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Nuclear Criticality Safety Calculations for a K-25 Site Vacuum Cleaner

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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

K/ER-314

Energy Systems Environmental Restoration Program

Nuclear Criticality Safety Calculations for a K-25 Site Vacuum Cleaner

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Environmental Management Activities at the
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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
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PREFACE

A modified Nilfisk Model GSJ-115 dry vacuum cleaner is used throughout the K-25 Site for cleanup of dry forms of highly enriched uranium (HEU). This report describes the calculations done with the SCALE (KENO V.a) computer code to establish the minimum nuclear critical mass for this vacuum cleaner. This report does not represent a complete nuclear criticality safety evaluation. Such an evaluation, of which this report may be a supporting document, is contained in K-25 Site Nuclear Criticality Safety Evaluations.

This work was performed under Work Breakdown Structure 1.4.12.4.2.01.46 (Activity Sheet 4701).

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ACRONYMS AND ABBREVIATIONS

DR	Deposit removal
HEU	Highly enriched uranium
PVC	Polyvinylchloride
SCALE	Standardized Computer Analysis for Licensing Evaluation

EXECUTIVE SUMMARY

A modified Nilfisk model GSJ dry vacuum cleaner is used throughout the K-25 Site to collect dry forms of highly enriched uranium (HEU). When vacuuming, solids are collected in a cyclone-type separator vacuum cleaner body. The cyclone drops particulates into a receptacle (a deposit bottle) that is screwed onto the bottom of the cyclone separator. Exhaust air from the portable vacuum cleaner is subjected to a three-stage filtration system—a prefilter and two cylindrical HEPA filters. As necessary, the receptacle and vacuum cleaner cyclone are disconnected for cleaning, and the product removed and sent to storage.

Calculations were done with the SCALE (KENO V.a) computer code to establish conditions at which a nuclear criticality event might occur if the vacuum cleaner was filled with fissile solution. Conditions evaluated included full (12-in. water) reflection and nominal (1-in. water) reflection, and full (100%) and 20% ^{235}U enrichment. Validation analyses of SCALE/KENO and the SCALE 27-group cross sections for nuclear criticality safety applications indicate that a calculated $k_{eff} + 2\sigma < 0.9605$ may be considered safely subcritical. Thus, a system with a calculated $k_{eff} + 2\sigma \geq 0.9605$ is considered unsafe and may be critical. The upper-bound uranium-fissile mass was calculated with an additional factor of safety of 0.01 corresponding to an acceptable criterium of $k_{eff} + 2\sigma < 0.95$.

Critical conditions were calculated to be 70 g U/L for 100% ^{235}U and full 12-in. water reflection. This corresponds to a minimum critical mass of approximately 1400 g ^{235}U for the approximate 20.0-L volume of the vacuum cleaner. The actual volume of the vacuum cleaner is smaller than the modeled volume because some internal materials of construction were assumed to be fissile solution. The model was an overestimate, for conservatism, of fissile solution occupancy. At nominal (1-in. water) reflection conditions, the critical concentration in a vacuum cleaner full of UO_2F_2 solution was calculated to be 100 g ^{235}U/L, or 2000 g mass of 100% ^{235}U. At 20% ^{235}U enrichment, full 12-in. water reflection and baseline materials, critical conditions were calculated to be 700 g total U/L. This corresponds to a minimum critical mass of 2800 g ^{235}U for the 20.0-L volume of the vacuum cleaner. At 15% ^{235}U enrichment and full reflection, critical conditions were not reached at any possible

concentration of uranium as a uranyl fluoride solution. At 17.5% ^{235}U enrichment, criticality was reached at approximately 1300 g U/L which is beyond saturation at 25 °C.

The vacuum cleaner geometry is well known and was accurately, though conservatively, modeled. The distribution of the materials of composition in the vacuum cleaner motor is not as well known so sensitivity studies were performed. These sensitivity studies showed that the material of composition has, at most, a 0.17% effect on *k*-effective at 12-in. water reflection and 70 g ^{235} U/L, well within 2σ variation. Results are summarized in Table Es.1. Calculations were performed to determine the concentrations at which criticality is possible at 12-in. water reflections and base-case assumptions. These results are shown in Fig. Es. 1.

