013© from the MCNP generated spectra (See Fluxes in Appendix B).

The locate file tells CINDER where the library and executable for CINDER are located. It can be modified from the default setting, but it is in the C: folder by default. The string for the location is limited to 80 characters, so burying the file inside multiple folders may prove problematic.   This file does not change from run to run unless the path for the CINDER files changes.

The material file is the largest of the files, as it includes the total number of nuclides to run, the total number of atoms/barn-centimeter, the AZS identifier for each nuclide, and the fraction of total atoms that is present from each nuclide. CINDER will recognize 0 as the fraction for each nuclide, so including every nuclide in a base file and writing values only for the nuclides present is acceptable. For DREAD, every stable isotope for each element up to lead is included in the material file. An example of a material file can be seen in Appendix B under Material. DREAD creates all of these files for the user and automatically runs the CINDER code with the desired spectrum and materials. The method for this is described in the next section.

The method CINDER uses to determine the activation and decay is the Bateman equation shown in Figure 11.



$$\frac{dN_m(t)}{dt} = -N_m(t)\beta_m + \bar{Y}_m + \sum_{k \neq m} N_k(t)\gamma_{k \to m}$$

$$\beta_m = \lambda^m + \varphi_n \sigma^m_{n,abs} + \varphi_g \sigma^m_{\mathrm{g},abs}$$

Number Density of Isotope *m*
Loss Fraction for Isotope *m*
"Other" Loss or Gain for Isotope *m*
Fraction of Isotope *k* that Transmute to Isotope *m*
Rate of Natural Decay for Isotope *m*
Neutron Flux
(n,abs) Cross-Section for Isotope *m*
Photoflux
(gamma,x) Cross-Section for Isotope *m*, resulting in isotope ≠*m*

Figure 11 - Bateman equation w/ variable explanations from CINDER User Manual prepared by Billy Martin 2014

The equation is a sum of the losses, gains, and transmutations of a particular isotope. CINDER solves all of the decay chains simultaneously for all of the isotopes present and generated in the input problem. The output files from cinder are very detailed and provide information about every nuclide at each time step. The two output files of most interest for this paper are the tables_by_grp and tables_by_major. The tables_by_grp file contains the gamma radiation information that is used to determine dose rates. It displays the gamma contribution including the number of gammas and the average energy for each isotope and a t all isotopes with an overall average energy. The tables_by_major file contains information about each isotope such as mass, curies, decay power, etc.

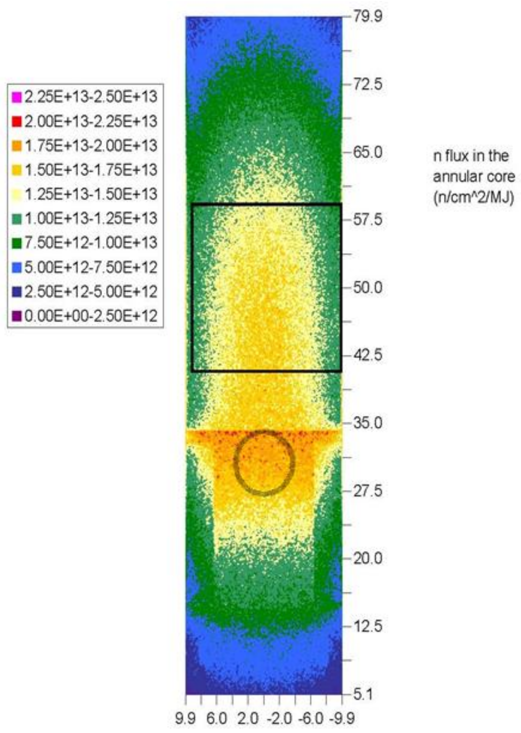


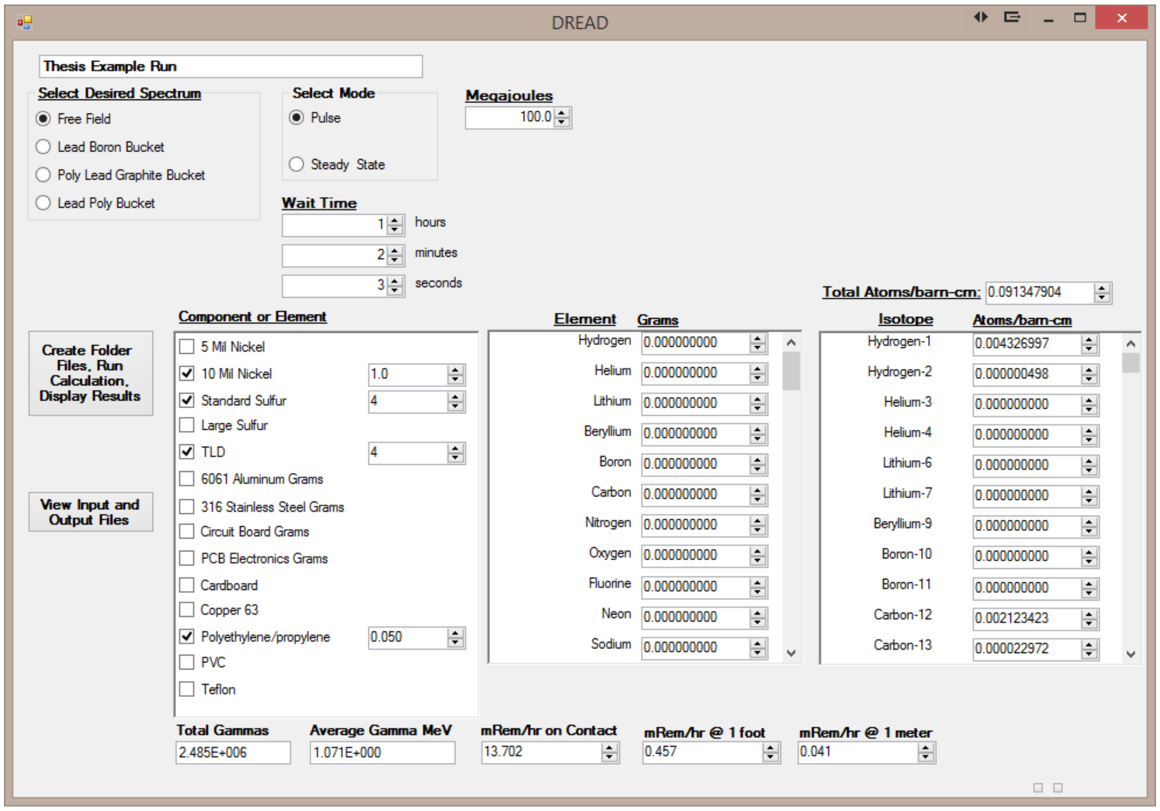
Figure 12 - example of flux differences in central cavity based on location- box vs. sphere

With the information from these two tables it is possible to determine dose rates, keeping in mind the limitations of using CINDER. The program does not account for self-shielding and assumes all of the atoms see the full flux that the user inputs. For smaller parts and materials this is very close to reality, but for larger objects or isotopes with very large neutron cross sections, the inside of the part or experiment will see a significantly lower flux than the portion nearest the reactor. The self-shielding also applies to determining a dose rate. If the part is assumed to be a point source then there is no accounting for self-shielding the gamma radiation it is emitting. Both of these cases will result in a conservative dose calculation, which is desired if determining a wait time to safely remove an experiment from the central cavity. Larger experiments that are outside the small 6-cm sphere that was determined to be the largest flux in the reactor will also have overestimated calculated dose. The flux in the reactor changes outside of the 6-cm sphere of interest as seen in Figure 12. For example, if the experiment were 9 inches in diameter and higher up in the cavity, such as the location of the cylinder in Figure 12, then the flux would be about half of that in the sphere region in Figure 12 which is what was analyzed in the computer models. A new flux tally would be required to get model results closer to empirical data.

DREAD

DREAD – Dose Rate Estimator for Activation and Decay – is a graphical user interface that the operator and experimenters who do not know how to code CINDER/MCNP can use to get a quick estimation of dose rates (and other activation information) when removing experiments from the central cavity at ACRR. The program was created using Microsoft Visual Studio in the C# programming language. This style of programming allows the programmer to easily create the layout of the windows they are working on and then program the objects created in the window to perform however he/she desires. This method was chosen because it is in a style similar to many common programs used in windows, it is easy to manipulate the user interface, the programming language is common, and it is simple to debug. The code is located in Appendix C.

DREAD has two slightly different user input choices based on the type of experiment being conducted. ACRR operates in steady state modes and in pulse modes. The most common mode is the pulse mode in a free field spectrum, which is the default setting in DREAD (see Figure 13). A typical DREAD run takes about 5 seconds to run and display results.


DREAD

Thesis Example Run

Select Desired Spectrum

- [✓ Free Field]
- Lead Boron Bucket
- Poly Lead Graphite Bucket
- Lead Poly Bucket

Select Mode

- [✓ Pulse]
- Steady State

Megajoules 100.0

Wait Time

1	hours
2	minutes
3	seconds

Create Folder Files, Run Calculation, Display Results

View Input and Output Files

Component or Element

	5 Mil Nickel	
✓	10 Mil Nickel	1.0
✓	Standard Sulfur	4
	Large Sulfur	
✓	TLD	4
	6061 Aluminum Grams	
	316 Stainless Steel Grams	
	Circuit Board Grams	
	PCB Electronics Grams	
	Cardboard	
	Copper 63	
✓	Polyethylene/propylene	0.050
	PVC	
	Teflon	

Element	Grams
Hydrogen	0.000000000
Helium	0.000000000
Lithium	0.000000000
Beryllium	0.000000000
Boron	0.000000000
Carbon	0.000000000
Nitrogen	0.000000000
Oxygen	0.000000000
Fluorine	0.000000000
Neon	0.000000000
Sodium	0.000000000

Total Atoms/barn-cm: 0.091347904

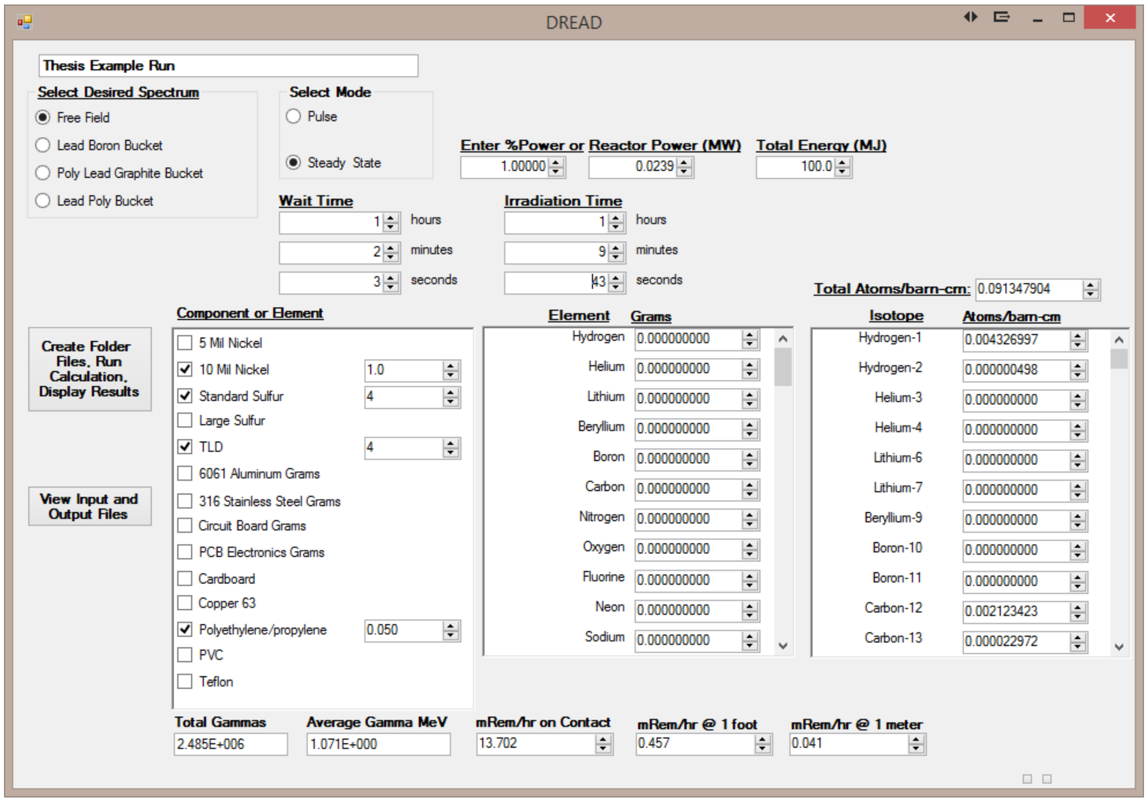
Isotope	Atoms/barn-cm
Hydrogen-1	0.004326997
Hydrogen-2	0.000000498
Helium-3	0.000000000
Helium-4	0.000000000
Lithium-6	0.000000000
Lithium-7	0.000000000
Beryllium-9	0.000000000
Boron-10	0.000000000
Boron-11	0.000000000
Carbon-12	0.002123423
Carbon-13	0.000022972

Total Gammas	Average Gamma MeV	mRem/hr on Contact	mRem/hr @ 1 foot	mRem/hr @ 1 meter
2.485E+006	1.071E+000	13.702	0.457	0.041

Figure 13- DREAD Thesis Example Run of a dosimetry packet for a 100 MJ reactor pulse with a decay time of 1 hour 2 minutes and 3 seconds

In the pulse mode, the user inputs the megajoules for the pulse, the time to wait before removing the experiment from the central cavity, and the material composition of the experiment. There are several common components that have been generated under the "Component or Element" menu (Figures 13 & 14). The user also can select the grams of any naturally occurring element. For isotopes that are enriched, the user enters the atoms/barn-cm or can request to generate a component in the component list, such as copper-63. In the example in Figure 13, the reactor is setup to perform a 100 MJ pulse on a dosimetry pack consisting of one nickel piece, four TLDs, four Sulfur tablets, and some plastic holding them together. The inputs to cinder can be seen in Appendix B for this example. The dose-rate results boxes in DREAD are hidden until the user runs the program and the output files from CINDER are read by DREAD and dose-rate calculations are performed. The total number of gammas and the average gamma MeV are read from the output files of CINDER. DREAD calculates the dose rates at the various distances and displays the on-contact, the 1-foot, and 1-meter expected dose rates. The assumption in DREAD for a pulse is a 1-second time interval over which all of the energy is deposited.

The steady-state mode is slightly different from the pulse mode. The user must input the power level, either in % power or in MW, and the amount of time to run at that power. A separate calculation screen appears to the right of these inputs and tells the user how many MJ their run will produce in the reactor (Figure 14).



DREAD
Create Folder Files, Run Calculation, Display Results
View Input and Output Files

Thesis Example Run

Select Desired Spectrum
- [✓ Free Field]
- Lead Boron Bucket
- Poly Lead Graphite Bucket
- Lead Poly Bucket

Select Mode
- Pulse
- [✓ Steady State]

Enter %Power or	Reactor Power (MW)	Total Energy (MJ)
1.00000	0.0239	100.0

Wait Time		Irradiation Time	
1	hours	1	hours
2	minutes	9	minutes
3	seconds	43	seconds

Total Atoms/barn-cm: 0.091347904

Component or Element	
☐ 5 Mil Nickel	
☑ 10 Mil Nickel	1.0
☑ Standard Sulfur	4
☐ Large Sulfur	
☑ TLD	4
☐ 6061 Aluminum Grams	
☐ 316 Stainless Steel Grams	
☐ Circuit Board Grams	
☐ PCB Electronics Grams	
☐ Cardboard	
☐ Copper 63	
☑ Polyethylene/propylene	0.050
☐ PVC	
☐ Teflon	

Element	Grams
Hydrogen	0.000000000
Helium	0.000000000
Lithium	0.000000000
Beryllium	0.000000000
Boron	0.000000000
Carbon	0.000000000
Nitrogen	0.000000000
Oxygen	0.000000000
Fluorine	0.000000000
Neon	0.000000000
Sodium	0.000000000

Isotope	Atoms/barn-cm
Hydrogen-1	0.004326997
Hydrogen-2	0.000000498
Helium-3	0.000000000
Helium-4	0.000000000
Lithium-6	0.000000000
Lithium-7	0.000000000
Beryllium-9	0.000000000
Boron-10	0.000000000
Boron-11	0.000000000
Carbon-12	0.002123423
Carbon-13	0.000022972

Total Gammas	Average Gamma MeV	mRem/hr on Contact	mRem/hr @ 1 foot	mRem/hr @ 1 meter
2.485E+006	1.071E+000	13.702	0.457	0.041

Figure 14 - Steady state example

This input will set up a different input deck configuration for CINDER by dividing the reactor power in MW by the initial default level of 1 MW to give a scaling factor to use when applying the spectrum flux to the experiment. There is currently only one step for this mode and it applies the flux evenly over the irradiation time. Further this mode treats the build-up and decay of the various radionuclides during the irradiation, which will result in a realistic activation profile at the end of the run and the end of the wait. The rest of the program is not affected by switching modes.

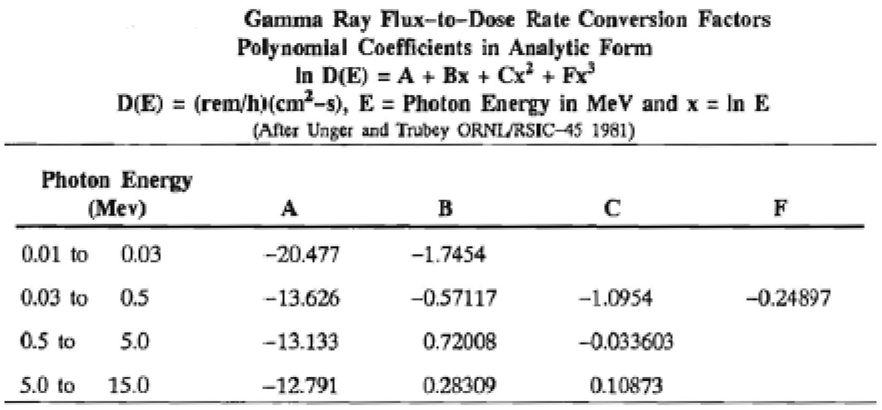
The user selects what spectrum they are interested in doing a prediction and spectrum's flux from MCNP is imported into the fluxes input file for CINDER. The material file is generated when the user runs the program and is generated based on the user inputs selected from the element grams or in the component section. Every atoms/barn-cm are updated whenever a value is changed in the elements or component section, so users desiring to use this feature are advised not to change the component or elements or their entries may be erased.

DREAD was written to give operators an idea of what dose rate to expect when removing experiments from the central cavity, but there is a large amount of data that is also produced from CINDER's calculations. The "View Input and Output Files" button opens the folder (has only been tested in Windows) where the input files and output files are located. Here, all of the input and output files from CINDER are located and can be opened in almost any text editing software.

From these files the user can access the information discussed in the CINDER section. If the experimenter wants to create a certain amount of curies of a particular isotope, DREAD can be used to provide an estimation of the number of curies created and what type of dose rate to expect from the irradiated material.

The dose calculation is based on a point source emitting gamma radiation uniformly in all directions.   Lines 2205 to 2234 convert the gamma rays at the source to a flux at the desired distance (30 cm) from the source using this equation: $\varphi = S/4\pi r^2$ where S is the source strength, r is the distance from the source in cm, and φ represents the flux per cm^2 - second. Simultaneously, the code multiplies the gamma flux by the corresponding gamma ray flux-to-dose conversion factor in Table I (Shleien, 1984).

Table I - Gamma flux-to-dose rate conversion factors



Gamma Ray Flux-to-Dose Rate Conversion Factors
Polynomial Coefficients in Analytic Form
$\ln D(E) = A + Bx + Cx^2 + Fx^3$
$D(E) = (\text{rem/h})(\text{cm}^2\text{-s})$, E = Photon Energy in MeV and $x = \ln E$
(After Unger and Trubey ORNL/RSIC-45 1981)

Photon Energy (Mev)	A	B	C	F
0.01 to 0.03	−20.477	−1.7454		
0.03 to 0.5	−13.626	−0.57117	−1.0954	−0.24897
0.5 to 5.0	−13.133	0.72008	−0.033603	
5.0 to 15.0	−12.791	0.28309	0.10873	

The dose at 30 cm (~1-foot) is then used to determine the approximate dose at 1 meter and on-contact. The 1 meter calculation used the $1/r^2$ point source approximation (Lamarsh, 1983), which is $30^2/100^2$ or a factor of 0.09. The dose on-contact is a little more difficult to estimate. This is due to detector geometry,

geometry of the irradiated material, and orientation of the material. The original factor is estimated to be 30 times larger than the dose rate at 1-foot for a standard size part. This value may be changed once validation experiments are performed to provide more realistic results.

4. Empirical Approach

Before DREAD can be implemented as a reliable method for predicting dose rates from an experiment given its geometry and material make up and the irradiation spectrum to which it will be exposed, it must be validated by comparing dose rate predictions for a large variety of experiments and spectrum combinations with the experimentally measured dose rates. Since it is desired to obtain dose rates on-contact and at 30 cm (one foot), and since the dose rates by definition are not known, or at least not known well, strict experimental procedures must be established and followed to ensure that ALARA is practiced and that the experimenter does not exceed the Sandia National Laboratory dose limit of 250 mrem/yr.

Performing potentially hazardous work at ACRR requires multiple levels of paperwork and approvals which are required per corporate policy and DOE orders. Two documents were required to be written prior to performing the dose rate measurements: a facility work plan (FWP) and an engineered job safety analysis (EJSA). The facility work plan describes the work taking place and ensures that it is not outside of the operating envelope described in the facility's documented safety analysis. It is reviewed and approved by the manager of the facility as well as the facility supervisor. The engineered job safety analysis describes the steps that take place to perform the work and a hazard analysis of each step is documented as well as how to control each hazard. It is reviewed and approved by the facility supervisor. The FWP and EJSA are performed under a radiological technical work document (RTWD) which describes the

Personal Protective Equipment hazards, hold and void points, acceptable dose rates, and various other details when handling experiments removed from the ACRR central cavity. The RTWD is reviewed and approved by a radiation protection department engineer, the facility supervisor, and the manager for the facility.

The description and steps in the EJSA and FWP are fairly simple: follow the guidance of the RTWD and use an appropriate gamma/beta meter to measure the dose rates of experiments that have been irradiated.

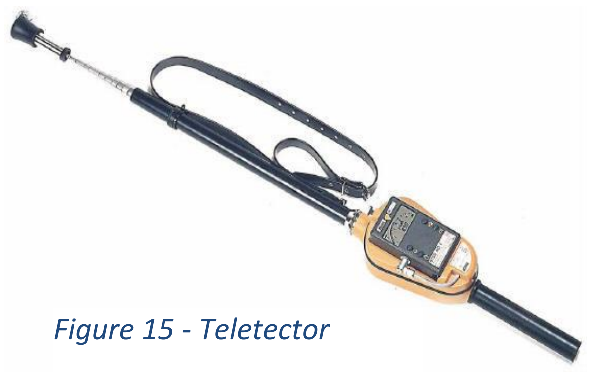


Figure 15 - Teletector

The detectors used for measuring dose rates of the experiments were the Thermo Eberline RO20 (Figure 15), the Teletector (Figure 16). The RO20 is calibrated to a Cs-137 source which emits gamma radiation at 662 keV energy. It is an air-filled ion chamber used for portable radiation measurement. The display can read from 0 to 5 mrem/hr and the adjustment dial can support readings up to 50 rem/hr. The

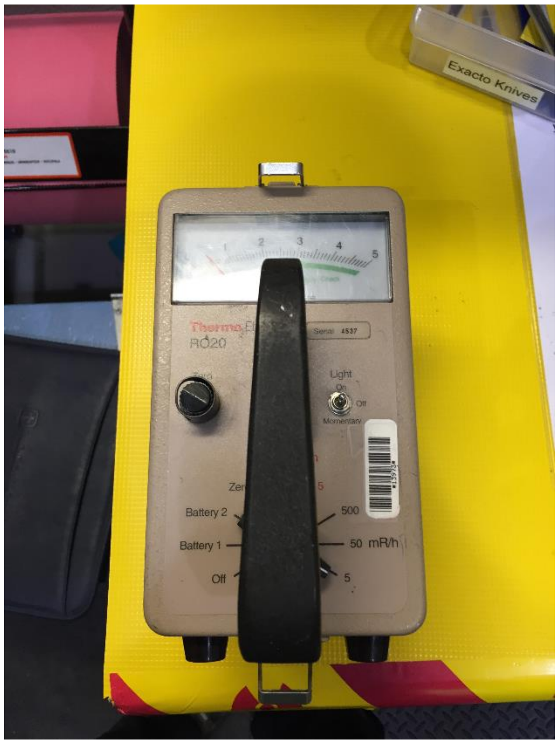


Figure 16 - Thermo Eberline RO20

response is accurate within 15% (+/-0.5 mrem) for photons from 33 keV to 1.3 MeV whether the user is taking reading through the window or through the sides of the instrument within about 5 seconds. The accuracy of the RO20 makes it the preferred instrument to use for accurate dose rate measurements. However, it requires the user to have his/her hand within about 6 inches of the part being measured to retrieve an on-contact dose rate. The Teletector has the advantage of allowing the user to distance himself/herself from the irradiated part by up to 15 additional feet. The teletector uses a ZP1300 gamma tube, which is a small sized Geiger counter tube that is approximately +/- 40% accurate. The small size prevents the detector from becoming saturated at higher dose rates. This detector is typically used when irradiated experiments are removed from the central cavity and when determining dose rates with the RO20 cannot safely be performed. The dose rate range on the teletector is from 10 μR/h to 1000 R/h and is digitally displayed on the instrument.

Worker safety is always prioritized ahead of dose-rate measurements, so on-contact reading measurements and 1-foot measurements are performed rapidly and the distances are eyed using the skill of the worker rather than a ruler or yardstick. The teletector is used for experiments exiting the cavity to obtain dose rates and ensure that minimum dose is received by the individual taking the measurement. Once the dose rate from an irradiated part is determined to be at an acceptable level (either initially upon removal or after sufficient decay), the

RO20 is used to obtain more accurate readings at measured distances for longer periods of time.

