Addendum to ICSBEP Logbooks 12r, 13r, 14r and 15r for Polyethylene and Graphite Reflected HEU Metal Critical Experiments

John T. Mihalczo

October 2023

![Oak Ridge National Laboratory logo]

Nuclear Energy and Fuel Cycle Division

ADDENDUM TO ICSBEP LOGBOOKS 12R.13R, 14R AND 15RFOR POLYETHYLENE AND GRAPHITE REFLECTED HEU METAL CRITICAL EXPERIMENTS

John T. Mihalczo

October 2023

CONTENTS

LIST OF FIGURES

ABSTRACT

This report documents the experimenters' data sheets that were recently (2023) discovered for critical experiments with highly enriched uranium metal with polyethylene and graphite reflectors. These data sheets were produced at the time of the measurements, when the dimensional inspection reports for the polyethylene and graphite were available. However, at this writing, those inspection reports are not available but may be in unmarked storage for the Y-12 National Security Complex. However, the data sheets presented herein contain sketches of the experimental configurations and other additional information that is not in the logbooks, such as dimensions and masses of the graphite measurements. This report reproduces the experimental data sheets that complement the logbooks. Some of the data on these sheets and the logbooks can be used to infer the dimensions and masses that are not documented. Some obvious mistakes in the logbook and data sheets have been corrected. In the reproduced data sheets, some of the information is not clearly visible: some information, such as average values, can be obtained from other data in the sheets or logbook. This report should be sent to the International Criticality Safety Benchmark Program at Idaho National Laboratory to complement the existing Oak Ridge Critical Facility logbooks there.

1. INTRODUCTION

This report documents the experimenters' data sheets that were recently (2023) discovered for critical experiments with highly enriched uranium (HEU) metal with polyethylene and graphite reflectors that were performed in the early 1960s at the Oak Ridge Critical Experiments Facility (ORCEF). These data sheets were produced at the time of the measurements, when the dimensional inspection reports for the reflector materials were available. However, at this writing, those dimensional inspection reports are not available but may be in unmarked storage for the Y-12 National Security Complex. However, the data sheets presented herein contain sketches of the experimental configurations and other additional information that is not contained in the logbooks, such as the dimensions and masses of the measurement materials. This report reproduces the data sheets that complement the logbooks. Some of the data on these sheets and the logbooks can be used to infer the dimensions and masses that are not documented. Some obvious mistakes in the logbook and data sheets have been corrected. In the reproduced data sheets, some of the information is not clearly shown: some information, such as average values, can be obtained from other readable data on the sheets or the logbook. Three documents related to these experiments have been published: a Y-12 report [1], a journal paper [2], and an ICSBEP benchmark, HEU-MET-FAST-071 [3]. In addition, a three-year effort is underway at the University of Tennessee, Knoxville's Department of Nuclear Engineering, supported by the DOE Office of Nuclear Energy's Nuclear Energy University Programs, to benchmark additional ~80 graphite-reflected critical experiments with HEU metal reflected with graphite greater than 2 in. thickness. This report should be sent to the International Criticality Safety Benchmark Program (ICSBEP) at Idaho National Laboratory to complement the existing Oak Ridge Critical Facility logbooks there. ICSBEP logbooks 12r, 13r, 14r and 15r correspond to ORCEF logbooks E-19, E-20, E-21 and E-22. The publication of this report was supported by Nuclear Data, Criticality Safety, and Radiation Transport Section of ORNL and the DOE/NNSA Nuclear Criticality Safety Program.

2. TYPES OF CRITICAL ASSEMBLIES

Three types of reflected HEU metal cylindrical and annular critical experiments were performed with the vertical assembly machine [4] at the Oak Ridge Critical Experiments Facility: (1) graphite reflected HEU metal assemblies with reflector under 10 in., (2) graphite reflected HEU metal assemblies with reflectors greater than 9 in., and (3) thick polyethylene reflected HEU metal assemblies. For the thick graphite and polyethylene reflected assemblies, the HEU metal and bottom reflector were assembled on the vertical lift

table that was inserted into the top and side reflector. A photograph of a graphite reflected assembly in the disassembled configuration is given in Figure 1. A photograph of an HEU metal polyethylene reflected assembly in the disassembled condition is shown in Figure 2.

Figure 3 shows a photograph of an unreflected uranium metal critical experiment in the disassembled condition from ICSBEP benchmark HEU-MET-FAST-051 [5]; this experiment used the same support structure and assembly procedures as those of the graphite reflected HEU metal experiments with reflectors smaller than 10 in. The low-mass support structure details are documented in an appendix of Reference 6.

Cylinder of Graphite
45.00 Inch Diameter
15.00 Inch High

Annuli of Graphite
45.00 Inch OD
15.03 Inch ID
8.00 Inch High

Support Structure for
Fixed Top and Side
Reflector

0.5-Inch-Thick
Steel Plate

Uranium Annuli
14.996 Inch OD
11.003 Inch ID

Cylinders of Graphite
15.00 Inch Diameter
15.00 Inch Total Height

Movable Core and
Bottom Reflector
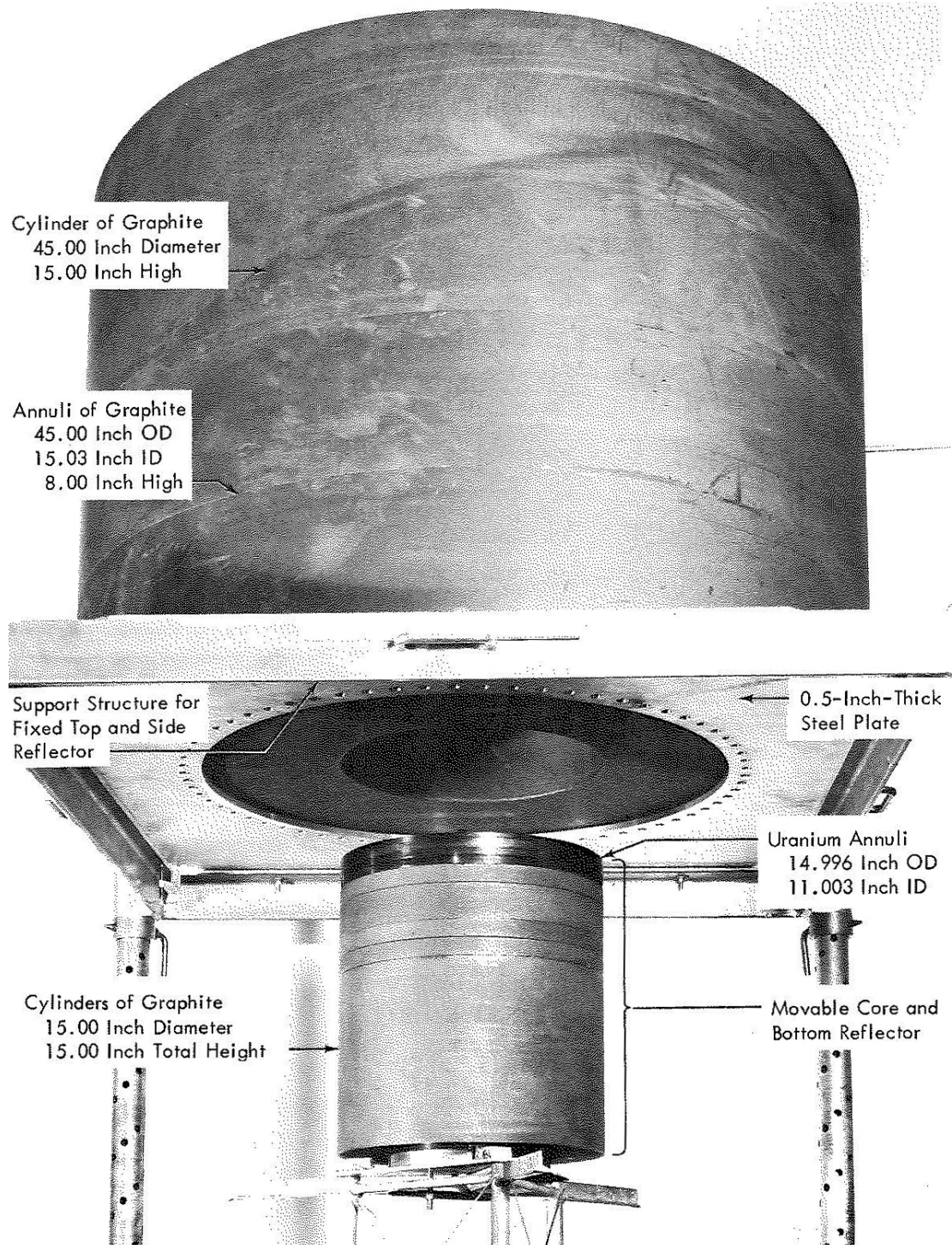
Figure 1. Typical configuration of HEU metal annulus with 15 in. thick graphite reflector on the vertical assembly machine in the disassembled condition. (The upper part of the low-mass lower support is shown under the bottom reflector in this photo.)

3
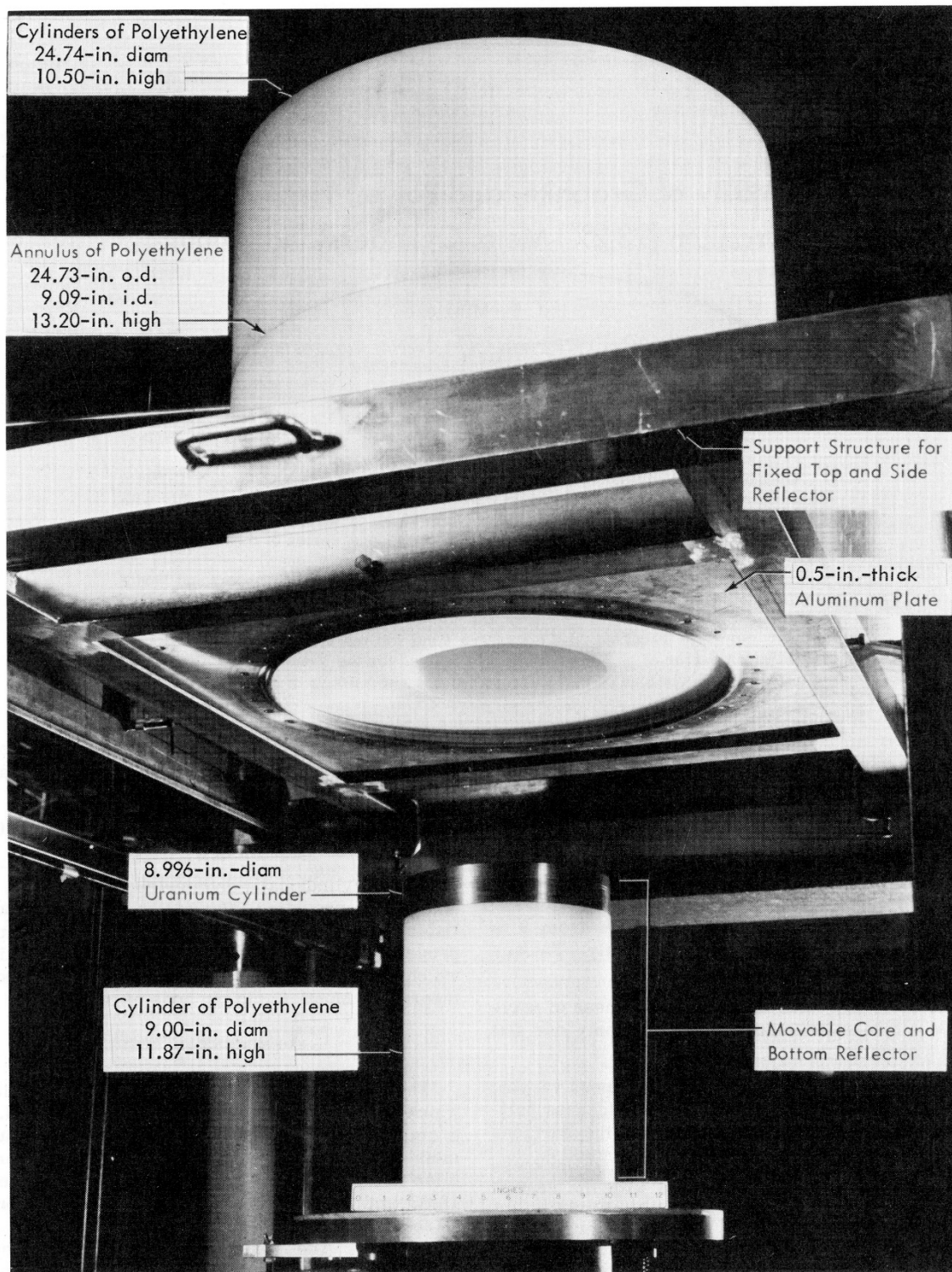
Figure 2. Typical polyethylene reflected HEU metal cylinder in the disassembled condition on the vertical assembly machine at ORCEF. (The upper part of the low mass support structure mounted on the aluminum support table of the vertical lift of the vertical assembly machine at ORCEF is shown in the bottom of this photograph.)

A photograph of an unreflected HEU metal cylinder on the vertical assembly machine with the upper section supported on the thin stainless-steel diaphragm and the lower section on a low-mass support stand is given in Figure 3. For the graphite reflected critical experiments, this support structure was used. The lower section was composed of HEU metal with the bottom and radial reflector, and the top section on the diaphragm consisted of the upper HEU metal and top and radial reflector. For some experiments all the HEU metal was on the upper section and the lower section was bottom reflector.
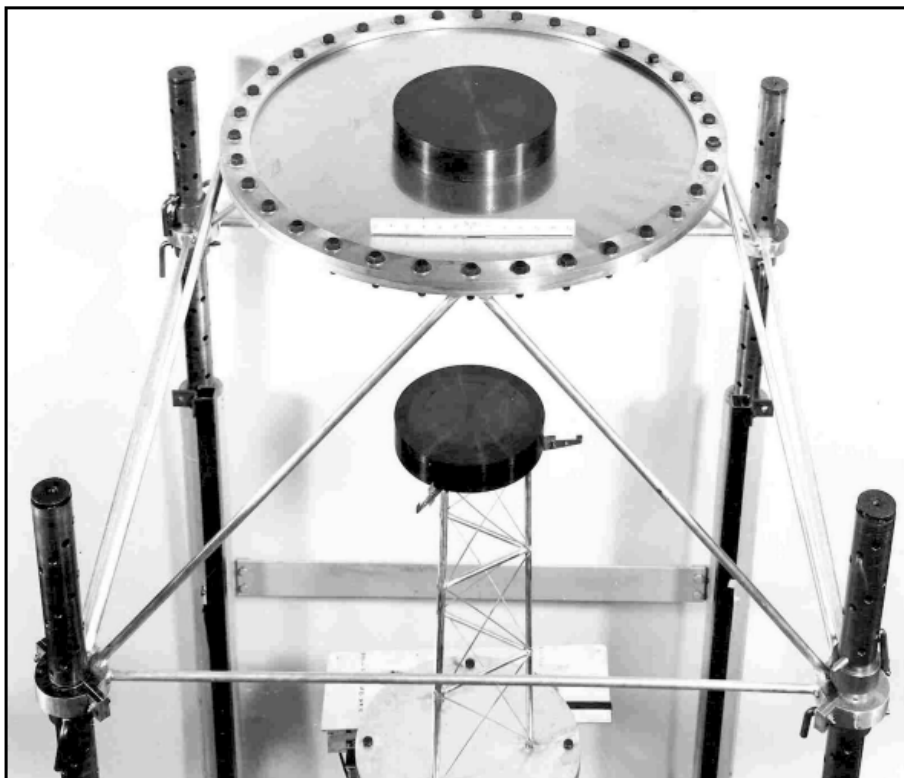
Figure 3. A typical uranium metal assembly for a solid 11 in. diameter uranium (93.14 wt % ^{235}U) metal cylinder of two interacting 11 in. diameter cylinders at close spacing in disassembled condition (from ICSBEP benchmark HEU-MET-FAST-051; this same low mass support structure was used for graphite reflector thickness less than 10 inches).

3. EXPERIMENTERS DATA SHEETS

The file for all experimental data sheets for these experiments is given in Appendix A. The information contained within the experimenters' data sheets is discussed for two examples of two HEU metal system: one with a thin graphite reflector and one with a thick graphite reflector. The discussion of these examples identifies the locations of various information on the data sheets. However, this can vary depending on the data sheet for a particular experiment. In addition, other data sheets can contain other information not in these examples. The experiment data sheets chosen as examples are as follows. (1) A 1 in. thick graphite reflected HEU metal annulus with an outside diameter of 13 in. and inside diameter of 7 in. with void inside the HEU metal. This experiment, which was performed on October 28, 1963, is a repeat of a previous experiment performed on January 25, 1963, with different HEU metal parts. This assembly has been benchmarked in HEU-MET-FAST-071 [3]. (2) An HEU metal cylinder reflected by 12 in. thick graphite reflector. Dimensions given as whole numbers or fractions are nominal. If the dimension contains numbers to the right of the decimal point, they are measured dimensions. Sometimes, a single experimental data sheet contains information for both configurations with both void and graphite inside

the HEU metal. In these cases, on the back side of the experimental data sheet, usually the data for the void assembly is on the left, and that for the graphite in the center is on the right.

3.1 HEU METAL ANNULUS WITH OUTSIDE AND INSIDE DIAMETERS OF 13 IN. AND 7 IN. WITH 1 IN. GRAPHITE REFLECTOR

Copies of back and front of sections of the experimental data sheets are isolated in different figures for discussion.

3.1.1 Top of the Front Page of the Experimental Data Sheet

The top of the front page of the data sheet (Figure 4) contains the experiment title on the upper left, and on the upper right at the top is a reference to the ORCEF logbook, page number and run number. The title of the experiment on the far left is the outer and inner diameter in inches of the HEU metal. In the center is the thickness of the graphite reflector, which in this case is 1 in. "No core" means no graphite in the center of the HEU metal annulus. In this case, the ORCEF logbook is 2 (E-20), page 252 and Run 70. Below this is a drawing of the assembled system. The assembly is divided with an upper section on a diaphragm and a lower section on a low-mass support stand. The diaphragm is designated as a horizontal line on the drawing that extends to the right and left beyond the reflector parts. The experimental geometries are all cylindrically symmetric with the centerline indicated as a dashed vertical line on the right of the assembly sketch.

13-7   1" GRAPHITE REFLECTOR (No Core)   Run #70 Pg 252 Bk #2   28 Oct 63

15-13   13-11   11-9   9-7

G-½" DISC   2467
G-⅜"-DISC   1841
G-⅛" DISC   460 A

2780-⅛	2779-¼	2775
2753-½	2743-⅜	2829
2782-¼	2778-¼	2774

VOID

2⅞"   1⅜"

2"A
2476

2757-1   2745   2738

— 10 MIL DIAPH.

2752-½   2742-⅜   2736
2744-⅛   2763
2751-½

2"   3"B

2747-1½   2740   VOID

2756-1

3712

3.8948   3.8870   3.8858

G-1 A
3682

58835
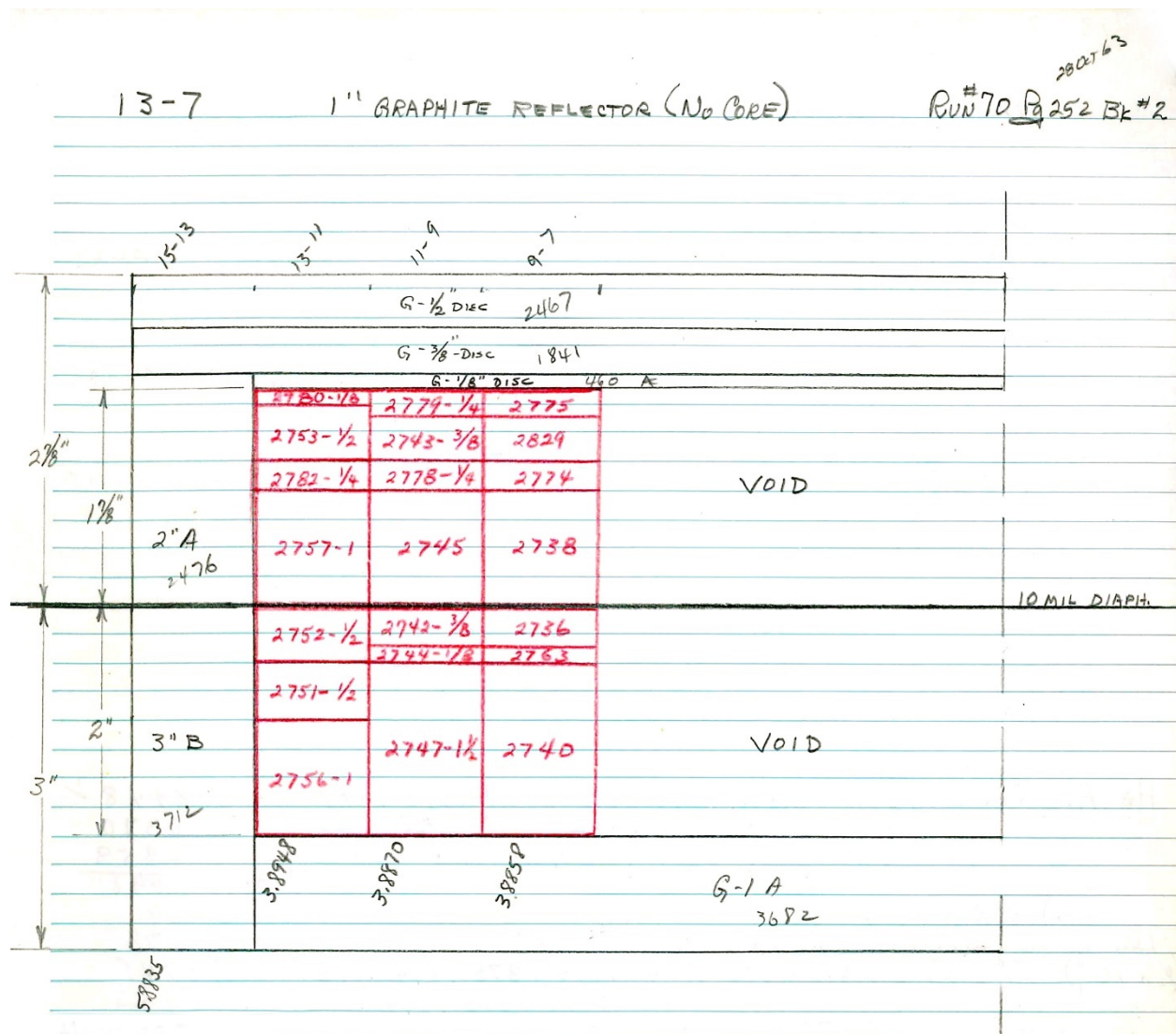
Figure 4. Title, logbook, run number (sometimes), and page number and sketch of the assembled system. (Red indicates HEU metal.)

There is usually a variety of information on the sketch. The HEU metal parts are outlined in red, and their numbers are designated in red. In this sketch, after the four-digit part numbers are some fractional thicknesses. For some of the drawings, the identification of the HEU metal parts provides only the last two or last four digits of the part number. Below the HEU metal parts in red, there are sometimes the measured (obtained as described in reference 6) height of a particular section of the HEU metal parts. For example, for the 13-11 annular HEU metal section, the measured height is 3.8948 in. Measured heights of stacks of HEU metal or graphite do not include the diaphragm thickness. The materials not designated in red are graphite parts. The annular sections of the experiment are labeled on top of the sketch: in this case, 15-13, 13- 11, 11-9, and 9-7, where these numbers are the outside and inside diameter of the HEU metal region. The nominal thicknesses of the graphite parts are given as whole numbers or fractions. If there more than one graphite part of the same dimensions was available, an additional letter was added to the thickness—for example 3" A. Within the sketch of each graphite part is a number that gives the mass of the part in grams to an uncertainty of 0.5 grams. For example, the reflector mass of the bottom 13 in. OD graphite reflector cylinder on the lower support structure is given as 3682 grams on the lower support stand. In some sketches like this one, the total measured heights of the HEU metal sections (sum of

heights on lower support stand and on the diaphragm) are given under the HEU metal sections in the bottom reflector. For example, in this sketch, the average measured height of the 13 in. OD, 11 in. ID HEU metal ring is 3.8958 in. using the procedures for height measurement described in HEU-MET-FAST-051 [5]. There may be other notes on the sketch that provide other information such as the actual measured thickness of the graphite parts. Some nominal heights are given on the far left of the sketch and are indicated by arrows. For this sketch, the measured height of the 15-13 annular graphite section on top and bottom is 5.8935 in. The sketch may also contain letters such as A, B, C, etc. with arrows that indicate height measurements for sections of the assembly, with the numerical values given on the back of the data sheet. These multiple thickness measurements are given, most of the time with an average value that is sometimes not readable even with a magnifying glass. In these cases, the average can be calculated from the multiple individual thicknesses. For some of the 15 in. thick graphite reflected systems, it is easier to consult the logbook for the HEU metal part stacking.

3.1.2   Other Information under the Sketch on the Front of the Data Sheet

Information on the masses and volumes is given on the front of the data sheet, below the sketch of the assembly. The numbers on the data sheets have too many significant figures beyond the decimal point, but that is the way they were listed at the time of the measurements. A typical bottom of the front page of an experimental data sheet is given in Figure 5 for the measurement shown in Figure 4.

Figure 5. Information below the sketch on the front of the experimental data sheet.

On this data sheet, the mass of HEU metal in the top section (54,246 g), the mass of HEU metal in the bottom section (57,892 g), and the total HEU metal mass (112,138 g) are given. On this data sheet, the mass of the graphite in the top section (7,244 g), the mass of graphite in the bottom section (7,314 g), and the total graphite mass (14,636 kg) are given.

In some of the drawings, the HEU metal part numbers may not be legible. Masses given can sometimes be used to determine the unknown part's mass: for example, the case in which there are just three parts in an assembly and two of them are clearly marked. The known masses of the two identified parts can be subtracted from the total mass to obtain the mass of the unknown uranium part number. The masses listed in descriptions of the HEU metal parts for the subtracted masses can be observed to determine the unknown part number by searching for a part in the list of HEU metal parts with the subtracted mass. For experiments after January 1965, most of the 7 in. diameter cylindrical parts had 0.375 in. diameter holes that were filled with 0.0365 in. diameter HEU metal plugs. In these cases, the fuel mass given on the front of the data sheet shows the addition of these masses with the total from the major parts to give the total mass of the assembly. The total volume of the HEU metal was and can now also be calculated from the descriptions of the HEU metal parts from the inspection report data included in reference [6]. With the total HEU metal mass and volume, an average density can be calculated for the assembly and is included on the front of the experimenters' data sheet. The average OD and ID of this HEU metal assembly with the weighted average calculated with the inner and outer part heights as weights were 7.00307 and 12.99599 in., respectively. For some reason, the square of these diameters is also given—not on this data sheet but on others.

The next item down on the data sheet is the volume of the HEU metal (designated as *Fuel* in the data sheet) of 6000.479 cm³. These are extremely accurate because the dimensions of the HEU metal parts are measured to 0.0001 in. [6]. Calculation of the HEU metal density for this experiment yields 18.6881 g/cm³.

At the time these experimental data sheets were prepared, the dimensional inspection reports for the graphite were available. Using these inspection report dimensions, the volume of the graphite was calculated and included on these data sheets. These volumes can be used to verify the assumed dimensions of the graphite parts in cases where they were not measured. These volumes can also be used in some cases to determine the dimensions. Using the graphite masses and the graphite volume, an average graphite density can be calculated: for this assembly, it was 1.68457 g/cm³. At the very bottom of this data sheet is an average reflector thickness.

3.1.3 Information on Top of the Back of the Data Sheet

A copy of the top of the back of an experimental data sheet is shown in Figure 6.
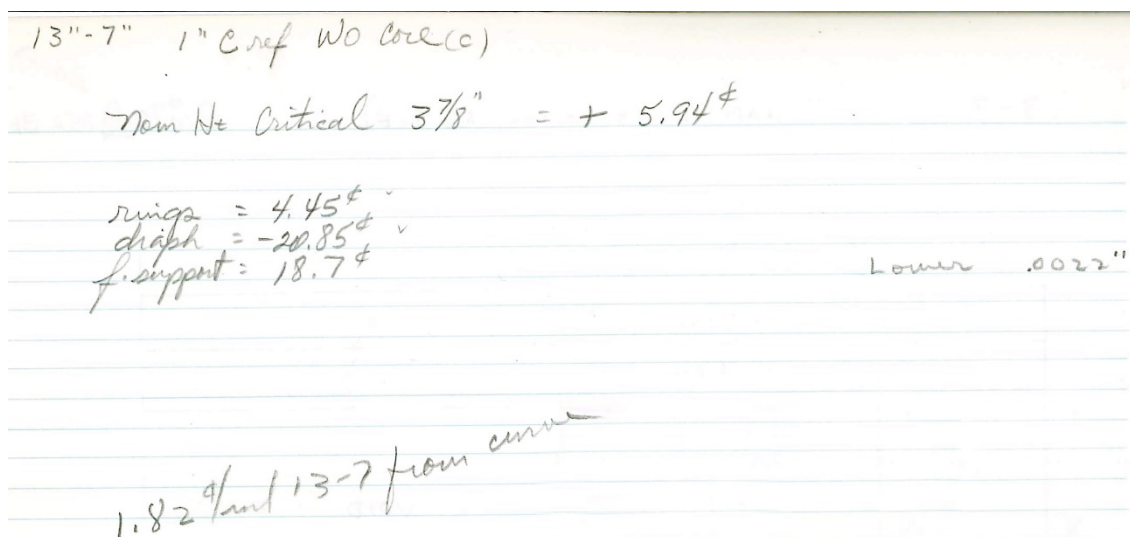
Figure 6. Information from the top of the back of the experimental data sheet.

9

The experiment identification is given at the very top, followed by the nominal height and the measured reactivity of the experimental configuration. The various reactivities that were measured are usually given in this part of the data sheet.

On this sheet, just below the nominal critical heights were the change in reactivities associated with the support structure, which consisted of the support ring for the stainless-steel diaphragm, the stainless-steel diaphragm that supported the upper section of the assembly, and the lower support structure. The removal of the support ring and the lower support stand reduced the reactivity because they reflect neutrons back into the assembly. The removal of the diaphragm increases the reactivity because the lower HEU metal gets closer to the upper portion. To evaluate these effects, a lower support stand was added to the top of the top reflector (supported by a crane adjacent to the top reflector but not touching it). To evaluate the diaphragm support ring, its thickness was doubled. The associated reactivity changes were + 4.45 cents for the addition of the diaphragm support ring, −20.85 cents for the doubling of the diaphragm thickness, and +18.7 cents for the addition of the support stand. Thus, the net change in reactivity associated with removable of the support structure was 2.3 cents. A correction should be made to the reactivity of the diaphragm because the effect is not linear with thickness, as demonstrated by other measurements [7]. This correction can be determined from calculations.

On this experimental data sheet, the next item down was an estimate of the reactivity as 1.82 cents per mil (0.001 in.).

Next down the page are the reactivity effects of changing the HEU metal heights of each radial section of the assembly, usually by 1/32 in. For this assembly, increasing the HEU metal height 1/16 of an inch increased the reactivity of the 9-7 ring, 11-9 ring, and 13-11 ring increased the reactivity 36.32, 39.17, and 26.80 cents, respectively for a total value of 102.39 cents. Adjacent to these measurements, the results are sometimes given in cents per thousandth of an inch or cents/mil. A measurement was performed for increasing the height of the annular 15-13 graphite ring around the HEU metal, and an estimate is given below these fuel values of 0.024 cents per mil.

3.1.4   Information on the Bottom of the Back of the Data Sheet

A copy of the lower half of the back of the experimental data sheet is shown in Figure 7.

Figure 7. Bottom section of the back of the data sheet.

In this section of the lower back of the data sheet, the measurements of the height of the different radial HEU metal sections and graphite sections are given. Each HEU metal section (both that on the diaphragm and the lower support stand) and measurements made at various azimuthal positions (in this case, six measurements) are given as described in reference [3], and the values are averaged. The measurement for this configuration were as follows: for the 13-11 HEU metal ring 3.895 three times, 3.894 and 3.897 for an average of 3.8948 in.; for the 11-9 HEU metal ring 3.885 twice, 3.886, 3.887, 3.891, 3.888 and an average of 3.8870 in.; for the 9-7 HEU metal ring 3.887 twice, 3,885 three times, and 3.886 for an average of 3.8858 in.

From these data, measured heights of the individual sections and the sum of the HEU metal part heights from the inspection reports can be used to obtain the average gap between parts vertically by subtracting the sum from the measured height and dividing by one less than the number of parts in the section.

Below the HEU metal section measurements are some dimensional measurements for the graphite parts. On this data sheet, the height of the two annular side reflectors is given as 5.009 in. Looking at the sum of the measured heights of these two parts as 5.0073 from the inspection reports available at the time of the measurements, there is a gap of 0.0017 in. between annular graphite parts, vertically.

Below these measurements is the measured height of the sum of the heights of the 13-11 HEU metal plus the height of the graphite part below it and the 0.125 in. thick metal ring: 5.0178 in. These two values were copied onto the data sheets from the dimensional inspection reports available at the time of the measurements and at the present time are only recorded here. On many data sheets it is stated that these parts are looked up, which means the values come from the inspection reports available at the time of the measurement.

Below this, measurements are given for the total height of the two 15 in. diameter parts of the top reflector: 0.875 four times and 0.874 three times, for an average value of 0.8746 in. At the bottom of the page on the left is an HEU metal height corrected to 3.8898 in. with a reactivity estimate of +3.64 cents above delayed critical. Below that is a height estimate for the assembly with an even height of 3.8876 in.

11

and exactly at delayed critical (keff = 1). On the bottom right, partially circled in red are the calculations to obtain these values.

On the right of this average is the difference between the measured height and the sum of the parts, or 0.026 in. So, the sum of the individual heights is 5.756 in. This annular section consists of three parts with existing measured heights. For the two parts with nominal heights of 2 and 3 in., the actual heights are known to be 2.0042 and 3.0030 in. Subtracting these two values from 5.756 in. gives the height of the remaining part as 0.749 inches. This is an example of how presently known data can be used to determine the presently unknown thickness of a part.

3.1.5   Information at the Bottom of the Back of the Data Sheet

This information can vary depending on the data sheet. For this particular data sheet, the reactivity of an even HEU metal height with no support structure as 3.8263 in. with a positive reactivity of +40.35 cents. This was determined from the reactivities measured as the HEU metal height was varied and from the correction for the support structure. Also given are some calculations that give a flat height of the HEU metal and graphite core at exactly delayed critical with a height of the fuel and graphite of 3.8074 in.

3.2   EXPERIMENT WITH A THICK GRAPHITE REFLECTOR

The experiment chosen as an example is a 12 in. thick graphite reflected HEU metal annulus with an OD of 11 in. and ID of 0 in. Items on the experimental data sheet discussed in Section 3.1 will not be repeated in discussion in this section, but the top and bottom sections of the front and back of the data sheet are presented.

3.2.1   Sketch of the Assembly

The sketches on this data sheet for the thick reflected experiments (Figure 8) are closer to scale. As a result, the last two digits of the HEU metal parts numbers are sometimes not given and not readable without a magnifying glass. In these cases, the logbook can be consulted for most experiments for a more enlarged drawing of the HEU metal section.
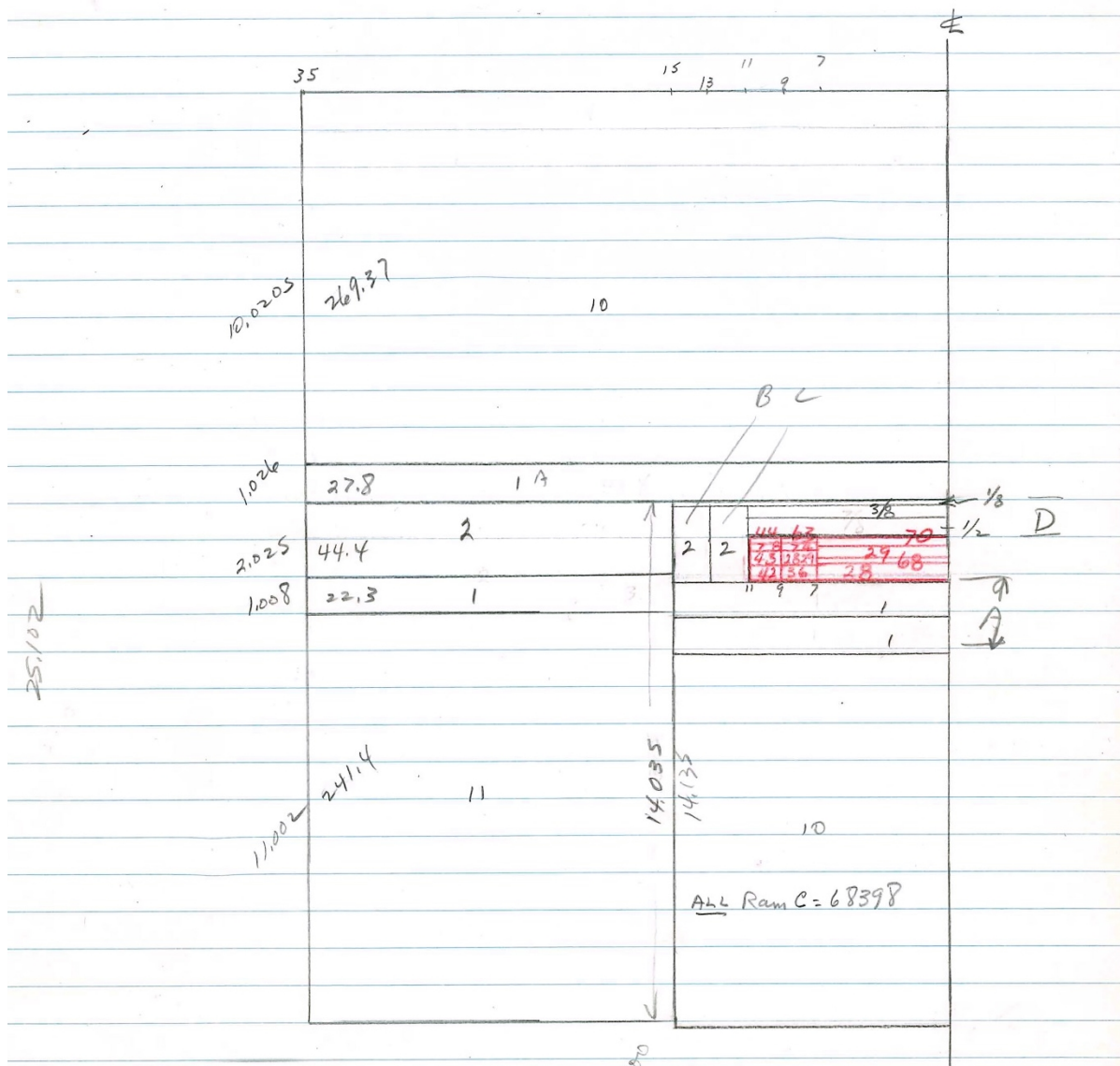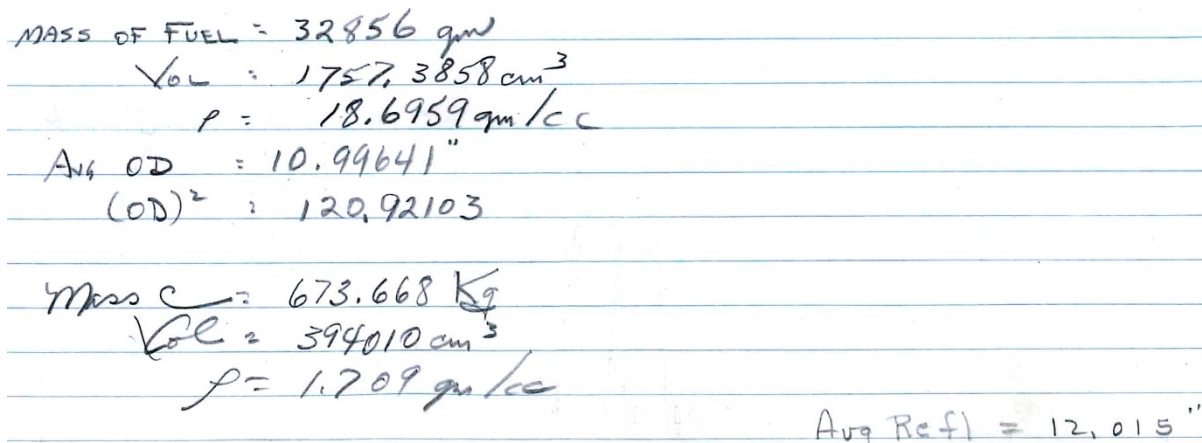
Figure 8. Sketch of the 11 in. diameter HEU metal cylinder with 12 in. thick graphite reflector.

On the far left of the sketch is the measured height from the bottom of the side reflector to the top of the top reflector. This measurement, with the thicknesses of the top and side reflector parts, can be used to determine the average gap between the top and side reflector parts. Nearly adjacent to the top and side reflector boundary are measurements of the thickness of the top and side reflector parts from the then available dimension analysis reports. For example, for the thicknesses at the boundary between the bottom reflector on the vertical lift and the side reflector, there are two measured heights. One is the measured height on the side reflector (14.035 in.), and the other is the measured height (14.135 in.) of the material on the vertical lift. The material on the vertical lift is slightly higher than the side reflector. As a result, on the assembly, the bottom of the bottom reflector protrudes slightly below the bottom of the side reflector.

On this sketch are certain capital letters that indicate measured heights for individual or combinations of parts such as A, B, C, and D. These results are given on the back of the experimental data sheets.

3.2.2 Information below the Sketch on the Front of the Experimental Data Sheet

The information below the sketch is of the same type as that described in Section 3.1.2 Figure and will not be repeated here.

MASS OF FUEL = 32856 gm
VOL = 1757.3858 cm³
ρ = 18.6959 gm/cc
Avg OD = 10.99641"
(OD)² = 120.92103

Mass C = 673.668 Kg
Vol = 394010 cm³
ρ = 1.709 gm/cc
Avg Refl = 12.015"

Figure 9. Information below the sketch on the front of the experimental data sheet below the sketch.

3.2.3 Information on Top of the Back of the Data Sheet

A copy of the top of the back of an experimental data sheet is shown in Figure 10. Some additional information appears on the back, such as the reactivities associated with 1/32 in. changes in height of two of the HEU metal ring sections, the 11-7 in. and the 9-7 radial sections. The change in height of the HEU metal in the center section was too large to measure.

Next down the page are reactivities associated with the addition of graphite to the top graphite reflector. Adding a 35 in. OD, 15 in. ID, 0.525 in. thick graphite section increased the reactivity 10.52 cents: adding 15 in. OD, 0 in, ID, 0.25 in. thick graphite cylinder inside the previous addition increased the reactivity another 7.02 cents: then adding an additional 15 in. OD, 0 in. ID, 0.5 in, thick on top of the pervious addition increase the reactivity another 11.81 cents.

Next are the height of the three radial sections of HEU metal, discussed in a previous section of this report.

Next down the page are the measured heights of various sections of graphite reflector. Section A consists of two pieces of bottom reflector with a thickness of 2.0022 in., which were measured for another measurement on Page 124 of ORCEF logbook 4 (E-22). Annular section B consists of one annular graphite part whose height was looked up in the dimensional inspection reports available at the time of the measurements and was 2.0043 in. Annular section C consists of one annular graphite part whose height was looked up in the dimensional inspection reports available at the time of the measurements and was 2.0020 in.

On top of the HEU metal were three 11 in. diameter graphite cylindrical parts with five measured thicknesses: 1.002 three times and 1.001 twice for an average value of 1.0016 in. (average is a correction of the data sheet).

Handwritten notes:

11" dia. cyl. ≠ 12" C.ref.

Nom. Ht. Critical – 1⅛"
   reactivity = – 3.52¢

1/32" fuel 11-9 = 47.47¢   +.5190¢/mil
          9-7 = 49.98¢   ? +.5993¢/mil
         7dia: NOT measurable.

all supports = 6.34¢
35-15 Ring .525" = 10.52¢
15 dia Top ¼" = 7.02¢   .0200°/mil
ADD ½" more 15 dia = 11.81¢
Ht. of fuel 11-9: 1.130-.130-.130-.131-.131-.131-.151 = 1.1305
        9-7: 1.130-.130-.130-.130-.130-.130 = 1.1300
        7dia: 1.128-.127-.128-.128-.128-.127-.128 = 1.1277
                        wt avg = 1.129

A = "A" 4-124   = 2.0022
B = Look up   = 2.0043
C = " " "   = 2.0020
D 1.002-.002-.001-.001-.002 = 1.0026

Figure 10. Information from the back of the experimental data sheet.

4.   CONCLUSIONS

This report documents experimental data from the experimenters' data sheets filled out at the time of the measurements when all inspection reports were available. The report described in detail the information on two data sheets. The HEU metal used for the experiments was well documented in previous reports. Not all the dimensional analyses for the graphite parts are presently available, but some of it can be obtained from these experimental data sheets. These dimensional analyses may be in unmarked boxes in Y-12 storage and are not retrievable at this time. This report presents experimental data such as some masses and dimensions not in the logbooks (ORCEF logbooks E-19, E-20, E-21, and E-22).

5.   REFERENCES

1.   J. T. Mihalczo, "Graphite and Polyethylene Reflected Uranium-Metal Cylinders and Annuli", Y/DR-81, Union Carbide Corp. Nuclear Division, Oak Ridge Y-12 Plant (April 1972).

2.   J. T. Mihalczo, "Criticality of Graphite– and Polyethylene–Reflected Uranium (93.2) Metal Cylinders and Annuli," *Nucl. Sci. Eng.*, 49, 489–504 (1972).

3. Shane E. Parkey, John T. Mihalczo, Raymond L. Reed, "Uranium (93.14) Metal Annuli with One-And Two-Inch Graphite Reflectors", NEA/NSC/DOC(95)03/II Volume II, HEU-MET-FAST-071 (2006).

4. "Oak Ridge Critical Facility Operating Procedures" Oak Ridge Y-12 Plant (Y-12), Oak Ridge, TN (United States) Y/DR-54 (1971) [OSTI #1894661].

5. Robert H. Elwood and John T. Mihalczo "Uranium (93.2) Metal Cylinders (7-inch, 9-inch, 11-inch, 13-inch,15-Inch Diameter Cylinders and Two 11-Inch Diameter Interacting Uranium (93.2) Metal Cylinders" NEA/NSC/DOC(95)03/II Volume II, HEU-MET-FAST-071 (2006) HEU-MET-FAST-051 (2002).

6. John T. Mihalczo, "Three Delayed Critical 15-inch-Diameter Interacting Enriched (93.14) Uranium Metal Cylinders without Moderator and Reflector" ORNL/TM-2019/1456 (Dec 2020) [OSTI #1735460].

7. John T. Mihalczo, "Uranium-Molybdenum Alloy Critical Experiment for the Health Physics Research Reactor" ORNL/TM2021/2234 (June 2022) [OSTI #1887715].

APPENDIX A.

This appendix contains copies of all the experimenters' data sheets prepared at the time of the measurements, when all the inspection reports were available. Some of the data on these data sheets are not available in the logbooks. Any errors in the data on the sheets have not been corrected but can be resolved by information in the logbooks.

64.4 mils gap

15-13   13-11   11-9

3 1/16

2"

2780
2766-7/16 2754-1/2 2743-7/8   2778-3/4
2885-1/6   2782   2743-7/8
2785-7/8   2750   2745-1
2784-3/8   2749
2787-1/2   2753
2786-1/2   2757-1   2747-1/6
2760-1/2   2794
2739-1   2752-1/2 2742-7/8
           2751-1/2
2735-1   2756-1   2747-1/2

5.0786   5.1501   5.1360

1 × 9" B   947

1 1/8 × 9"   1084

1" × 9" A   947

2" × 9" A   1921

5.1487
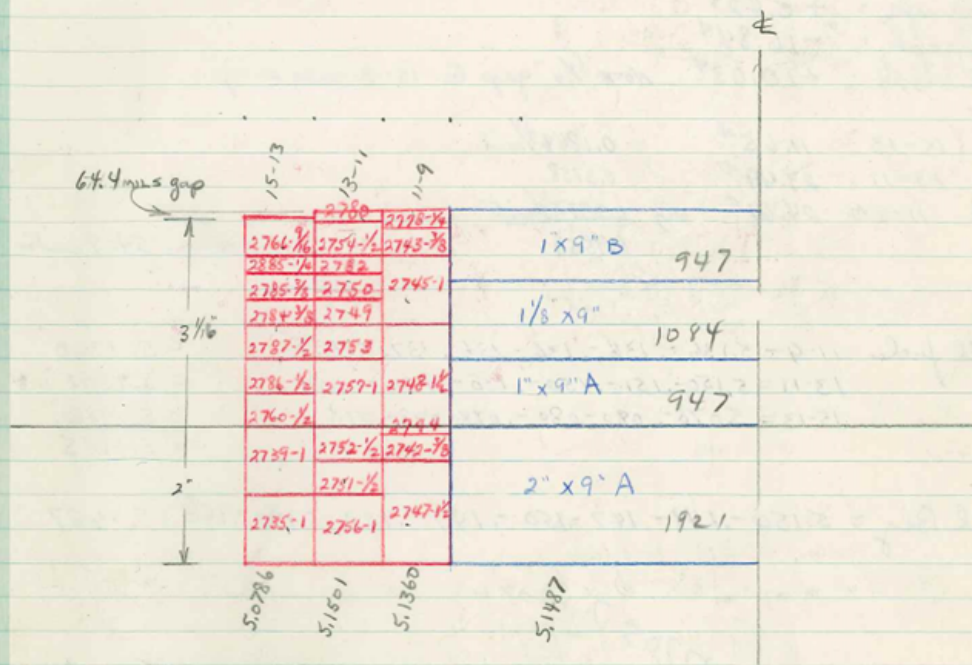
MASS TOP FUEL = 107711 gm   TOTAL = 177.057 Kg
      BOTTOM = 69346 gm

MASS TOP POLY = 2978 gm   TOTAL = 4.899 Kg
     BOTTOM = 1921 gm

AVG. O.D. ALL FUEL (O'T'D) = 14.99505" OD^2 = 224.85152
AVG. I.D. ALL FUEL (N'T'D) = 9.00215" ID^2 = 81.03870

FUEL VOLUME = 9473.86788 cm^3
      ρ = 18.68898 gm/cc

POLY VOLUME = 5370.12870 cm^3
      ρ = 0.912268 gm/cc

15-9 Bent # Poly Core

Nom. Wt. Critical   15-13 = 5 1/16"
                     13-9 = 5 1/8"   = +33.58¢

Rings = +5.42¢
Diaph = -16.84¢
S. Stand = +10.03¢   NOTE 1/16" gap @ 15-13 area only

1/16" 15-13 : 11.65¢   0.1864¢/mil
1/16" 13-11 : 23.49¢   0.3758
1/16" 11-9 = 24.61¢   or 0.3937¢/mil
                            _____
                            0.9559   reduce 54.9 mils

Wt. all fuel 11-9 = 5.136 -.136 -.136 -.136 -.1375 -.135   = 5.1360"   +12.7
              13-11 = 5.150 -.151 -.150 -.150 -.150 -.150   = 5.1501"   -1.4
              15-13 = 5.078 -.080 -.080 -.078 -.078 -.078   = 5.0786"   +70.1
                                                             = 5.1185"

Wt all Poly = 5.150 -.148 -.147 -.150 -.147 -.152 -.150 -.146 = 5.1487
                    .150 -.146

5.1185 = 177,057

                    34.59157 Kg/in

EVEN FUEL HT = 5.1487"   5.1185
SKY HOOK REACT +52.51¢   +54.85¢
                    -1.8990 Kg

O reactivity = 5.0938" (not consid. poly)
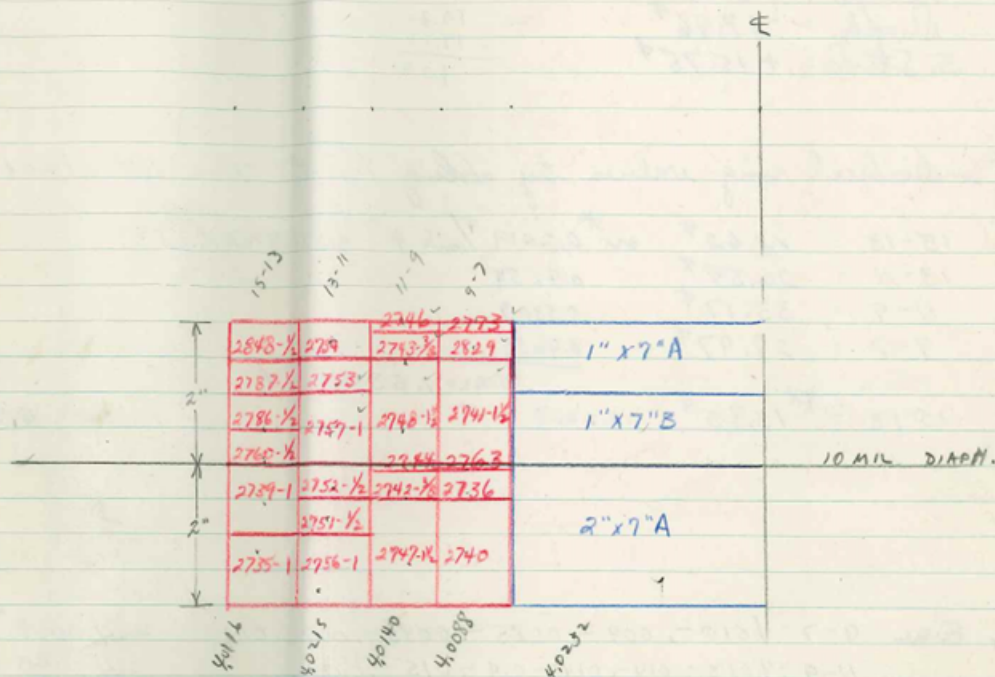
MASS OF TOP FUEL = 84925 gm   TOTAL = 169.687 Kg
         BOTTOM   84762 gm

MASS OF TOP POLY = 1163 gm   TOTAL CORE MASS = 2.326 Kg
         BOTTOM = 1163

AVG I.D. ALL FUEL (WT'D) = 7.00258"
AVG O.D. ALL FUEL (WT'D) = 14.99493"
AVG Ht. ALL FUEL (WT'D) = 4.01434"

FUEL VOLUME = 9083.5743 cm³
FUEL ρ = 18.68064 gm/cc
CORE VOLUME (MEAN ID) = 2539.1101 cm³
CORE ρ = 0.91607

A-4

15-7   Bare + Poly Core

Nom. Ht. Critical = 4"   + 4.51¢ reactivity
                (at Ht. 4.0143")

     Range : + 3.55¢
     Dropk : −17.96¢ $14.80
     S. Stard : + 15.75¢   −17.80
                                         1.34

Get individual ring values by adding 1/16" to Nom. Ht. above.

+ 1/16"   15-13 :   12.62¢   or *0.2019 ¢/mil + **0.2208 = AVG .2113
+   13-11 :   26.59¢   0.4254
+   11-9 :   33.17¢   0.5307
+   9-7 :   28.97¢   0.4635
                                          TOTAL = 1.6309 ¢/mil
− 1/16"   15-13 : **13.80¢   0.2208   reduce 10.9 mils

ALL FUEL   9-7 = 4.010 −.009 −.0085 −.0085 −.007 −.010   = 4.0088"   +14.4
          11-9 = 4.013 −.014 −.014 −.014 −.015 −.014   = 4.0140   +9.2
          13-11= 4.022 −.021 −.020 −.020 −.023 −.023   = 4.0215   +1.7
          15-13= 4.010 −.013 −.013 −.010 −.012 −.012   = 4.0116   +11.6
                                                              4.0143"
         all
Ht. of Poly = 4.023 −.021 −.023 −.025 −.021 −.023 −.026 −.024 = 4.0232 ✓

                 ¢ Poly
EVEN FUEL ∧ HEIGHT = 4.0232"
SKY HOOK REACTIVITY = +17.79¢   42-27 grs/mil

O reactivity = 4.0123" (not consid. Poly)

                10.9 mils :
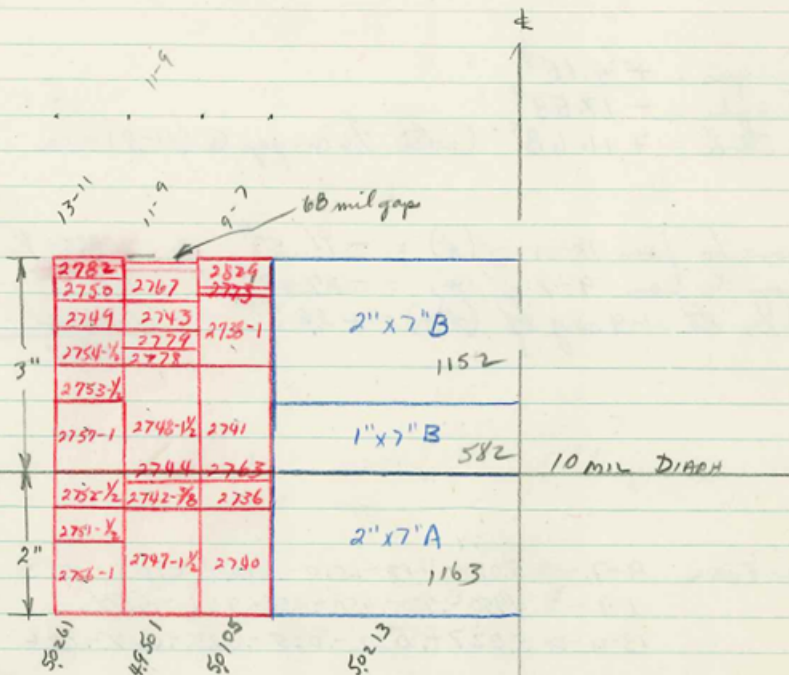
FUEL TOP <u>86249 gm</u>   FUEL BOTTOM <u>57892 gm</u>

TOTAL MASS OF FUEL = 144.141 Kg

MASS OF TOP POLY = 1734 gm   TOTAL: 2.897 Kg
          BOTTOM = 1163 gm

AVG. O.D. all fuel (WT'D) = 12.995899" $(OD)^2 = 168.89339$
AVG. I.D. all fuel (WT'D) = 7.002813" $(ID)^2 = 49.03938$

FUEL VOLUME = 7707.60168 cm³
     ρ = 18.701148 gm/cc

POLY VOL = 3169.244766 cm³
     ρ = 0.914097 gm/cc

13-7 Bare + Poly Core

$*\left[\text{Mem. Ht. Critical} = (13-11) \& (9-7) = 5"\right.$
$\left. \qquad\qquad\qquad\qquad\qquad 11-9 = 4\frac{5}{16}"\right] \longrightarrow +21.22^{¢}$

Rings = + 4.15¢
Diaph = − 17.53¢
5. Stand = + 11.68¢ (with $\frac{1}{16}"$ air gap @ (11-9) area

Remove $\frac{1}{16}"$ from 13-11 of (*) = − 11.57¢ or 0.1851 ¢/mil
** Remove $\frac{1}{16}"$ from 9-7 of (*) = − 27.40¢   0.4384
Add $\frac{1}{16}"$ to 11-9 ring of (**) = + 26.89¢ $\underline{0.4302}$
                                                         1.0537

                                          reduce 54¢/mil

ALL FUEL 9-7 → 5.010 − .010 − .010 − .010 − .0105 − .013   = 5.0105" +10.8
          11-9 → 4.950 − .950 − .950 − .950 − .951 − .950   = 4.9501" +71.2
          13-11 → 5.027 − .027 − .025 − .025 − .027 − .026   = $\underline{5.0261"}$ −4.8
                                                      wt. avg = 4.9966"

$\overset{\text{all}}{\text{Ht}}$ of Poly = 5020 − .020 − .018 − .024 − .022 − .026 − .021 − .020 = 5.0213 ✓

                $\$ Poly$
EVEN FUEL HT = 5.0213"
SKY HOOK REACTIVITY = + 57.39¢

0 reactivity = 4.9669" (poly not consid)

29.7 mils

SOLID

11" DIA, CYLINDER "INFIN." POLYETHYLENE REFLECTOR   Pg 240
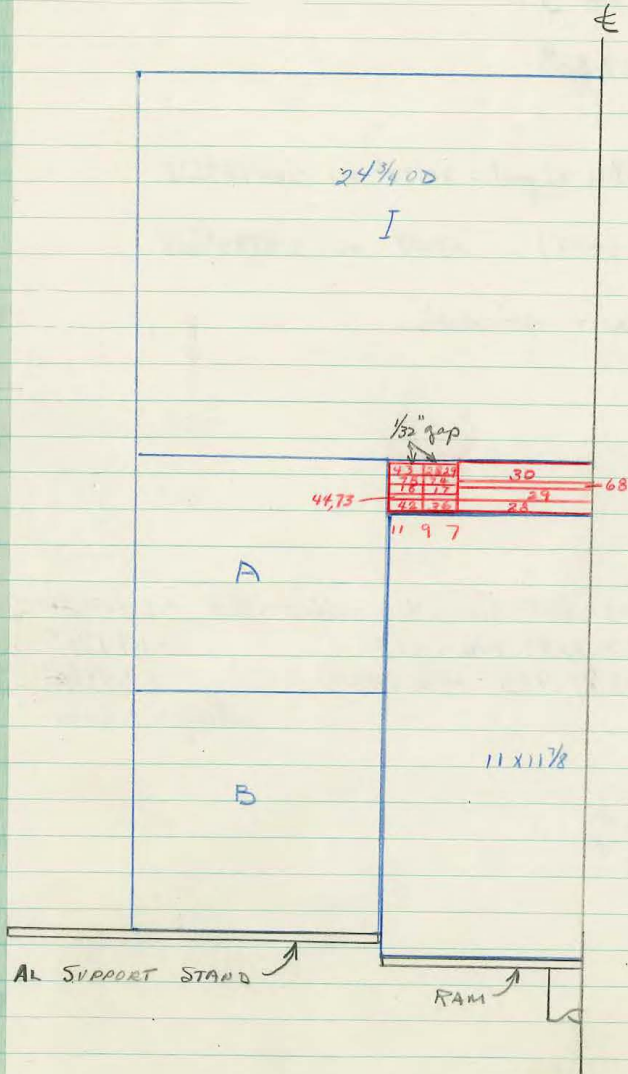
MASS OF FUEL = 41431 gm
    VOLUME = 2219.80046 cm³
        ρ = 18.66429 gm/cc
MASS OF POLY =
    VOLUME =
        ρ = 0.916 gm/cc
AVG. O.D. FUEL = 10.99698"
        (²) = 120.93356

24¾ OD

I

1/32" gap

44.73   .30   ·68
              .29
              .25
11 9 7

A

11 × 11⅞

B

AL SUPPORT STAND

RAM

A-8

11" DIA. SOLID   Def. Poly ref.

Nom. Ht. Critical : $(11"×7") = 1\frac{3}{32}"$ }   reactivity = + 25.52¢
                      $(7"dia) = 1\frac{3}{16}"$ }

$\frac{3}{16}"$ GAP BETWEEN I & A = − 17.30¢

11   9   7   ₵
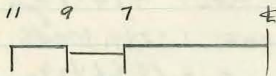
$\frac{1}{32}"$ (11-9) fuel = 20.31¢ or 0.6499¢/mil
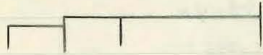
$\frac{1}{32}"$ (9-7) = 27.48 or 0.8793¢/mil

7" DIA = NOT MEAS.