Table Es. 1. Calculations at critical conditions for 100% enrichment

Motor parts									Concentration	Reflection
Baseline, Case 1 (100% iron)			Case 2 (100% copper)			Case 3 (50% copper/50% iron)				
k_{eff}	2σ	$k_{eff} + 2\sigma$	k_{eff}	2σ	$k_{eff} + 2\sigma$	k_{eff}	2σ	$k_{eff} + 2\sigma$		
0.9314	0.0094	0.9408	0.9310	0.011	0.942	0.9294	0.0096	0.9386	70 g U/L	12 in.
0.9332	0.0108	0.944	0.9176	0.0116	0.9292	0.9176	0.0112	0.9288	100 g U/L	1 in.

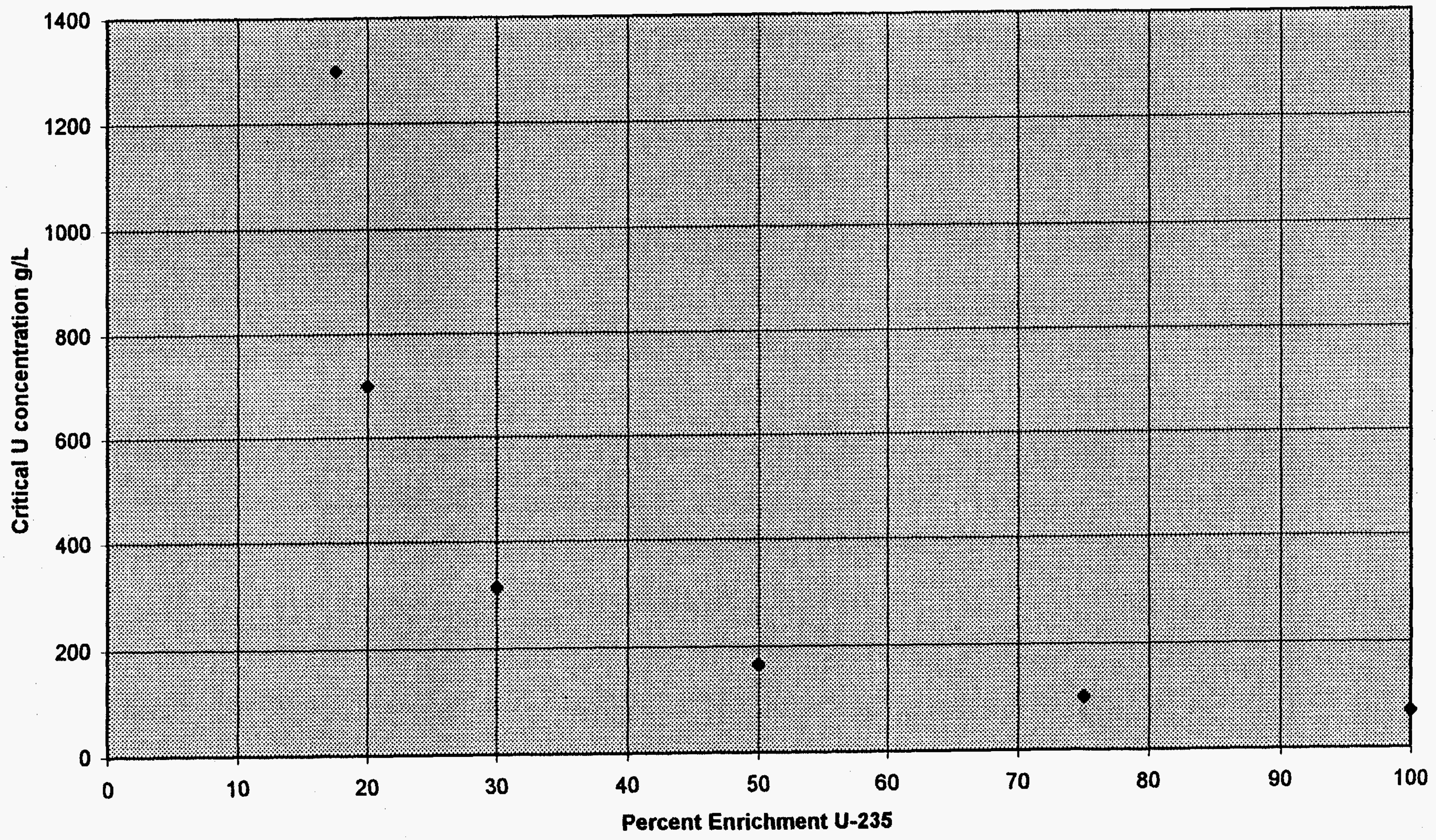

Fig. Es. 1. Critical uranium concentrations as a function of enrichment for baseline materials, Case 1, 12-in. water reflection.