Prior to the completion of DREAD, dose rates were collected on numerous samples but only on-contact measurements were taken. The samples were measured using multiple types of meters. Once DREAD was completed it was realized that the data from these samples was not consistent and could not be extrapolated to other distances with any accuracy or consistency. To address this issue, measurements were taken at both one foot and on-contact to provide a measurement that should be more successfully predicted (the one foot measurement) and to determine a relationship between the on-contact and one foot measurements that can be used as a calibration factor in DREAD (Figures 17&18).

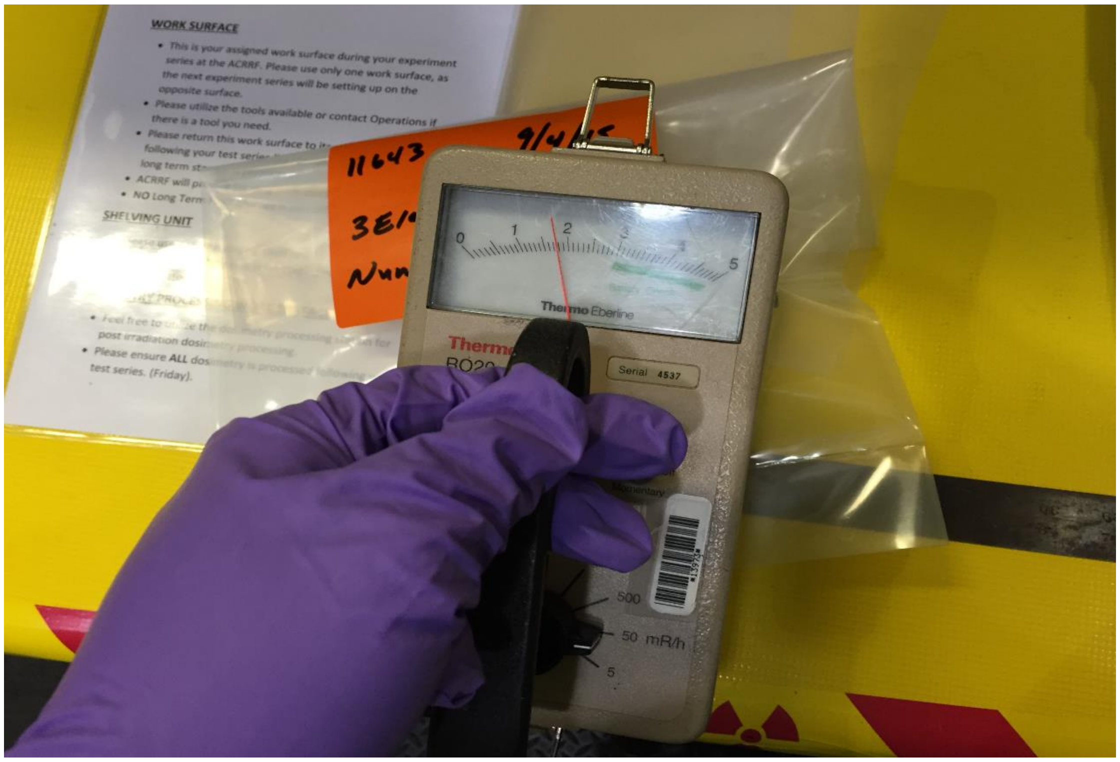


Figure 17 - Example of On-Contact dose rate measurement

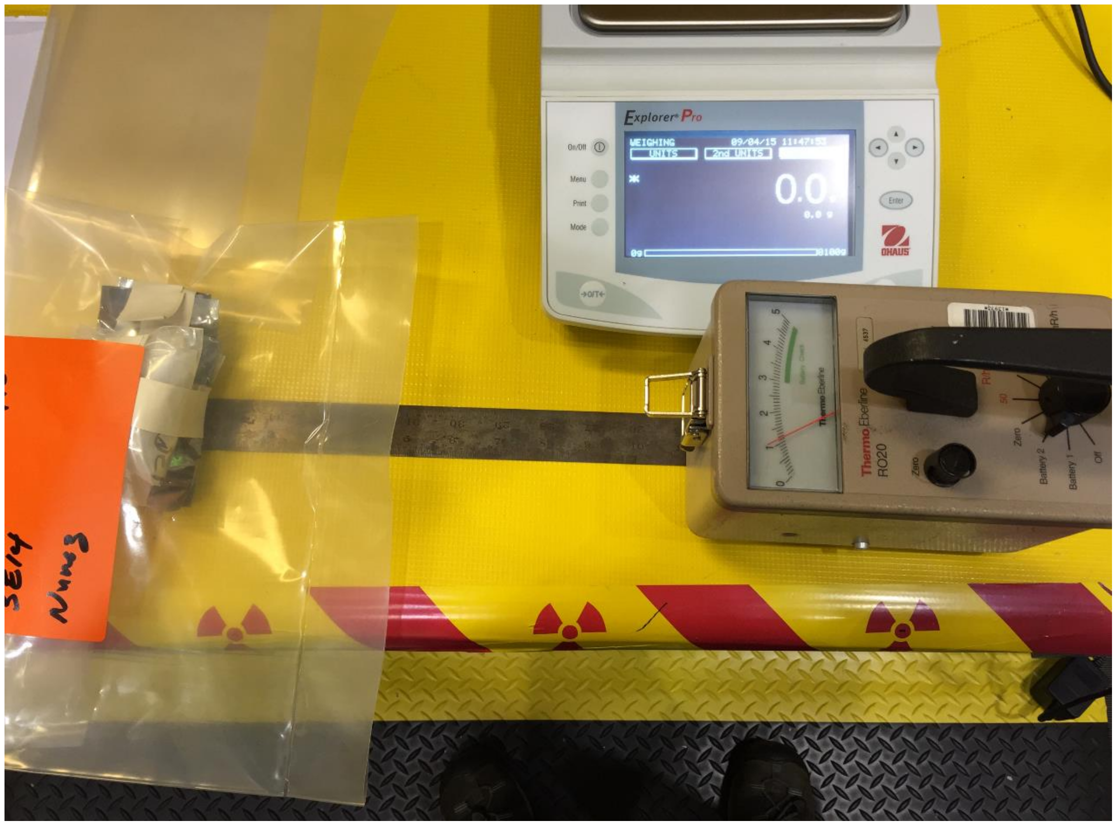


Figure 18 - Example of 1-foot dose rate measurement

The process for collecting data requires several factors to be recorded for completeness. These factors are: the spectrum used, the time of irradiation or pulse mode, the time after irradiation before a measurement was conducted, the measured radiation at 1-foot and on-contact, and any notes about the objects size/ composition that would affect dose rate readings. The more data obtained from each type of spectrum-modified experiment will result in better correction factors in DREAD. However, there is a tradeoff, high-dose rates and more samples results in more dose to the worker collecting the dose-rate information. Optimizing the number and length of the measurements is important for ALARA reasons. The maximum total effective dose for obtaining measurements for this project was 100 mrem which was determined by the operations staff. To stay below this limit, a maximum of 40 samples was proposed, using only the teletector to measure parts over 500 mrem/hr on-contact dose rates. The length of the measurements was determined by how quickly the detector readings stabilized. The Teletector is very quick to respond and gives nearly instantaneous readings. It also has a peak hold function which makes determining the highest dose rate measured very easy to determine. The RO-20 readings take up to 5 seconds to reach a final stable reading and requires the user to select the appropriate range on the detector for the dose rate measurement.

Another means that can be used to validate the accuracy of DREAD is to make a “curie measurement.” Here small samples of pure materials are irradiated and the absolute activity is measured for comparison to the activity (curie) prediction by DREAD. The absolute activities were determined by measuring small samples with a portable gamma spectrometer. Because there was no gamma ray spectrometer available locally to make these measurements, they were made by a separate organization at SNL, which limited the number of measurements that could be made. Additional such measurements can be done in the future and added to the data base in DREAD to improve its predictive capabilities.

5. Results

The experimental results were tabulated along with the results from DREAD and are summarized in Tables II through VI. Many different types of experiments were weighed and the materials were characterized to accurately model activation in DREAD. These experiments ranged from dosimetry of a single electronics chip (Figure 19) to complicated setups containing a wide variety of electronics, cables, housings, and dosimetry (Figure 20). The dose rates from some experiments were measured, but since the material composition was unknown or is still

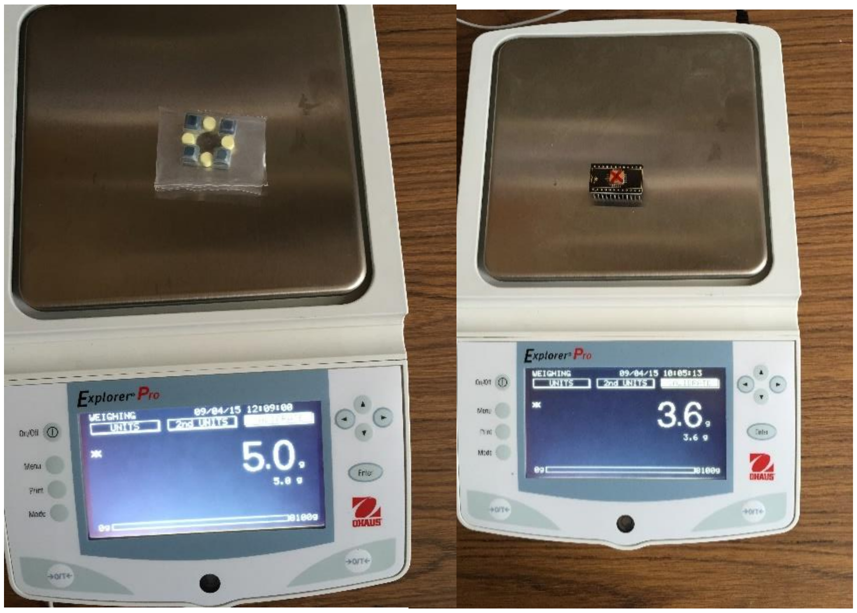


Figure 19 - Dosimetry pack (left) Microchip (right)

Figure 20 - Example of more complex electronics assembly

undergoing determination the results could not yet be included in DREAD. Any future experiment with known composition and dose rates can later be added to the summary tables and factors in DREAD can be adjusted as necessary.

The tables for all of the experiments show what spectrum was used, whether it was a pulse or, if steady-state, the run time, the elapsed time before the experiment was measured, the on-contact and 1-foot measurements, and the DREAD predictions. The data for every spectrum provide similar results. The longer wait times result in the DREAD 1-foot over estimation converging on the actual measured dose rate or, in some cases, falling below the measured dose rate. Table VI represents the average percent difference between the 1-foot measurements from DREAD and actual values and the average ratio between actual on-contact and 1-foot measurements.

The free field spectrum results are presented in Table II. All of the data for this spectrum were collected in the pulse mode. Only one sample's wait time was over night, but the difference between the actual and DREAD dose rates is very small compared with the shorter wait times. The average 1-foot to on-contact ratio and the difference between the on-contact and 1-foot, free-field measurements were in the middle for the four spectra.

Table II - Free Field Results of DREAD vs. Actual Dose Rates

#	Bucket	Pulse/Run Time	Wait Time	On-Contact mrem/hr	1-foot mrem/hr	DREAD on-contact	DREAD 1 ft
1	Free Field	Pulse	31 min	1300	60	2000	67
2	Free Field	Pulse	48 min	1500	65	2100	70
3	Free Field	Pulse	104 min	1300	48	1600	53
4	Free Field	Pulse	19 hr	130	5	180	6
5	Free Field	Pulse	35 min	2100	90	3056	101
6	Free Field	Pulse	90 min	1500	70	2376	79
7	Free Field	Pulse	18 hr	800	50	1536	52
8	Free Field	Pulse	40 min	600	25	951	31
9	Free Field	Pulse	45 min	500	22	837	27
10	Free Field	Pulse	20 min	2000	100	4048	135

The lead boron bucket was used for a variety of electronic parts for short, steady-state runs with rapid experiment recovery from the central cavity. Table III shows the results of these operations. Several of the sample points were also collected for pulse mode operations. These results are very similar to those of the free field pulse results. Sample #8 has a large difference between the on-contact reading and the DREAD prediction. This was a larger piece of electronics and the measurements were all measured from the edge of the experiment parts, so the distance from the most radioactive parts may have been farther than the DREAD model. The lead boron bucket average 1-foot measurement had the largest discrepancy from the DREAD model at 22% higher predictions from DREAD. This over prediction may be due to larger experiments and the method for collecting the data for measurements at 1-foot. The difference is not large enough to warrant changes to the DREAD code.

Table III - Lead Boron Bucket Results of DREAD vs. Actual Dose Rates

#	Bucket	Pulse/Run Time	Wait Time	On-Contact mrem/hr	1-foot mrem/hr	DREAD on-contact	DREAD 1 ft
1	LB 44"	~7 min	30 s	14	-	3.2	-
2	**LB 44"**	**~14 min**	**60 s**	**2.75**	**-**	**3.4**	**-**
3	LB 44"	~6 min	60 s	9	0.5	16.2	0.523
4	**LB 44"**	**~6 min**	**30 s**	**14**	**1.1**	**34**	**1.197**
5	LB 44"	~6 min	5 min	700	20	805	27.9
6	**LB 44"**	**~6 min**	**5 min**	**1100**	**50**	**1784**	**59.4**
7	LB 44"	~6 min	20 min	250	9	440	14
8	**LB 44"**	**~6 min**	**2 hr**	**60**	**5.1**	**203**	**6.7**
9	LB 44"	Pulse	45 min	160	8	273	9.1
10	**LB 44"**	**Pulse**	**1 hr**	**800**	**28**	**1011**	**33**
11	LB 44"	Pulse	2 hr	170	7	225	7.5

The poly lead graphite bucket (Table IV) and lead poly bucket (Table V) displayed similar results to each other and a similar trend to the free field and lead boron bucket. These spectra are not used as frequently as the lead boron bucket or free field spectrums. The buckets average between 5 to 10 times as many thermal neutrons per megawatt of power on the experiment. Since most activation is due to thermal neutrons, the experiments were activated significantly and resulted in higher dose rates. All of the measurements were taken quickly so the experiment could be stored in a shielded cell immediately and reduce exposure to personnel involved in removing the experiment packages from the central cavity. A sheet of paper was used as a reference for taking a 1-foot measurement. The center of the teletector was located at 12 inches from the edge of the experiment and the edge of the detector was on the 11-inch side of the paper. The total dose received taking measurements was less than 10 mrem, well below the administrative limit of 100 mrem.

Table IV - Poly Lead Graphite Bucket Results of DREAD vs. Actual Dose Rates

#	Bucket	Pulse/Run Time	Wait Time	On-Contact mrem/hr	1-foot mrem/hr	DREAD on-contact	DREAD 1 ft
1	PLG	Pulse	3 hr	6500	250	8424	280
2	PLG	Pulse	3.5 hr	6800	250	9154	305
3	PLG	Pulse	3 hr	4000	140	5148	171
4	PLG	12 min	2 hr	5800	225	7930	264
5	PLG	18 min	2 hr	10000	415	14243	474

Table V - Lead Poly Bucket Results of DREAD vs. Actual Dose Rates

#	Bucket	Pulse/Run Time	Wait Time	On-Contact mrem/hr	1-foot mrem/hr	DREAD on-contact	DREAD 1 ft
1	LP	Pulse	2 hr	5500	278	7100	237
2	LP	Pulse	3 hr	9000	500	12698	423
3	LP	Pulse	1.5 hr	5000	260	7260	242
4	LP	Pulse	5	14000	720	19426	647
5	LP	30 min	20 hr	5500	220	7321	244

Table VI - Comparison of DREAD vs. Actual results and factors between 1-foot and on-contact

Spectrum	Average % DREAD vs. Actual	Average Factor between 1-foot and on-contact
Free Field	16% higher	23
Lead Boron	22% higher	22
Poly Lead Graphite	18% higher	26
Lead Poly	12% higher	20
Average	**17%**	**22.75**

The average over estimation at 1-foot was calculated as well as the average factor for actual dose rates measured by the instruments at 1-foot and on-contact as shown in Table VI. The 17% average over-estimation of DREAD is within the error range for the teletector, which was the most frequently used instrument for the higher dose rates. The lower dose rates obtained with the RO20 were taken after longer decay times and were closer to the DREAD predictions. The over estimations are desired to provide conservative results to allow for safe experiment handling. The factor of 22.75 difference between the on-contact and 1-foot measurements could be entered into DREAD to replace the factor of 30, but it is only about a 32% over estimation if left alone, which would continue to ensure conservative estimations continue and prevent operators from exceeding administrative dose rate limits.

DREAD was also used to generate decay trends for different materials and the dose rates of each material at 1-foot at different times. These graphs (Figures 21 to 23) are useful to experimenters and operators to help determine materials to use for experiment support and, more importantly, what not to use. This was done by entering 1 gram of each material separately at different wait times for a 10 MJ pulse.

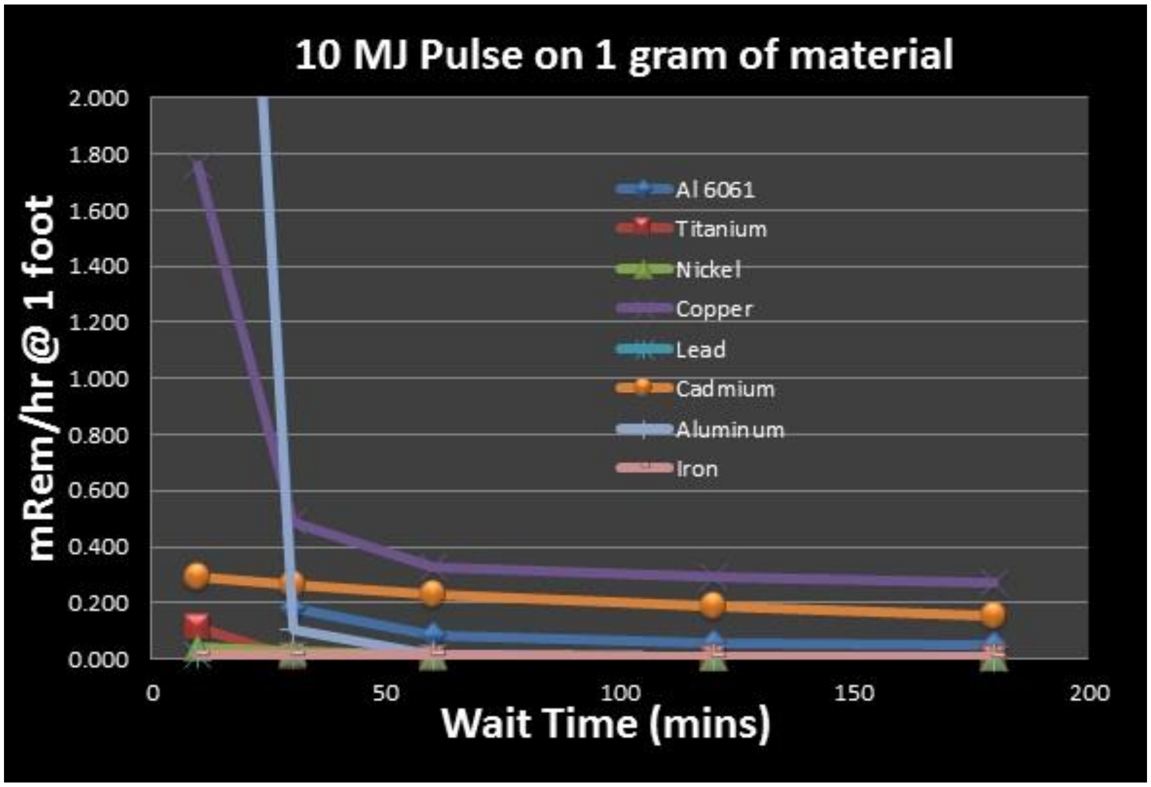


Figure 21 - 10 MJ pulse on 1 gram of commonly used metals

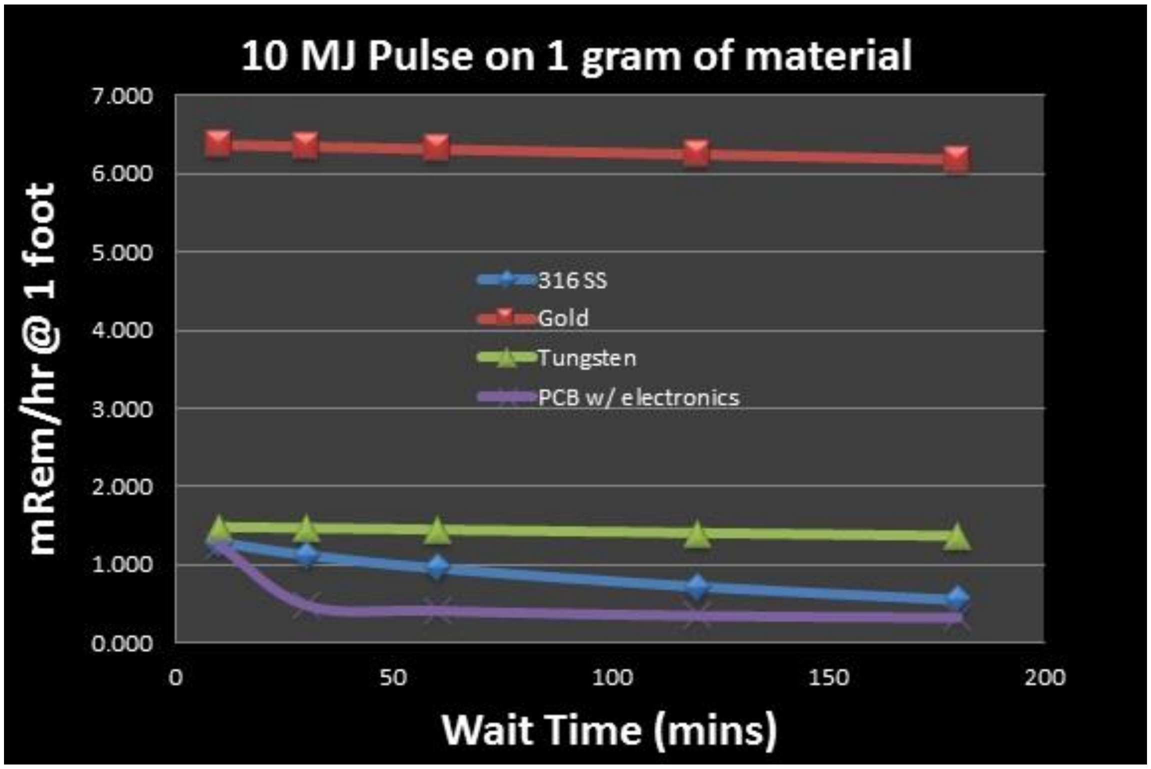


Figure 22 - 10 MJ pulse on metals with higher activation and dose rates

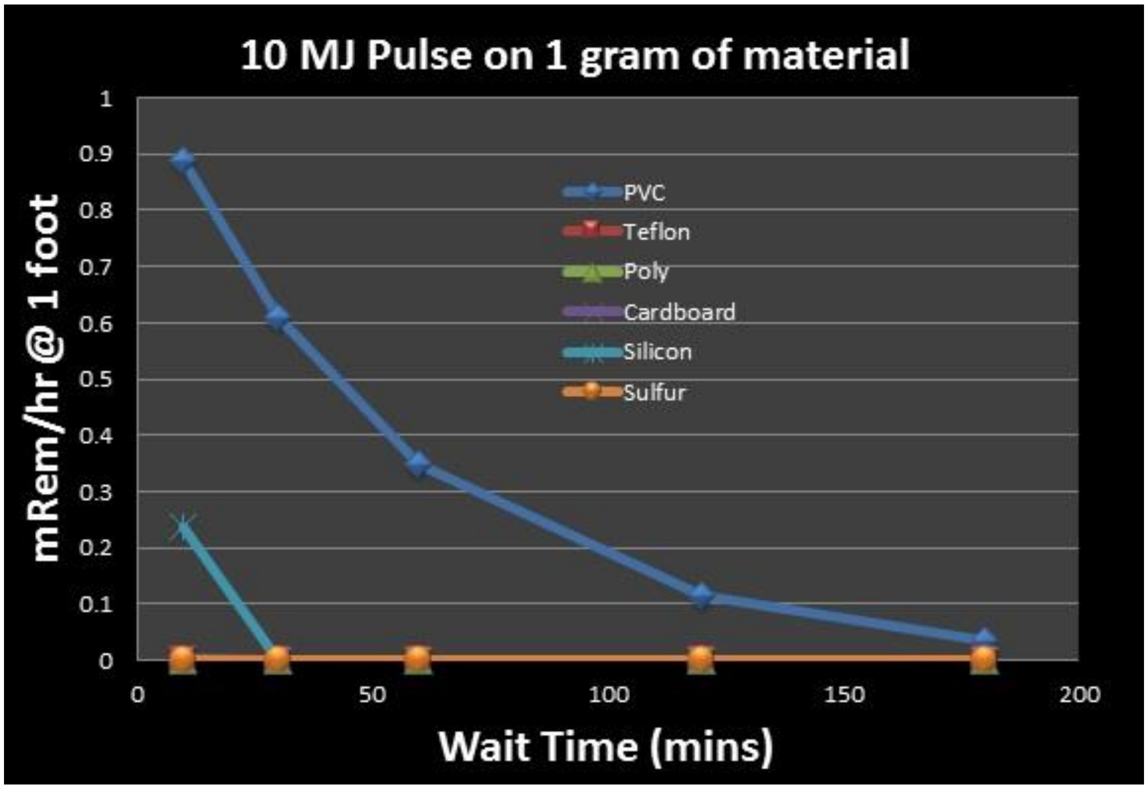


Figure 23 - 10 MJ pulse on 1 gram of common non-metals

DREAD was also used to predict curie amounts for medical isotope generation. The reactor was run to activate a small sample of copper-63 beads and create copper-64. The tables_by_major curie estimate was within 10% of the experimentally measured curie content obtained from a gamma-ray spectroscopy measurement. A request has been made to run more variations of the experiment and to estimate a larger variety of isotopes by the University of New Mexico medical school.