Wt. of fuel 11-9 = 1.409 -.409 -.409 -.409 -.410 -.410 -.409 -.409 = 1.4092"
              9-7 : 1.417 -.417 -.417 -.418 -.416 -.417   = 1.4170"
              7 dia : 1.445 -.447 -.448 -.445 -.446 -.445   = 1.4460"
                                                          wt avg = 1.4261"

7 dia —— 0
9-7 up 29 mils − +25.49¢
11-9 up 36.8 mils + 32.35¢

83.36¢ = 1.4460"
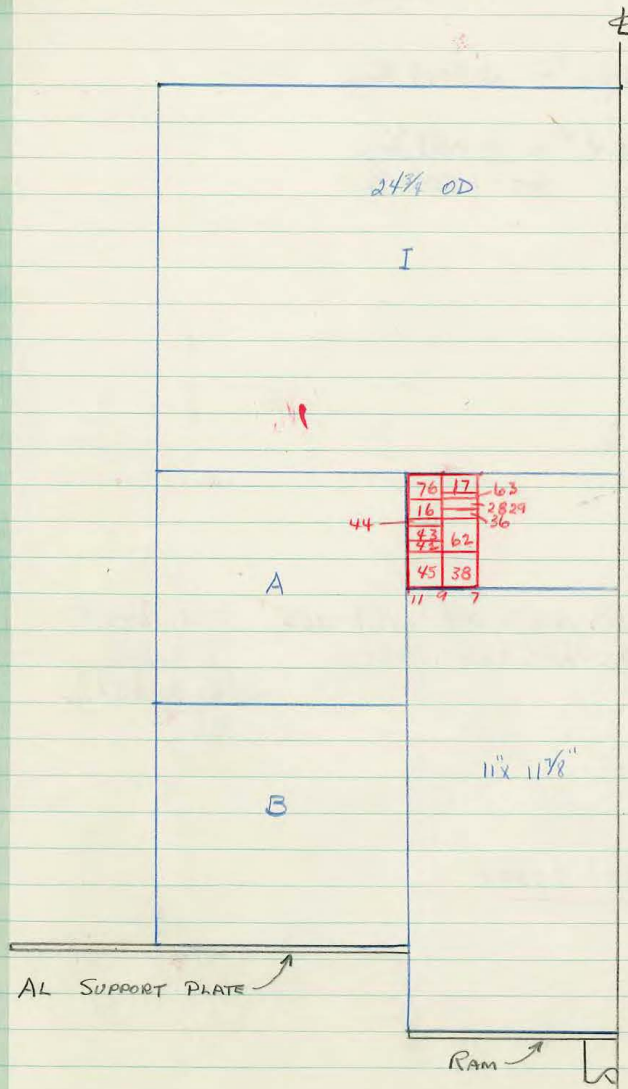
MASS OF FUEL = 54770 gm

VOLUME = 2928.25225 cm³

ρ = 18.70399 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D FUEL = 10.99671"

$(^2)$ = 120.92763

AVG. I.D. FUEL = 7.00329"

$(^2)$ = 49.04607

24¾ OD

I

A

B

76 | 17 | 63
16 | | 28 29
44 | | 36
43 | 62 |
45 | 38 |

11 9 7

11"x 11⅞"

AL SUPPORT PLATE

RAM

11-7   Inf. Poly. ref. # No Core

Nom. Wt. Critical = $3\tfrac{5}{32}$"   reactivity = 23.40$^{\cent}$

11   9   7

$\tfrac{1}{32}$" (11-9) = 25.06$^{\cent}$ or 0.8019 $^{\cent}$/mil
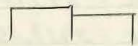
$\tfrac{1}{32}$" (9-7) = 23.4$^{\cent}$ or 0.7488 $^{\cent}$/mil

TOT. = 1.5507 $^{\cent}$/mil

$\overset{3.158}{}$
Wt. of fuel 11-9 = 3.165 - .164 - .165 - .165 - .164 - .164 - .165   = 3.1645"
$\overset{3.159}{}$
9-7 = 3.166 - .166 - .166 - .166 - .166 - .166 - .   = 3.1660"

wt. avg 3.1651"

+ 23.40$^{\cent}$ = 3.1651"
O react → 3.1651 - .0151 = 3.1500"
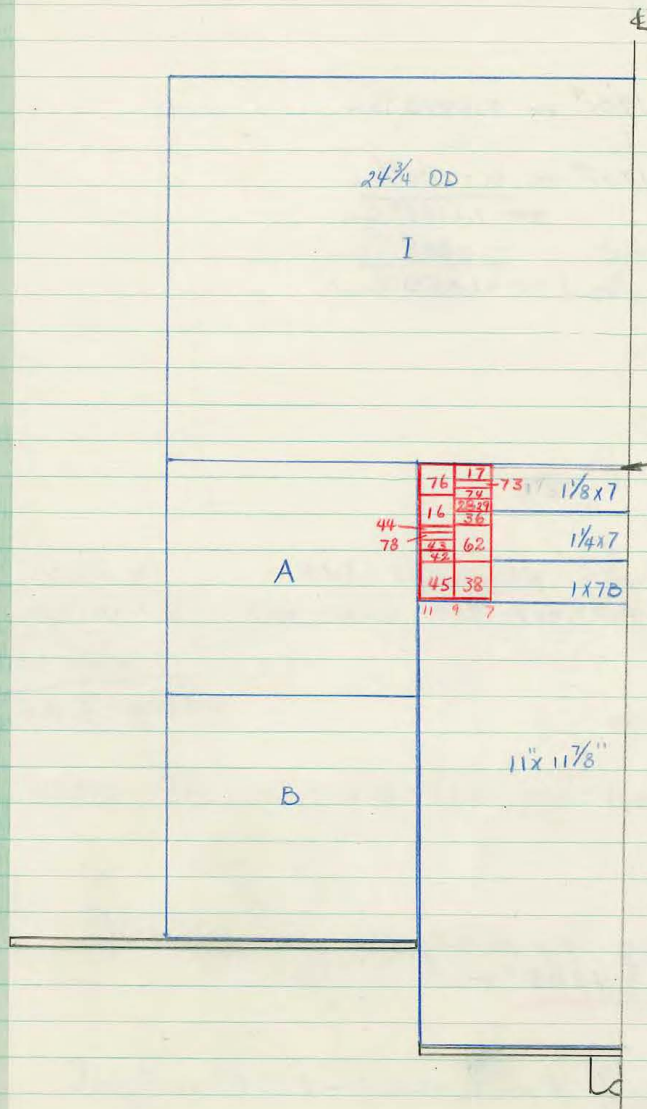
MASS OF FUEL = 59120 gm
VOLUME = 3161.18382 cm³
ρ = 18.70185 gm/cc
MASS OF POLY:
VOLUME =
ρ = 0.916 gm/cc
Avg. O.D. fuel = 10.99672"
(²) = 120.92785
Avg. I.D. fuel = 7.00319"
(²) = 49.04467

24¾ OD

I

← 27 mil gap

A

76 | 17
16 | 74
   | 26 29
   | 36
44
78 | 43 | 62
   | 42
45 | 38

73 — 1⅛ x 7
1¼ x 7
1 x 7B

11 9 7

B

11"x 11⅞"

A-12

11-7   Inf. Poly ref + Poly Core

Nom. Ht. Critical : Fuel = $3\frac{13}{32}''$ }   reactivity = $-1.97^{¢}$
                     P.Core = $3\frac{3}{8}''$ }
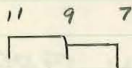
$\frac{1}{32}''$ (11-9) : $17.01^{¢}$ or $0.5443^{¢}/mil$
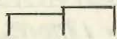
$\frac{1}{32}''$ (9-7) : $17.97^{¢}$ or $\underline{0.5750^{¢}/mil}$
                                TOT = $1.1193^{¢}/mil$
                        Core* $\underline{-.0823^{¢}/mil}$
                        Grand TOT = $1.0370^{¢}/mil$

Ht of fuel $\overset{3.409}{11-9}$: $3.415 - .415 - .415 - .415 - .415 - .415$ = $3.4150''$
            $\overset{3.410}{9-7}$: $3.427 - .427 - .427 - .427 - .428 - .428 - .427$ = $\boxed{3.4272''}$
                                                                                          $-8 mil$
                                                                                    use $3.419''$
                                                                          wt avg = $3.4168''$

Ht. of Poly Core = $3.398 - .400 - .398 - .400 - .399 - .402 - .400 - .398 = 3.3993''$

$-1.32^{¢} = 3.4192''$ * avg gap on Poly core is considered
Oreact → $3.4192 + .0013 = 3.4205''$ *

*[CORE vs NO CORE DERIVATIONS] 1 mil core = -0.078 mil fuel

Core raise 19.9 mils = $-1.63^{¢}$
9-7   0
11-9 raise 4.2 mils — $+2.28^{¢}$

A-13

℄

24 3/4" OD

I
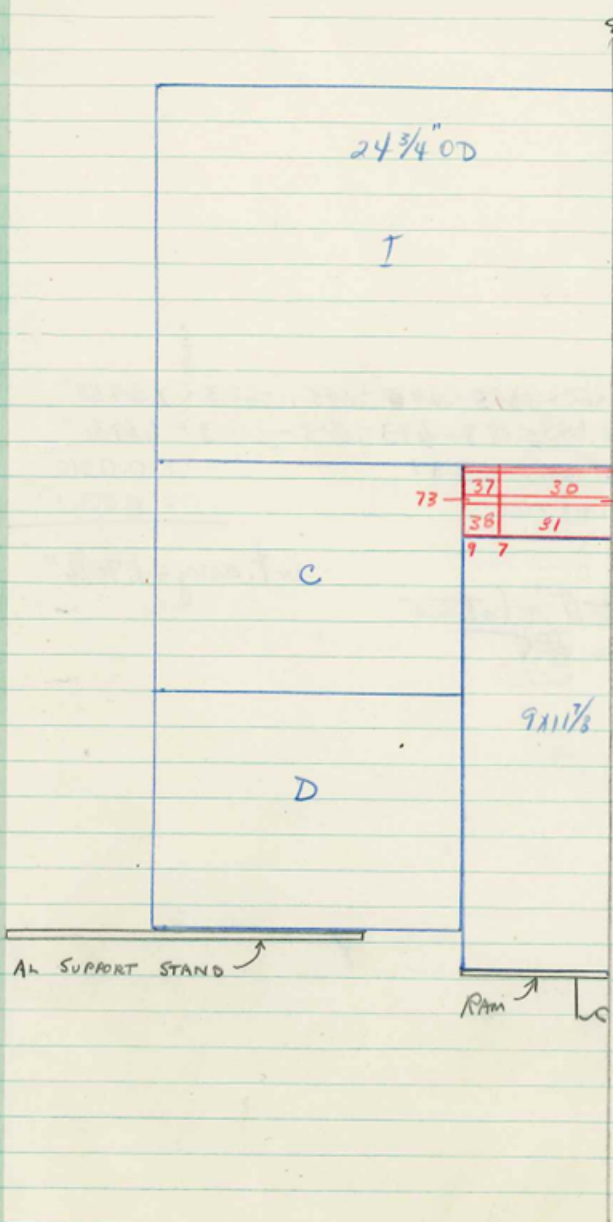
MASS OF FUEL = 33276 gm

VOLUME = 1779.84137 cm³

ρ = 18.69604 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D. FUEL = 8.99609"

(²) = 80.92963

SEE TOP VIEW FOR THIS 1/32"

73 — | 37 | 30 | — 68
| 36 | 31 |
9 7

C

9 X 11 7/8

D

AL SUPPORT STAND

RAM

9" DIA

5" X 5" X 1/2"
MASS = 240 gm

2 1/2" X 2 1/2"
X 1/32"

MASS = 60.5 gm

BLUE AREA
IS 1/32" gap
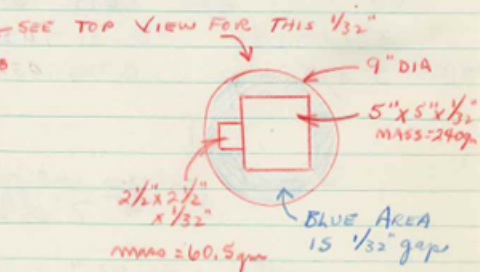
9" dia. Solid Inf. Poly. ref.

Nom. Wt. Critical = $1\frac{11}{16}"$ $\begin{bmatrix} 1(2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{32}) \\ +1(5 \times 5 \times \frac{1}{32}) \end{bmatrix}$ · reactivity = $-1.25^{¢}$

NO EVALUATION OF FUEL

At of fuel 9-7 = 1.693 - .693 - .693 - .695 - .695 - .695 - .693 = 1.6938"

7 dia = 1.693 - .693 - .693 - .693 - .693 - .693 - .693 = 1.6930"

$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{32}$ = 0.031 - .0305 - .0315 - .031 = 0.0310"

#140 $5 \times 5 \times \frac{1}{32}$ = 0.0315 - .032 - .315 - .31 = 0.0315"

wt. avg = 1.7086"

Small pieces "weighted" relative to 7" dia SR↑

$-1.25^{¢} = 1.7086"$
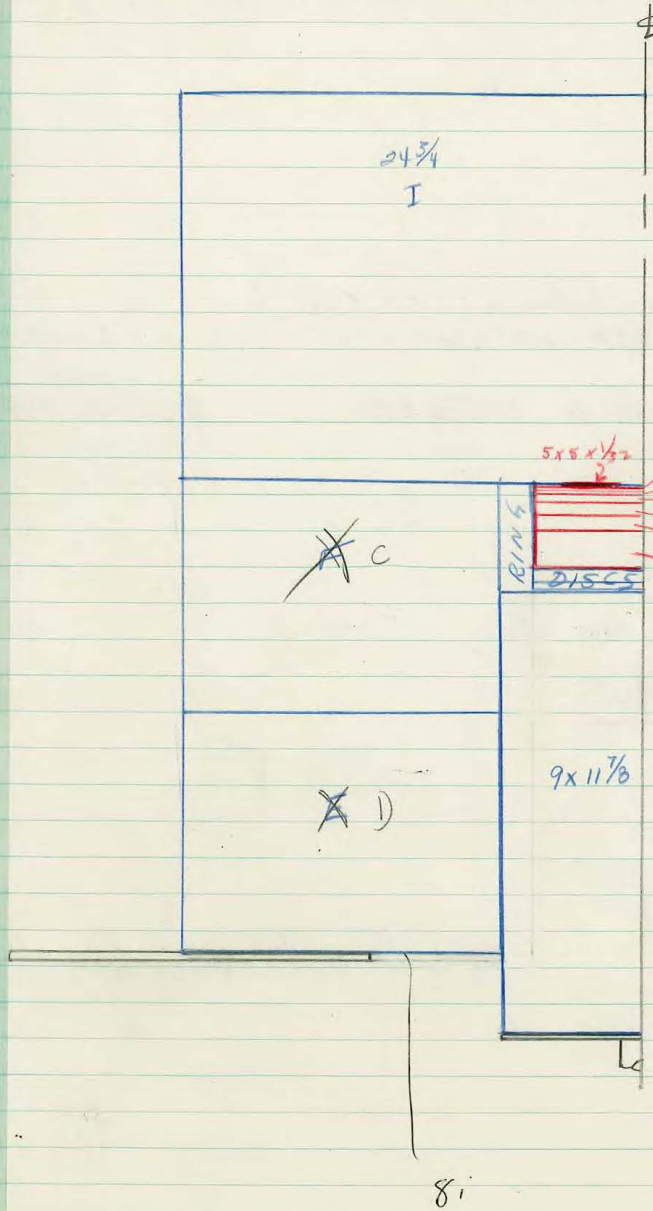
(Incl. 5×5×1/32)

MASS OF FUEL = 26893 gm
VOLUME = 1435.2340 cm³
ρ = 18.7377 gm/cc
MASS OF POLY =
VOLUME =
ρ = 0.916 gm/cc
AVG. O.D. OF FUEL = 6.99600"
(²) = 48.94401

24 3/4
I

5×5×1/32
69
68
70
29
28
31

RING

DISCS

C

D

9 × 11 7/8

2.2574 End hght

3.09

3/4 Discs

8'

7" DIA. SOLID   Poly reflected

nom Ht. Critical = 2¼" + (5"×5"× 1/32")   reactivity = 5.84¢
                                =46gm

                                                    4.332
                                                    2076
                                                    2256

fuel height 7"dia (NOT including (5"×5"× 1/32")
    2.256 – .258 – .257 – .256 – .259 – .258 – .258 → 2.2574
                                                        +.021
    Use 21 mils calc. for 5×5 to 7"dia.   Tot. Ht. = 2.2784"

React: +5.84¢ = 2.2784"

A-17

Period

PLEX1

1362	3301
1370	3291
1373	6592
1400	6603
1368	6614

136h
6390 1399
11366

1365
11370

1361
11385

1360
11364

1359
11377

PLEX1

PLEX1

— not followed thru.

24¾ OD

I

J 2.1252   2.1252

50	81	44
86	52	78 43
60	51	42
35	56	45

15   13   11   9

Void

F

E

15 x 11⅞
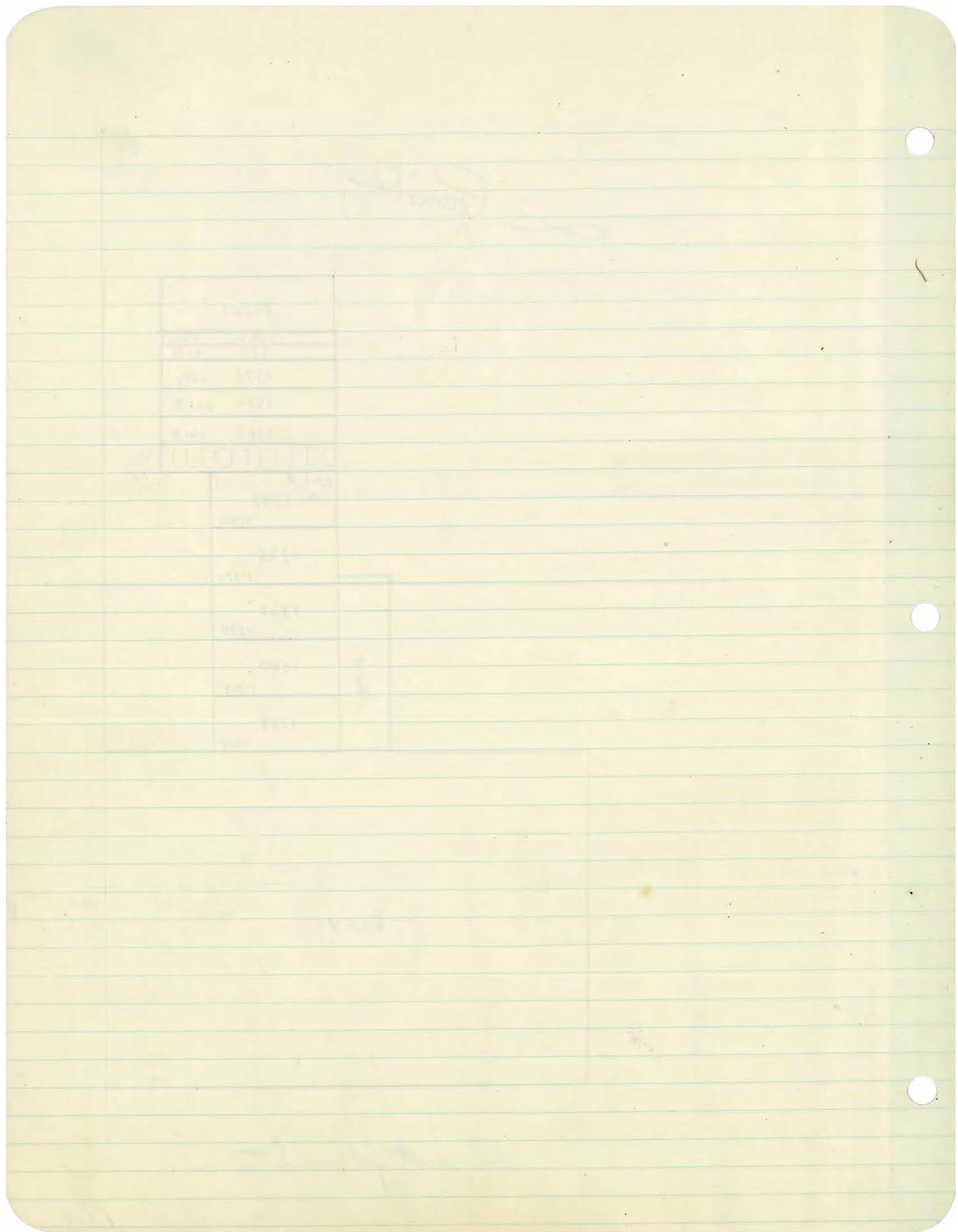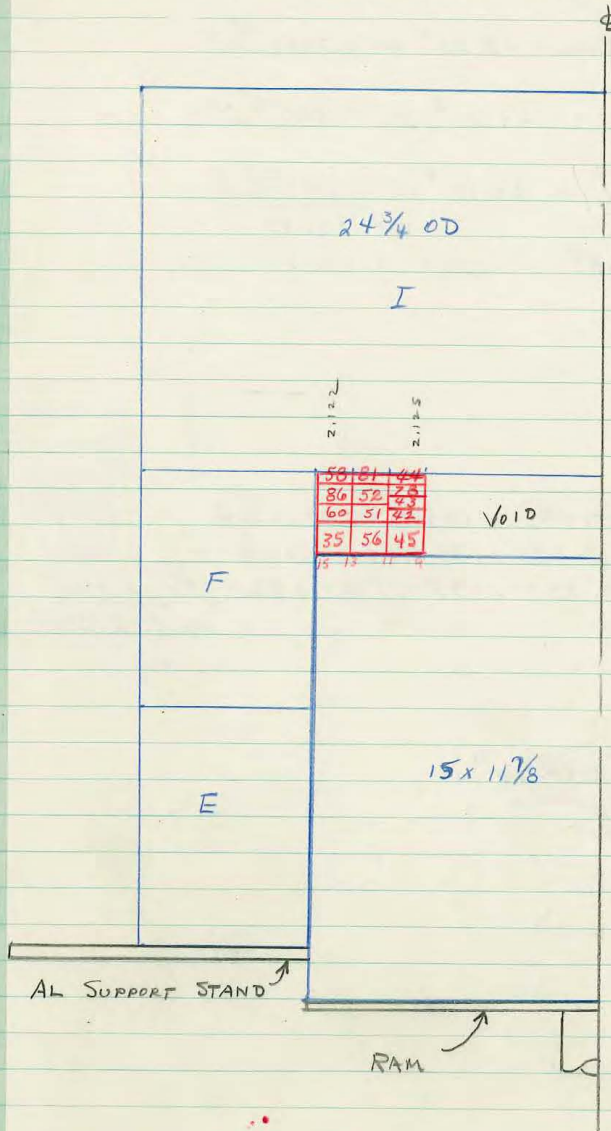
MASS OF FUEL = 73709 gm

VOLUME = 3940.58319 cm³

ρ = 18.70509 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D. FUEL = 14.99439"

$(^2)$ = 224.80174

AVG. I.D. FUEL = 9.00179"

$(^2)$ = 81.03222

AL SUPPORT STAND

RAM

15-9   Poly & No Core

Nom. Ht. Critical = 2⅛"   Reactivity = +8.93¢
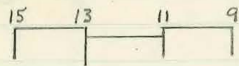
```
 15   13   11    9
 ┌────┬────┬────┐
 │    │    │    │        1/32" (11-9) FUEL = 23.26¢ or 0.7443 ¢/mil
 └────┴────┴────┘

 ┌────┬────┬────┐
 │    │    │    │        1/32" (13-11)  = 23.21¢ or 0.7427 ¢/mil
 └────┴────┴────┘

 ┌────┬────┬────┐
 │    │    │    │        1/32" (15-13) = 23.13¢ or 0.7401 ¢/mil
 └────┴────┴────┘
```
                                                        toT = 2.2271
3/16" SEPARATION OF I & F = 24.68¢   Core ≃ = 0.2208 ¢/mil
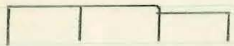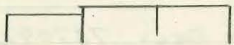
FUEL Ht. 15-13 = 2.124 -.124 -.125 -.124 -.124 -.124   = 2.1241"
         13-11 = 2.132 -.131 -.132 -.130 -.130 -.129   = 2.1306"
         11-9 = 2.136 -.136 -.137 -.137 -.136 -.136 -.135 = 2.1361"
                                            Avg wt. = 2.1296"

   +8.93¢ = 2.1296"
    O react = 2.1296 - .004 = 2.1256"

24¾ OD

I

2.371   2.376

86 | 52 | | 79
84 | 49 | 48 | 78 44
60 | 51 | 42
35 | 56 | 45

1⅜" x 9"

1" x 9"

18 13   11   9

F

E

15 x 11⅞

15 x 11⅞

AL SUPPORT STAND

RAM
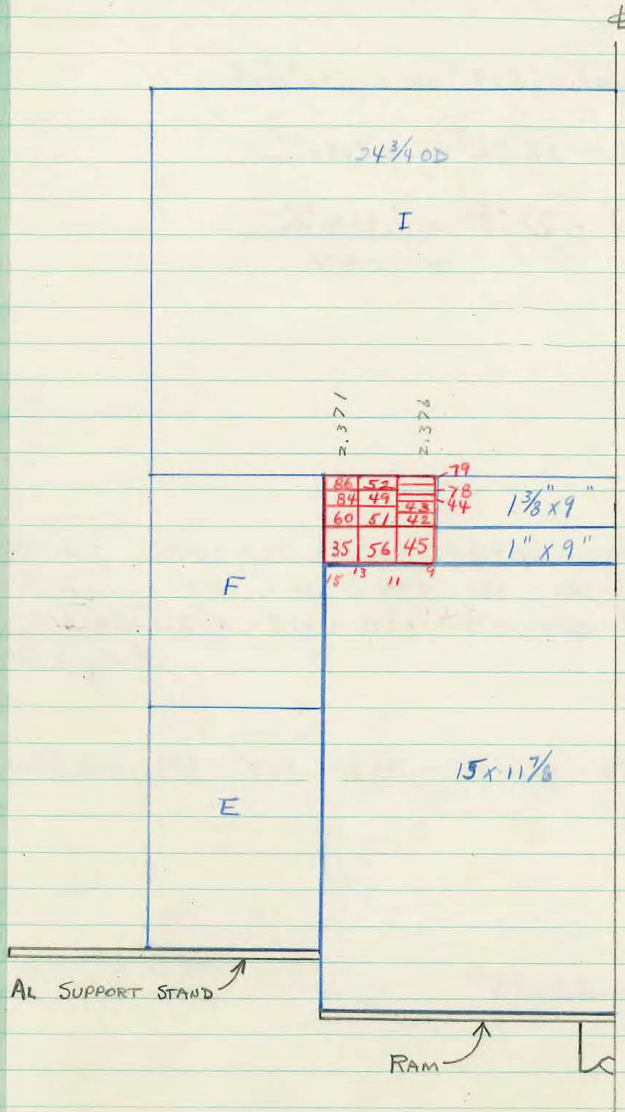
MASS OF FUEL = 82391 gm

VOLUME = 4403.24904 cm³

ρ = 18.71141 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D. FUEL = 14.99428"

(²) = 224.82843

AVG I.D. FUEL = 9.00176"

(²) = 81.03168

A-22

15-9   Poly + Core

Nom. Wt. Critical = 2 3/8"   Reactivity = + 21.15¢

15   13   11   9
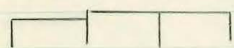
$\frac{1}{32}"$ (15-13) fuel = 18.29¢ or 0.5852¢/mil
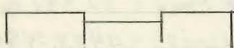
$\frac{1}{32}"$ (13-11) = 25.76¢ or 0.8243¢/mil
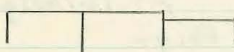
$\frac{1}{32}"$ (11-9) = 23.05¢ or 0.7376¢/mil
                         TOT = 2.1471

fuel height 15-13 = 2.372 -. 372 -. 376 -. 373 -. 375 -. 372 -. 377   = 2.3745"
            13-11 = 2.382 -. 382 -. 382 -. 381 -. 382 -. 381 -. 380   = 2.3814"
            11-9 = 2.383 -. 384 -. 384 -. 383 -. 383 -. 383 -. 383 -. 382 = 2.3831"
                                                              wt. avg = 2.3791"

Wt of Poly Core = 2.382 -. 382 -. 382 -. 381 -. 381 -. 383 -. 384 -. 382 = 2.3821"

+ 21.15¢ = 2.3791"
O react = 2.3791 -. 0098 = 2.3693"

Ȼ

24¾ OD

I

VOID

14	14
66	55
84	49
86	52
60	51
35	56

F

15 13 11

15 × 11⅞

E

AL SUPPORT STAND →

RAM →
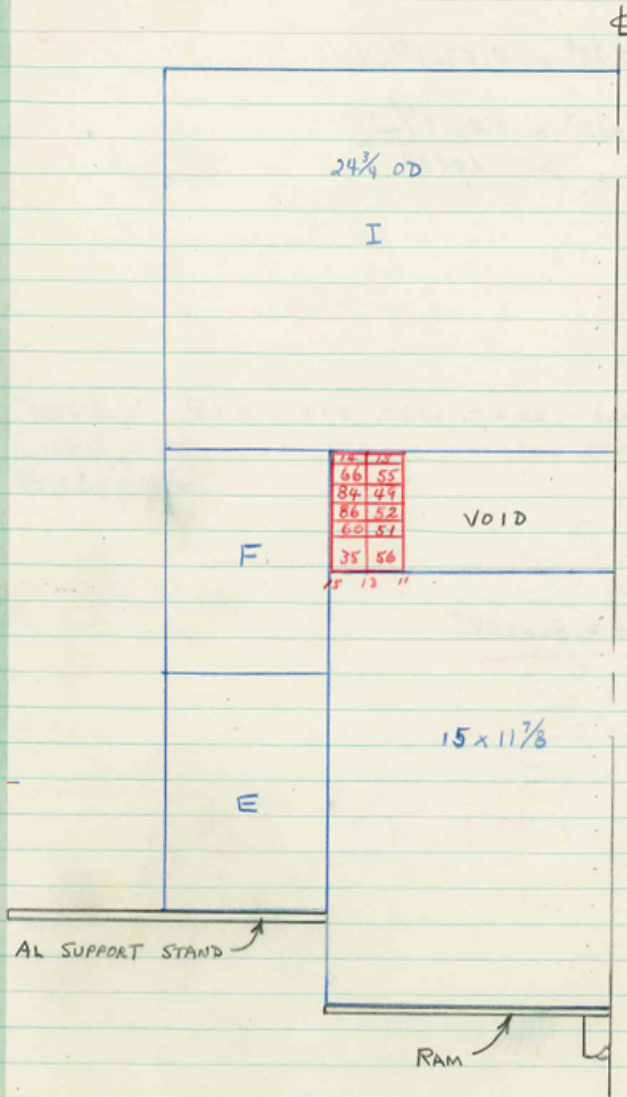
MASS OF FUEL = 80631 gm

VOLUME = 4307.63973 cm³

$\rho = 18.71813$ gm/cc

MASS OF POLY =

VOLUME =

$\rho = 0.916$ gm/cc

AVG. O.D. FUEL = 14.99513"

(²) = 224.85392

AVG I.D. FUEL = 11.00265"

(²) = 121.05830

3214	3297
• 66	7605
84	5039
86	6717
60	6743
35	6743 13409
15	3259
55	6514
49	4360
52	5811
51	5822
56	11565

A-24

15-11   Poly ≠ No Core

Nom. 1st. Critical = 3$\frac{7}{32}$"   reactivity = +13.94¢
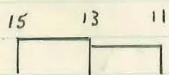
$\frac{1}{32}$" (15-13) = 17.88¢ or 0.5721 ¢/mil

$\frac{1}{32}$" (13-11) = 14.12¢ or 0.4518 ¢/mil

TOT = 1.0239

FUEL HEIGHT 15-13: 3.220 - .221 - .222 - .219 - .219 - .219 = 3.2200"
 $^{3.216}$
 $^{3.231}$ 13-11: 3.229 - .229 - .230 - .229 - .231 - 230 - .231 = 3.2298"

wt. avg = 3.2245"

+13.94¢ = 3.2245"
Or react = 3.2245 - .0136 = 3.2109"

less 340 gm

A-25
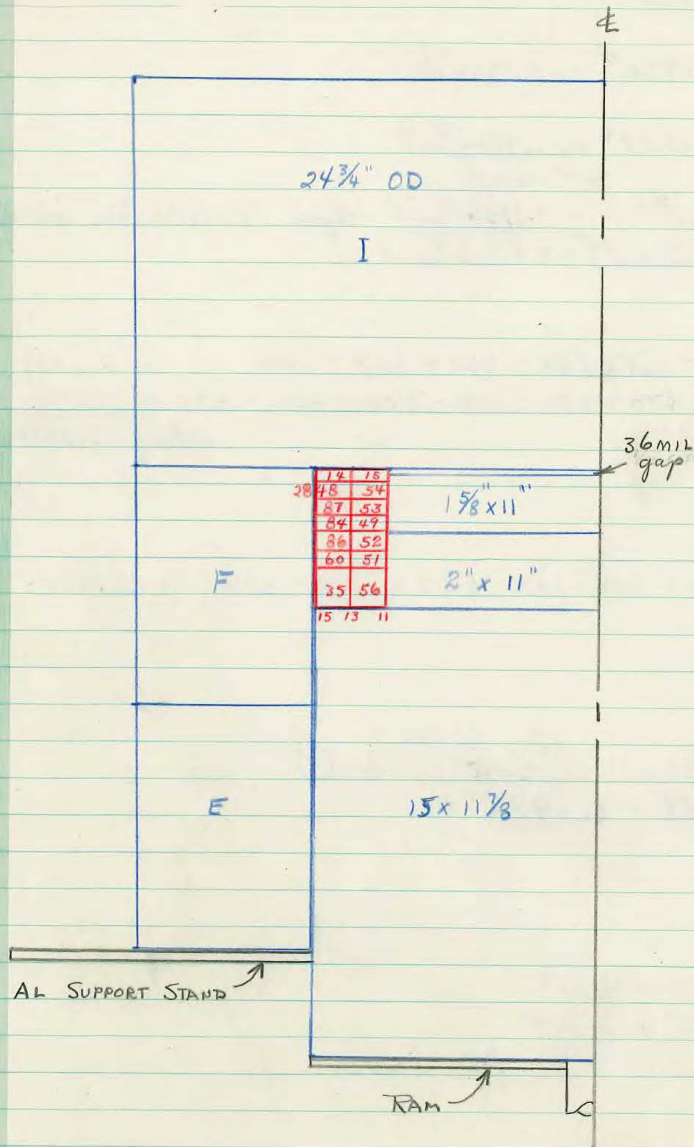
MASS OF FUEL = 91656 gm

VOLUME = 4898.95263 cm³

ρ = 18.70930 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D. FUEL = 14.99507"

(²) = 224.85212

AVG I.D. FUEL = 11.00283"

(²) = 121.06226

24¾" OD

I

36 MIL gap

1⅝ x 11"

2" x 11"

F

E

15 x 11⅞"

AL SUPPORT STAND

RAM

15-11   Poly + Core

Nom. Ht. Critical = Fuel $3\frac{21}{32}$"   Reactivity = $+20.92$¢
                    Core $3\frac{5}{8}$"
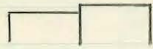
15   13   11

$\frac{1}{32}$" (15-13) = 17.80¢ or 0.5696¢/mil

$\frac{1}{32}$" (13-11) = 15.07¢ or 0.4822¢/mil

                                TOT = 1.0518
                    Core* -0.1156 ¢/mil → (from Core vs No Core derivation)
                    Grand T = 0.9362 ¢/mil

FUEL HEIGHT 15-13 = $3.663 - .664 - .665 - .667 - .667 - .665$ = 3.6651"
$\overset{3.660}{\underset{3.67}{}}$
            13-11 = $3.670 - .670 - .670 - .670 - .670 - .670 - .670$ = $\underline{3.6700}$"
                                                            mt avg = 3.6673"

Ht. of Poly Core = $3.632 - .633 - .634 - .633 - .635 - .634 - .634$ = 3.6335"

                                            over Poly Core
$+19.50$¢ = 3.6700"   *(36 mil gap ∧ 15 considered)
Oreact→ = $3.6700 - .0208 = 3.6492$" *

13-11 ——— O
Core raise 36.5 mil = -4.21¢
15-13 raise 4.9   = $+2.79$¢
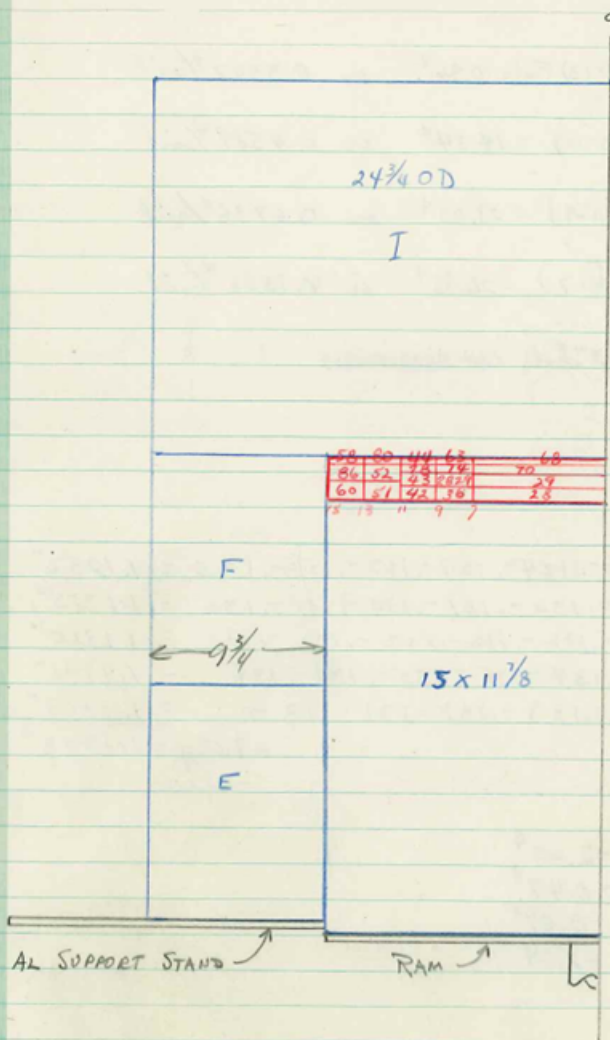
MASS OF FUEL : 61074 gm

VOLUME = 3271.21964 cm³

ρ = 18.67010 gm/cc

MASS OF POLY :

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D. FUEL : 14.99516"

(²) : 224.85482

24¾ OD

I

F

9¾

15 × 11⅞

E

AL SUPPORT STAND

RAM

2475
15
575

mass/mil of 15" die : 0.05403 Kg

15" DIA. <u>SOLID</u>   POLY. REF.

Nom. Wt. Critical = 1⅛"   reactivity = +8.77¢
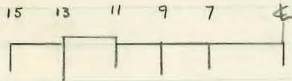
1/32" (15-13) Fuel = 10.46¢   or 0.3347 ¢/mil

1/32" (13-11) = 14.34¢   or 0.4588 ¢/mil

1/32" (11-9) = 21.05¢   or 0.6736 ¢/mil

1/32" (9-7) = 26.85¢   or 0.8592 ¢/mil

1/32" 7" dia "NOT MEASURABLE"

fuel height
                1.124
15-13 = 1.124 -.126 -.124 -.124 -.127 -.127 -.125 = 1.1252"
13-11 = 1.132 -.131 -.132 -.131 -.134 -.131 -.130 = 1.1315"
11-9 = 1.132 -.132 -.132 -.132 -.132 -.132 -.132 = 1.1320"
9-7 = 1.134 -.134 -.134 -.134 -.135 -.134 -.134 = 1.1341"
7 dia = 1.131 -.132 -.133 -.131 -.131 -.130   = 1.1313"
                                    wt. avg = 1.1303"

7" dia ——→ 0
9-7 down = − 2.8 mil = −2.40¢
11-9 down = − 0.7   −0.47¢
13-11 down = − 0.2   −0.09¢
15-13 Up = + 6.1   +2.04

<u>7.85¢ = 1.1313"</u>   (0¢ = 1.129")

≃ 60.96 KG

A-29

749¢
149¢c

24 3/4 OD

TOP
I

55	67
63	73
51	92

1 5/8 x 9"

| 57 | 76 |

1 5/16 x 9"

| 56 | 45 |

1" x 9"

13   11   9

Q

13 x 24 3/4

13" x 11 7/8"

H

13 x 24 3/4

AL SUPPORT PLATE

RAM
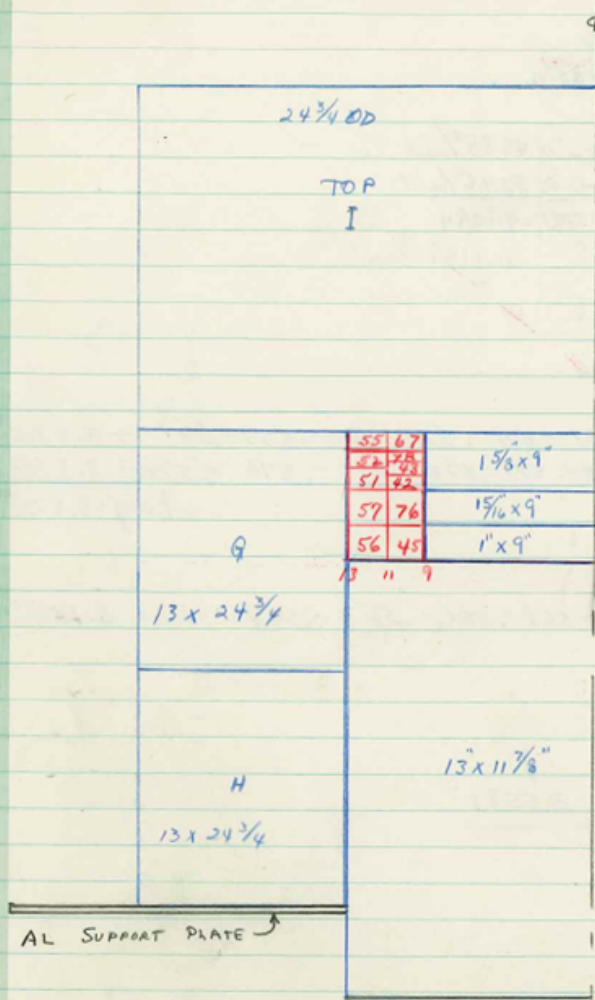
MASS OF FUEL = 75.626 Kg
     VOLUME = 4038.60186 cm³
          ρ = 18.72578 gm/cc

MASS OF POLY =
     VOLUME =
          ρ = 0.916 gm/cc

AVG. OD FUEL = 12.99622"   OD² = 168.90173
     ID = 9.00142"   ID² = 81.02556
AVG OD POLY =   (²) =

13"-9" "INFINITE" POLY REF + POLY CORE

Nom. Ht. Critical = 3 9/16"   reactivity = + 13.15¢

SEPARATED G FROM H (1/8") = nil
SEPARATED I FROM G (1/8") = - 11.33¢

1/32" FUEL (13"-11") = +15.59¢ or 0.4988¢/mil
1/32" FUEL (11"-9") = +16.55¢ or 0.5296¢/mil
                        TOT = 1.0284
            core ² ~   0.1148 ¢/mil

FUEL HEIGHT 13-11 = 3.571 -.571 -.571 -.571 -.570 -.571 -.571 = 3.5708"
             11-9 = 3.570 -.570 -.571 -.572 -.573 -.570 -.570 = 3.5708"
                                                    wt. avg = 3.5708"

Ht. of Poly Core = 3.567 -.566 -.567 -.568 -.566 -.567 -.567 -.567 = 3.5668"

+ 13.15¢ = 3.5708"
0 react = 3.5708 - .0127 = 3.5581"

TOP 24¾" OD

I

15 | 16
49 | 43
51 | 45 | 44
57 | 76
56 | 45

VOID

13 11 9

G
13 X 24¾

13" x 11⅞"

H
13 x 24¾

AL SUPPORT PLATE

RAM
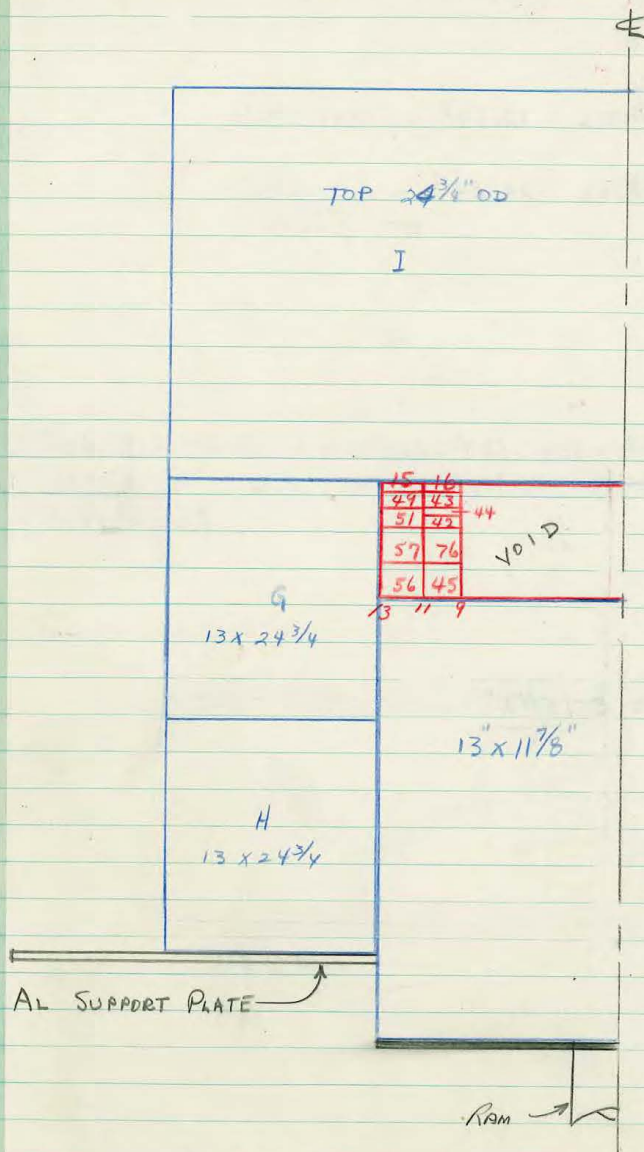
MASS OF FUEL = 67.018 Kg

VOLUME = 3581.55294 cm³

ρ = 18.71199 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG OD FUEL = 12.99627"   OD² = 168.90303   AVG ID = 9.00138"   ID² = 81.02484

A-32

13-9　　Inf. Poly ref & <u>No</u> Core

Nom. Ht. Critical = 3 5/32"　　　　　　reactivity = + 8.43¢

13　11　9
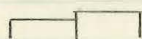
1/32" (11"×9") FUEL = 12.83¢ or 0.4105¢/mil

1/32" (13"×11") FUEL = 22.24¢ or 0.7116¢/mil

TOT = 1.1221

FUEL HT = 13-11 = 3.165 - .165 - .164 - .164 - .166 - .165 - .165 = 3.1648"
　　　　　11-9 = 3.168 - .168 - .168 - .168 - .170 - .170 - .170　　= 3.1688"

wt. avg = 3.1666"

+ 8.43¢ = 3.1666"
O react → 3.1666 - .0075 = 3.1591"

24¾ OD

I

55 67 37
82 43 2824   1⅜ X 7
51 42 36
56 45 38   ¹⁵/₁₆ X 7
13 11 9 7

G

13 X 24¾

13 X 11⅞

H

13 X 24¾

AL SUPPORT PLATE

RAM →
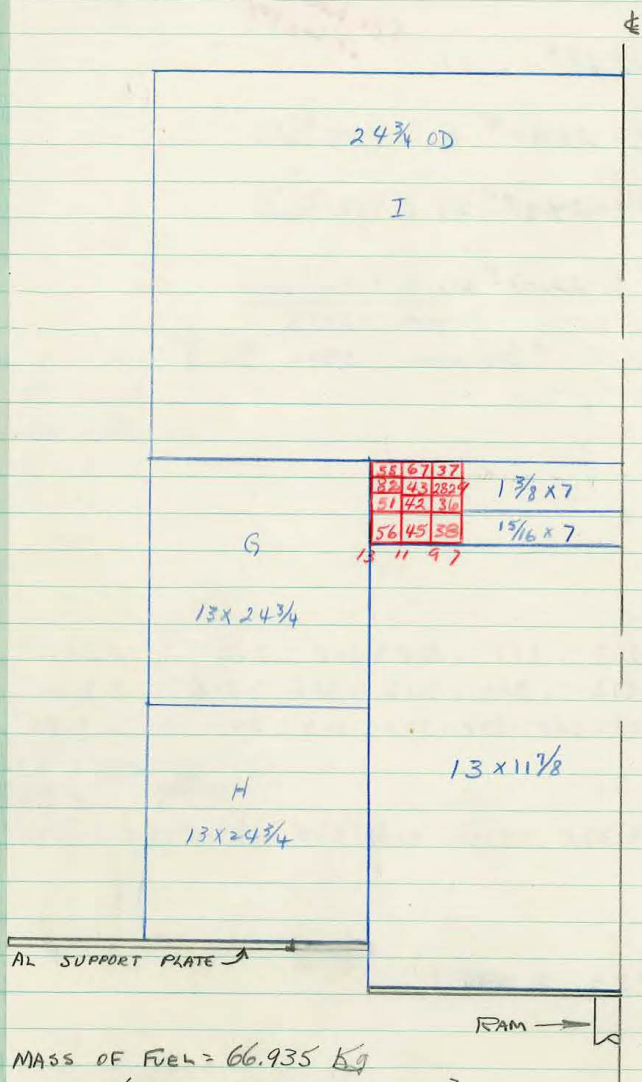
MASS OF FUEL = 66.935 Kg

VOLUME = 3573.53412 cm³

ρ = 18.73075 gm/cc

MASS OF POLY =

VOLUME :

ρ = 0.916 gm/cc

AVG. O.D. FUEL = 12.99619"   OD² : 168.90095

ID : 7.00291"   ID² : 49.04074

OD POLY   :   (²) =

13-7 "INFINITE" POLY Ref + Core

nom. Ht. Critical : 2 5/16" —— Not Agree with ρ 798.3/oy   JTM 11/24/64   CORRECT

reactivity = + 40.0¢
27.3

See bottom of hot page

1/8" SEPARATION OF G & I = − 12.68¢
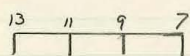
13 11 9 7   1/32" (13-11) = 23.69¢ or 0.7580¢/mil

1/32" (11-9) = 24.38¢ or 0.7801¢/mil

1/32" (9-7) = 22.17¢ or 0.7094¢/mil
TOT = 2.2475
* Core value = .0922 ¢/mil

FUEL HEIGHT 13-11 = 2.317 ⁻.317 ⁻.317 ⁻.317 ⁻.317 ⁻.316 = 2.3168"
11-9 = 2.316 ⁻.316 ⁻.316 ⁻.316 ⁻.316 ⁻.316 = 2.3160"
9-7 = 2.323 ⁻.323 ⁻.325 ⁻.327 ⁻.327 ⁻.323 ⁻.322 = 2.3246"
− 8 mils
are 2.3166"
wt. avg. 2.3164"

Ht of Poly Core = 2.315 ⁻.314 ⁻.315 ⁻.315 ⁻.313 ⁻.315 ⁻.315 ⁻.315 = 2.3146"

+ 40.0¢ = 2.3164"
O react = 2.3164 − .0177 = 2.2987"

A-35
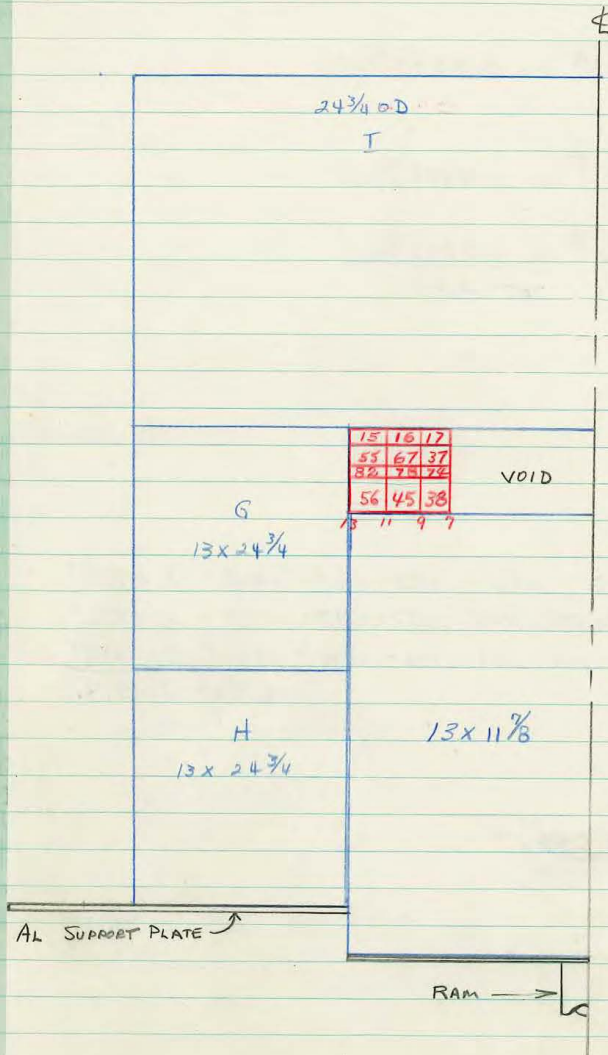
MASS OF FUEL = 60.548 Kg
        VOLUME = 3236.55265 cm³
              ρ = 18.70755 gm/cc
MASS OF POLY =
        VOLUME =
              ρ = 0.916 gm/cc
AVG OD FUEL = 12.99650"   OD² = 168.90901
        ID = 7.00268"   ID² = 49.03752
AVG OD POLY =   (²) =

A-36

13-7   "INFINITE" POLY REF & No Core

Nom. Ht. Critical = $2\frac{3}{32}$"   reactivity = + 27.92¢
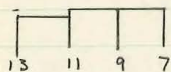
$\frac{1}{32}$" (13-11) = 23.11¢ or 0.7395¢/mil
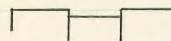
$\frac{1}{32}$" (11-9) = 27.9¢ or 0.8928¢/mil
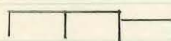
$\frac{1}{32}$" (9-7) = 26.21¢ or 0.8387¢/mil

TOT = 2.4710

FUEL HEIGHT 13-11 = 2.097 - .097 - .096 - .097 - .098 - .096 = 2.0968"
             11-9 = 2.097 - .097 - .098 - .048 - .097 - .097 - .097 = 2.0972"
             9-7 = 2.100 - .100 - .100 - .101 - .101 - .100 - .100 = 2.1002"
                                              wt.avg = 2.0978"

+27.92¢ = 2.0978"
O react → 2.0978 - .0112 = 2.0866"
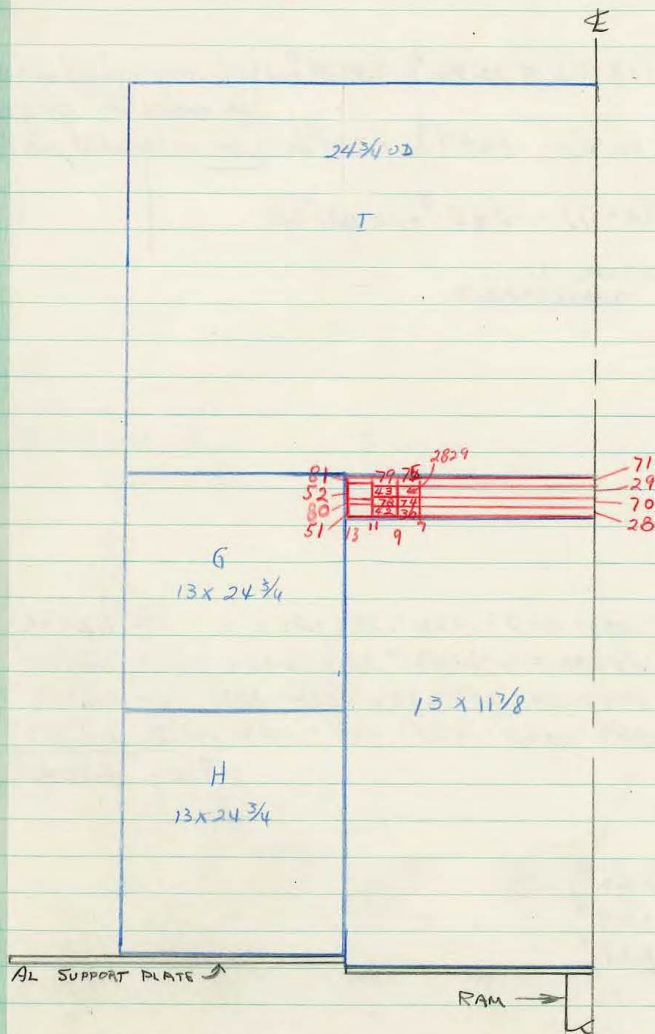
MASS OF FUEL = 50,971 Kg

    VOLUME = 2726.21470 cm³

      ρ = 18.69661 gm/cc

MASS OF POLY =

    VOLUME =

      ρ = 0.916 gm/cc

AVG OD FUEL = 12.99577"   OD² = 168.89003

OD POLY =   (²) =

A-38

13" dia <u>SOLID</u> "INFINITE" Ref

Nom Ht. Critical 1¼"   Reactivity = 44.2¢

13 11   9   7   →
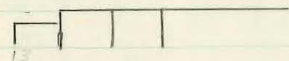
⅟₃₂" (13-11) = 15.42¢ or 0.4934¢/mil | If mass diff. need
                                      | consideration they may
⅟₃₂" (11-9) = 21.97¢ or 0.7030¢/mil | be calculated VIA Pg 205

⅟₃₂" (9-7) = 24.0¢ or 0.7680¢/mil .
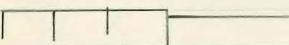
7" DIA.
NOT MEASUREABLE   —

FUEL HEIGHT 13-11: 1.257-.256-.257-.256-.256-.255   = 1.2561"
             11-9: 1.252-.252-.252-.252-.252-.252   = 1.2520"
             9-7: 1.255-.254-.254-.256-.256-.256-.255   = 1.2551"
             7" DIA: 1.254-.254-.253-.253-.254-.254-.253 = 1.2535"
                                            wt. avg. 1.2541"

7" dia =   0
9-7 down 1.6 mils = -1.22¢
11-9 up   1.5 mils = +1.05¢
13-11 down 2.6 mils = -1.28¢

+42.75¢ = 1.2535"   (est 1.240" @ 0)

¢

24¾ OD

I
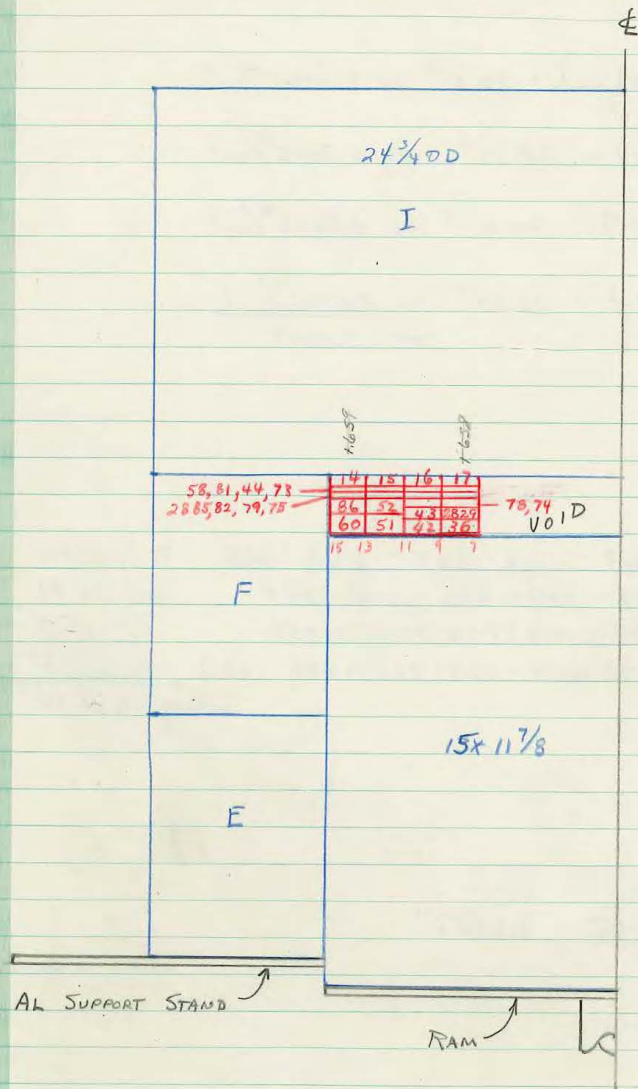
MASS OF FUEL = 70363 gm

VOLUME = 3762.72642 cm³

ρ = 18.70000 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

Avg. O.D. FUEL = 14.99608"

(²) = 224.88241

Avg. I.D. = 7.00263"

(²) = 49.03682

58, 81, 44, 73
28 85, 82, 79, 75

14	15	16	17
86	52	43 28 29	78, 74
60	51	42	36
15	13	11	9	7

VOID

F

15 x 11⅞

E

AL SUPPORT STAND

RAM

15-7   Poly & <u>No</u> Core

Nom. Ht. critical = $1\frac{21}{32}''$ Reactivity = $+30.01$¢

15 13 11 9 7
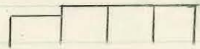
$\frac{1}{32}''$ (15-13) fuel = 20.5¢ or 0.6560 ¢/mil
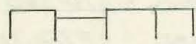
$\frac{1}{32}''$ (13-11) = 23.94¢ or 0.7660 ¢/mil
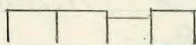
$\frac{1}{32}''$ (11-9) = 30.01¢ or 0.9603 ¢/mil

$\frac{1}{32}''$ (9-7) = 21.24¢ or <u>0.6796 ¢/mil</u>

TOT = 3.0619

fuel height 15-13 = 1.664 - .663 - .664 - .665 - .664 - .664   = 1.6640"
             13-11 = 1.664 - .664 - .664 - .665 - .664 - .664   = 1.6641"
             11-9 = 1.657 - .658 - .659 - .657 - .657 - .658 - .658   = 1.6577"
             9-7   = 1.662 - .662 - .663 - .663 - .665 - .666 - .666   <u>= 1.6638"</u>
                                                    wt avg = 1.6625"

30.01¢ = 1.6625"
0 reactivity ht = 1.6625 - .0098 = 1.6527"
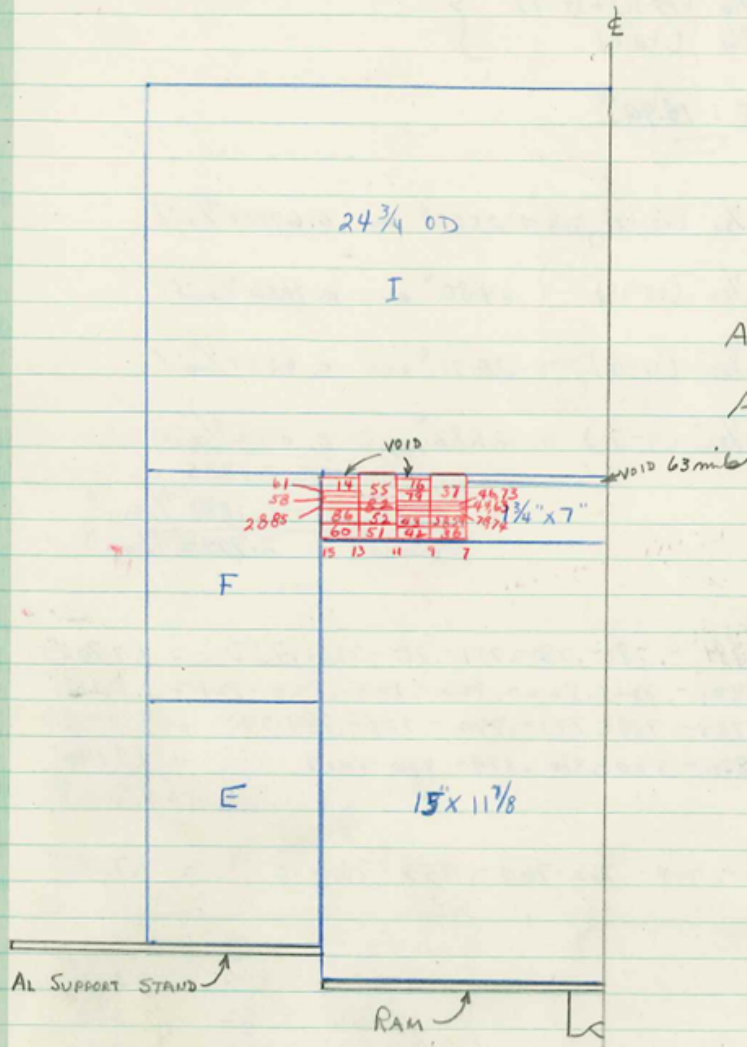
MASS OF FUEL = 76330 gm