1. INTRODUCTION

A modified Nilfisk model GSJ dry vacuum cleaner is used throughout the K-25 Site for cleanup of dry forms of highly enriched uranium (HEU). Figure 1 presents a photograph of the vacuum cleaner mounted on a trolley; the vacuum cleaner might also be mounted in a fixed geometry, such as in a glove box. Figure 2 gives important dimensions of the trolley-mounted vacuum cleaner. Vacuum cleaner motors were purchased from Nilfisk of America, Inc., and attached to a vacuum cleaner body fabricated by Machine Kinetics Corp. of Knoxville, Tennessee, to K-25 Site specifications. When vacuuming, solids are collected in a cyclone-type separator, the body. The cyclone drops particulates consisting of uranium and other materials into a deposit bottle that is screwed onto the bottom of the cyclone separator. Exhaust air from the portable vacuum cleaner is subjected to a three-stage filtration system: a prefilter and two cylindrical HEPA filters. As necessary, the deposit bottle and vacuum cleaner cyclone are disconnected for cleaning, and the product removed and sent to storage.

This report describes calculations done with the SCALE (KENO V.a)[1] computer code to establish conditions for a nuclear criticality event. Nuclear criticality conditions were calculated with full (12-in. water) reflection and nominal (1-in. water) reflection and for full (100%) and 20% ^{235}U enrichment with full reflection. An iterative approach was used to establish the uranium mass at critical conditions. Collection of liquids with the vacuum cleaner is prohibited. However, assuming the vacuum cleaner is full of liquid, calculations were begun at low concentrations of uranium in solution, and then, the concentration increased until critical conditions were reached. The mass of uranium in the vacuum cleaner was then calculated by multiplying the highest concentration with $k_{eff} + 2\sigma < 0.95$, by the vacuum cleaner volume.

This vacuum cleaner is used throughout the K-25 Site for collecting dry forms of compounds of uranium in the powder form or small chunks. Thus, a nuclear criticality safety analysis is required for each use. *This report presents a calculational criticality analysis of the vacuum cleaner. It does not represent a complete criticality safety evaluation and does not constitute nuclear criticality safety approval for operation.* However, this report may be

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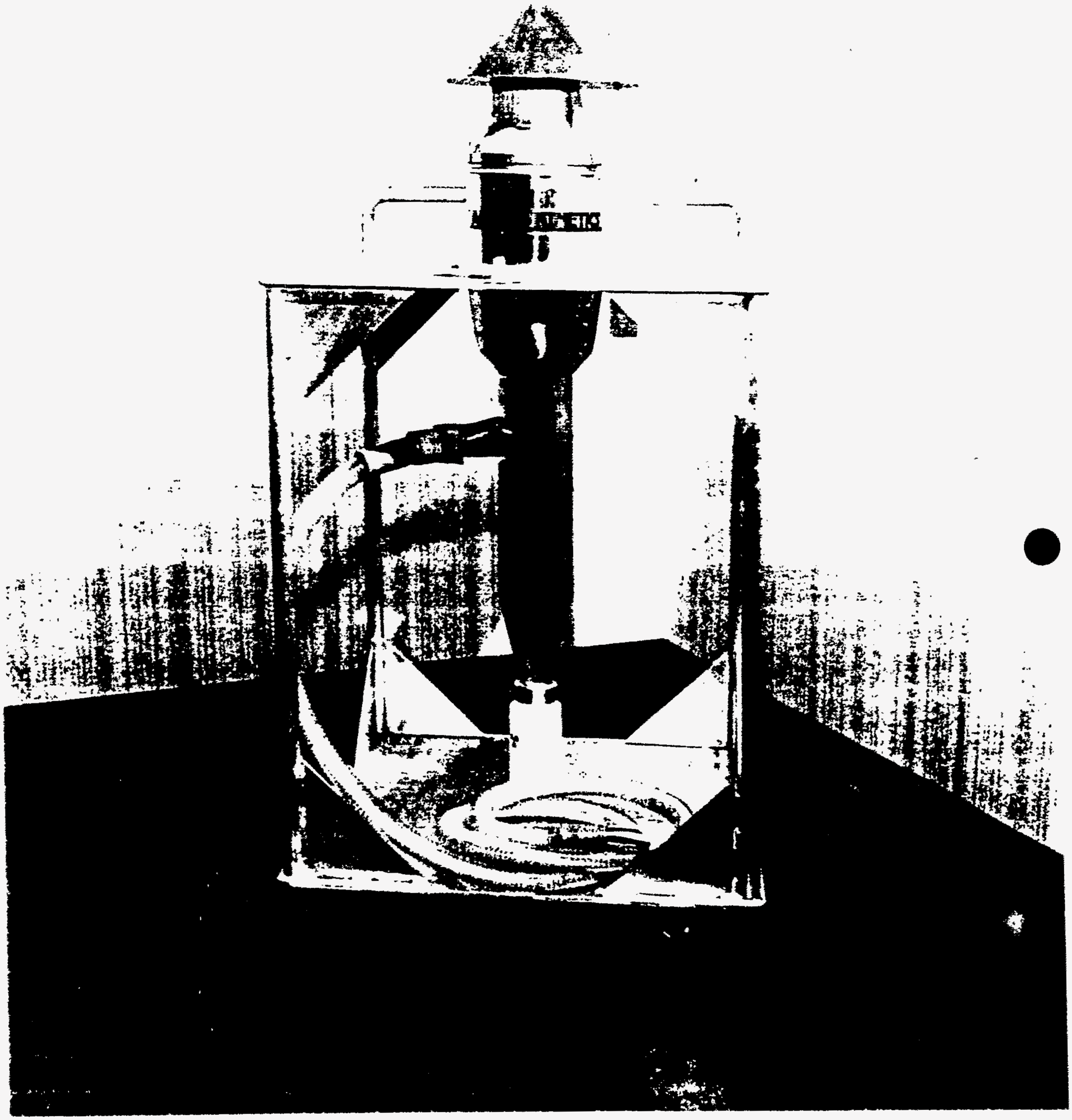