6. Conclusion

Longer waits resulted in the actual dose rate approaching the estimations of DREAD. The convergence could be due to long lived activated impurities that do not contribute much for the short wait times, but start to contribute for long wait times once the shorter lived known materials entered into DREAD begin to decay away. The higher dose rates were also measured with the teletector which does not scale with increasing energy and has a larger error band. The error band for this detector spans the results from DREAD. The error band of the RO20 combined with instrument calibration allowable errors and detector variances also is within the tolerance for the DREAD results.

The estimates that DREAD calculates are conservative, consistent, and accurate. An average estimate of 17% above the actual dose rates measured provides operators and experiments with a very good approximation of what they can expect to handle when removing experiments from the central cavity. The tool is installed on the computers for the reactor operators and is currently being utilized to effectively estimate the activation of smaller electronic parts and assemblies. As the program evolves and expands, its usefulness for operators and experimenters will do the same.

The DREAD code could be changed to calculate on-contact readings based on what spectrum is chosen and adjust to the averages for each bucket. However, the small amount of additional conservatism would likely be valued over a lower than actual estimation.

Future Work

There are several constraints inherent in DREAD that should be examined for the next revision. The size of the experiments is limited and DREAD does not perform well for larger experiments that are outside of the center flux originally tallied in MCNP. DREAD currently cannot give estimates of the dose rates expected from the spectrum modifier buckets, which are the first to exit the cavity. MCNP runs with tallies of the entire bucket with different ratios for different heights inside of the central cavity/bucket could help correct this issue. New buckets (water bucket, cd poly bucket. etc.) should be added as they are made available. A spectrum could be added to the code would that allow for dose rate estimations in the external cavities at ACRR.

In addition to the calculation limits, other features could be added to make DREAD a more user-friendly program. Adding more commonly used materials such as coaxial cables, fiber optic cables, and connectors would aid in speed and consistency for different runs. DREAD could also be used to automatically generate graphs in Microsoft excel for the decay rates of the materials rather than numerous runs manually entered by the user.

Appendix A – MCNP Code

```
STANDARD ACRR Model (Extended Cavity, 32" Pedestal, Pb-B4C Bucket)
C
C  Original Model Developed by W. Fan
C  Modified by P. Cooper and E. Parma with new cavity
C  Macrobody Model Developed by R. DePriest
C  New 44" Pb-B4C Bucket LB44 Model Developed by T. Trinh
C  New information and energy groups updated for Cinder by J. Greenberg
C
C    standard 236-element core configuration with new cavity
C    no FREC
C    room temp 70c cross sections with S(a,b)
C    LB-44-cl-32 - 44inch lead/boron bucket on 32inch pedestal
C    tally is a 6cm diameter sphere at fuel centerline
C       89 and 640 neutron energy groups
C       48 gamma energy groups
C
C     control rods   : variable
C     safety rods    : variable
C     transient rods : variable
C
C
C        1         2         3         4         5         6         7         8
C 345678901234567890123456789012345678901234567890123456789012345678901234567890
C ******************************************************************************
C *                          CELL CARDS                                        *
C ******************************************************************************
C
C
C  Universe definitions for the standard 236-element core.
C
C    U=1:fuel rods            U=2:water rods
C    U=3:control rods         U=4:safety rods
C    U=5:transient rods       U=6:nickel rods
C    U=7:90% fuel rods        U=9:al rods (empty)
C
C   ********  U=8 is the reactor core fill.  *******
C
C
C  Regular Fuel Elements
```

```
C
10  0           -10             U=1  IMP:N,P=1 $Void
11  1   -3.3447    10 -11         U=1  IMP:N,P=1 $UO2-BeO fuel
14  0            11 -14         U=1  IMP:N,P=1 $Void
15  2   -8.4000    14 -15         U=1  IMP:N,P=1 $Niobium
16  0            15 -16         U=1  IMP:N,P=1 $Void Gap
17  4   -2.8000   -17             U=1  IMP:N,P=1 $Lower BeO Plug
18  4   -2.8000   -18             U=1  IMP:N,P=1 $Upper BeO Plug
19  3   -8.0300    17 -19         U=1  IMP:N,P=1 $Lower SS Plug
20  3   -8.0300    18 -20         U=1  IMP:N,P=1 $Upper SS Plug
21  3   -8.0300    19  20  16 -21  U=1  IMP:N,P=1 $SS304
22  5   -1.0000    21 -22         U=1  IMP:N,P=1 $Water
C
C
C  Water Rods
C
23  5   -1.0000   -22             U=2  IMP:N,P=1 $Water
C
C
C  Control Rods:  Poison section
C
25  8   -2.4800   -25             U=3  IMP:N,P=1 $B4C poison
26  0            25 -26         U=3  IMP:N,P=1 $Void Cap
27  3   -8.0300    26 -27         U=3  IMP:N,P=1 $Poison sleeve
28  3   -8.0300   -28             U=3  IMP:N,P=1 $Magnaform plug
29  5   -1.0000    27  28 -29      U=3  IMP:N,P=1 $Water
C
C  Control Rods:  Fuel follower
C
30  0           -30             U=3  IMP:N,P=1 $Void
31  1   -3.3447    30 -31         U=3  IMP:N,P=1 $UO2-BeO fuel
32  0            31 -32         U=3  IMP:N,P=1 $Void
33  2   -8.4000    32 -33         U=3  IMP:N,P=1 $Niobium
34  0            33 -34         U=3  IMP:N,P=1 $Void gap
35  4   -2.8000   -35             U=3  IMP:N,P=1 $BeO plug
36  0           -36             U=3  IMP:N,P=1 $Void
37  3   -8.0300    34  35 36 -37   U=3  IMP:N,P=1 $SS304
38  5   -1.0000    37 -38         U=3  IMP:N,P=1 $Water
C
C
C  Safety Rods:  Poison section
C
39  8   -2.4800   -39             U=4  IMP:N,P=1 $B4C poison
```

```
40  0           39 -40        U=4  IMP:N,P=1 $Void cap
41  3   -8.0300    40 -41        U=4  IMP:N,P=1 $Poison sleeve
42  3   -8.0300   -42           U=4  IMP:N,P=1 $Magnaform plug
43  5   -1.0000    41  42 -43     U=4  IMP:N,P=1 $Water
C
C  Safety Rods:  Fuel follower
C
44  0          -44           U=4  IMP:N,P=1 $Void
45  1   -3.3447    44 -45        U=4  IMP:N,P=1 $UO2-BeO fuel
46  0           45 -46        U=4  IMP:N,P=1 $Void
47  2   -8.4000    46 -47        U=4  IMP:N,P=1 $Niobium
48  0           47 -48        U=4  IMP:N,P=1 $Void gap
49  4   -2.8000   -49           U=4  IMP:N,P=1 $BeO plug
50  0          -50           U=4  IMP:N,P=1 $Void
51  3   -8.0300    48 49  50 -51   U=4  IMP:N,P=1 $SS304
52  5   -1.0000    51 -52        U=4  IMP:N,P=1 $Water
C
C
C  Transient Rods:  Void section
C
53  0          -53           U=5  IMP:N,P=1 $Void
54  7   -2.7000    53 -54 58 60 61 U=5  IMP:N,P=1 $Al tubing
55  5   -1.0000    54 -55        U=5  IMP:N,P=1 $Water
56  7   -2.7000    55 -56        U=5  IMP:N,P=1 $Al guidex
57  5   -1.0000    56 -57        U=5  IMP:N,P=1 $Water
58  7   -2.7000   -58           U=5  IMP:N,P=1
C
C  Transient Rods:  Poison section
C
59  8   -2.4800   -59           U=5  IMP:N,P=1 $Poison
60  7   -2.7000    59 -60        U=5  IMP:N,P=1 $Inner sleeve
61  0          -61           U=5  IMP:N,P=1 $Void
62  7   -2.7000   -62  54        U=5  IMP:N,P=1 $End plug
C
C
C  Nickel Rods
C
65  6   -8.9000   -21           U=6  IMP:N,P=1 $Nickel
66  5   -1.0000    21 -22        U=6  IMP:N,P=1 $Water
C
C
C  90% Fuel Element
C
```

```
70  0            -10             U=7  IMP:N,P=1 $Void
71  11  -3.0102    10 -11          U=7  IMP:N,P=1 $UO2-BeO fuel
74  0             11 -14          U=7  IMP:N,P=1 $Void
75  2   -8.4000    14 -15          U=7  IMP:N,P=1 $Niobium
76  0             15 -16          U=7  IMP:N,P=1 $Void Gap
77  4   -2.8000   -17              U=7  IMP:N,P=1 $Lower BeO Plug
78  4   -2.8000   -18              U=7  IMP:N,P=1 $Upper BeO Plug
79  3   -8.0300    17 -19          U=7  IMP:N,P=1 $Lower SS Plug
80  3   -8.0300    18 -20          U=7  IMP:N,P=1 $Upper SS Plug
81  3   -8.0300    19  20  16 -21  U=7  IMP:N,P=1 $SS304
82  5   -1.0000    21 -22          U=7  IMP:N,P=1 $Water
C
C
C  Empty Aluminum Rod
C
600  0            -90             U=25  IMP:N,P=1 $Void
601  7   -2.7000    90 -21          U=25  IMP:N,P=1 $Al Rod
602  5   -1.0000    21 -22          U=25  IMP:N,P=1 $Water
C
C
C  Empty Aluminum Rod
C
90  0            -90             U=9  IMP:N,P=1 $Void
91  7   -2.7000    90 -21          U=9  IMP:N,P=1 $Al Rod
92  5   -1.0000    21 -22          U=9  IMP:N,P=1 $Water
C
C
C  Core  (UNIVERSE = 8)
C
  1  0  -300 311 210 211 213 220  fill=8   IMP:N,P=1
C
  2  5   -1.0000  -320     lat=2   U=8  IMP:N,P=1
             fill -12:12 -12:12 0:0
C
C
C  This fuel loading reflects the board as of May 2003.
C
C       1         2         3         4         5         6         7         8
C 3456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
C
                2 24r
               2 24r
              2 24r
              2 9r 2  6  1     1  1  1  1  1  1  1  1    1  6  2 2   $ interface with frec
             2 8r 6  6  1  1    1  1  1  1  1  1  1    1  1  6  6 2
            2 7r 6  1  1  1  1    1  1  1  1  1  1   1  1  1  1  6 2
           2 6r 6  7  1  1  1  3   1   1  5   1   1  3  1  1  1  7  6 2
          2 5r 6  7  1  1  1  1  1   1  1  1  1  1   1  1  1  1  7  6 2
         2 4r 6  7  1  1  1  1  1   1  1  1  1  1   1  1  1  1  1  7  6 2
        2 3r 9  6  1  1  1  4  1   1   2 2 2 2   1   1  1  1  1  1  6  2 2
       2 2r 2  9  6  1  1  1  1   1   2 2 2 2 2   1   1  1  1  1  6  6  2 2
      2  2 2  6  6  1  1  1  1   1   2 2 2 2 2 2   1   1  1  1  1  6  2  2 2
        2 2  2  6  1  1  3  1   1   2 2 2 2 2 2 2   1   1  3  1  1  6  2  2 2   $ center line
         2 2  6  6  1  1  1  1   1   2 2 2 2 2 2   1   1  1  1  1  9  6  2 2 2
          2 2  6  1  1  1  1  1   1   2 2 2 2 2   1   1  1  1  1  1  9  2 2 2r
           2 6  1  1  1  1  5  1   1   2 2 2 2   1   1  5  1  1  1  1  2 2 3r
            2 6  1  1  1  1  1  1   1  1  1  1  1   1  1  1  1  1  1  1  2 2 4r
             2 6  1  1  1  1  1  1    1  1  1  1   1  1  1  1  1  1  1  2 2 5r
              2 6  1  1  1  1  3   1   1  4   1   1  3  1  1  1  1  2 2 6r
               2 6  7  1  1  1    1  1  1  1  1  1    1  1  1  1  2 2 7r
                2 6  6  6  1    1  1  1  1  1  1  1  1    1  9  9  2 2 8r
                 2 2  9  6     6  6  1  1  1  1  6  6    6  6  2 2 9r
                  2 2  2     9  2  6  7  7  7  6  2  6     2  2 2 10r
                   2 2 2 2      25  6  6  6  6  9        2 2 2 2 11r
                    2 24r
C
C
C ********  END OF UNIVERSE DEFINITIONS AND CORE FILL  ********
C
C
C  NEW CENTRAL CAVITY
C
C   To add 32-in pedestal, remove C from line 2.
C   To add 8-in pedestal, remove C from line 2 and 3.
C   You must also remove the C's from the cells in the pedestal
C    descriptions (Cells 110-116).
C
C    Use Line 4 of Cell 100 to exclude surface of buckets and experiments.
C     Exclude surface 706 for Pb-B4C; Exclude surface 711 for Al dosimetry bucket;
C     Exclude surface 725 for LP-1
C     Exclude surfaces 730, 731, and 734 for Boom Box
C
100  702 -1.0245e-3  -100
110
C                  113 114 116
                 1001            IMP:N,P=1 $Void
```

```
C   for LB44                     899              IMP:N,P=1 $Void
101  3  -8.0300    100 -101             IMP:N,P=1 $Stainless liner
102  7  -2.7000   -311  101 -102        IMP:N,P=1 $Aluminum
103  5  -1.0000   -311  102             IMP:N,P=1 $Water
C
C
C  Central Cavity Additions (32" and 8" Pedestals)
C
C  32-in pedestal
C
110  7  -2.7000      -110  111  112        IMP:N,P=1 $32-in pedestal
111  702 -1.0245e-3  -111                 IMP:N,P=1 $32-in pedestal inset
112  702 -1.0245e-3  -112                 IMP:N,P=1 $Inset Notch
C
C
C  8-in pedestal
C
C 113  7  -2.7000   -113                 IMP:N,P=1 $Bottom plate
C 114  7  -2.7000   -114                 IMP:N,P=1 $Top plate
C 115  702 -1.0245e-3   -115                 IMP:N,P=1 $Center Void
C 116  7  -2.7000   -116  115            IMP:N,P=1 $Support Tube
C
C
C   End of Central Cavity Additions
C
C
C  Top and Bottom Grid Plates
C
200  7  -2.7000   -200  311  201        IMP:N,P=1 $Top plate
201  5  -1.0000   -200  220 -201        IMP:N,P=1 $Water
202  7  -2.7000   -202  311             IMP:N,P=1 $Bottom plate
C
C
C  Nickel Plate and Window to the Radiography Lab
C
210  6  -8.9000   -210                  IMP:N,P=1 $Nickel Plate
211  5  -1.0000   -211  210 -900        IMP:N,P=1 $Water
212  0            -212 -900             IMP:N,P=1 $Void
213  7  -2.7000   -213  212 -900        IMP:N,P=1 $Aluminum
C
C
C  FREC-II Side Ni Plate
C
```

```
220  6  -8.9000   -220                 IMP:N,P=1
C
C
C  Surrounding Water
C
230  5  -1.0000   -900  220 213 212 211 202 200
                        300 311         IMP:N,P=1
C
C
C
C   EXPERIMENTAL or SPECTRUM MODIFYING BUCKETS  (700's)
C
C  Pb-B4C Bucket  (700-706)
C  Weight of Bucket per L. Martin (8/21/2003) - 446 lbs
C  Weight of Model Bucket                    - 450.81
C  Density of B4C layer changed to 2.12 g/cc to make weight 446.19 lbs
C
C
C 700  702  -1.0245e-3  -700             IMP:N,P=1 $Inside Bucket
C 701   7   -2.7100  -701  700           IMP:N,P=1 $1/16" Al liner
C 702  700  -11.350  -702 701 7091 7092   IMP:N,P=1 $1" Pb on bottom
C 703  701  -2.5300  -703  7091 7092      IMP:N,P=1 $Boral on bottom
C 707   0           -707  702           IMP:N,P=1 $Slop between Cannister and Pb
C 708   8   -2.1200  -708                IMP:N,P=1 $B4C layer on the bottom
C
C 704   7   -2.7100  -704  703  707  708
C                         7091 7092      IMP:N,P=1 $Al layer
C 705   8   -2.1200  -705  704           IMP:N,P=1 $B4C layer
C 706   7   -2.7100 -706 705 7091 7092    IMP:N,P=1 $Al exterior
C 7091  3   -8.0300 -7091                IMP:N,P=1 $Dowel 1
C 7092  3   -8.0300 -7092                IMP:N,P=1 $Dowel 2
C
C
C
C
C  Standard Aluminum Experiment Bucket (710-711)
C   Add -900 to 710 and 711 if using 24" Bucket
C
C 710  702 -1.0245e-3  -710               IMP:N,P=1 $Inside Bucket
C 711  7   -2.7000     -711  710           IMP:N,P=1 $Aluminum Bucket
C
C
C
```

```
C
C  Pb-Poly Bucket (720-725) -- Designated as LP-1
C
C 720  702 -1.0245e-3  -720                IMP:N,P=1 $Bottom of Inside
C 721  7   -2.7000  -721  720  726         IMP:N,P=1 $1/16" Al Liner
C 722  700 -11.350  -722  721  724  726    IMP:N,P=1 $0.4" Pb Layer
C 723  704 -0.9450  -723  722  726         IMP:N,P=1 $0.8" HDPE
C 724  704 -0.9450  -724                   IMP:N,P=1 $HDPE fill-in
C 725  7   -2.7000  -725  721  723  726    IMP:N,P=1 $Al Container
C 726  702 -1.0245e-3  -726                IMP:N,P=1 $Top of Inside
C
C
C
C
C
C  Boombox for NG testing (730-738)
C
C 730  765 -7.28    -730  736  737  738    IMP:N,P=1 $Lower Boom Box
C 731  765 -7.28    -731  733              IMP:N,P=1 $Upper part of clamping ring
C 732  765 -7.28    -732  733              IMP:N,P=1 $Lower part of clamping ring
C 733  702 -1.0245e-3  -733                IMP:N,P=1 $"Void" in clamping ring
C 734  702 -1.0245e-3  -734 732            IMP:N,P=1 $"Void" at ring lip
C 735  765 -7.28    -735                   IMP:N,P=1 $Plug
C 736  702 -1.0245e-3  -736 735            IMP:N,P=1 $"Void" around the plug
C 737  702 -1.0245e-3  -737                IMP:N,P=1 $Lower "void"
C 738  702 -1.0245e-3  -738                IMP:N,P=1 $Lip "void"
C
C
C
C
C
C
C New 44" Pb-B4C Bucket
C Base Plate w/ B4C Volume
C From Ktech drawing labeled "PbB BASEII"
C  800  8   -1.274704138 (-802):(817 -815):(818 -816)       IMP:N,P=1 $ B4C Cavity
C  801  766 -7.83 -803:-809                                 IMP:N,P=1 $ All-threads
C    From McMaster-Carr catalog, Item # 98914A033, Threaded Rods and Studs, General Purpose Steel
C  802  767 -7.82 (805 -806):(811 -812)                     IMP:N,P=1 $ Washers
C    From McMaster-Carr catalog, Item #94744A285, Zinc-Plated Steel Washer for Soft Materials (Type
C  803  767 -7.82 (803 -807):(809 -813)                     IMP:N,P=1 $ All-thread nuts
C    From McMaster-Carr catalog, Item # 93939A823, Hex Nut, Grade 8 Steel
C  804  702 -1.0245e-3 (803 -804):(809 -810):(803 -805):(809 -811):
```

```
C                 (806 807 803 -808):(812 813 809 -814) IMP:N,P=1 $ Void inside this thread, washe
C  805  7 -2.704  (-817 819):(-818 820)               IMP:N,P=1 $ Al6061 plugs
C    From McMaster-Carr catalog, Item # 44705K334, Low-Pressure Aluminum Threaded Square-Socket Plug
C  806  702 -1.0245e-3 (-819):(-820)                  IMP:N,P=1 $ Void in this area
C  807  7 -2.704       (-800:-801) 802 804 808 810 814 815 816
C                                                     IMP:N,P=1 $ Al6061 Base Plate
C Containment Base
C From Ktech drawing labeled "CONTAINMENT BASE II"
C  830  702 -1.0245e-3  801 -830                      IMP:N,P=1 $ Void
C  831  7 -2.704       (830 833 834 -831):(831 -832)       IMP:N,P=1 $ Al6061 Containment Base
C  832  766 -7.83      -833:-834                      IMP:N,P=1 $ All-threads, General Purpose St
C Lead Material
C Unchamfered lead rings
C  840  702 -1.0245e-3 -853                           IMP:N,P=1 $ Void inside lead rings
C  841  766 -7.83      -847:-848                      IMP:N,P=1 $ All-threads, General Purpose St
C  842  702 -1.0245e-3 (847 -843):(848 -844)          IMP:N,P=1 $ Void between All-threads and Pb
C  843  702 -1.0245e-3 -849:-851                      IMP:N,P=1 $ Void inside Al6061 tubing
C  844  7 -2.704  (849 -850):(851 -852)               IMP:N,P=1 $ Al6061 tubing
C  845  702 -1.0245e-3 (850 -845):(852 -846)          IMP:N,P=1 $ Void between tubing and Pb hole
C  846  700 -11.35     (862 863 860 843 844 845 846 -842):(-840 843 844 845 846):
C                 (853 -854 843 844 845 846)          IMP:N,P=1 $ Unchamfered lead rings
C Inner Aluminum 6061 Sleeves (Items #14 and 15 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C  860  7 -2.704       -860                           IMP:N,P=1 $ Al6061 bottom plate
C  861  702 -1.0245e-3 (-861 1001):-863               IMP:N,P=1 $ Aluminum sleeve void
C  862  7 -2.704        861 -862                      IMP:N,P=1 $ Al6061 sleeve
C Al6061 Double Wall Weldment (Item #9 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C  870  702 -1.0245e-3 (840 842 831 854 -868):
C                 (840 842 831 854 -870):
C                 (840 842 831 854 -872)              IMP:N,P=1 $ Void Between Pb Ring and Double
C  871  7 -2.704       (868 -869):(870 -871):(872 -873):
C                 (874 -875):(876 -877):(878 -879)     IMP:N,P=1 $ Al6061 Inner and Outer Skins
C  872  8 -1.449249072 (869 -874):(871 -885):(886 -876):
C                      (873 -883):(-878 884)     IMP:N,P=1 $ B4C Powder
C PbB Top: Top Plate (Item #1 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C  880  702 -1.0245e-3 -880:-881:(-887 848):(-888 847):
C                 -891:-892:-893:-894                 IMP:N,P=1 $ Voids
C  881  7 -2.704       (880 881 -882 887 888 889 890 891 892 893 894):
C                 (883 -884):(885 -886)               IMP:N,P=1 $ Top Plate
C Modified Hex Head Plugs, 1/4 NPT, AL6061-T6 (Item #16 in DWG titled "LEAD BORON BUCKET ASSEMBLY")
C From McMaster-Carr catalog, Item # 3867T65, High-Pressure Aluminum Pipe Fitting
C  882  7 -2.704       (-821 852):(-822 852):(-823 850):(-824 850)
C                                                     IMP:N,P=1 $ Modified Hex Head Plugs
C Outside World
```

```
C  889  702 -1.0245e-3 -899 800 831 832 875 877 879 821 822 823 824
C                   882 847 848 850 852              IMP:N,P=1 $ Enclosing surface
C
C    EXPERIMENT PACKAGES (1000's)
C   1001  702 -1.0245e-3 -1001 1002                  IMP:N,P=1 $ 6 cm dia scoring sphere
C   1002  6   -8.902     -1002                       IMP:N,P=1 $ Ni Foil
1001  702 -1.0245e-3 -1001                           IMP:N,P=1 $ 6 cm dia scoring sphere
C
C
C
C
C    EXTERNAL WORLD
C
C
C
900 0            900                 IMP:N,P=0 $Outside world

C       1         2         3         4         5         6         7         8
C 345678901234567890123456789012345678901234567890123456789012345678901234567890
C ******************************************************************************
C *                          SURFACE CARDS                                    *
C ******************************************************************************
C
C    Fuel Elements
C
10  RCC  0.000  0.000  23.32  0.000  0.000  52.25  0.2413  $Void
11  RCC  0.000  0.000  23.32  0.000  0.000  52.25  1.6840  $Fuel
14  RCC  0.000  0.000  23.32  0.000  0.000  52.25 1.72025  $Void
15  RCC  0.000  0.000  23.32  0.000  0.000  52.25 1.77125  $Niobium
16  RCC  0.000  0.000  23.32  0.000  0.000  52.25 1.82225  $Void gap
17  RCC  0.000  0.000 21.415  0.000  0.000  1.905 1.48700  $Lower plug
18  RCC  0.000  0.000  75.57  0.000  0.000  1.905 1.48700  $Upper plug
19  RCC  0.000  0.000  16.32  0.000  0.000  7.000 1.82225  $Lower plug
20  RCC  0.000  0.000  75.57  0.000  0.000  5.000 1.82225  $Upper plug
21  RCC  0.000  0.000  16.32  0.000  0.000  98.89 1.87325  $
22  RCC  0.000  0.000  16.32  0.000  0.000  98.89 5.00000  $Water
C
C   Control Rods
C
25 3 RCC 0.000  0.000  78.11  0.000  0.000  52.25 1.46050  $B4C poison
26 3 RCC 0.000  0.000  78.11  0.000  0.000  98.89 1.50495  $Void cap
27 3 RCC 0.000  0.000  78.11  0.000  0.000  98.89 1.74625  $poison sleeve
28 3 RCC 0.000  0.000  75.57  0.000  0.000   2.54 1.74625  $Magnaform plug
```