VOLUME = 4076.28029 cm³

ρ = 18.72540 gm/cc

MASS OF POLY =

VOLUME =

ρ = 0.916 gm/cc

AVG. O.D. FUEL = 14.99589"

$(^2)$ = 224.87671

AVG. I.D. FUEL = 7.00243"

$(^2)$ = 49.03402

24 3/4 OD

I

VOID

VOID 63 mils

3/4" × 7

F

E

15" × 11 7/8

AL SUPPORT STAND

RAM

15-7 Poly + Core

Nom. Wt. Critical = $1\frac{25}{32}$" (15-13) + (11-9) }   Reactivity = +24.34¢
$1\frac{7}{16}$ (13-11) + (9-7)
$1\frac{3}{4}$ (core)

3/16" gap between I & F : 16.90¢
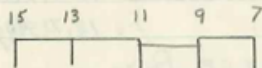
$\frac{1}{32}$" (15-13) fuel = 21.22¢ or 0.6790 ¢/mil
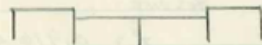
$\frac{1}{32}$" (13-11) = 24.80¢ or 0.7936 ¢/mil
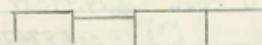
$\frac{1}{32}$" (11-9) = 20.71¢ or 0.6627 ¢/mil
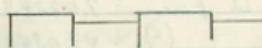
$\frac{1}{32}$" (9-7) = 21.82¢ or 0.6982 ¢/mil
                                    TOT = 2.8335
                          * Core = -0.1080 ¢/mil
                          Grand T = 2.7255 ¢/mil

fuel height 15-13 = 1.781 - .780 - .780 - .781 - .780 - .780 - .780 = 1.7802"
             13-11 = 1.821 - .821 - .822 - .822 - .823 - .823 - .821 = 1.8218"
             11-9 = 1.789 - .789 - .790 - .790 - .789 - .789 - .790 = 1.7894"
             9-7 = 1.820 - .820 - .820 - .819 - .820 - .819 = 1.8196"
                                          wt. Ht = 1.8008

Ht of Poly Core = 1.758 - .758 - .760 - .760 - .757 - .760 = = 1.7588"

13-11 — 0
9-7 up 2.2 = +1.536¢
11-9 up 32.4 = +21.471¢
15-13 up 41.6 +28.248¢
Core up 63 = -16.80¢
  +68.79¢ = 1.8218"
Ⓞ reactiv. = 1.8218 - .0252 = 1.7966"

15-13/ — 0
13-11 down - 41.6 - 33.01ᵈ
11-9 down - 9.2 - 6.09¢
9-7 down - 39.4 - 37.5
-42.26¢ = 1.7802"
Ⓞ —→ 1.780 + .0149 = 1.7951"

Void over the core
is considered

* (Core vs No Core derivation)

Avg intil Ht = 15.292 including fuel
Avg OD = 29.0036

Rad. C = 112637
Graph. C = 165447
TOT = 278084

MASS OF FUEL = 59036 gm
  Vol = 5056.3080 cm³
  ρ = 18.6617 gm/cc
MASS OF GRAPHITE = 278084 gm
  Avg. (OD) FUEL = 14.99579"
  (OD)² = 224.87377
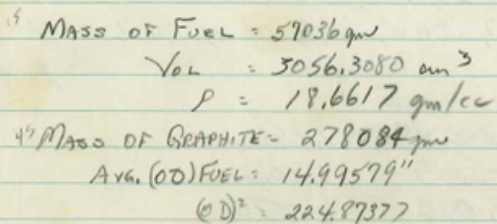
Reff. Avg ($\frac{Rad + Top + Bottom}{3}$) = 7.0187"

mass of C = 278.084 Kg
  Vol = 162507 cm³
  ρ = 1.711 gm/cc

15" DIA. Solid & 7" ref

Nom. Ht. Critical = 15-13 & 9 dia - 1¹/₁₆"   also Top Ref ¹/₁₆" extra
                              13-9 = 1¹/₃₂"

Reactivity = +17.15¢

Value of diaph = - 5.06¢
      Supports = 23.03¢
Value of 15-13 fuel = 24.98¢   ¢/mil
          13-11 = 30.41¢   0.7993 .7806
   ¹/₃₂"   11-9   = 36.93¢   0.9728 .9903
          9-7   =   38.27¢   +.1849 1.154
          7 dia =   —   +.2246 1.196

                                    OK ↖

Make increment C evaluations
    15 dia x ¹/₈" = 15.74¢   .126
.8" 25 x 21   = 7.65¢   .0096
    19-17 (⁷/₈") = 13.62¢   .0156
    15-17 est = 14.5 for ⁷/₈   .0167

Wt. of fuel 15-13 = 1.065 - .065 - .065 - .065 - .065   1.0650
            13-11 = 1.038 - .039 - .038 - .038 - .038 - .038 = 1.0381
            11-9 = 1.042 - .042 - .042 - .042 - .043   = 1.0422
            9-7 = 1.068 - .068 - .067 - .068, .069, .069, .068 = 1.0681"
            7 dia = 1.067 - .067 - .067, .066, .066, .067, .067, .067 = 1.0667"
                                                      wt avg = 1.0560

Wt of graphite A = 7.050 - .057 - .058 - 0.48 =   7.0532
                B = 1.008 - .003 - .005 - .009 =   1.0062
                C = 6.020 - .012 - 5.996 - .000 = 6.0070
                D = Look Up   = 6.0221
        dia up→ E = 8.990 - .987 - .984 - .987 = 8.9870
           "   F = 8.918 - .914 - .917 - .917 = add (88 mils) To Avg ⇒ = 9.0045
           "   G = 9.000 - .000 - 8.996 - 8.994 = 8.9975
           "   H = Look Up   = 9.0003
           "   I = Look Up   = 9.0063
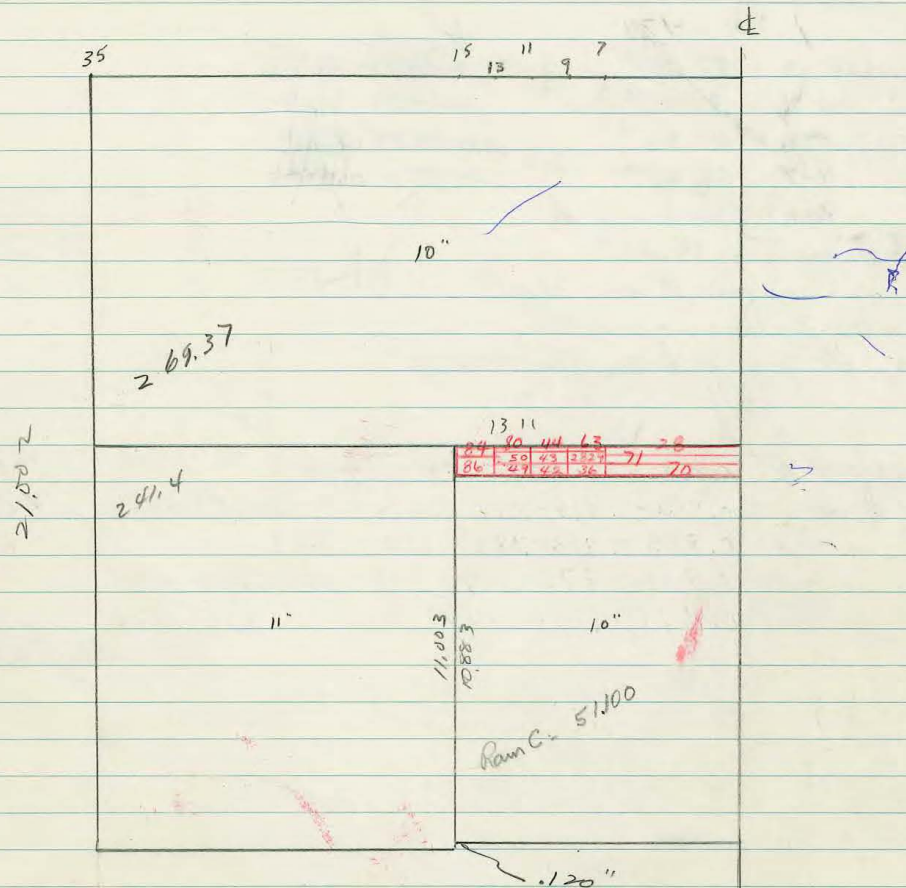
MASS OF FUEL = 47402 gm

V_{OL} = 2541.3707 cm^3

ρ = 18.6521 gm/cc

AVG OD = 14.99478"

C OD = 224.84342

C mass = 561.870 Kg

C Vol = 328584

ρ = 1.710 gm/cc

Avg Refl = 10.0068"

A-46

15" Dia. Cyl. #10" graphite ref.

Nom. Ht Critical = 7/8" *
    reactivity = 9.56¢

1/32" fuel 15-13 = 27.64¢   ¢/mil
          13-11 = 35.57¢   0.8844 .863/1
          11-9 = 43.56¢   +.382 1.11/r
          9-7 = 35.47¢   +.3939 1.30/1
          7 dia. = Could not do.   +.350 1.10/0
all supports = 14.25¢
{ 32 mil gap over 15" dia = 32.27¢   OK
{ created by lowering ram same.
ADDED   1/8" graphite on top of fuel = +12.32¢

Ht. of   15-13:   0.878-.878-.878-.877-.877-.877   = 0.8775
       13-11:   0.880-.879-.879-.878-.878-.881-.880   = 0.8792
       11-9:   0.883-.883-.882-.882-.883   = 0.8826
       9-7:   0.878-.878-.879-.878-.879-.879-.878   = 0.8784
       7 dia: 0.874, .874, .874, .874, .875, .875   = 0.8743
                                 wt avg = 0.8782

* 1/8" protruding out on 35-15 ring at bottom

15,000   15

683.6

30.96 c"

8

330.1

15.988

8   328.8

15.756

15   11
13   44   9
58   80   63
66   55   67   37   24   28

2   2

½
1½

A

10   Ram C = 71071

.234"

MASS OF FUEL = ~~57779~~ 38041 gm
    Vol = 2030.5003 cm³
    ρ = 18.7347   rechecked √R√
    Avg OD = 14.99652"
    (OD)² = 224.89561

Mass C = 1413.571 kg
Vol C = 804925 cm³
ρ = 1.756 gm/cc

Avg Refl = 14.9971"

A-48
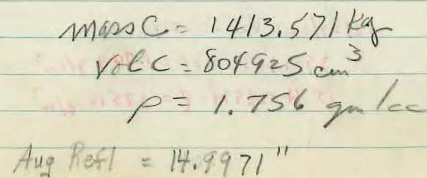
15 dia Solid & 15" Cref.

Nom. Critical At. = 15-7 = $^{11}/_{16}$ " .6875 ⎫
7 dia = $^{13}/_{16}$ " .750 ⎬ reactivity = ∞
⎭

all supports = 2.80$^{¢}$
2 (2½ x 2½) @ $\overset{inner\ edge}{at\ 7OD}$ = 17.50$^{¢}$

2 (2½ x 2½) @ $\overset{outer}{edge\ of}$ 15OD = 12.48$^{¢}$

2 (2½ x 2½) @ $\overset{outer}{edge\ of}$ 13OD = 16.11$^{¢}$
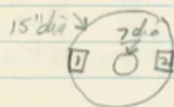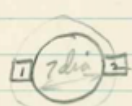
½" (45-15) Cen top = 9.97$^{¢}$ .0199$^{¢}$

At of 15-13 = 0.685 - .685 - .685 - .685 - .685 - .685   0.6850
13-11 = 0.689 - .689 - .689 - .689 - .689 - .689 - .689   .6890
11-9 = 0.692 - .692 - .692 - .692 - .691 - .692   .6918
9-7 = 0.688 - .688 - .697 - .688 - .688 - .688 - .688   .6878
7 dia = 0.750 - .749 - .749 - .750 - .749 - .750   .7495
                                                          wt avg = .7015

A = Sam as 4-177 = 5.0052"

ρ of C of ram under fuel = $\frac{71071\ gm}{42\,893.226\ cm^3}$ = 1.6569 gm/cc ⎫
ρ of C 2 -8" (45+15) poured = $\frac{65 8900\ gm}{370450.08 cm^3}$ = 1.7786 gm/cc ⎬ 45" dia assumed
45" TOP   est. $\frac{683,600}{374502.69 cm^3}$ = 1.8253 gm/cc ⎭ to be 45.000 also
                                                                        wt of Big is est.

12/24/00 V.1 + Top   wt ρ by mass = 1.79506 gm/cc
590938.38 → ρ = 1.749 g/cm³
if H = 14.974 ρ = 1.7516 g/cm³

A-49

15"-7"   1" GRAPHITE REFLECTOR   WITHOUT G.CORE   Pg 274
15"-7"   1" GRAPHITE REFLECTOR   WITH G.CORE   Pg 276
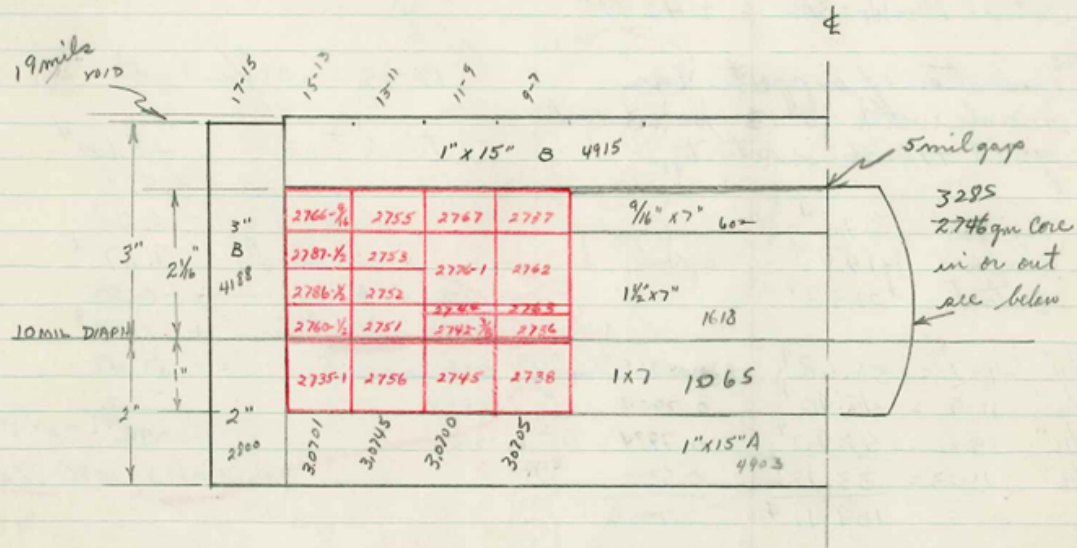
WITHOUT CORE

MASS TOP GRAPHITE = 9103 gm   TOTAL = 16.806 Kg
BOTTOM   = 7703 gm

MASS TOP FUEL = 87564 gm   TOTAL = 129.884 Kg
BOTTOM   = 42320 gm

AVG O.D. ALL FUEL WT'D = 14.99479"
AVG I.D. ALL FUEL WT'D = 7.00320"
AVG Ht ALL FUEL WT'D = 3.07135"

FUEL VOLUME = 6949.28412 cm³
FUEL ρ = 18.6902 gm/cc

Vol of graphite 19 mil gap (not incl.)
   = 9950.37988 cm³
   ρ = 1.68898 gm/cc

Avg Refl = 0.9958"

WITH CORE

11323 gm   TOTAL = 20,091 Kg
8768 gm

SAME
SAME

SAME
SAME
SAME

SAME
SAME

Vol of graphite 19 or 5 mil gap (not incl.)
   = 11885.60511 cm³
   ρ = 1.69036 gm cc

ρ of Core only = 1.69947

A-50

15"-7" 1" Cref W/WD Core (C)

WITHOUT Core

Critical Nom Ht = 3¹/₁₆" = + 43.49¢

NOTE:
* Evaluation of supports was
made with 15-13 ¹/₁₆" removed
gives +10.36¢ reactivity.

$ring = 3.48$¢
$diaph = -14.9$¢
$S.stand = 21.48$¢

¹/₁₆"	9-7 = 36.68¢	0.5868¢/mil ✓
¹/₁₆"	11-9 = 49.40¢	0.7804 ✓
¹/₁₆"	13-11 = 49.90¢	0.7984 ✓
¹/₁₆"	15-13 = 33.13¢	0.5300 ✓
	169.11¢	2.7056

Ht all FUEL

15-13 = 3.070 - .070 - .067 - .072 - .010 - .072 = 3.0701"
13-11 = 3.075 - .073 - .075 - .075 - .075 - .074 = 3.0745 ✓
11-9 = 3.070 - .070 - .070 - .069 - .070 - .071 = 3.0700
9-7 = 3.072 - .070 - .070 - .069 - .070 - .072 = 3.0705
wt. avg = 3.0713"

Core ht only = 3.066 - .065 - .066 - .066 - .066 = 3.0658
1 x 15 DISC = 0.998" vol = 3066.42718 cm²
1 x 15" = 0.9995" vol = 3071.44267 cm²
17" ring = 5.043 - .043 - .046 - .045
.046 - .041 - .049 = 5.0447 → vol = 4165.51894 cm³ w/o ¹/₁₆ void
4180.54708 cm³ with ¹/₁₆ void

EVEN FUEL HT. = 3.0713"
SKY HOOK REACT. = +33.43¢
mil { 19 mil carbon void
     17-15 ring not considered }
0 React Ht = 3.059"

With Core

17-15 = .02¢/mil ist.

Critical Ht ave = +8.66¢
$ring = 3.51$¢
$diaph = -12.48$
$S.stand = 19.17$¢

17-15 ↑ 19 ——— = + 0.38
React. without core = + 43.49¢
all support = - 23.47
15-7 ——— 0
+ 20.42¢ = 3.0713"
0 = 3.0713 - .0075 = 3.0638"

17-15 ↑ 19 ——— = + 0.38¢
React. with core = + 8.66¢
all support = - 10.20
15-7 ——— 0
Core (-.0061) ↑ 5 = - 0.03
- 1.19¢ = 3.0713"
0 = 3.0713 + .0004 = 3.0717"

15-7 = 2.5¢/mil from curve
Core - .0061
2.4939¢/mil

EVEN FUEL HT. = 3.0713"
SKY HOOK REACT. = -1.54¢
{ 19 mil carbon void 17-15
  5 mil void over core
  not considered }
0 React Ht = 3.0708"

19-17   17-15   15-13   13-11   11-9   9-7   ₵

6.45321

13/16
1334 | | 1 X 15 B | 4915
2⅛ 3"A | | 28.8 mils 1 X 15 A | 4903
3440 4232 | 58 ⅞ 80 3216-⅜ | VOID |
| 2784 2241-⅞ 46-⅞ 2762-1 | |
| 2760-⅛ 2754 ½ 2767-⅛ | | 10 mil DIAPH.
| 44 03 ⅞ |
| 2716-½ 2751 ½ 2742 2736 ⅞ | VOID |
1½ 1½ | |
2438 2098 | 2735-1 2758-1 2745-1 2738-1 | VOID |

2.5053 2.5048 2.4920 2.5028   1 X 19 B   7838

1 X 19 A   7828
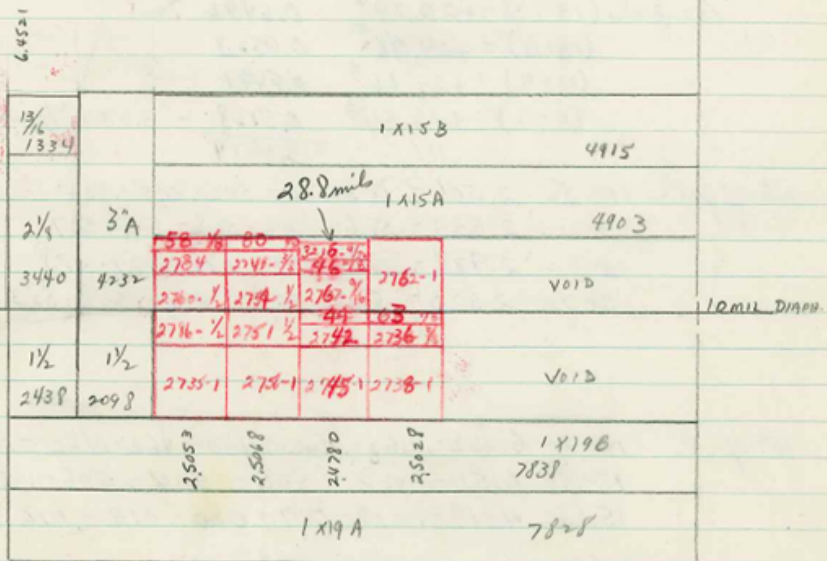
MASS OF FUEL = 105699 gm
    VOLUME = 5653.82352 cm³
      ρ = 18.69513 gm/cc

MASS OF GRAPHITE = 39026 gm
    VOLUME = 22977.67966 cm³ ✓
      ρ = 1.69843 gm/cc ✓

AVG. O.D. ALL FUEL (WT'D) = 14.99440"   OD² = 224.83203
        ID = 7.00357"   ID² = 49.04999
19-17 Carbon OD = 18.99648"   —   360.86625

Avg Refl = 2.0019"

15-7   2" ref ¢ No Cov

Nom. Ht. Critical   (15-13)+(13-11)+(9-7) = 2½"
                     11-9 = 2¹⁵/₃₂"   → + 2.27¢

        Rings = + 2.80¢
Diaphragm = -18.56¢
S. Stand = +13.89¢

¹/₃₂" fuel (15-13) = +20.29¢   0.6492 ¢/mil ✓
          (13-11) = +29.76¢   0.9523
          (11-9) = +29.66¢   0.9491
          (9-7) = +16.54¢   0.5168   3.080 ¢/mil
                              ‾‾‾‾‾‾
                               3.0674

Ht of fuel 15-13 = 2.506-.503-.506-.506-.505-.506   = 2.5053"
            13-11 = 2.505-.506-.507-.508-.508-.507   = 2.5068"
            11-9 = 2.978-.478-.479-.476-.479-.478   = 2.4780"
            9-7 = 2.503-.503-.503-.502-.503-.503   = 2.5028"
                                                   wt avg = 2.4990"

Ht of C   19-17 = 6.462-.462-.462-.460-.462-.462-.460   = 6.4614"
          17-15 = 6.511-.507-.505-.504-.506-.508-.509   = 6.5071"
          15 dia = 4.019-.019-.017-.020-.018-.016-.018   = 4.0181"

     Even Fuel Ht = 2.4990"
     Sky Hook React = + 4.14¢

        0 React = 2.498" ✓

Reactivity   → = +2.27
19-17 mil   = 0
15-7   = 0
all support =   - +1.87
                  ‾‾‾‾‾‾‾‾‾‾‾
                  +4.14¢ = 2.4990"
        0 = 2.4990 - .0013 = 2.4977"

A-53
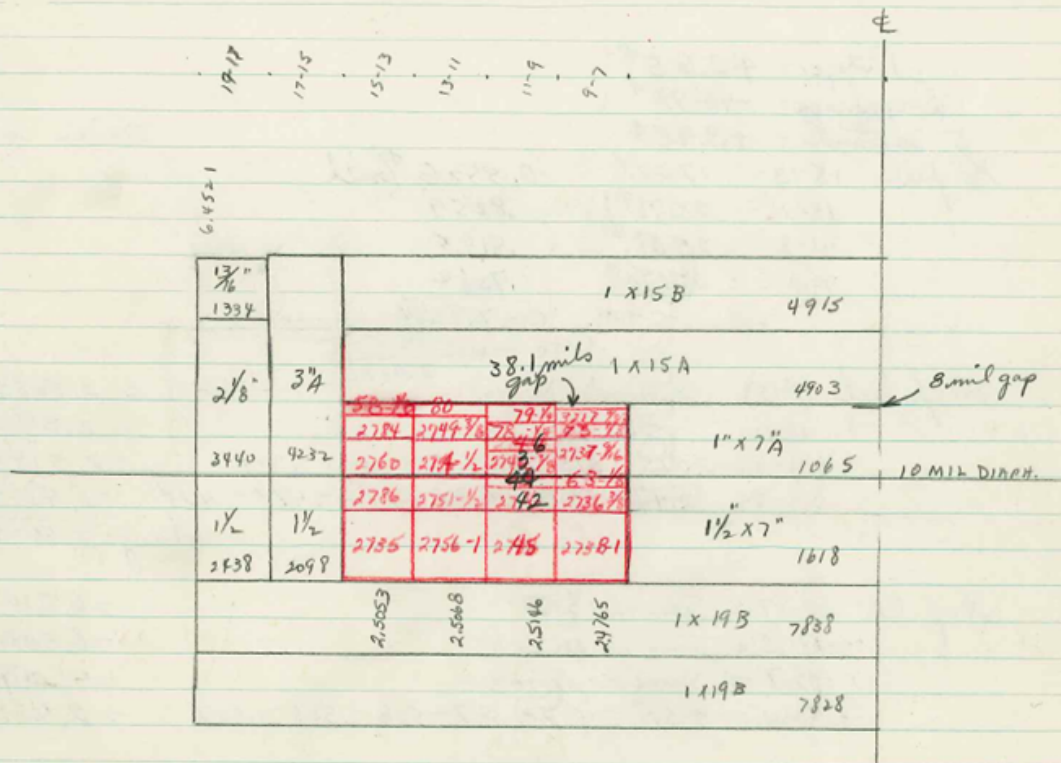
MASS OF FUEL = 105792 gm
    VOLUME = 5664.05719 cm³
    ρ = 18.67777 gm/cc

MASS OF GRAPHITE = 41709 gm
    VOLUME = 24559.66978 cm³
    ρ = 1.69827 gm/cc

AVG. OD. ALL FUEL (W'T'D) = 14.99440"   OD² = 224.83203
    ID = 7.00263"   ID² = 49.03682
19-17 Carbon OD = 18.99648"   ————   : 360.86625

Avg Refl = 2.0019"

15-7   2" ref. + core

Nom. Ht. Critical   15"-9" = 2½" & 9"-7 = 2$\frac{15}{32}$" → reactivity = −5.43¢

Ring = +2.65¢
Diaphragm = −15.73¢
S. Stand = +9.95¢   Raise .001"

$\frac{1}{32}$" fuel 15-13:   17.27¢   0.5526 ¢/mil
              13-11:   25.81¢   .8259
              11-9:   25.61^d .8195
              9-7:   22.70^d .7264
                              avg 2.9244
                         Core − .00^{69}
                              2.9175

Ht. of fuel 15-13: Same as No core   = 2.5053"
            13-11: Same   = 2.5068
            11-9: 2.515 − .515 − .516 − .513 − .515 − .514   = 2.5146
            9-7: 2.478 − .476 − .474 − .476 − .477 − .478   = 2.4765
                                             wt avg = 2.5025"

Ht of C 19-17: Same as 103   = 6.4614" (⁰⁰)
         17-15: Same as 103   = 6.5071"
         15-7: Same as pg 103   = 4.9181"
         Core = 2.508 − .507 − .507 − .506 − .505 − .507   = 2.5066"

        0 React Ht = 2.5035"

React ——————— > = − 5.43¢
all support = +3.13
19-17 mil   = 0
15-7   = 0
Core (−) mil = 0
                − 2.30¢ = 2.5025"
        ① = 2.5025" + .0007 = 2.5032"

A-55

15 - 7 -   3" C   VOID

1⅛" U Top Mass = 47768 gm

Top C Mass = 37188

10 Mil Diaph.

1" U Bottom Mass = 42370 gm

Bott. C Mass = 33855

Pos.	#		Mass
1	2758	(⅛")	1685
2	2848	(½")	6748
3	2787	(½")	6788
4	2781	(⅛")	1449
5	2757	(1")	11575
6	2744	(⅛")	1223
7	2776	(1")	9694
8	2763	(⅛")	953
9	2762	(1")	7703
10	2735	(1")	13409
11	2756	(1")	11567
12	2745	(1")	9634
13	2738	(1")	7710

224,89201

Pos	Size	Mass
1	1" x 5" (19-21) Ring	8827
2	1" x ¾ (17-19) Ring	1255
3	1" x ¾" (15-17) Ring	1060
4	9/16 x 15" Disc	2763
5	¼" x 15" Disc	1224
6	1" x 19" Disc A	7828
7	1" x 19 Disc B	7838
8	1" x 1½" (17-19) Ring	2452
9	1" x 1½" (15-17) Ring	2100
10	3/8 x 15" Disc	1841
11	1" x 1" (19-21) Ring	1828
12	1" x 1" (17-19) Ring	1644
13	1" x 1" (15-17) Ring	1454
14	1" x 21" Disc	9666
15	2" x 21" Disc	19263

Avg Final OD = 14.99640"

ID = 7.00375"

49.05251

Fuel vol. = 4816.68180 cm³

ρ = 18.70333 gm/cc

graphite vol. = 41813.76277 cm³

ρ = 1.69903 gm/cc

Avg Refl = 3.0101"

15"-7" 3" C ref WO core

Nom. Wt Critical = 2⅛" = + 22.05¢

rings + diaph = - 15.2¢
5. stand = ? assumed nil

21-19 ring center = 0.0176¢/mil (taken from 15.7 3"w/ pg 111)

With Carbon Core added:
Nom. Wt Critical = 2⅛" = + 10.2¢

diaph + rings = - 13.02¢
5. stand = ? assumed nil

avg. Wt. wt. = 2.1283"

React ———— = + 22.05¢   Rings 2.75
all support = + 4.40   Stand 10.8
19+17 assum nil ————   Diaph. 1.795
           + 26.45¢ = 2.1283"
    O = 2.1283 - .0086 = 2.1197"

EVEN FUEL WT. = 2.1283"

⑦
①

MASS OF FUEL = 90707 gm

VOLUME = 4855.84466 cm³

ρ = 18.67996 gm/cc

MASS OF GRAPHITE = 68280 gm

VOLUME = 40011.89834 cm³

ρ = 1.70649

AVG. O.D. ALL FUEL (W'T'D) = 14.99439"   OD² = 224.83173

I.D = 7.00297"   ID² = 49.04158

21-19 OD Carbon = 20.99959"   440.98278

Avg Ref = 3.0001"

A-58

Nom. Ht. Critical   (9-7 & 13-11) = 2 5/32" } reactivity   + 1.39¢

                     (11-9 & 15-13) = 2 1/8" }

                                                                    54¢ac

        Range = + 3.59¢   Lower .0019"
        Diaphragm = − 20.38¢
        S. Stand = + 11.73¢

    1/32" ful 15-13 =   25.08¢   0.8025 ¢/mil
all   13-11 =   33.88¢ & 35.64¢ avg 34.76   1.1123
           11-9 =   23.94¢ & 26.03¢ avg 24.98   0.7660
Nom.   9-7   =   23.70¢   0.7584
    1/4" C on 19-17 ring =   4.4¢   3.4392 +/mil

Ht all fuel 15-13 = 2.130 −.130 −.129 −.130 −.130 −.129   = 2.1296"
             13-11 = 2.161 −.161 −.161 −.163 −.163 −.164   = 2.1621"
             11-9 = 2.137 −.136 −.136 −.136 −.136 −.134   = 2.1358"
             9-7   = 2.165 −.165 −.163 −.164 −.165 −.165   = 2.1645"
                                                    wt avg = 2.1462"

Ht Carbon   21-19 = 8.165 −.160 −.155 −.150 −.155 −.162 −   = 8.1578" (+11)
             19-17 = 8.020 −.017 −.014 −.014 −.020 −.022 −.023 = 8.0185" (−120)
             17-15 = 8.204 −.208 −.201 −.192 −.198 −.199 −.204 = 8.2008" (+59¢)
             15-7 = Same as 1 2 3   = 6.0168"
                                                                    ok

        Correct flat fuel Ht = 2.1443" ✓

    Reactivity = ─────→ = + 1.39¢
    all support   = + 5.06
    21 - 15 ↑↓ NIL   =   0
    15 - 7   =   0
                    + 6.45¢ = 2.1462"
        0 = 2.1462 − .0018 = 2.1444"

MASS OF FUEL = 91182 gm
 VOLUME = 4878.46714 cm³
  ρ = 18.690707 gm/cc

MASS OF GRAPHITE = 70551 gm
 VOLUME = 41360.76837 cm³
  ρ = 1.70574 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 14.99480" OD² = 224.84402
    I.D. = 7.00335"   ID² = 49.04691
21-19 OD carbon = 20.99959"   —— 440.98278

Avg. Refl = 2.999"

15-7   3"ref + Core

Nom. Ht. Critical = 15-9 = 2$\frac{5}{32}$" & 9-7 = 2$\frac{1}{8}$"   Reactivity = + 15.69¢

Rings = + 2.92¢
Diaphragm = − 16.10¢
5. Stand = + 9.58¢   Lower .0055"

$\frac{1}{32}$" fuel   15-13 = 24.38¢   0.7801 ¢/mil
           13-11 = 33.78¢   1.0809
           11-9 = 29.90¢   0.9568
           9-7 = 21.45¢   0.6864
                              ‾‾‾‾‾‾‾‾‾
                                3.5042
                   Cord (−)   .0100
                              ‾‾‾‾‾‾‾‾‾
                                3.4942

Ht. of fuel   15-13 = 2.160 −.160 −.161 −.160 −.164 −.161   = 2.1610"
           13-11 = same Pg III   = 2.1621"
           11-9 = 2.162 −.163 −.163 −.160 −.163 −.163   = 2.1623"
           9-7 = 2.132 −.132 −.131 −.131 −.130 −.130   = 2.1310"
                                              av'avg = 2.1561"

Ht. of Carbon   21-19 = Same as Pg III   = 8.1578" ✓
           19-17 =   = 8.0185" (−138)
           17-15 =   = 8.2008" (+54)
           15-7 =   = 6.0168"
           Core = 2.137 −.135 −.135 −.138 −.139 −.137 −.137 = 2.1368"

        correct flat fuel Ht = 2.1506" ✓   [core gap not considered] ok

React. ‾‾‾‾‾‾‾ = + 15.69¢
all support = + 3.60
21-15 mil = 0
15-7 ‾‾‾‾ = 0
Core ↑19.3 = − 0.19
                ‾‾‾‾‾‾‾‾‾‾‾
                + 19.10¢ = 2.1561"
        0 = 2.1561 −.0054 = 2.1507"

15"-7"   5" GRAPHITE REFLECTOR & No CORE   Pg 162

11.1871   25-21   21-19   19-17   17-15   15-13   13-11   11-9   9-7

1⅛"			1⅛" 1997	"/16 1111	13/16 1170

⅛ x 15   625
⅜ x 15   1841

1.2"   ⅞
4895   1½ 1233

1½ x 15   7485

2"   2438
3546   1½
2098

1 x 15   C   4915

4½"
18455   4"
3"   3"B   1 x 15 B   4915
5325   6513   4188

28.8 mil — gap — 32.5 mils   1 x 15 A   4913

Red box:
14-9/32	82-¼	16-9/32	74-¼
66-7/16	55	67	37
84-7/8	49	43 44	2639 65
60-½	51-½	42-3/8	36

VOID
VOID

1.7280   1.6993   1.7204   1.6556

1"   1"   1"
1828   1644   1456

½ x 15   2467

3"
12350

2 x 21   .19263

½ x 25   .6868

2 x 25   .27650

10 mil DIAM

MASS OF FUEL = 72382 gm
   VOLUME = 3879.89390 cm³
   ρ = 18.65566 gm/cc

MASS OF GRAPHITE = 151179 gm
   VOLUME = 88025.00261 cm³
   ρ = 1.71745 gm/cc   Avg. Refl. = 4.998"

AVG. O.D. ALL FUEL (w't'd) = 14.99612"   OD² = 224.88361
             I.D = 7.00250"   ID² = 49.03500
25-21 OD Carbon = 24.99799"   624.89950

15-7   5"ref & <u>No</u> Core   1.703

Nom. Ht. Critical (13-11) & (9-7) = 1.6875 (1 11/16") ——> reactivity = +3.28¢
                    (15-13) & (11-9) = 1.71875 (1 23/32")

        Rings = +3.63¢
    Diaphragm = -13.92¢
    S. Stand = +5.46¢   Lower 0.0019"
1/32" fuel 15-13 = +27.51¢   0.8803¢/mil ⎤
          13-11 = +36.76¢   1.1763   ⎥ = 4.1692 ¢/mil
          11-9 = +37.16¢   1.1891   ⎥
          9-7   = +28.86¢   0.9235   ⎦
        25-21
600 mils carbon = +5.39¢   .00898¢/mil
    Ht of fuel 15-13 = 1.728 -.728 -.727 -.728 -.729 -.728 = 1.7280"
              13-11 = 1.700 -.698 -.699 -.700 -.699 -.700 = 1.6993"
              11-9 = 1.728 -.728 -.728 -.729 -.728 -.728 = 1.7281"
              9-7   = 1.696 -.696 -.695 -.697 -.695 -.695 = 1.6956"
                                                wt val Avg = 1.7134"

    Ht of Carbon 25-21 = 5.5115 + [5.6900   ]   = 11.2015" (-520)
                 21-19 = 5.4986 + [6.140 -.142 -.141 -.150 -.146 -.148 -.150] = 11.6438" (-79)
                 19-17 = 5.5053 + [6.205 -.195 -.194 -.190 -.199 -.201 -.200] = 11.7030" (-18)
                 17-15 = 5.5052 + [6.226 -.223 -.224 -.224 -.224 -.225] = 11.7295" (+9)
                 15 dia = 5.0031 + [5.016 -.016 -.016 -.016 -.017 -.017 -.016] = 10.0193"

                                                          Raise 0.0010"

        Corrected flat fuel = 1.7125"

        React. ———— = +3.28¢
        all support   = +4.73
        25-21 ↑519 = +4.66
        15-7   ————   0
                      + 12.67¢ = 1.7134"
              O = 1.7134 - .0030 = <u>1.7104"</u>

NOTE: FUEL SAME AS <u>No</u> CORE CONF.
GRAPHITE SAME AS <u>NO</u> CORE CONF. EXCEPT CORE IS ADDED.

15-7"   GRAPHITE
    5" REFLECTOR + GRAPHITE CORE   Pg 164

	1/8"	1/16 1111	1 3/16 1170	1/8 x 15 623 / 3/8 x 15 1841	
1, 2" 4895	1997	1 1/2 1233	7/8 1233	1 1/2 x 18 7485	
	2" 3546	2438			
4 1/2"		1 1/2 2098		1 x 15 C 4915	
18455		4"		1 x 15 B 4915	
	3" 5325	6513	3"B 4188	1 x 15 A 4903	27.3 mils gap
			28.8 mil VOID 32.5 mil VOID		
			14-9/32	82-1/4	16-9/32	74-1/4	9/16 x 7 602	
			66-9/16	55	67	37	1/4 x 7 266	
			84-3/8	49	43	2829	3/8 x 7 404	10 MIL DIAPH
	1" 1828	1" 1644	1" 1456	60-1/2	51	42-3/8	36	1/2 x 7 B 536	
				1/2 x 15 2467	
3" 12350				2 x 21 19263	
				1/2 x 25 6868	
				2 x 25 27650	

MASS OF FUEL = 72382 gm
   VOLUME = 3879.89390 cm³
      ρ = 18.65566 gm/cc

MASS OF GRAPHITE = 152987 gm
   VOLUME = 89098.38333 cm³
      ρ = 1.71705 gm/cc   Avg Refl = .4998"

Avg. O.D. ALL FUEL (w't'd) = 14.99612"   OD² = 224.88361
          I.D. = 7.00250"   ID² = 49.03500
25-21 OD Carbon = 24.99799"   624.89950

A-64

15-7   5" ref + core

Nom. Ht. Critical (13-11) & (9-7) = 1"/16   reactivity = + 1.70¢
                   (15-13) & (11-9) = 1²³/32

        Rings   = + 3.58¢
        Diaphragm = - 15.22¢
        S. Stand = + 5.67¢   Lower 0.0017"

1/32" fuel   15-13 =   31.30¢   1.0016¢/mil → TOTAL = 45353
             13-11 =   38.69¢   1.2380
             11-9 :   41.49¢   1.3276   wt vol Avg = 4.5353¢/mil
             9-7 :   30.25¢   0.9680   Core: +.0079
≈ 600 mils carbon on 25-21 =≈ 5.39¢ or .00898¢/mil ← this data from No core run.   45432

    Measurements same as 15-7 (5") & No Core
         Fuel 15-13 :)   = 1.7280"
              13-11 :) as Pg 162   = 1.6993"
              11-9 :)   = 1.7281"
              9-7 :)   = 1.6956"
                    wt vol Avg = 1.7077"

    Carbon 25-21 :)   = 11.2015" (-506)
            21-19 :)   = 11.6438" (-64)
            19-17 :)   = 11.7030" —
            17-15 :)   = 11.7295" (+22)
             Sdia :)   = 10.0193"
         Core Only = 1.700 - .700 - .700 - .701 - .702 - .703 - .700   = 1.7008"

                                                     Raise 0.0010"

Pg 167 →   "clean"
NOTE: changed to comparable configuration but put all fuel
      on top of diaphragm : reactivity = + 8.26¢
                            diaphragm = +0.58¢

        corrected flat fuel height = 1.7070"
React = +1.70¢; all support = +5.97¢ ; 25-21 ↑519 = +4.66¢;
15-7 = 0 ; Core ↑6.9 = +.05 = [+12.38¢ = 1.7077"]
            0 = 1.7077 - .0027 = 1.7050"

15"-7"   7" GRAPHITE ≠ N₀ CORE **ALSO + CORE**   Pg 282

29   25   21   19   17   15   13   ¢

3/4
1364

1½   1.2   2⅛   ¹¹/₁₆   1   1 X 13   3682
7427   4895   3440   960   1262
                                         ¹³/₁₆
                              3   1170

                              3   1   1½   1½ X 13   5509
                              5325   1456   1890

                                                                             ½ X 15   2467

                              2⅜
                              3863   3 B   1 X 15 D   4781
                                           4188

                                                                             1 X 15 C   4915

9   7   1 X 15 B   4915
             28700   5
                             8827   4   1 X 15 A   4903
43550   6513   3A | 2885 | 82 | 74 | 75 | 3/8 X 7   404 ⎫
                                                 4232 | 66 | 55 | 67 | 37 | 9/16 X 7   602 ⎬ IN OR OUT
                                                         | 58 | 80 | 78 | 74 | ½ X 7   536 ⎭
                                                         | 60 | 51 | 42 | 36 |

                                   2 X 25
                                       27650   15 MIL DIAM.

                                   ½ X 25   6868

             1½   1½   1½
5   4½   2677 2438 2098   1½ X 15   7485

24550   18455   1 X 21   9666

                                              2 X 21   19263

No Core   61071
MASS OF FUEL = 62699 gm   Avg Refl = 6.997"
   VOL. = 3268.67272 cm³   + Core Same
   ρ = 18.68323 gm/cc   + Core graphite MASS = 282906 gm
No Core   VOL = 164062.42686 cm³
MASS OF GRAPHITE = 281364 gm   ρ = 1.72437 gm/cc
   VOL = 163150.50258 cm³   Avg. O.D. fuel = 14.99585 (224.87551)
   ρ = 1.7245 gm/cc   Avg. I.D. = 7.00248 (49.03472)

A-66

15-7   7" ref. & No Core   SEE + Core Below

Nom. Wt. Critical = 1 7/16"   reactivity = +17.55¢

Fuel value (1/32") :   15-13 = +42.61¢   1.3635 ¢/mil   REACTIVITY = +17.55¢
                       13-11 = +65.86¢   2.1075   29-25 ↓95mils = -0.10
                       11-9 = +47.40¢   1.5168   25-21 ↑264mils = +1.05
                       9-7 = +40.98¢   1.3113   21-19 ↓349mils = -3.62
                                              ‾‾‾‾‾‾   19-17 ↓64mils = -0.99
                                              6.2991   17-15 ↓41mils = -0.99
                                                               ALL SUPPORT = -2.67¢

              (½ a)
    ring & ring support = + 4.32¢
    support stand }
         diaphragm } = - 1.65   1.4443" = +10.28¢
                                           -1.6 mils = 1.4427" clean ∞
   1/8" x 13" dia carbon top = +17.24¢
   (773 mils) 21-19 (3/4") = 8.97¢
_____

    15-7   7" ref + core   Wt: 1 7/16" → reactivity +18.41¢

        diaphragm = - 2.68¢   + Core
    ring & ring support & support stand = + 5.74¢   React = + 18.41¢
                                                     ALL SUPR = - 3.06
         Fuel value (1/32") 15-13 = 28.00¢   0.8960 ¢/mil   ALL Carbon = - 4.60
                             13-11 = 49.01¢   1.5683   Core = NIL
                             11-9 = 34.55¢   1.1056   1.4443" = +10.75¢
                             9-7 = 39.0¢   1.2480   -2.2 mils = 1.4421" clean
                                               ‾‾‾‾‾‾
                                               4.8179

Wt. of fuel 15-13 = 1.444 - 445 - 444 - 445 - 445 - 445   1.4446"
             13-11 = 1.445 - 445 - 445 - 445 - 445 - 445 - 445   1.4450"
             11-9 = 1.443 - 444 - 445 - 445 - 445 - 446   = 1.4446"
             9-7 = 1.443 - 443 - 443 - 442 - 442 - 443 - 443   = 1.4427"
                                                                  wt avg = 1.4443"

Put measured carbon heights in the drawing
   Core = 1.447 - 447 - 446 - 445 - 445 - 445 - 447 = 1.4460"
  29-25 = 15.522 - .538 - .550 - .550 = 15.5400"
  23-21 = 15.179 - .175 - .186 - .180 = 15.1800"
  21-19 = 15.794 - .795 - .796 - .790 = 15.7937"   13" dia = 14.005 - .026 - .027 - .015
  19-17 = 15.515 - .506 - .505 - .508 = 15.5085"   = 14.0182"
  17-15 = 15.491 - .486 - .490 - .477 = 15.4860"
  15-13 = 14.049 - .029 - .050 - .036 = 14.0410"

35

15 13 " 9 7

35" x 10"

3556 TOT F+V

21.496"

SOURCE HOLE   AIR VENT HOLE

35"X15"X ½"   11.6 Kg

14	33	16	520
66	55	67	37
5	80	42	36

28 65   Void or Core as noted.

35"X15"X 11"

11.527"

1 d	4781
1 c	4915
1 B	4915
1 A	4903

$X_{core} = \frac{3}{8}" + \frac{9}{16}" + \frac{9}{32}"$

mass = 1304

C
Ram No Core = 49276

Ram C + Core = 50580

	1½	5509	A
3 37½	1 c	3745	
	1 B	3760	
1½ 1870	1 A	3682	
	1½	7484	

AL SUPPORT   RAM →

.285
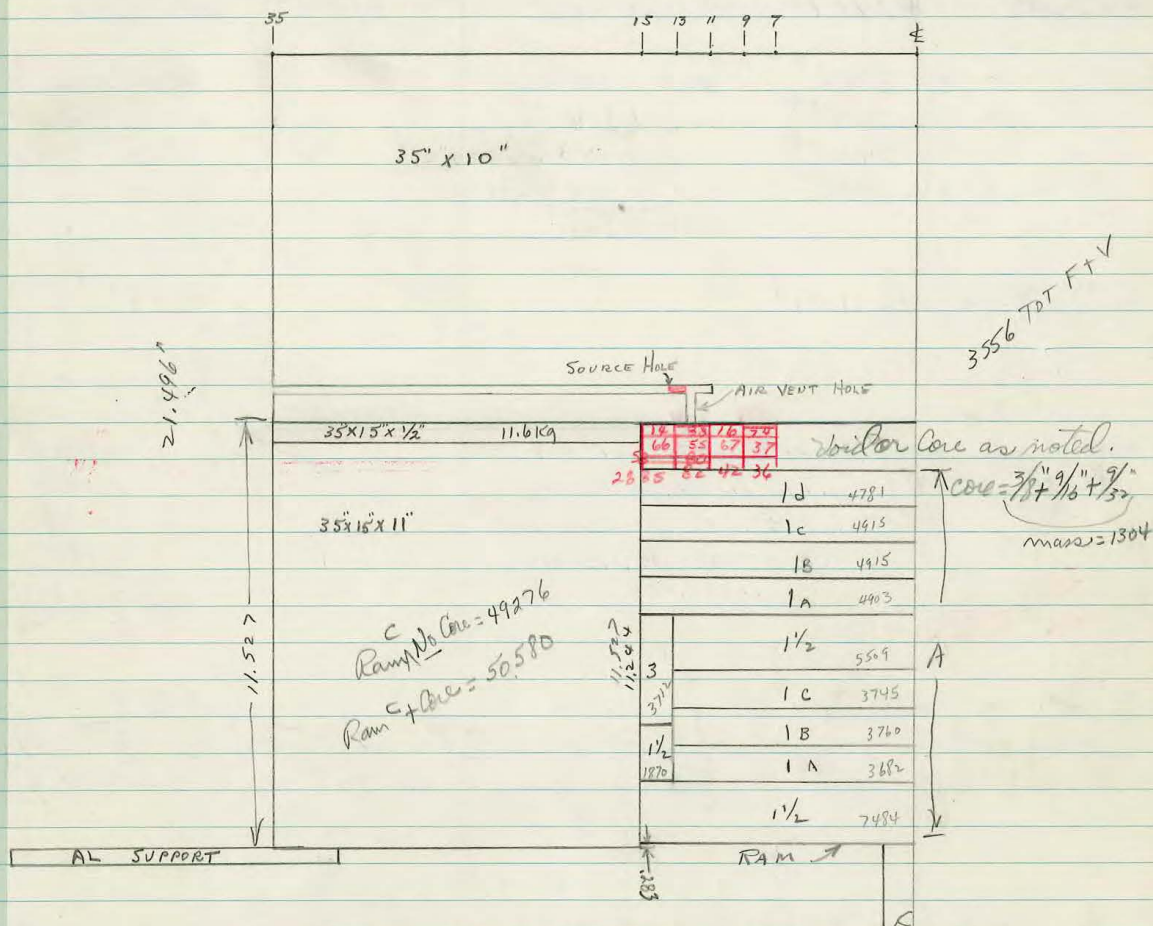
MASS OF FUEL = 51166 gm
   Vol. = 2745.4359 cm³
   ρ = 18.6367 gm/cc
MASS OF GRAPHITE = 49427 gm   (Ram)
Ram GRAPHITE & CORE = 50580 gm

Core – No Core
Same
except Carbon

AVG. WTD OD = 14.99716"   OD² = 224.91480
      ID = 7.00216"   ID² 49.03024

Avg. Refl. = 10.012"

TOT. No Core C = 49.276 + 241.4 + 11.6 + 269.37 = 571.646 Kg; Vol = 335358cm³ ρ = 1.704gm/cc
Total with Core 571.646 + 1304 = 572.950 Kg; Vol = 336169 cm³; ρ = 1.704 gm/cc

15-7   10" Cref. & Void Core & ½ Core as noted

Clean Critical Nom. Ht. = (15-13)&(11-9) = $1\frac{7}{32}$" ; (13-11)&(9-7) = $1\frac{3}{16}$"

Reactivity = +24.07¢ with no core   + 31.29¢ with core

$\frac{1}{32}$" Value 15-13 = 37.06¢ or ✓ 1.186 ¢/mil   36.16¢ or 1.157 ¢/mil
         13-11 = 56.68¢   ✓ 1.814 ¢/mil   49.39¢ or 1.580 ¢/mil
         11-9 = 54.47¢   ✓ 1.743 ¢/mil   47.26¢   1.512 ¢/mil
         9-7 = 34.48¢   1.103 ¢/mil   32.09¢   1.026 ¢/mil
                    TOTAL 5.846

all
Support value = 11.01¢   8.84¢

Wt of fuel 15-13 = 1.228÷.228÷.228÷227÷227   Same   1.2276"
         13-11 = 1.196÷196÷196÷196÷196÷196   Same   1.1960
         11-9 = 1.228÷228÷228÷228÷228   1.2280
         9-7 = 1.193÷193÷194÷193÷194   1.1935
                   .194÷.194 = 1.1935   w̄ avg = 1.2128

                                          graphite
              with Core
Clean critical compared to above but with the $[\frac{1}{2}" \times (35" \times 15")]$
disc removed = The ½" piece = 22.39¢ or 0.04478¢/mil

A 10.017÷.020÷.016÷.012 = 10.0162   A = Same   = 10.0162
                                     Core = 1.223÷.222÷.221÷.222 = 1.2220

                                                1.222

45   25   15 13 " 9 7   ₵
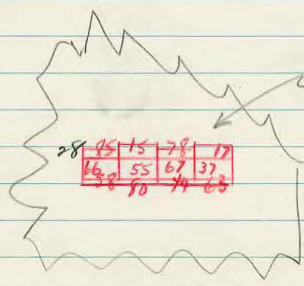
FUEL FOR No Core.
GRAPHITE IS SAME

28 95 15 78 17
66 55 67 37
38 80 74 63

2813 cm³ 70T V+F

30.00"

683.6

13-11

28 55 42 18 74   9/16   B
66 55 67 38   1/8 9/32
58 80 74 63

2202 cm³

1/2
1 1/2   A

Carbon
No Core   8   330.1

mass=
1413.571 Kg
Vol=
80487 cm³
ρ=1.756 gm/cc

Carbon
+ Core

mass=1414.601
Vol=80548.3 cm³
ρ= 1.756 gm/cc

8   328.8

10   Range) = 71.07¹
    No Core
    Range) = 72.10¹
    + Core

VOL. FUEL = 2152.2276 cm³ Core No Core   Vol= 2166.5832
MASS OF FUEL= 40133 gm   40406 gm
   Avg OD Fuel= 14.99625" (²) = 224.88751   Same
   Avg ID Fuel= 7.00220" (²)= 49.03080   7.00164" (²) = 49.02296
MASS OF GRAPHITE=
   FUEL ρ= 18.6471 gm/cc   — 18.6496 gm/cc
                              Avg. Refl = 14.997"

A-70

15-7 ≠ 15" C.ref. + Core   No Core ↓

Man. Wt. Critical : (15-11 ≠ 9-7) @ ¹⁵/₁₆" ;   (15-13 ≠ 11-9) @ ³¹/₃₂" ; (13-11 ≠ 9-7) @ ¹⁵/₁₆"
                    (11-9) @ ³¹/₃₂"

reactivity = − 5.54¢   + 24.90¢

		¢/mil		¢/mil
¹/₃₂" fuel value: 15-13 :	39.88¢	1.2761	39.89¢	1.2764
13-11 :	48.44¢	1.5500	44.51¢	1.4243
11-9 :	47.14¢	1.5084	45.63¢	1.4601
9-7 :	27.68¢	.8858	36.93¢	1.1817

all supports = 2.22¢   2.47¢

                        .951   .948 .951   .9495
Wt. of fuel : 15-13 = 0.951 · .948 · .948   Same only on 15-13   .9495
              13-11 : 0.942 · .942 · .942   .9420   0.972 · .972 · .972 · .971 · .971 · .972   .9716
              11-9 : 0.971 · .971 · .971 · .972 · .972 · .972   .9715   0.940 · .940 · .940 · .939 · .939 · .940   .9396
Lorkhp   9-7 0.941 · .941 · .962 · .941 · .941   .9411   0.941 · .941 · .942 · .941 · .941 · .940   .9413
in ↴   .940   .971 · .971 · .971 · .972 · .972 · .971
                    as drawn ↴
                          wt avg = 0.9509   wt avg = .9572

       5.005
A = ‾‾‾‾‾   5.005 · .005 · .006 · .005 = .0052
B = 0.970 · .971 · .970 · .969   = 0.9700
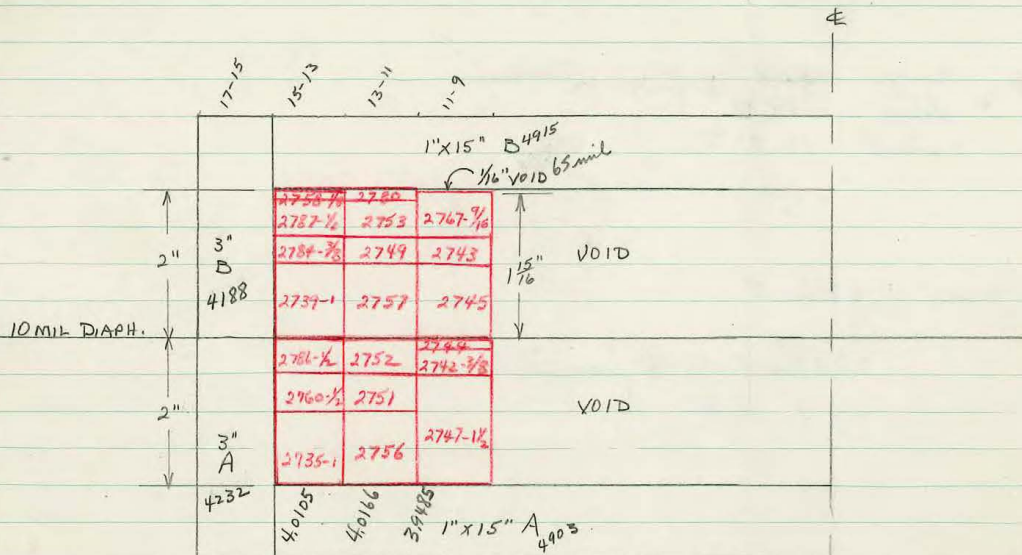
MASS OF TOP GRAPHITE = 9103 gm   TOTAL = 18.238 Kg
BOTTOM   = 9135 gm

MASS OF TOP FUEL   = 68795 gm   TOTAL = 138.140 Kg
BOTTOM   = 69345 gm

AVG. O.D. ALL FUEL (wt'd) = 14.99475"   AVG. I.D. (wt'd) = 9.00175"
AVG. Ht ALL FUEL (wt'd) =   224.84252   81.03150

FUEL VOLUME = 7394.96904 cm^3
FUEL ρ = 18.68026 gm/cc

graphite volume = 10768.40825 cm^3
        ρ = 1.69365 gm/cc

Avg Rfl = 0.999"

15"-9"   1" Cnf. WO Core

Nom. Ht Critical   4" on 15-11) & 3 5/16 on 11-9 = + 20.95¢

    rings = 5.19¢
    diaph = −19.38¢
    S. stand = 16.32¢

11-9 fuel @ .63¢/mil

    1.83¢/mil 15-9 from Curve
    1.87 used

Ht ALL FUEL = 15-13 = 4.009 −.009 −.011 −.013 −.012 −.009   = 4.0105 "
             13-11 = 4.015 −.017 −.017 −.017 −.018 −.016   = 4.0166 ✓
             11-9 = 3.946 −.946 −.948 −.951 −.952 −.948   = 3.9485
                                             w.avg = 3.9953 "

1 × 15 B = 0.998
1 × 15 A = 0.9995
(17-15) 3+3 = 6.035 −.035 −.035 −.037 −.034 −.035   = 6.0351 · (+40 mils)

CARBON TOP   17-15   3.029
           15   0.998

EVEN FUEL HT. = 4.0133 "   or   3.9953 "
SKY HOOK REACTIVITY = + 59.77¢   + 18.92 ¢

    O React fuel Ht = 3.9898 ✓

REACT. = + 20.95¢
ALL SUPPORT = − 2.13
             + 18.82 = 3.9953 "
        O = 3.9953 −.0102 = 3.9851 "
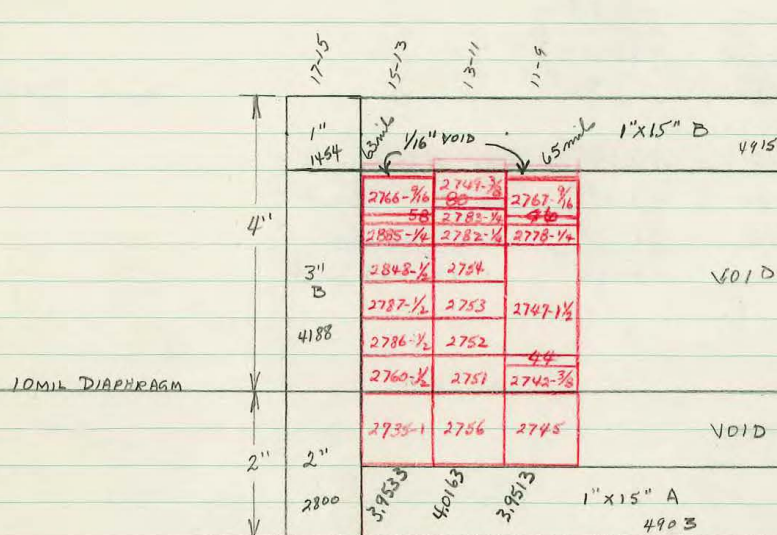
MASS OF TOP GRAPHITE = 10557 gm   TOTAL = 18.260 Kg
BOTTOM   = 7703 gm

MASS OF TOP FUEL = 10289 / gm   TOTAL = 137.501 Kg
BOTTOM   = 34610

AVG. O.D. ALL FUEL (WT'D) = 14.99515" $(^2)$ 224.85452
AVG. I.D. ALL FUEL (WT'D) = 9.00169" $(^2)$ 81.03042
~~AVG He. ALL FUEL (WT'D) =~~

FUEL VOLUME = 7355.77849 cm³
FUEL ρ = 18.6929 gm/cc

graphite vol. = 10741.91021 cm³
        ρ = 1.69988 gm/cc

Avg. Refl = 0.999"

A-74

15":9"   1"C r/f WO Core(c)

$$3\,\tfrac{15}{16}" \text{ on } (15-13) \,\text{¢}\, (11-9) + 4" \text{ on } 13-11 = +0.67\text{¢}$$

rings = 5.58¢
diaph = -10.52¢
S. stand = 17.36¢   Raise .0064"

$\tfrac{1}{16}$ Ring 11-9 = 39.49¢   or 0.6318¢/mil ✓
$\tfrac{1}{16}$ 13-11 = 43.28¢   or 0.6924¢/mil ✓
$\tfrac{1}{16}$ 15-13 = 31.78¢   or 0.5084¢/mil ✓
                    114.55¢   1.8328¢/mil

Ht. all Fuel 15-13: 3.955-.95-.952-.955-.952-.954   = 3.9533"
              13-11: 4.015-.015-.015-.017-.018-.017-.017   = 4.0163 ✓
              11-9: 3.952-.951-.951-.948-.952-.954   = 3.9513
                                            wt avg 3.9737"

    1 X 15 B = 0.998
    1 X 15 A = 0.9995
(17-15) 2737 ¾ = 5.797-.748-.748-.02-.798-.781   5.7958   60093 (+27)

                                                              ok

                                            Reoct =   +0.67¢
                                            all support   -12.42
                                            15-9   →   0
EVEN FUEL HT. = 4.0163"   -11.75¢ = 3.9737
SKY HOOK REACTIVITY = +61.33¢
                                            0 = 3.9737+.0064 = 3.9801"

Corrected flat fuel Ht = 3.9673"
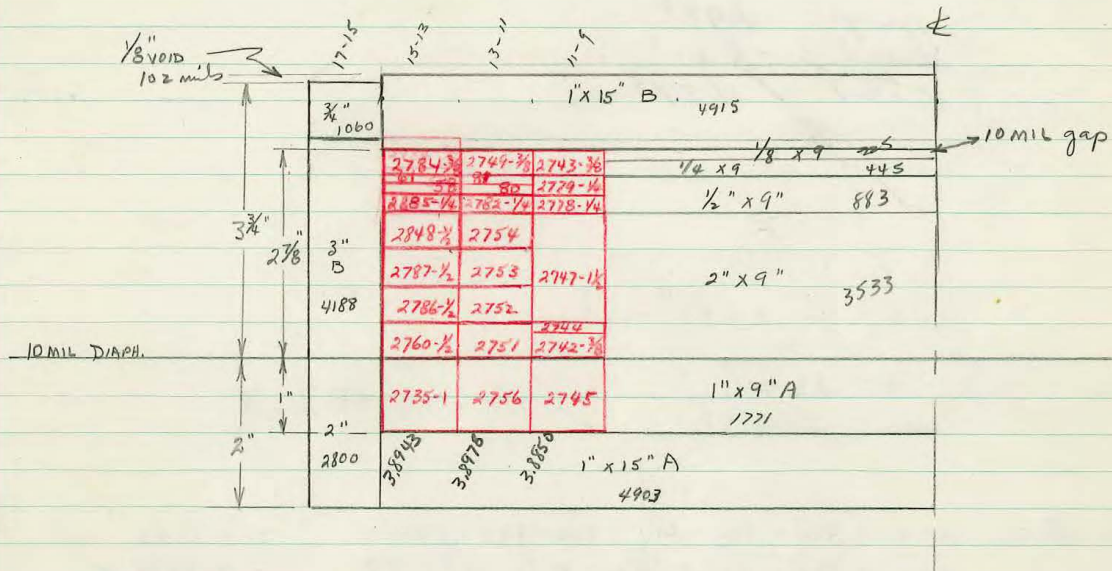
MASS OF TOP GRAPHITE = 15249 gm   TOTAL = 24.723 Kg
BOTTOM   = 9474 gm

MASS OF TOP FUEL = 99970 gm   TOTAL = 134.580 Kg
BOTTOM   = 34610 gm

AVG. O.D. ALL FUEL (w'T'D) = 14.99487" OD^2 = 224.84597
AVG. I.D. ALL FUEL (w'T'D) = 9.00215" ID^2 = 81.03870
~~AVG. Ht. ALL FUEL (w'T'D) =~~

FUEL VOLUME = 7205.20898 cm³
FUEL ρ   = 18.6781 gm/cc

graphite vol = 14620.87038 cm³
          ρ = 1.69093 gm/cc

Avg. Refl = 0.999"

15"-9" 1" Circf + Core(C)

Nom. Ht 3⅞" Critical   +21.0¢

  rings = 4.94¢
  graph = -8.21¢
  s.stand = 11.57¢

               Lower   .0069"

17-15 = ≐.0245¢/mil

15-9 = 1.64¢/mil
Core ≈ .0343   > TOT = 1.6743¢/mil

Ht. all Fuel 15-13: 3.894 - .895 - .897 - .894 - .892 - .894   = 3.8943"
    13-11 = 3.898 - .898 - .898 - .898 - .898 - .897   = 3.8978 ✓
    11-9 = 3.884 - .884 - .884 - .886 - .887 - .885   = 3.8850
                w.tavg : 3.8928"
Carbon
1st Core Only 13.889 - .888 - .889 - 887 - 887 - 885 - .887   = 3.8874
  1 X 15 B = 0.998
  1 X 15 A = 0.9995
(17-15) 2+3+¾ = 5.797 - .798 - 798 - 802 - .799 - 781   = 5.7958   (-97)

EVEN FUEL HT. = 3.8928"
SKY HOOK REACTIVITY = +12.70¢   (NOT considered: ⅛"VOID 17-15 carbon)
             10 mil gap over core).