Fig 1. K-25 Site portable dry HEU vacuum cleaner.

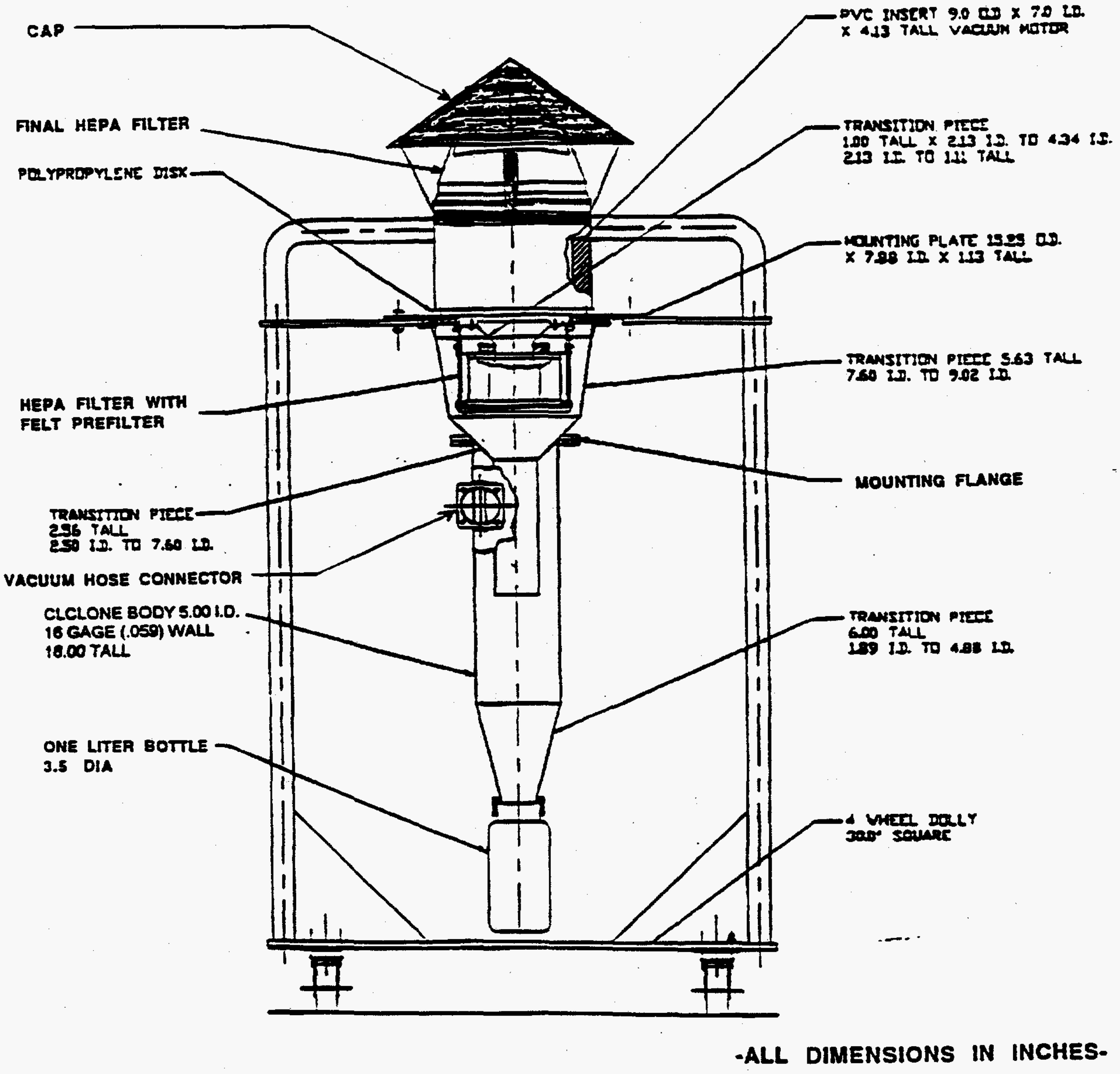


Fig 2. Schematic of K-25 Site portable dry vacuum cleaner.

used to support a complete evaluation. Such an evaluation, and conditions of approval for operation, are given in K-25 Site Nuclear Criticality Safety Approvals. This report gives calculated reactivity or neutron multiplication factors of the vacuum cleaner for specific conditions of uranium loading (mass), ^{235}U enrichment, moderation levels, and reflection. No attempt is made to specify the safe enrichment or conditions of operations (and related control parameters) for the system.

2. VACUUM CLEANER DESCRIPTION

A modified Nilfisk model GSJ dry vacuum cleaner is used to clean up dry forms of highly enriched uranium (HEU) at the K-25 Site. Figure 1 presents a photograph of the portable vacuum cleaner. The body (a cyclone-type separator) of the vacuum cleaner was fabricated by Machine Kinetics Corp. of Knoxville, Tennessee, to K-25 Site specifications. The body is attached to a motor, model number GSJ-115, purchased from Nilfisk of America, Inc. K-25 Site drawings M1E703045 A021 through A027 give complete dimensions and a description for the fixed vacuum cleaner used in the Deposit Removal (DR) Program's DR Room glove box. The body of the portable and fixed vacuum cleaners are identical. Figure 2 gives important general dimensions.

2.1 VACUUM CLEANER BODY

The vacuum cleaner uses a standard approximately 1.5-in.-diam dry vacuum hose and optional attachments. Solids are collected in a cyclone-type separator which is primarily a cylinder 5.0 in. outside diam. Figure 3 shows detailed dimensions of the cyclone separator. The material of construction is 304 stainless steel (SS). The cyclone drops particulates into a deposit bottle that is screwed into the bottom of the cyclone. The 1-L polypropylene deposit bottle dimensions are approximately 3.5 in. diam and 8 in. high. The vacuum cleaner hose mounts at the side of the cylindrical vacuum cleaner body so that the tangential inlet air creates a centrifugal, cyclone effect. Gravity causes the collected particulates to drop into the deposit bottle at the bottom.