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29 3 RCC 0.000  0.000  75.57  0.000  0.000 101.43 5.00000  $Water
30 3 RCC 0.000  0.000  23.32  0.000  0.000  52.25 0.24130  $Void
31 3 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.68400  $Fuel
32 3 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.72025  $Void
33 3 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.77125  $Niobium
34 3 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.82225  $Void gap
35 3 RCC 0.000  0.000  20.78  0.000  0.000   2.54 1.82225  $BeO plug
36 3 RCC 0.000  0.000 -79.22  0.000  0.000 100.00 1.82225  $Void
37 3 RCC 0.000  0.000 -79.22  0.000  0.000 154.79 1.87325  $SS304
38 3 RCC 0.000  0.000 -79.22  0.000  0.000 154.79 5.00000  $Water
C
C    Safety Rods
C
39 4 RCC 0.000  0.000  78.11  0.000  0.000  52.25 0.57150  $B4C poison
40 4 RCC 0.000  0.000  78.11  0.000  0.000  98.89 0.83185  $Void cap
41 4 RCC 0.000  0.000  78.11  0.000  0.000  98.89 1.74625  $Poison sleeve
42 4 RCC 0.000  0.000  75.57  0.000  0.000   2.54 1.74625  $Magnaform plug
43 4 RCC 0.000  0.000  75.57  0.000  0.000 101.43 5.00000  $Water
44 4 RCC 0.000  0.000  23.32  0.000  0.000  52.25 0.24130  $Void
45 4 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.68400  $Fuel
46 4 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.72025  $Void
47 4 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.77125  $Niobium
48 4 RCC 0.000  0.000  23.32  0.000  0.000  52.25 1.82225  $Void gap
49 4 RCC 0.000  0.000  20.78  0.000  0.000   2.54 1.82225  $BeO plug
50 4 RCC 0.000  0.000 -79.22  0.000  0.000 100.00 1.82225  $Void
51 4 RCC 0.000  0.000 -79.22  0.000  0.000 154.79 1.87325  $SS304
52 4 RCC 0.000  0.000 -79.22  0.000  0.000 154.79 5.00000  $Water
C
C    Transient Rods
C
53 5 RCC 0.000  0.0 -76.2762  0.000  0.0  73.1012 1.20000  $Void
54   RCC 0.000  0.000 -79.22  0.000  0.000 200.00 1.27000  $Al tubing
55   RCC 0.000  0.000 -79.22  0.000  0.000 200.00 1.49860  $Water
56   RCC 0.000  0.000 -79.22  0.000  0.000 200.00 2.02438  $Al guidex
57   RCC 0.000  0.000 -79.22  0.000  0.000 200.00 5.00000  $Water
58 5 RCC 0.000  0.000 -3.175  0.000  0.000  3.174 1.20000
59 5 RCC 0.000  0.000 -0.001  0.000  0.000 76.201 0.88000  $Poison
60 5 RCC 0.000  0.000 -0.001  0.000  0.000 76.201 1.20000  $Inner sleeve
61 5 RCC 0.000  0.000  76.20  0.000  0.000 123.80 1.20000  $Void
62 5 RCC 0.000  0.000 -100.0  0.000  0.00 23.7238 1.20000  $End plug
C
C    Aluminum Rods
C
```

```
90  RCC  0.000  0.000  15.41  0.000  0.000  66.14 1.77125  $Void in Al rod
C
C    Central Cavity Surfaces
C
100 RCC  0.000  0.000  -67.395  0.000  0.000  202.395 11.6450  $Void
101 RCC  0.000  0.000  -67.395  0.000  0.000  202.395 12.2800
102 RCC  0.000  0.000  -67.395  0.000  0.000  202.395 13.9700
C
C   Cavity Additions
C
110 RCC  0.000  0.000 -67.395  0.000  0.000 81.28 11.4300  $32-in pedestal
111 RCC  0.000  0.000 8.4748  0.000  0.000 2.8702  8.2550  $32-in inset
112 RPP -0.9525 0.9525  -8.255  8.255  11.345  13.885      $Inset Notch
113 RCC  0.000  0.000 13.885  0.000  0.000  1.270 10.3188  $Bottom plate (8-in)
114 RCC  0.000  0.000 32.935  0.000  0.000  1.270 10.3188  $Top plate (8-in)
115 RCC  0.000  0.000 15.155  0.000  0.000  17.78  5.7150  $Center void (8-in)
116 RCC  0.000  0.000 15.155  0.000  0.000  17.78  6.3500  $Support tube (8-in)
C
C    Top and Bottom Grid Plates
C
200 RCC  0.000  0.000  80.55  0.000  0.000   2.54 53.3500  $Top plate
201 PY  -34.925                                   $Cutoff of top plate
202 RCC  0.000  0.000  11.33  0.000  0.000   5.08 47.0000  $Bottom plate
C
C
C    Window to Radiography Lab
C
210  1 RPP  38.100 39.370  -26.670 26.670  16.41 80.55     $Ni plate
211  1 RPP  38.100 39.370  -38.100 38.100  16.41 80.55     $Water
212  1 RPP  48.895 100.00  -26.670 26.670  16.41 80.55     $Void
213  1 RPP  39.370 100.00  -38.100 38.100  16.41 80.55     $Aluminum
C
C   Nickel Plate near FREC-II
C
220  RPP  -36.830 36.830  -36.195 -34.925  16.41 83.09     $Nickel Plate
C
C    Hexes for the lattice, inner and outer core, and core boundary
C
320  RHP  0.0 0.0 -132.0  0.0 0.0 400.0 2.0855 0.0 0.0    $Lattice element
300  1 RHP  0.0 0.0 16.41 0.0 0.0 64.14 42.7 0.0 0.0      $outer core bound
310  1 RHP  0.0 0.0 -67.395  0.000  0.000  202.395 11.65 0. 0.0      $Inner liner of cavity
311  1 RHP  0.0 0.0 -67.395  0.000  0.000  202.395 12.285 0. 0.      $Outer liner of cavity
C
```

```
C
C   Buckets  (700's)
C
C  Pb-B4C Bucket
C
 700 7 RCC  0.0 0.0 6.35     0.0 0.0 85.09    6.27380 $Void
 701 7 RCC  0.0 0.0 6.26872  0.0 0.0 85.17128 6.35508 $0.032" Al liner
 702 7 RCC  0.0 0.0 3.65125  0.0 0.0 87.78875 9.76630 $Pb layers
 703 7 RCC  0.0 0.0 3.01625  0.0 0.0  0.63500 9.17575 $Boral
 704 7 RCC  0.0 0.0 1.90500  0.0 0.0 89.53500 10.1600 $Al layer
 705 7 RCC  0.0 0.0 1.90500  0.0 0.0 89.53500 11.1125 $B4C
 706 7 RCC  0.0 0.0 0.00000  0.0 0.0 91.44000 11.4300 $Al layer
 707 7 RCC  0.0 0.0 3.65125  0.0 0.0 87.78875 9.84250
 708 7 RCC  0.0 0.0 1.90500  0.0 0.0  0.63500 7.62000 $B4C bottom
7091 7 RCC  0.0 -8.890 0.00  0.0 0.0 91.44000 0.31750 $Dowel 1
7092 7 RCC  0.0  8.890 0.00  0.0 0.0 91.44000 0.31750 $Dowel 2
C
C  14" Aluminum Bucket
C
 710 7 RCC  0.0 0.0 0.15875  0.0 0.0 35.40125 11.27125   $Void
 711 7 RCC  0.0 0.0 0.00000  0.0 0.0 35.56000 11.43000   $Al bucket
C
C USE these for a 24" Aluminum Bucket
C
C 710 7 RCC  0.0 0.0 0.15875  0.0 0.0 60.80125 11.27125   $Void
C 711 7 RCC  0.0 0.0 0.00000  0.0 0.0 60.96000 11.43000   $Al bucket
C
C  LP-1 Surfaces
C
 720 7 RCC  0.0 0.0 5.74675  0.0 0.0 62.18825  7.46125   $Inside
 721 7 RCC  0.0 0.0 5.58800  0.0 0.0 73.15200  7.62000   $Al liner
 722 7 RCC  0.0 0.0 3.55600  0.0 0.0 64.37900  8.63600   $Pb
 723 7 RCC  0.0 0.0 2.54000  0.0 0.0 65.39500 10.66800   $HDPE
 724 7 RCC  0.0 0.0 3.55600  0.0 0.0  1.01600  7.62000   $HDPE fill-in
 725 7 RCC  0.0 0.0 0.00000  0.0 0.0 78.74000 11.43000   $Al Container
 726 7 RCC  0.0 0.0 67.9350  0.0 0.0 10.80500  7.46125
C
C  Boom Box Surfaces
C
 730  7 RCC  0.0 0.0 0.0      0.0 0.0 65.786   9.8425
 731  7 RCC  0.0 0.0 65.913   0.0 0.0  3.048   9.8425
 732  7 RCC  0.0 0.0 65.786   0.0 0.0  0.127   8.1280
 733  7 RCC  0.0 0.0 65.786   0.0 0.0  3.175   5.0800
 734  7 RCC  0.0 0.0 65.786   0.0 0.0  0.127   9.8425
 735  7 RCC  0.0 0.0 59.436   0.0 0.0  6.350   6.6675
 736  7 RCC  0.0 0.0 59.436   0.0 0.0  6.350   6.7945
 737  7 RCC  0.0 0.0  2.540   0.0 0.0 54.864   7.9375
 738  7 RCC  0.0 0.0 57.404   0.0 0.0  2.032   5.0800
C
C
C New 44" Pb-B4C Bucket
C Base Plate w/ B4C Volume
C From Ktech drawing labeled "PbB BASEII"
C
800  7 RCC  0.000  0.000  0.000  0.000  0.000  1.905  11.43  $ Base Plate Bottom
801  7 RCC  0.000  0.000  1.905  0.000  0.000  1.905  7.9375 $ Base Plate Top
802  7 RCC  0.000  0.000  2.2225 0.000  0.000  1.27   7.62   $ B4C Cavity
C Bolts/Bolt Holes
C Big Bolts/Bolt Holes
C From McMaster-Carr catalog, Item # 98914A033, Threaded Rods and Studs
803  7 RCC  8.890  0.000  0.000  0.000  0.000  1.905  0.53594  $ All-Thread #1
804  7 RCC  8.890  0.000  1.524  0.000  0.000  0.381  0.65151  $ All-Thread Hole #1
805  7 RCC  8.890  0.000  1.2954 0.000  0.000  0.2286 0.674688 $ All-Thread Washer Void #1
806  7 RCC  8.890  0.000  1.2954 0.000  0.000  0.2286 1.27     $ All-Thread Washer #1
807  7 RCC  8.890  0.000  0.50165 0.000 0.000  0.79375 0.9525  $ All-Thread Nut #1
808  7 RCC  8.890  0.000  0.000  0.000  0.000  1.524  1.5875   $ All-Thread Nut Hole #1
809  7 RCC -8.890  0.000  0.000  0.000  0.000  1.905  0.53594  $ All-Thread #2
810  7 RCC -8.890  0.000  1.524  0.000  0.000  0.381  0.65151  $ All-Thread Hole #2
811  7 RCC -8.890  0.000  1.2954 0.000  0.000  0.2286 0.674688 $ All-Thread Washer Void #2
812  7 RCC -8.890  0.000  1.2954 0.000  0.000  0.2286 1.27     $ All-Thread Washer #2
813  7 RCC -8.890  0.000  0.50165 0.000 0.000  0.79375 0.9525  $ All-Thread Nut #2
814  7 RCC -8.890  0.000  0.000  0.000  0.000  1.524  1.5875   $ All-Thread Nut Hole #2
C Small Bolts/Bolt Holes
C From McMaster-Carr catalog, Item # 44705K334, Low-Pressure Aluminum Threaded Square-Socket Plug
815  7 RCC  0.000  5.3975 0.000  0.000  0.000  2.2225 0.71374 $ Small Hole #1
816  7 RCC  0.000 -5.3975 0.000  0.000  0.000  2.2225 0.71374 $ Small Hole #2
817  7 RCC  0.000  5.3975 0.000  0.000  0.000  1.2192 0.71374 $ Plug #1
818  7 RCC  0.000 -5.3975 0.000  0.000  0.000  1.2192 0.71374 $ Plug #2
819  7 RPP -0.357188 0.357188  5.040313  5.754688 0.000 0.862648 $ Plug #1 9/32" Hole
820  7 RPP -0.357188 0.357188 -5.754688 -5.040313 0.000 0.862648 $ Plug #2 9/32" Hole
C
C Containment Base
C From Ktech drawing labeled "CONTAINMENT BASE II"
C
830  7 RCC  0.000  0.000  1.905  0.000  0.000  1.905  7.9883 $ Inner void
831  7 RCC  0.000  0.000  1.905  0.000  0.000  1.905  9.779  $ Inner Disc Region
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832  7 RCC  0.000  0.000  1.905  0.000  0.000  0.635  11.43  $ Outer Disc Region
833  7 RCC  8.890  0.000  1.905  0.000  0.000  1.905  0.53594 $ All-thread #1, General purpose steel
834  7 RCC -8.890  0.000  1.905  0.000  0.000  1.905  0.53594 $ All-thread #2, General purpose steel
C
C Lead Bottom, Floor, and Rings (Items #4, 5, and 6 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C Drawn March 22, 2010 by S. Padias
C Unchamfered lead components
C
840  7 RCC  0.000  0.000  3.810  0.000  0.000  2.540  9.7663  $ Lead bottom disc
C 841  7 RCC  0.000  0.000  6.350  0.000  0.000  100.33 6.477   $ Inner lead void
842  7 RCC  0.000  0.000  6.350  0.000  0.000  100.33 9.7663  $ Lead ring
843  7 RCC  8.89   0.000  3.810  0.000  0.000  106.68 0.65532 $ Right-side big lead hole
844  7 RCC -8.89   0.000  3.810  0.000  0.000  106.68 0.65532 $ Left-side big lead hole
845  7 RCC  0.000  8.89   3.810  0.000  0.000  106.68 0.32639 $ Top-side small lead hole
846  7 RCC  0.000 -8.89   3.810  0.000  0.000  106.68 0.32639 $ Bottom-side small lead hole
C From McMaster-Carr catalog, Item # 98914A033, Threaded Rods and Studs
847  7 RCC  8.89   0.000  3.810  0.000  0.000  113.665 0.53594 $ Right-side All-Thread
848  7 RCC -8.89   0.000  3.810  0.000  0.000  113.665 0.53594 $ Left-side All-Thread
C General Purpose Aluminum Tubing
C From McMaster-Carr catalog, Item # 89965K42, General Purpose Aluminum Tubing
849  7 RCC  0.000  8.89   3.810  0.000  0.000  111.76  0.2286  $ Top-side inner radius Al6061 Tubing
850  7 RCC  0.000  8.89   3.810  0.000  0.000  111.76  0.3175  $ Top-side outer radius Al6061 Tubing
851  7 RCC  0.000 -8.89   3.810  0.000  0.000  111.76  0.2286  $ Bottom-side inner radius Al6061 Tub
852  7 RCC  0.000 -8.89   3.810  0.000  0.000  111.76  0.3175  $ Bottom-side outer radius Al6061 Tub
C Chamfered lead components
853  7 TRC  0.000  0.000  106.68 0.000  0.000  3.81   6.477  7.62  $ Chamfered lead ring void
854  7 RCC  0.000  0.000  106.68 0.000  0.000  3.81   9.7663  $ Chamfered lead ring radius
C
C Inner Aluminum 6061 Sleeves (Items #14 and 15 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C
860  7 RCC  0.000  0.000  6.35   0.000  0.000  0.08255 6.477  $ Al6061 Base Plate
861  7 RCC  0.000  0.000  6.43255 0.000 0.000  100.1776 6.39445 $ Al6061 Sheet void
862  7 RCC  0.000  0.000  6.43255 0.000 0.000  100.1776 6.477 $ Al6061 Sheet
863  7 RCC  0.000  0.000  106.6102 0.000 0.000 0.0698   6.477 $ Void
C
C PbB base II Double Wall Weldment (Item #9 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C
868  7 RCC  0.000  0.000  2.54   0.000  0.000  107.315 9.8425 $ Inner Surface of Inner Skin II L1
869  7 RCC  0.000  0.000  2.54   0.000  0.000  107.315 10.16  $ Inner Skin II L1
870  7 RCC  0.000  0.000  109.855 0.000  0.000  0.254  9.8425 $ Inner Surface of Inner Skin II L2
871  7 RCC  0.000  0.000  109.855 0.000  0.000  0.254  10.16  $ Inner Skin II L2
872  7 RCC  0.000  0.000  110.109 0.000  0.000  0.381  9.8425 $ Inner Surface of Inner Skin II L3
873  7 RCC  0.000  0.000  110.109 0.000  0.000  0.381  10.16  $ Inner Skin II L3
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874  7 RCC  0.000  0.000  2.54   0.000  0.000  107.315 11.1125 $ B4C Powder Region L1
875  7 RCC  0.000  0.000  2.54   0.000  0.000  107.315 11.43  $ Outer Skin II L1
876  7 RCC  0.000  0.000  109.855 0.000  0.000  0.254  11.1125 $ B4C Powder Region L2
877  7 RCC  0.000  0.000  109.855 0.000  0.000  0.254  11.43  $ Outer Skin II L2
878  7 RCC  0.000  0.000  110.109 0.000  0.000  0.381  11.1125 $ B4C Powder Region L3
879  7 RCC  0.000  0.000  110.109 0.000  0.000  0.381  11.43  $ Outer Skin II L3
C
C PbB Top: Top Plate (Item #1 in DWG titled "LEAD BORON BUCKET ASSEMBLY II")
C
880  7 RCC  0.000  0.000  110.49 0.000  0.000  0.4318 7.62    $ Lower void
881  7 TRC  0.000  0.000  110.9218 0.000 0.000 0.8382 7.62 8.103935 $ Upper void
882  7 RCC  0.000  0.000  110.49 0.000  0.000  1.27   11.43   $ Al6061 Disc
883  7 RCC  0.000  0.000  110.49 0.000  0.000 -0.381  10.1727 $ Lower B4C Cap void
884  7 RCC  0.000  0.000  110.49 0.000  0.000 -0.381  11.0998 $ B4C Cap
885  7 TRC  0.000  0.000  109.855 0.000 0.000  0.254  10.4267 10.1727 $ Inner chamfer
886  7 TRC  0.000  0.000  109.855 0.000 0.000  0.254  10.8458 11.0998 $ Outer chamfer
C Top Plate holes
887  7 RCC -8.89   0.000  110.49 0.000  0.000  1.27   0.65151 $ Left Large hole
888  7 RCC  8.89   0.000  110.49 0.000  0.000  1.27   0.65151 $ Right Large hole
889  7 RCC  0.000 -8.89   110.49 0.000  0.000  1.27   0.65151 $ Bottom Large hole
890  7 RCC  0.000  8.89   110.49 0.000  0.000  1.27   0.65151 $ Top Large hole
891  7 RCC  -2.54  8.89   110.49 0.000  0.000  1.27   0.3175  $ Small Hole #1
892  7 RCC   2.54  8.89   110.49 0.000  0.000  1.27   0.3175  $ Small Hole #2
893  7 RCC  -2.54 -8.89   110.49 0.000  0.000  1.27   0.3175  $ Small Hole #1
894  7 RCC   2.54 -8.89   110.49 0.000  0.000  1.27   0.3175  $ Small Hole #2
C Modified Hex Head Plugs, 1/4 NPT, AL6061-T6 (Item #16 in DWG titled "LEAD BORON BUCKET ASSEMBLY")
C From McMaster-Carr catalog, Item # 3867T65, High-Pressure Aluminum Pipe Fitting
821  7 RCC  0.000 -8.89   111.76 0.000  0.000 -1.27   0.65151 $ Bottom Hex Thread
822  7 RCC  0.000 -8.89   111.76 0.000  0.000  0.635  0.79375 $ Bottom Hex Head
823  7 RCC  0.000  8.89   111.76 0.000  0.000 -1.27   0.65151 $ Top Hex Thread
824  7 RCC  0.000  8.89   111.76 0.000  0.000  0.635  0.79375 $ Top Hex Head
C
C Enclosing surface for the 44" Pb-B4C bucket
C
899  7 RCC  0.000  0.000  0.000  0.000  0.000  117.475 11.43  $ Enclosing surface
C
C
C  EXPERIMENT SURFACES
C
1001 6 SO   3.                                 $ 6 cm dia scoring sphere
1002 6 rcc  0. -0.013301675 0.   0. 0.026603351 0.   0.635     $ Nickel Foil
C
C    External Cutoff
```

```
C
900 RCC  0.000  0.000 -67.395  0.000  0.000  202.395 72.0000

C ***************************
C *     TRANSFORMATIONS     *
C ***************************
C
C  TR1 rotates the hexes for the outer core bound and the cavity liner
C
*TR1   0 0 0 30 60 90 120 30 90
C
C  TR3-->Movement of control rods -0.001 (full up) to -55.001 (full down)
C
C
C   Measured Up DC with 32-in pedestal is -39.731               (03/03/2004)
C   Measured Down DC is -30.851                                (03/03/2004)
C    -->Up DC position of 1527 Rod Units
C    -->Down DC position of 2415 Rod Units
C   Measured Up DC with 8-in + 32-in pedestal is -40.421         (03/01/2004)
C   Measured Down DC with 8-in + 32-in pedestal is -31.291       (03/01/2004)
C    -->Up DC position of 1428 Rod Units
C    -->Down DC position of 2371 Rod Units
C   Measured Up DC with Pb-B4C on 32-in pedestal is -22.951      (03/09/2004)
C   Measured Down DC with Pb-B4C on 32-in pedestal is -10.741    (03/09/2004)
C    -->Up DC position of 3205 Rod Units
C    -->Down DC position of 4426 Rod Units
C   Measured DC with LP-1 on 32-in pedestal is -31.941           (03/11/2004)
C   Measured Down DC with LP-1 on 32-in pedestal is -23.721      (03/11/2004)
C    -->Up DC position of 2306 Rod Units
C    -->Down DC position of 3128 Rod Units
C
*TR3   0 0 -41.50
C
C  TR4-->Movement of safety rods 0.001 (full up) to -54.999 (full down)
C
C    Measured worth of safety rods:  -$2.12                      (03/30/2004)
C
*TR4   0 0  0.001
C
C  TR5-->Movement of transient rods 0 (full down) to 90 (full up)
C
C    Measured worth of transient rods:  -$4.14                   (03/30/2004)
C
```

```
*TR5   0 0  90
C
C  TR6-->Moves experiment package from origin (0 0 0) to fuel centerline
C
*TR6   0  0  49.445
C
C  TR7-->Puts buckets on 8" (34.205) or 32" (13.885) pedestals
C   Use 32" pedestal for LP-1
C   Use 8" for Standard Al buckets
C
*TR7   0  0  13.885
C
C ********************
C *  MATERIAL CARDS  *
C ********************
C  Materials cards use the latest available cross sections
C
C  UO2-BeO fuel (3.3447 g/cc)  (XSEC Temp - 293.6 K)
C
C
M1      4009.70c -0.2827602   8016.70c -0.5277690  92235.70c -0.0662957
        92238.70c -0.1222844  92234.70c -0.0004547  92236.70c -0.0004358
MT1     beo.60t      $ S(alpha, beta) for UO2-BeO (Temp - 294 K)
C
C
C  UO2-BeO fuel (3.0102 g/cc)  -- This is the 90% fuel
C                               (XSEC Temp - 293.6 K)
C   Included as a separate material to avoid warning message
C
C
M11     4009.70c -0.2827602   8016.70c -0.5277690  92235.70c -0.0662957
        92238.70c -0.1222844  92234.70c -0.0004547  92236.70c -0.0004358
MT11    beo.60t      $ S(alpha, beta) for BeO (Temp - 294 K)
C
C     NIOBIUM (8.4 g/cc)
C
M2     41093.70c  1.0000
C
C
C  SS-304L from Ktech Materials Database Rev. 118
C   Material Number:  3410
C     Values are weight %
C      Si: 0.0100  Cr: 0.1900  Mn: 0.0200  Fe: 0.6800  Ni: 0.1000
```

```
C
C FM multiplier (neutrons):  1.76109641E-10  3410  -4   1
C FM multiplier (photons):   1.76109641E-10  3410  -5  -6
C
C  Density:  7.896 g/cc
C
M3     14028.70c -0.009187  14029.70c -0.000483  14030.70c -0.000329
       24050.70c -0.007930  24052.70c -0.159029  24053.70c -0.018380
       24054.70c -0.004661  25055.70c -0.020000  26054.70c -0.038390
       26056.70c -0.624930  26057.70c -0.014691  26058.70c -0.001989
       28058.70c -0.067198  28060.70c -0.026776  28061.70c -0.001183
       28062.70c -0.003834  28064.70c -0.001009
C
C
C     BeO (2.8 g/cc)
C
M4      4009.70c  0.5000     8016.70c  0.4998096    8017.70c  0.0001904
MT4     beo.60t      $ S(alpha, beta) for BeO (Temp - 294 K)
C
C     Water (1 g/cc)
C
M5    1001.70c  0.6665667    1002.70c  0.000100
      8016.70c  0.3332063    8017.70c  0.000127
MT5    lwtr.60t     $ S(alpha, beta) for water (Temp - 294 K)
C
C
C  Ni reflector
C          Values are weight %
C          Ni-58: 67.19780  Ni-60: 26.77586  Ni-61:  1.18346
C          Ni-62:  3.83429  Ni-64:  1.00859
C    Converted Data from Nuclear Wallet Card to w/o with "Weight_Frac" program
C  Density:  8.9020 g/cc
C
C
M6    28058.70c -0.6719780 28060.70c -0.2677586 28061.70c -0.0118346
      28062.70c -0.0383429 28064.70c -0.0100859
C
C
C  Al-6061 from Ktech Materials Database Rev. 118
C    Material Number:  3110
C     Values are weight %
C      Mg: 0.0110  Al: 0.9670  Si: 0.0080  Ti: 0.0007
C      Cr: 0.0020  Mn: 0.0013  Fe: 0.0056  Ni: 0.0004
```