① Best Fuel Ht = 3.8857" ✓   reactiv =   +21.00¢
          all support =   - 8.30
          15-9 - -   0
          Core ↑5.4   + .18   ①=3.8928-.0088=3.8840"
          17-15 ↑10z =   +2.49
             +14.79 = 3.8928"
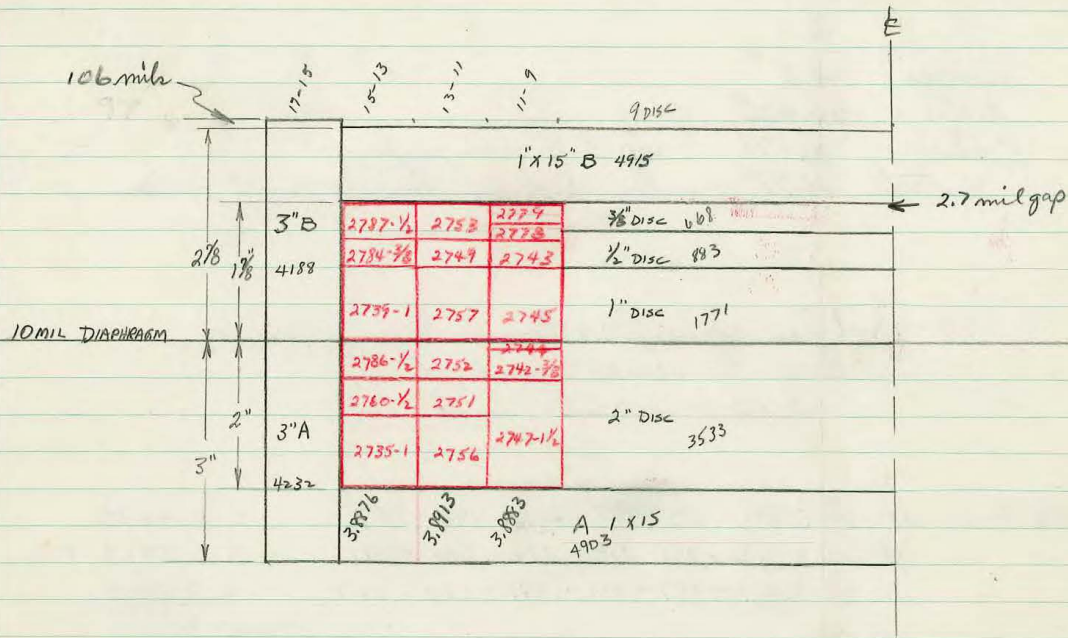
MASS OF TOP GRAPHITE = 12425 gm   TOTAL = 25.093 Kg
BOTTOM   = 12668 gm

MASS OF TOP FUEL = 65088 gm   TOTAL = 134.433 Kg
BOTTOM   = 69345 gm

AVG. OD ALL FUEL (W'TD) = 14.99469" $OD^2 = 224.84072$
AVG. I.D. ALL FUEL (W'TD) = 9.00186" $ID^2 = 81.03348$
~~AVG. 1/4 ALL FUEL (W'TD)~~

FUEL VOLUME = 7198.07352 cm^3
FUEL ρ = 18.67624 gm/cc

graphite Vol = 14823.98294 cm^3
        ρ = 1.692729 gm/cc

Avg. Refl = 0.999"

15'-9" 1"C ref. + C Core

Nom. Ht Critical = 3⅞"   = +21.73$^{¢}$

rings = 4.8$^{¢}$
diaph = −14.42$^{¢}$
s.stand = 10.87$^{¢}$ (up ≈ ½" from surface
s.stand 16.87$^{¢}$ when dropped down against carbon ⟩ 13.87

15-9 fuel from curve = 1.64$^{¢}$/mil ⟩ 1.6839$^{¢}$/mil
     Core ≈ .0439$^{¢}$/mil
     17-15 = .0245/mil

Ht. all FUEL 15-13 = 3.885-.885-.888-.891-.890-.887   = 3.8876"
      13-11 = 3.892-.891-.890-.892-.892-.891   = 3.8913 ✓
      11-9 = 3.887-.887-.886-.891-.892-.887   = 3.8883
                              wt avg = 3.8890"

Ht. of Core only = 3.888-.888-.889-.889-.891-.887   = 3.8886
  1×15 B = 0.998
  1×15 A = 0.9995
(17-15) 3+3 = 6.035-.035-.035-.037-.034-.035 = 6.0351

CARBON TOP   12-15 = 5.004"
     15" Disc = 1.998
     1" disc =

EVEN FUEL HT. = 3.8890"
SKY HOOK REACTIV. = +14.48$^{¢}$

    1" Disc =

O React Ht = 3.8810" ✓

  17-15 ↓106.0 = −2.59$^{¢}$
  React. = +21.73$^{¢}$
  all support = −7.25
  15-9 → = 0
  Core (mil) = 0
     +11.89$^{¢}$ = 3.8890"
    O = 3.8890 − .0070 = 3.8820"

15"-9"   2" GRAPHITE ≠ No CORE

MASS OF FUEL = 110.555 Kg
    VOLUME = 5913.68103 cm³
    ρ = 18.69478 gm/cc

MASS OF GRAPHITE = 41343 gm
    VOLUME = 24249.85413 cm³
    ρ = 1.70487 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 14.99501"   OD² = 224.85032
                I.D. = 9.00188"   ID² = 81.03384
19-17 OD Carbon   = 18.99977"   ———— 360.99126

Avg Rifl = 2.000"

15-9   2" ref + NO core

⌐ Nom. Ht. Critical = 3³⁄₁₆"   reactivity = + 24.89¢
         recheck after all below = + 24.26¢
         Rings = + 4.22¢   115
     Diaphragm = − 18.40¢
Support Stand = + 13.33¢

         fuel
remove ¹⁄₃₂" 15-9 : ≃ 62.59¢
       ¹⁄₃₂" 11-9 = 21.47¢   0.6870¢/mil ✓
       ¹⁄₃₂" 13-11 = 28.35¢   0.9072   ✓
       ¹⁄₃₂" 15-13 = 20.50¢   0.6560 ✓ total → 2.2502¢/mil

Ht of fuel = 15-13 = 3.192 −.193 −.191 −.196 −.192 −.192 = 3.1926"
           13-11 = 3.200 −.200 −.199 −.200 −.200 −.202 = 3.2001"
           11-9 = 3.192 −.192 −.191 −.192 −.192 −.192 = 3.1918"
                                              wt avg = 3.1948"

Ht of 19-17 ring : 7.200 −.206 −.212 −.214 −.208 −.208 −.207 −.210 = 7.2081"
       17-15 ring : 7.206 −.214 −.217 −.208 −.209 −.209 −.207 = = 7.2100"
       15 dia = Same as 91   = 4.0147"

     Even Fuel Ht = 3.1948
     Sky Hook Reac = + 25.64

     o React Ht = 3.1834 "

     React   =   + 24.58¢
   all support   =   + 0.85
     15-9   → =   0
                    +25.43¢ = 3.1948"
                    0 = 3.1948 −.0113 = 3.1835"

A-81

15"-9"   2" GRAPHITE + GRAPHITE CORE

¢

3/4 1255	3/4 1060		1×15 B 4915	
	7/8 1233		1×15 A 4903	
2 3/8 3863	1 1/4 2100	58 80 46 / 3214-9/16 3215 3216 / 2885-1/4 2782 2778-1/4 / 2760 2753 2742-3/4	1/4×9 445 / 3/8×9 668 / 1/2"×9" 883	36.5 mils gap
	2"	2939-1 2752-1/2 2776 / 2751	2"×9"	10 MIL DIAM
4" 6513	2770	2735 2756 2745	3533	
		3.1693 3.1690 3.1643	1"×17"D 6268	
			1"×17"A 6261	

MASS OF FUEL = 109568 gm
VOLUME = 5863.68688 cm³
ρ = 18.68585 gm/cc

MASS OF GRAPHITE = 46670 gm
VOLUME = 27424.84131 cm³
ρ = 1.70174 gm/cc

AVG. O.D. ALL FUEL (WT'D) = 14.99525"   OD² = 224.85752
          I.D. = 9.00212"   ID² = 81.03816
19-17 OD Carbon = 18.99877"   ——— 360.95326

Avg. Refl = 2.000"

15-9   2" ref + core.

Nom. Ht. critical = Fuel = 3$\frac{5}{32}$" C.Core = 3$\frac{1}{8}$ → reactivity = +27.93¢

Rings = + 4.14¢
Diaphragm = −13.98¢
S. Stand = + 13.18¢

remove $\frac{1}{32}$" fuel 15-13 ring : +20.96¢   0.6707 ¢/mil
$\frac{1}{32}$"   13-11   : +22.77¢   0.7286
$\frac{1}{32}$"   11-9   : +22.54¢   0.7212
                                         2.1205 ¢/mil
            Core ⌐   .0183
                                         2.1388

Ht of fuel 15-13 = 3.168−.168−.169−.171−.171−.169   = 3.1693"
           13-11 = 3.168−.169−.169−.170−.170−.168   = 3.1690"
           11-9 = 3.164−.165−.164−.164−.164−.165   = 3.1643"
                                            wt avg 3.1678"

Ht of C   19-17 = 7.155−.155−.155−.163−.163−.167−.165−.158 = 7.1601"
          17-15 = 7.156−.160−.158−.154−.153−.160−.154   = 7.1564"
          15+9 = Same as Pg 91   = 4.0147"
          Core = 3.133−.133−.136−.133−.131−.133−.131 = 3.1328"

        Even Fuel Ht = 3.1678"
        Sky Hook React = + 24.59¢

        O React Ht = 3.1562" ✓

React.   = + 27.93¢
all support   = − 3.34
15-9   → =   0
Core ↑ 3.5 :   + 0.06
                 + 24.65 = 3.1678"
O = 3.1678 − .0115 = 3.1563"

21-19 19-17 17-15 15-13 13-11 11-9   ₵

1⅛	13/16"	13/16"			1×15C 4915
1997	1334	1170			
	1"	¾"			1×15B 4915
	1144	1060			
3"					1×15A 4903
5325	2⅜	2⅞"	14-³/₃₂	15	16
	3863	3776	66·⁷/₁₆	55	67
			84⅞	49	43
			60·½	51	42⅞
2"	1½	1½	35-1	56	45
3546	2438	3098			

VOID   (between 16/67/43 column)
VOID

10 MIL DIAPH.

2.7258   2.7295   2.7268

1×19B   7838
1×19A   7828

| 1½" |
| 2677 |

1×21   9656

MASS OF FUEL = 94316 gm
    VOLUME = 5048.53923 cm³
        ρ = 18.68183 gm/cc

MASS OF GRAPHITE = 70993 gm
    VOLUME = 41645.11420 cm³
        ρ = 1.70471 gm/cc

Avg O.D. ALL FUEL (w't'd) = 14.99515"   OD² = 224.85452
             I.D. = 9.00160"   ID² = 81.02880
21-19 OD Carbon = 20.99948"   ———   440.97816

avg. Refl = 3.001"

Nom. Ht. Critical = $2\frac{23}{32}$"   reactivity = + 25.38¢

     Rings = + 4.14¢
  Diaphragm = − 19.62¢
  S. Stand = + 8.33¢

$\frac{1}{32}$" fuel 15-13 = 22.22¢   0.7110 ¢/mil ✓
           13-11 = 31.01¢   0.9923 ✓
           11-9 = 23.96¢   <u>0.7667</u> ✓
                  total 2.4700 ¢/mil

Ht. of fuel 15-13 = 2.726 −.724 −.726 −.726 −.727 −.726   = 2.7258"
          13-11 = 2.730 −.727 −.729 −.730 −.730 −.731   = 2.7295"
          11-9 = 2.728 −.727 −.727 −.727 −.726 −.726   <u>= 2.7268"</u>
                                           avg = 2.7261"

Ht of Carbon 21-19 = 8.670 −.668 −.685 −.670 −.678 −.680 −.672 = 8.6747" (−52)
            19-17 = 8.715 −.715 −.717 −.712 −.710 −.713 −.715 = 8.7138"
            17-15 = 8.760 −.758 −.754 −.750 −.750 −.757 −.760 = 8.755" (+30)
            15 Dia = 6.014 −.016 −.016 −.015 −.016 −.019 −.022 = 6.0168"
                                               0-12

    Corrected flat fuel Ht = 2.7158" ✓

React   = + 25.38
all support = + 7.15
15-9   = 0
21-15 mil = 0
              + 32.53 = 2.7261"
0 = 2.7261 − .0131 = <u>2.7130</u>"

MASS OF FUEL = 93279 gm
   VOLUME = 4995.48490 cm³
     ρ = 18.67266 gm/cc

MASS OF GRAPHITE = 75779 gm
   VOLUME = 44459.96809 cm³
     ρ = 1.70443 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 14.99481"   OD² =   224.84432
           ID = 9.00163"   ID² =   81.02934
21-19 OD Carbon = 20.99948   440.97816
   Avg Refl = 3.001"

A-86

15-9   3" ref + Core

Nom. Wt. Critical = 2"/16"   reactivity = + 7.11$

        Rings = + 4.07$
        Diaphragm = -17.10$
    S. Stand = + 8.18$ Lower   .0044"

1/32" fuel 15-13 = 31.08$ - 0.9945$/mil ✓
            13-11 = 28.91$ 0.9251 ✓
            11-9 = 24.68$ 0.7898 ✓   wt Vol Avg = 2.7094$/mil

            core ————   2.7094
                                 .0180
                                2.7274

Wt. of fuel 15-13 = 2.700 -.700 -.701 -.700 -.702 -.702   = 2.7008"
             13-11 = 2.697 -.698 -.696 -.695 -.697 -.698   = 2.6968"
             11-9 = 2.699 -.699 -.699 -.698 -.699 -.698   = 2.6986"
                                        wt vol Avg = 2.6988

Wt of Carbon = 21-19 = Same as 1 2 3   = 8.6747" (-23)
               19-17 = Same as 1 2 3   = 8.7138" (+18)
               17-15 = Same 1 2 3   = 8.7555" (+57)
               15-9 = Same as 1 2 3   = 6.0168"
               Core = 2.700 -.698 -.699 -.702 -.698 -.697 -.700 = 2.6991"

                                                    Lower .0003

        Corrected flat fuel height = 2.6947" ✓

    React   = + 7.11$
    all support   = + 4.85
    15-9   ——— = 0
    21-15 mil   = 0
    Core ↓ mil   = 0
                     +11.96$ = 2.6988"
              0 = 2.6988 - .0043 = 2.6945"

TOP 1⅞" U MASS = 58632 gm

TOP C MASS = 38807 gm

Total U   93.242

Total C   12.662

BOTT. 1" U MASS = 34610 gm

BOTT C MASS = 33855 gm

Pos	#		MASS
1	2758	(⅛)	1685
2	2766	(9/16)	7605
3	2787	(½")	6788
4	2848	(½")	6748
5	2780	(⅛")	1440
6	2755	(9/16")	6514
7	2757	(1")	11575
8	2744	(⅛")	1223
9	2767	(9/16")	5410
10	2776	(1")	9644
11	2735	(1")	13409
12	2756	(1")	11567
13	2745	(1")	9634

Pos	Size	Mass
1	1"x5" (19-21)	8827
2	1"x ¾" (17-19)	1255
3	1"x 4" (17-19)	6513
4	1"x 2" (15-17)	2800
5	1"x 3" (15-17)B	4188
6	⅛"x 15" Disc	625
7	1" x 15" Disc B	4915
8	1" x 15" Disc D	4781
9	1" x 15" Disc A	4903
10	1"x1" (19-21)	1828
11	1"x1" (17-19)	1644
12	1"x1" (15-17)	1454
13	1" x 21" Disc	9666
14	2" x 21" Disc	19263

Avg O.D. Fuel (wtd) = 14.995094" OD^2 = 224.85284

Avg I.D. Fuel (wtd) = 9.00144" ID^2 = 81.02592

Fuel vol = 4989.79152 cm³

ρ = 18.686552 gm/cc

graphite vol = 42676.06307 cm³

ρ = 1.70264 gm/cc

Avg Refl = 3.005"

15"-9"   3" C ref. w/o Core

Nom. Ht. Critical = 2¹¹/₁₆"   = + 2.27$^{¢}$

Stand + rings = 13.43$^{¢}$
       diaph = −15.02$^{¢}$

wt ht = 3.6947"

Reactivity _____ = + 2.27$^{¢}$
all support _____ = + 1.59
   15 + 9   = 0
   19 − 15   mil   = 0
                   _____
                   + 3.86 = 3.6947"

0 = 3.6947 − .0015 = 3.6932" but has
                              extra ⅛" × 15" Carbon
fuel = 2.47$^{¢}$/mil   on top.
from pg 123

EVEN FUEL HT. = 3.6947" ✓
SKY HOOK REACTIVITY = + 3.86$^{¢}$ (carbon 21-15 ring $^{wt.}$error not complied)
                                    (also contain ⅛" × 15" dia extra carbon $^{wt.}$).

15"-9"   3"C   C center   ~46

Top 1 11/16" U mass = 58632 g

Top C mass = 38807 gm

Top Core C mass = 2985 gm

Bott. 1" U mass = 34610 gm

Bott C mass = 33855 gm

Bott Core C mass = 1771
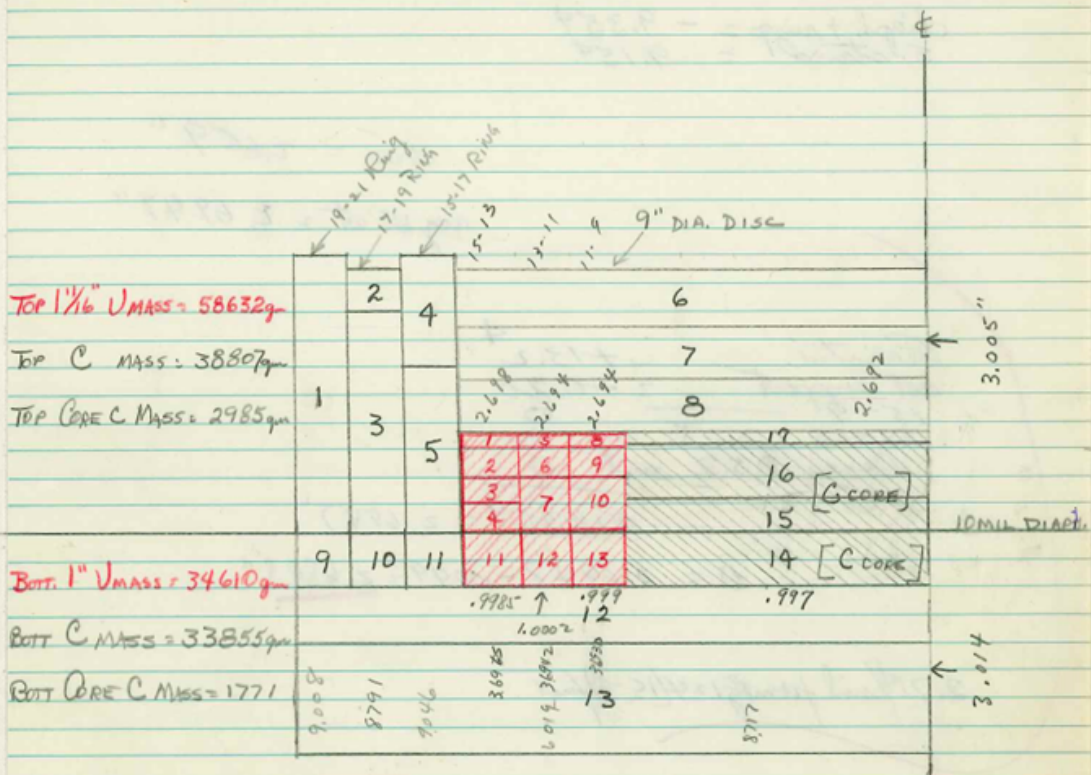
Pos	#		MASS
1	2758	(1/8")	1685
2	2766	(9/16")	7605
3	2787	(1/2")	6788
4	2848	(1/2")	6748
5	2780	(1/8")	1440
6	2755	(9/16")	6514
7	2757	(1")	11575
8	2744	(1/8")	1223
9	2767	(9/16")	5410
10	2776	(1")	9644
11	2735	(1")	13409
12	2756	(1")	11567
13	2745	(1")	9634

Pos	Size	Mass
1	1"x5" (19-21)	8827
2	1"x3/4" (17-19)	1255
3	1"x4" (17-19)	6513
4	1"x2" (15-17)	2800
5	1"x3" (15-17) B	4188
6	1"x15" Disc B	4915
7	1"x15" Disc D	4781
8	1"x15" Disc A	4903
9	1"x1" (19-21)	1828
10	1"x1" (17-19)	1644
11	1"x1" (15-17)	1454
12	1"x21" Disc	9666
13	2"x21" Disc	19263
14	1"x9" Disc A	1771
15	9/16"x9" Disc	998
16	1"x9" Disc B	1762
17	1/8"x9" Disc	225

Avg. O.D. Fuel (w't'd) = 14.995094"
Avg. I.D. Fuel (w't'd) = 9.00144"
Fuel Volume = 4989.79152 cm³
ρ = 18.686552 gm/cc
Graphite Vol = 45104.95629 cm³
ρ = 1.71639 gm/cc

Avg Rift = 3.006"

15"-9"   3" C ref. + C core

Nom. Ht Critical = 2"/16 = +13.2¢

diaph + ring = − 9.35¢
5. stand' = 9.15¢

core = 2,659"

avg Ht wt = 2.6947"

Reactiv. = +13.2¢
all support = +0.20
15-9   0
21-15 mil 0
Core ↑5.7 mil 0
          +13.40¢ = 2.6947"
0 = 2.6947−.0049 = 2.6898"

2.71¢/mil from Pg 124 (15-9 fuel

EVEN FUEL HT. = 3.6947"
SKY NOOK REACT. = +13.40¢   (Carbon 21-15 ring Ht error not considered)

15"-9"   5" REFLECTOR & No CORE   ≈ ß 168

1.4468	25-21	21-19	19-17	17-15	15-13	13-11	11-9		

1"   1"   3/4"   1/2 × 15   2467
1828   1644   1060

        1/8"   1/16"   1 1/2 × 15
        1997   960   7485

                2 1/8"   1 × 15 c   4915
7"   3440   2 4/16"
28700   3776   1 × 15 B   4915

        5"
                4"   1 × 15 A   4903
8827   6513   3"A | 2825 | 82 | 78 |
                               | 58 | 80 | 44 |
                       4252 | 85-3/8 | 50 | 43 |
                               | 84-3/8 | 49 | 42 |
                               | 86-1/2 | 52 | 45-1 |
                               | 60-1/2 | 51 | |

                                                        10 mil DIAPH.

                | 2.1371 | 2.1438 | 2.1296 | 1 × 21   9666

3"
12350   2 × 21   19263

                                                        2 × 25   27650

MASS OF FUEL = 73831 gm
    VOLUME = 3956.29816 cm³
        ρ = 18.66163 gm/cc

MASS OF GRAPHITE = 156591 gm   Avg Refl = 4.996"
    VOLUME = 91129.58482 cm³
        ρ = 1.71833 gm/cc
AVG O.D. ALL FUEL (WT'D) = 14.99529"   OD² = 224.85872
        ID = 9.00179"   ID² = 81.03222
25-21 OD Carbon = 24.99750"   624.87500

15-9   5" ref & No Core

Nom. Ht. Critical = 2⅛"   reactivity = −13.39¢

    Rings = + 5.25¢
  Diaphragm = + 0.49¢
  S. Stand = + 6.07¢   Raise 0.0086"

1/32" fuel 15-13 = 29.34¢   0.9389 ¢/mil ✓
        13-11 = 31.96¢   1.0227 ✓
        11-9 = 28.41¢   0.9091 ✓   wt vol Avg = 2.8707¢/mil
⅛" graphite 15" chat op = −21.13¢   2.8707

Ht. of fuel 15-13 = 2.136 −.138−.137−.136−.139−.137   = 2.1371"
       13-11 = 2.143−.144−.145−.144−.144−.143   = 2.1438"
       11-9 = 2.130−.130−.130−.129−.129−.130   = 2.1296"
                     wt vol Avg = 2.1372"

                                                  (.128)
Ht. of Carbon 25-21 : 7.0000 + 5.0092   = 12.0092"
    21-19 : [7.128−.133−.123−.119−.119−.121−.123−.130] +5.007 = 12.1252" (−38)
    19-17 : [7.125−.125−127−127−130−.126−.125−125] +5.007 = 12.1269" (−36)
    17-15 : [7.132−.134−.129−.137−.132−.133−133] +5.007 =12.1213"(−16)
    15 dia = 10.0147"   = 10.0147"
                                    Raise .0068"

Corrected flat fuel height = 2.1526" ✓

Reactivity   = −13.39¢
all support   = − 10.83
15-9   = 0
                −24.22¢ = 2.1372"
    0 = 2.1372 +.0084 = 2.1456"

NOTE: FUEL SAME AS <u>No</u> Core run
GRAPHITE SAME AS <u>No</u> Core run but +core.

15"-9"   5" REFLECTOR + CORE (GRAPHITE)   Pg 171

11.9969

1"	1"	3/4" 1060		1/2 X 15	2467
1828	1644	9/16			
1 1/8"	"	960		1 1/2 X 15	7485
1997	2 1/8				
	3440	2 11/16		1 X 15 C	4915
7"		3776		1 X 15 B	4915
28700	5"				
	8827	4"		1 X 15 A	4903

2885	82-1/4	78	1/4 X 9	445
58	80	44	3/8 X 9	668
85-3/8	50	43	1/2 X 9	883
84-3/8	49	42		
86-1/2	52	45-1	1 X 9	1771
60-1/2	51			

6513 3A   4?3?

	1 X 21	9666
3"	2 X 21	19263
12350		
	2 X 25	27650

MASS OF FUEL = 73831
    VOLUME: 3956.29816 cm³
        ρ = 18.66163 gm/cc

MASS OF GRAPHITE = 160358 gm
    VOLUME: 93351.21881 cm³   Avg Refl = 4.996"
        ρ = 1.71779 gm/cc

AVG. O.D. ALL FUEL (W'TD) = 14.99529"   OD² = 224.85872
            I.D. = 9.00179"   ID² = 81.03222
25-21 OD Carbon = 24.99750"   ─────
                                              624.87500

A-94

15-9   5"ref + Core

Dem. Wt. Critical = 2⅛"   reactivity = +17.07 ¢

        Rings = + 5.29¢
    Diaphragm = 0.0¢
    S. Stand = +4.97¢   Lower 0.0079"

¹/₃₂" fuel 15-13 = 26.93¢   0.8617 ✓
          13-11 = 40.74¢   1.3036 ✓
          11-9 = 39.69¢   1.2700   wt vol Avg = 3.435 ¢/mil
                            ‾3.4353‾
                            +.002
          Core   3.4373

Wt. of fuel 15-13 = Same as No Core   = 2.1371"
           13-11 = Same   = 2.1438"
           11-9 = Same   = 2.1296"
                              wt vol Avg = 2.13725"
                                                              (-128)
Wt of Carbon 25-21 : 7.0000+5.0092   (-103)   = 12.0092"
            21-19 :   Same   (+10)   = 12.1252"
            19-17 : Same — 168   (+14)   = 12.1269"
            17-15 = Same as B₂168   (+9)   = 12.1213"
            15 dia = 10.0147"   = 10.0147"
            Core = 2.130 -.131 -.130 -.130 -.130 -.130 -.133 -.128 = 2.1302"
                                                      Raise 0.0003"

corrected flat fuel height = 2.1296" ✓

    Reactivity   = +17.07¢
    all support   = - 10.26
    15-9   ——   = 0
    Core ↑ 7.0   = + 0.01
                         +6.82¢ = 2.1372
                 ① = 2.1372 -.0019 = 2.1353"

15"-9"   10" GRAPHITE REFLECTOR   WITH OR WITHOUT CORE AS NOTED

35   15 13 11 9 7   ₵

10"

269.37

TOT V+F = 43.87 cm²

½" (0.525") 11.6 Kg   2886 13 11   79
                       2885 83   96
                             82   78
                       86 52   44
                       60 51   43
                                   42

Void or Core as Noted.
Core = 1"A + ½"

24.548

241.4

Ram C No Core = 49277
Ram C + Core = 51931

A

1d
1c
1B
1A
1½
3   1c
     1B
½   1A
     1½
RAM

AL SUPPORT

Core – No Core
Same except Carbon
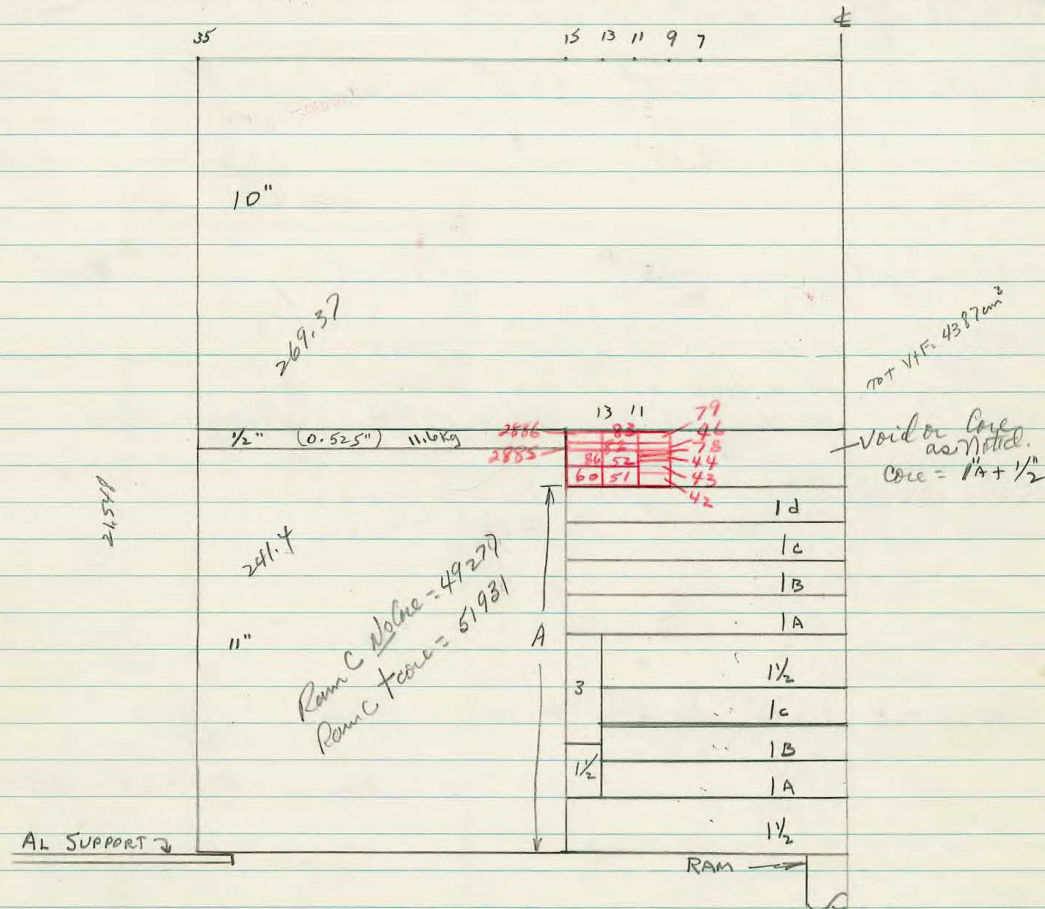
MASS OF FUEL = 52233 gm
    VOL = 2796.9770 cm³
    ρ = 18.6748 gm/cc
MASS Ram GRAPHITE = 49277 gm
Ram C + Core = 51931 gm   Avg Refl = 9.997"

Avg w/o OD = 14.99548"
    (OD)² = 224.86442
    ID = 9.00227"
    (ID)² = 81.04086   + Core
Mass of C = 571.640 Kg   524.301 Kg
C Vol = 335346 cm³   336986 cm³
    ρ = 1.704 gm/cc   1.704

15-9   10" C ref ≠ No Core   or Core as NOTED

Clean Critical Norm. 1 ft = 1½"
reactivity = +20.11¢ No Core   with Core ⇒ +34.97¢

1/32" Value 15-13 = 35.28¢   33.3¢ Use 34.3¢ or 1.09 ¢/mil   41.92¢ or 1.341
            13-11 = 61.08¢   1.954 ✓   56.74¢ or 1.815
            11-9 = 56.58¢   1.310 ✓   51.40 or 1.644
                                         Total 4.861   9.800

All Support Value = 7.25¢   11.43¢

Wt. of fuel 15-13 = 1.507 -.508 -.506 -.507   1.5071   Same
                         .508 -.507 .507
            13-11 = 1.512 -.512 .512   1.5120
                         .512 -.512 .512
            11-9 = 1.516 -.515 -.516 -   1.5156   wt avg = 1.5110"
                   .515 -.516 -.516
                                  carbons
(⅛) 15" dia (⅛) 7" dia on top of 10" ref = +9.42¢   (page 61)
    15" dia (⅜)   on top   = +18.16¢

A Same as (15-7) Pg 52 = 10.0162   Same —   = 10.0162

                                      Core = 1.497 -.499 -.499 -.499 = 1.4985
                                                              1.4985"

1.511" w/fld
1.509"

No Core
&
Core
+ Core

45   15 13 11 9   ₵

15

683.6

F+V = 3450 cm³   3

CORE IN OR
CORE OUT

13 11
27 85 82 78   9/16
66 55 67   1/4
84 49 42   3/8

1
2   1
1
1
1

8
330.1

31012

B

8
328.8

15.988
16.001

10
No Core Ram C = 75751
+ Core Ram C = 77862
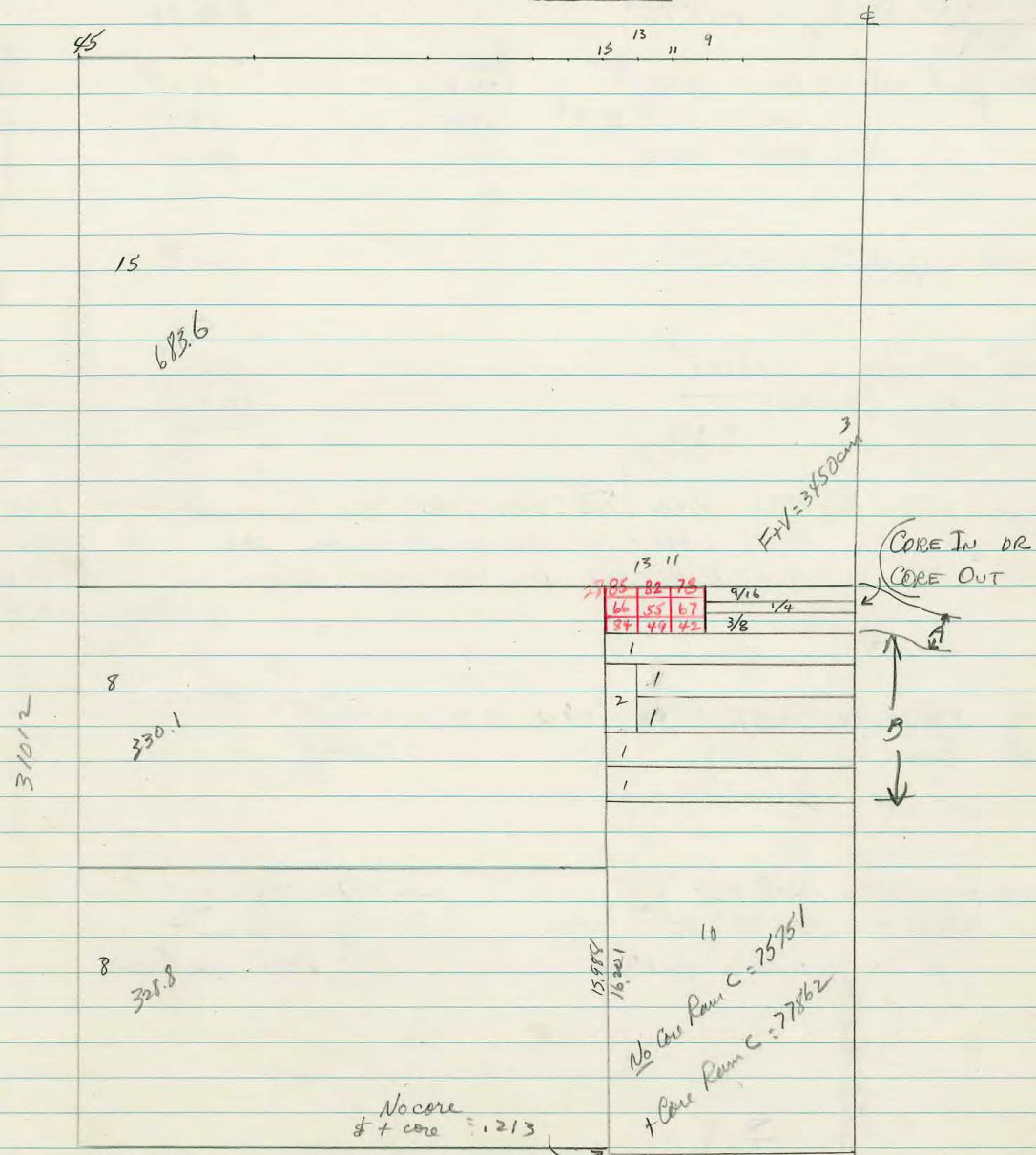
No core
& + core = .213

fuel mass = 41285 gm
Vol = 2205.7297 cm³
ρ = 18.7171 gm/cc
OD = 14.99571" (²) = 224.87131
ID = 9.00136" (²) = 81.02448

⌀ = 14.998"

15-9 & 15" C. ref

No Core	+ Core

Nom At critical = $1\frac{3}{16}$" $1\frac{3}{16}$"

    reactivity = +11.70¢   +16.36

$\frac{1}{32}$" fuel value: 15-13 = 48.00¢   ¢/mil 1.5360   48.71¢   ¢/mil 1.5587

         13-11 = 56¢ ± 3¢   1.7920   54.1¢   1.7312

         11-9 = 41.3¢   1.3216   40.66¢   1.3011

all supports = +2.57¢   SAME

$\frac{1}{2}$" x 25" dia. C. = 12.67¢   14.27¢

  1" x 17" Carbon = —   14.4¢

  1" x 15" = 13.36

fuel measured: 15-13 = 1.192 - .192 - .192 - .192 - .192 Same   1.1920

        13-11 = 1.191 - .191 - .192 - .191 - .192 - .192 - .192   1.1915

        11-9 = 1.190 - .191 - .191 - .191 - .190 - .190   1.1905

                w+avg = 1.1914

A: 1.193 - .192 - .192 - .191 - 190 - 193 = 1.1918"

B = Same as 4-189   = 5.0091

Mass of C = 1418.251 Kg   = 1420.362 Kg

Vol C = 804 808 cm³   = 806 053 cm³

ρ = 1.762 gm/cc   = 1.762 gm/cc

15" – 11"   1" GRAPHITE REFLECTOR + G. CORE
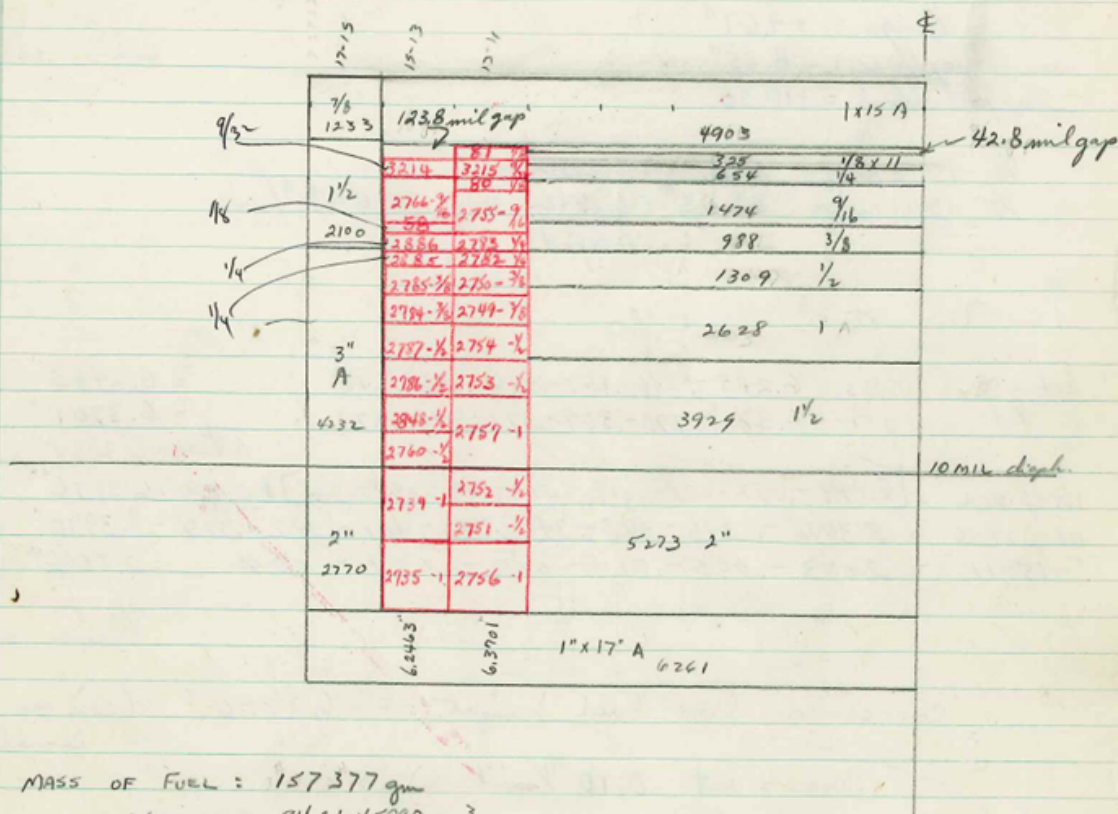
MASS OF FUEL : 157377 gm
    VOLUME = 8421.45990 cm³
      ρ = 18.68761 gm/cc

MASS OF GRAPHITE = 38079 gm
    VOLUME = 22706.6314 cm³
      ρ = 1.6770 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 14.99545"   OD² = 224.86352
        I.D. = 11.00272"   ID² = 121.05984
17-15 OD avg Carbon = 16.99941"   (²) = 288.97994

Avg Refl = 0.996"

15-11   1" ref. + core

Nom. Wt. Critical → 13"×11" = 6¹¹/₃₂ ; 15"-13" = 6⁷/₃₂ ; C.Core = 6⁵/₁₆"   = +7.22¢

        Rings = +9.67¢
     Diaphragm = −8.35¢   Lower .0088"
 Support Stand = +10.38¢

    ⅛" 15-13 ring = 30.4¢ ✓ 0.2432 ¢/mil
    ⅛" 13-11 ring = 33.03¢ ✓ 0.2642   Avg 0.507 ¢/mil
                              0.5074
                               10

1⁄₄t of fuel 15-13 = 6.245 − .246 −.247 −.246 −.246 −.248   = 6.2463"
             13-11 = 6.370 − .370 −.369 −.371 −.370 −.371   = 6.3701 "
                                                              4 avg − 6.3034"

1⁄₄t of core = [6.098 −.097 −.098 −.098 −.097 −.098 −.097 −.098] + 0.250 = 6.3476"
1⁄₄t of 17-15 = 8.396 −.396 −.398 −.398 −.396 −.401 −.397 −.394 = 8.3970"   (+94)
 1⁄₄t 15-11 = 2.003 −.005 −.010 −.009 −.009 −.004   = 2.0066"
1×15A
                                                  Lower .004"

     Corrected flat fuel height = 6.2906" (core gap not
                                              considered)

          Core = est 0.10 ¢/mil

        All support −   −11.70¢
        13-11 →   0 —   0
  15-13 Up 123.8mils — +30.10¢
  Core Up 22.5mils — + 2.2¢
            Support −

    6.3701" = +20.60¢
       0¢ → 6.3701 −.0339 = 6.3362" all considered

                                  31 233.1942
                                  8526.5628

15"-11"   2" GRAPHITE REFLECTOR & No CORE   Ø91

MASS OF FUEL = 133146 gm
    VOLUME = 7119.05134 cm³
    ρ = 18.70277 gm/cc

MASS OF GRAPHITE = 47813 gm
    VOLUME = 27982.70022 cm³
    ρ = 1.70866 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 14.99512   OD² = 224.85362
         I.D. = 11.00281   ID² = 121.06182
19-17 OD Carbon = 18.99724   = 360.89512

AVG. Refl = 1.997"

15-11   2" ref ≠ no core

Nom. Ht. Critical ≈ 5 5/16" ——> 19.68¢

    Rings = +8.01¢
 Diaphragm = -13.72¢
Support Stand = 9.88¢

remove 1/16" 13-11 ring = 33.92¢   removed from "clean" i.e.   0.5427¢/mil
remove 1/32" from 15-11 = 31.57¢ ←   1.0102¢   0.4675 for 15-13
   1/16 = 29.22   1.0102

Ht of fuel 15-13 = 5.330 - .328 - .328 - .331 - .331 - .330   = 5.3296"
         13-11 = 5.330 - .328 - .329 - .330 - .327 - .329   = 5.3288"
                                                    w avg = 5.3292"

Ht of 19-17 ring = 9.362 - .362 - .352 - .358 - .358 - .362 - .362 = 9.3594" (+30)
   17-15 ring = 9.327 - .327 - .331 - .337 - .335 - .335 - .331 - .327 = 9.3312" –
   15 dia   - 4.016 - .014 - .016 - .013 - .014 - .014 - .016   = 4.01471"

   Even Fuel Ht = 5.3292"
   Sky Hook React = +15.51¢

      0 React Fuel Ht = 5.3149" ✓ (Ignoring reflector diff) nil?

$$\text{MASS OF FUEL} = 121412 \text{ gm}$$
$$\text{VOLUME} = 6494.73868 \text{ cm}^3$$
$$\rho = 18.6939 \text{ gm/cc}$$

$$\text{MASS OF GRAPHITE} = 58820 \text{ gm}$$
$$\text{VOLUME} = 34545.41657 \text{ cm}^3$$
$$\rho = 1.70268 \text{ gm/cc}$$

AVG. O.D. ALL FUEL (w/ D) = 14.99537" $OD^2 = 224.86112$
I.D. = 11.00277" $ID^2 = 121.06094$
19-17 OD carbon   = 18.99681" $(^2) = 360.87879$

AVG. Refl = 1.997"

15-11   2"ref + C Core

Nom Wt. Critical = $4\frac{27}{32}$"   — 11.72¢

          Rings = +7.47¢
     Diaphragm = −12.83¢
  Support Stand = +9.60¢

$\frac{1}{32}$" fuel from 15-13 ring = 15.70¢   0.502¢/mil ✓   (p. 94)

Wt of fuel 15-13 = 4.856 − .958 − .861 − .861 − .864 : 861   = 4.8601"
           13-11 : 4.864 − .861 − .862 − .864 − .864 : 864   = 4.8631"
                                                          wt avg = 4.8614"

Wt of 19-17 ring = 8.900 − .902 − .901 − .898 − .895 − .896 − 900   = 8.8988"
       17-15 ring = 8.907 − .905 − .906 − .911 − .905 − .906 − .905 − .908 = 8.9066"
       15-11 ring = same as Ba 91   = 9.0147"
       Core only = [4.592 − .540 − .590 − .582 − .584 − .590 − .590] + 0.250 = 4.8382"

       Even Fuel Wt = 4.8614"
       Sky Hook React = − 15.96 ¢

Core ¢/mil = + 0.1076 (Core vs No Core relationship)
1.2¢/mil of 15-11 fuel from curve = 15.3 mil

    flat "0" reactivity = 4.8614 + .035 = 4.8747"

  all
  Support = − 4.2¢
  4.861" fuel = −11.72¢   1.2¢ (15-11 fuel) + (0.1076 core) = 1.3076 mil TOT
  24.9 mil Core = + 2.67¢   ∴ 7.3 mils to be added
  ∴ 4.8614 ⟶ − 13.35¢
       flat "0" reactivity ⟶ 4.8614 + 0.0102 = (4.8716")

15"-11"   3" GRAPHITE REFLECTOR & No CORE   ≈ Pg 129

(rotated column labels: 21-19, 19-17, 17-15, 15-13, 13-11)
(rotated left label: 10.2846)

			red boxes		reference	
3/4 1364	3/4 1255	13/16 1170			1x15 C	4915
	1 1644	2			1x15 B	4915
5		2770			1x15 A	4903
	4	3A	66-9/16 · 55			
			2885-1/4 · 82			
			87-1/2 · 53			
			86-1/2 · 52			
	6513	4732	39-1 · 57			
8827			60-1/2 · 51			
2	1½ 2438	1½ 2098	35-1 · 56			
3546			43323	43306	1x19 B	7838
1½ 2677					1x19 A	7828
					1x21	9666

MASS OF FUEL = 108123 gm
$\quad$ VOLUME = 5786.21057 cm³
$\quad\quad$ ρ = 18.68632 gm/cc

MASS OF GRAPHITE = 78599 gm
$\quad$ VOLUME = 46073.92605 cm³
$\quad\quad$ ρ = 1.70593 gm/cc

AVG. O.D. ALL FUEL (w'td) = 14.99498 $\qquad$ OD² = 224.84942
$\qquad\qquad$ I.D. = 11.00279 $\qquad$ ID² = 121.06138
21-19 OD Carbon = 20.99926 $\qquad$ — 440.96892

$\qquad$ Avg Refl = 2.997"

15-11   3" ref & No Core

Nom. Ht. Critical = 4 5/16"   reactivity = + 27.22¢

        Rings = + 7.38¢
    Diaphragm = − 15.62¢
Support Stand = + 6.85¢   Lower .0220"

$\frac{1}{32}$" fuel   15-13 = 22.79¢ ✓ 0.7292¢/mil
            13-11 = 23.64¢ ⎛ 0.7564   wt vol Avg = 1.484¢/mil
                              ⎝ _____
                                1.4856

Ht. of fuel   15-13 = 4.330 −.329 −.332 −.333 −.335 −.335   = 4.3323"
          13-11 = 4.329 −.329 −.334 −.329 −.334 −.329   = 4.3306"
                                        wt vol Avg = 4.3315"

Ht of Carbon = 21-19 = 10.288 −.298 −.294 −.296 −.298 −.290 −.288 = 10.2931"
          19-17 = 10.300 −.303 −.298 −.298 −.292 −.285 −.290 −.297 = 10.2953"
          17-15 = 10.330 −.333 −.328 −.325 −.324 −.326 −.331   = 10.3281"
          15 dia = Same as 12 3   = 6.0168
                                        Raise .0004"

        corrected flat fuel height   = 4.3099" ∟

        all support   + 1.39¢
        reactivity   − 27.22¢
        15-13 − 0 −
        13-11 hp 0.7 mils ↑ 0.5 ¢

        4.3315" = +29.11¢
        "0" react = 4.3315 −.0195 = 4.3120"

21-19	19-17	17-15	15-13	13-11				℄

	3/4" 1364	13/16" 1334	3/4" 1060			1×15 C	4915	
		3/4" 1255	13/16" 1170			1×15 B	4915	
			1" 1456			1×15 A	4903	4 mil gap
	5"	4"	3"A		66 7/16 / 55	9/16×11	1474	
		6513	4232		87-1/2 / 53			
					86-1/2 / 52	2×11	5273	
	8827				39-1 / 57			10 MIL DIAPH.
					60-1/2 / 51			
	2	1 1/2 2438	1 1/2 2098		35-1 / 56	1 1/2 ×11	3929	
	3546			90753	40738			
	1 1/2 2677					1×19 B	7838	
						1×19 A	7828	
						1×21	9666	

MASS OF FUEL = 101794 gm

$\quad$ VOLUME = 5442.85522 cm³

$\quad\quad \rho = 18.70231$ gm/cc

MASS OF GRAPHITE = 88711 gm

$\quad$ VOLUME = 52057.55651 cm³

$\quad\quad \rho = 1.704094$ gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 14.99496"   OD² = 224.84882

$\quad\quad$ I.D. = 11.00277"   ID² = 121.06094

21-19 O.D. Carbon = 20.99926"   440.96892

$\quad$ Avg Refl = 2.997"

A-108

15-11   3" ref. + Core

Nom. Ht. Critical = 4 1/16"   reactivity = +17.96¢

        Rings = +6.61¢
    Diaphragm = -12.7¢
    S. Stand = 5.61¢   Lower .0119"

(77¢/mils)
    3/4" reflector 21-19 ring removed = 5.96¢   or .0077 ¢/mil

        1/32" fuel 15-13 = 22.27¢ ✓ 0.7126¢/mil
                    13-11 = 26.71¢ ✓ 0.8547   wt. vol Avg = 1.556 ¢/mil
                                     1.5673
                                      .0959
                          + Core = 1.6632

Ht. of fuel 15-13 = 4.075 -.074 -.075 -.074 -.076 -.078   = 4.0753"
             13-11 = 4.075 -.074 -.072 -.073 -.074 -.075   = 4.0738"
                                        wt vol Avg = 4.0744"

Ht. of carbon: 21-19: Same as Pg 129   = 10.2931" (+218)
               19-17 = 10.120 -.123 -.120 -.116 -.109 -.112 -.112 -.120 = 10.1165" (+40)
               17-15 = 10.095 -.093 -.093 -.092 -.092 -.089 -.090 = 10.0920" (+23)
               15-11 = Same as 123   = 6.0168" (-58)
               Core = 4.076 -.072 -.072 -.071 -.071 -.070 -.068 -.074 = 4.0717"

                                                            Raise .0010"

Corrected flat fuel height = 4.0633" good ✓

    React   +17.96¢
    all Support   - +0.48¢
    15-13   - 0   - 0¢
    13-11 up 1.5   → +1.28¢
        Core = +.095¢/mil   -   0
                            +19.72

+19.72¢ = 4.0753"
    0 = 4.0753 -.0118 = 4.0635"

15" - 11"   5" GRAPHITE REFLECTOR & No CORE   Pg 174

	3/4 1364	13/16 1334	3/4 1060			1/2 x 15	2467
1,194							
4895	1 1828	1 1644	1 1/2 2098			1 1/2 x 15	7485
	1 1/2					1 x 15 C	4915
	2677	2 3/8	1 1456			1 x 15 B	4915
7	2 3546	3863	2 2770			1 x 15 A	4903
28700				45 -3/8 50			
				84 -3/8 49			
				87 -1/2 53			
	3 5325	4 6513	3A 4232	35 -1 56			
				86 -1/2 52			
				60 -1/2 51			10 MIL DIAPH.
		3.2617	3.2485			1 x 21	9666
3						2 x 21	19263
12350							
						2 x 25	27650

MASS OF FUEL = 81417 gm
    VOLUME = 4358.89380 cm³
        ρ = 18.67836 gm/cc

MASS OF GRAPHITE = 166919 gm
    VOLUME = 97043.54597 cm³
        ρ = 1.72004 gm/cc   Avg Refl = 4.996"

AVG. O.D. ALL FUEL (WT'D) = 14.99456"   OD² = 224.83682
                I.D. = 11.00270"   ID² = 121.02970
25-21 OD Carbon = 24.99772"   624.88600

A-110

15-11   5"ref ‡ No Core

Neu. Ht. Critical = 3¼"   reactivity = + 32.81¢

    Rings = + 6.56¢
    Diaphragm = nil   Lower 9.0278"
    S. Stand = + 4.40¢

1/32" Fuel 15-13 = 25.56¢   0.8179¢/mil
1/32" Fuel 13-11 = 23.61¢   0.7555   wt vol Avg = 1.573¢/mil
                          1.5734

Wt of fuel 15-13 = 3.259 - .260 - .260 - .264 - .264 - .262 - .263   = 3.2617"
        13-11 = 3.264 - .263 - .263 - .263 - .264 - .264   = 3.2635"
                                wt vol Avg = 3.2625"

Wt of carbon = 25-21 = [8.200 - .196 - .190 - .195 - .184 - .180 - .184] + 5.0092 = 13.1990 " (+63)
           21-19 = [8.295 - .299 - .301 - .309 - .307 - .305 - .303] + 5.0007 = 13.3034" (+4%)
           19-17 = [8.196 - .196 - .198 - .199 - .196 - .196 - .194] + 5.0007 = 13.1971" (-10)
           17-15 = [8.275 - .273 - .271 - .271 - .278 - .277 - .277] + 5.0007 = 13.2752 " (+63)
           15 dia = 10.0147   = 10.0147"

                                          Raise .0011"

Corrected flat fuel height = 3.2358"

All Support —— -10.96¢
Reactivity —— +32.81¢
15-13 up 1.8 mils = +1.47¢
13-11   0
             +23.32¢

3.2635" = +23.32¢
"0" react = 3.2635 - .0148 = 3.2487"

13, 1905 25-21   21-19 · 19-17 · 17-15 · 15-13 · 13-11

1.194	1⅛	¾ 1255	¾ 1060	½ × 15	2467
4895	1997				
		1 1644	⅞ 1233	1½ × 15	7485
	2 3546	2⅜	1½ 2098	1 × 15 C	4915
7		3863		1 × 15 B	4915
28700			2 2770	1 × 15 A	4403
	5	4	2885 ¾ / 82	⅛ × 11 / 325	
			84 -⅜ / 49	½ × 11 / 1309	
			87 -½ / 53	1 × 11 / 2628	
	8827	6513	3A / 35 -1 / 56		
			4232 / 86 -½ / 52	1½ × 11 / 3929	
			60 ½ / 51		

31,389   31,415

	1 × 21 9666
3	
12350	2 × 21
	19263
	2 × 25
	27650

MASS OF FUEL = 78367 gm
    VOLUME = 4193.93364 cm³
        ρ = 18.68579 gm/cc
MASS OF GRAPHITE = 174438 gm
    VOLUME = 101697.06903 cm³   Avg. Refl = 4.996"
        ρ = 1.71527 gm/cc
Avg. O.D. ALL FUEL (W'T'D) = 14.99456"   OD² = 224.83682
        I.D. = 11.00291"   ID² = 121.06402
25-21 OD Carbon = 24.99772"   624.88600

A-112

15-11   5"ref + Core

New. Ht. Critical = 3 1/8"   reactivity = + 15.14¢

    Rings + Support Stand = +11.31¢
             diaphragm = -1.52¢   →recheck @ slower period: +0.14¢   Avg = -0.64

                                                              Lower 0.0023"

1/32" fuel 15-13 = 32.64¢ ∨ 1.0444 ¢/mil
        13-11 = 39.49¢ / 1.2636   wt val Avg = 2.308 ¢/mil
                          2.3080
                          0996
              + Core = 53876

Ht. of fuel 15-13 = 3.140 -.139 -.1375 -.141 -.138 -.138   = 3.1389"
         13-11 = 3.139 -.142 -.143 -.142 -.142 -.141   = 3.1415"
                                        wt val Avg = 3.1401"

Ht of Carbon 25-21: Same as Pg 174   13.1990" (+81)
      21-19: [9.125 -.135 -.127 -.127 -.131 -.124 -.122] +5.0007 = 13.1279" (+10)
      19-17: [9.164 -.169 -.175 -.172 -.169 -.166 -.162] +5.0007 = 13.1688" (+50)
      17-15: [9.150 -.153 -.153 -.162 -.158 -.158 -.154] +5.0007 = 13.1561" (+33)
      15diap 10.0147   = 10.0147"
      core · 3.137 -.142 -.142 -.144 -.141 -.141   = 3.1411"

                                                              Lower .0007"

        Corrected flat fuel height = 3.1371" ✓

Reactivity: + 15.14¢
All Support -   11.31¢
15-13 Up 2.6 mil = + 2.71¢
13-11   0
Core = -.0796 ¢/mil   0
                     + 6.54¢

+6.54¢ = 3.1415"
   0 = 3.1415 - .0027 = 3.1388"

Avg. Refl = 10.004"

No Core	+Core
MASS OF FUEL : 54907 gm	54147 gm
Vol = 2935.3629 cm³	2894.7150 cm³
ρ = 18.7053 gm/cc	18.7054 gm/cc
MASS RAM GRAPHITE 49427 gm	55298 gm.
OD (AVG) = 14.99547"	14.99583"
(OD)² = 224.86412	224.87491
ID (AVG) = 11.00248"	11.00215"
(ID)² = 121.05456	121.04730
mass of C = 582.347 Kg	588.218 Kg
Vol C = 344194 cm³	344628 cm³
ρ = 1.692 gm/cc	1.706 gm/cc

A-114
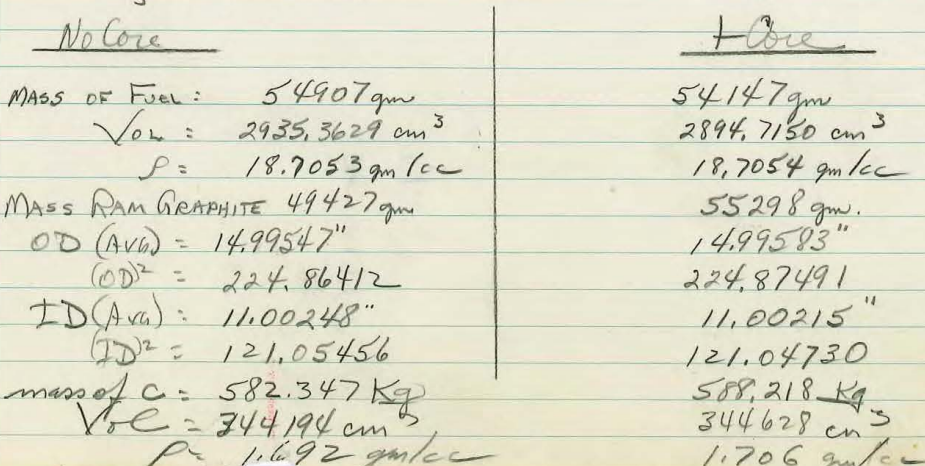
15-11   10"C ref. ≠ No Core   + Core

Clean Critical Nom. Ht. = 2³/₁₆"   2⁵/₃₂"
    reactivity = +14.83¢   +19.41¢

¼₂" value 15-13 = $\frac{40.05¢}{48.5}$ 1.281¢/mil   41.93 or 1.341¢/mil
           13-11 = $\frac{54.3¢}{39.73}$ 1.271¢/mil   40.96 or 1.310¢/mil
                              255 =   2.651

all Support Value = 7.74¢   6.85¢

Ht of fuel 15-13 = 2.197÷.197÷.197÷.197÷.197 = 2.1970   2.1662"
            13-11 = 2.197÷.197÷.197÷.197÷.197   2.166÷.166÷.166÷.166 = 2.1662"

Use ½ graphite ring (35-15) ℊ52 ao
        being 0.04478¢/mil

½" (15"dia) on top = 22.30¢

A = Sam as (15-7) Pg 52 = 10.0162   A Same   = 10.0162

                                       Core = 2.165÷.163÷.166÷.163 = 2.164₂

No Core
& + Core

15 13"

15 x 45

16.5?
16705

+ Core

2725	82
66	55
84	49
60	51

9/16 1/8

1

683.6

2885

15	
66	55
84	49
60	51

4992 cm³ V+F

No Core

1   39.5

1 x 15

1 x 13

B   2

1

1 x 15

1

NC = 31.963
+C = 31.960

8

330.1

8   328.8

10 x 15

Ram C No Core = 75751
Ram C + Core = 80178

16.96?
16.734

No Core = .258"
+ Core = .287

Avg Refl = 14.998"

mass (No Core fuel) = 42745 gm   mass (+ Core fuel) = 42412 gm
    Vol = 2283.9899 cm³   2265.3245 cm³
    ρ = 18.7150 gm/cc   18.7222 gm/cc
    OD = 14.99.58" (²) = 224.86741   — Same
    ID = 11.00215" (²) = 121.04730   11.00262" (²) = 121.05764

A-116

15-11

No Core	Core
Nom Ht: 15-13 @ 1¹¹⁄₁₆"	fuel = 1¹¹⁄₁₆" ~~15½~~ "
13-11 @ 1²³⁄₃₂"	

No Core

Reactivity = + 5.70¢

Supports = +2.08¢
   fuel 15-13 = —
      13-11 = —
45"×15"×½" = 10.67¢
15"×½" C = 7.76¢
45"×½" C = 18.43¢

Core

− 5.31¢

3.14¢
33.85¢ including ¹⁄₃₂" add. C Core
36.16   "   " " " " "

18.25¢

Ht. of 15-13 = 1.696÷.696÷.696÷.696 = 1.6960
13-11 = 1.725÷.725÷.725÷.725
÷.725÷.725   1.7250
w.t avg - 1.7093

Same   = 1.6960
1.695 ÷.695÷.695÷.695÷.695÷.695 = 1.6950
w.t avg 1.6955

A = 1.689÷.689÷.689÷.689÷.689 = 1.6890"
B = Same as 4-189   = 5.0091

Mass of C = 1457.751 Kg
Vol = 828052 cm³
ρ = 1.760 gm/cc

= 1462.178 Kg
= 830701 cm³
= 1.760 gm/cc

15-13 Ring Only & 10" GRAPHITE REFLECTOR { Σ + Core { + No Core

4-
Pg 82

35

15 13 11 9 7

10"

50±0.01

269.37

Fuel with Core →

Core →

13 11

4"

87.3 Kg

14886 cm³
F+V

13 x ½

1½   1½

2   11 x 2

1654¼/gm

15 x 1
15 x 1
15 x 1
15 x 1
13 x 1
13 x 1
13 x 1½
13 x 1
15 x 1½

11" 241.4

Ram C No Core = 49277
Ram C + Core = 65821

3

1½

Ram
.440"
+core

.158"
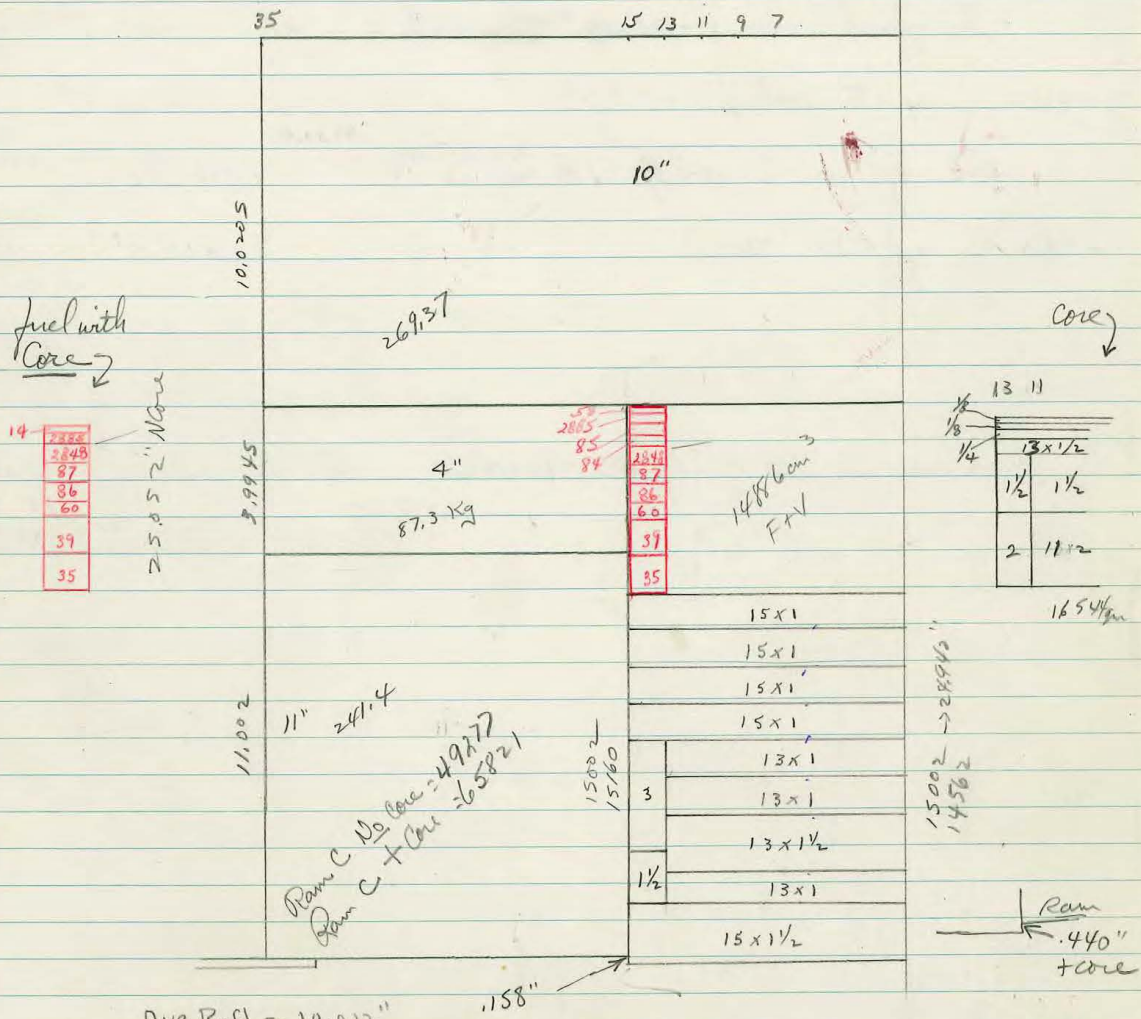
Avg. Refl = 10.012"

No CORE

MASS OF FUEL = 69048 gm
  Vol = 3693.6704 cm³
  ρ = 18.6936 gm/cc
MASS RAM GRAPHITE 49277 gm
  FUEL OD(AVG) = 14.99506"
  (OD)² = 224.85182
  ID(AVG) = 13.00218"
  (ID)² = 169.05668

TOT.
mass C = 647347 Kg
Vol = 380093
ρ = 1.703 gm/cc

CORE

61078 gm
3264.7910 cm³
18.7080 gm/cc
65821 gm
14.99528"
224.85842
13.00226
169.05876

mass C =
663891 Kg
Vol C =
389981 cm³
ρ = 1.702

A-118

15-13 Ring Only $\not{}$ 10" ref(c)

<u>No Core</u>   + Core

Clean Critical Nom. Wt. = 5½" (5.128)   4$\frac{17}{32}$"
     reactivity = −5.92$\not{c}$ +15.47$\not{c}$

+ 1/32" fuel value = +20.24$\not{c}$ 0.6476$\frac{\not{c}}{mil}$ +1/32" = +35.17$\not{c}$ 1.1254$\frac{\not{c}}{mil}$

All Supports value = +7.23$\not{c}$ +6.04$\not{c}$

   Wt. of fuel 15-13 = 5.144 $\frac{.144\ .144\ .143}{.144\ .143}$ 5.1436   4.546 $\frac{-.546\ -.546\ -.546}{.546\ .546}$ = 4.546

+ 0.525" C ref Top (35-15) —————   +15.38$\not{c}$

A = Same as 15-7   Pg 52 = 10.0162   A = Same   = 10.0162

                                              Core = 4.505 $\frac{.505}{.502\ .508}$ = 4.5050

5.144 sum
5.1164

4.546 as to
4.538

A diagram with dimensions and labels:

- 45×15   683.6
- 2   90.9
- 8   330.1
- 33.040"
- 324.8
- 8
- Tot. Ram C = 88325
- 10
- 17.982
- 1.8423
- 1/8, 1/8, 17/32, 3/8, 1/4, 1/2, 1 1/2
- A, B
- (red) 74, 2425, 84, 87, 95, 60, 39
- 2, 1, 1, 1, 1
- +3/32
- .431"

mass of fuel = 45960 gm

    Vol = 2458.0773 cm³

    ρ = 18.6975 gm/cc

OD = 14.99556"; (²) = 224.86681

ID = 13.00214" (²) = 169.05564
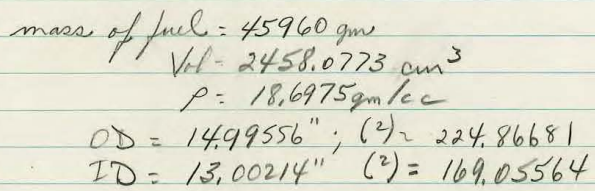
Mass of C = 1511.725 Kg

    Vol = 858655 cm³

    ρ = 1.760 gm/cc

Avg. Refl = 15.000"

15-13 ≠ 15" C. Ref. + Core

Nom. Ht₈ = $3\frac{13}{32}$"

reactivity = $-8.67^{¢}$

$\frac{1}{32}$" fuel value = $44.54^{¢}$ $1.4252^{¢}/mil$

all supports = $2^{¢}$

Carton value = —
45" x 15" 12" C = $11.03^{¢}$

fuel measured 15-13 = 3.422 ÷ .422 ÷ .422 ÷ .422 ÷ .422 ÷ .422 = 3.422"

A = 3.412 ÷ .415 ÷ .415 ÷ .415 ÷ .413 = 3.4140"
B = Same as 4-189   = 5.0091

45

15

683.6

33.957"

2   80.9

1   39.5

2848

84
87.
86.
60
39

15×1

13×1

2

1

A

1

1

mass C = 1538.651 Kg
Vol = 874479 cm³
ρ = 1.759 gm/cc

8   330.1

8   328.8

Raw C = 75751

10

.347"

Y+F: 1053/cm³

mass of fuel = 48911 gm
Vol = 2613.9202 cm³
P = 18.7117 gm/cc

OD = 14.99537"; (²) = 224.8612
ID = 13.00236"; (²) = 169.06136
Avg. Refl = 15.000"
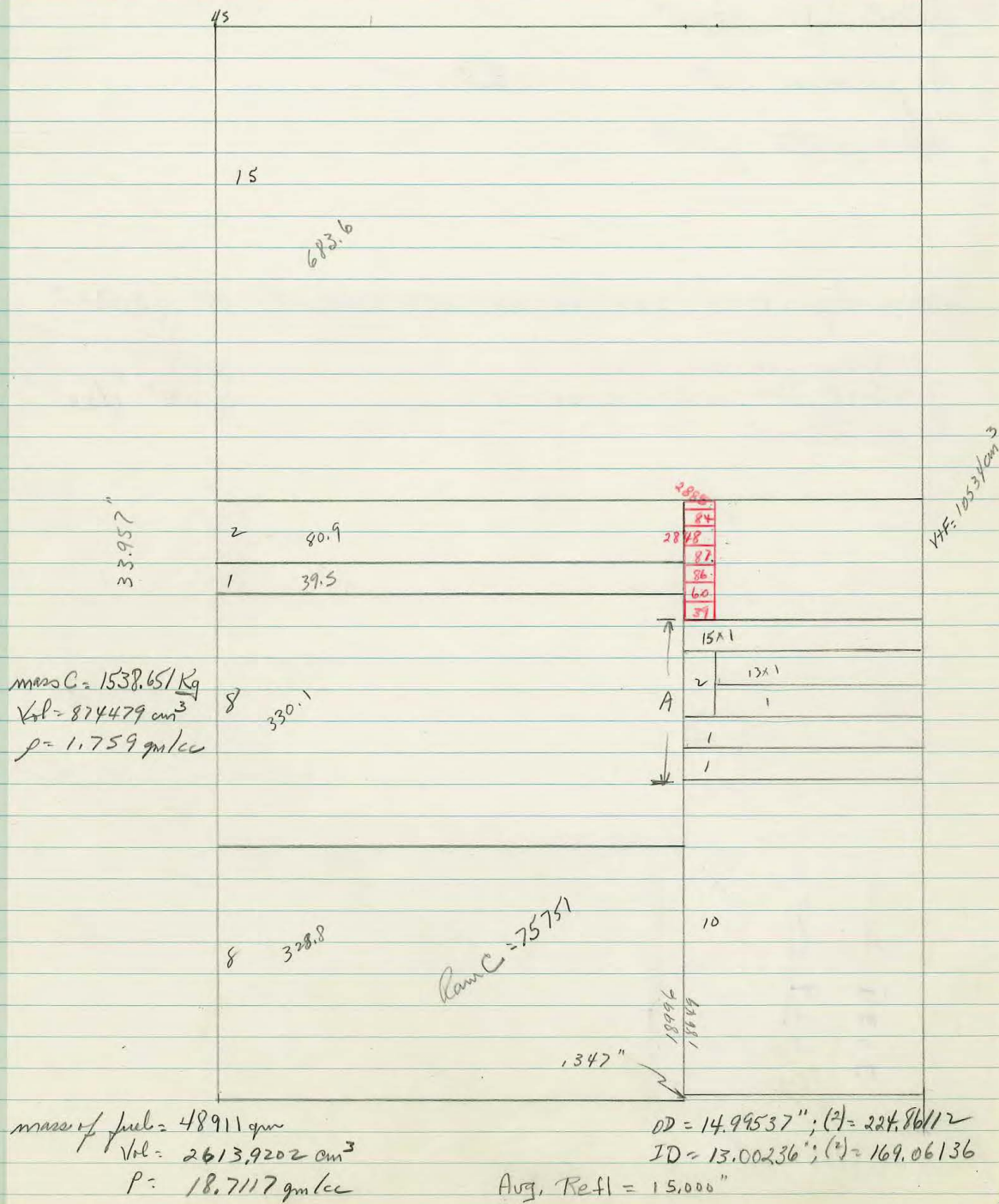
15-13 & 15" GRAPHITE Ref.

Nom. Ht = $3\frac{5}{8}$"

reactivity = +12.62¢

$\frac{1}{32}$" fuel value = 32¢   1.0240 ¢/mil ✓

all supports = 2.01¢

measured fuel 15-13 = 3.640-.640-.640-.639-.639-.640-.640 = 3.6397

A=3.022-.020-.021-.019-.016   .7019
→ =3.008-.010-.008-.012-.007-.010   3.0091" Use
Ⓐwith calipers

1a 4/23 JTM

35

15 13 11 9 7

1   27.8

10

≥69.37

1/16" GAP

1   22.3   B   1

82 79 74   25
50 46 2333
09 02 36   30

Aↆ   1

11

10

24114

Ram C= 57265

MASS OF FUEL= 40060gm
        VoL = 2143.4925 cm³
        ρ = 18.6891 gm/cc
Avg OD = 12.99515
    (OD)² = 168.87392

MASS OF C = 618135 gm TOTAL
Avg OD C = 363517 cm³ - 2144 cm³ = 361373 m³
        ρC = 1.711 gm/cc avg
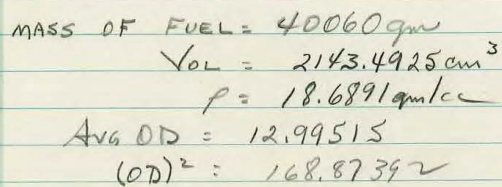
Avg Refl = 11.013"

13" DIA. cyl. ≠ 11"graphite reflector

Nom. Ht. Critical = 7"disc $\frac{15}{16}$" ≠ (13-7)= 1"
    reactivity = 15.02 ¢

¢/mil

$\frac{1}{32}$" fuel   13-11 = 42.09   1.3468   1.313
            11-9 = 48.54   1.5532   1.511
            9-7 = 52.17   1.6694   1.630
            7 dia = not measurable ⟵

all Supports = 9.45 ¢

OK

$\frac{1}{32}$" (2½ x 2½) in center = 20.98 ¢ (Pc #1)
7"dia ⟶ ◯ $\frac{1}{32}$ x 2½ x 2½ = 12.56 ¢ (Pc #2)

Wt of fuel   13-11 = 1.006-.006-.006-.006-.006-.006   = 1.0060
           11-9 = 1.005-.005-.005-.005-.006-.005   = 1.0051
           9-7 = 1.005-.005-.005-.005-.004-.005-.006-.005 = 1.0050
           7 dia = 0.940-.940-.939-.940-.939-.939-.939   = 0.9394
                                              wt avg = 0.9862

A = Look Up   = 0.9995"
B = Look Up   = 1.0000

937

A-125

13" dia (SOLID) & 16" GRAPHITE REF.   Pg 4-137

45
35   25   15   11   7

15
683.6

13 11   1/8
17/32   1/32 GAP
C   B   2   17/32   1/2   1/32 GAP
2   80.9   16 16 17   70
                    55 67 37   30

A   2 2   1/6 and 1/2
           Fuse 1 1/2

8
330.1

8   328.8

10
Ram C = 87150

mass of fuel = 33983 gm   Mass of C = 1510.550 Kg
      Vol = 1818.7280 cm³   Vol C = 858171 cm³
      ρ = 18.6850 gm/cc   ρ = 1.760
Avg OD = 12.99654" (OD)² = 168.91005   Avg R.N = 15.996"
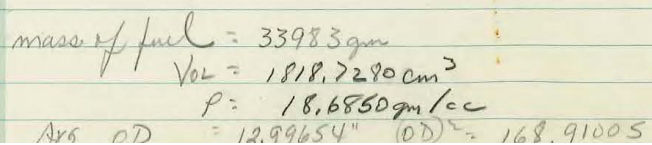
13" dia Solid $\neq$ 16" C. ref.

Nom. Ht. Critical = 13-7 = $\frac{27}{32}$" .84375 ⟩ reactivity + 13.29¢

  7" = $\frac{13}{16}$" .8125 ⟩

  Top ref = $\frac{5}{32}$" Too much

all supports = 40¢

  $\frac{1}{32}$" 9-7 = 40.57¢   ¢/mil

  11-9 : 42.34¢   ~~1.298¢~~ ~~1.711~~

  13-11 : 36.08¢   ~~1.358~~   ~~1.583~~

                    ~~1.1545~~   ~~1.143~~

  45" OD graphite $\frac{1}{2}$" = 15.68¢   ↑   ~~1.0~~3/4 ¢/mil

  1 ($2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{32}$) @ edge of 7" dia = 13.64¢   ⊡

  1 ($2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{32}$) @ center of 7" dia = 13.75¢   ⊡

Nt/flywheel = 13-11 = 0.845 - .845 - .845 - .845 - .845 - .845   = 0.8450

  11-9 = 0.845 - .845 - .845 - .845 - .845 - .845   = 0.8450

  9-7 = 0.850 - .850 - .850 all way   = 0.8500

  7 dia = 0.813 - .813, .813, .813, .812, .813, .813   = 0.8128

                                          wt avg = 0.8366

A = 6.007 - .009 - .008 - .009   = 6.0082"

B = Look Up   = 2.0043

C = 1.155 - .159 - .159 - .160 - .158   = 1.1582

A-127

13-7   1" GRAPHITE REFLECTOR (No CORE)   RUN 67 Pg 100 BK #1
                                                                      ℄

.15-13   13-11   11-9   9-7   > DISC

                    G - 3/8 DISC   1841

                    G - 1/2 DISC   2467

                    G - 1/8 DISC B 462

2781-1/8	2778-1/4	2775
2751-1/2	2742-3/8	2829
2782-1/4	2779	2774
2756-1	2745	2762

2 7/8"

1 7/8"   G-2"B
          2439   VOID

                                                                  10 MIL DIAPH.

2754-1/2 (2744-1/8 2763)	2743-3/8	2736-3/8
2752-1/2		
2757-1	2748-1 1/2	2741

2"   VOID

3"   G-3"B
      3712

3.8954   3.8673   3.8848   3682   G-1"A
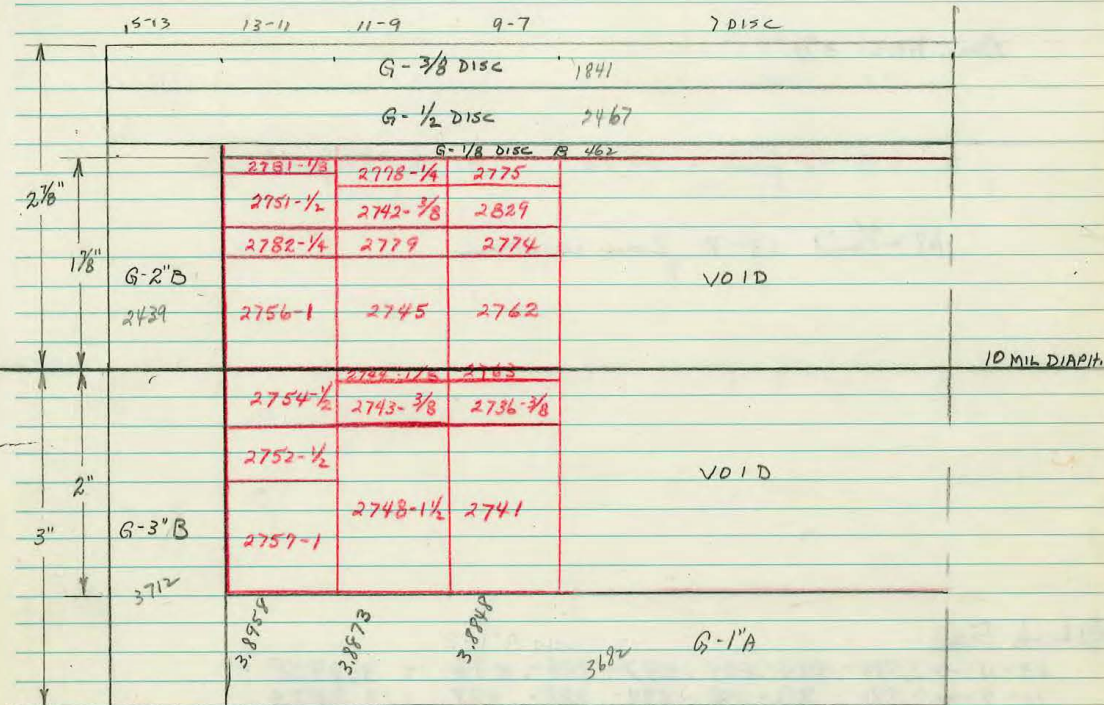
MASS OF TOP FUEL = 54276 gm   TOTAL = 112.210 Kg
BOTTOM   = 57934

MASS OF TOP GRAPHITE = 7209 gm   TOTAL = 14.603 Kg
BOTTOM   = 7394

(WEIGHTED)
AVG. O.D. OF ALL FUEL = 12.99599"
AVG. I.D. OF ALL FUEL = 7.00307"

AVG. WT'D HT FUEL (ALL) = 3.88 ft"

FUEL VOL = 5986.82333 Cm³
FUEL ρ = 18.74283 gm/cc

VOL of all C. stacked = 8668 63524 cm³
        ρ = 1.68457 gm/cc

        Avg Refl = 1.001"

Critical = -14.37$^{¢}$
Rings = 5.85$^{¢}$
Kraph = -18.31$^{¢}$
fuel sup.= 12.06$^{¢}$ Raise .0085"

Nom. Ht.= 3⅞"

$\frac{1}{16}$" (13-11) fuel = 30.46$^{¢}$ or 0.487$^{¢}$/mil

.182$^{¢}$/mil 13-7 from curve

ALL Ht. Fuel
13-11 → 3.894 - .894 - .895 - .897 - .899 - .896 = 3.8958 "
11-9 → 3.886 - .886 - .188 - .888 - .888 - .888 = 3.8873
9-7 → 3.885 - .884 - .885 - .884 - .884 - .887 = 3.8848
                                          wt avg = 3.8900"

(1×13) + high fuel + (⅛ × 13B) = 5.0208
(15-13 3B) + (15-13 2B) = 5.018 - .020 - .018 - .021 - .018 - .018 = 5.0188
all Carbon stacked @ 15-13 = 5.906 - .907 - .905 - .909 - .908 - .908 - .905 = 5.9068

                              13-7 ───   =   0
                              React.   = -14.37$^{¢}$
                              all support   = + 0.40
                                                 -13.97 =
                                                        3.8900
EVEN FUEL HT. = 3.8900"
SKY HOOK REACT. = -13.97$^{¢}$
                              0 = 3.8900 + .0076 = 3.8976

2 Oct 63

Top labels: 15-13   13-11   11-9   9-7

G - ½" DISC   2467

G - ⅜" DISC   1841

G - ⅛" DISC   460 A

2780-⅛	2779-¼	2775
2753-½	2743-⅜	2829
2782-¼	2778-¼	2774
2757-1	2745	2738

2⅜"   1⅞"   2"A   2476

VOID

10 MIL DIAPH.

2752-½	2742-⅜	2736
	2744-⅛	2763
2751-½		
	2747-1½	2740
2756-1		

3"   2"   3"B   3712

VOID

3.8948   3.8870   3.8858

G-1 A   3682
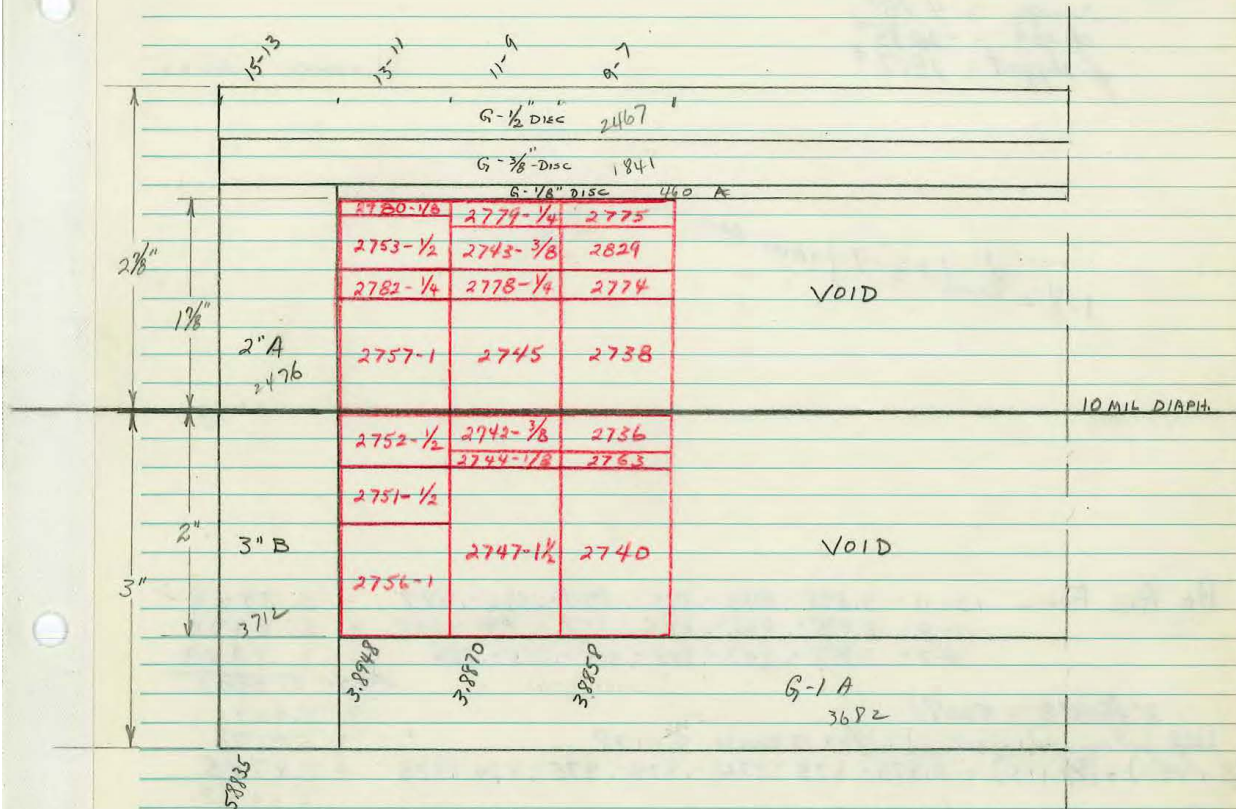
57885

MASS OF TOP FUEL = 54246 gm   TOTAL = 112.138 Kg
BOTTOM   = 57892

MASS OF TOP GRAPHITE = 7244   TOTAL = 14.638 Kg
BOTTOM   = 7394

AVG O.D. (WT'D) ALL FUEL = 12.99616"   168.900174
AVG I.D (WT'D) ALL FUEL = 7.00307"   49.042989

AVG Ht (WT'D) ALL FUEL = ~~3.870064~~ 3.889797

FUEL VOL = 6000.9740 cm³
FUEL ρ = 18.6881 gm/cc

Vol of graphite = 8582.05072 cm³
ρ = 1.70565 gm/cc

Avg Refl = 0.999"

13"-7" 1" C ref WO Core (c)

Nom Ht Critical 3⅞" = + 5.94¢

rings = 4.45¢
diaph = -20.85¢
f. support = 18.7¢

Lower .0022"

1.82 ¢/mil 13-7 from curve

Ht All Fuel 13-11: 3.895 -.893 -.895 -.894 -.895 -.897 = 3.8948"
11-9: 3.885 -.886 -.885 -.887 -.891 -.888 = 3.8870
9-7: 3.887 -.887 -.885 -.885 -.885 -.886 = 3.8858
w'avg = 3.8898"

2" A + 3" B = 5.009" = 5.009
High fuel ring + (1 × 13 disc) + (⅛ × 13 disc) = 5.0178 = 5.0178
(½ × 15") + (⅜ × 15) = 0.875 -.875 -.874 -.874 -.875 -.874 -.875 = 0.8745
5.8923

Reac't = = + 5.94¢
all support = - 2.30
13-7 = 0
+3.64

EVEN FUEL HT. = 3.8898"
SKY HOOK REACT. = + 3.64¢

0 = 3.8898 - .0020 = 3.8878"

0 Reactivity Ht = 3.8876"

13"-7"   1" GRAPHITE REFLECTOR + GRAPHITE CORE   Run 84 Pg 25B

1/16" VOID

15-13 | 13-11 | 11-9 | 9-7 | 7 DISC

G-3/4"
734

1"×13" B   3760

8.6 mil gap

VOID 1/16" (9-7) 65.5 mils

2782-1/4	2778	2774-1/4
2755-9/16	2767	2773-1/8
		2829-3/8
2757-1	2745	2738

7"×1/4" 246

9/16" 402

2"A
2476   1 1/16"

1 3/4"

1" A
1065

2752-1/2	2742-3/8	2736
	2744-1/8	2763
2751-1/2		
	2747-1 1/2	2740
2756-1		

3"B
3712

2"
2131

2"

3.8303   3.8218   3.7605

1"A
3682
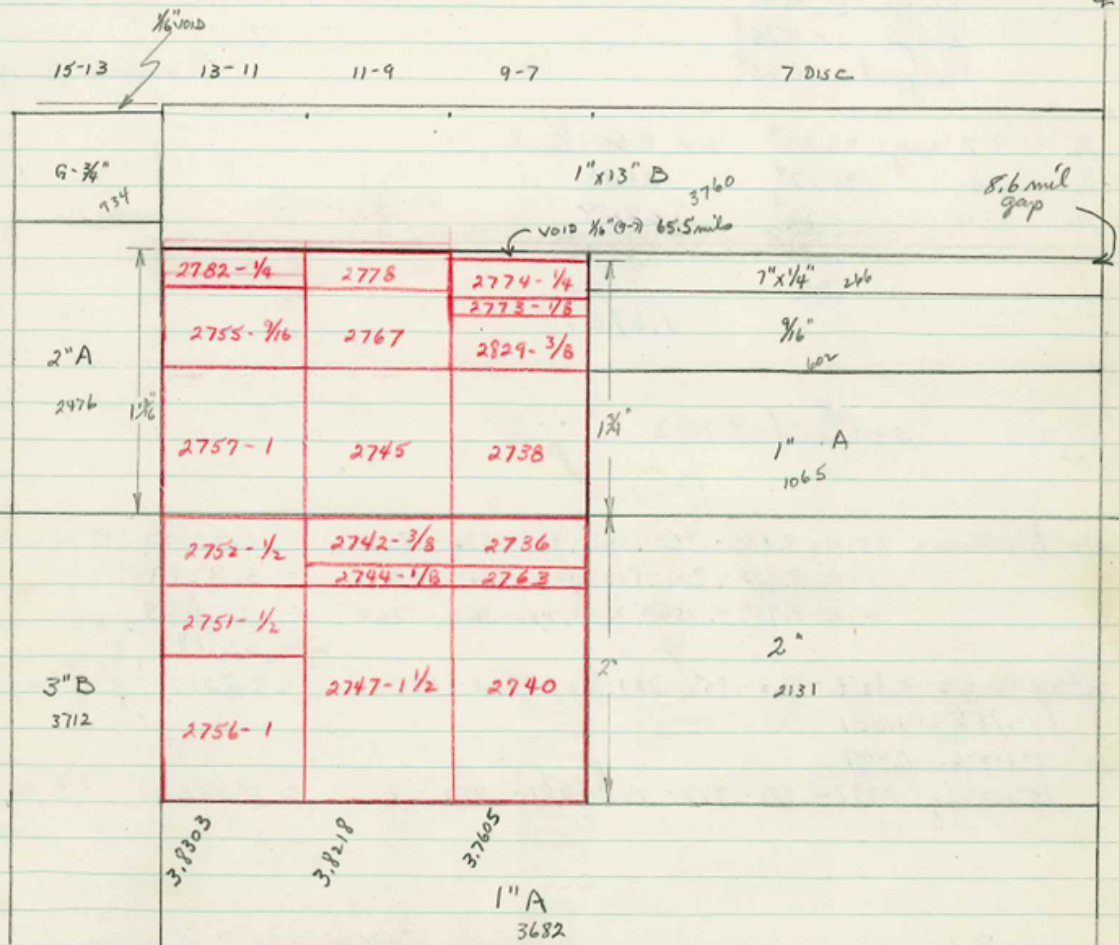
MASS OF TOP GRAPHITE = 9103 gm   TOTAL = 18.628 Kg
BOTTOM = 9525 gm

MASS OF TOP FUEL = 51955 gm   TOTAL = 109.847 Kg
BOTTOM = 57892 gm
AVG O.D FUEL (all) w/td = 12.99605"   AVG I.D w/td = 7.00295"
AVG Ht. Fuel (all) w/td = 168.89731   49.04130
FUEL VOL = 5875.54499 cm³
FUEL ρ = 18.6956 gm/cc
graphite vol = 10937.41987 cm³   Avg Refl =
ρ = 1.70314 gm/cc

A-132

13-7   1" Ref + Core (C)

Critical Nom. Ht $3\frac{13}{16}"$ on (13-11) & (11-9) + $3\frac{3}{4}"$ on (9-7) = + 7.26¢

Rings = 3.98¢
Diaph = -15.64¢
F. support = 16.63¢   Lower .0014"

$\frac{1}{16}$ - 9·7 ring : 36.32¢   or 0.5811¢/mil
$\frac{1}{16}$ 11-9   : 39.27¢   0.6283
$\frac{1}{16}$ 13-11 : 26.80¢   0.4288
                ─────   ──────
                102.39¢   1.6382
                   Core   .0345
                                 ──────
                                 1.6727

       .024¢/mil at 15-13

Ht. All Fuel = 13-11 = 3.830 - .830 - .830 - .830 - .832 - .830   = 3.8303" ✓
            11-9 = 3.822 - .821 - .822 - .822 - .824 - .820   = 3.8218
            9-7 = 3.759 - .759 - .761 - .760 - .762 - .762   = 3.7605
                                              wt avg = 3.8088"

Ht of Core = 3.822 - .822 - .822 - .821 - .823 - .821 - .821 -.   = 3.8217 (+26 mil)
   1" × 13" B = 1.001
   1" × 13" A = 0.999
   15" × 13" ring = 5.787 - .781 - .779 - .782 - .781 - .782 - .7   = 5.7820   (+26 mil)
                                                                      ok

Even Fuel Height = 3.8263"
   Skyhook Reactivity = +40.35¢ (includes $\frac{1}{16}$" void graphite 15-13 ring)

                         15-13 ↑40 = +0.96¢
                         React   = +7.26
   0 React Ht = 3.8074" all support = -4.97
                         13-7   = 0
                         Core ↓12.9 = -0.44
                                    ──────
                                    +2.81 = 3.8088"
                         0 = 3.8088 - .0016 = 3.8072"
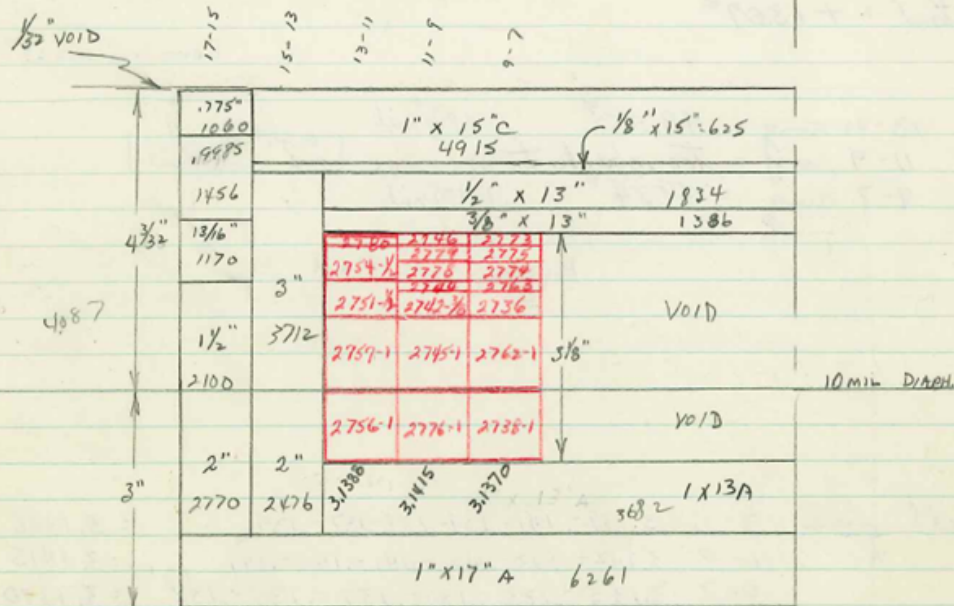
MASS OF TOP FUEL = 61563 gm   TOTAL = 90.484 Kg
         BOTTOM = 28921 gm

MASS OF TOP GRAPHITE = 18258 gm   TOTAL = 33.447 Kg
         BOTTOM = 15189 gm

AVG. O.D. ALL FUEL (WT'D) = 12.99607"   OD² = 168.89783
AVG. I.D. ALL FUEL (WT'D) = 7.00348"   ID² = 49.04873
~~AVG. HT. ALL FUEL (WT'D) =~~

FUEL VOL. = 4842.29248 cm³
FUEL ρ = 18.68619 gm/cc

graphite volume = 19687.74009 cm³
           ρ = 1.69887 gm/cc

Avg. Reft = 1.998"

A-134

13"-7"   2" C.ref. ≠ No Core

Critical Nom. Ht = 3⅛"   = +16.55¢

   rings = +3.45¢
   diaph = −15.48¢
   s.stand = +13.07¢

                                                   Lower .0059"

1/16"   13-11 ring = 48.55¢   .7768¢/mil   [65.6¢ or]
1/16"   11-9 ring = too much to measure [Est 1.05¢/mil]
1/16"   9-7 ring = 49.34¢   .7894¢/mil

                  Avg = 2,615 ¢/mil

Wt of all fuel 13-11 = 3.139−.141−.139−.138−137−.139   = 3.1388"
            11-9 = 3.142−.143−.142−.141−.140−.141   = 3.1415 ✓
            9-7 = 3.135−.135−.139−.137−.138−.138   = 3.1370
                                wt. Wt. = 3.1392"

Top Carbon   17-15 =   Same as 13-7 with core   (7.1435")
           15-13 =   (7.0777")
           13 disc =

                    React   = +16.55¢
                    all support = − 1.04
Bottom Carbon   17-15 =   13-7   = 0
           15-13 =   17-15 mil = 0
           13 disc =   +15.51 = 3.1392
                  0 = 3.1392 −.0059 = 3.1333

EVEN FUEL WT. = 3.1392"
SKY HOOK REACTIVITY = +15.51¢   (1/32" carbon gap 17-15 ring not considered)

  0 React Ht = 3.1333"

A-135

66 mil void

17-15   15-13   13-11

.775"
1060

.9985
1456

13/16
1170

1½
2100

2"
2770

B
3"
3712

2"
2476
A

1" x 15" B
4915

⅛" x 15" 625 gm

½" x 13"   1334

3/8 x 13   1386
⅛ x ?   130

½" x 7" =   536

1½" x 7" = 1618

1" x 7"   1065
     A

1" x 13" A
       3682

1" x 17" A 6261

65.4 mil — 1/16" VOID

2746 2773
2755-¾   2779-44 2725
         2728   2724
2751-X   2744   2243
         2742-¾   2736

2757-1   2745   2762

2756-1   2776   2738

3.0738   3.1415   3.1370

4 3/32   3 1/8   3 3/16

1"   3"

10 mil DIAPH.
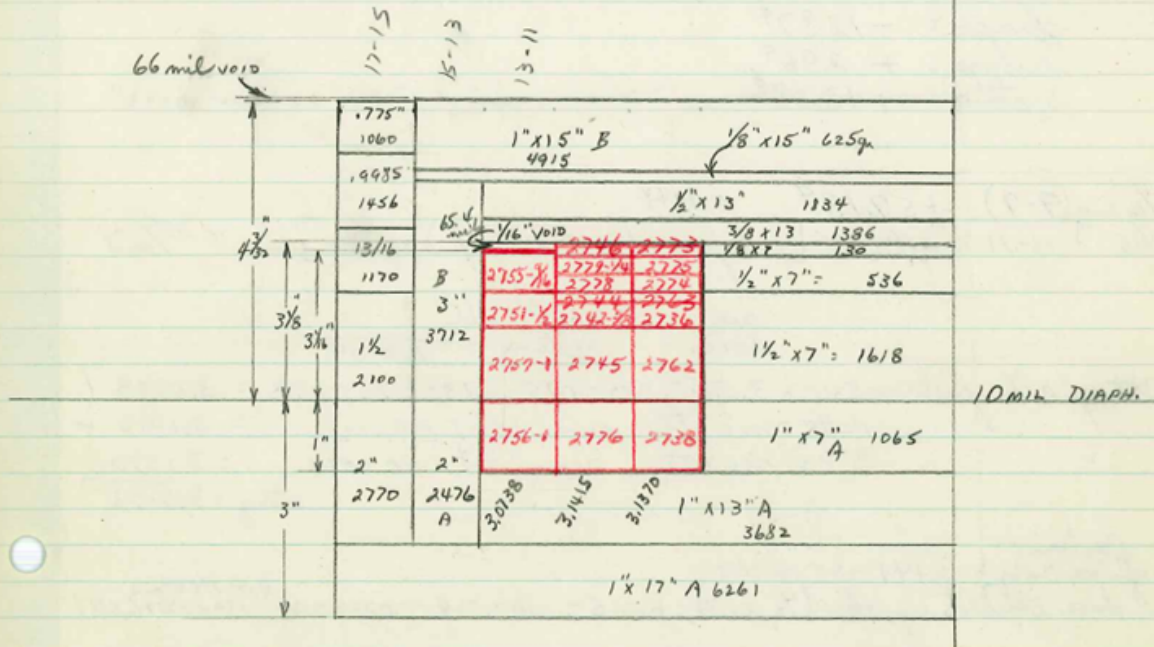
MASS OF TOP FUEL = 60811 gm   TOTAL = 89.732 Kg
       BOTTOM = 28921 gm

MASS OF TOP GRAPHITE = 20542 gm TOTAL = 36.796 Kg   OF THIS CORE = 3.349 Kg
       BOTTOM = 16254

AVG. O.D. ALL FUEL (WT'D) = 12.99618"   OD² = 168.90069
AVG. I.D. ALL FUEL (WT'D) = 7.00348"   ID² = 49.04873
~~AVG HT. ALL FUEL (WT'D) =~~

FUEL VOLUME = 4802.33484 cm³
FUEL   ρ = 18.68507 gm/cc

graphite volume = 21670.59229 cm³
          ρ = 1.6979692 gm/cc

AVG REFL = 1.998"

13"-7" 2" C ref. + C core

Nom. Ht. Critical = 3⅛" on (6-9) & (9-11)
                    3/16 on (13-11) ring = +18.97¢

        diaph.: -12.87¢
        rings: + 2.96¢
        s.stand: + 13.08¢   Lower .0093"

1/16" ring (9-7) = +57.15¢   0.9144
1/16   13-11 = +41.92 [est. from (15-9 & 2"ref) pg 100] or 0.67¢/mil

                    avg = 1.685¢/mil
                    Core = .0159
                                    1.7009
Wt of all fuel 13-11 = 3.075-.075-.075-.073-.072-.073 = 3.0738"
                11-9 = - see other run 13-7 no core   = 3.1415 ✓
                9-7 = see other run 13-7 no core   = 3.1370
                                        wt avg = 3.1132"

                Carbon
Wt of Core Only = 3.141 NOT NEEDED
all discs stacked up thru (½ × 13) = 6.015-.019-.024-.021-.016-.015-.022 = 6.0188   NOT NEEDED

Measure all stacked 15"dia = 7.145-.142-.143-.142-.147-.142   = 7.1435
(17-15) ring all   = 7.081-.078-.073-.070-.081-.079-.082   = 7.0777

        React ——— = +18.97¢
        all support   = - 3.17
        13-7   = 0
        Core ↓27.8   = - 0.44   ⊙ = 3.1132-.0090 = 3.1042"
        17-15 mil   = 0
                    +15.36¢ = 3.1132"

EVEN FUEL Wt. = 3.1655"
SKY HOOK REACT. = + 59.61¢ (66 mil carbon void (17-15) not considered)

corrected flat fuel Wt = 3.1039" ✓

use this : 3.106" calc from ring value est. reported.

A-137
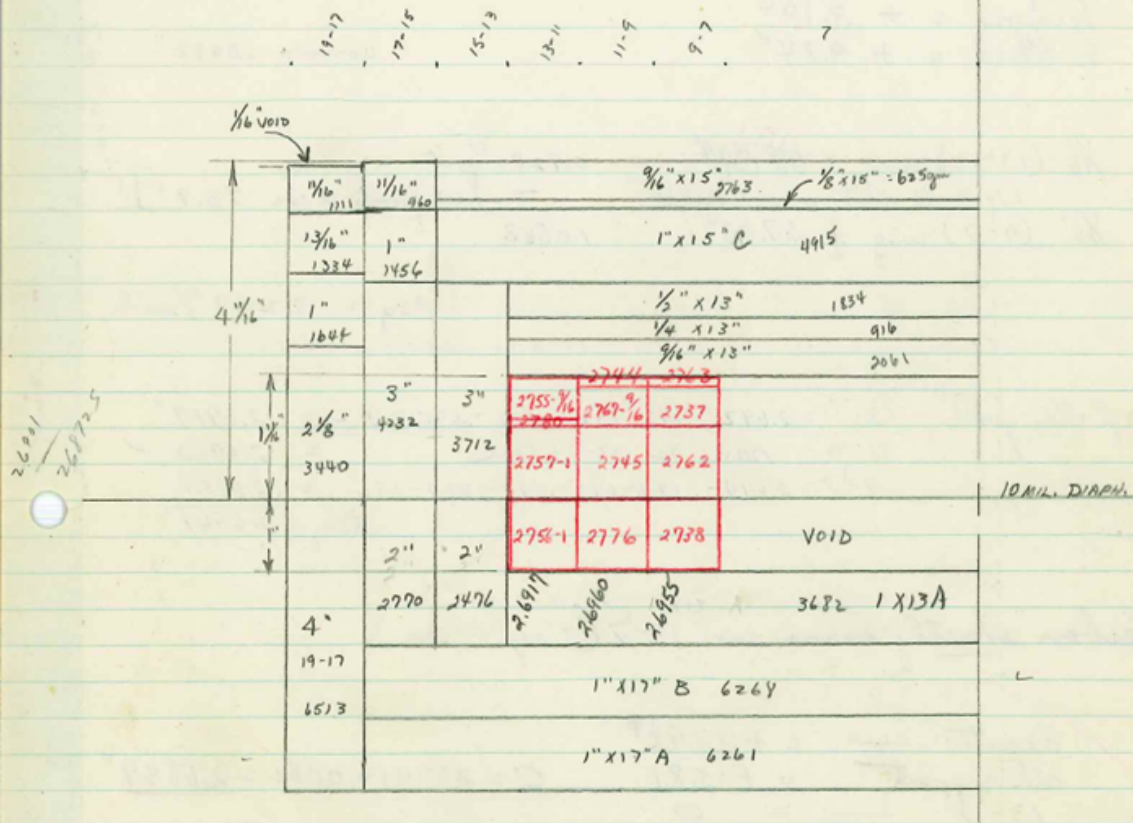
MASS OF TOP FUEL = 48788 gm   TOTAL = 77.709 Kg
       BOTTOM = 28921 gm

MASS OF TOP GRAPHITE = 31003gm   TOTAL = 58.973 Kg
       BOTTOM = 29035gm

AVG. O.D. ALL FUEL (WT'D) = 12.99625"   OD² = 168.90251
AVG I.D. ALL FUEL (WT'D) = 7.00328"   ID² = 49.04593
AVG Ht. ALL FUEL (WT'D) =
     FUEL VOLUME = 4156.02026 cm³   vol. of graphite = 34543.76000cm³
        FUEL ρ = 18.69793 gm/cc   ρ = 1.70719 gm/cc
     AVG REFL = 2.999"

13-7   3"C ref # <u>No</u> Core

Nom. Wt Critical 2"/16   +2290¢ reactivity

Diaph = −16.84¢
Ring = + 3.19¢
S. Stand = + 9.84¢   Lower −.0082"

1/16" (13-11) ring = 58.01¢   0.9281¢/mil
    11-9 is not measurable   — [est from 3"w core 75.9¢] of 1.214¢/mil
1/16" (9-7) ring = 67.93¢   1.0868

                              Avg = 3.229¢/mil

Wt of all fuel 13-11 = 2.692 −.692 −.692 −.692 −.690 −.692 = 2.6917"
              11-9 = same as 13-7 + Core   = 2.6960 ✓
              9-7 = 2.694 −.697 −.695 −.694 −.697 −.696 = 2.6955
                                    wt avg = 2.6941"

Carbon <u>exactly</u> same as 13-7 (3"ref + core)

Reactv ——— = +22.90¢
all support   = + 3.81   0 = 2.6941 −.0082 = 2.6859"
13-7 ——— = 0
19-17 mil = 0
              +26.71 = 2.6941"

EVEN FUEL HT. = 2.6941"
SKY HOOK REACTIVITY = +26.71¢   (1/16" carbon gap 19-17 ring not considered)

0 Reactivity Ht = 2.6859" ✓

A-139

. 18-17 . 17-15 . 15-13 . 13-11 . . .   ₵

90 MIL gap

11/16" 1111	11/16" 960		9/16" x 15 2763	1/8" x 15 625	
13/16" 1334	1" 1456	4 MIL gap	1" x 15 C 4915		
1" 1699			1/2" x 13 1834		
			1/4" x 13 916		
		9/16" VOID	9/16" x 13 2061		
2 1/8 3990	3" 4232	3" 3712	2755-3/16 · 2744 · 73-63 · 2780 · 2767-9/16 · 2736 7/8	1/8" x 7 130	
				9/16 x 7 602	
			2757 1 · 2745 · 2762	1" x 7" B 1065	
	2"	2"	2756-1 · 2776 · 2738	1" x 7" A 1065	10 MIL DIAPH.
4" 6513	2770	2476	2697 · 2660 · 2637?	3682 1 x 13 A	
			1" x 17" B 6268		
			1" x 17" A 6261		

MASS OF FUEL, TOP = 48309 gm   TOTAL = 77. 230 Kg
               BOTTOM = 28 921 gm

MASS OF GRAPHITE TOP: ————   TOTAL = 61,835 Kg   OF THIS, CORE = 2.862 Kg
               BOTTOM : ————

AVG. O.D. ALL FUEL (WT'D) = 12.99625"   OD² = 168.90251
AVG. I.D. ALL FUEL (WT'D) = 7.00348"   ID² = 49.04873
AVG. Ht. ALL FUEL (WT'D):
          FUEL VOLUME = 4131.86627 cm³
          FUEL   ρ = 18.69131 gm/cc
graphite volume = 36245.96655 cm³
          ρ = 1.70598 gm/cc   AVG. REFL = 2.899"

13-7   3" Cruf + C Core

Nom Ht Critical = 13-11 = 2 11/16 " ⎫
                   11-9 = 2 11/16 " ⎬ → ∞ period
                   9-7   = 2 5/8 "   ⎭

       Δ graph = −14.35¢
       Rings   = +3.54¢
       S. Stand = +9.44¢

1/16" 13-11 = +48.68¢ or 0.7285¢/mil   13-11 = 2 11/16 ⎫
1/16" 11-9 = +63.16¢   1.010¢   11-9 = 2 5/8 ⎬ → −6.16¢
1/16" 9-7   = +57.00¢ or 0.912¢/mil   9-7   = 2 11/16 ⎭

            ↑
   Avg = 2.701 ¢/mil   13-11 = 2 5/8 ⎫
   Core   .0074   11-9 = 2 11/16 ⎬ → +8.32¢
          2.7084   9-7   = 2 11/16 ⎭

Wt of all fuel 13-11: Same as 13-7 Pg 43   = 2.6917"
               11-9: 2.695−.696−.696−.693−.697−.699 = 2.6960 ✓
               9-7: 2.638−.637−.637−.637−.636−.637   = 2.6370
                                        w't avg = 2.6785"

Wt of core only = 2.696−.695−.696−.696−.700−.702−.696 = 2.6972
11/16 + 1/8 + 1/2 X 13 = 1.315−.317−.315−.315−.315−.316−.314 = 1.3153

15" dia. all = 8.710−.718−.715−.710−.709−707−.7   = 8.7115
17-15 ring = 8.724−.719−.722−.730−724−.720   = 8.7231
19-17 ring = 8.635−.633−.632−.633−.630−634   = 8.6328

                              Reactivity
                              all support   = +1.37¢ ⎫
                              13-7   = 0   ⎬ = +1.24
                              19-17 mil   = 0   ⎭
                              Core + 18.7   = −0.13
EVEN FUEL HT. = 2.6960"   0 = 2.6785−.0004 = 2.6781"
SKY HOOK REACT. = +58.51¢   (90 mil carbon gap 19-17 ring not considered)

Corrected flat fuel Ht = 2.6785"

A-141
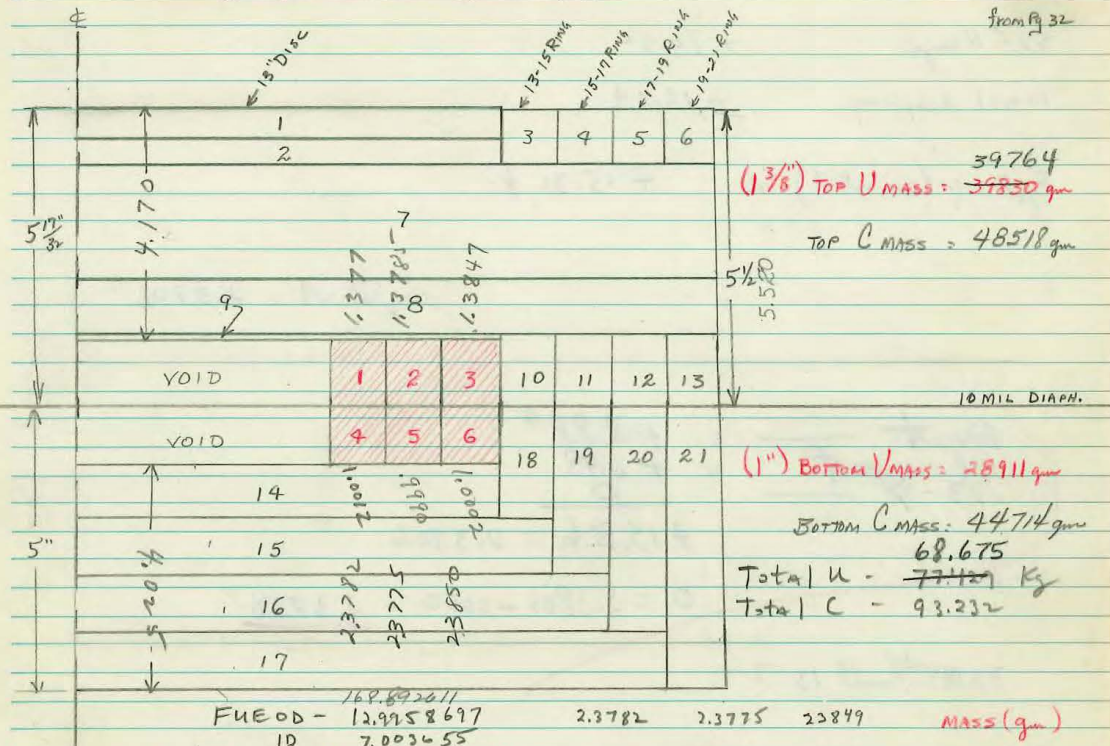
$(1\frac{3}{8}")$ TOP U MASS = ~~39830~~ gm   39764

TOP C MASS = 48518 gm

10 MIL DIAPH.

$(1")$ BOTTOM U MASS = 28911 gm

BOTTOM C MASS: 44714 gm

Total U - ~~77.429~~ Kg   68.675

Total C - 93.232

AVG REEL = 3.998"

					MASS (gm)
FUE OD -	12.9258697		2.3782	2.3775	23849
ID	7.003255				
1	#2762	(1" 7-9); 2829 (⅜")			7703 + 2895
2	#2776	(1" 9-11); 2742 (⅜")			9644 + 3617
3	#2750	(⅜" 11-13); 2781 (⅛"); 2749 (⅜"); 2754 (½")			4336+1449+4360+5826
4	#2738	(1" 7-9)			7710
5	#2745	(1" 11-9)			9634
6	#2756	(1" 11-13)			11567
1	1⅞₂" x 13" DISC				2007
2	½" x 13" A DISC				1834
3-4-5-6	1" RINGS		1262 + 1454 + 1644 +		1828
7	2" x 21" DISC				19263
8	1" x 21" DISC				9666
9	⅛" x 13" DISC				461
10-11-12-13	1½" RINGS		1870 + 2100 + 2452 +		2677
14	1" x 13" #A				3682
15	1" x 15" #C				4915
16	1" x 17" #B				6268
17	1" x 19" #B				7838
18	1" x 2" B (13-15)				2439
19	1" x 3" A (15-17)				4232
20	1" x 4" (17-19)				6513
21	1" x 5" (19-21)				8827

Fuel vol = 3671.94103 cm³
ρ = 18.70264 gm/cc
graphite Vol = 54747.39855 cm³
ρ = 1.70294 gm/cc

13"-7"   4" C ref WO Core

Clean critical   + 8.88 ¢

SS + Ring   + 10.3~

10 mil diaphragm   − 16.8 ¢

Expt ρ (corrected) =   + 15.36 ¢

                                        avg ht. wt. = 2.3806"

React   = + 8.88 ¢
all support   = + 6.48
13-7   =   0
                  + 15.36 = 2.3806

              0 = 2.3806 − .0050 = 2.3756"

3.0185 ¢/mil 13-7

EVEN FUEL HT. = 2.3806"
SKY HOOK REACT. = + 15.36 ¢   (extra carbon on top not considered)

Column labels (vertical): 10.2910, 21-19, 19-17, 17-15, 15-13, 13-11, 11-9, 9-7

	21-19	19-17	17-15	15-13	13-11	11-9	9-7		
3/4	11/16	11/16	1½				½ x 13		1834
1364	1111	960							
1	13/16	2	1870				1 x 13B		3760
1828	1334								
1½	1½	2770					1 x 13A		3682
	2438		3¾						
2677									
		2 1/16		36.5 mils gap			1½ x 13		5509
2	2⅜		4628	15 -⅝	44	17 -³/₃₂			
				82 -¼	79 -¼	63			
3546	3863	3776		49 -⅜	78 -¼	74	VOID		
				51 -½	43- ⅞	2824			
					42- ⅞	2736			10 MIL DIAPH.
1	1	1	56 -1	45	38	VOID		
1644	1456	1262						
3			2,4160	2,3813	2478	1 x 19 B		7838
5325						1 x 19 A		7828
						2 x 21		19263