```
C      Cu: 0.0030  Zn: 0.0010
C
C FM multiplier (neutrons):  3.55249469E-10  3110  -4   1
C FM multiplier (photons):   3.55249469E-10  3110  -5  -6
C
C  Density:  2.704 g/cc
C
M7     12000.66c -0.011000  13027.70c -0.967000  14028.70c -0.007350
       14029.70c -0.000387  14030.70c -0.000263  22000.66c -0.000700
       24050.70c -0.000084  24052.70c -0.001674  24053.70c -0.000193
       24054.70c -0.000049  25055.70c -0.001300  26054.70c -0.000316
       26056.70c -0.005147  26057.70c -0.000121  26058.70c -0.000016
       28058.70c -0.000269  28060.70c -0.000107  28061.70c -0.000005
       28062.70c -0.000015  28064.70c -0.000004  29063.70c -0.002055
       29065.70c -0.000945  30000.42c -0.001000
C
C
C    B4C poison (2.48 g/cc)
C    Composition data taken from Jeff Wemple (KTech) Memo dated June 18, 2010
C    and titled "Re: Drawing of new Lead-boron bucket"
C    Manufacturer of powder is READE ADVANCED MATERIALS
C    Density of packed powder in the 44" Pb-B4C bucket is 1.2505 (half of 2.51 g/cc)
C
M8      6000.70c  0.20000   5010.70c  0.159200   5011.70c  0.640800
C
C
C  Natural Lead
C  True Weight %:  Pb-204:  1.37808  Pb-206: 23.95550
C                  Pb-207: 22.07430  Pb-208: 52.59212
C  Weight % based on Available MCNP XSEC:
C                  Pb-206: 24.29024  Pb-207: 22.38275
C                  Pb-208: 53.32701
C
C    Converted Data from Nuclear Wallet Card to w/o with "Weight_Frac" program
C  Density is 11.35 g/cc from Nuclear Wallet Cards.
C
C
M700  82206.70c -0.2429024  82207.70c -0.2238275
      82208.70c -0.5332701
C
C
C Boral Plate Composition
C
```

```
C  Composition found in Nuclear Science and Engineering
C   Vol. 65, No. 1, pgs. 41-48, January 1978.
C   Values are weight %
C        B: 27.40   C:  7.61  Al: 63.68
C       Cu:  0.09  Zn:  0.16  Fe:  0.45
C       Cr:  0.10  Mn:  0.10  Mg:  0.05
C       Ti:  0.10  Li:  0.26
C
C   Density:  2.53 g/cc
C
C
M701   5010.70c -0.050242   5011.70c -0.223758    6000.70c -0.076100
      13027.70c -0.636800  29063.70c -0.000616   29065.70c -0.000284
      30000.42c -0.001600  26056.70c -0.004500   24050.70c -0.000042
      24052.70c -0.000837  24053.70c -0.000097   24054.70c -0.000024
      25055.70c -0.001000  12000.66c -0.000500   22000.66c -0.001000
       3006.70c -0.000171   3007.70c -0.002429
C
C
C
C  Air
C   Standard Density:  1.205e-3 g/cc @ 20 deg C, 1 atm
C   Albuquerque:       1.0245e-3 g/cc in ABQ
C  See Attix p.531-532
C
M702   7014.70c -0.752308   7015.70c -0.002960   8016.70c -0.231687
       8017.70c -0.000094   6000.70c -0.000124  18000.42c -0.012827
C
C
C   HELIUM  For Leak Test
C    @ 2 atm density = 3.57e-4 g/cc
C
M703   2003.70c 0.00000137  2004.70c  0.99999863
C
C
C HDPE-> (C2H4)n    --          --
C                  |   H    H   |
C                  |   |    |   |
C                 -|-  C -- C  -|-
C                  |   |    |   |
C                  |   H    H   |
C                  --         --
C
```

```
M704   1001.70c  0.666667   6000.70c  0.333333
MT704  poly.60t
C
C
C   A517 Carbon Steel  (den = 7.28 g/cc)
C     Modified to match the mill test cert.
C     from Tubos de Acero de Mexico, S.A.
C
C   Summary of MatMCNP Calculations:
C
C  Isotope  Number Fraction    Weight Fraction       Atoms/b-cm
C   C-12       0.0118115          0.0025688          0.0009385
C   C-13       0.0001326          0.0000312          0.0000105
C  Si-28       0.0048924          0.0024807          0.0003887
C  Si-29       0.0002484          0.0001305          0.0000197
C  Si-30       0.0001638          0.0000890          0.0000130
C  Cr-50       0.0000184          0.0000167          0.0000015
C  Cr-52       0.0003557          0.0003348          0.0000283
C  Cr-53       0.0000403          0.0000387          0.0000032
C  Cr-54       0.0000100          0.0000098          0.0000008
C  Mn-55       0.0078340          0.0078003          0.0006225
C  Fe-54       0.0568920          0.0556172          0.0045205
C  Fe-56       0.8930822          0.9053674          0.0709617
C  Fe-57       0.0206252          0.0212829          0.0016388
C  Fe-58       0.0027448          0.0028820          0.0002181
C  Cu-63       0.0007628          0.0008700          0.0000606
C  Cu-65       0.0003400          0.0004001          0.0000270
C  Mo-92       0.0000068          0.0000114          0.0000005
C  Mo-94       0.0000043          0.0000072          0.0000003
C  Mo-95       0.0000073          0.0000126          0.0000006
C  Mo-96       0.0000077          0.0000133          0.0000006
C  Mo-97       0.0000044          0.0000077          0.0000003
C  Mo-98       0.0000111          0.0000197          0.0000009
C  Mo-100      0.0000044          0.0000080          0.0000004
C
C  The total compound atom density (atom/b-cm):  0.07945702
C
M765    06000.70c  0.0119440  14028.70c  0.0048924  14029.70c  0.0002484
        14030.70c  0.0001638  24050.70c  0.0000184  24052.70c  0.0003557
        24053.70c  0.0000403  24054.70c  0.0000100  25055.70c  0.0078340
        26054.70c  0.0568920  26056.70c  0.8930822  26057.70c  0.0206252
        26058.70c  0.0027448  29063.70c  0.0007628  29065.70c  0.0003400
        42000.66c  0.0000460
```

```
C
C
C
C  General Purpose Steel, Grade B7
C   7 Comment Cards
C
C  1
C  2 The weight fraction for elements of General Purpose Steel, Grade B7 is
C  3 The weight fractions are used for each element.
C  4 The density of natural cadmium is 7.83 g/cc,
C  5 The MCNP material number is found after the material.
C  6 The line below "7" gives the density.
C  7
C
C   Summary of MatMCNP Calculations:
C
C  Isotope  Number Fraction    Weight Fraction       Atoms/b-cm
C   C-12       0.0194064          0.0042483          0.0016694
C   C-13       0.0002178          0.0000517          0.0000187
C  Mn-55       0.0087306          0.0087500          0.0007510
C   P-31       0.0006194          0.0003500          0.0000533
C   S-32       0.0006498          0.0003790          0.0000559
C   S-33       0.0000051          0.0000031          0.0000004
C   S-34       0.0000288          0.0000178          0.0000025
C   S-36       0.0000001          0.0000001          0.0000000
C  Si-28       0.0045003          0.0022968          0.0003871
C  Si-29       0.0002285          0.0001208          0.0000197
C  Si-30       0.0001506          0.0000824          0.0000130
C  Cr-50       0.0004466          0.0004069          0.0000384
C  Cr-52       0.0086125          0.0081607          0.0007409
C  Cr-53       0.0009766          0.0009432          0.0000840
C  Cr-54       0.0002431          0.0002392          0.0000209
C  Mo-92       0.0001696          0.0002843          0.0000146
C  Mo-94       0.0001057          0.0001811          0.0000091
C  Mo-95       0.0001819          0.0003150          0.0000157
C  Mo-96       0.0001906          0.0003335          0.0000164
C  Mo-97       0.0001091          0.0001929          0.0000094
C  Mo-98       0.0002758          0.0004925          0.0000237
C  Mo-100      0.0001101          0.0002006          0.0000095
C  Fe-54       0.0557637          0.0548720          0.0047968
C  Fe-56       0.8753707          0.8932369          0.0753001
C  Fe-57       0.0202161          0.0209977          0.0017390
C  Fe-58       0.0026904          0.0028434          0.0002314
```

```
C
C  The total compound atom density (atom/b-cm):  0.08602087
C
C  This material contains an isotope that is often
C  modified by an S(alpha,beta). Check MCNP
C  Manual Appendix G to see if an
C  S(alpha,beta) is required.
C
C  MCNP Material 766
C
M766    06000.70c  0.0196242
        25055.70c  0.0087306
        15031.70c  0.0006194
        16000.66c  0.0006838
        14028.70c  0.0045003
        14029.70c  0.0002285
        14030.70c  0.0001506
        24050.70c  0.0004466
        24052.70c  0.0086125
        24053.70c  0.0009766
        24054.70c  0.0002431
        42000.66c  0.0011428
        26054.70c  0.0557637
        26056.70c  0.8753707
        26057.70c  0.0202161
        26058.70c  0.0026904
C
C  Caution: The natural zaid is used for Carbon.
C
C  Caution: The natural zaid is used for Sulfur.
C
C  Caution: The natural zaid is used for Molybdenum.
C
C  If the natural zaid is used for any element, the atom fractions of each isotope
C  of that element are added together and listed with the natural zaid just once.
C
C  To convert a particle flux to rad[Material]
C  use FM  1.76023016E-10 766  -4 1 for neutrons
C   or FM  1.76023016E-10 766  -5 -6 for photons.
C
C
C  Carbon Steel
C   8 Comment Cards
```

```
C
C  1
C  2 The weight fraction for elements of carbon steel is used.
C  3 The weight fractions are used for each element.
C  4 Data obtained from MCNP Primer by C.D. Harmon and R.D. Busch (1994)
C  5 The density of natural cadmium is 7.82 g/cc,
C  6 The MCNP material number is found after the material.
C  7 The line below "8" gives the density.
C  8
C
C   Summary of MatMCNP Calculations:
C
C  Isotope  Number Fraction    Weight Fraction       Atoms/b-cm
C   C-12       0.0225772          0.0049399          0.0019386
C   C-13       0.0002534          0.0000601          0.0000218
C  Fe-54       0.0571155          0.0561733          0.0049043
C  Fe-56       0.8965919          0.9144202          0.0769875
C  Fe-57       0.0207062          0.0214957          0.0017780
C  Fe-58       0.0027556          0.0029108          0.0002366
C
C  The total compound atom density (atom/b-cm):  0.08586678
C
C  This material contains an isotope that is often
C  modified by an S(alpha,beta). Check MCNP
C  Manual Appendix G to see if an
C  S(alpha,beta) is required.
C
C  MCNP Material 767
C
M767    06000.70c  0.0228306
        26054.70c  0.0571155
        26056.70c  0.8965919
        26057.70c  0.0207062
        26058.70c  0.0027556
C
C  Caution: The natural zaid is used for Carbon.
C
C  If the natural zaid is used for any element, the atom fractions of each isotope
C  of that element are added together and listed with the natural zaid just once.
C
C  To convert a particle flux to rad[Material]
C  use FM  1.75917531E-10 767  -4 1 for neutrons
C   or FM  1.75917531E-10 767  -5 -6 for photons.
```

```
C
C
C ********************
C * TALLIES  *
C ********************
C
C
F24:N   1001
FC24    neutron fluence  n/cm**2/source neutron - 63 group
E24     1.00000E-11  5.00000E-09  1.00000E-08
                                                    1.50000E-08  2.00000E-08  2.50000E-08
                                     3.00000E-08  3.50000E-08  4.20000E-08
                                                    5.00000E-08  5.80000E-08  6.70000E-08
                                                    8.00000E-08  1.00000E-07  1.52000E-07
                                                    2.51000E-07  4.14000E-07  6.83000E-07
                                                    1.12500E-06  1.85500E-06  3.05900E-06
                                                    5.04300E-06  8.31500E-06  1.37100E-05
                                                    2.26000E-05  3.72700E-05  6.14400E-05
                                                    1.01300E-04  1.67000E-04  2.75400E-04
                                                    4.54000E-04  7.48500E-04  1.23400E-03
                                                    2.03500E-03  2.40400E-03  2.84000E-03
                                                    3.35500E-03  5.53100E-03  9.11900E-03
                                                    1.50300E-02  1.98900E-02  2.55400E-02
                                                    4.08700E-02  6.73800E-02  1.11100E-01
                                                    1.83200E-01  3.02000E-01  3.88700E-01
                                                    4.97900E-01  6.39279E-01  8.20850E-01
                                                    1.10803E+00  1.35335E+00  1.73774E+00
                                                    2.23130E+00  2.86505E+00  3.67879E+00
                                                    4.96585E+00  6.06500E+00  1.00000E+01
                                                    1.49182E+01  1.69046E+01  2.00000E+01
                                                    2.50E+01
C
F44:N  1001
FC44   total neutron fluence  n/cm**2/source neutron
C
C
MODE N
C  20B
KCODE 10000000 1.0 3 2000
c KCODE 100000 1.0 3 2000
KSRC   20 0 50  0 20 60  30 0 40  0 30 60
C    PRINT  10 60 100 110
RAND  GEN=2 SEED=19073486328125 STRIDE=152917
```

```
1115        PRDMP  50 50 0 1 0
```

APPENDIX B – Example CINDER Files

Input:

```
Thesis Example Run
1.0,100.0,1.0E-20,1.0E-20, , , , ,0,0,2,-1,0,0, , ,1,1, ,1000,10000,1000,10000
Thesis Example Run
fluxname
maters
1 1.0
1 's'

1 0.0
3723 's'
```

Fluxes:

```
                                    fluxes File          63
fluxname                                  2.00111E13
9.4200E09 3.0235E10 5.0838E10 6.4828E10 7.4435E10 8.0443E10 8.3643E10 1.1756E11
1.3080E11 1.2267E11 1.2753E11 1.5871E11 1.9902E11 3.1977E11 2.9680E11 2.6857E11
2.7631E11 2.7467E11 2.7916E11 2.7945E11 2.7651E11 2.7672E11 2.9405E11 3.0182E11
3.1505E11 2.7916E11 3.3811E11 3.4493E11 3.6870E11 3.0278E11 3.6467E11 3.6151E11
4.0255E11 1.1534E11 1.1489E11 1.3439E11 4.0025E11 3.6491E11 4.2993E11 2.2570E11
2.5442E11 3.7782E11 5.4444E11 6.2048E11 7.7693E11 9.7421E11 5.8161E11 5.2261E11
6.9985E11 8.2463E11 7.8493E11 6.1056E11 8.2111E11 7.1229E11 6.5644E11 3.9800E11
3.2268E11 1.2249E11 9.3896E10 4.8859E09 9.1226E07 1.8821E07 1.4959E06
```

Locate:

```
C:\Cinder2008\Data\c90lib0742

C:\Cinder2008\Data\cindergl.dat
```

Material:

```
Thesis Example Run
maters282 0.091347904
0010010 0.04736832344
0020010 0.00000544861
0030020 0.00000000000
0040020 0.00000000000
0060030 0.00000000000
0070030 0.00000000000
0090040 0.00000000000
0100050 0.00000000000
0110050 0.00000000000
0120060 0.02324544377
0130060 0.00025147483
0140070 0.00000000000
0150070 0.00000000000
0160080 0.00000000000
0170080 0.00000000000
0180080 0.00000000000
```

0190090	0.01929183524
0200100	0.00000000000
0210100	0.00000000000
0220100	0.00000000000
0230110	0.00000000000
0240120	0.00000000000
0240120	0.00000000000
0240120	0.00000000000
0270130	0.67168639259
0280140	0.00000000000
0290140	0.00000000000
0300140	0.00000000000
0310150	0.00000000000
0320160	0.19512931252
0330160	0.00154065513
0340160	0.00032037774
0360160	0.00002051010
0350170	0.00000000000
0370170	0.00000000000
0360180	0.00000000000
0380180	0.00000000000
0400180	0.00000000000
0390190	0.00000000000
0400190	0.00000000000
0410190	0.00000000000
0400200	0.00943082372
0420200	0.00006293697
0430200	0.00001313331
0440200	0.00020330822
0460200	0.00000039028
0480200	0.00001818858
0450210	0.00000000000
0460220	0.00000000000
0470220	0.00000000000
0480220	0.00000000000
0490220	0.00000000000
0500220	0.00000000000
0500230	0.00000000000
0510230	0.00000000000
0500240	0.00000000000
0520240	0.00000000000
0530240	0.00000000000
0540240	0.00000000000
0550250	0.00000000000
0540260	0.00000000000
0560260	0.00000000000
0570260	0.00000000000
0580260	0.00000000000
0590270	0.00000000000
0580280	0.02138320562
0600280	0.00823764765
0600280	0.00035810643
0620280	0.00114175452
0640280	0.00029073073
0630290	0.00000000000
0650290	0.00000000000
0640300	0.00000000000
0660300	0.00000000000
0670300	0.00000000000
0680300	0.00000000000
0700300	0.00000000000
0690310	0.00000000000
0710310	0.00000000000
0700320	0.00000000000
0720320	0.00000000000
0730320	0.00000000000
0740320	0.00000000000
0760320	0.00000000000
0750330	0.00000000000
0740340	0.00000000000

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0760340 0.00000000000
0770340 0.00000000000
0780340 0.00000000000
0800340 0.00000000000
0820340 0.00000000000
0790350 0.00000000000
0810350 0.00000000000
0780360 0.00000000000
0800360 0.00000000000
0820360 0.00000000000
0830360 0.00000000000
0840360 0.00000000000
0860360 0.00000000000
0850370 0.00000000000
0870370 0.00000000000
0840380 0.00000000000
0860380 0.00000000000
0870380 0.00000000000
0880380 0.00000000000
0890390 0.00000000000
0900400 0.00000000000
0910400 0.00000000000
0920400 0.00000000000
0940400 0.00000000000
0960400 0.00000000000
0930410 0.00000000000
0920420 0.00000000000
0940420 0.00000000000
0950420 0.00000000000
0960420 0.00000000000
0970420 0.00000000000
0980420 0.00000000000
1000420 0.00000000000
0960440 0.00000000000
0980440 0.00000000000
0990440 0.00000000000
1000440 0.00000000000
1010440 0.00000000000
1020440 0.00000000000
1040440 0.00000000000
1030450 0.00000000000
1020460 0.00000000000
1040460 0.00000000000
1050460 0.00000000000
1060460 0.00000000000
1080460 0.00000000000
1100460 0.00000000000
1070470 0.00000000000
1090470 0.00000000000
1060480 0.00000000000
1080480 0.00000000000
1100480 0.00000000000
1110480 0.00000000000
1120480 0.00000000000
1130480 0.00000000000
1140480 0.00000000000
1160480 0.00000000000
1130490 0.00000000000
1150490 0.00000000000
1120500 0.00000000000
1140500 0.00000000000
1150500 0.00000000000
1160500 0.00000000000
1170500 0.00000000000
1180500 0.00000000000
1190500 0.00000000000
1200500 0.00000000000
1220500 0.00000000000
1240500 0.00000000000
1210510 0.00000000000
```

1230510	0.00000000000
1200520	0.00000000000
1220520	0.00000000000
1230520	0.00000000000
1240520	0.00000000000
1250520	0.00000000000
1260520	0.00000000000
1280520	0.00000000000
1300520	0.00000000000
1270530	0.00000000000
1240540	0.00000000000
1260540	0.00000000000
1280540	0.00000000000
1290540	0.00000000000
1300540	0.00000000000
1310540	0.00000000000
1320540	0.00000000000
1340540	0.00000000000
1360540	0.00000000000
1330550	0.00000000000
1300560	0.00000000000
1320560	0.00000000000
1340560	0.00000000000
1350560	0.00000000000
1360560	0.00000000000
1370560	0.00000000000
1380560	0.00000000000
1380570	0.00000000000
1390570	0.00000000000
1360580	0.00000000000
1380580	0.00000000000
1400580	0.00000000000
1420580	0.00000000000
1410590	0.00000000000
1420600	0.00000000000
1430600	0.00000000000
1440600	0.00000000000
1450600	0.00000000000
1460600	0.00000000000
1480600	0.00000000000
1500600	0.00000000000
1440620	0.00000000000
1470620	0.00000000000
1480620	0.00000000000
1490620	0.00000000000
1500620	0.00000000000
1520620	0.00000000000
1540620	0.00000000000
1510630	0.00000000000
1530630	0.00000000000
1520640	0.00000000000
1540640	0.00000000000
1550640	0.00000000000
1560640	0.00000000000
1570640	0.00000000000
1580640	0.00000000000
1600640	0.00000000000
1590650	0.00000000000
1560660	0.00000000000
1580660	0.00000000000
1600660	0.00000000000
1610660	0.00000000000
1620660	0.00000000000
1630660	0.00000000000
1640660	0.00000000000
1650670	0.00000000000
1620680	0.00000000000
1640680	0.00000000000
1660680	0.00000000000
1670680	0.00000000000

```
1680680 0.00000000000
1700680 0.00000000000
1690690 0.00000000000
1680700 0.00000000000
1700700 0.00000000000
1710700 0.00000000000
1720700 0.00000000000
1730700 0.00000000000
1740700 0.00000000000
1760700 0.00000000000
1750710 0.00000000000
1760710 0.00000000000
1740720 0.00000000000
1760720 0.00000000000
1770720 0.00000000000
1780720 0.00000000000
1790720 0.00000000000
1800720 0.00000000000
1800730 0.00000000000
1810730 0.00000000000
1800740 0.00000000000
1820740 0.00000000000
1830740 0.00000000000
1840740 0.00000000000
1860740 0.00000000000
1850750 0.00000000000
1870750 0.00000000000
1840760 0.00000000000
1860760 0.00000000000
1870760 0.00000000000
1880760 0.00000000000
1890760 0.00000000000
1900760 0.00000000000
1920760 0.00000000000
1910770 0.00000000000
1930770 0.00000000000
1900780 0.00000000000
1920780 0.00000000000
1940780 0.00000000000
1950780 0.00000000000
1960780 0.00000000000
1980780 0.00000000000
1970790 0.00000000000
1960800 0.00000000000
1980800 0.00000000000
1990800 0.00000000000
2000800 0.00000000000
2010800 0.00000000000
2020800 0.00000000000
2040800 0.00000000000
2030810 0.00000000000
2050810 0.00000000000
2040820 0.00000000000
2060820 0.00000000000
2070820 0.00000000000
2080820 0.00000000000
```

APPENDIX C – DREAD C# Code

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;

namespace DREAD
{
    public partial class DREAD : Form
    {
        public DREAD()
        {
            InitializeComponent();
        }

        private void listBox1_SelectedIndexChanged(object sender, EventArgs e)
        {

        }

        private void Form1_Load(object sender, EventArgs e)
        {

        }

        private void listView1_SelectedIndexChanged(object sender, EventArgs e)
        {

        }

        private void label1_Click(object sender, EventArgs e)
        {

        }

        private void label2_Click(object sender, EventArgs e)
        {

        }

        private void numericUpDown2_ValueChanged(object sender, EventArgs e)
        {

        }

        private void dateTimePicker1_ValueChanged(object sender, EventArgs e)
        {

        }

        private void dateTimePicker1_ValueChanged_1(object sender, EventArgs e)
        {

        }

        private void numericUpDown3_ValueChanged(object sender, EventArgs e)
        {

        }

        private void dateTimePicker1_ValueChanged_2(object sender, EventArgs e)
        {

        }

        private void textBox2_TextChanged(object sender, EventArgs e)
        {

        }

        private void button1_Click(object sender, EventArgs e)
        {

        }

        private void files_Click(object sender, EventArgs e)
        {
            System.Diagnostics.Process.Start("c:\\cinder\\" + titleTextBox.Text);
        }

        private void checkedListBox1_SelectedIndexChanged(object sender, EventArgs e)
        {

        }

        private void label7_Click(object sender, EventArgs e)
        {

        }

        private void textBox2_TextChanged_1(object sender, EventArgs e)
        {

        }

        private void execute_Click(object sender, EventArgs e)
        {
            System.IO.Directory.CreateDirectory("c:\\cinder\\" + titleTextBox.Text);
            input_Click(null, null);
            fluxes_Click(null, null);
            materials_Click(null, null);
            locate_Click(null, null);
            run_Click(null, null);
           // System.Threading.Thread.Sleep(10000);
            //results_Click(null, null);
        }

        private void input_Click(object sender, EventArgs e)
        {
            var filestream = new System.IO.StreamWriter("c:\\cinder\\" + titleTextBox.Text + "\\input");
            filestream.WriteLine(titleTextBox.Text);
            filestream.Write((vol.Value).ToString("F1"));//volcc Volume in cubic centimeters of the region. 1.0
            filestream.Write(",");
            if (pulse.Checked)
            {
                filestream.Write(MJ.Value);
            }
            if (ss.Checked)
            {
                filestream.Write(reactorpower.Value);
            }; //flxmlt Scaling factor to be applied at all times to the flux input from the fluxes file and the spallation production rate of the splprods file. flxmlt < 0 indicates that the constant power approximation is to be used. 1.0
            filestream.Write(",");
            filestream.Write("1.0E-20");// flosig Parameter used in justifying termination of chains based on activity. See subsection Chain Termination for details. flosig can not be set to a value larger than the default. 10−12
            filestream.Write(",");
            filestream.Write("1.0E-20");
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(0);
            filestream.Write(",");
            filestream.Write(0);
            filestream.Write(",");
            filestream.Write(2); //nfe
            filestream.Write(",");
            filestream.Write(-1);
            filestream.Write(",");
            filestream.Write(0);
            filestream.Write(",");
            filestream.Write(0);
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(1);
            filestream.Write(",");
            filestream.Write(1);
            filestream.Write(",");
            filestream.Write(" ");
            filestream.Write(",");
            filestream.Write(1000);
            filestream.Write(",");
            filestream.Write(10000);
            filestream.Write(",");
            filestream.Write(1000);
            filestream.Write(",");
            filestream.WriteLine(10000);
            filestream.WriteLine(titleTextBox.Text);
            filestream.WriteLine("fluxname");
            filestream.WriteLine("maters");
            if (pulse.Checked)
            {
                filestream.WriteLine("1 1.0");
                filestream.WriteLine("1 's'");
            }
            if (ss.Checked)
            {
                filestream.WriteLine("1 1.0");
                filestream.Write(seconds.Value + minutes.Value * 60m + hours.Value * 3600m);
                filestream.WriteLine(" 's'");
               // filestream.Write(minutes.Value);
               // filestream.WriteLine(" 'm'");
               // filestream.Write(hours.Value);
               // filestream.WriteLine(" 'h'");
            }
            filestream.WriteLine("");
            filestream.WriteLine("1 0.0");
            filestream.Write(secs.Value + mins.Value * 60m + hrs.Value * 3600m);
            filestream.WriteLine(" 's'");
           // filestream.Write(mins.Value);
           // filestream.WriteLine(" 'm'");
            //filestream.Write(hrs.Value);
            //filestream.WriteLine(" 'h'");
            filestream.Close();
        }

        private void fluxes_Click(object sender, EventArgs e)
        {
            var filestream = new System.IO.StreamWriter("c:\\cinder\\" + titleTextBox.Text + "\\fluxes");
            filestream.WriteLine("                                        fluxes File          63");
            filestream.Write("fluxname                                         ");
            if (lbb.Checked)
            {
                filestream.WriteLine("1.18547E13");
```