MASS OF FUEL = 69383 gm
    VOLUME = 3709.97139 cm³
    ρ = 18.70176 gm/cc

MASS OF GRAPHITE = 91566 gm   AVG REFL = 3.999"
    VOLUME = 53610.96306 cm³
    ρ = 1.70797 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 12.99632"   OD² = 168.90433
        I.D. = 7.00307   ID² = 49.04298
21-19 OD Carbon = 20.99894"   440.95548

13-7   4"ref ≠ No Core   2375

Nom. Ht. Critical- ⎡ 13-11 ⎤ 2 13/32"   reactivity = +42.0¢
                    │ 9-7 │
                    ⎣ 11-9   2 3/8" ⎦

        Rings = + 3.70¢
        Diaphragm = -16.39¢
        S. Stand = +7.04¢   Lower 0.0158"

less 1/32" fuel 13-11 = 23.05¢   0.7376¢/mil
                   11-9 = 42.0¢   1.344+   note: removed from already low ring
                    9-7 = 29.28¢   0.9369   wt vol Avg = 3.0185 ¢/mil
                                    3.0185

ADD 486 mils graphite on 15-13 ring = 11.93 or 0.0245¢/mil

Wt of fuel 13-11 = 2.416 - .416 - .415 - .417 - .416 - .416   = 2.4160"
            11-9 = 2.381 - .381 - .380 - .382 - .381 - .383   = 2.3813"
             9-7 = 2.420 - .418 - .416 - .416 - .418 - .419   = 2.4178"
                                        wt vol Avg = 2.3947"

Wt of Carbon 21-19 = Same as Pg 146   = 10.3054"(-40)
             19-17 = Same as 146   = 10.3873" —
             17-15 = 10.384 - .386 - .383 - .384 - .381 - .379 - .584   = 10.3830"(-10)
             15-13 = Same as 146   = 10.2652"(-135)
             13 dia = 8.010 - .014 - .017 - .015 - .011 - .012 - .010   = 8.0127"

                                        Raise 0.0012"

        corrected flat fuel height = 2.3801" ✓

        Reactivity = —— = + 42.0¢
        all supports   = + 5.65
        13-7   —— =   0
        21-13 mil   =   0
                          +47.65 = 2.3947"
                O = 2.3947 - .0157 = 2.3790"

3/4	11/16	7/8						1/2 x 13	1834
1364	111L	1233	1 1/2						
1	13/16		1870					1 x 13 B	3760
1828	1334	1 1/2							
1 1/2	1 1/2	2098						1 x 13 A	3682
2677	2438		3 3/4					1 1/2 x 13	5509
		3A							
2	2 3/8			50 - 3/4	74 1/4	75		1 x 7 B	
3546	3863	4232	4628	49 - 7/8	78 - 1/4	74			1065
				51 - 1/2	43 - 3/8	2829		3/8 x 7	404
					42 - 3/8	2236			
	1	1	1	56 - 1	45	38		1 x 7 A	
	1644	1456	1262						1065
3				23.3790	23.813	23.857		1 x 19 B	7838
5325								1 x 19 A	7828
								2 x 21	19263

MASS OF FUEL = 68748 gm
 VOLUME = 3674.02121 cm³
  ρ = 18.71192 gm/cc

MASS OF GRAPHITE: 94157 gm
 VOLUME: 55120.86160 cm³
  ρ = 1.70795 gm/cc

AVG REEL = 3.999"

AVG. O.D. ALL FUEL (W'T'D): 12.99592"   OD²: 168.89593
 I.D: 7.00342"   ID²: 49.04789
21-19 OD Carbon = 20.99894"   440.95548

A-146

13-7   4" rep. + core

Nom. Ht. Critical = 2⅜"   reactivity : + 34.53¢

        Rings = + 3.54¢
    Diaphragm = -15.31¢
    S. Stand = + 2.84¢   Lower   0.0140"

1/32" fuel   13-11 = 28.38¢   0.9081 ¢/mil
            11-9 : 40.26¢   1.2883
             9-7 = 28.08¢   0.8985   wt vol Avg = 3.095 ¢/mil
                               3.0949   Core = .0182
                                                         3.1132

add 130 mils on 21-19 ring = 0.13¢   .001 ¢/mil
add 486 mils   15-13 ring = 12.42¢   .0245 ¢/mil
less 242 mils   15-13 ring = 8.44¢   .0348 ¢/mil
  Ht of fuel 13-11 : 2.380 -.379 -.380 -.379 -.380 -.381   = 2.3798"
            11-9 : Same as Pg 143   = 2.3813"
             9-7 : 2.384 -.385 -.385 -.388 -.386 -.387   = 2.3858"
                                        wt vol Avg = 2.3779"

Ht of Carbon : 21-19 : 10.302 -.298 -.307 -.312 -.310 -.298 -.297 .   = 10.3034" (-76)
              19-17 : 10.390 -.389 -.392 -.388 -.382 -.383   = 10.3873" —
              17-15 : 10.388 -.387 -.390 -.386 -.383 -.383   = 10.3861" —
              15-13 : 10.264 -.272 -.266 -.266 -.266 -.264 -.259   = 10.2652" (-113)
              13 dia : Same as Pg 143   = 8.0127"
              Core : 2.388 -.388 -.387 -.387 -.388 -.387 -.388 -.389 = 2.3878"

                                                    Raise 0.0011"

            Corrected flat fuel height = 2.3650" ✓

    Reactivi ————— = + 34.53¢
    all supports   = + 8.93
    13-7 ————   =   0
    21-13 mil   =   0
    Core + 9.9   = - 0.18
                    + 43.28¢ = 2.3779"
      ① = 2.3779 - .0139 = 2.3640"

25   21   19   17   15   13   11   9   7

```
1.2          11/16    7/8    1
4895         1111     1233  1262   1 1/2        1 1/2 X 11
             3                     1588                        3929
      5      1
      5325   1644     1
                      1456   2             1 X 13 C      3745
             2 3/0           2439
             3863    3B                    1 X 13 B      3760
      7              4188    2
                             2476          1 X 13 A      3682
   28700     5                             1 1/2 X 13
             4                                           5509
      8827   4
             6513    3A     3       15-4/32  16   17
                     4232   3712    80-1/8   44   63
                                    55-3/16  67   37      VOID
                                    56-1     45-1  38-1
      6868         1/2 X 25                              15 MIL DIAM.

   1      1      1 1/2   1 1/2
   4234   1828                    1 1/2 X 15             7485
                  2438   2098
          1 1/2
          2677                    1 X 19                 7828
   4 1/2                          1 X 21                 9666
   18455
                                 2 X 21                  19263
```

MASS OF FUEL = 56909 gm   AVG. OD OF FUEL = 12.99659"
  VOLUME = 3040.29 511 cm³   OD² = 168.91135
     ρ = 18.71825 gm/cc   AVG ID OF FUEL = 7.00271"
MASS OF GRAPHITE = 186929 gm   ID² = 49.03794
  VOLUME = 108786.13539 cm³
     ρ = 1.71831 gm/cc   AVG REFL = 6.001"

13-7   6" ref $\neq$ No Core

Nom. Ht. Critical = $1\frac{31}{32}$"   two runs $+15.71 \rangle +15.11$ ¢
support stand = 2.74¢   reactivity = $+14.51$
support ring = 1.68¢
diaphragm = -11.70¢
$\frac{1}{2}$" al diaph. support = $\stackrel{.}{=}$ 2.82¢

		¢	¢/mil		
		34.10	0.9632		red is avg ↑∀↓↑↓
$\frac{1}{32}$" fuel	13-11 =	31.56¢	1.0094		
	11-9 =	57.70¢	1.8464		
	9-7 =	38.11¢	1.2195		
			4.0758		

				React = $+15.11$ ¢	
-389 mils graphite (TOP)	25-21 =	1.69¢	.00434	↓218mils = -0.94 ¢	
-227	21-19 =	1.42¢	.00625	↓ 45 = -0.28 ¢	
-248	19-17 =	2.59¢	.01044	↓ 108 = -1.12 ¢	
-193	17-15 =	3.01¢	.01559	↑ 54 = $+0.84$ ¢	
-244	15-13 =	5.62¢	.02303	↓ 58 = -1.33 ¢	
-125	13-11 =	6.47¢	.05176	↓ 13 = -0.67 ¢	
-125	11-9 =	10.13¢	.08104	↓ 13 = -1.05	
-125	9-7 =	3.3¢	.02640	↓ 13 = -0.34 ¢	
-125	7" dia =	5.52¢	.04416	↓ 13 = -0.57 ¢	
+125	11" dia =	11.88¢	.09504	all supports = $+4.46$ ¢	

1.9706" = $+14.11$ ¢
(-3.4 mil) = 1.9672" — clean

Ht of carbon 25-21 = 14.210 - .186 - .180 - .180 = 14.1890"
21-19 = 14.020 - .007 - .020 - .018 = 14.0162"
19-17 = 14.080 - .074 - .078 - .085 = 14.0792"
17-15 = 13.912 - .929 - .912 - .914 = 13.9167"
15-13 = 14.028 - .025 - .020 - .043 = 14.0290"
15 dia = 12.006 - .023 - .011 - .015 = 12.0137"

Ht of fuel 13-11 = 1.970 - 970 - 969 - 970 - 970 - 970 = 1.9698"
11-9 = 1.971 - 971 - 971 - 970 - 970 - 971 - 971 = 1.9707"
9-7 = 1.972 - 972 - 972 - 972 - 972 = 1.9720"
wt avg = 1.9706"

25 ·   21   19   17   15   13   11   9   7

.8 3283		11/16 1111	7/8 1233	1 1262	1½ 1588
	3 5325	1 1664	1 1456		1½ × 11 3929
		2⅜ 3863	2 2439		1 × 13 C 3715
			3B 4188		1 × 13 B 3760
7 28700			2 2476		1 × 13 A 3682
	5 8837	4 6513			1½ × 13 5509
		3A 4232	3 3712		1½ VOID

Red grid:
13 80	16 48	13 63
55	67	87
56	45	38

9/16 × 7   602
3/8 × 7   404
1 × 7   1065

15 MIL DIAPH

6868	½ × 25		
1 4234	1 1828	1½ 2438	1½ 2098
	1½ 2677		1½ × 15 7485
4½ 18455			1 × 19 7828
			1 × 21 9666
			2 × 21 19263

MASS OF FUEL = (Same as 255) 56909 gm
ρ = Same = 18.71825 gm/cc
MASS OF GRAPHITE = 187.388 gm
VOLUME = 109524.4782 cm³
ρ = 1.71092 gm/cc

AVG REFL = 6.001"

13-7   6" ref + core

Nom. Ht. Critical = 1 31/32" }
              Core = 1 15/16" }

two runs
reactivity = +30.82 } 32.46 } +31.64

diaphragm = -7.08¢
½" al support = +1.80¢
sun g = +1.02¢
s. stand = +3.88¢
1/32" fuel 13-11 = 30.00¢   or   0.9600 ¢/mil
          11-9 = 41.74¢   1.3356 ¢/mil
          9-7 = 29.00¢   0.9280 ¢/mil
                                  3.2236 ¢/mil

Center of

(-)⅛" carbon 7"dia. located 3/32" below fuel top = 10.71¢   or @ 1.875/mm Bot
(+)⅛ located 0.9375" above bottom of fuel = 1.75¢
   "   "   1.1875   "   = 2.44¢
   "   "   1.625   "   = 4.93¢
   "   "   1.750   "   = 8.79¢

≈ 11¢ per ⅛" at top of graphite core = 11.0¢ = .0880 ¢/mil

Ht. of carbon 25-21: 13.988 - .988 - .980 - .984   = 13.9850"
               21-19: Same as 25S   14.0162"
               19-17: Same   14.0792"
               17-15: Same   13.9167"
               15-13: Same   14.0290"
               13 dia: Same   12.0137"
               Core = 1.937 - 936 - 935 - 937 - 939 - 937 = 1.9368"

Ht. of fuel 13-11 = Same as pg 25S : 1.9698"
             11-9 = Same   25S   : 1.9707"
             9-7 = Same   25S   : 1.9720"
                          wt av = 1.9706"

Reactivity = +31.64¢
all supports = + 0.38¢
25-21 ↓14 mils = -0.06
21-19 ↓45   = -0.28
19-17 ↓108   = -1.12
17-15 ↑53   = +0.82   1.9706" = +30.32¢
15-13 ↑58   = -1.33   (-9.4 mils): 1.9612" = clean ∞
Core ↑33   = +2.90
13-11 ↓13   = -0.67
11-9 ↓13   = -1.05
9-7   ↑13   = -0.34
7dia ↓13   = -0.57

29   25   21   19   17   15   13   11   9   7

3/4 1364   3/4 1255   13/16 1170

3/4 3664   3   12350   1 1/8 1997   11/16 1111   7/8 1233   1 1262   2 2082   2×11   5273

2 1/8   2A 2476   1 1/2 1588   1 1/2 ×11   3929

3 5325   3440   2 2770

1 × 13 C   3745

9   2 3/8 3863   3 3712   1 × 13 B   3760

7 28700   3B   1 × 13 A   3682

43550   4188

5   1 1/2 × 13   5509

8827   4 6513   3A 4232   3 3/4 4628   81 MILS VOID   1/8 × 7   130

13	16	63 73
55	67	37
49	74	75
51	42	36

9/16×7   602

1×7   1065

15 MIL DIAPH.   1/2 × 25   6868

1 4985   2 × 25   27650

5 24550   1 4234   1 1828   1 1/2 2438   1 1/2 2098   1 1/2 × 15   7485

1 1/2 2677   1 × 19   7825

4 1/2 18455   1 × 21   9666

1 1/2 7427   2 × 21   19263

AUG REFL = 8,000"

A-152

13-7   8" ref. ≠ No Core   <u>SEE + Core</u>
                                       <u>below</u>

Nom. Wt. Critical = $\begin{array}{l}9-7 = 1^{11/16}"\\13-9 = 1^{23/32}\end{array}\Big\}$ 1.71   reactivity = + 0.87¢

    diaphragm   = -12.86¢   MASS OF FUEL = 49499 gm₃
ring & ring support = + 3.08¢   VOL = 2650.81152 cm³
    support stand = ≃ 2.00¢ calc from prev. runs.   ρ = 18.67314 gm/cc

1/32" fuel 13-11 = 35.00¢   or   1.1200 ¢/mil   MASS OF GRAPHITE = 324650 gm₃
         11-9 = $\begin{array}{l}37.99¢\\39.79\end{array}\Big\}$ 38.89¢ or 1.2444 ¢/mil   VOL = 188052.2300 cm³
                                              1.726388 gm/cc
          9-7 = 41.15¢   or   1.3168 ¢/mil   FUEL OD = 12.99608"
                              3.6812   168.89809
                                          ID = 7.00250"
                                              49.0350

13-7 8" ref <u>+ core</u>   1.7143" clean ∞

Nom. Ht. = Same   reactivity = + 16.23¢

  diaph = $\begin{array}{l}-13.80¢\\-12.18¢\end{array}\Big\}$ -12.99¢   ρ OF FUEL = 18.67314 gm/cc
all support = + 5.37¢   MASS OF GRAPHITE = 326447 gm
                                   VOL = 189084.41993 cm³
                                   ρ = 1.72646 gm/cc

1/32" fuel 13-11 = 33.54¢ or 1.0732 ¢/mil
         11-9 = 39.91¢   1.2771 ¢/mil   1.7094" clean ∞
          9-7 = 40.75¢   1.3040 ¢/mil
                          3.6543

Wt of fuel 13-11 = 1.729-729-729-730-729-730-731-730   = 1.7296"
         11-9 = 1.724 - 724-724-724-724-724   = 1.7240"
          9-7 = 1.694 -694-694-696-695-694   = 1.6945"
                                              wt'd avg = 1.7183

Wt of Carbon = 29-25 = 17.300 -.287 -.290 -.290 = 17.2917"
            25-21 = 17.995 - 18.010 -.002 - 17.980 = 17.9967"
            21-19 = 17.929 - .925 - .926 - .928 -.928 = 17.9272"
            19-17 = 17.976 - .970 - .980 - .974 = 17.9750"
            17-15 = 17.731 - .734 - .735 - .743 = 17.7357"
            15-13 = 17.774 - .760 -.775 - .760 = 17.7672"
            13 disc 16.016 -.008 - .006 - .025 = 16.0137"
            7' core = 1.636 -637-636-638-636-638-636 = 1.6367"
                                              1.688"

13"·7" & 16" GRAPHITE REFLECTOR ≠ No Core

7883

402 cm³

11.6

½ x 25   686V

½ x 35

1   45.4

15   683.6

½   70.3

1   39.5

8

33·01

8

3·18

1850

Ram C = 81982

10

¼"
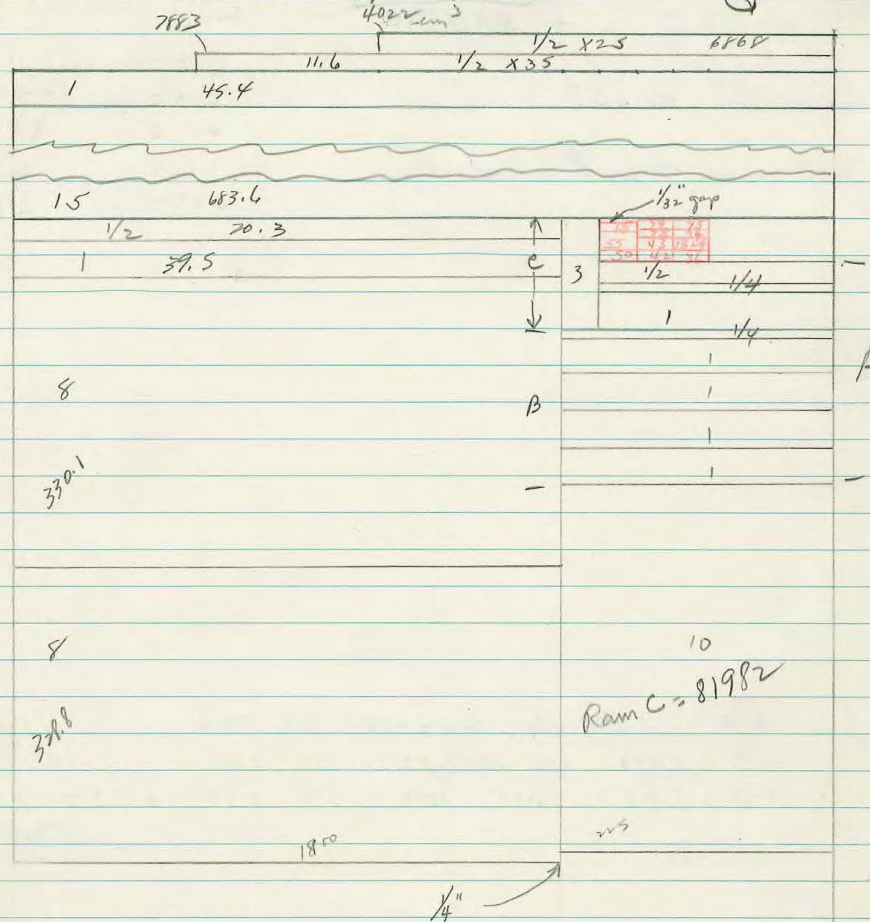
Mass of fuel = 35800 gm
 Vol = 1914.2743 cm³
  ρ = 18.7016 gm/cc
Fuel OD = 12.99591"   (²) = 168.89367
  ID = 7.00312"   (²) = 49.04368

Mass of C = 1548150 gms
 Vol = 884226 - 2732 = 881494 cm³
 ρ = 1.756 gm/cc

Aug REFL = 16.000"

A-154

13-7 & 16" C. up. No Core

nom. Ht. Critical: (11-7) = 1¼" & (13-11) = 1⁷⁄₃₂"
reactivity = + 7.54¢

Supports: +1.65¢

fuel value → not measured

25 × 1 = 10.76¢

fuel 13-11 = 1.220 - .220 - .220 - .219 - .219 - .219   = 1.2195
11-9 = 1.256 - .256 - .256 - .257 - .256 - .256 = 1.2561
9-7 = 1.255 - .255 - .254 - .254 - .254 - .255 - .255 = 1.2545
                                                    wt avg = 1.2410

A   Same 4-20¢ = 6.0120"
B   Same 4-20¢ = 4.2527"
C   Same 4-20¢ = 3.0030"

1.241 8
1.240 1

A-155

MASS OF FUEL = 35976 gm
    Vol = 1923.9732 cm³
      ρ = 18.7007 gm/cc
Fuel OD = 12.9957"(²) = 168.879641
      ID = 7.00172"(²) = 49.02408

MASS C = 1537881 gm
   Vol = 874399 cm³
     ρ = 1.758 gm/cc

AVG REFL = 16.000"

13-7 ≠ 16" C. w/ + Core

Nom. Ht. Critical : (13-9) - 1¼" & (9-7) - 1⁷/₃₂"

Reactivity = + 27.06¢

fuel value = not measured

25" x ½" C = 10.76¢

Fuel 13-11 = 1.255 + .255 + .255 + .255 + .255 + .255 + .255 .   = 1.2550
    11-9 =   = 1.2561   = 1.2561
    9-7: 1.224 + .224 + .224 + .224 + .224 + .225 = 1.2241   = 1.2241
                                                    Wt avg = 1.2471

A = 6.015 + .012 + .011 + .010   = 6.0120
B = 4.255 + .252 + .252 + .252   = 4.2527
C = Look up   = 3.0030
D = 1.251 + .252 + .251 + .251   = 1.2510

1.247⁰
1.247

13-9

GRAPHITE — C — 1.72176

3745 g

1" C Refl
+
C Core

(p. 62
Bk 1)

2781 2780 2783	2767	✓ G 1/4 2212	
1.7233126 2755		✓ G 5/16	
2782		✓ G 3/8 668 g	
GRAPHITE 2750	2747	✓ G 1/2 583 g 1.694012	
2749		✓ G 9/16 979 g 1.701888	P C in hole
2754		✓ G 1 1771 g c = 1.698747	1.69282
2753	2742 2776	✓	
6781 g		G 1 1/2 2075 g	
14.974 13.015 1.983	2756 2745	1.710628	

H 5.5 4.078625 4.06375
           4.0711875 — Av.
M   47.088 39.124   7661 g   Av U
ρ   18.68402 18.700979

Λ₁

1.7268458	2752	2746	
		2742	
GRAPHITE 2751		GRAPHITE 2"	
2757	2748	3533 gm	
3710 g 15.030 13.010		1.69448	

13.001   .999

GRAPHITE — A   1.69422
3682 g

Λ₁ 9.001747
Λ₂ 10.99677 ring
Λ₃ 11.00283 ring
Λ₄ 12.99591
Λ₅ 13.00

4.00375
2.0965
6.0702

H 3" 2.01225 2.0065
           2.009375
M   23,208 19.317   Av H of fuel
ρ   18.66806 18.7003   6.0805625

Total MASS = U = 128.737 Kg   Av. ρ 18.6932

Tot. Mass of C = 28.647 Kg   Σ ρ = 1.707

13-9 RING 1" GRAPHITE REFLECTOR
AVG REFL = 0.998"

Measurements

Clean Critical $-1.46 ¢$

REACTIVITY EFFECTS

    Lower Support $.5.4 + 4.87 ¢ \rightarrow + 5.15 ¢$

    10 mil Diaphram $- 8.27 ¢$

    Support ring $6.96 ¢$

    Planks $- 0.63 ¢$

CORRECTED REACTIVITY $-5.3 ¢$

$S_8 \quad 16 \, gr \quad 10^{-5} \quad$ TOC HANSEN

$\qquad K = 1.003341$

$C \, Ht = 6.062"$
$\quad + \quad .006 \quad$ (7 pcs, 1 mil per spacer)
$\quad \overline{6.068"}$

19.8 MIL GAP

¼ × 15	1224	
3/8 × 15	1341	
3/8 × 13	1386	
½ × 9	883	1/8 × 9 = .225
1" × 9" B	1763	
1½ × 9"	2675	
1" × 9" A	1771	10 MIL SS DIAPH.
2" × 9"	3533	
1" × 13" A	3682	

Red cell labels:
3215-¾, 2743-7/8, 2755-⅜, 2778-¾, 2783-¼, 2776-1, 2782-¼, 2756-⅜, 2749-⅜, 2745-1, 2754-½, 2753-½, 2757-1, 2748-1¼, 4-4, 2752-½, 2742-⅜, 2751-½, 2747-1¼, 2756-1

¾ 934   3¾   4628   3" 3712
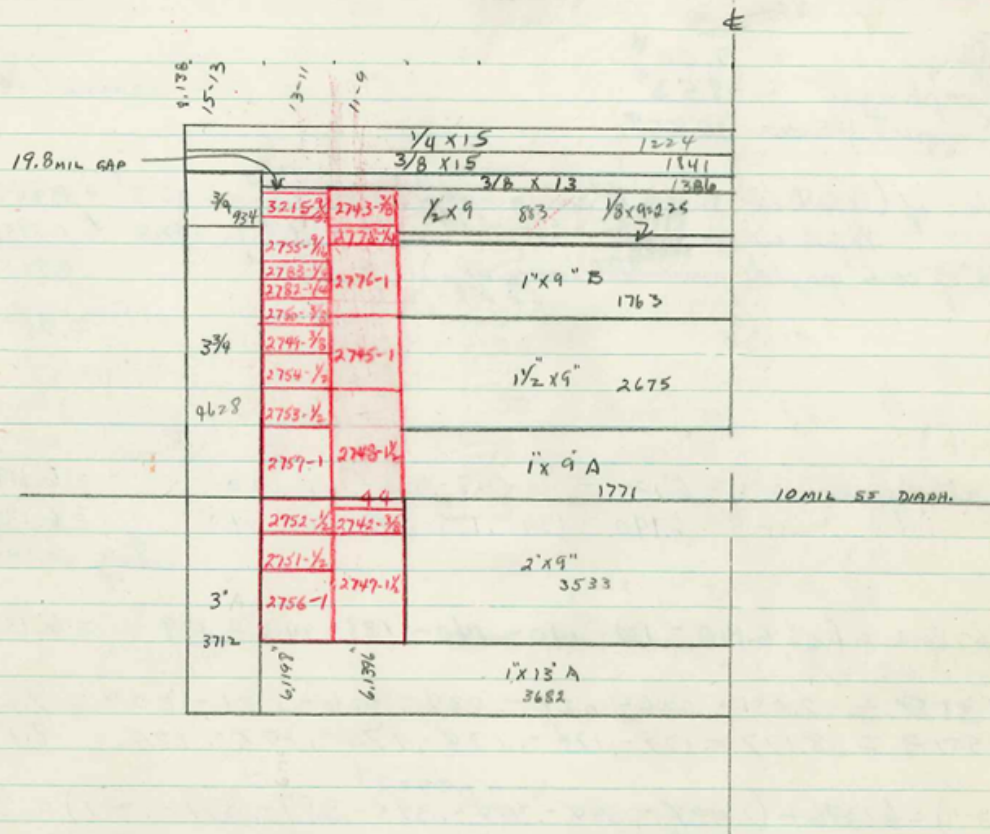
MASS OF FUEL = 129702 gm
VOLUME = 6930.41620 cm³
ρ = 18.7148 gm/cc

MASS OF GRAPHITE = 28257 gm
VOLUME = 16708.56935 cm³
ρ = 1.69116 gm/cc

AVG. O.D. ALL FUEL (WT'D) = 12.99597"   OD² = 168.89523
AVG. I.D. ALL FUEL (WT'D) = 9.00197"   ID² = 81.03546
15-13 OD Carbon   " = 14.99865"   (²) = 224.95950

AVG Refl = 0.999"

13-9   1" ref.+ core

Nom. Ht. Critical =   13-11 = 6³/₃₂"   & 11-9 = 6⅛"   = -25.00¢

Rings   =   7.00¢
Diaphragm   = -8.53¢   Raise .0641"
Support Stand = 10.35¢

Value of (⅛ fuel on 13-11 + ⅛" core graphite) = +54.9¢ = 30.5¢ ✓ 0.2440¢/mil
  "   "   ⅛ fuel on 11-9 + ⅛" " " ,   = +59.8¢ = 35.4 ✓ 0.2832
⅛" of core graphite removed (leaving gap)   = 24.4¢   0.5272
                                                                + Core = 0.5693

Ht. all fuel   13-11 = 6.120 -.119 -.117 -.120 -.121 -.122 ⟶   = 6.1198"
               11-9 = 6.140 -.139 -.139 -.140 -.140 -.140   = 6.1396"
                                                          av'av; = 6.1288"

Ht of core only = 6.140 -.139 -.140 -.140 -.138 -140 -.139 - 14 = 6.1394"
(¼ & ¾ #3) (others) =
   13-9 = 2.031 -.026 -.028 -.029 -.026 -.031 -.029 = 2.0285"
   15-13 = 8.177 -.177 -.174 -.174 -.175 -.177 -.174 = 8.1754"   ok

                              1.3925
(13-9) = 6.1396 + (1.394 -.394 -.394 -.395 -.389 -.391 -.391) = 7.5321"
              compare for gap at where? mil
(3 + 3¾ + ¾) = 7.530 -.524 -.535 -.534 -.526 -.531   = 7.5300"

            Corrected flat fuel Ht = 6.1929" ✓

    Reactivity =   -25.00¢
    all Support   -8.82¢
    13-11 ———   0¢
    11-9 down 19.8 mils = -5.60¢
    Core (=+0.042/mil) down 19.6 +0.82¢
                        -40.97¢

  -40.92¢ = 6.1198"
     0 = 6.1198 + 0.0719 = 6.1917"
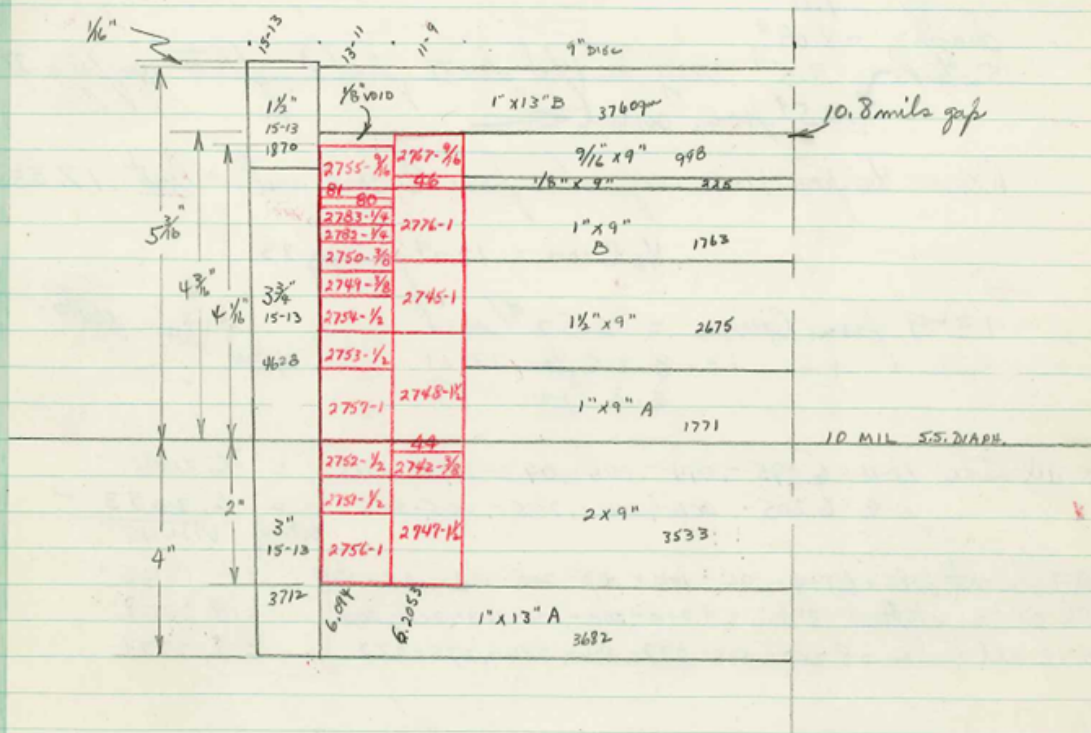
MASS OF TOP GRAPHITE = 17690 gm   TOTAL = 28.617 Kg
BOTTOM   = 10 927

MASS OF TOP FUEL = 87484 gm   TOTAL = 129.960 Kg
BOTTOM   = 42476

AVG O.D. ALL FUEL (W'T'D) = 12.99591" $(OD)^2 = 168.89367$
AVG I.D. ALL FUEL (W'T'D) = 9.00184" $(ID)^2 = 81.03312$
~~AVG HT. ALL FUEL (W'T'D) =~~

FUEL VOLUME = 6948.39069 cm³
FUEL ρ = 18.70361 gm/cc

graphite vol = 16787.9179 cm³
       ρ = 1.70461 gm/cc

    AVG REFL = 0.998"

13"-9" 1"ref + C Core

Nom. Ht. Critical = 6⅜₆ on 13-11 ≠ 6³⅛₆ on 11-9   = +13.25¢

rings = 7.11¢
diaph = -8.09¢
? S.stand = 3.5¢ very doubtful due to fuel & reflector configuration.
↓ 10.5¢ from curve ←

Remove ¹⁄₁₆" from 11-9 ring also from C core and we lost 17.55¢

¹⁄₁₆ C core = 12.2¢ from pg 85 ?

13-9 from Curve = 0.52¢/mil
                  ic = 0.25 for 13-11   Total Value = .56/16¢/mil
                      0.27 for 11-9

Ht. all FUEL 13-11 = 6.095 - .094 - .094 - .093 - .093 - .095 = 6.094"
✗   11-9 = 6.205 - .206 - .206 - .205 - .205 - .205 = 6.2053 ✓
                                                  wtavg 6.1445"

all Core ht. only = 6.194 - .194 - .194 - .198 - .200 - .194 - .195 - .195 = 6.1945
all carbon stacked 13"dia = 8.200 - .200 - .201 - .203 - .201 - .200 = 8.2008
15-13 all carbon = 8.280 - .275 - .277 - .274 - .284 - .275 - .277 = 8.2774

Reactivity   +13.25¢
all Support   - 9.52¢
13-11   _____   0
11-9 down 111.3 mils -30.05¢
Core = 0.0416¢/mil est. curve
      down 100.5 mils = +4.18
                      -30.54¢

-30.54¢ = 6.0940"
    0 = 6.0940 + .0543 = 6.1483"

Diagram labels:
- 17-15, 15-13, 13-11, 11-9
- 1", 17-15, 1454
- 9/16" x 15"   2763
- 1/2" x 15"   2467
- 16 mil gap   3/8 x 15"   1841
- 1½"   2100   9/16 x 13"   2061
- 2781   2746
- 2755-9/16   2767
- 3¾"   2754-½   2745-1
- 15-13   2753-½   VOID
- 2⅝"   2752-½   5 3/16
- 3776   4628   2757-1   2746-1½
- 2750   2744
- 2749-⅞   2742
- 2751-½   2"   VOID
- 3"   3"   2751-½
- A   2756-1   2747-1½
- 4"   4232   37/2
- 5⅜"   VOID   5 3/16
- 10 MIL SS DIAPH
- 5/2/26   5.2025
- 1" x 13" A   3682
- 1" x 17" A   6261
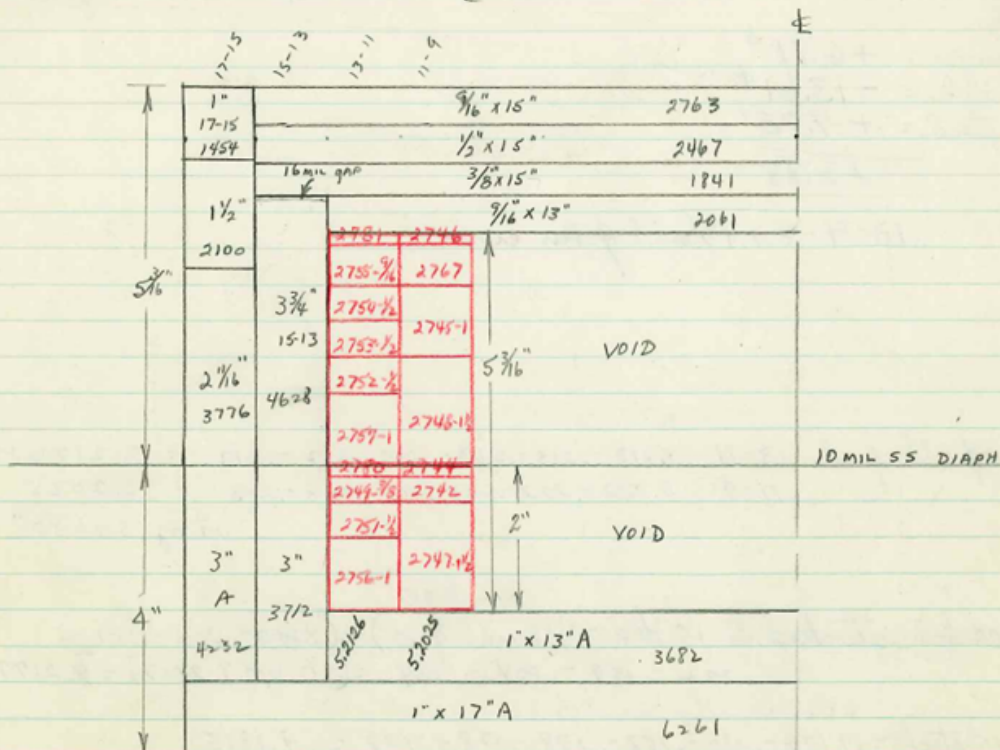
MASS OF TOP GRAPHITE = 21090 gm   TOTAL = 38.977 Kg
BOTTOM   = 17887 gm

MASS OF TOP FUEL = 67701 gm   TOTAL = 110.166 Kg
BOTTOM   = 42465 gm

AVG. O.D. ALL FUEL (WT'D) = 12.99604 "
AVG. I.D. ALL FUEL (WT'D) = 9.00191 "
AVG HT. ALL FUEL (WT'D) = 5.20800 "

FUEL VOLUME = 5889.38567 cm³
FUEL ρ = 18.70585 gm/cc

Vol of graphite not including 16 mil gap = 22923.41374 cm³
graphite ρ = 1.70031 gm/cc

AVG REFL = 2.001"

13"-9"   2"C ref ≠ No Core

Clean Critical Nom. Ht = 5 3/16" = +18.34¢ reactivity

rings = +6.71¢
diaph = −13.61¢
s.stand = +9.78¢
          ————
           +2.88

13-9 = 1.1¢/mil from curve

Ht. of all fuel 13-11 = 5.212 -.213 -.213 -.212 -.212 -.212 = 5.2126 ✓
                11-9 = 5.202 -.202 -.203 -.202 -.203 -.203 = 5.2025
                                                    wt. avg = 5.2080"

                                        see draw.
all carbon stacked to 15"dia = (16 mil gap) + (9.200 -.202 -.201
      15-13   .202 -.199 -.204 -.204 = (0.016 + 9.2017) = 9.2177
      1/2 Disc

(17-15) stack = 9.179 -.180 -.187 -.178 -.178 -.187 = 9.1815

Carbon Bottom 17-15 =
      15-13 =
      1/2 Disc =

EVEN FUEL HT. = 5.2080"
SKY HOOK REACT. = +15.46¢   (16 mil gap 15-13 carbon not considered)
     O react = 5.2080 -.0140 = 5.1940"

Diagram labels (top to bottom, right column values):

- 1/2" x 15" — 1841
- 9/16" x 15" — 2763
- 3/8" x 13" — 1386
- 1/16" VOID   9/16" x 13' — 2061   10.9 mil gap under 9/16 x 13
- 1/4" x 9" — 445
- 9/16" x 9" — 998
- 1/2" x 9" — 883
- 1 1/2" x 9" — 2675
- 2" x 9" — 3533
- 1" x 13" A   3682
- 1" x 13" A   6261

Left dimension labels: 4 13/16", 2 11/16", 2", 5"

Red grid cell numbers: 2762, 2778-3/8, 2754-3/4, 2767-3/16, 2753, 2743-3/8, 2752, 2748, 2757-1, 2760, 2744, 2749-3/4, 2742, 2751-1/2, 2756-1, 2747-1/2

Other numbers: 1841, 2763, 1386, 1456, 3 3/4", 3", 15-13, 4628, 4188, 4232, 3712, 4.7730, 4.8302

MASS OF TOP FUEL = 59 050 gm   TOTAL = 101.515 Kg
        BOTTOM = 42 465 gm

MASS OF TOP GRAPHITE: 24494 gm   TOTAL = 45,914 gm   Core = 8.534 Kg of total
        BOTTOM = 21420 gm

AVG. O.D. ALL FUEL (W'T'D) = 12.99601"   OD² = 168.89627
AVG I.D. ALL FUEL (W'T'D) = 9.00215"   ID² = 81.03870
~~AVG Ht. ALL FUEL (W'T'D)~~

FUEL VOL = 5426.57854 cm³
FUEL ρ = 18.70699 gm/cc

graphite volume = 27428.55743 cm³
        ρ = 1.6739487 gm/cc

AVG REFL = 2.001"

13"-9"   2" C ref + C core.

Critical Nom. Ht =   13-11 = 4¾"   reactivity = + 15.99¢
                      11-9 = 4¹³⁄₁₆"

rings = + 5.31¢
diaph. = - 12.43¢
S.stand = + 9.48¢

* ¹⁄₁₆" fuel 13-11 = 31.40¢ [est from 15-11 2"ref+core] or 0.502¢/mil
    11-9 est from Curve 0.69¢/mil   ToT = 1.1068
                                               with Core 1.201

Ht of all fuel   13-11 = 4.775 - .772 - .773 - .772 - .773 = 4.7730"
                 11-9 = 4.829 - .829 - .830 - .831 - .831 - .831 = 4.8302 ✓
                                            wt. avg = 4.7990"

carbon
Ht Core only = 4.820 - .819 - .817 - .818 - .820 - .823 - .820 - .818 = 4.8193
stack all discs up thru (3/8 × 13) + [diff of (11-9 fuel) and core) =
                  center is higher
∴ [Stack all carbon 15" dia = 8.858 - .855 - .861 - .858 - .860 - .854 - .856
          to this must be added (*).] - [.0285 (correction
       for piece thickness)] = (8.8574 + *0.0109 - 0.0285) = 8.8398

(17-15) stack = 8.853 - .856 - .855 - .857 - .861 - .858 = 8.8566

Reactivity   +15.99¢
all Support   - 2.36¢
13-11
11-9 down 57.2 mils = - 39.46¢   all gaps
Core = 0.0942¢/mil ↓46.3 = - 4.36¢   considered
                          -30.19¢ @ 4.7730"
                      O = 4.7730 + .0251 = 4.7981"

Note: (13-11) + (11-9) rings of fuel assumed near equal value per unit ht.

EVEN FUEL HT. = 4.8016"
SKY HOOK REACT. = + 13.63¢   (¹⁄₃₂" carbon gap 13-9 (over fuel) +
                                   10.9 mil gap over core not considered)

* EVEN FUEL HT. = 4.8302"
  SKY HOOK React = + 42.34¢   (10.9 mil carbon gap over core not considered)

73.5 mil gap

19-17 | 17-15 | 15-13 | 13-11 | 11-9 | 9-7

11/16" 1111	3/4" 1060	1"x15"B 4915
1" 1644	1" 1456	1/2"x15" 2467
2 1/8" 3440	1 1/2" 2100	15 mil gap 1"x15"A 4903

1/2" x 13" 1854

3 3/4" 4628

Red cells:
2782-1/8 2778
2749-3/8 2742
80   44
2753-1/2
2752-1/2   2743-1 1/8
2751-1/2
2757-1   2745
2756-1   2776

3"A 4232
2 3/8" 3863

3 1/2"   VOID

3 1/2"

10 MIL DIAPH.

1"   VOID

4" 6513 | 2" 2770 | 2" 2476 | 4.2668 | 4.2597 | 1"x13"A 3682

1"x17"B 6268

1"x17"A 6261

4"

MASS OF FUEL TOP = 69025 gm   TOTAL = 90.236 Kg
            BOTTOM = 21211 gm

MASS OF GRAPHITE TOP = 37653 gm   TOTAL = 65.623 Kg
               BOTTOM = 27970 gm

AVG O.D. ALL FUEL (W'T'D) = 12.99610" $OD^2 = 168.89861$
AVG. I.D. ALL FUEL (W'T'D) = 9.00173" $ID^2 = 81.12839$
AVG. HT. ALL FUEL (W'T'D) = 4.26466"

FUEL VOLUME = 4817.55012 cm^3 Vol. of graphite = 38464.42840 in^3
FUEL ρ = 18.73068 gm/cc $\rho = 1.706069$ gm/cc

AVG REFL = 2.997"

A-168

13-9   3"ref & <u>No Core</u>

Nom. Ht. Critical   4¼" = + 24.87¢ reactivity

Diaph. = − 9.79¢
Rings = + 6.07¢
S.Stand = + 8.15¢

Lower .013"

1/16" 13-11 ring = 46.13¢ 0.7380 ¢/mil
1/16" 11-9 ring = 51.65¢ 0.8264
                          1.5644 ¢/mil
19-17 Carbon = .0077¢/mil (taken from Pg 131 15-11 3"rf)

Ht. of all fuel 13-11: 4.268 −.268 −.269 −.269 −.270 .269 = 4.2688" ✓
                11-9 : 4.261 −.260 −.260 −.260 −259 −.258 = 4.2597
                                              wt avg = 4.2646"

½ × 13 = 0.4987
15" dia = 10.265 −.261 −.265 −.260 −.262 −266   = 10.2631
17-15 ring = 10.266 −.270 −.273 −.265 −.264 −.267   = 10.2675
19-17 ring = 10.192 −.194 −.190 −.194 −.194 −.198 −.196 = 10.1940 (−70)

Reactivity = + 24.87¢   Raise .0003"
all support = − 4.43¢   + 26.96¢ = 4.2688"
13·11 _____ 0   0 = 4.2688 −.0172 = 4.2516"
11-9 up 9.1 mils = +7.52¢
15 mil gap = −1.0¢
            + 26.96¢

EVEN FUEL HT. = 4.2646"
SKY HOOK REACT. = + 21.00¢   (15 mil gap 15-13 Carbon not considered ser drawing)
                                    ↑
        correct flat fuel Ht = 4.2519" ✓
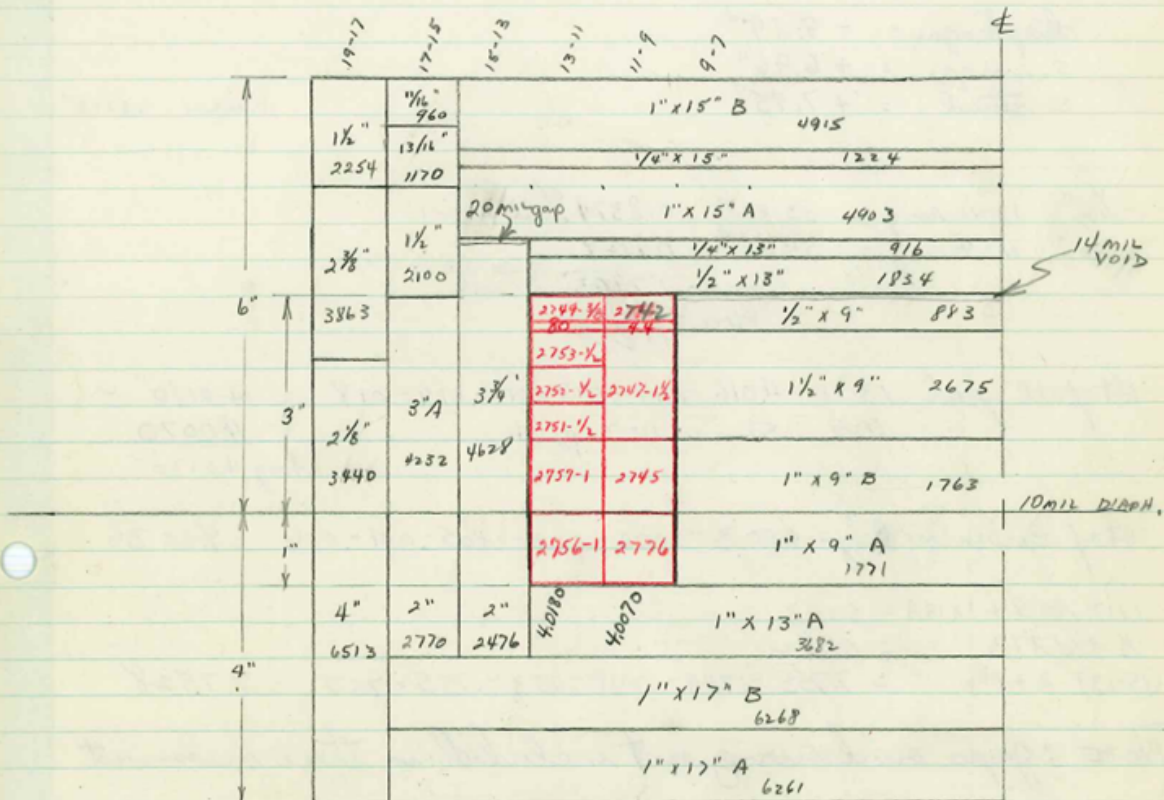
MASS OF FUEL TOP = 63700   TOTAL = 84,911 Kg
     BOTTOM = 21211 gm

MASS OF GRAPHITE TOP = 41760 gm   TOTAL = 72.566 Kg   OF THIS THE CORE = 7.092 Kg
     BOTTOM = 30806 gm

AVG. O.D. ALL FUEL (W'T'D) = 12.99613"   Vol. of graphite not incl. 20 or 14 mil
AVG. I.D. ALL FUEL (W'T'D) = 9.00171"   gap = 43082.02634 cm³
AVG. HT. ALL FUEL (W'T'D) = 4.0120" ρ = 1.68436 gm/cc

FUEL VOLUME = 4532.2135 cm³
FUEL ρ = 18.71434 gm/cc

                            AVG REFL = 2.996"

A-170

13-9   3"ref + C core

Nom. Ht. Critical   4" =   − 13.58¢ reactivity

  diaphragm = − 9.29¢
  s. rings = + 6.96¢
  s. stand = + 7.75¢   Raise .0106"

  1/16" 13-11 ring = 52.34¢ 0.8374 ¢/mil
  1/16" 11-9 ring = 59.56¢ 0.9529
                         ‾‾‾‾‾‾
                         1.7903 ¢/mil
                       − .1017
             +Core = 1.8920

  Wt of all fuel 13-11 = 4.016 −.017 −.019 −.019 −.019 −.018 = 4.0180" ✓
                 11-9 = Same as 11-7 pg 64   = 4.0070
                                              wt avg 4.0130"

  Wt of Carbon Core Only = 4.003 −.002 −.005 −.005 −.001 −.006 = 4.0036

  1×17 A&B + 1×13A = 3.003
  ½ 4/4 × 13   = 0.752
  (15-13) 2 + 3¾ = 7.755 −.749 −.748 −.753 −.755 −.757 = 7.7528

NOTE : gaps on drawing not included in these measurement

  15" dia. all stacked = 10.015 −.005 −.07 −0.012 −.007 −.010 = 10.0093
  17-15 ring = 10.015 −.012 −.010 −.011 −.004 −.009 −.010   = 10.0101
  19-17 ring = 10.025 −.017 −.012 −.017 −.027 −.030   = 10.0213
                                                              OK
  React   = −13.58¢
  all Support = − 5.42¢ } = −7.06¢ @ 4.0180"
  13-11
  11-9 up 11.0 mil = + 10.48¢ }   O = 4.0180 + .0037 = 4.0217"
  Core up 14.4   = + 1.46¢ }

  EVEN FUEL HT. = 4.0120"
  SKY HOOK REACT. = −19.00¢   (20 mil gap 15-13 Carbon see drawing)
                              (not considered also 14 mil gap over core)

     O React Ht = 4.0226"

  Core = .1017 ¢/mil

MASS OF FUEL = 77595 gm
    VOLUME = 4145.01903 cm³
    ρ = 18.72005 gm/cc

MASS OF GRAPHITE = 99992 gm
    VOLUME = 59533.91117 cm³
    ρ = 1.67958 gm/cc

AVG. O.D. ALL FUEL (W'T'D) = 12.99611"   OD² = 168.89887
    I.D. = 9.00178"   ID² = 81.03204
21-19 OD Carbon = 20.99950"   440.97900
    AVG REFL = 3.999"

13-9   4" ref & No Core

Nom. Wt. Critical = $3\frac{21}{32}$"   reactivity = + 28.14¢

     Rings = + 5.15¢
Diaphragm = − 11.52¢
S. Stand = + 4.81¢   Lower 0.0189"

19-17 graphite ring (121 mils) = 1.18¢ or .00975¢/mil

$\frac{1}{32}$" fuel 13-11 = 23.13¢   0.7401¢/mil
          11-9 = 26.33¢   0.8425   Avg = 1.582¢/mil
                          $\overline{1.5826}$

Wt. of fuel : 13-11 = 3.668−.667−.666−.668−.668−.669   = 3.6676"
            11-9 = Same as Pg 152   = 3.6625"
                                       wt vol Avg = 3.6652"

Wt. of Carbon : 21-19 = 11.743−.750−.690−.746−.759−.757−.754−.759−.747 = 11.7518"   (+87)
              19-17 = 11.688−.689−.689−.689−.693−.70−.704−.694 = 11.6931"   (+80)
              17-15 = 11.728−.724−.728−.738−.738−.731−.730   = 11.7310"   (+60)
              15-13 = 11.752−.748−.750−.766−.757−.772−.772   = 11.7595"   (+93)
              13 dia = Same as Pg 143   = 8.0127"
                                                                 ok

       corrected flat fuel height = 3.6463" ✓

Reactivity _____ = + 28.14¢
Support (all)   = ± 1.56¢
                     + 29.70 = 3.6652"
                       Ⓞ = 3.6652 − .0187 = 3.6465"

MASS OF FUEL = 74293 gm
  VOLUME = 3967.13665 cm³
    ρ = 18.72710 gm/cc

MASS OF GRAPHITE = 104648 gm
  VOLUME = 61260.27052 cm³
    ρ = 1.70825 gm/cc

AVG. O.D. ALL FUEL (WT'D) = 12.99592"   OD² = 168.89393
        ID = 9.00171"   ID² = 81.03078
21-19 OD Carbon = 20.99956"   ———   440.98152
        AVG REFL = 4.001"

13-9   4" ref + Core

Nom. 1st. Critical = $3\frac{1}{2}$"   reactivity = + 4.64¢

    Rings = + 4.79¢
    Diaphragm = -10.52¢
    S. Stand = + 4.57¢   Lower 0.0076"

$\frac{1}{32}$" fuel 13-11 = 29.28¢   0.9369 ¢/mil
        11-9 = 36.40¢   1.1648   wt vol Avg = 2.101¢/mil
                         $\overline{2.1017}$
          + Cor .0847   2.186¢
add 319 mils graphite 19-17 ring = 1.95¢ or .0061 ¢/mil

Ht of fuel = 13-11 = 3.513 -.513 -.510 -.513 -.514 -.515   = 3.5130"
         11-9 = 3.502 -.502 -.502 -.504 -.502 -.502   = 3.5023"
                           wt vol Avg = 3.5081"

Ht of Carbon = 21-19 : 11.492 -.494 -.499 -.508 -.507 -.503 -.497 -.492   = 11.4990"
           19-17 : 11.375 -.378 -.373 -.375 -.375 -.370 -.371   = 11.3738"(-.250)
           17-15 : 11.503 -.506 -.513 -.508 -.508 -.504 -.513   = 11.5078"
           15-13 = 11.538 -.543 -.544 -.538 -.537 -.532 -.539   = 11.5378"(.739)
           13 dia Same as Pg 1 & 3   = 8.0127"
           Core = 3.505 -.506 -.504 -.505 -.504 -.508 -.505   = 3.5048"

                                          ok
corrected flat fuel height = 3.4995"
Core Value ≈ .088 ¢/mil

Reaction ———— = + 4.64
all Support ———— = + 1.16
13-9 ———— 0
Core up 3.3 = + 0.29
        + 6.09 = 3.5081"
          0 = 3.5081 - .0027 = 3.5054

Diagram labels:
- 1 | 45.4
- 15 | 683.6
- ½ | 20.3
- 1 | 39.5
- 8
- 330.1
- 33.570
- 8 | 328.8
- B, A (vertical dimensions)
- 1 | 3/4 | 57 | 16
- 1½ × 15
- ½
- 1
- 2
- 1 × 13
- 1 × 15
- 1
- 10
- Ram C = 82984
- ¼"

No Core

Mass of fuel = 37181 gm
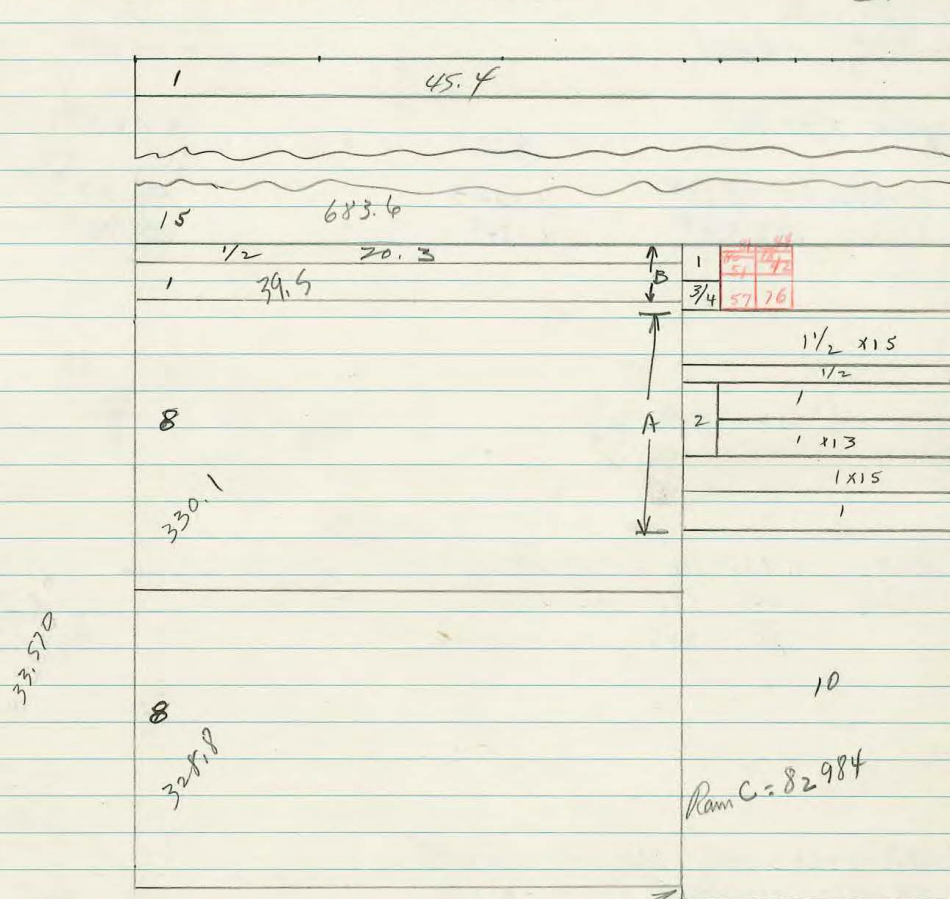
$Vol = 1985.3615 \, cm^3$

$\rho = 18.7275 \, gm/cc$

OD of fuel = 12.99598" $(OD^2) = 168.89549$

ID of fuel = 9.00193" $(ID^2) = 81.034743$

Mass C = 1530684 gm

$Vol \; C = 874927 \, cm^3 - 3821 \, cm^3 = 871106 \, cm^3$

$\rho = 1.757 \, gm/cc$

Avg Refl = 16.001"

+ Core

same
——
——
——
——

1533782 gm

$872934 \, cm^3$

1.757 gm/cc

13-9 ≠ 16" C ref

No Core   Core

Nom. Wt. = 1¾"   1¾"
  reactivity: −4.43¢   + 30.88¢

Supports = +1.96¢   + 1.27¢

                                          $\frac{t}{unit}$ $\frac{t}{unit}$
fuel 11-9 (1/32") = 38.51¢   1.2323   46.87¢   1.5000
      13-11 = 38.59¢   1.2348   55.70¢   1.7824

35" x 15" x ½" C =   + 9.12¢   ——

fuel ht: 13-11 = 1.755 ÷ .756 ÷ .755 ÷ .755 ÷ .755 ÷ .755 = 1.7551   Same   1.7551
       11-9 = 1.757 ÷ .757 ÷ .756 ÷ .757 ÷   Same   1.7566
              .757 ÷ .756   = 1.7566   av'ay = 1.7557

A = 6.017 −.012 −.005 −.005 −.010 = 6.0098"
B = 1.756 ÷.750 ÷.749 ÷.756 ÷.757 = 1.7536

Tow. ht. 35.63

1   45.4
15   683.6

1/2   70.3
1   24.5
2   40.9

15 13 "
81
86
85
82

D 3¾
54
53
52
61
57

8
330.1

50.33
18.63

X Core

⅛
80
50
54   ½   3/8
53
52   1
51
57   1½

TOT. RawC = 94595
+ Core

C

1½
½
2 1
   1
1
1

A

10

Total RawC = 85416
No Core

19.763

8
328.