```
    filestream.WriteLine("4.5874E06 1.6409E07 2.5971E07 3.9814E07 4.5155E07 5.1342E07 5.1096E07 7.2961E07 ");
    filestream.WriteLine("8.2414E07 8.0008E07 7.4634E07 9.7301E07 1.1131E08 1.4882E08 1.0155E08 7.6311E07 ");
    filestream.WriteLine("7.7003E07 9.6131E07 2.0502E08 6.2407E08 1.8018E09 4.4514E09 9.7984E09 1.8309E10 ");
    filestream.WriteLine("3.1169E10 2.0502E08 6.8902E10 9.2876E10 1.1992E11 1.2393E11 1.7689E11 2.0276E11 ");
    filestream.WriteLine("2.4172E11 7.4279E10 8.2663E10 9.1027E10 2.8699E11 2.8765E11 3.6069E11 2.1235E11 ");
    filestream.WriteLine("2.3394E11 3.6439E11 5.2508E11 5.9132E11 7.5022E11 9.3830E11 5.3357E11 5.0295E11 ");
    filestream.WriteLine("6.7080E11 7.5442E11 7.5433E11 4.9778E11 6.5335E11 5.4393E11 4.4518E11 2.4688E11 ");
    filestream.WriteLine("1.8798E11 6.6964E10 5.1793E10 2.6944E09 4.8302E07 1.4841E07 1.3461E06 ");
}
if (plg.Checked)
{
    filestream.WriteLine("2.17147E13");
    filestream.WriteLine("5.6764E10 1.5277E11 2.0943E11 2.4936E11 2.6321E11 2.7426E11 2.7203E11 3.6487E11 ");
    filestream.WriteLine("3.8463E11 3.4708E11 3.4037E11 4.0595E11 4.7467E11 6.7186E11 4.9556E11 3.7466E11 ");
    filestream.WriteLine("3.4469E11 3.2664E11 3.1952E11 3.1553E11 3.1538E11 3.1714E11 3.2417E11 3.2847E11 ");
    filestream.WriteLine("3.3369E11 3.1952E11 3.4211E11 3.4464E11 3.4925E11 3.4043E11 3.5225E11 3.5316E11 ");
    filestream.WriteLine("3.6030E11 1.1703E11 1.1729E11 1.2071E11 3.6437E11 3.5767E11 3.8401E11 2.2058E11 ");
    filestream.WriteLine("2.1562E11 3.7511E11 4.7976E11 5.3164E11 6.3792E11 8.0169E11 4.6710E11 4.7392E11 ");
    filestream.WriteLine("5.7948E11 6.4301E11 6.8383E11 5.1246E11 6.8105E11 6.0354E11 5.3691E11 3.1820E11 ");
    filestream.WriteLine("2.6449E11 1.0183E11 7.7623E10 4.1275E09 7.7138E07 1.7697E07 2.1680E06 ");
}
if (lp.Checked)
{
    filestream.WriteLine("2.28739E13");
    filestream.WriteLine("1.5149E11 4.0994E11 5.6798E11 6.7825E11 7.1438E11 7.3620E11 7.2450E11 9.6230E11 ");
    filestream.WriteLine("9.9398E11 8.7480E11 8.3354E11 9.5091E11 1.0301E12 1.1948E12 5.7537E11 3.3082E11 ");
    filestream.WriteLine("2.8871E11 2.6691E11 2.5547E11 2.4840E11 2.4379E11 2.4258E11 2.4225E11 2.4162E11 ");
    filestream.WriteLine("2.4070E11 2.5547E11 2.3839E11 2.3695E11 2.3585E11 2.3315E11 2.3279E11 2.3058E11 ");
    filestream.WriteLine("2.2972E11 7.5791E10 7.5668E10 7.5916E10 2.2881E11 2.2721E11 2.3343E11 1.3336E11 ");
    filestream.WriteLine("1.2285E11 2.3961E11 2.7826E11 3.1877E11 3.8288E11 4.8510E11 2.8947E11 3.0901E11 ");
    filestream.WriteLine("3.7372E11 4.1902E11 4.7512E11 3.5757E11 4.7920E11 4.3356E11 3.8991E11 2.3935E11 ");
    filestream.WriteLine("2.0202E11 7.9012E10 6.2090E10 3.4373E09 6.3060E07 1.8563E07 9.3297E05 ");
}
if (freefield.Checked)
{
    filestream.WriteLine("2.00111E13");
    filestream.WriteLine("9.4200E09 3.0235E10 5.0838E10 6.4828E10 7.4435E10 8.0443E10 8.3643E10 1.1756E11 ");
    filestream.WriteLine("1.3080E11 1.2267E11 1.2753E11 1.5871E11 1.9902E11 3.1977E11 2.9680E11 2.6857E11 ");
    filestream.WriteLine("2.7631E11 2.7467E11 2.7916E11 2.7945E11 2.7651E11 2.7672E11 2.9405E11 3.0182E11 ");
    filestream.WriteLine("3.1505E11 2.7916E11 3.3811E11 3.4493E11 3.6870E11 3.0278E11 3.6467E11 3.6151E11 ");
    filestream.WriteLine("4.0255E11 1.1534E11 1.1489E11 1.3439E11 4.0025E11 3.6491E11 4.2993E11 2.2570E11 ");
```

```
                filestream.WriteLine("2.5442E11 3.7782E11 5.4444E11 6.2048E11 7.7693E11 9.7421E11
5.8161E11 5.2261E11 ");
                filestream.WriteLine("6.9985E11 8.2463E11 7.8493E11 6.1056E11 8.2111E11 7.1229E11
6.5644E11 3.9800E11 ");
                filestream.WriteLine("3.2268E11 1.2249E11 9.3896E10 4.8859E09 9.1226E07 1.8821E07
1.4959E06 ");
            }
            filestream.Close();
        }

        private void materials_Click(object sender, EventArgs e)
        {
            nuclidesum.Value = (H1.Value + H2.Value + He3.Value + He4.Value + Li6.Value + Li7.Value +
Be9.Value + B10.Value + B11.Value + C12.Value + C13.Value + N14.Value + N15.Value + O16.Value + O17.Value +
O18.Value + F19.Value + Ne20.Value + Ne21.Value + Ne22.Value + Na23.Value + Mg24.Value + Mg25.Value +
Mg26.Value + Al27.Value + Si28.Value + Si29.Value + Si30.Value + P31.Value + S32.Value + S33.Value + S34.Value +
S36.Value + Cl35.Value + Cl37.Value + Ar36.Value + Ar38.Value + Ar40.Value + K39.Value + K41.Value + Ca40.Value +
Ca42.Value + Ca43.Value + Ca44.Value + Ca46.Value + Sc45.Value + Ti46.Value + Ti47.Value + Ti48.Value +
Ti49.Value + Ti50.Value + V51.Value + Cr50.Value + Cr52.Value + Cr53.Value + Cr54.Value + Mn55.Value + Fe54.Value
+ Fe56.Value + Fe57.Value + Fe58.Value + Co59.Value + Ni58.Value + Ni60.Value + Ni61.Value + Ni62.Value +
Ni64.Value + Cu63.Value + Cu65.Value + Zn64.Value + Zn66.Value + Zn67.Value + Zn68.Value + Zn70.Value +
Ga69.Value + Ga71.Value + Ge70.Value + Ge72.Value + Ge73.Value + Ge74.Value + As75.Value + Se74.Value +
Se76.Value + Se77.Value + Se78.Value + Se80.Value + Br79.Value + Br81.Value + Kr78.Value + Kr80.Value +
Kr82.Value + Kr83.Value + Kr84.Value + Kr86.Value + Rb85.Value + Sr84.Value + Sr86.Value + Sr87.Value + Sr88.Value
+ Y89.Value + Zr90.Value + Zr91.Value + Zr92.Value + Zr94.Value + Nb93.Value + Mo92.Value + Mo94.Value +
Mo95.Value + Mo96.Value + Mo97.Value + Mo98.Value + Ru96.Value + Ru98.Value + Ru99.Value + Ru100.Value +
Ru101.Value + Ru102.Value + Ru104.Value + Rh103.Value + Pd102.Value + Pd104.Value + Pd105.Value +
Pd106.Value + Pd108.Value + Pd110.Value + Ag107.Value + Ag109.Value + Cd106.Value + Cd108.Value + Cd110.Value
+ Cd111.Value + Cd112.Value + Cd114.Value + In113.Value + Sn112.Value + Sn114.Value + Sn115.Value +
Sn116.Value + Sn117.Value + Sn118.Value + Sn119.Value + Sn120.Value + Sn122.Value + Sn124.Value + Sb121.Value
+ Sb123.Value + Te120.Value + Te122.Value + Te123.Value + Te124.Value + Te125.Value + Te126.Value + I127.Value
+ Xe124.Value + Xe126.Value + Xe128.Value + Xe129.Value + Xe130.Value + Xe131.Value + Xe132.Value +
Xe134.Value + Xe136.Value + Cs133.Value + Ba132.Value + Ba134.Value + Ba135.Value + Ba136.Value + Ba137.Value
+ Ba138.Value + La139.Value + Ce136.Value + Ce138.Value + Ce140.Value + Ce142.Value + Pr141.Value +
Nd142.Value + Nd143.Value + Nd145.Value + Nd146.Value + Nd148.Value + Sm144.Value + Sm149.Value +
Sm150.Value + Sm152.Value + Sm154.Value + Eu151.Value + Eu153.Value + Gd154.Value + Gd155.Value +
Gd156.Value + Gd157.Value + Gd158.Value + Gd160.Value + Tb159.Value + Dy156.Value + Dy158.Value +
Dy160.Value + Dy161.Value + Dy162.Value + Dy163.Value + Dy164.Value + Ho165.Value + Er162.Value + Er164.Value
+ Er166.Value + Er167.Value + Er168.Value + Er170.Value + Tm169.Value + Yb168.Value + Yb170.Value + Yb171.Value
+ Yb172.Value + Yb173.Value + Yb174.Value + Yb176.Value + Lu175.Value + Hf176.Value + Hf177.Value + Hf178.Value
+ Hf179.Value + Hf180.Value + Ta180.Value + Ta181.Value + W180.Value + W182.Value + W183.Value + W184.Value +
W186.Value + Re185.Value + Os184.Value + Os187.Value + Os188.Value + Os189.Value + Os190.Value + Os192.Value
+ Ir191.Value + Ir193.Value + Pt192.Value + Pt194.Value + Pt195.Value + Pt196.Value + Pt198.Value + Au197.Value +
Hg196.Value + Hg198.Value + Hg199.Value + Hg200.Value + Hg201.Value + Hg202.Value + Hg204.Value + Tl203.Value
+ Tl205.Value + Pb204.Value + Pb206.Value + Pb207.Value + Pb208.Value + K40.Value+

            var filestream = new System.IO.StreamWriter("c:\\cinder\\" + titleTextBox.Text + "\\material");
            filestream.WriteLine(titleTextBox.Text);
            filestream.Write("maters");
            filestream.Write("282 ");//total nuclides written to file including 0 atom ones
            filestream.WriteLine((nuclidesum.Value).ToString("F9"));//sum of all nuclides atom densities


            filestream.Write("0010010 "); filestream.WriteLine((H1.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0020010 "); filestream.WriteLine((H2.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0030020 "); filestream.WriteLine((He3.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0040020 "); filestream.WriteLine((He4.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0060030 "); filestream.WriteLine((Li6.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0070030 "); filestream.WriteLine((Li7.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0090040 "); filestream.WriteLine((Be9.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0100050 "); filestream.WriteLine((B10.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0110050 "); filestream.WriteLine((B11.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("0120060 "); filestream.WriteLine((C12.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0130060 "); filestream.WriteLine((C13.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0140070 "); filestream.WriteLine((N14.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0150070 "); filestream.WriteLine((N15.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0160080 "); filestream.WriteLine((O16.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0170080 "); filestream.WriteLine((O17.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0180080 "); filestream.WriteLine((O18.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0190090 "); filestream.WriteLine((F19.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0200100 "); filestream.WriteLine((Ne20.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0210100 "); filestream.WriteLine((Ne21.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0220100 "); filestream.WriteLine((Ne22.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0230110 "); filestream.WriteLine((Na23.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0240120 "); filestream.WriteLine((Mg24.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0240120 "); filestream.WriteLine((Mg25.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0240120 "); filestream.WriteLine((Mg26.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0270130 "); filestream.WriteLine((Al27.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0280140 "); filestream.WriteLine((Si28.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0290140 "); filestream.WriteLine((Si29.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0300140 "); filestream.WriteLine((Si30.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0310150 "); filestream.WriteLine((P31.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0320160 "); filestream.WriteLine((S32.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0330160 "); filestream.WriteLine((S33.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0340160 "); filestream.WriteLine((S34.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0360160 "); filestream.WriteLine((S36.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0350170 "); filestream.WriteLine((Cl35.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0370170 "); filestream.WriteLine((Cl37.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0360180 "); filestream.WriteLine((Ar36.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0380180 "); filestream.WriteLine((Ar38.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0400180 "); filestream.WriteLine((Ar40.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0390190 "); filestream.WriteLine((K39.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0400190 "); filestream.WriteLine((K40.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0410190 "); filestream.WriteLine((K41.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0400200 "); filestream.WriteLine((Ca40.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0420200 "); filestream.WriteLine((Ca42.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0430200 "); filestream.WriteLine((Ca43.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("0440200 "); filestream.WriteLine((Ca44.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0460200 "); filestream.WriteLine((Ca46.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0480200 "); filestream.WriteLine((Ca48.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0450210 "); filestream.WriteLine((Sc45.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0460220 "); filestream.WriteLine((Ti46.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0470220 "); filestream.WriteLine((Ti47.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0480220 "); filestream.WriteLine((Ti48.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0490220 "); filestream.WriteLine((Ti49.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0500220 "); filestream.WriteLine((Ti50.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0500230 "); filestream.WriteLine((V50.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0510230 "); filestream.WriteLine((V51.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0500240 "); filestream.WriteLine((Cr50.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0520240 "); filestream.WriteLine((Cr52.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0530240 "); filestream.WriteLine((Cr53.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0540240 "); filestream.WriteLine((Cr54.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0550250 "); filestream.WriteLine((Mn55.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0540260 "); filestream.WriteLine((Fe54.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0560260 "); filestream.WriteLine((Fe56.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0570260 "); filestream.WriteLine((Fe57.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0580260 "); filestream.WriteLine((Fe58.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0590270 "); filestream.WriteLine((Co59.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0580280 "); filestream.WriteLine((Ni58.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0600280 "); filestream.WriteLine((Ni60.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0600280 "); filestream.WriteLine((Ni61.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0620280 "); filestream.WriteLine((Ni62.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0640280 "); filestream.WriteLine((Ni64.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0630290 "); filestream.WriteLine((Cu63.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0650290 "); filestream.WriteLine((Cu65.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0640300 "); filestream.WriteLine((Zn64.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0660300 "); filestream.WriteLine((Zn66.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0670300 "); filestream.WriteLine((Zn67.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0680300 "); filestream.WriteLine((Zn68.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0700300 "); filestream.WriteLine((Zn70.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0690310 "); filestream.WriteLine((Ga69.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("0710310 "); filestream.WriteLine((Ga71.Value / nuclidesum.Value).ToString("F11"));
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                filestream.Write("0720320 "); filestream.WriteLine((Ge72.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0730320 "); filestream.WriteLine((Ge73.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0740320 "); filestream.WriteLine((Ge74.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0760320 "); filestream.WriteLine((Ge76.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0750330 "); filestream.WriteLine((As75.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0740340 "); filestream.WriteLine((Se74.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0760340 "); filestream.WriteLine((Se76.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0770340 "); filestream.WriteLine((Se77.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0780340 "); filestream.WriteLine((Se78.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0800340 "); filestream.WriteLine((Se80.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0820340 "); filestream.WriteLine((Se82.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0790350 "); filestream.WriteLine((Br79.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0810350 "); filestream.WriteLine((Br81.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0780360 "); filestream.WriteLine((Kr78.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0800360 "); filestream.WriteLine((Kr80.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0820360 "); filestream.WriteLine((Kr82.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0830360 "); filestream.WriteLine((Kr83.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0840360 "); filestream.WriteLine((Kr84.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0860360 "); filestream.WriteLine((Kr86.Value / nuclidesum.Value).ToString("F11"));

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                filestream.Write("0870370 "); filestream.WriteLine((Rb87.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0840380 "); filestream.WriteLine((Sr84.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0860380 "); filestream.WriteLine((Sr86.Value / nuclidesum.Value).ToString("F11"));

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                filestream.Write("0880380 "); filestream.WriteLine((Sr88.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0890390 "); filestream.WriteLine((Y89.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0900400 "); filestream.WriteLine((Zr90.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0910400 "); filestream.WriteLine((Zr91.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0920400 "); filestream.WriteLine((Zr92.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0940400 "); filestream.WriteLine((Zr94.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0960400 "); filestream.WriteLine((Zr96.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0930410 "); filestream.WriteLine((Nb93.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0920420 "); filestream.WriteLine((Mo92.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("0940420 "); filestream.WriteLine((Mo94.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("0970420 "); filestream.WriteLine((Mo97.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("0980420 "); filestream.WriteLine((Mo98.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1000420 "); filestream.WriteLine((Mo100.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("0960440 "); filestream.WriteLine((Ru96.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("0990440 "); filestream.WriteLine((Ru99.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1000440 "); filestream.WriteLine((Ru100.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1010440 "); filestream.WriteLine((Ru101.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1020440 "); filestream.WriteLine((Ru102.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1040440 "); filestream.WriteLine((Ru104.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("1040460 "); filestream.WriteLine((Pd104.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1050460 "); filestream.WriteLine((Pd105.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1060460 "); filestream.WriteLine((Pd106.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1080460 "); filestream.WriteLine((Pd108.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1100460 "); filestream.WriteLine((Pd110.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("1150490 "); filestream.WriteLine((In115.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("1240500 "); filestream.WriteLine((Sn124.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1260520 "); filestream.WriteLine((Te126.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1280520 "); filestream.WriteLine((Te128.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1300520 "); filestream.WriteLine((Te130.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1270530 "); filestream.WriteLine((I127.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1240540 "); filestream.WriteLine((Xe124.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1260540 "); filestream.WriteLine((Xe126.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1280540 "); filestream.WriteLine((Xe128.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1300540 "); filestream.WriteLine((Xe130.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1320540 "); filestream.WriteLine((Xe132.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1340540 "); filestream.WriteLine((Xe134.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1360540 "); filestream.WriteLine((Xe136.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1330550 "); filestream.WriteLine((Cs133.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1380560 "); filestream.WriteLine((Ba138.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1520620 "); filestream.WriteLine((Sm152.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1540620 "); filestream.WriteLine((Sm154.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("1520640 "); filestream.WriteLine((Gd152.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1540640 "); filestream.WriteLine((Gd154.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1550640 "); filestream.WriteLine((Gd155.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1560640 "); filestream.WriteLine((Gd156.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1570640 "); filestream.WriteLine((Gd157.Value / nuclidesum.Value).ToString("F11"));
            filestream.Write("1580640 "); filestream.WriteLine((Gd158.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("1560660 "); filestream.WriteLine((Dy156.Value / nuclidesum.Value).ToString("F11"));
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            filestream.Write("1630660 "); filestream.WriteLine((Dy163.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1640680 "); filestream.WriteLine((Er164.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1660680 "); filestream.WriteLine((Er166.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1680680 "); filestream.WriteLine((Er168.Value / nuclidesum.Value).ToString("F11"));

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            filestream.Write("1730700 "); filestream.WriteLine((Yb173.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1740700 "); filestream.WriteLine((Yb174.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1760700 "); filestream.WriteLine((Yb176.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1750710 "); filestream.WriteLine((Lu175.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1760710 "); filestream.WriteLine((Lu176.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1740720 "); filestream.WriteLine((Hf174.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1760720 "); filestream.WriteLine((Hf176.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1770720 "); filestream.WriteLine((Hf177.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1780720 "); filestream.WriteLine((Hf178.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1790720 "); filestream.WriteLine((Hf179.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1800720 "); filestream.WriteLine((Hf180.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1800730 "); filestream.WriteLine((Ta180.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1810730 "); filestream.WriteLine((Ta181.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1800740 "); filestream.WriteLine((W180.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1820740 "); filestream.WriteLine((W182.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1830740 "); filestream.WriteLine((W183.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1840740 "); filestream.WriteLine((W184.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1860740 "); filestream.WriteLine((W186.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1850750 "); filestream.WriteLine((Re185.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1870750 "); filestream.WriteLine((Re187.Value / nuclidesum.Value).ToString("F11"));

            filestream.Write("1840760 "); filestream.WriteLine((Os184.Value / nuclidesum.Value).ToString("F11"));
```

```
                filestream.Write("1860760 "); filestream.WriteLine((Os186.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1870760 "); filestream.WriteLine((Os187.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1880760 "); filestream.WriteLine((Os188.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1890760 "); filestream.WriteLine((Os189.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1900760 "); filestream.WriteLine((Os190.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1920760 "); filestream.WriteLine((Os192.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1910770 "); filestream.WriteLine((Ir191.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1930770 "); filestream.WriteLine((Ir193.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1900780 "); filestream.WriteLine((Pt190.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1920780 "); filestream.WriteLine((Pt192.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1940780 "); filestream.WriteLine((Pt194.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1950780 "); filestream.WriteLine((Pt195.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1960780 "); filestream.WriteLine((Pt196.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1980780 "); filestream.WriteLine((Pt198.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1970790 "); filestream.WriteLine((Au197.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1960800 "); filestream.WriteLine((Hg196.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1980800 "); filestream.WriteLine((Hg198.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("1990800 "); filestream.WriteLine((Hg199.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2000800 "); filestream.WriteLine((Hg200.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2010800 "); filestream.WriteLine((Hg201.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2020800 "); filestream.WriteLine((Hg202.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2040800 "); filestream.WriteLine((Hg204.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2030810 "); filestream.WriteLine((Tl203.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2050810 "); filestream.WriteLine((Tl205.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2040820 "); filestream.WriteLine((Pb204.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2060820 "); filestream.WriteLine((Pb206.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2070820 "); filestream.WriteLine((Pb207.Value / nuclidesum.Value).ToString("F11"));

                filestream.Write("2080820 "); filestream.WriteLine((Pb208.Value / nuclidesum.Value).ToString("F11"));




                filestream.Close();
            }

            private void locate_Click(object sender, EventArgs e)
            {
                var filestream = new System.IO.StreamWriter("c:\\cinder\\" + titleTextBox.Text + "\\locate");
                filestream.WriteLine("C:\\Cinder2008\\Data\\c90lib0742");
                filestream.WriteLine("");
                filestream.WriteLine("C:\\Cinder2008\\Data\\cindergl.dat");
                filestream.Close();
```

```
        }

        private void dateTimePicker1_ValueChanged_3(object sender, EventArgs e)
        {

        }

        private void textBox3_TextChanged(object sender, EventArgs e)
        {

        }

        private void label3_Click(object sender, EventArgs e)
        {

        }

        private void waittime_ValueChanged(object sender, EventArgs e)
        {

        }

        private void checkedListBox2_ItemCheck(object sender, ItemCheckEventArgs e)
        {

        }

        private void checkedListBox2_ItemCheck_1(object sender, ItemCheckEventArgs e)
        {

        }

        private void checkedListBox2_SelectedIndexChanged(object sender, EventArgs e)
        {

        }

        private void pulse_Click(object sender, EventArgs e)
        {
            if (pulse.Checked)
            {
                energy.Hide();
                energyvalue.Hide();
                radtimelabel.Hide();
                powerlabel.Show();
                MJ.Show();
                percentpowerlabel.Hide();
                percentpower.Hide();
                reactorpower.Hide();
                reactorpowerlabel.Hide();
                hourlabel.Hide();
                hours.Hide();
                minutelabel.Hide();
                minutes.Hide();
                secondlabel.Hide();
                seconds.Hide();
            }
        }

        private void ss_Click(object sender, EventArgs e)
        {
            if (ss.Checked)
            {
                radtimelabel.Show();
                reactorpower.Show();
                reactorpowerlabel.Show();
                powerlabel.Hide();
                MJ.Hide();
                percentpower.Show();
                percentpowerlabel.Show();
                hourlabel.Show();
                hours.Show();
                minutelabel.Show();
                minutes.Show();
                secondlabel.Show();
                seconds.Show();
                energy.Show();
                energyvalue.Show();
            }
        }

        private void pulse_CheckedChanged(object sender, EventArgs e)
        {

        }

        private void dataGridView1_CellContentClick(object sender, DataGridViewCellEventArgs e)
        {

        }

        private void reactorpower_ValueChanged(object sender, EventArgs e)
        {
            percentpower.Value = reactorpower.Value * 10000 / 239;
            energyvalue.Value = reactorpower.Value * (hours.Value * 3600 + minutes.Value * 60 + seconds.Value);

        }

        private void percentpower_ValueChanged(object sender, EventArgs e)
        {
            reactorpower.Value = percentpower.Value * 239 / 10000;
            energyvalue.Value = reactorpower.Value * (hours.Value * 3600 + minutes.Value * 60 + seconds.Value);

        }

        private void percentpowerlabel_Click(object sender, EventArgs e)
        {

        }

        private void textBox1_TextChanged(object sender, EventArgs e)
        {

        }

        private void label3_Click_1(object sender, EventArgs e)
        {

        }

        private void numericUpDown4_ValueChanged(object sender, EventArgs e)
        {
            energyvalue.Value = reactorpower.Value * (hours.Value * 3600 + minutes.Value * 60 + seconds.Value);
        }

        private void hours_ValueChanged(object sender, EventArgs e)
        {
            energyvalue.Value = reactorpower.Value * (hours.Value * 3600 + minutes.Value * 60 + seconds.Value);

        }

        private void minutes_ValueChanged(object sender, EventArgs e)
        {
            energyvalue.Value = reactorpower.Value * (hours.Value * 3600 + minutes.Value * 60 + seconds.Value);