No Core

mass = 43519 gm
Vol = 2320.9376 cm³   [8195 cm³]
ρ = 18.7506 gm/cc
OD = 12.99587" (²) = 168.89263
ID = 11.00271" (²) = 121.05962

Mass C = 1614016 gm
Vol C = 920416 cm³
ρ = 1.753 gm/cc

Avg. Refl = 15.992"

+ Core

40592 gm
2162.1503 cm³
18.7739 gm/cc
12.99574 (²) = 168.88925
11.00251 (²) = 121.05522

Mass C = 1623195 gm
Vol = 926353 cm³
ρ = 1.752 gm/cc

13-11 #16" C.ref.   13-11 #16" C.ref + Core

Nom. Wt. = 3¾"   3½"
  reactivity = +30.36¢   +14.24¢

Supports = 2.19¢   2.19¢
1/32" fuel = 42.27¢   1.3522¢/mil   ─────

Measured fuel ht 13-11 =   3.512 +.512 -.512 -.512 = 3.5120
3.770 +.770 -.770 -.770 = 3.7700   +.512 -.512 -.512

A = Same as 4-200   = 6.0098"
B = Look Up   = 3.7533"
C = 3.507 +.513 +.512 +.514 = 3.513 = 3.5115"

3.770 - | 3.770
      - | 3.7+9

3.512
3.50

15 13 11   ₵

35

15 13 11

10

.0156

269.37

FUEL & GRAPHITE
ON TOP OF 11"
RAM GRAPHITE
FOR "CORE" RUN

2   44.4 Kg

B   3/4

15 x 1/4
13 x 1/4
13 x 9/16   C

15 13 11
9/16   1/4   1/8   1/4
                    1/8

1
55
49
54
53
52
51

3/4   49
       54
       53
       52
       51

11 x 1/2

4   87.3 Kg

2

1 1/2

No Core

Mass C = 707992
Vol c = 415568 cm³
ρ = 1.704 gm/cc

15-13   57
2   56

15-18
3¾   57

2   56

11

Core

Mass C = 719482
Vol c = 423284 cm³
ρ = 1.700 gm/cc

24.4

3/8
1/2
15 x 1
15 x 1
15 x 1
15 x 1
13 x 1
13 x 1
13 x 1½
13 x 1
15 x 1½

TOTAL Ram C No Core = 65468

3

15-13
1½

A

1/8

TOTAL Ram C + Core = 75709

11440

24 TOTAL

B 49210

Avg. Refl = 10.997"

No Core

MASS OF FUEL = 57257 gm
    VOL = 3050.4312 cm³   [1077/cm³]
    ρ = 18.7701 gm/cc
MASS RAM GRAPHITE = 65522
    Avg OD FUEL = 12.99602"
        (OD)² = 168.89653
    Avg ID FUEL = 11.00291
        (ID)² = 121.06402

Core

50743 gm
2703.2447 cm³
18.7711 gm/cc
75709 gm
12.99603"
168.89679
11.00290
121.06380

A-180
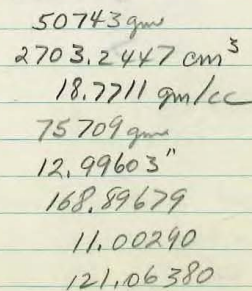
13-11 Ring Only ≠ 11" w/(C)

	No Core	+ Core

"Clean" Critical Nom. Wt. = 4 15/16" * .... 4 3/8" * #

reactivity = +17.50¢ .... -7.06¢

1/32" fuel value = 25.19¢ .... 26.32¢ ***

all supports value = 5.75¢ .... 5.41¢

(Boo) x 1/32 C = 2.75¢ .... 13.39¢

.525" Carbon on 11 1/16" Top = 29.95¢ .... 30.07¢

∴ 1/16" C Top = 3.57¢ .... 13.39¢

(35-15) x 0.525

Wt of fuel 13-11 =

4.955 - .955 - .955 - .956 - .956 - .955 - .955 = 4.9550

4.391 - .391 - .391 - .391 - .391 - .391 = 4.3910

A 11.026 - .026 - .025 - 0.24 = 11.0252

B 17.062 - .063 - .057 - .067 = 17.0622

C 0.814 - .815 - .818 - 813 = 0.8150

A ← Same = 11.0252

B = (-A) = 5.332 - .332 - .335 - 332 = 5.3330

Core Only: 4.378 - 383 - 380 - 380 = 4.3802

C = 13 x 1/8 ; look up = 0.1240

4.955 min 4.941

4.941 av 4.406

*** Void 1/32" over 15-13 carbon

* Has Extra 1/16" C on Top (35"OD)

** SHY 1/16" C on Top (35"OD) also 1/16" excess

A-181

11" DIA CYL. (SOLID) ; 12" GRAPHITE REF.
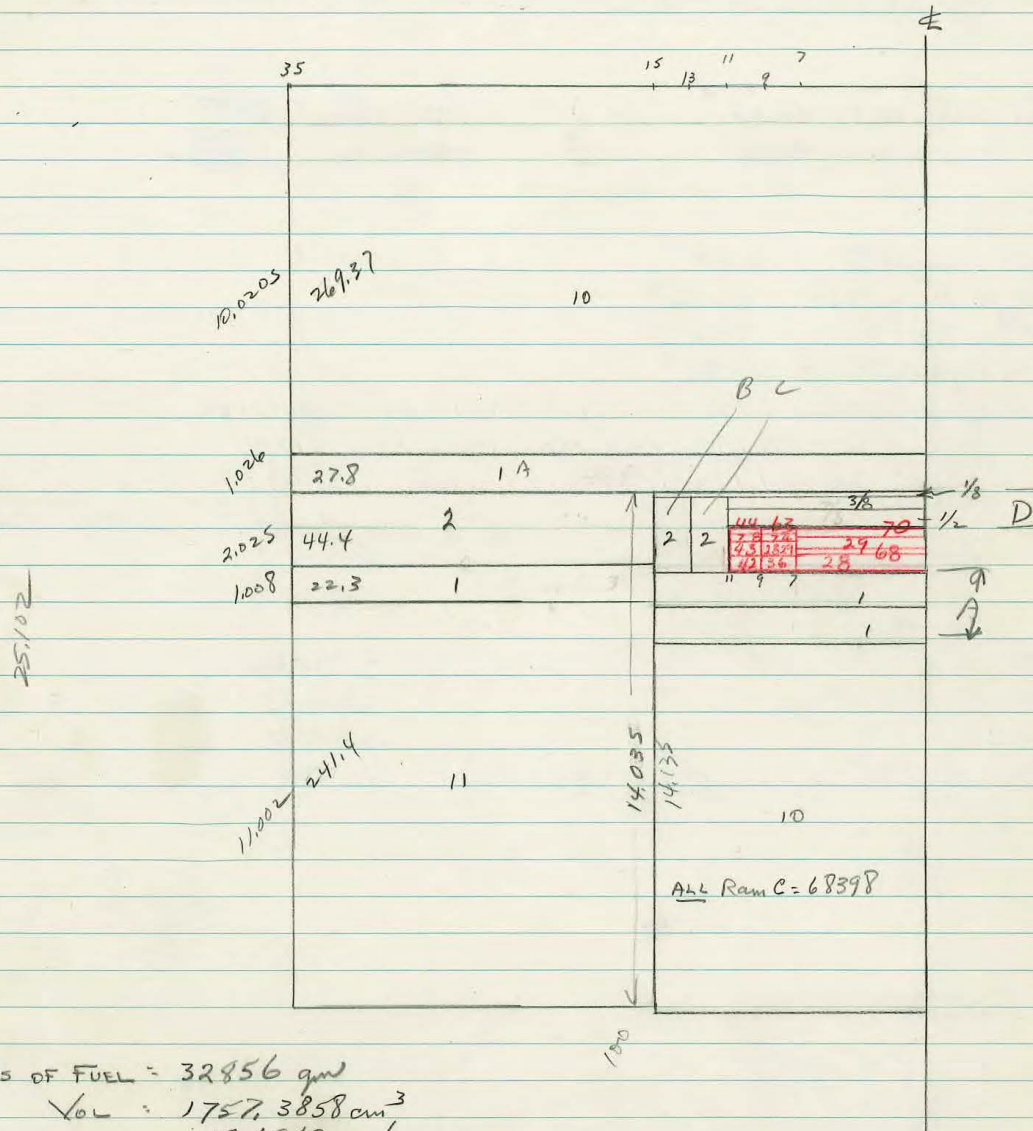
35   15 13 11 9 7   ₵

10.0205   269.37   10

B C

1.026   27.8   1 A   3/8   1/8   D
         2   2 2 44 63   70   1/2
2.025   44.4   7 3 54   29 68
                        2 2 43 7341
1.008   22.3   1   42 36   28
                     3   11 9 7
                                          1
25/02   1   9
                                                   A

1.002 241.4   11   14.0835
                         14133   10

                    ALL Ram C = 68398

                    1000

MASS OF FUEL = 32856 gm
    Vol = 1757.3858 cm³
      ρ = 18.6959 gm/cc
Avg OD = 10.99641"
   (OD)² = 120.92103

Mass C = 673.668 Kg
    Vol = 394010 cm³
      ρ = 1.709 gm/cc   Avg Refl = 12.015"

A-182

11" dia. cyl. & 12" C.ref.

Nom. Ht. Critical = 1⅛"
   reactivity = -3.52¢

1/32" fuel 11-9 = 47.47¢   +.5190¢/mil ~~1.85~~
         9-7 = 49.98¢   ?   +.5993¢/mil ~~1.86~~
       7dia: NOT measurable   ↑

all supports = 6.34¢
35-15 Ring .525" = 10.52¢   .0200 ¢/mil O/K
15"dia Top ¼" = 7.02¢
ADD ½" more 15"dia = 11.81¢
Ht. of fuel 11-9: 1.130 - .130 - .130 - .131 - .131 - .131 - .131   = 1.1305
        9-7: 1.130 - .130 - .130 - .130 - .130 - .130   = 1.1300
       7dia: 1.128 - .127 - .128 - .128 - .128 - .127 - .128 = 1.1277
                                                  wt av = 1.1292

A = "A" 4 - 124   = 2.0022
B = Look up   = 2.0043
C =   "   "   = 2.0020
D 1.002 - .002 - .001 - .001 - .002 = 1.0026

11" dia CYL (SOLID) & 17" GRAPHITE REF.

+.008

45

2
91.5

683.6 calc. No.

17.008

15

95

2
80.9   80.9 Kg

C   D

15 13 11 9 7

78 63   70
43 67
42 37 24 28

1½

3 4½
⅜

1½   2

A

B

8
330.1

1

1

1

17.992

⅛
⅜

10

8
328.8

16.9872

ALL RamC = 87779

18.0208"

-.012"   +.016"

MASS OF FUEL = 28935 gm
    VOL = 1550.6038 cm³
    ρ = 18.6604 gm/cc
MASS OF GRAPHITE = 1602.679 Kg
    AVG OD FUEL = 10.99659"
    (OD)² = 120.92506
    Vol of C = 910.776 cm³
    ρ = 1.746 gm/cc
    AVG REFL = 17.006"

A-184
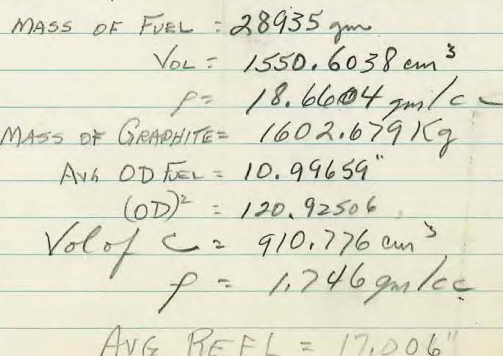
11" dia cyl & 17" C. ref.

Nom Ht critical = 11-9 & 7"dia = 1"
  9-7 = $3\frac{1}{32}$"

Reactivity = Sub. but close
Supports = est 2.0¢
fuel value ?

Ht. of 11-9 = 1.004 -.004 -.005 -.005 -.005 -.006   = 1.0048"
  9-7 = 0.973 -.973 -.973 -.973 -.972 -.973 -.974   = 0.9730"
  7 dia = 1.004 -.005 -.006 -.005 -.004 -.004 -.005 = 1.0047"
                                              av tmg = .9963

A = 3.505 -.507 -.507 -.508   = 3.5072"
B = 7.016 -.017 -.016 -.015   = 7.0160
C = 4.503 -.505 -.505 -.503   = 4.2776
D = Lock Up   = 4.5000
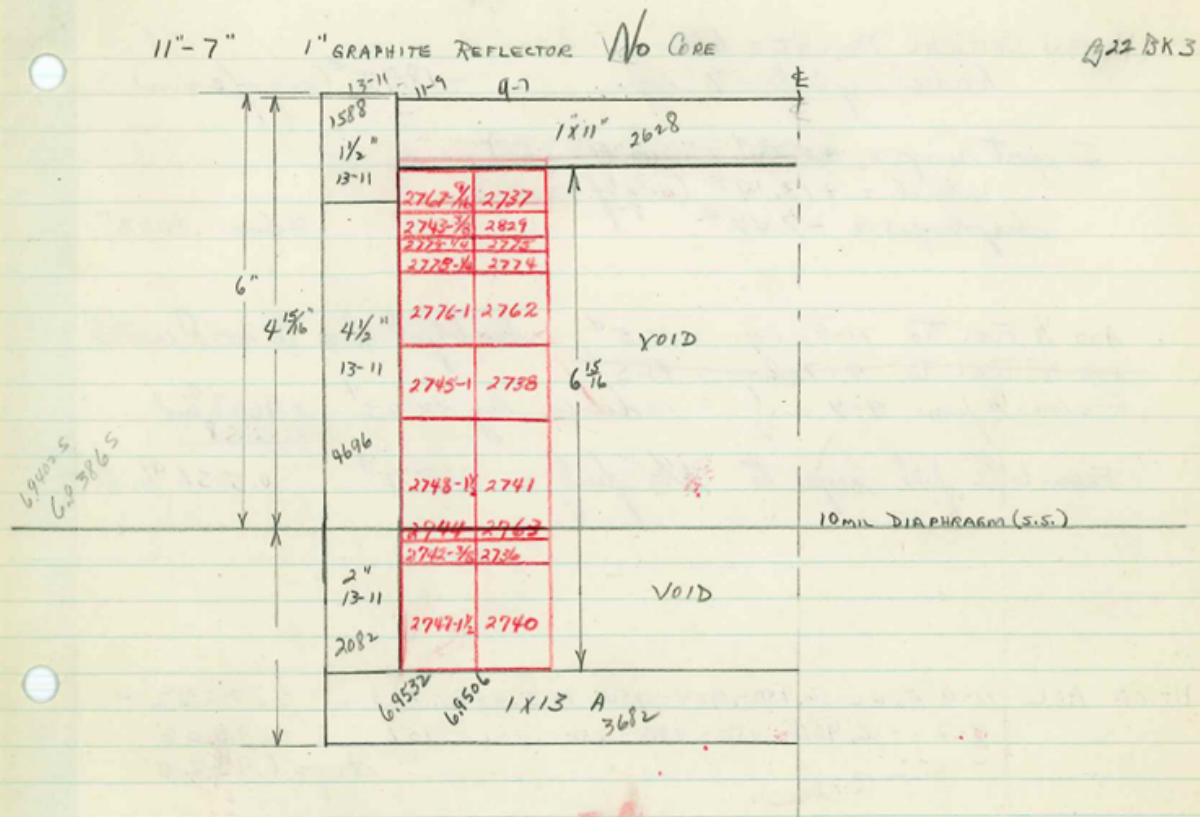
MASS OF TOP GRAPHITE = 8912 gm   TOTAL = 14.676 Kg
BOTTOM   = 5764 gm

MASS OF TOP FUEL = ~~64446~~ 85658 gm   TOTAL = ~~99.138~~ 120,350 Kg
BOTTOM   = 34692 gm

AVG. O.D. ALL FUEL (W'T'D) = 10.99673"   OD² = 120.92807
AVG I.D. ALL FUEL (W'T'D) = 7.00292"   ID² = 49.04088
AVG HT. ALL FUEL (W'T'D) =

FUEL VOLUME = 6432.18690 cm³
FUEL ρ = 18.7106 gm/cc

graphite vol = 8695.03454 cm³
ρ = 1.68785 gm/cc

AVG REFL = 1.000"

A-186

11-7   1"C ref ≠ Void Core

CLEAN CRITICAL Mem. Ht. = 6 15/16"
      Radial reflector = 7" high   = −18.72¢ (avg of 2 runs)

Support rings = +5.28¢ (avg of 2 runs)
      stand = +13.19¢ (avg of 2 runs)
   diaphragm = −7.44¢   Raise .0608"

ADD 1/8" FUEL TO 11-9 ring = 20.5¢ doubtful due to void created
~~ADD 1/8" FUEL TO 9-7 ring = 15.5¢~~
Remove 1/8 from 9-7 ring = reduces by 33.73¢ 0.2698 ¢/mil
                                              11−9 = .2358
From 6 15/16" fuel up to 7 1/16" fuel = +63.2¢ 0.5056 ¢/mil
                                1/8"

Ht OF ALL 11-9 FUEL = 6.950−.954−.954−.953−.955−.953 = 6.9532" ✓
        9-7 = 6.950−.950−.950−.950−.951−.951 = 6.9506
                                 wt avg = 6.9520"

ALL (C) 13"−11" = 9.014"−.014−.014−.014−.011−.014 = 9.0135
   1"X11" DISC = 1.002

EVEN FUEL HEIGHT = 6.9520"
SKY HOOK REACTIVITY = −29.75¢ (includes extra 1/16 graphite on 13-11 ring)

   0 React 1¢ = 7.0128" ✓

  REACT : −18.72¢
 ALL SUPPORT = −11.03¢
      −29.75 = 6.9520"
       0 = 6.9520 + .0589 = 7.0109"

Diagram labels (top): 13'-11"   11'-9"   9'2"   ₵

- ½" X 13"   1834 gm
- 70 mil AIR VOID
- 10 MIL GAP   ½" X 11"   1309
- 2767-9/16 | 2737   9/16" X 7"   602
- 1/8" X 7   180
- 2776-1 | 2762-1   3/8" X 7"   404
- ½" X 7"   536
- 5 1/16"   4 1/16"   4½" 13"X11" 4696
- 2745-1 | 2738   1" X 7" A   1065
- 2748-1½ | 2741   1½" X 7"   1618
- 2744 | 2763
- 2742-3/8 | 2736
- 2" 13"X11" 2082
- 2747-1½ | 2740   2" X 7"   2131
- 6.0748   6.9707
- 1" X 13" A   3682
- 10 MIL DIAPH.
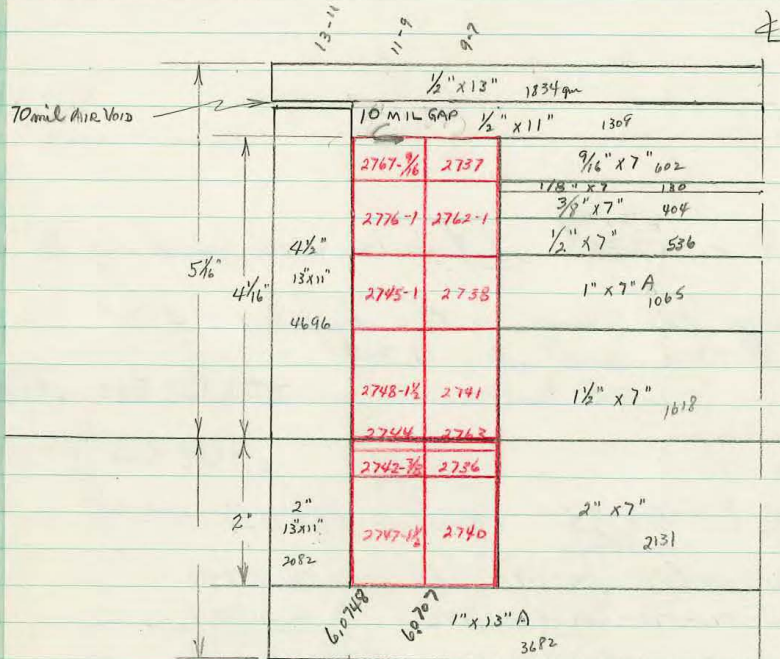
MASS OF TOP GRAPHITE = 12244 gm   TOTAL = 20.139 Kg
    BOTTOM   = 7895

MASS OF TOP FUEL   = 70467 gm   TOTAL = 105.159 Kg
    BOTTOM   = 34692

AVG. O.D. ALL FUEL (WT'D) = 10.99674" OD^2 = 120.92829
AVG. I.D. ALL FUEL (WT'D) = 7.00285" ID^2 = 49.03990
AVG. H. ALL FUEL (WT'D) =

FUEL VOLUME = 5618.94825 cm^3
FUEL ρ = 18.71506 gm/cc

graphite vol = 11904.73979 cm^3
     ρ = 1.69167 gm/cc

    AVG REFL = 1.000"

A-188

11"-7"   1" C ref. + C Core

Nom. Ht. Critical 6 1/16" = − 4.45¢

rings = 6.31¢
diaph = − 8.15¢
S. stand = 10.28¢   Raise   .0163"

add 1/16" to 11-9 = 17.36¢ *but* carbon was raised by 1/16".

Now interchange the 2 rings = the difference = 4.71¢
Add 1/16" C. to core and it = 9.71¢

                    T5 ¢/mil .7828   Total ¢/mil F&C = .8855

11-9 = 17.36
9-7 = 22.07   1/16"   0.7878 ¢/mil
1/16" total fuel + 1/16" C = 58.95   w/o/c = 49.24 ← used
                        9.77

HT ALL FUEL 11-9 = 6.075, .075, .075, .074, .075, .075   = 6.0748 ✓
             9-7 = 6.072, .071, .070, .069, .070, .072   = 6.0707
                                              wt. avg 6.0729"

Wt of all Core only = 6.085
Wt of all Carbon DIA .13" = 8.086, .087, .084, .084, .087, .084, .084 = 8.0851

13 - 11 = .030 ¢/mil est ¢

EVEN FUEL HT. = 6.0729"
                                        Carbon
SKY HOOK REACTIVITY = −12.89¢ (includes a 70 mil gap 13-11 see drawing)
                                (also 10 mil gap over fuel)

0 React Ht = 6.0892" ✓

13-11 ↑70 = + 2.1 ¢
REACT   = − 9.45
ALL SUPPORT = − 8.44
11-9 ↑ 10.2 }= + 8.33
9-7 ↑ 14.3 }
Core (.1028 ¢/mil) =   0
                    −2.46¢ = 6.085"
                      0   = 6.085 + .0027 = 6.0877"
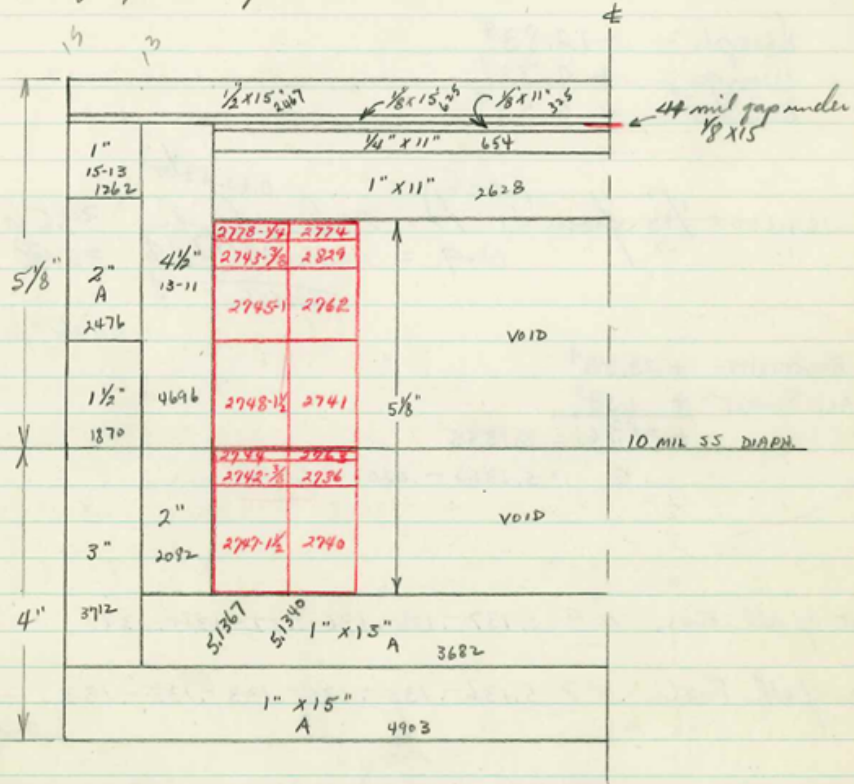
MASS OF TOP GRAPHITE = 17003 gm   TOTAL = 31.382 Kg
BOTTOM = 14379 gm

MASS OF TOP FUEL = 54.224 gm   TOTAL = 88.916 Kg
BOTTOM = 34692 gm

AVG. O.D. ALL FUEL(W'T'D) = 10.99685"
AVG. I.D. ALL FUEL(W'T'D) = 7.00285"
AVG. HT. ALL FUEL(W'T'D) = 5.135499"

FUEL VOLUME = 4751.71751 cm³
FUEL ρ = 18.71239 gm/cc

Vol. of graphite (not incl) 44 mil gap = 18563.08641
ρ = 1.69055 gm/cc

AVG REFL = 2.000"

A-190

11"-7"   2" ref ≠ No Core

Clean Critical Nom. Ht. = 5⅛"   = +23.38¢ reactivity

Diaph = -12.83¢
Rings = + 4.72¢
S. Stand = + 6.53¢

remove 1/16" from (9-7°) = reduced by 39.06¢ (reference to clean
    "   "   "   11-9 = reduced by 35.98¢ ("   " ")
                          0.6249¢/mil
                          0.5757
                          ——————
                          1.2006

                          1.2006¢/mil

REACTIVITY = +23.38¢
ALL SUPPORT = + 1.58¢
            ——————
            +24.96 = 5.1355"
        0   = 5.1355 - .0207 = 5.1148"

Ht. of all FUEL 11-9 = 5.137 - .136 - .136 - .137 - .138 - .137   = 5.1367" ✓

Ht. of all FUEL 9-7 = 5.136 - .135 - .135 - .133 - .133 - .133   = 5.1340
                                                    ∞ avg = 5.1355"

15-13 ring up to (⅛ x 15 disc) = 8.560 - .558 - .556 - .556 - .557 - .558 = 8.5575
13-11 ring = 8.517 - .512 - .509 - .509 - .501 - .513 = 8.5101

add Disc ⅛ & ½ x 15 on top of 15-13 ring = 9.194 - .195 - .192₂
                    .193 - .196 - .195 - .194 = 9.1941

(1 & ¼ & ⅛ X 11) = 1.378 - .379 - .378 - .379 - .379 = 1.3786

∞ 41 mil gap under (⅛ x 15) from 13" dia. inward.

EVEN FUEL Ht. = 5.1354"
SKY HOOK REACTIVITY = +24.96¢   (44 mil carbon gap over ⅛ x 11 dia not)
                                 ↑ considered
0 React Ht = 5.1147" ✓

A-191

11" - 7"   2" graphite reflector + graphite Core   ≈24
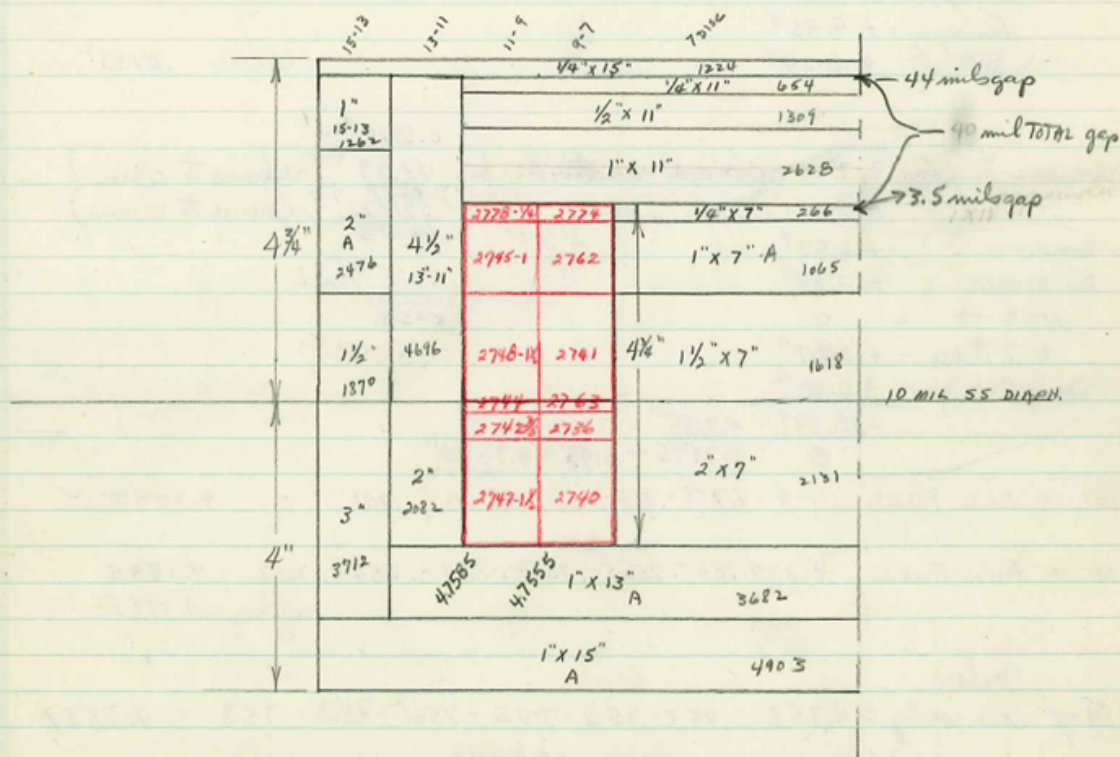
MASS OF TOP GRAPHITE = 19068 gm TOTAL = 35.578 Kg   OF THIS THE CORE IS = 5.080 Kg
BOTTOM   = 16510 gm

MASS OF TOP FUEL = 47708 gm TOTAL = 82.400 Kg
BOTTOM   = 34692 gm

AVG O.D. ALL FUEL (WT'D) = 10.99687"   522543975/475175
AVG I.D. ALL FUEL (WT'D) = 7.00283"   332648 4879/47502
AVG HT. ALL FUEL (WT'D) = 4.75716"

FUEL VOLUME = 4401.16968 cm³
FUEL ρ   = 18.72229 gm/cc

Vol. of graphite net mil gaps = 21048.44479 cm³
            ρ = 1.690291 gm/cc
                    AVG REFL = 1.998"

A-192

11"-7"   2"ref + C Core

Clean Critical Nom. Ht = 4¾" = +16.03¢

Diaph = -12.88¢
Rings = + 4.35¢
S. Stand = + 6.24¢   Lower .0133"

                            0.6926¢/mil
                    only
remove ¹⁄₁₆" from 9-7 = reduced reactivity by 43.29¢ (reference to clean)
    "   "   "   only   "   "   6387
                   11-9 =   39.42¢ (reference to clean)
                                                 13313

REACTIVITY =   +16.03¢
ALL SUPPORTS: + 2.29¢   Cor   1.3313 ¢/mil
  11-9 →   =   0   .11042
  9-7 ↑3.0 = + 2.07¢   1.4355
 Core ↑4.8 = +0.50¢
            +20.89¢ = 4.7585"
              O   = 4.7585 - .0145 = 4.7440"

HT. OF ALL FUEL 11-9 = 4.758 - .758 - .758 - .759 - .760 - .758   =   4.7585" ✓

HT. OF ALL FUEL 9-7 = 4.756 - .7565 - .756 - .754 - .756 - .757   4.7555
                                                       wt avg = 4.7571"

          Carbon
Ht of Core only = 4.753 - .753 - .753 - .755 - .756 - .753 - .753 = 4.7537
                              =0.0048
stack all discs thru ¼"× 11" = (4.7585 - Core Only) + [8.513 - .510 - .514₂
                          .516 - .517 - .515] = (8.514 + .0048) = 8.5189

13-11 ring = 8.517 - .512 - .509 - .509 - .501 - .513 = 8.5101

all carbon on, with top(¼×15) resting on the 15-13 ring
    ∴ measure all top (thereby giving us the 15-13 ring)
      → 8.814 - .814 - .813 - .810 - .812 - .814 - .814 - = 8.8130 (+56)

EVEN FUEL HT. = 4.7571"
SKY HOOK REACT. = +18.32¢   (44 mil & 3.5 mil carbon gaps (see drawing)
                               not considered

O React Ht = 4.7434" ✓
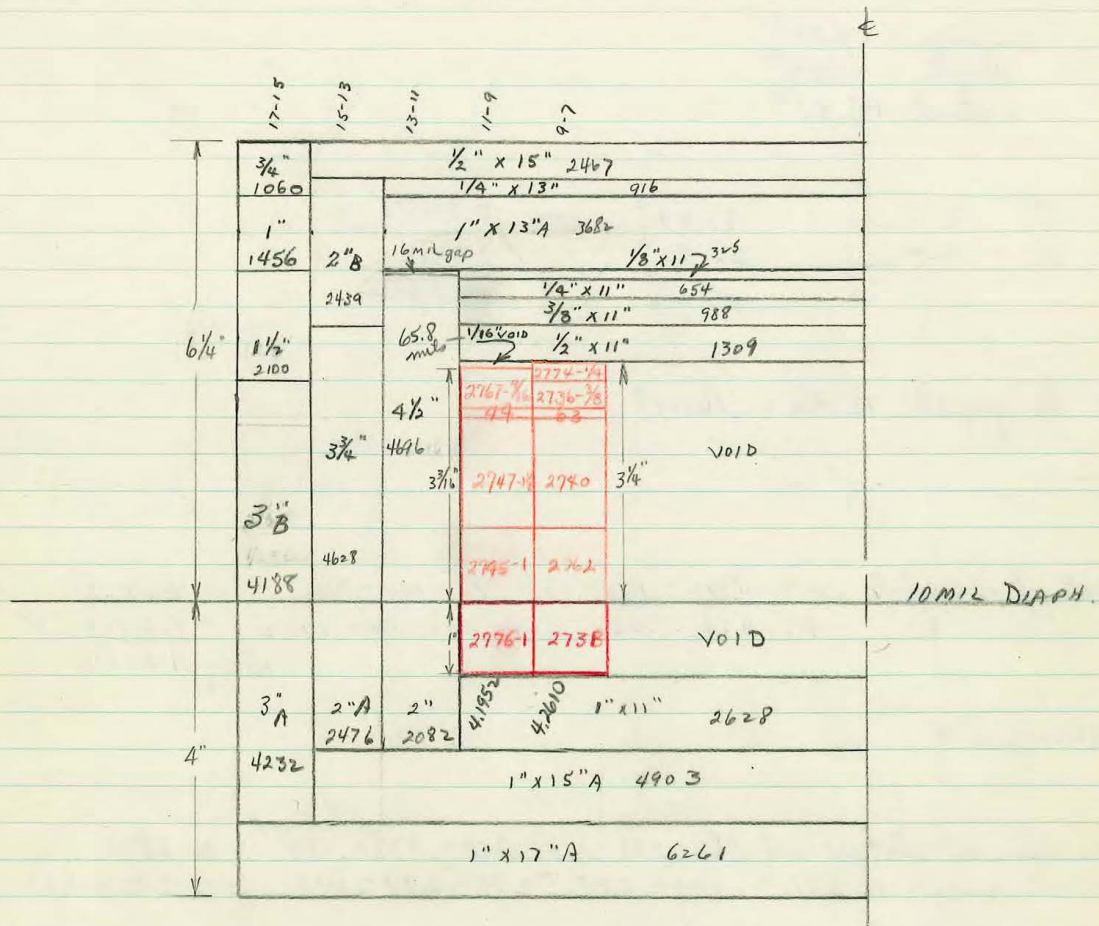
MASS OF FUEL TOP = 55752 gm   TOTAL = 73.106 Kg
        BOTTOM = 17354 gm

MASS OF GRAPHITE TOP = 30908   TOTAL = 53.490 Kg
        BOTTOM = 22582 gm

AVG. O.D. ALL FUEL (WT'D) = 10.99650"   OD² = 120.92301
AVG I.D. ALL FUEL (WT'D) = 7.00316"   ID² = 49.04424
AVG. HT. ALL FUEL (WT'D) =
        FUEL VOL = 3908.10107 cm³   Graphite volume = 31400.18957 cm³
        FUEL ρ = 18.706271 gm/cc   ρ = 1.70.3503 gm/cc
            AVG REFL = 2.999"

A-194

11-7   3" Cref & No̲ Core

Nom. Ht Critical = (11-9): $4^{3}/_{16}$" $(9-7)=4^{1}/_{4}$" $\longrightarrow$ +1.04¢ reactivity

ring = +4.27¢
diaph. = -9.54¢
5 stand. = +6.51¢   ok

$^{1}/_{16}$" 11-9 ring = 46.24¢   or 0.7398¢/mil
$^{1}/_{16}$" 9-7 ring = 52.40¢   0.8384
                                        ‾‾‾‾‾‾
                                        1.5782

TOP $^{1}/_{16}$ graphite 15" dia = 16.11¢

Ht. of all fuel 11-9 = 4.194 - .197 - .196 - .195 - .194 - .195 = 4.1952"
                 9-7 : 4.262 - .262 - .261 - .259 - 260 - .262   = 4.2610 ✓
                                                    wt avg = 4.2244"

4.2610 fuel +

15 Dia. all stacked = 10.280 - .281 - 280 - .280 - .279 - .280 = 10.2800 (+56)
17-15 ring = 10.291 - .296 - .297 - .295 - .297 - .296 = 10.2953 (+71)
($^{1}/_{2}$+$^{3}/_{8}$+$^{1}/_{4}$+$^{5}/_{8}$ X 11) = 1.254 - .256 - .253 - .255 - .256 - .258 = 1.2553

                                        REACT = +1.04¢
                                        ALL SUPPORT = -0.20
                                                    +0.84 = 4.2244"
EVEN FUEL HT. = 4.2610"   0 = 4.2244 - .0005 = 4.2239"
SKY HOOK REACTIVITY = +48.47¢

O React Ht = 4.2244" ✓

14 mil gap

	½" x 15"	2467
1" 1456	¼" x 15"	625
	¼" x 13"	916
1½" 1870	½" x 13"	1834
2" 2770	1½" x 11"	3929
3"B 4188	½" x 7"	536
	1½" x 7"	1618
	1" x 7" B	1065
	1" x 7" A	1065
3"A 4232	1" x 11"	2628
	1" x 15" A	4903
	1" x 17" A	6261

(diagram annotations: 6", 3", 4", 1", 3¾" 4628, 4½" 4696, 2"A 2476, 2" 2082, 4.0070, 4.0097)

(red annotations: 2742, 2736-⅜, 44, 63, 2747-1½, 2740, 2745-1, 2762, 2976-1, 2988)

10 MIL DIAPH.
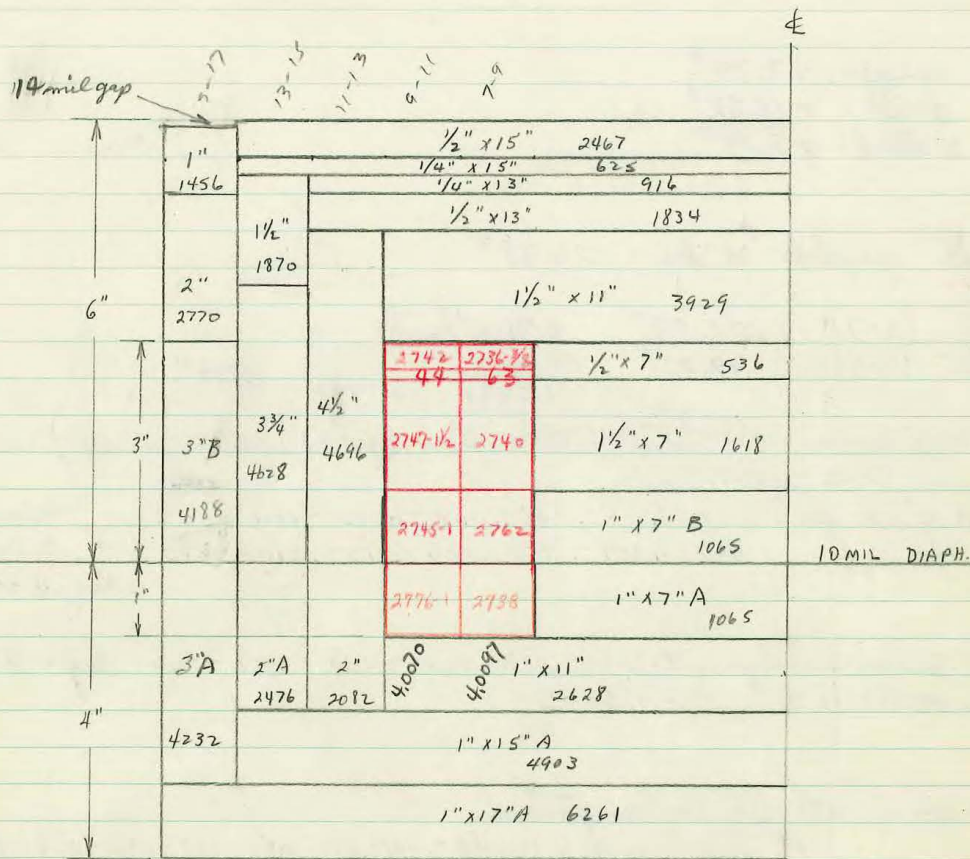
MASS OF FUEL TOP = 52029 gm   TOTAL = 69.383 Kg
        BOTTOM = 17354 gm

MASS OF GRAPHITE TOP = 32598 gm   TOTAL = 56.245 Kg   OF THIS, Core = 4.284 Kg
        BOTTOM = 23647 gm

AVG. O.D. ALL FUEL (WT'D) = 10.99657"
AVG. I.D. ALL FUEL (WT'D) = 7.00317"   Vol of TOTAL G. = 33641.24758 cm^3
AVG. H. ALL FUEL (WT'D) = 4.00820" ρ = 1.67190 gm/cc

        FUEL VOLUME = 3708.11356 cm^3
        FUEL ρ = 18.71113 gm/cc
                AVG REFL = 3.000"

11-7   3" ref + C core

Nom Ht. Critical = 4"   = −20.65¢

rings : +7.74¢
diaph : −10.82¢
s. stand : +7.39¢   Raise .0161"

⅛" graphite 15" dia = 26.38¢

$\frac{1}{16}$" (9-7) = 52.59¢   0.8414 ¢/mil
$\frac{1}{16}$" (11-9) = 44.21¢ $\frac{0.7073}{1.5487}$
                              .0077
                         → TOTAL = 1.5564 ¢/mil

17-15 Carbon = .0022 ¢/mil (taken from (g 131) 15-11 3" ref)
      Core = .0077 ¢/mil

Ht. of all fuel 11-9 : 4.008 −.008 −.008 −.0065 −.006 −.005 = 4.0070"
                9-7 : 4.009 −.010 −.009 −.010 −.010 −.010 = 4.0097 ✓
                                                    w. tang = 4.0082"

Ht of Carbon Core only = 4.006 −.007 −.0011 −.008 −.007 −.006   Avg = 4.0075"
Core + (1½ × 11) =   + 1.5025

Measure with all Carbon stacked
        15" dia. Area h = 10.040 −.041 −.042 −.043 −.037 −.036 −.036 = 10.0392
        17-15 ring = 10.052 −.048 −.056 −.051 −.050 −.057 = 10.0523

                                                            OK

                    REACT.   = −20.65¢
                    ALL SUPPORT   = − 4.31¢
                    11-9 ↑2.7 = + 1.90¢
                    9-7 →   = 0
                    Core ↑2.2 = + 0.01¢
EVEN FUEL HT. = 4.0082"   17-15 ↑14 = + 0.10¢
SKY HOOK REACT. = −24.96¢   −22.95¢ = 4.0097"
                              0 = 4.0097 + .0147 = 4.0244"

O React Ht = 4.0243" ✓

Top column labels (diagonal): 18-17x64   19-17   17-15   15-13   13-11   11-9   9-7   ₵

Within diagram (black):
3/4 7/8   1½"   ₅ 63 mils   ¼ x 13   916
1255 1233   3/8 x 13 1386
                                  3/8 x 11 988
13/16   1870 1½"
1334   1588   1½ x 11
      2 11/16   4212
1"   2B
1644 3776   2439   1½ x 11
1½"   2439
2438
             4½
      3B 3"
2 3/8"
      4188 3712 4696   47 -1½   40   10 mil Diaph
3863

4" 3A 2" 2"   45 -1   38
    4232 2476 2082
6513   1 x 11
                                      2628

                                 1 x 15
                                      4903

                                 1 x 17
                                      6268

                                 1 x 19
                                      7828

Red cells:
3216 - ⅞ 3217
49 1½   63
43 -⅞   2329
42 -⅞   36
47 -1½   40
45 -1   38
3.6625   3.6205

Calculations:

MASS OF FUEL = 63427 gm
    VOLUME = 3392.02059 cm³
    ρ = 18.69888 gm/cc

MASS OF GRAPHITE = 81407 gm
    VOLUME = 48201.48740 cm³
    ρ = 1.68888 gm/cc   AVG REFL = 4.002"

AVG. O.D. ALL FUEL (w'T'D) = 10.99678"   OD² = 120.92917
            I.D. = 7.00284"   ID² = 49.03976
19-17 OD Carbon = 18.99662"   — 360.87176

Nom. Ht. Critical = $3\frac{24}{32}$ reactivity = $-4.38¢$

$\quad\quad$ Ring = $+4.38¢$
$\quad$ Diaphragm = $-11.01¢$
$\quad$ S. Stand = $+5.01¢$ Raise 0.0014"

$(-)\quad \frac{1}{32}$" fuel $\quad$ 11-9 = $28.34¢$ $\quad$ 0.9068¢/mil $\Big\}$ = 2.0719
$(-)\quad\quad\quad\quad\quad$ 9-7 = $36.41¢$ $\quad$ 1.1651 $\quad$ add 9-7 = $\boxed{16.05¢\; ??}$ $\quad\quad$ Avg = 2.014¢/mil

add 238" graphite on 15-13 ring = $+5.83¢$ $\quad$ .0245¢/mil

Ht. of Carbon = 19-17 = 11.483 - .475 - .473 - .471 - .463 - .467 - .479 $\quad$ = 11.4730"
$\quad\quad\quad\quad\quad$ 17-15 = 11.600 - .600 - .601 - .599 - .605 - .598 - .596 - .594 = 11.5991"
$\quad\quad\quad\quad\quad$ 15-13 = 11.556 - .551 - .554 - .546 - .558 - .568 - .556 $\quad$ = 11.5555"
$\quad\quad\quad\quad\quad$ 13-11 = 11.645 - .648 - .649 - .646 - .639 - .645 - .651 - .649 = 11.6465"
$\quad\quad\quad\quad\quad$ 11 dia = 8.027 - .037 - .031 - .029 - .037 - .032 - .027 $\quad$ = 8.0314"
$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad$ Raise 0.0021

Ht of fuel $\quad$ 11-9 = 3.664 - .662 - .660 - .663 - .661 - .665 $\quad$ = 3.6625"
$\quad\quad\quad\quad\quad$ 9-7 = 3.670 - .671 - .672 - .670 - .670 - .670 $\quad$ = 3.6705"
$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad$ wt vol Avg = 3.6661"

13-11 up to disc = $\quad$ - - - $\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad$ = 11.0030"
11 dia up to 2nd $\frac{3}{8}$" price = 3.6705 + [7.392 - .397 - .392 - .400 - .399 - 392] = 11.0658

gap difference = 63 mils gap

$\quad\quad\quad$ corrected flat fuel height = 3.6696"

REACTIVITY = $\quad\quad -4.38¢$
ALL SUPPORT = $\quad +1.62¢$
$\quad$ 11-9 ↑ 8.0 = $\quad +7.25¢$ $\quad\quad +9.20¢$ = 3.6705"
$\quad$ 9-7 → = $\quad\quad$ 0 $\quad\quad\quad\quad$ 0 : 3.6705 - .0044 = 3.6661"
$\quad$ 15-13 ↑ 111 = $\quad +2.71¢$
$\quad$ 13-11 ↑ 63 = $\quad \underline{+2.00¢}$
$\quad\quad\quad\quad\quad\quad\quad$ →

MASS OF FUEL = 61 251 gm
   VOLUME = 3273.31780 cm³
      ρ = 18.71220 gm/cc

MASS OF GRAPHITE = 85998 gm   AVG REFL = 4.000"
   VOLUME = 50314.14519 cm³
      ρ = 1.70922 gm/cc

AVG. O.D. ALL FUEL (W'TD) = 10.99685"   OD² = 120.93070
                I.D. = 7.00281"   ID² = 49.03934
19-17 Carbon OD avg w'td = 18.99662" ——   360.87157

11-7   4" ref + core

Nom. Ht. Critical = 3¹⁷/₃₂"   reactivity = + 14.36¢

        Rings = + 2.15¢
    Diaphrag = − 10.15¢   Lower 0.0100"
    S. Stand = + 5.76¢

¹/₃₂" fuel 11-9 = 26.51¢   0.8483¢/mil
            9-7 = 25.04¢   0.8012   Avg = 1.649¢/mil
                          ‾‾‾‾‾‾‾
                          1.6495
13-11 est .030¢/mil   − .0646
   Core .0646¢/mil   ‾‾‾‾‾‾
                          1.7141 ¢/mil

Wt. of Carbon = 19-17 =   16ᵛ   11.4730"(-65)ᵛ
                17-15 =   11.5991" (+62)
                15-13 =   11.5555" (+12)
                13-11 = Same as 11"dia →   = 11.5048"(-32)
   8.022" ← 11 dia = 11.505−.498−.498−.500−.511−.514−.508 = 11.5048"
            core = 3.510−.509−.510−.509−.510−.509   = 3.509₅"
                                                              ᵥ̄k

Wt. of fuel = 11-9 = 3.532−.533−.532−.534−.533−.532   = 3.5326"
              9-7 = 3.544−.544−.544−.544−.544−.544   = 3.5440"↙
                                      wt vol Avg = 3.5376"

13-11 thru 1½ = 11.004−11.000−10.897−11.005−.006−.006   = 11.0030"
11 dia thru 2ⁿᵈ 1½ = 3.544 + [7.521−.521−.523−.519−.523−.521−.521] = 11.0652"
                              + .500
gap diff = 62 mils   11"dia

        Corrected flat fuel height = 3.5276"

[USE]   React = + 14.36¢
REACT =   + 14.36¢   all Support = + 2.24
ALL SUPPORT = + 2.24   11-9 ↓23.1 = −19.59
  11-9 ↑11.4 = + 9.67   9-7 ↓44.5 = −35.65
  9-7 → = 0   13-11 ↑62 = + 1.86
  13-11 ↑62 = + 1.86   Core → ‾‾‾‾‾‾‾0
  Core ↑34.5 = + 2.22   − 36.78¢ = 3.5095"
            ‾‾‾‾‾‾‾‾
            + 30.35 = 3.5440"

O = 3.5440 − .0177 = 3.5263"   O = 3.5095 + .0214 = 3.5309"

A-201

16.1899	25-21	21-19	19-17	12-15	15-13	13-11	11-9	9-7	℄

3/4 — 1364 (21-19); 11/16 1111 (19-17); 3/4 1060 (12-15); 1 1262 (15-13); 1/4 × 13 916; 1/2 × 13 1834

1.0 4234; 1 1828; 3/4 1255; 1 1456; 1 × 13 A 3682

1.19 4895; .81 1334; 2A 2476; 1/4 × 11 654; 1/2 × 11 1309

1 1644; 2 2770; 1½ 1588; 1 × 11 2628

3

5325; 2⅞ 3863; 3B 4188; 3 3712; 2 2082; 1½ × 11 A 3929

7

28700; 5 8827; 4; 3⅜ 4232; 3¾ 4628; 4½ 4696; 2 × 11 5273

35.5 mil GAP

[red grid cells:]
43 ⅝ | 38-17 3/32 ⅛
42 ⅜ | 36
76-1 | 62
45-1 | 38

2.7853   2.7908   1 × 21 9666

10 MIL DIAPH.

4½ 18455

2 × 21 19263

1½ 2677 | 1½ 2430 | 1½ 2098

1/2 × 15 2467

1 × 15 4903

1/2 × 25 6868

2 × 25 27650

25-21 OD Carbon = 24.99787"   (²) = 624.89350
FUEL MASS: 47944 gm; VOLUME: 2563.51344 cm³; ρ = 18.70245 gm/cc
GRAPHITE MASS: 221745 gm; VOLUME: 131620.74551 cm³ ρ = 1.68472 gm/cc
OD (AVG) FUEL (WT'D) = 10.99653"   OD² = 120.92367
        ID = 7.00331"   ID² = 49.04635   AVG REFL = 6.997"

11-7　　7" ref & No core

Nom. Ht. Critical　11-9 = $2\frac{3}{4}$"
　　　　　　　　　9-7 = $2\frac{25}{32}$"　　　reactivity = $-3.17^{\cent}$

extra braces on sides = $+1.27^{\cent}$ ⎱ 8.16
　　　Rings ⎰ $+6.89^{\cent}$ ⎱　　　　　　　　Raise .0034"
　　S. Stand
　　Diaphragm = $-1.99^{\cent}$
80 4 mils (25×21) = $+2.90^{\cent}$ or $.00361^{\cent}/mil$
　$\frac{1}{32}$" fuel 11-9 :　37.65$^{\cent}$　or $1.2048^{\cent}/mil$　Av. = $2.37^{9}^{\cent}/mil$
　　　　　　9-7 :　36.63$^{\cent}$　or $1.172^{\cent}/mil$

Wt of fuel 11-9 : 2.756-.755-.754-.756-.755-.756　= 2.7553"
　　　　　9-7 : 2.790-.790-.793-.791-.791-.790　= 2.7908"
　　　　　　　　　　　　　　　　　　　wt Vol Avg = 2.77107"

Wt of carbon = 25-21 : Same as 181　　　　　　= 16.1983" (-580)
　　　　　21-19 : Same　　　　　　　　= 16.8013" (+224)
　　　　　19-17 : Same　　　　　　　　= 16.6786" (-100)
　　　　　17-15 : Same　　　　　　　　= 16.8108^{4}(+374)
　　　　　15-13 : Same　　　　　　　　= 16.7736"
　　　　　13-11 : Same but - (.0625") + (.125)　= 16.7748"
　　　　　11 dia : Same - (.0625 + .0625)" + (.125)　= 14.0358"

　　　　　　　　　　　　　　　　　　　Raise .0005

　　(19-17) C ring = .0049$^{\cent}$/mil　from p.181

　　Corrected flat fuel height = 2.7750" ✓
REACT.　　　= $-3.17^{\cent}$
ALL SUPPORT　: -6.17
11-9 ↑ 35.5　= $+42.77$　　$+35.52^{\cent}$ = 2.7908"
9-7 →　　　= 0　　↑ 0 = 2.7908 - .0149 = 2.7759"
25-21 ↑ 580　= $+2.09$

Column headers (left to right): 7/16, /899 | 25-21 | 21-19 | 19-17 | 17-15 | 15-13 | 13-11 | 11-9 | 9-7 | ₵

		3/4	11/16	3/4	1				1/8 X13	460
		1364	1111	1060	1262				9/16 X 13	2061
	1.0	1	3/4	1					1 X 13	3682
	4234	1828	1255	1456	2A				1/4 X 11	654
	1.19		.81 / 1334		2476	1 1/2			9/16 X 11	1474
	4895	3	1 ÷ / 1644	2 / 2770		1588			1 X 11	2628
		5325			3. / 3712	2 / 2082			1 1/2 X 11	3429
	7		2 3/8 / 3863	3B / 4188						
	28700								2 X 11	5273
		5 / 8827			4 1/2	29.2 mil gap			26.3 mil GAP	
			4 / 6513	3A / 4232	3 3/4 / 4628	4696	16 - 7/52 / 44 - 7/5 / 67 - 9/16 / 43 - 5/8 / 42 - 3/4 / 45 - 1	3.4 1/4 / 63 / 37 / 2829 / 36 / 38	1/2 X 7 / 130 / 3/8 X 7 / 404 / 9/16 X 7 / 602 / 1 1/2 X 7 / 1618	
						2.7263	2.6971	1 X 21	9666	
	4 1/2 / 18455							2 X 21	19263	
		1 1/2 / 2677	1 1/2 / 2430	1 1/2 / 2098				1/2 X 15	2467	
								1 X 15	4903	
								1/2 X 25	6868	
								2 X 25	27650	

25-21 OD Carbon . 24.99787"   (²) = 624.89350

FUEL MASS = 46932 gm ; VOLUME = 2510.32506 cm³ ; ρ = 18.69558 gm/cc

GRAPHITE MASS = 223101 gm ; VOLUME = 133286.20002 cm³ ; ρ = 1.67384 gm/cc

AVG. O.D. FUEL (WIT'D) = 10.99663"   OD² = 120.92587   AVG REFL = 6.997"

I.D. = 7.00296"   ID² = 49.04144

A-204

11-7   7"ref + Core

Nom. 1st. Critical   11-9 = $2\frac{23}{32}$"   reactivity = −0.34¢
                        9-7 = 2"/16"

Value of S.stand + rings + other supports "arms" = +6.84¢
                                    diaphragm = −2.71¢
                                                        Raise 0.0019"

    25-21 ring graphite = .00361¢/mil (taken from the coreless run)
0.311" on 19-17 ring = 1.54¢   .0049¢/mil
1/32" fuel 11-9 = 35.43¢   1.1337¢/mil
          9-7 = 34.86¢   1.1155   wt vol Avg = 2.249¢/mil
                                2.2492
                               −.0494
Core = .0494¢/mil   2.2986

Ht. of fuel 11-9 = 2.727−.726−.726−.727−.726−.726   = 2.7263"
             9-7 = 2.696−.697−.695−.696−.699−.700   = 2.6971" ✓
                                    wt vol Avg = 2.7133"

Ht of Carbon 25-21 = 16.200−.218−.206−.183−.183−.200 = 16.1983" (−518)
             21-19 = 16.796−.803−.802−.803−.803−.801 = 16.8013" (+84)
             19-17 = 16.669−.682−.677−.686−.681−.677 = 16.6786" (−37)
             17-15 = 16.809−.797−.815−.822−.813−.809 = 16.8108" (+94)
             15-13 = 16.765−.775−.781−.784−.775−.762 = 16.7736" (+56)
             13-11 = 16.708−.713−.716−.713−.712−.712 = 16.7123"
             11 dia = 14.024−.038−.045−.037−.038−.037 = 14.0358"
             Core = 2.700   = 2.700"
                                                        Raise .001

        Corrected flat fuel height = 2.7162" ✓
REACT. =   −0.34¢
ALL SUPPORT: −4.13
11-9 ↓ 29.2 = −33.10
9-7 →   0   ↗ −35.85¢ = 2.6971"
25-21 ↑ 518 = +1.86   0 = 2.6971+.0155 = 2.7126"
Core ↓ 2.9 = ± 0.14

~913 # TOTAL
~250 # per Run

15 MIL DIAPH →

Column labels: 29   25   21   19   17   15   13

29	25	21	19	17	15	13		
3/4 3664	.8 3283	3/4 1364	11/16 1111	3/4 1080	3/4 934	9/16 × 13		2061
1 1/2	1.2	1 3/4 1255 1 7/8 1334		2	2B	3/8 × 13		1386
7427	4895	1997	1 1644	2770	2434	1/2 × 13		1834
3	3	2	2 1/8	2 1/16	2A	1 × 13 B		3760
	12350	3546	3440	3776 2476		1 × 13 A		3682
14600		3	2 3/8		1 1/2 1588	9/16 × 11		1474
				3		1 1/2 × 11 B		4212
		5325	3863 3B 4188	3712	2 2082	1 1/2 × 11 A		3929
9	7	5 4			4 1/2	2 × 11		5273
43550	28700	8827 6513	3A 4222	3 3/4 4628				
					4696		1 × 19 B	7838
			2 × 25					27650
1 4985	1 4234	1' 1828			1 × 19 A			7828
			1/2 × 25					6868
5	4 1/2	1 1/2 2677	1 1/2 2438	1 1/2 6098	1 1/2 × 15 A			7485
24550	18455			1 × 21				9666
			2 × 21					19263

red cells: 79 67 37 75 / 78 42 36 74 VOID / 45 38

MASS OF FUEL = 42277 gm
  VOLUME = 2260.74271 cm³
    ρ = 18.70049 gm/cc
MASS OF GRAPHITE = 372743 gm
  VOLUME = 215874.52837 cm³
    ρ = 1.72666 gm/cc
WT'D OD OF FUEL = 10.99646"
  (²) = 120.92213
  ID = 7.00300"
  (²) = 49.04200

AVG REFL = 8.999"

11-7   9"ref & No Core

Nom. Ht. Critical = $2\frac{7}{16}$"   reactivity = $-10.35^{¢}$

support stand & ring
ring support   } = $-5.22^{¢}$
diaphragm

fuel value 11-9 = $+23.39^{¢}$ 0.7484 ¢/mil
            9-7 = $+23.11^{¢}$ .7395
                                        ‾‾‾‾‾‾‾
                                        1.4879

values run few days later: Use
calc from   11-9 = 42.84   1.3646 ¢/mil
11-7 meas ——> 9-7 = 28.3¢   0.9056
                                        ‾‾‾‾‾‾‾
                                        2.2752

Ht. of Carbon 29-25 = 20.272 - .278 - .289 - .295   = 20.2835"
               25-21 = 20.004 - 19.980 - .984 - 20.007 = 19.9937"
               21-19   19.920   19.920
               19-17 = 20.802 - .800 - .800 - .802   = 20.8017
               17-15 = 20.479 - .484 - .484 - .473   = 20.4800"
               15-13 = 20.552 - .551 - .548 - .536   = 20.5467"
               13-11 = 20.441 - .450 - .435 - .470   = 20.4490"
               11 dia = (same as 13-11) - 2.4443   = 18.0047"

Ht. of fuel 11-9 = 2.444 - 445 - 444 - 443 - 444 - 446   = 2.4443"
             9-7 = 2.443 - 442 - 443 - 443 - 444 - 443 - 444   = 2.4431"
                                                        wt avg = 2.4437"

Reactivity = $-10.35^{¢}$
all supp. = $+5.22^{¢}$
29-25 ↑160 mils = $+0.01^{¢}$
25-21 ↑450   = $+0.09$
21-19 ↑523   = $+0.20$
19-17 ↓358   = -0.21
17-15 ↓ 36   = -0.59
15-13 ↓10 3   = -1.60
13-11 ↓ 5   = -0.11
‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾‾
    2.4437" = $-7.34^{¢}$
(+3.2 mils) 2.4469" = clean ∞

29   25   21   19   17   15 13 11 9 7

1 X 13 A   3682
3/8 X 13   1386
1 X 13 C   3745
1 X 13 B   3760
1/4 X 11   654
3/8 X 11   988
1 1/2 X 11 B 4212
1 1/2 X 11 A 3929
2 X 11   5273
1 X 7B   1065
3/8 X 7   404
1 X 7A   1065
1 X 19B   7838
2 X 25   27650
1 X 19 A   7828
1/2 X 25   6868
1 1/2 X 15A 7485
1 X 21   9666
2 X 21   19263

Gap = 0.101"
13-11 ring

29 MILS VOID

15 MIL DIAPH.

MASS OF FUEL = 41764 gm
    VOLUME = 2233.36207 cm³
        ρ = 18.70005 gm/cc
MASS OF GRAPHITE = 374040 gm
    VOLUME = 217392.14212 cm³
        ρ = 1.72057 gm/cc
WT'D OD FUEL = 10.99678"
    (²) = 120.92917
    ID = 7.00307"
    (²) = 49.04298

AVG REFL = 9.002"

A-208

11-7   9" ref + Core

Nom. Ht. Critical = $2\frac{13}{32}$"   reactivity = +15.29¢

Support stand & ring
& ring support   } = −3.98¢
& diaphragm

fuel value 11-9 = 44.58¢   1.4265¢/mil
            9-7 = 47.48¢   1.5193¢/mil
                                  2.9458¢/mil

$\frac{1}{8}$" ×13"dia C = 5.42¢   or .04336¢/mil

$\frac{13}{16}$" (814 mils) 19-17 C = 4.71¢   or .00578¢/mil

Wt of carbon 29-25   Same as Pg 293   = 20.2835"
              25-21   19.9937"
              21-19   19.920"
              19-17   20.8017"
              17-15   20.4500"
              15-13   20.5467
              13-11 = (20.486 −.495 −.487 −.473) − 0.101 = 20.3842"
                                    20.452
              11 dia = (20.486 −495·487·473) − 2.446   = 18.0392"
              Core = 2.384−385·384·384·386·386·384   = 2.3847"

      13-11 ring Three 6½" ring↑ = 17.004

Wt. of fuel 11-9 = 2.414 −414 −413 −413 −413 −413 −414   = 2.4134"
             9-7 = 2.415 −.415 −414 −414 −415 −415   = 2.4146"
                                          wtd avg = 2.4139"

React = +15.29¢
all support = +3.98
all carbon = −3.96
    2.4139" = +15.31¢
(−5.2 mils) = 2.4087" = clean ∞

A-209

11"-7'" & 17" GRAPHITE REFLECTOR   also + Core   Pg 4-205

E

45x2   91.5   .   . . . .

45x15   683.6   C D)   1/32" GAP
                                                   |76|28| 3/8   core or
2   80.9   2 2 |67|36| 1/2   No Core   E
                                                   |76|62| 7x1   3/8
1   39.5   1½ 1½   9/32

                                              1   ½
                                         9/16   ¼

8   330.1   D   B
                          A   c   18

                                     B
                                     A

                                                   RamC = 92.65'
                                                   Incl Core

8   228.1   10

                                              Ram = 89.646
                                     .163"
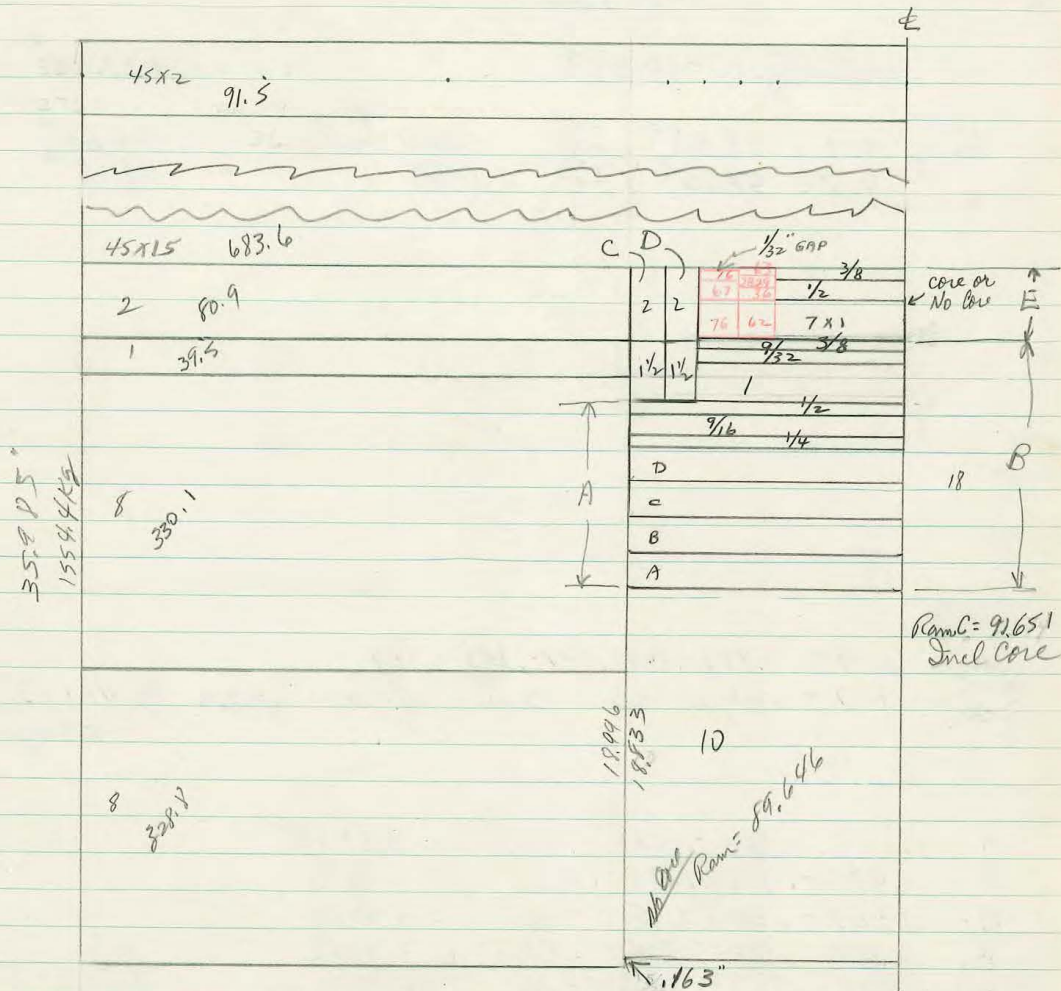
MASS OF FUEL = 32208 gm   + Core
      Vol = 1724.3438 cm³   Same
      ρ = 18.6784 gm/cc
Fuel OD = 10.9967"   (²) = 120.92741
      ID = 7.0034"   (²) = 49.04761

Mass of C = 1644.046 Kg   — 1646.051 Kg
      Vol = 934863 cm³   — 936145 cm³
      ρ = 1.758 gm/cc   ρ = 1.758 gm/cc

      AUG REFL = 16.999"

A-210

11-7 #17" C. ref   Core & No Core

<u>No Core</u>   <u>Core</u>

Nom. Ht. Critical = 9-7 = 1⅛   Same Core 1⅛
                 11-9 = 1²⁷/₃₂

     reactivity = −10.38¢   +33.75¢

1/32" of 11-9 = 58.38¢ ±5¢ −0¢ 1.8681 ¢/mil   56.73¢   1.8153 ¢/mil
        9-7 = 44.65¢ ±5¢ −0¢ 1.4288   39.48¢   1.2633

fuel 11-9 = 1.849 − .849 − .849 − .849 − .849   = 1.8490
     9-7 − same as 15 dia cyl. #10" graph Pg 4-103 = 1.8826
                                                wt avg = 1.8639

A = 5.328 − .325 − .325 − .322   = 5.3250"
B = 6.990 − .988 − .988 − .988   = 6.9885
C = 3.509 − .508 − .505 − .508   = 3.5075
D = 3.504 − .504 − .504 − .505   = 3.5042
E = 1.879 − .879 − .879 − .879   = 1.8790

MASS OF FUEL = 47 559 gm

$\quad$ Vol = 2538.2633 cm³

$\quad\quad$ ρ = 18.7368 gm/cc

$\quad$ Avg OD = 10.99683"   (²) = 120.9302?

$\quad$ Avg ID = 9.00179"   ( ) = 81.03222

Mass C = 766.732 Kg.

$\quad$ Vol C = 451692 cm³

$\quad\quad$ ρ = 1.697 gm/cc   AVG. REFL. = 11.998"

A-212
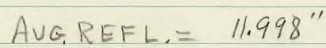
11-9 Ring Only & 12" ref.

Nom. Wt. Critical = 4 $\frac{15}{16}$"   (3500 ref. TOP is $\frac{1}{16}$" TOO MUCH)
            reactivity = +11.69¢

$\frac{1}{32}$" fuel value = 24.84¢   ✓ .7948 ¢/mil
       all supports = 4.28¢
   $\frac{1}{2}$" 35(OD) TOP = 21.17¢
∴ $\frac{1}{16}$" graphite 35(OD) TOP = 2.64¢

            $\frac{21.17}{8}$

fuel ht   11-9 = (4.943 - .943 - .943 - .942 - .943 - .943 - .944   = 4.9430"

A = 2.002, .002, .003, .002   = 2.0022"
B = 6.521 - .522 - .518 - .520   = 6.5202
C = 6.500 - .505 - .502 - .502   = 6.5022
D = 1.566 - .566 - .563 - .563 - .563 - .565   = 1.5643

4.943
- 9

4.934"

ℓ

35

| 1/2 | 11.6 | | 15 15 11 9 7 | | | | |
| 1 | 26.8 | | 1841 | 625 | 1/8 -3/8 | mass = 40866 ← ρ = 1.7279 |

10

269.37

←B→

			15 x 1/2	
2	44.4 Kg	3/4	1	1/8 3/8	1	
4	87.3 Kg	3 3/4	4 1/2	1 1/2 43	2	ρ = .7979 Core. 23 Ram C = .79834
		15-13		1 1/2 47	9 x 1 1/2	

15 x 1
1
1
1

| | 2 | 2 | 2 | 2 | 2 | A |
| 11 | 24/.4 | | | | | |

3 | 13 x 1
1
1

1 1/2 | 1 1/2

15 x 1 1/2

Tot = 28.593
Tot = 17.0215

MASS OF FUEL = 43372 gm
VOL = 2313.1833 cm³
ρ = 18.7499 gm/cc
Mass of C = 763.170 Kg
Vol = 448495 cm³
ρ = 1.701 gm/cc

AVG. OD fuel = 10.99689"
(OD)² = 120.93158
ID fuel = 9.00202"
(ID)² = 81.03636

AUG REFL = 12.001"

11-9 Ring only 12" ref. carbon + Core

"Clean" critical Nom. Ht. = 4½"
                    reactivity = + 28.89¢

    -1/32" fuel value = 29.91¢ *   .9571 ¢/mil
all supports value = 3.42¢

fuel Ht 11-9 = 4.505 - .505 - .505 - .505 - .505 - .505   = 4.5050

A = 12.006 - .015 - .020 - .020 = 12.0152
B = 17.042 - .040 - .040 - .045 = 17.0417
Core = 4.497 - .500 - .500   = 4.4990

4.505
- 1/27/8
4.478

* Has void 1/32" over fuel
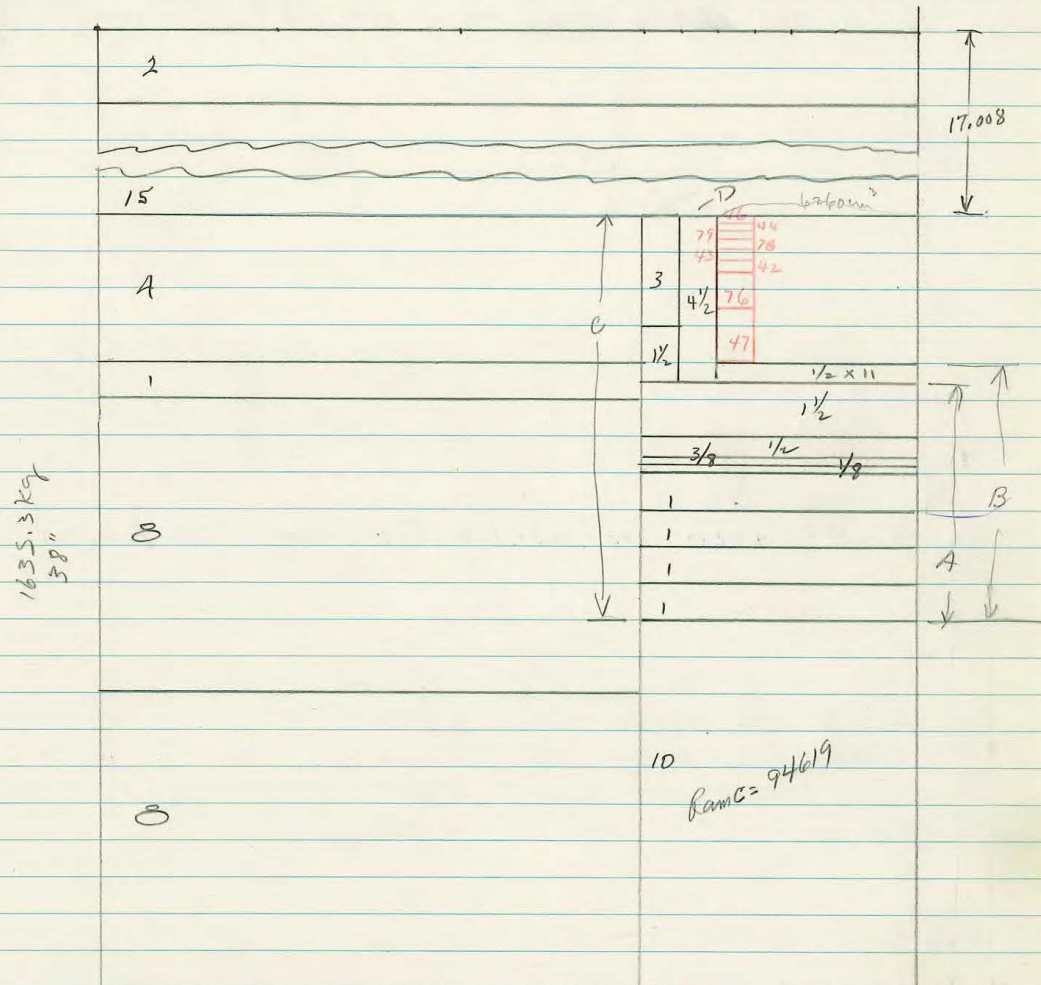
Mass of fuel = 38607 gm

Vol = 2063.8061 cm³

ρ = 18.7066 gm/cc

OD fuel = 10.99660" (²) = 120.92521

ID fuel = 9.00176" (²) = 81.03168

Mass C = 1729.919 Kg.

Vol = 984125 cm³

ρ = 1.757 gm/cc

AVG REFL = 17.004"

11-9 ‡ 17" C. ref <u>No</u> Core

Nom. Wt. Critical = 4"
    reactivity = +25.95¢
1/32" (11-9) = 58.25 + 48.22 ÷ 2 = 53.24¢ or 1.7036 ¢/mil ✓

fuel ht : 11-9 - 4.020 - .020 - .019 - .019 - .019 - .020   = 4.0195

A = 6.503 - .516 - .515 - .511 = 6.5112
B = 7.002 - .012 - .015 - .016 = 7.0112
C = 11.036 - .025 - .037 - .030 = 11.0320
D = Lookup   = 4.5500

Rad. Refl = 16.9945

4.5500
4.019
————
1 - 1

2   91.5

15   683.6

4   161.8

1   39.5

1635.3 Kg

8   330.1

10   RawC = 100685

8   328.8

1½

4½

3

67
28
42
76
47

9/16   ¼
3/8
1
1½

½   9/32
¼   3/8
17/32
9/16

½
1
1
1
1

.251
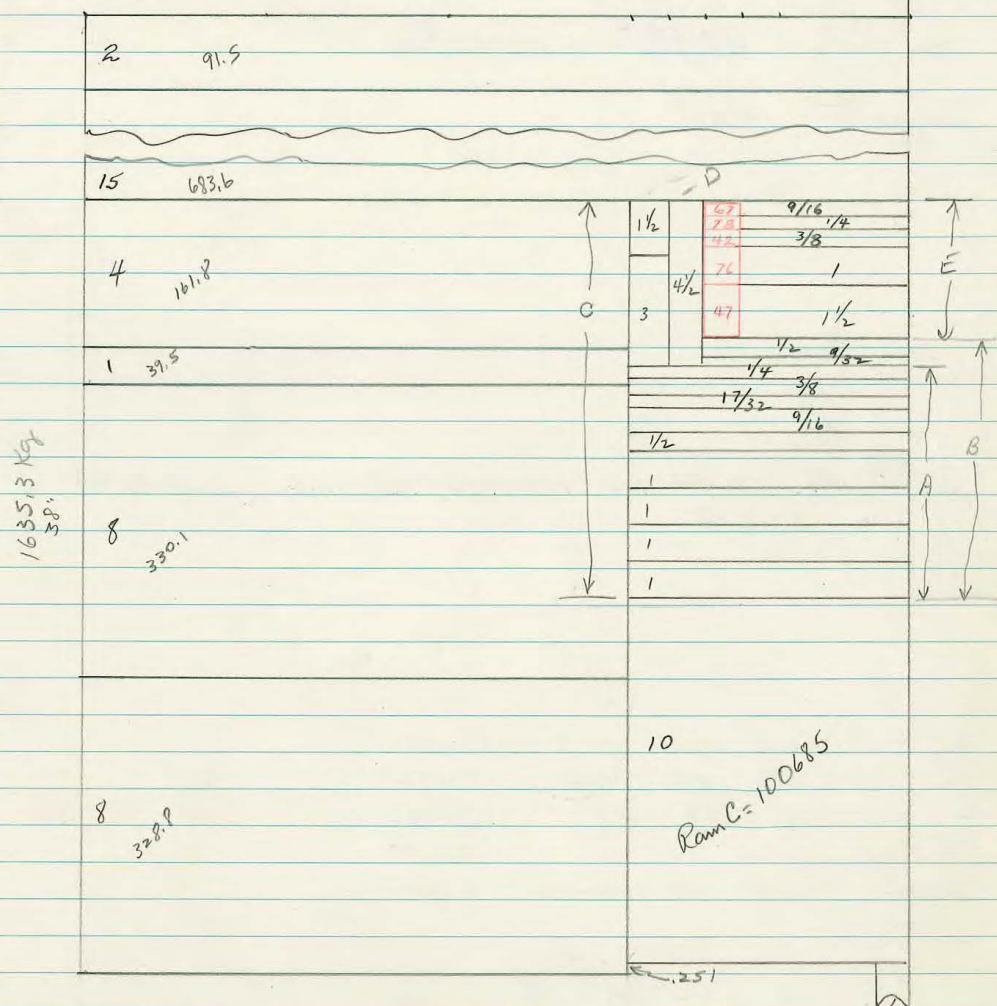
Mass of fuel: 35518 gm
Vol = 1898.2418 cm³
ρ = 18.7109 gm/cc
OD = 10.99654" (²) = 120.92389
ID = 9.00166" (²) = 81.02988

MASS = 1735.985 Kg
Vol = 987174 cm³
ρ = 1.758
AVG REFL = 17.007"

11-9 ≠ 17" C. ref + Core

Nom. Ht. = 3 11/16"
reactivity = −22.32¢

1/32" fuel = 47.98¢ or 1.5353¢/mil ✓

Supports = 1.31¢

fuel ht: 11-9 = ~~3.727~~ ~~.727~~ ~~.727~~ ~~.726~~ ~~.726~~ ~~.722~~ = ~~3.7266~~
    3.6970

A = 6.235 − .235 − .228 − .233 = 6.2327
B = 7.013 − .026 − .018 − .020 = 7.0192
C = 10.745 − .740 − .746 − .739 = 10.7425
D: Look Up   = 4.5000
Core E = 3.697 − .690 − .690 − .690 = 3.6917

3.697
+ .15
—————
3.71 ÷ 2

45×1 45.4

45×2 91.5

45×15 683.6

c D E   63   F

2815

$45 \times 15 \times 4$ 2   2   2   [41]   2

161.8   37   9/16

3   40   1½

½   20.3   4½   4½   3/8   ½

2   80.9   1½   9/16

1

½

9/16

1½

$45 \times 15 \times 8$ 1

A   330.1   1

1

40.469"

22.496 / 22.080

8   328.8   10   Ram C = 107766

B

18.0

.415"
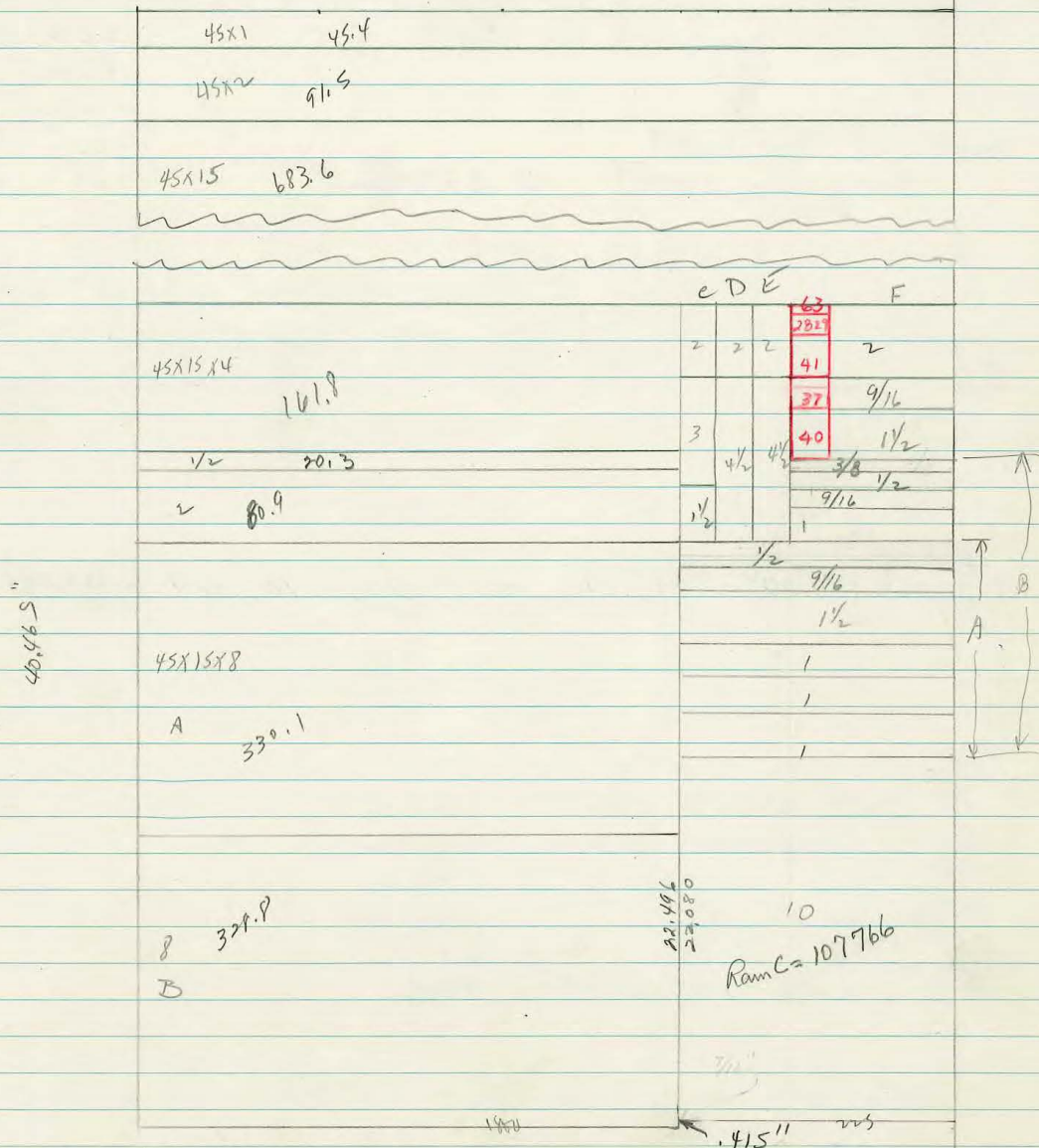
mass of fuel = 31320 gm

$Vol = 1670.8090 \text{ cm}^3$

$\rho = 18.7454 \text{ gm/cc}$

$OD = 8.99636" \quad (^2) = 80.93449$

$ID = 7.00246" \quad (^2) = 49.03444$

$\text{Mass of } C = 1850.166 \text{ Kg}$

$Vol C = 1052924 \text{ cm}^3$

$\rho = 1.757 \text{ gm/cc}$

AVG REFL = 18.005"

A-220

9-7 & 18" C. ref + Core

nom. Wt. = 4¹/₁₆"
reactivity = + 11.01 ¢

45×15×1 C (TOP) = 6.30 ¢
        ¹/₃₂" fuel = 27.28 ¢   ✓ .8730 ¢/mm²

9-7
Wt. of fuel : 4.068 - .069, .070, .071, .070, .070, .069 = 4.0695

A   5.575 - .568 - .570 - .572   = 5.5712
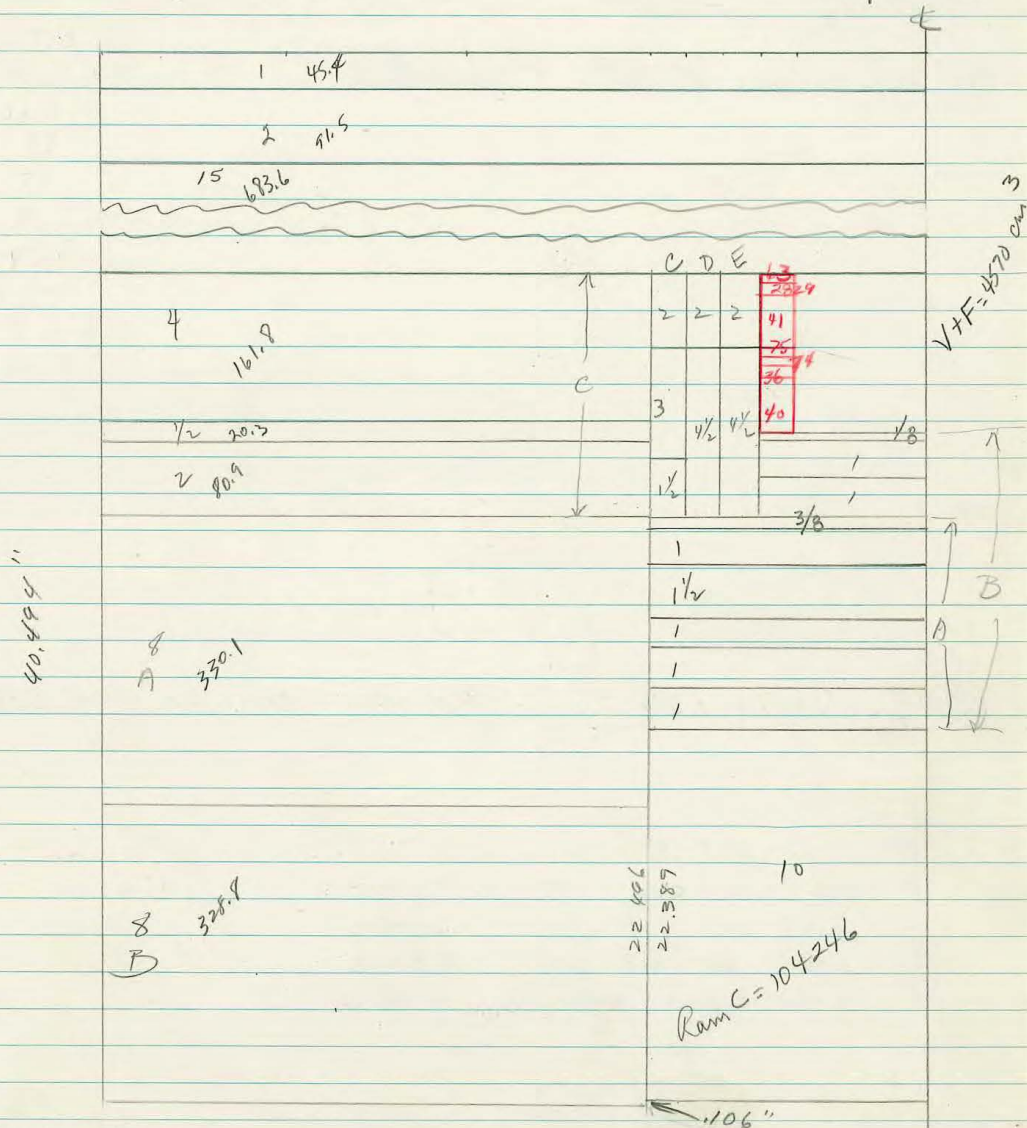B   8.016 - .014 - .015 - .012   = 8.0142
C   = 6.5092
D   [Same as 8-213   = 6.5012
E   = 6.4982
F core = 4.065 - .065 - .065 - .065 = 4.0650

1   45.4

2   91.5

15   683.6

C   D   E

V+F = 4570 cm³

4   161.8

2   2   2   **13** / **2829** / **41** / **75** / **74** / **36** / **40**

c

3   4½   4½

½   20.3

2   80.9

1½

⅛

3/8

40.889"

1

1½

8   330.1

A

1

1

1

B

A

8   328.9

B

22.406   22.389

10

Ram C = 104246

.106"

mass of fuel = 33726 gm
    Vol = 1800.8645 cm³
      ρ = 18.7276 gm/cc
   OD = 8.99634" (²)= 80.93413
   ID = 7.00271" (²)= 49.03794

   AVG REFL = 18.001"

Mass of C = 1846.646 gm
   Vol = 1050816 cm³
    ρ = 1.757 gm/cc

9-7 #18" C. ref

Nom. 1st. Critical = 4$\frac{3}{8}$"
reactivity = -5.37$\cent$

$\frac{1}{32}$" fuel value = 38.36$\cent$ / 1.2275$\cent$/mil

1st. of fuel 9-7 : 4.387 - .387 - .386 - .387 - .387 - .387 = 4.3868

A 5.877 - .875 - .875 - .880 = 5.8767
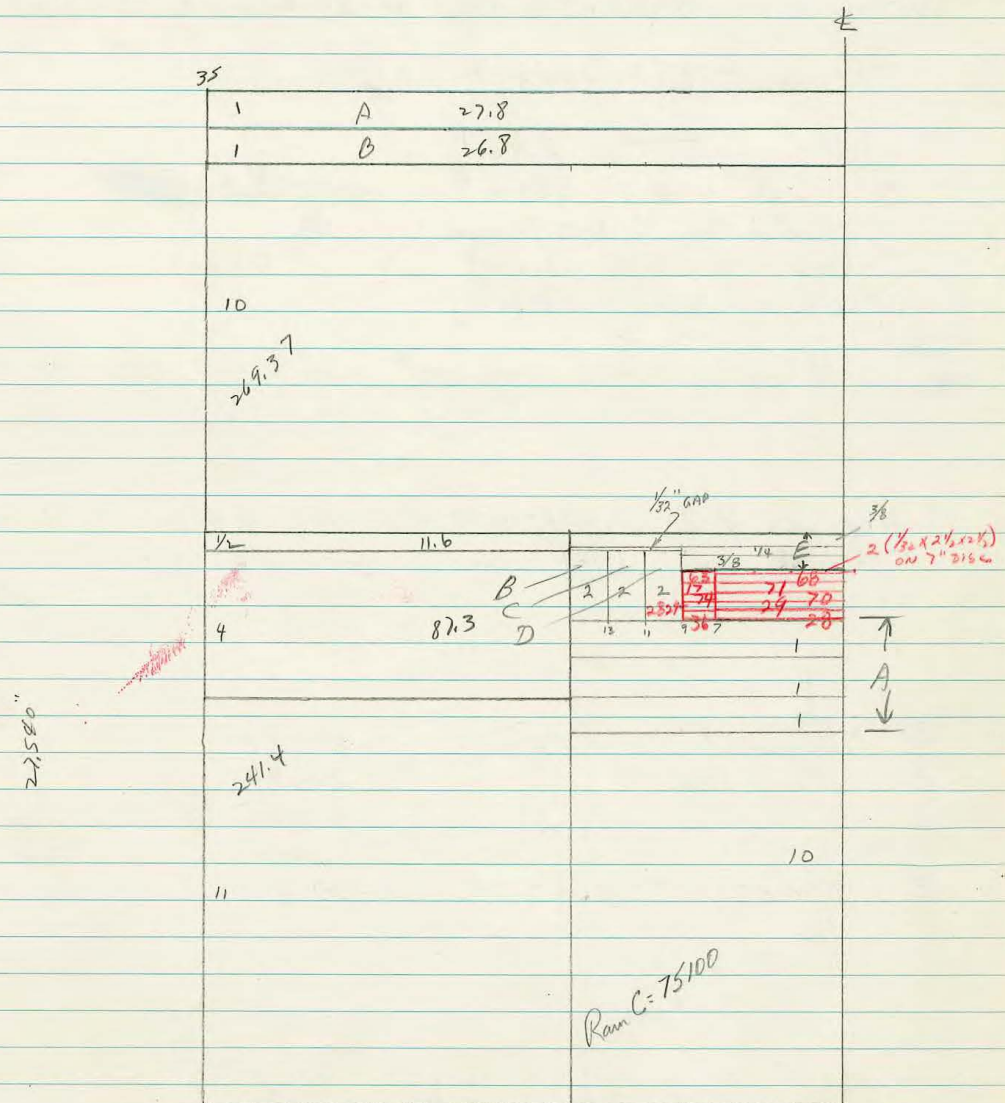B 8.003 - .005 - .000 - 7.998 = 8.0015
C 6.508 - .510 - .508 - .511 = 6.5092
D 6.502 - .500 - .503 - .500 = 6.5012
E 6.497 - 6.501 - 6.499 - 6.496 = 6.4982

$\frac{4.386\cent}{4.39}$

35

| 1 | A | 27.8 |
| 1 | B | 26.8 |

10

269.37

1/32" GAP

3/8

1/2   11.6

3/8   1/4   E   2 (1/32 x 2½ x 2½)
                        ON 7" DISC

B   2 2 2   71 68
C   29 70
87.3   D   13 11 9 5 6 7   28

4

27.580"

241.4

10

11

Ram C = 75100

A

MASS OF FUEL = 27067 + 120 = 27187 gm

$\quad$ VOL = 1452.670 + 6.4121 = 1459.0291 cm^3

$\quad\quad \rho = 18.6336$ gm/cc

AVG OD = 8.99673"

$\quad$ (OD)^2 = 80.94115

MASS of C = 739.370 Kg

$\quad$ VOL = 432746 cm^3

$\quad\quad \rho = 1.708$ gm/cc

AVG Refl = 13.013"

9" dia cyl #13 r/f.

Nom Ht critical = 9-7 ring @ $1\frac{13}{32}$"   NOTE: GAP $\left(\frac{1}{32}"\right)$ over 15-9 Carbon
                7" disc @ $1\frac{2}{32}$" + 2 $\left(\frac{1}{32} \times 2\frac{1}{2} \times 2\frac{1}{2}\right)$ pieces

reactivity = +19.35¢

all supports = 2.96¢
$\frac{1}{32}$" fuel 11-9 = 39.46¢   1.2627 ¢/mil ~~¢/mil~~
    7" dia $\frac{1}{32}$" = Not Meas.   ↑
#1 $\left(\frac{1}{32}" \times 2\frac{1}{2}" \times 2\frac{1}{2}"\right)$ = 20.49¢   O|C
#2 $\left(\frac{1}{32} \times 2\frac{1}{2} \times 2\frac{1}{2}\right)$ = 18.36¢

7" dia $\frac{1}{8}$" gap over 15-9 C = 26.03¢   .208

Wt of fuel 9-7 = 1.414-.414-.415-.414-.415-.415-.415-.415 = 1.4146"
          7" dia = 1.381-.381-.381-.382-.382-.381   -1.3813
                                                    w t avg = 1.3944"
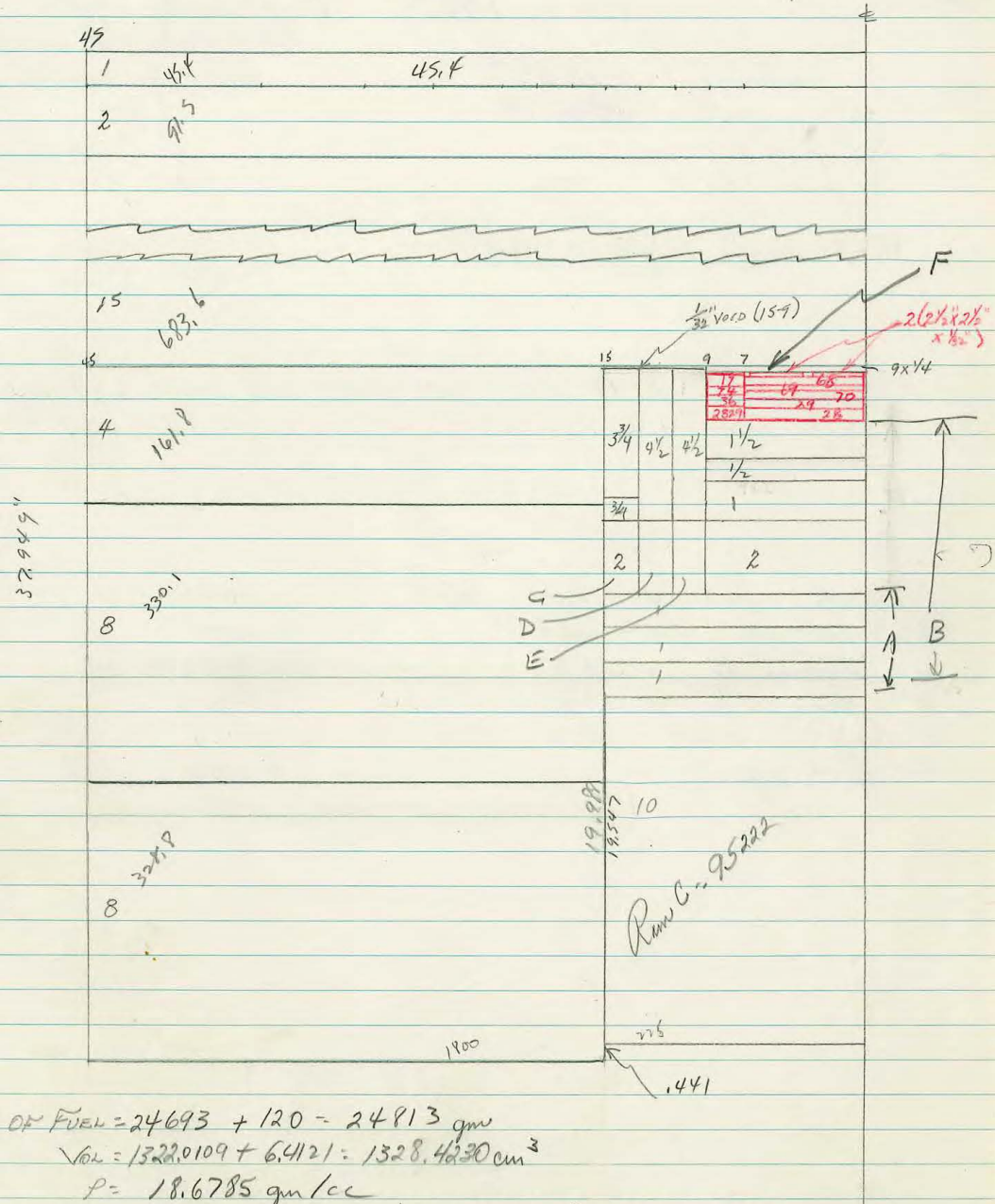

A = Same "A" 4-144   = 3.0042
B = Look Up   = 2.0043
C =   "   "   = 2.0020
D =   "   "   = 2.0000
E = 1.006-.007-.004-.005 = 1.0055

MASS OF FUEL = 24693 + 120 = 24813 gm
   VOL = 1322.0109 + 6.4121 = 1328.4230 cm³
   ρ = 18.6785 gm/cc
MASS OF GRAPHITE = 1736.422 Kg ; Vol = 987727 cm³   ρ = 1.757
   AVG OD of FUEL = 8.99683"
   (OD)² = 80.94295

Avg Refl = 18.004"

9" dia cyl (solid) & 18" C ref.

Nom. Ht. critical   7" dia = 1¼" + 2 (2½" x 2½" x 1/32")
             9-7 = 1 9/32"   (ref. exas top = ¼"
                         & voil over 7" dia as shown)
   reactivity = +11.57¢   also ± ½" exas on bottom (45-15)
   all supports = est. @ 14
   1/32" fuel 9-7 = ___   ↑ see pg 134
   1/32" fuel 7 dia = ___

1 (2½ x 2½ x 1/32) on 7" dia = 14.98¢

Ht of fuel 9-7 = 1.288 - .288 - .288 - .288 - .287 - .288 - .289 - .288 = 1.2880
        7 dia = 1.257 - .257 - .256 - .257 - .257 - .257 - .256 = 1.2567
                                    w† avg = 1.2690

A = 3.005 - .004 - .004 - .000 - .3008   = 3.0042"
B = 8.010 - .010 - .008 - .008 -   = 8.0090
C = Same "B" 4 - 128   = 6.5202
D = Same as "E" 4 - 128   = 6.5022
E = 6.497 - 6.500 - .502 - .580   = 6.4997
F = Look Up   = 0.2500

Top dimensions: 3.464 32.83 13.64 12.55 1060   1.625 2.467

3/4 ... 1/2 1/4   Vol = 8118 cm³

3"   2 54.   29   25   21 19 17 15 13 11 9

10   269.37

12.9430"

C D E   F

9 × 8/32

V + F = 5443 cm³

1/2	11.6 Kg
1	22.3
2	44.4
4	87.3

2 2 2   15 36 37

3/4   38

3¾ 4½ 4½   41   40

13 11 9 7

30.591 4½.309 cm³

11 2411.4   10   Raw C = 837.05

A   B

MASS OF C = 827.993 Kg
Vol = 484584 cm³
ρ = 1.707 gm/cc
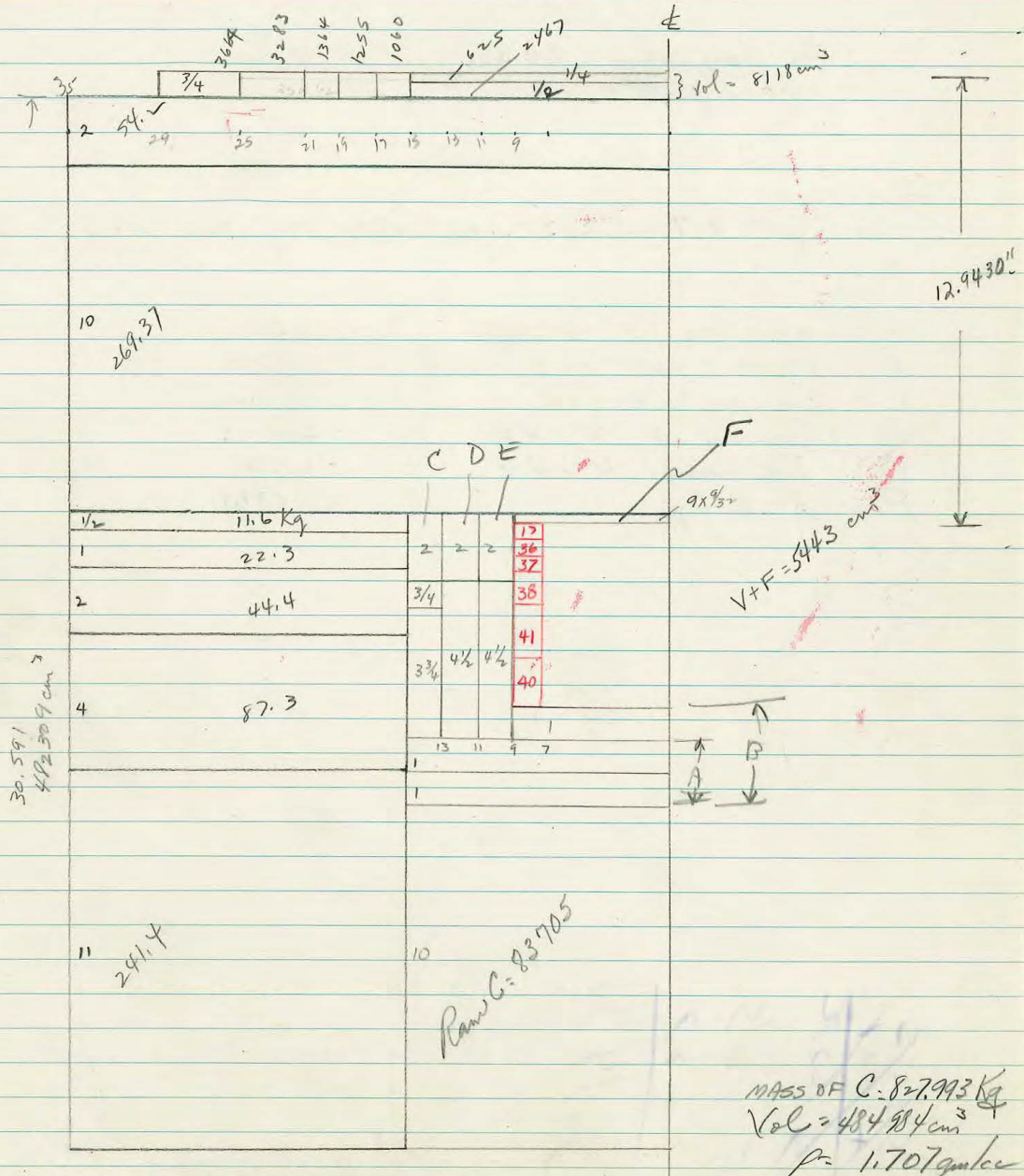
MASS OF FUEL = 40244 gm
Vol = 2145.2837 cm³
ρ = 18.7592 gm/cc

Avg OD = 8.99638"   Avg ID = 7.00255"   Avg REFL = 12.976"
(OD)² = 80.93485   (ID)² = 49.03570

A-228

9-7 Ring only & 13" ref.
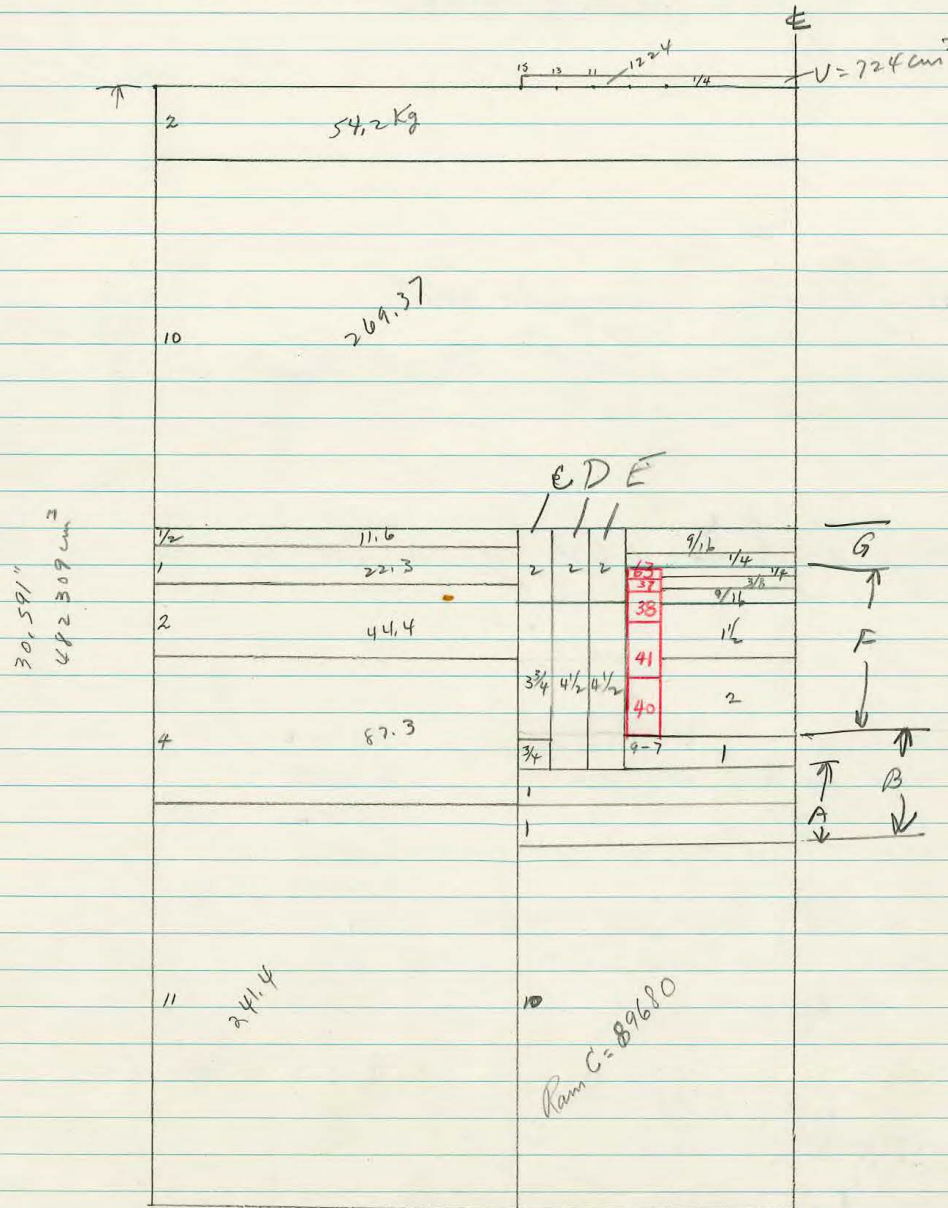
"Clean" Nom. Critical Ht. = $5\frac{7}{32}$"
         reactivity = +26.51¢

    $\frac{1}{32}$" fuel value = 26.95¢   ✓ .8624 ¢/mil
    all supports = 2.55¢

fuel Ht 9-7 = 5.225 – .225 – .225 – .226 – .226 – .225 = 5.2253

A = Same as "A" 4-128   = 2.0022"
B = 3.003 – .004 – .003 – .004   = 3.0035
C = Same as "C" 4-144   = 6.5202
D = Same as D 4-144   = 6.5022
E = Same as E 4-144   = 6.4997
F = Look up   = 0.2790

MASS OF FUEL = 36135 gm

    VOL = 1927.4673 cm³

    ρ = 18.7473 gm/cc

    OD fuel = 8.99624"   (²)= 80.93233

    ID fuel = 7.00268   (²)= 49.03752

Mass of C = 821.474 Kg

    Vol = 481106 cm³

    ρ = 1.707 gm/cc

    AVG REFL = 13.013"

A-230

9-7 Ring only & 13" ref + Core

"Clean" Nom. Ht. Critical = 4"/16"
                    reactivity: - 2.82¢

              gap
51 mil∧(9"dia) "/16 above fuel = 9.01¢
∴ 13 mil void = 2.3¢
∴ 1/32" fuel = 23.36¢   √ 0.7475¢/mil
all supports = 2.22¢

Wt of 9-7 fuel = 4.695 -.695 -.696 -.695 -.697 -.695 -.695 = 4.6954

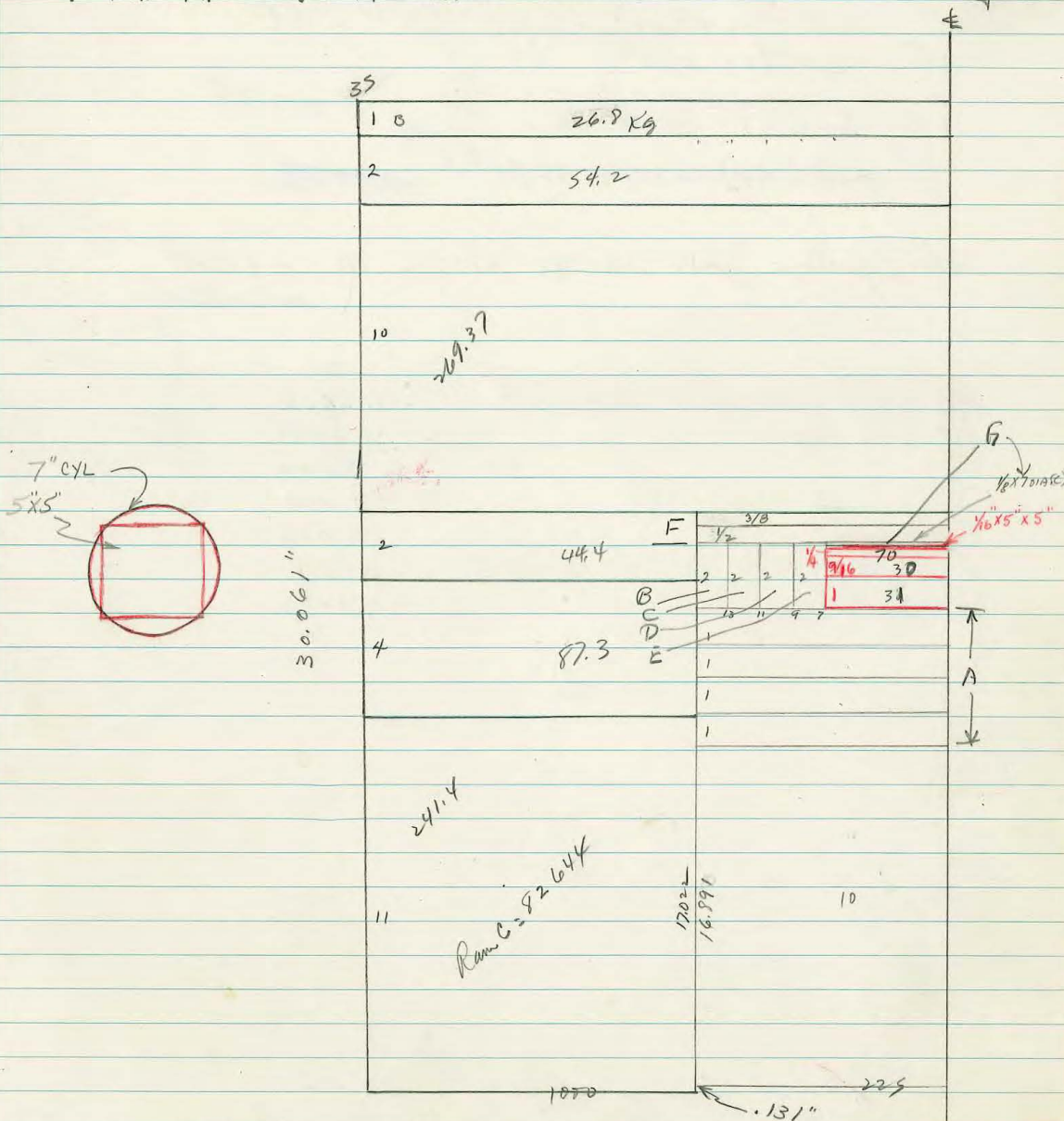A = Same as "A" 4-122   = 2.0022"
B = Same as "B" 4-122   = 3.0035
C =   Same   "   = 6.5202
D =   "   "   = 6.5022
E =   "   "   = 6.4997
F = 4.694 -.692 -.694 -.693   = 4.6932
G = 0.815 -.813 -.813 -.814   = 0.8137

4.6957
+ 4.702"

Diagram annotations:

35

1	0	26.8 Kg
2		54.2
10		-69.37

7" CYL
5"X5"

30.061"

| 2 | 44.4 | F | 3/8 |
| 4 | 87.3 | | 1/2 |

B
C
D
E

G
1/8"X 70(ASC)
1/16"X5"X5"

1/4	70
9/16	30
1	31

A

241.4

Raw C = 82644

11

170.22
16.991

10

1080   225

.131"

MASS OF FUEL = 21442 + 477 gm = 21919 gm
   VOL = 1144.2859 + 25.6049 = 1169.8908 cm³
   ρ = 18.7359 gm/cc
Avg. OD = 6.99623"
   (OD)² = 48.94729

Mass of C = 806.114 Kg
   Vol = 472783 cm³
   ρ = 1.705 gm/cc

Avg. Refl = 14.008"

7" dia cyl & 14" ref.

Nom. Ht. Critical = 7" dia = $1\frac{13}{16}$ + 1 ($\frac{1}{16} \times 5 \times 5$)
　　　　reactivity = +8.66¢
all supports = 1.88¢

1 ($\frac{1}{32} \times 2\frac{1}{2} \times 2\frac{1}{2}$) = 20.64¢　　　　　　　4.07¢

　　factor (1.54)(20.64) = 31.79¢ × 4　~~.0112/mil~~

ht. of fuel = 1.816 - .816 - .817 - .817 - .816 - .8165 = 1.8164
　　　　　　　　　　　　　　　　　　　　　　　　not mil 5×5

A = 4.008 - .006 - .007 - .006 - .006　　　= 4.0066"
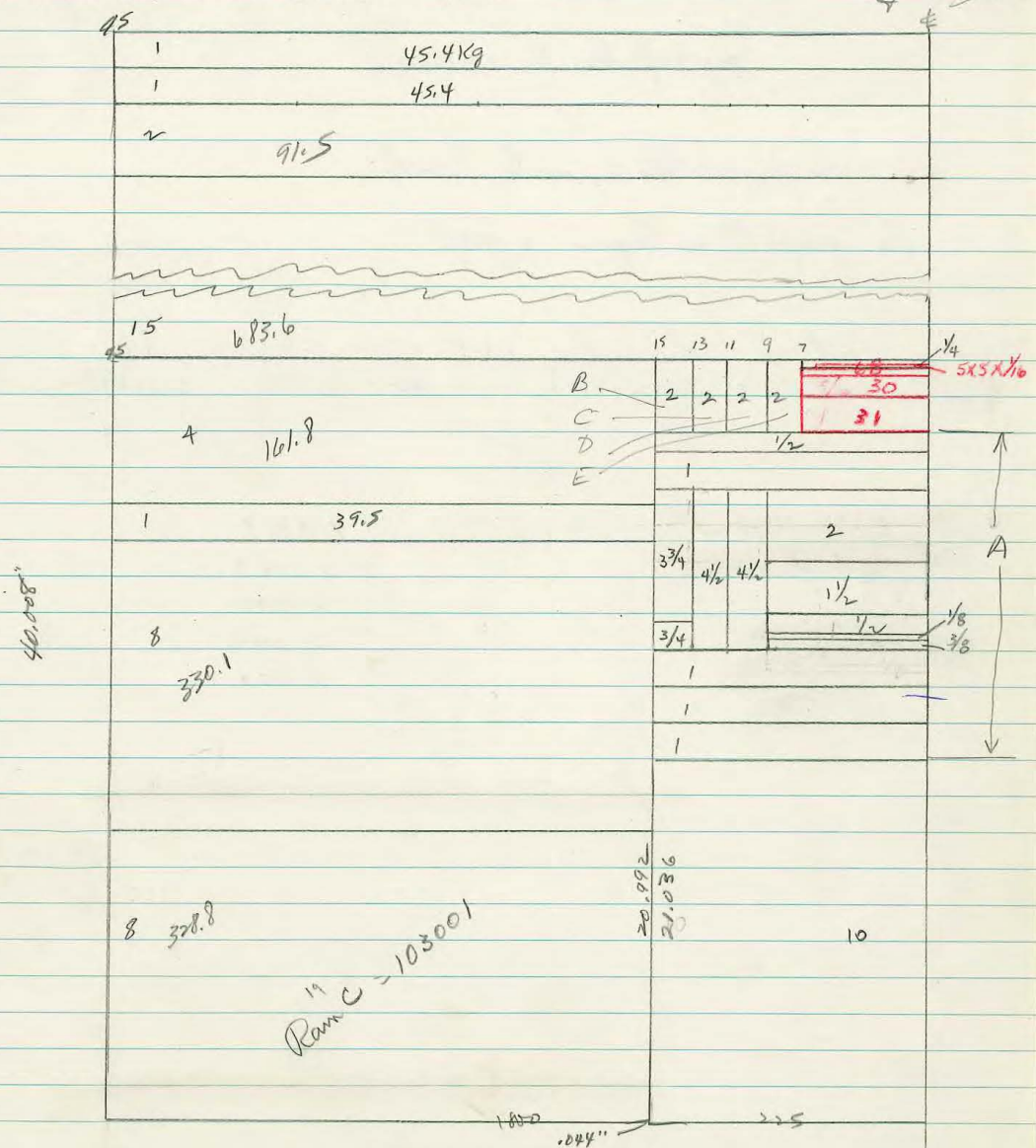B = Look Up　　　　　　　　　　　　　　　= 2.0043
C = 　"　 "　　　　　　　　　　　　　　　= 2.0020
D = 　"　 "　　　　　　　　　　　　　　　= 2.0000
E = 　"　 "　　　　　　　　　　　　　　　= 2.0000
F = 0.881 - .880 - .880 - .878 - .880　　= 0.8798
G = Look Up　　　　　　　　　　　　　　= 0.1250

146?

MASS OF FUEL = $19968 + 477 = 20445$ gm

VOL = $1067.9630 + 25.6049 = 1093.5679$ cm^3

$\rho = 18.6956$ gm/cc

MASS OF GRAPHITE: 1829.101 kg ; Vol = 1041625 cm^3 ; $\rho = 1.756$ gm/cc

AVG (OD) FUEL = 6.99633"

$(OD)^2 = 48.94867$

A-234

9-7 Ring only & 13" ref.

"Clean" Nom. Critical Ht. = 5⁷⁄₃₂"
        reactivity = +26.51¢

  ¹⁄₃₂" fuel value = 26.95¢   ✓ .8624 ¢/mil
  all supports = 2.55¢

fuel Ht 9-7 = 5.225 -.225 -.225 -.226 -.226 -.225 = 5.2253

A = Same as "A" 4-128   = 2.0022"
B = 3.003 -.004 -.003 -.004 = 3.0035
C = Same as "C" 4-144   = 6.5202
D = Same as D 4-144   = 6.5022
E = Same as E 4-144   = 6.4997
F = Look hp   = 0.2790

$V = 724 \, cm^3$

2   54.2 Kg

10   269.37

30.591"
482.309 cm³

1/2   11.6
1   221.3
2   44.4
4   87.3

11   241.4

€ D E

2 2 2   9/16   1/4
           37
           38
3¾ 4½ 4½ 41
           40
¾   9-7   1
1
1

Ram C = 89680

G
F
A B

MASS OF FUEL = 36135 gm
   Vol = 1927.4673 cm³
   ρ = 18.7473 gm/cc
OD fuel = 8.99624"   (²) = 80.93233
ID fuel = 7.00268   (²) = 49.03752

Mass of C = 821.474 Kg
   Vol = 481106 cm³
   ρ = 1.707 gm/cc

AVG REFL = 13.013"

9-7 Ring only & 13" ref + Core

"Clean" Nom. Ht. Critical = 4"¹¹⁄₁₆"
                    reactivity = − 2.82$

gap
51 mil (9"dia) ¹¹⁄₁₆" above fuel = 9.01$
∴ 13 mil void = 2.3$
∴ ¹⁄₃₂" fuel = 23.36$ √ 0.7475$/mil
all supports = 2.22$

Ht of 9-7 fuel = 4.695 −.695 −.696 −.695 −.697 −.695 −.695 = 4.6954

A = Same as "A" 4−122   = 2.0022"
B = Same as "B" 4−122   = 3.0035
C =   Same   "   = 6.5202
D =   "   "   = 6.5022
E =   "   "   = 6.4997
F = 4.694 −.692 −.694 −.693   = 4.6932
G = 0.815 −.813 −.813 −.814   = 0.8137

4.695
+ 4.702"

$$\text{MASS OF FUEL} = 21442 + 477 \text{ gm} = 21919 \text{ gm}$$
$$\text{VOL} = 1144.2859 + 25.6049 = 1169.8908 \text{ cm}^3$$
$$\rho = 18.7359 \text{ gm/cc}$$
$$\text{Avg. OD} = 6.99623"$$
$$(\text{OD})^2 = 48.94729$$
$$\text{Avg. Refl} = 14.008"$$

$$\text{Mass of C} = 806.114 \text{ Kg}$$
$$\text{Vol} = 472783 \text{ cm}^3$$
$$\rho = 1.705 \text{ gm/cc}$$

7" dia cyl & 14" ref.

Nom. Ht. Critical = 7" dia = $1\frac{13}{16}$ + 1 ($\frac{1}{16}\times 5 \times 5$)
        reactivity = +8.66¢
    all supports = 1.88¢

1 ($\frac{1}{32}\times 2\frac{1}{2}\times 2\frac{1}{2}$) = 20.64¢   4.07¢
        factor (1.54)(20.64) = 31.79¢ × 4
                                    ~~.0172/mil~~

1 Wt. of fuel = 1.816 -.816 -.817 -.817 -.816 -.8165 = 1.8164
                                                    not mil 5×5

A = 4.008 -.006 -.007 -.006 -.006   = 4.0066"
B = Look Up   = 2.0043
C =   "   "   = 2.0020
D =   "   "   = 2.0000
E =   "   "   = 2.0000
F = 0.881 -.880 -.880 -.878 -.880   = 0.8798
G = Look Up   = 0.1250

Diagram with various annotations:

45
1	45.4 Kg
1	45.4
2	91.5

15   683.6

45

4   161.8

1   39.5

8   330.1

B
C
D
E

15 13 11 9 7   ¼
| 2 | 2 | 2 | 2 | 68 / 30   5×5×½₆
                    31
                    ½
1

2

3¾ 4½ 4½   1½

3/4   ½   ⅛
                    ⅜

1
1
1

40.008"

A

8   328.8

Ram C = 103001

20.992
21.036

1800
.044"

10

225

MASS OF FUEL = 19968 + 477 = 20445 gm
    VOL = 1067.9630 + 25.6049 = 1093.5679 cm³
    ρ = 18.6956 gm/cc
MASS OF GRAPHITE: 1829.101 kg ; VOL = 1041625 cm³ ; ρ = 1.756 gm/cc
    AVG (OD) FUEL = 6.99633"
        (OD)² = 48.94867

A-240

7" dia (solid) & 19" Cₓ ref.

Nom. Ht. Critical = 1⁷/₁₆ + 1 (5×5×¹/₁₆)   reactivity = close only

Top Ref has ¼" excess

all supports = nil (0.06ᵈ)

½" graphite on Top = 3.93ᵈ

Ht. of 7" dia fuel = 1.695 - .195 - .695 - .695 - .696 - .6955 - .695.
/ NOT INCL (5×5)   ← NOTE   = 1.6952 not incl 5×5

A = 9.035 - .027 - .033 - .032   = 9.0317"
B = Look Up   "   "   = 2.0043
C =   "   "   = 2.0020
D =   "   "   = 2.0000
E =   "   "   = 2.0000