        }

        private void seconds_ValueChanged(object sender, EventArgs e)
        {
            energyvalue.Value = reactorpower.Value * (hours.Value * 3600 + minutes.Value * 60 + seconds.Value);
```

```

}

private void reactorpowerlabel_Click(object sender, EventArgs e)
{

}

private void pulsetimelabel_Click(object sender, EventArgs e)
{

}

private void vScrollBar1_Scroll(object sender, ScrollEventArgs e)
{

}

private void checkBox1_CheckedChanged(object sender, EventArgs e)
{

}

private void label11_Click(object sender, EventArgs e)
{

}

private void panel2_Paint(object sender, PaintEventArgs e)
{

}

private void numericUpDown24_ValueChanged(object sender, EventArgs e)
{

}

private void panel3_Paint(object sender, PaintEventArgs e)
{

}

private void DREAD_Load(object sender, EventArgs e)
{

}

private void groupBox1_Enter(object sender, EventArgs e)
{

}

private void nickelgram5mil_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void nickel10_CheckedChanged(object sender, EventArgs e)
{
    if (nickel10.Checked)
    {
        nickelgram10mil.Show();
    }
    else
    {
        nickelgram10mil.Value = 0;
        nickelgram10mil.Hide();
    }
}
```

```

        private void nickelgram10mil_ValueChanged(object sender, EventArgs e)
        {

            AtomCalc();
        }

        private void checkBox8_CheckedChanged(object sender, EventArgs e)
        {
            if (copper63.Checked)
            {
                copper63gram.Show();
            }
            else
            {
                copper63gram.Value = 0;
                copper63gram.Hide();
            }
        }

        private void checkBox9_CheckedChanged(object sender, EventArgs e)
        {
            if (cardboard.Checked)
            {
                cardboardgrams.Show();
            }
            else
            {
                cardboardgrams.Value = 0;
                cardboardgrams.Hide();

            }
        }

        private void checkBox10_CheckedChanged(object sender, EventArgs e)
        {
            if (pcbelectronics.Checked)
            {
                pcbelectronicsgrams.Show();
            }
            else
            {
                pcbelectronicsgrams.Value = 0;
                pcbelectronicsgrams.Hide();
            }
        }

        private void checkBox11_CheckedChanged(object sender, EventArgs e)
        {
            if (circuitboard.Checked)
            {
                circuitboardgrams.Show();
            }
            else
            {
                circuitboardgrams.Value = 0;
                circuitboardgrams.Hide();
            }
        }

        private void SS316_CheckedChanged(object sender, EventArgs e)
        {
            if (SS316.Checked)
            {
                SS316gram.Show();
            }
            else
            {
                SS316gram.Value = 0;
                SS316gram.Hide();
            }
        }

        private void al6061_CheckedChanged(object sender, EventArgs e)
        {
            if (al6061.Checked)
            {
                Al6061gram.Show();
            }
            else
            {
                Al6061gram.Value = 0;
                Al6061gram.Hide();
            }
        }

        private void tld_CheckedChanged(object sender, EventArgs e) //10 top pieces weigh 3.4078 g
        {
            if (tld.Checked)
            {
                tldgram.Show();
            }
            else
            {
                tldgram.Value = 0;
                tldgram.Hide();
            }
        }

        private void sulfurlarge_CheckedChanged(object sender, EventArgs e)
        {
            if (sulfurlarge.Checked)
            {
                sulfurgramlarge.Show();
            }
            else
            {
                sulfurgramlarge.Value = 0;
                sulfurgramlarge.Hide();
            }
        }

        private void sulfur_CheckedChanged(object sender, EventArgs e)
        {
            if (sulfur.Checked)
            {
                sulfurgramstandard.Show();
            }
            else
            {
                sulfurgramstandard.Value = 0;
                sulfurgramstandard.Hide();
            }
        }

        private void checkBox7_CheckedChanged(object sender, EventArgs e)
        {
            if (poly.Checked)
            {
                polygram.Show();
            }
            else
            {
                polygram.Value = 0;
                polygram.Hide();
            }
        }

        private void Ni60_ValueChanged(object sender, EventArgs e)
        {
        }

        private void ss_CheckedChanged(object sender, EventArgs e)
        {

        }

        private void MJ_ValueChanged(object sender, EventArgs e)
        {

        }


        private void nickel5_CheckStateChanged(object sender, EventArgs e)
        {
            if (nickel5.Checked)
            {
                nickelgram5mil.Show();
            }
            else
            {
                nickelgram5mil.Value = 0;
                nickelgram5mil.Hide();
            }

        }

        private void SS316gram_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        public void AtomCalc()
        {
            //calc value from inputs for isotopes = total grams from all entries * weight percent for isotope of element * Avagadro's number * 1e-24 to convert cm^3 to barn-cm for cinder volume / isotopic mass


            H1.Value = ((H.Value + circuitboardgrams.Value * 0.01776m + pcbelectronicsgrams.Value * .01456m + polygram.Value * .143736m + pvcgram.Value * .048402m + cardboardgrams.Value * .059m) * .99977m * 6.0221413e-1m / 1m);
            H2.Value = ((H.Value + circuitboardgrams.Value * 0.01776m + pcbelectronicsgrams.Value * .01456m + polygram.Value * .143736m + pvcgram.Value * .048402m + cardboardgrams.Value * .059m) * .00023m * 6.0221413e-1m / 2m);

            He3.Value = ((He.Value) * .000001m * 6.0221413e-1m / 3m);
            He4.Value = ((He.Value) * .999999m * 6.0221413e-1m / 4m);

            Li6.Value = ((Li.Value) * .065785m * 6.0221413e-1m / 6m);
            Li7.Value = ((Li.Value) * .934215m * 6.0221413e-1m / 7m);

            Be9.Value = ((Be.Value) * 1.00000m * 6.0221413e-1m / 9m);

            B10.Value = ((B.Value) * .184309m * 6.0221413e-1m / 10m);
            B11.Value = ((B.Value) * .815691m * 6.0221413e-1m / 11m);

            C12.Value = ((C.Value + SS316gram.Value * 0.0008m + circuitboardgrams.Value * 0.18192m + pcbelectronicsgrams.Value * .31539m + polygram.Value * .856164m + pvcgram.Value * .384141m + teflongram.Value * .24m + cardboardgrams.Value * .44m) * .988416m * 6.0221413e-1m / 12m);
            C13.Value = ((C.Value + SS316gram.Value * 0.0008m + circuitboardgrams.Value * 0.18192m + pcbelectronicsgrams.Value * .31539m + polygram.Value * .856164m + pvcgram.Value * .384141m + teflongram.Value * .24m + cardboardgrams.Value * .44m) * .011584m * 6.0221413e-1m / 13m);

            N14.Value = ((N.Value + SS316gram.Value * 0.001m + cardboardgrams.Value * .003m) * .996102m * 6.0221413e-1m / 14m);
            N15.Value = ((N.Value + SS316gram.Value * 0.001m + cardboardgrams.Value * .003m) * .003898m * 6.0221413e-1m / 15m);

```

```
O16.Value = ((O.Value + circuitboardgrams.Value * 0.33856m + pcbelectronicsgrams.Value * .10074m + cardboardgrams.Value * .446m) * .997290m * 6.0221413e-1m / 16m);
O17.Value = ((O.Value + circuitboardgrams.Value * 0.33856m + pcbelectronicsgrams.Value * .10074m + cardboardgrams.Value * .446m) * .000404m * 6.0221413e-1m / 17m);
O18.Value = ((O.Value + circuitboardgrams.Value * 0.33856m + pcbelectronicsgrams.Value * .10074m + cardboardgrams.Value * .446m) * .002306m * 6.0221413e-1m / 18m);

F19.Value = ((F.Value + tldgram.Value * 0.0139m + teflongram.Value * .76m) * 1.00000m * 6.0221413e-1m / 19m);

Ne20.Value = ((Ne.Value) * .896388m * 6.0221413e-1m / 20m);
Ne21.Value = ((Ne.Value) * .002008m * 6.0221413e-1m / 21m);
Ne22.Value = ((Ne.Value) * .100803m * 6.0221413e-1m / 22m);

Na23.Value = ((Na.Value) * 1.00000m * 6.0221413e-1m / 23m);

Mg24.Value = ((Mg.Value + Al6061gram.Value * 0.01m + circuitboardgrams.Value * 0.00145m + pcbelectronicsgrams.Value * .00067m) * .779500m * 6.0221413e-1m / 24m);
Mg25.Value = ((Mg.Value + Al6061gram.Value * 0.01m + circuitboardgrams.Value * 0.00145m + pcbelectronicsgrams.Value * .00067m) * .102801m * 6.0221413e-1m / 25m);
Mg26.Value = ((Mg.Value + Al6061gram.Value * 0.01m + circuitboardgrams.Value * 0.00145m + pcbelectronicsgrams.Value * .00067m) * .117699m * 6.0221413e-1m / 26m);

Al27.Value = ((Al.Value + Al6061gram.Value * 0.96m + circuitboardgrams.Value * 0.04650m + pcbelectronicsgrams.Value * .04943m + tldgram.Value * 0.68773m) * 1.00000m * 6.0221413e-1m / 27m);

Si28.Value = ((Si.Value + Al6061gram.Value * 0.006m + SS316gram.Value * 0.0075m + circuitboardgrams.Value * 0.26201m + pcbelectronicsgrams.Value * .07890m) * .918665m * 6.0221413e-1m / 28m);
Si29.Value = ((Si.Value + Al6061gram.Value * 0.006m + SS316gram.Value * 0.0075m + circuitboardgrams.Value * 0.26201m + pcbelectronicsgrams.Value * .07890m) * .048336m * 6.0221413e-1m / 29m);
Si30.Value = ((Si.Value + Al6061gram.Value * 0.006m + SS316gram.Value * 0.0075m + circuitboardgrams.Value * 0.26201m + pcbelectronicsgrams.Value * .07890m) * .032999m * 6.0221413e-1m / 30m);

P31.Value = ((P.Value + SS316gram.Value * 0.00045m) * 1.00000m * 6.0221413e-1m / 31m);

S32.Value = ((sulfurgramstandard.Value * 0.250m + sulfurgramlarge.Value * 2.25m + S.Value + SS316gram.Value * 0.0003m + cardboardgrams.Value * .002m) * .9471530m * 6.0221413e-1m / 32m);
S33.Value = ((sulfurgramstandard.Value * 0.250m + sulfurgramlarge.Value * 2.25m + S.Value + SS316gram.Value * 0.0003m + cardboardgrams.Value * .002m) * .0077120m * 6.0221413e-1m / 33m);
S34.Value = ((sulfurgramstandard.Value * 0.250m + sulfurgramlarge.Value * 2.25m + S.Value + SS316gram.Value * 0.0003m + cardboardgrams.Value * .002m) * .0016523m * 6.0221413e-1m / 34m);
S36.Value = ((sulfurgramstandard.Value * 0.250m + sulfurgramlarge.Value * 2.25m + S.Value + SS316gram.Value * 0.0003m + cardboardgrams.Value * .002m) * .0001120m * 6.0221413e-1m / 36m);

Cl35.Value = ((Cl.Value + pcbelectronicsgrams.Value * .17018m + pvcgram.Value * .567457m) * .747256m * 6.0221413e-1m / 35m);
Cl37.Value = ((Cl.Value + pcbelectronicsgrams.Value * .17018m + pvcgram.Value * .567457m) * .252744m * 6.0221413e-1m / 37m);

Ar36.Value = ((Ar.Value) * .003004m * 6.0221413e-1m / 36m);
Ar38.Value = ((Ar.Value) * .000598m * 6.0221413e-1m / 38m);
Ar40.Value = ((Ar.Value) * .996399m * 6.0221413e-1m / 40m);

K39.Value = ((K.Value) * .929371m * 6.0221413e-1m / 39m);
K40.Value = ((K.Value) * .000120m * 6.0221413e-1m / 40m);
K41.Value = ((K.Value) * .070510m * 6.0221413e-1m / 41m);

Ca40.Value = ((Ca.Value + tldgram.Value * 0.0148m + pcbelectronicsgrams.Value * .00024m + cardboardgrams.Value * .03m) * .966575m * 6.0221413e-1m / 40m);
Ca42.Value = ((Ca.Value + tldgram.Value * 0.0148m + pcbelectronicsgrams.Value * .00024m + cardboardgrams.Value * .03m) * .006773m * 6.0221413e-1m / 42m);
Ca43.Value = ((Ca.Value + tldgram.Value * 0.0148m + pcbelectronicsgrams.Value * .00024m + cardboardgrams.Value * .03m) * .001447m * 6.0221413e-1m / 43m);
Ca44.Value = ((Ca.Value + tldgram.Value * 0.0148m + pcbelectronicsgrams.Value * .00024m + cardboardgrams.Value * .03m) * .022921m * 6.0221413e-1m / 44m);
Ca46.Value = ((Ca.Value + tldgram.Value * 0.0148m + pcbelectronicsgrams.Value * .00024m + cardboardgrams.Value * .03m) * .000046m * 6.0221413e-1m / 46m);
Ca48.Value = ((Ca.Value + tldgram.Value * 0.0148m + pcbelectronicsgrams.Value * .00024m + cardboardgrams.Value * .03m) * .002237m * 6.0221413e-1m / 48m);

```

```
Sc45.Value = ((Sc.Value) * 1.00000m * 6.0221413e-1m / 45m);

Ti46.Value = ((Ti.Value + Al6061gram.Value * 0.0015m + circuitboardgrams.Value * 0.00010m) * .079201m * 6.0221413e-1m / 46m);
Ti47.Value = ((Ti.Value + Al6061gram.Value * 0.0015m + circuitboardgrams.Value * 0.00010m) * .072978m * 6.0221413e-1m / 47m);
Ti48.Value = ((Ti.Value + Al6061gram.Value * 0.0015m + circuitboardgrams.Value * 0.00010m) * .738451m * 6.0221413e-1m / 48m);
Ti49.Value = ((Ti.Value + Al6061gram.Value * 0.0015m + circuitboardgrams.Value * 0.00010m) * .055322m * 6.0221413e-1m / 49m);
Ti50.Value = ((Ti.Value + Al6061gram.Value * 0.0015m + circuitboardgrams.Value * 0.00010m) * .054049m * 6.0221413e-1m / 50m);

V50.Value = ((V.Value) * .002451m * 6.0221413e-1m / 50m);
V51.Value = ((V.Value) * .997549m * 6.0221413e-1m / 51m);

Cr50.Value = ((Cr.Value + Al6061gram.Value * 0.003m + SS316gram.Value * 0.18m + circuitboardgrams.Value * 0.00020m) * .041737m * 6.0221413e-1m / 50m);
Cr52.Value = ((Cr.Value + Al6061gram.Value * 0.003m + SS316gram.Value * 0.18m + circuitboardgrams.Value * 0.00020m) * .836994m * 6.0221413e-1m / 52m);
Cr53.Value = ((Cr.Value + Al6061gram.Value * 0.003m + SS316gram.Value * 0.18m + circuitboardgrams.Value * 0.00020m) * .096736m * 6.0221413e-1m / 53m);
Cr54.Value = ((Cr.Value + Al6061gram.Value * 0.003m + SS316gram.Value * 0.18m + circuitboardgrams.Value * 0.00020m) * .024534m * 6.0221413e-1m / 54m);

Mn55.Value = ((Mn.Value + Al6061gram.Value * 0.0015m + SS316gram.Value * 0.02m + circuitboardgrams.Value * 0.00015m + pcbelectronicsgrams.Value * .00015m) * 1.00000m * 6.0221413e-1m / 55m);

Fe54.Value = ((Fe.Value + Al6061gram.Value * 0.007m + SS316gram.Value * 0.68m + circuitboardgrams.Value * 0.00035m + pcbelectronicsgrams.Value * .02674m) * .056456m * 6.0221413e-1m / 54m);
Fe56.Value = ((Fe.Value + Al6061gram.Value * 0.007m + SS316gram.Value * 0.68m + circuitboardgrams.Value * 0.00035m + pcbelectronicsgrams.Value * .02674m) * .919015m * 6.0221413e-1m / 56m);
Fe57.Value = ((Fe.Value + Al6061gram.Value * 0.007m + SS316gram.Value * 0.68m + circuitboardgrams.Value * 0.00035m + pcbelectronicsgrams.Value * .02674m) * .021604m * 6.0221413e-1m / 57m);
Fe58.Value = ((Fe.Value + Al6061gram.Value * 0.007m + SS316gram.Value * 0.68m + circuitboardgrams.Value * 0.00035m + pcbelectronicsgrams.Value * .02674m) * .002925m * 6.0221413e-1m / 58m);

Co59.Value = ((Co.Value + pcbelectronicsgrams.Value * .00850m) * 1.00000m * 6.0221413e-1m / 59m);

Ni58.Value = ((nickelgram5mil.Value * 0.140m + nickelgram10mil.Value * 0.280m + Ni.Value + SS316gram.Value * 0.14m + pcbelectronicsgrams.Value * .01450m) * .671878m * 6.0221413e-1m / 58m);
Ni60.Value = ((nickelgram5mil.Value * 0.140m + nickelgram10mil.Value * 0.280m + Ni.Value + SS316gram.Value * 0.14m + pcbelectronicsgrams.Value * .01450m) * .267759m * 6.0221413e-1m / 60m);
Ni61.Value = ((nickelgram5mil.Value * 0.140m + nickelgram10mil.Value * 0.280m + Ni.Value + SS316gram.Value * 0.14m + pcbelectronicsgrams.Value * .01450m) * .011834m * 6.0221413e-1m / 61m);
Ni62.Value = ((nickelgram5mil.Value * 0.140m + nickelgram10mil.Value * 0.280m + Ni.Value + SS316gram.Value * 0.14m + pcbelectronicsgrams.Value * .01450m) * .038349m * 6.0221413e-1m / 62m);
Ni64.Value = ((nickelgram5mil.Value * 0.140m + nickelgram10mil.Value * 0.280m + Ni.Value + SS316gram.Value * 0.14m + pcbelectronicsgrams.Value * .01450m) * .010080m * 6.0221413e-1m / 64m);

Cu63.Value = ((Cu.Value + Al6061gram.Value * 0.003m + circuitboardgrams.Value * 0.05100m + pcbelectronicsgrams.Value * .15000m + copper63gram.Value * 1.0m/0.684792m) * .684792m * 6.0221413e-1m / 63m);
Cu65.Value = ((Cu.Value + Al6061gram.Value * 0.003m + circuitboardgrams.Value * 0.05100m + pcbelectronicsgrams.Value * .15000m) * .315208m * 6.0221413e-1m / 65m);

Zn64.Value = ((Zn.Value + Al6061gram.Value * 0.0025m) * .480805m * 6.0221413e-1m / 64m);
Zn66.Value = ((Zn.Value + Al6061gram.Value * 0.0025m) * .279625m * 6.0221413e-1m / 66m);
Zn67.Value = ((Zn.Value + Al6061gram.Value * 0.0025m) * .041357m * 6.0221413e-1m / 67m);
Zn68.Value = ((Zn.Value + Al6061gram.Value * 0.0025m) * .191688m * 6.0221413e-1m / 68m);
Zn70.Value = ((Zn.Value + Al6061gram.Value * 0.0025m) * .006524m * 6.0221413e-1m / 70m);

Ga69.Value = ((Ga.Value) * .594205m * 6.0221413e-1m / 69m);
Ga71.Value = ((Ga.Value) * .405795m * 6.0221413e-1m / 71m);

Ge70.Value = ((Ge.Value) * .198044m * 6.0221413e-1m / 70m);
Ge72.Value = ((Ge.Value) * .271834m * 6.0221413e-1m / 72m);
Ge73.Value = ((Ge.Value) * .077816m * 6.0221413e-1m / 73m);
Ge74.Value = ((Ge.Value) * .371501m * 6.0221413e-1m / 74m);
Ge76.Value = ((Ge.Value) * .080806m * 6.0221413e-1m / 76m);
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As75.Value = ((As.Value) * 1.00000m * 6.0221413e-1m / 75m);

Se74.Value = ((Se.Value) * .008332m * 6.0221413e-1m / 74m);
Se76.Value = ((Se.Value) * .090092m * 6.0221413e-1m / 76m);
Se77.Value = ((Se.Value) * .074329m * 6.0221413e-1m / 77m);
Se78.Value = ((Se.Value) * .234563m * 6.0221413e-1m / 78m);
Se80.Value = ((Se.Value) * .502114m * 6.0221413e-1m / 80m);
Se82.Value = ((Se.Value) * .090570m * 6.0221413e-1m / 82m);

Br79.Value = ((Br.Value) * .500650m * 6.0221413e-1m / 79m);
Br81.Value = ((Br.Value) * .499350m * 6.0221413e-1m / 81m);

Kr78.Value = ((Kr.Value) * .003301m * 6.0221413e-1m / 78m);
Kr80.Value = ((Kr.Value) * .021801m * 6.0221413e-1m / 80m);
Kr82.Value = ((Kr.Value) * .113323m * 6.0221413e-1m / 82m);
Kr83.Value = ((Kr.Value) * .113787m * 6.0221413e-1m / 83m);
Kr84.Value = ((Kr.Value) * .570642m * 6.0221413e-1m / 84m);
Kr86.Value = ((Kr.Value) * .177146m * 6.0221413e-1m / 86m);

Rb85.Value = ((Rb.Value) * .717006m * 6.0221413e-1m / 85m);
Rb87.Value = ((Rb.Value) * .282994m * 6.0221413e-1m / 87m);

Sr84.Value = ((Sr.Value) * .005363m * 6.0221413e-1m / 84m);
Sr86.Value = ((Sr.Value) * .096679m * 6.0221413e-1m / 86m);
Sr87.Value = ((Sr.Value) * .069435m * 6.0221413e-1m / 87m);
Sr88.Value = ((Sr.Value) * .828524m * 6.0221413e-1m / 88m);

Y89.Value = ((Y.Value) * 1.00000m * 6.0221413e-1m / 89m);

Zr90.Value = ((Zr.Value) * .507061m * 6.0221413e-1m / 90m);
Zr91.Value = ((Zr.Value) * .111809m * 6.0221413e-1m / 91m);
Zr92.Value = ((Zr.Value) * .172781m * 6.0221413e-1m / 92m);
Zr94.Value = ((Zr.Value) * .178911m * 6.0221413e-1m / 94m);
Zr96.Value = ((Zr.Value) * .029438m * 6.0221413e-1m / 96m);

Nb93.Value = ((Nb.Value) * 1.00000m * 6.0221413e-1m / 93m);

Mo92.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .139163m * 6.0221413e-1m / 92m);
Mo94.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .089541m * 6.0221413e-1m / 94m);
Mo95.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .156660m * 6.0221413e-1m / 95m);
Mo96.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .166604m * 6.0221413e-1m / 96m);
Mo97.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .096947m * 6.0221413e-1m / 97m);
Mo98.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .248845m * 6.0221413e-1m / 98m);
Mo100.Value = ((Mo.Value + SS316gram.Value * 0.03m) * .102240m * 6.0221413e-1m / 100m);

Ru96.Value = ((Ru.Value) * .052573m * 6.0221413e-1m / 96m);
Ru98.Value = ((Ru.Value) * .018115m * 6.0221413e-1m / 98m);
Ru99.Value = ((Ru.Value) * .124874m * 6.0221413e-1m / 99m);
Ru100.Value = ((Ru.Value) * .124553m * 6.0221413e-1m / 100m);
Ru101.Value = ((Ru.Value) * .170331m * 6.0221413e-1m / 101m);
Ru102.Value = ((Ru.Value) * .318120m * 6.0221413e-1m / 102m);
Ru104.Value = ((Ru.Value) * .191433m * 6.0221413e-1m / 104m);

Rh103.Value = ((Rh.Value) * 1.00000m * 6.0221413e-1m / 103m);

Pd102.Value = ((Pd.Value) * .009768m * 6.0221413e-1m / 102m);
Pd104.Value = ((Pd.Value) * .108771m * 6.0221413e-1m / 104m);
Pd105.Value = ((Pd.Value) * .220131m * 6.0221413e-1m / 105m);
Pd106.Value = ((Pd.Value) * .271985m * 6.0221413e-1m / 106m);
Pd108.Value = ((Pd.Value) * .268301m * 6.0221413e-1m / 108m);
Pd110.Value = ((Pd.Value) * .121044m * 6.0221413e-1m / 110m);

Ag107.Value = ((Ag.Value + circuitboardgrams.Value * 0.05000m + pcbelectronicsgrams.Value * .03000m) * .513762m * 6.0221413e-1m / 107m);
Ag109.Value = ((Ag.Value + circuitboardgrams.Value * 0.05000m + pcbelectronicsgrams.Value * .03000m) * .486238m * 6.0221413e-1m / 109m);

Cd106.Value = ((Cd.Value) * .011777m * 6.0221413e-1m / 106m);
Cd108.Value = ((Cd.Value) * .008543m * 6.0221413e-1m / 108m);
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Cd110.Value = ((Cd.Value) * .122113m * 6.0221413e-1m / 110m);
Cd111.Value = ((Cd.Value) * .126284m * 6.0221413e-1m / 111m);
Cd112.Value = ((Cd.Value) * .240208m * 6.0221413e-1m / 112m);
Cd113.Value = ((Cd.Value) * .122736m * 6.0221413e-1m / 113m);
Cd114.Value = ((Cd.Value) * .291113m * 6.0221413e-1m / 114m);
Cd116.Value = ((Cd.Value) * .077228m * 6.0221413e-1m / 116m);

In113.Value = ((In.Value) * .042185m * 6.0221413e-1m / 113m);
In115.Value = ((In.Value) * .957815m * 6.0221413e-1m / 115m);

Sn112.Value = ((Sn.Value) * .009144m * 6.0221413e-1m / 112m);
Sn114.Value = ((Sn.Value) * .006333m * 6.0221413e-1m / 114m);
Sn115.Value = ((Sn.Value) * .003291m * 6.0221413e-1m / 115m);
Sn116.Value = ((Sn.Value) * .141960m * 6.0221413e-1m / 116m);
Sn117.Value = ((Sn.Value) * .075631m * 6.0221413e-1m / 117m);
Sn118.Value = ((Sn.Value) * .240550m * 6.0221413e-1m / 118m);
Sn119.Value = ((Sn.Value) * .086040m * 6.0221413e-1m / 119m);
Sn120.Value = ((Sn.Value) * .329072m * 6.0221413e-1m / 120m);
Sn122.Value = ((Sn.Value) * .047545m * 6.0221413e-1m / 122m);
Sn124.Value = ((Sn.Value) * .060434m * 6.0221413e-1m / 124m);

Sb121.Value = ((Sb.Value) * .568078m * 6.0221413e-1m / 121m);
Sb123.Value = ((Sb.Value) * .431922m * 6.0221413e-1m / 123m);

Te120.Value = ((Te.Value) * .000846m * 6.0221413e-1m / 120m);
Te122.Value = ((Te.Value) * .024361m * 6.0221413e-1m / 122m);
Te123.Value = ((Te.Value) * .008572m * 6.0221413e-1m / 123m);
Te124.Value = ((Te.Value) * .046025m * 6.0221413e-1m / 124m);
Te125.Value = ((Te.Value) * .069205m * 6.0221413e-1m / 125m);
Te126.Value = ((Te.Value) * .185890m * 6.0221413e-1m / 126m);
Te128.Value = ((Te.Value) * .318150m * 6.0221413e-1m / 128m);
Te130.Value = ((Te.Value) * .346951m * 6.0221413e-1m / 130m);

I127.Value = ((I.Value) * 1.00000m * 6.0221413e-1m / 127m);

Xe124.Value = ((Xe.Value) * .000898m * 6.0221413e-1m / 124m);
Xe126.Value = ((Xe.Value) * .000853m * 6.0221413e-1m / 126m);
Xe128.Value = ((Xe.Value) * .018609m * 6.0221413e-1m / 128m);
Xe129.Value = ((Xe.Value) * .259205m * 6.0221413e-1m / 129m);
Xe130.Value = ((Xe.Value) * .040279m * 6.0221413e-1m / 130m);
Xe131.Value = ((Xe.Value) * .211694m * 6.0221413e-1m / 131m);
Xe132.Value = ((Xe.Value) * .270340m * 6.0221413e-1m / 132m);
Xe134.Value = ((Xe.Value) * .106434m * 6.0221413e-1m / 134m);
Xe136.Value = ((Xe.Value) * .091686m * 6.0221413e-1m / 136m);

Cs133.Value = ((Cs.Value) * 1.00000m * 6.0221413e-1m / 133m);

Ba130.Value = ((Ba.Value) * .001003m * 6.0221413e-1m / 130m);
Ba132.Value = ((Ba.Value) * .000970m * 6.0221413e-1m / 132m);
Ba134.Value = ((Ba.Value) * .023568m * 6.0221413e-1m / 134m);
Ba135.Value = ((Ba.Value) * .064758m * 6.0221413e-1m / 135m);
Ba136.Value = ((Ba.Value) * .077727m * 6.0221413e-1m / 136m);
Ba137.Value = ((Ba.Value) * .111976m * 6.0221413e-1m / 137m);
Ba138.Value = ((Ba.Value) * .720000m * 6.0221413e-1m / 138m);

La138.Value = ((La.Value) * .000882m * 6.0221413e-1m / 138m);
La139.Value = ((La.Value) * .999118m * 6.0221413e-1m / 139m);

Ce136.Value = ((Ce.Value) * .001794m * 6.0221413e-1m / 136m);
Ce138.Value = ((Ce.Value) * .002470m * 6.0221413e-1m / 138m);
Ce140.Value = ((Ce.Value) * .883173m * 6.0221413e-1m / 140m);
Ce142.Value = ((Ce.Value) * .112563m * 6.0221413e-1m / 142m);

Pr141.Value = ((Pr.Value) * 1.00000m * 6.0221413e-1m / 141m);

Nd142.Value = ((Nd.Value) * .267127m * 6.0221413e-1m / 142m);
Nd143.Value = ((Nd.Value) * .120616m * 6.0221413e-1m / 143m);
Nd144.Value = ((Nd.Value) * .237433m * 6.0221413e-1m / 144m);
Nd145.Value = ((Nd.Value) * .083316m * 6.0221413e-1m / 145m);
Nd146.Value = ((Nd.Value) * .173882m * 6.0221413e-1m / 146m);
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        Nd148.Value = ((Nd.Value) * .059027m * 6.0221413e-1m / 148m);
        Nd150.Value = ((Nd.Value) * .058600m * 6.0221413e-1m / 150m);

        Sm144.Value = ((Sm.Value) * .029382m * 6.0221413e-1m / 144m);
        Sm147.Value = ((Sm.Value) * .146459m * 6.0221413e-1m / 147m);
        Sm148.Value = ((Sm.Value) * .110567m * 6.0221413e-1m / 148m);
        Sm149.Value = ((Sm.Value) * .136868m * 6.0221413e-1m / 149m);
        Sm150.Value = ((Sm.Value) * .073580m * 6.0221413e-1m / 150m);
        Sm152.Value = ((Sm.Value) * .270263m * 6.0221413e-1m / 152m);
        Sm154.Value = ((Sm.Value) * .232880m * 6.0221413e-1m / 154m);

        Eu151.Value = ((Eu.Value) * .474814m * 6.0221413e-1m / 151m);
        Eu153.Value = ((Eu.Value) * .525186m * 6.0221413e-1m / 153m);

        Gd152.Value = ((Gd.Value) * .001932m * 6.0221413e-1m / 152m);
        Gd154.Value = ((Gd.Value) * .021338m * 6.0221413e-1m / 154m);
        Gd155.Value = ((Gd.Value) * .145808m * 6.0221413e-1m / 155m);
        Gd156.Value = ((Gd.Value) * .202969m * 6.0221413e-1m / 156m);
        Gd157.Value = ((Gd.Value) * .156173m * 6.0221413e-1m / 157m);
        Gd158.Value = ((Gd.Value) * .249461m * 6.0221413e-1m / 158m);
        Gd160.Value = ((Gd.Value) * .222318m * 6.0221413e-1m / 160m);

        Tb159.Value = ((Tb.Value) * 1.00000m * 6.0221413e-1m / 159m);

        Dy156.Value = ((Dy.Value) * .000537m * 6.0221413e-1m / 156m);
        Dy158.Value = ((Dy.Value) * .000923m * 6.0221413e-1m / 158m);
        Dy160.Value = ((Dy.Value) * .022921m * 6.0221413e-1m / 160m);
        Dy161.Value = ((Dy.Value) * .187062m * 6.0221413e-1m / 161m);
        Dy162.Value = ((Dy.Value) * .253852m * 6.0221413e-1m / 162m);
        Dy163.Value = ((Dy.Value) * .249618m * 6.0221413e-1m / 163m);
        Dy164.Value = ((Dy.Value) * .285086m * 6.0221413e-1m / 164m);

        Ho165.Value = ((Ho.Value) * 1.00000m * 6.0221413e-1m / 165m);

        Er162.Value = ((Er.Value) * .001346m * 6.0221413e-1m / 162m);
        Er164.Value = ((Er.Value) * .015691m * 6.0221413e-1m / 164m);
        Er166.Value = ((Er.Value) * .332368m * 6.0221413e-1m / 166m);
        Er167.Value = ((Er.Value) * .228243m * 6.0221413e-1m / 167m);
        Er168.Value = ((Er.Value) * .270866m * 6.0221413e-1m / 168m);
        Er170.Value = ((Er.Value) * .151486m * 6.0221413e-1m / 170m);

        Tm169.Value = ((Tm.Value) * 1.00000m * 6.0221413e-1m / 169m);

        Yb168.Value = ((Yb.Value) * .001194m * 6.0221413e-1m / 168m);
        Yb170.Value = ((Yb.Value) * .029282m * 6.0221413e-1m / 170m);
        Yb171.Value = ((Yb.Value) * .139176m * 6.0221413e-1m / 171m);
        Yb172.Value = ((Yb.Value) * .215400m * 6.0221413e-1m / 173m);
        Yb173.Value = ((Yb.Value) * .160922m * 6.0221413e-1m / 173m);
        Yb174.Value = ((Yb.Value) * .321897m * 6.0221413e-1m / 174m);
        Yb176.Value = ((Yb.Value) * .132189m * 6.0221413e-1m / 176m);

        Lu175.Value = ((Lu.Value) * .973865m * 6.0221413e-1m / 175m);
        Lu176.Value = ((Lu.Value) * .026135m * 6.0221413e-1m / 176m);

        Hf174.Value = ((Hf.Value) * .001559m * 6.0221413e-1m / 174m);
        Hf176.Value = ((Hf.Value) * .051850m * 6.0221413e-1m / 176m);
        Hf177.Value = ((Hf.Value) * .184393m * 6.0221413e-1m / 177m);
        Hf178.Value = ((Hf.Value) * .271973m * 6.0221413e-1m / 178m);
        Hf179.Value = ((Hf.Value) * .136552m * 6.0221413e-1m / 179m);
        Hf180.Value = ((Hf.Value) * .353673m * 6.0221413e-1m / 180m);

        Ta180.Value = ((Ta.Value) * .000119m * 6.0221413e-1m / 180m);
        Ta181.Value = ((Ta.Value) * .999881m * 6.0221413e-1m / 181m);

        W180.Value = ((W.Value) * .001175m * 6.0221413e-1m / 180m);
        W182.Value = ((W.Value) * .262270m * 6.0221413e-1m / 182m);
        W183.Value = ((W.Value) * .142406m * 6.0221413e-1m / 183m);
        W184.Value = ((W.Value) * .306582m * 6.0221413e-1m / 184m);
        W186.Value = ((W.Value) * .287567m * 6.0221413e-1m / 186m);

        Re185.Value = ((Re.Value) * .371482m * 6.0221413e-1m / 185m);
        Re187.Value = ((Re.Value) * .628518m * 6.0221413e-1m / 187m);

        Os184.Value = ((Os.Value) * .000193m * 6.0221413e-1m / 184m);
        Os186.Value = ((Os.Value) * .015543m * 6.0221413e-1m / 186m);
        Os187.Value = ((Os.Value) * .019263m * 6.0221413e-1m / 187m);
        Os188.Value = ((Os.Value) * .130821m * 6.0221413e-1m / 188m);
        Os189.Value = ((Os.Value) * .160425m * 6.0221413e-1m / 189m);
        Os190.Value = ((Os.Value) * .262232m * 6.0221413e-1m / 190m);
        Os192.Value = ((Os.Value) * .411523m * 6.0221413e-1m / 192m);

        Ir191.Value = ((Ir.Value) * .370564m * 6.0221413e-1m / 191m);
        Ir193.Value = ((Ir.Value) * .629436m * 6.0221413e-1m / 193m);

        Pt190.Value = ((Pt.Value) * .000117m * 6.0221413e-1m / 190m);
        Pt192.Value = ((Pt.Value) * .007694m * 6.0221413e-1m / 192m);
        Pt194.Value = ((Pt.Value) * .326697m * 6.0221413e-1m / 194m);
        Pt195.Value = ((Pt.Value) * .337579m * 6.0221413e-1m / 195m);
        Pt196.Value = ((Pt.Value) * .253228m * 6.0221413e-1m / 196m);
        Pt198.Value = ((Pt.Value) * .074685m * 6.0221413e-1m / 198m);

        Au197.Value = ((Au.Value + circuitboardgrams.Value * 0.05000m + pcbelectronicsgrams.Value *
.04000m) * 1.00000m * 6.0221413e-1m / 197m);

        Hg196.Value = ((Hg.Value) * .001465m * 6.0221413e-1m / 196m);
        Hg198.Value = ((Hg.Value) * .098392m * 6.0221413e-1m / 198m);
        Hg199.Value = ((Hg.Value) * .167328m * 6.0221413e-1m / 199m);
        Hg200.Value = ((Hg.Value) * .230274m * 6.0221413e-1m / 200m);
        Hg201.Value = ((Hg.Value) * .132044m * 6.0221413e-1m / 201m);
        Hg202.Value = ((Hg.Value) * .300641m * 6.0221413e-1m / 202m);
        Hg204.Value = ((Hg.Value) * .069856m * 6.0221413e-1m / 204m);

        Tl203.Value = ((Tl.Value) * .293190m * 6.0221413e-1m / 203m);
        Tl205.Value = ((Tl.Value) * .706810m * 6.0221413e-1m / 205m);

        Pb204.Value = ((Pb.Value) * .013781m * 6.0221413e-1m / 204m);
        Pb206.Value = ((Pb.Value) * .239555m * 6.0221413e-1m / 206m);
        Pb207.Value = ((Pb.Value) * .220743m * 6.0221413e-1m / 207m);
        Pb208.Value = ((Pb.Value) * .525921m * 6.0221413e-1m / 208m);



        nuclidesum.Value = (H1.Value + H2.Value + He3.Value + He4.Value + Li6.Value + Li7.Value +
Be9.Value + B10.Value + B11.Value + C12.Value + C13.Value + N14.Value + N15.Value + O16.Value + O17.Value +
O18.Value + F19.Value + Ne20.Value + Ne21.Value + Ne22.Value + Na23.Value + Mg24.Value + Mg25.Value +
Mg26.Value + Al27.Value + Si28.Value + Si29.Value + Si30.Value + P31.Value + S32.Value + S33.Value + S34.Value +
S36.Value + Cl35.Value + Cl37.Value + Ar36.Value + Ar38.Value + Ar40.Value + K39.Value + K41.Value + Ca40.Value +
Ca42.Value + Ca43.Value + Ca44.Value + Ca46.Value + Sc45.Value + Ti46.Value + Ti47.Value + Ti48.Value +
Ti49.Value + Ti50.Value + V51.Value + Cr50.Value + Cr52.Value + Cr53.Value + Cr54.Value + Mn55.Value + Fe54.Value
+ Fe56.Value + Fe57.Value + Fe58.Value + Co59.Value + Ni58.Value + Ni60.Value + Ni61.Value + Ni62.Value +
Ni64.Value + Cu63.Value + Cu65.Value + Zn64.Value + Zn66.Value + Zn67.Value + Zn68.Value + Zn70.Value +
Ga69.Value + Ga71.Value + Ge70.Value + Ge72.Value + Ge73.Value + Ge74.Value + As75.Value + Se74.Value +
Se76.Value + Se77.Value + Se78.Value + Se80.Value + Br79.Value + Br81.Value + Kr78.Value + Kr80.Value +
Kr82.Value + Kr83.Value + Kr84.Value + Kr86.Value + Rb85.Value + Sr84.Value + Sr86.Value + Sr87.Value + Sr88.Value
+ Y89.Value + Zr90.Value + Zr91.Value + Zr92.Value + Zr94.Value + Nb93.Value + Mo92.Value + Mo94.Value +
Mo95.Value + Mo96.Value + Mo97.Value + Mo98.Value + Ru96.Value + Ru98.Value + Ru99.Value + Ru100.Value +
Ru101.Value + Ru102.Value + Ru104.Value + Rh103.Value + Pd102.Value + Pd104.Value + Pd105.Value +
Pd106.Value + Pd108.Value + Pd110.Value + Ag107.Value + Ag109.Value + Cd106.Value + Cd108.Value + Cd110.Value
+ Cd111.Value + Cd112.Value + Cd114.Value + In113.Value + Sn112.Value + Sn114.Value + Sn115.Value +
Sn116.Value + Sn117.Value + Sn118.Value + Sn119.Value + Sn120.Value + Sn122.Value + Sn124.Value + Sb121.Value
+ Sb123.Value + Te120.Value + Te122.Value + Te123.Value + Te124.Value + Te125.Value + Te126.Value + I127.Value
+ Xe124.Value + Xe126.Value + Xe128.Value + Xe129.Value + Xe130.Value + Xe131.Value + Xe132.Value +
Xe134.Value + Xe136.Value + Cs133.Value + Ba132.Value + Ba134.Value + Ba135.Value + Ba136.Value + Ba137.Value
+ Ba138.Value + La139.Value + Ce136.Value + Ce138.Value + Ce140.Value + Ce142.Value + Pr141.Value +
Nd142.Value + Nd143.Value + Nd145.Value + Nd146.Value + Nd148.Value + Sm144.Value + Sm149.Value +
Sm150.Value + Sm152.Value + Sm154.Value + Eu151.Value + Eu153.Value + Gd154.Value + Gd155.Value +
Gd156.Value + Gd157.Value + Gd158.Value + Gd160.Value + Tb159.Value + Dy156.Value + Dy158.Value +
Dy160.Value + Dy161.Value + Dy162.Value + Dy163.Value + Dy164.Value + Ho165.Value + Er162.Value + Er164.Value
+ Er166.Value + Er167.Value + Er168.Value + Er170.Value + Tm169.Value + Yb168.Value + Yb170.Value + Yb171.Value
+ Yb172.Value + Yb173.Value + Yb174.Value + Yb176.Value + Lu175.Value + Hf176.Value + Hf177.Value + Hf178.Value
+ Hf179.Value + Hf180.Value + Ta180.Value + Ta181.Value + W180.Value + W182.Value + W183.Value + W184.Value +
W186.Value + Re185.Value + Os184.Value + Os187.Value + Os188.Value + Os189.Value + Os190.Value + Os192.Value
+ Ir191.Value + Ir193.Value + Pt192.Value + Pt194.Value + Pt195.Value + Pt196.Value + Pt198.Value + Au197.Value +
Hg196.Value + Hg198.Value + Hg199.Value + Hg200.Value + Hg201.Value + Hg202.Value + Hg204.Value + Tl203.Value
+ Tl205.Value + Pb204.Value + Pb206.Value + Pb207.Value + Pb208.Value + K40.Value + Ca48.Value + V50.Value +
Ge76.Value + Se82.Value + Rb87.Value + Zr96.Value + Mo100.Value + Cd113.Value + Cd116.Value + In115.Value +
Te128.Value + Te130.Value + Ba130.Value + La138.Value + Nd144.Value + Nd150.Value + Sm147.Value +
Sm148.Value + Gd152.Value + Lu176.Value + Hf174.Value + Re187.Value + Os186.Value + Pt190.Value);

        }

        private void label8_Click(object sender, EventArgs e)
        {

        }

        private void listBox1_SelectedIndexChanged_1(object sender, EventArgs e)
        {

        }

        private void numericUpDown15_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown191_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown20_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown52_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown30_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown1_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown63_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown68_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown87_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown96_ValueChanged(object sender, EventArgs e)
        {

        }
        private void numericUpDown93_ValueChanged(object sender, EventArgs e)
        {

        }



        private void titleTextBox_TextChanged(object sender, EventArgs e)
        {

        }

        private void sN119_ValueChanged(object sender, EventArgs e)
        {

        }

        private void numericUpDown138_ValueChanged(object sender, EventArgs e)
        {

        }

        private void sulfurgramstandard_ValueChanged_1(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void sulfurgramlarge_ValueChanged_1(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void tldgram_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void Al6061gram_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void panel3_Paint_1(object sender, PaintEventArgs e)
        {

        }

        private void S_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void H_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void He_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void Li_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void Be_ValueChanged(object sender, EventArgs e)
        {
```

```
        AtomCalc();
    }

    private void B_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void C_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void N_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void O_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void F_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ne_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Na_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Mg_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Al_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Si_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void P_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Cl_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ar_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void K_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ca_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Sc_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ti_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void V_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Cr_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void numericUpDown230_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Fe_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Co_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ni_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Cu_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Zn_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ga_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ge_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void As_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Se_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Br_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Kr_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Rb_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Sr_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Y_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Zr_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Nb_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Mo_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Tc_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ru_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Rh_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Pd_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ag_ValueChanged(object sender, EventArgs e)
    {
```

```
        AtomCalc();
    }

    private void Cd_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void In_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Sn_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Sb_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Te_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void I_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Xe_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Cs_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ba_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void La_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Ce_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Pr_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Nd_ValueChanged(object sender, EventArgs e)
    {
        AtomCalc();
    }

    private void Pm_ValueChanged(object sender, EventArgs e)
    {
```

```
    AtomCalc();
}

private void Sm_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Eu_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Gd_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Tb_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Dy_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Ho_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Er_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Tm_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Yb_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Lu_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Hf_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Ta_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void W_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Re_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Os_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Ir_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Pt_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Au_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Hg_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Tl_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}

private void Pb_ValueChanged(object sender, EventArgs e)
{
    AtomCalc();
}



private void nuclidesum_ValueChanged(object sender, EventArgs e)
{

}

private void panel4_Paint(object sender, PaintEventArgs e)
{

}

private void hrs_ValueChanged(object sender, EventArgs e)
{

}

private void run_Click(object sender, EventArgs e)
{
    //System.Diagnostics.ProcessStartInfo info = new System.Diagnostics.ProcessStartInfo("cmd.exe");
    //info.WorkingDirectory = "c:\\cinder\\" + titleTextBox.Text;
    //info.Arguments = "/C C:\\Cinder2008\\cinder.exe";
    //System.Diagnostics.Process.Start(info);
    //System.Diagnostics.Process.


    String command = @"/C C:\\Cinder2008\\cinder.exe";
    System.Diagnostics.ProcessStartInfo cmdsi = new System.Diagnostics.ProcessStartInfo("cmd.exe");
    cmdsi.Arguments = command;
    cmdsi.WorkingDirectory = "c:\\cinder\\" + titleTextBox.Text;
    System.Diagnostics.Process cmd = System.Diagnostics.Process.Start(cmdsi);
    cmd.WaitForExit(); //wait indefinitely for the associated process to exit.
```

```
            results_Click(null, null);



        }

        private void circuitboardgrams_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void pcbelectronicsgrams_ValueChanged(object sender, EventArgs e)
        {
            AtomCalc();
        }

        private void textBox1_TextChanged_1(object sender, EventArgs e)
        {

        }

        private void results_Click(object sender, EventArgs e)
        {

            label5.Show();
            label6.Show();
            label14.Show();
            label15.Show();
            label16.Show();
            textBox1.Show();
            textBox2.Show();
            numericUpDown5.Show();
            numericUpDown3.Show();
            numericUpDown6.Show();
            double mRem;

            // Read each line of the file into a string array. Each element
            // of the array is one line of the file.
            string[] lines = System.IO.File.ReadAllLines("c:\\cinder\\" + titleTextBox.Text + "\\tables_by_grp");

            foreach (string line in lines)
            {
                if (line.StartsWith("  TOTAL GAMMAS/(CC-S)"))
                  {
                      string[] substrings=line.Split(new char[] { '|' });
                      textBox1.Text = substrings[2];
                      numericUpDown1.Value = Decimal.Parse(textBox1.Text,
System.Globalization.NumberStyles.Any);
                  }

                if (line.StartsWith("   GROUP MID POINTS:"))
                  {
                     string[] substrings=line.Split(new char[] { '|' });
                     textBox2.Text = substrings[2];
                     numericUpDown2.Value = Decimal.Parse(textBox2.Text,
System.Globalization.NumberStyles.Any);
                     break;
                  }
            }


            double E = Math.Log(System.Convert.ToDouble(numericUpDown2.Value));

            if (numericUpDown2.Value <= 0.03m)
            {
                mRem = 1000.0 * System.Convert.ToDouble(numericUpDown1.Value) / (4.0 * Math.PI * 30.0 * 30.0) *
Math.Exp(-20.477 + -1.7454 * E);
                numericUpDown3.Value = System.Convert.ToDecimal(mRem);
            }

```

```
                if (numericUpDown2.Value <= 0.5m & numericUpDown2.Value > 0.03m)
                {
                     mRem = 1000.0 * System.Convert.ToDouble(numericUpDown1.Value) / (4.0 * Math.PI * 30.0 * 30.0)
* Math.Exp(-13.626 + -0.57117 * E + -1.0954 * E * E  + -.024897 * E * E * E);
                     numericUpDown3.Value = System.Convert.ToDecimal(mRem);
                }

                if (numericUpDown2.Value < 5.0m & numericUpDown2.Value > 0.5m)
                {
                    mRem = 1000.0 * System.Convert.ToDouble(numericUpDown1.Value) / (4.0 * Math.PI * 30.0 * 30.0) *
Math.Exp(-13.133 + 0.72008 * E + -0.033603 * E * E);
                    numericUpDown3.Value = System.Convert.ToDecimal(mRem);
                }

                if (numericUpDown2.Value <= 15.0m & numericUpDown2.Value > 5.0m)
                {
                    mRem = 1000.0 * System.Convert.ToDouble(numericUpDown1.Value) / (4.0 * Math.PI * 30.0 * 30.0) *
Math.Exp(-12.791 + 0.28309 * E + 0.10873 * E * E);
                    numericUpDown3.Value = System.Convert.ToDecimal(mRem);
                }

                numericUpDown5.Value = numericUpDown3.Value * 30m; // assume linear within 1-foot
                numericUpDown6.Value = numericUpDown3.Value * 0.09m; // I/I0 = r0^2/r^2  30^2/100^2

            }

            private void button4_Click_1(object sender, EventArgs e)
            {
                panel2.Show();
                label22.Show();
                label23.Show();
                button4.Hide();
            }

            private void numericUpDown3_ValueChanged_1(object sender, EventArgs e)
            {

            }

            private void numericUpDown13_ValueChanged(object sender, EventArgs e)
            {
                AtomCalc();
            }

            private void cardboardgrams_ValueChanged(object sender, EventArgs e)
            {
                AtomCalc();
            }

            private void panel1_Paint(object sender, PaintEventArgs e)
            {

            }

            private void pvc_CheckedChanged(object sender, EventArgs e)
            {
                if (pvc.Checked)
                {
                    pvcgram.Show();
                }
                else
                {
                    pvcgram.Value = 0;
                    pvcgram.Hide();
                }
            }

            private void teflon_CheckedChanged(object sender, EventArgs e)
            {
                if (teflon.Checked)
                {
                    teflongram.Show();
                }
                else
                {
                    teflongram.Value = 0;
                    teflongram.Hide();
                }
            }

            private void polygram_ValueChanged(object sender, EventArgs e)
            {
                AtomCalc();
            }

            private void pvcgram_ValueChanged(object sender, EventArgs e)
            {
                AtomCalc();
            }

            private void teflongram_ValueChanged(object sender, EventArgs e)
            {
                AtomCalc();
            }

            private void Ca42_ValueChanged(object sender, EventArgs e)
            {

            }


        }
    }
```

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