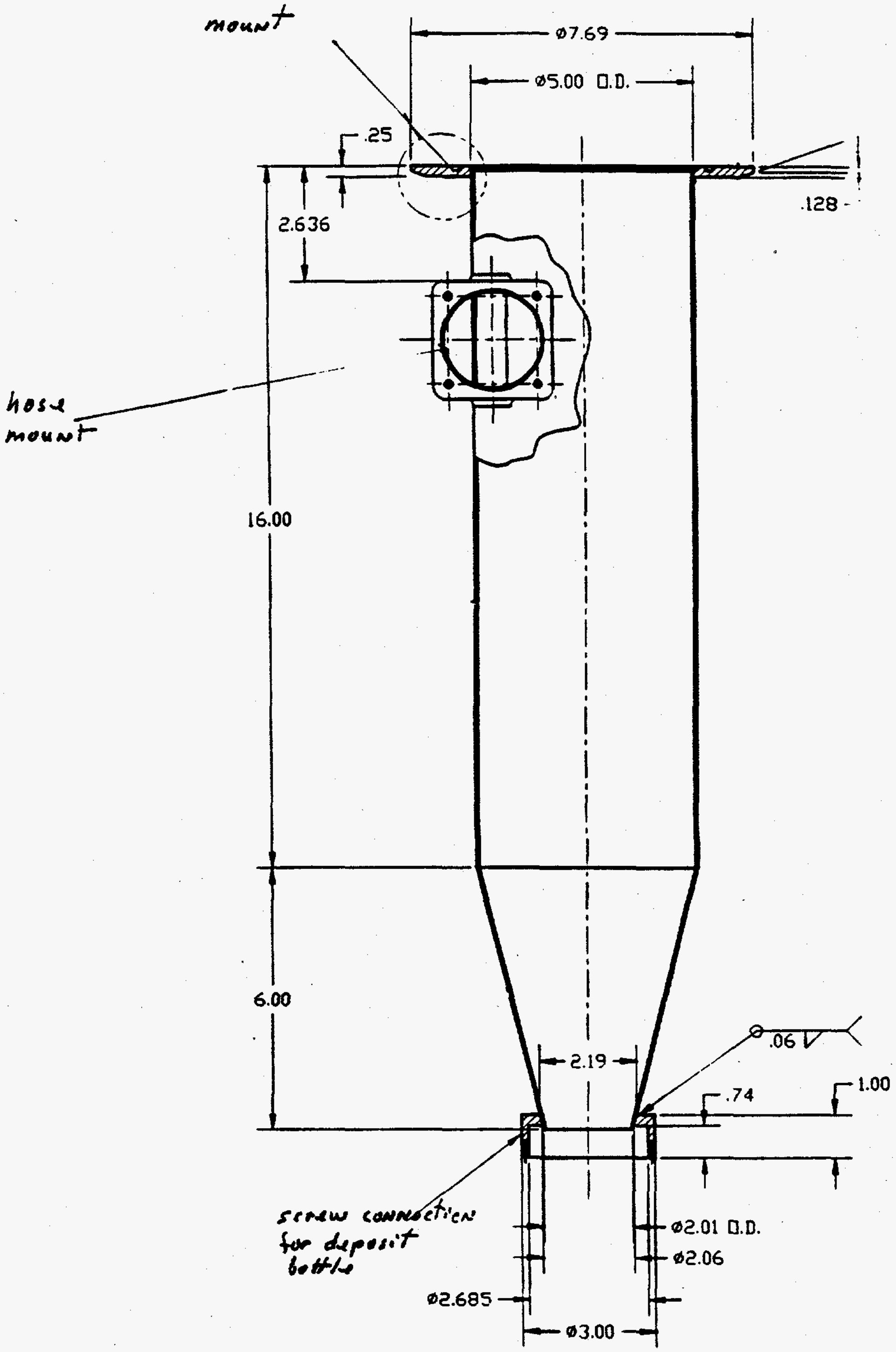


Fig. 3. Cyclone body.

The cyclone inner body is fixed atop the cyclone body by placing the mounting flange shown in Fig. 4 onto the mount shown in Fig. 3. Note that the vacuum cleaner inlet (downcomer) is below the hose inlet to keep from sucking dust and particulates directly onto the system filters. The cyclone body is removable from the inner body which facilitates cleaning the interior metal surfaces.

The filter retainer (see Fig. 5) is mounted on top of the cyclone inner body. A cylindrical HEPA filter, purchased from Nilfisk, slides inside the filter retainer. The HEPA filter is approximately 5-1/2 in. diam and 3 in. high with a filter area of 3721 cm^2. A Nilfisk microfilter, felt "sock" prefilter surrounds the HEPA filter. This prefilter typically retains 99.97% (ref. 2) of all particles down to 2 μm size, protecting the motor and filtering out many respirable particles.

The air funnel to the vacuum cleaner (shown in Fig. 6) attaches to the base plate and directs air into the vacuum cleaner motor. The vacuum cleaner motor and surrounding casing are mounted to the base plate.

2.2 VACUUM CLEANER MOTOR

The vacuum cleaner motor is Nilfisk model number GSJ-115. Tables 1 and 2 were supplied by Nilfisk of American, Inc.,[3] which gives the motor features and an exploded view of various parts. In Table 2, the motor top and casing is primarily plastic; the fan is primarily aluminum; the motor is primarily aluminum with some steel; and the armature and field coil are primarily copper and steel. Nilfisk staff supplied the following weights:

armature	1.25 lbs	copper and steel
field coil	2 lbs	copper and steel
fan assembly	1.25 lbs	aluminum
motor assembly	2.25 lbs	aluminum and steel

ORNL staff weighed the motor to be 8.25 lbs total. The difference between this total weight and the weights supplied by Nilfisk staff is taken as the weight of the plastic casing. The plastic casing was modeled as UO_2F_2 solution for conservatism. This baseline analysis

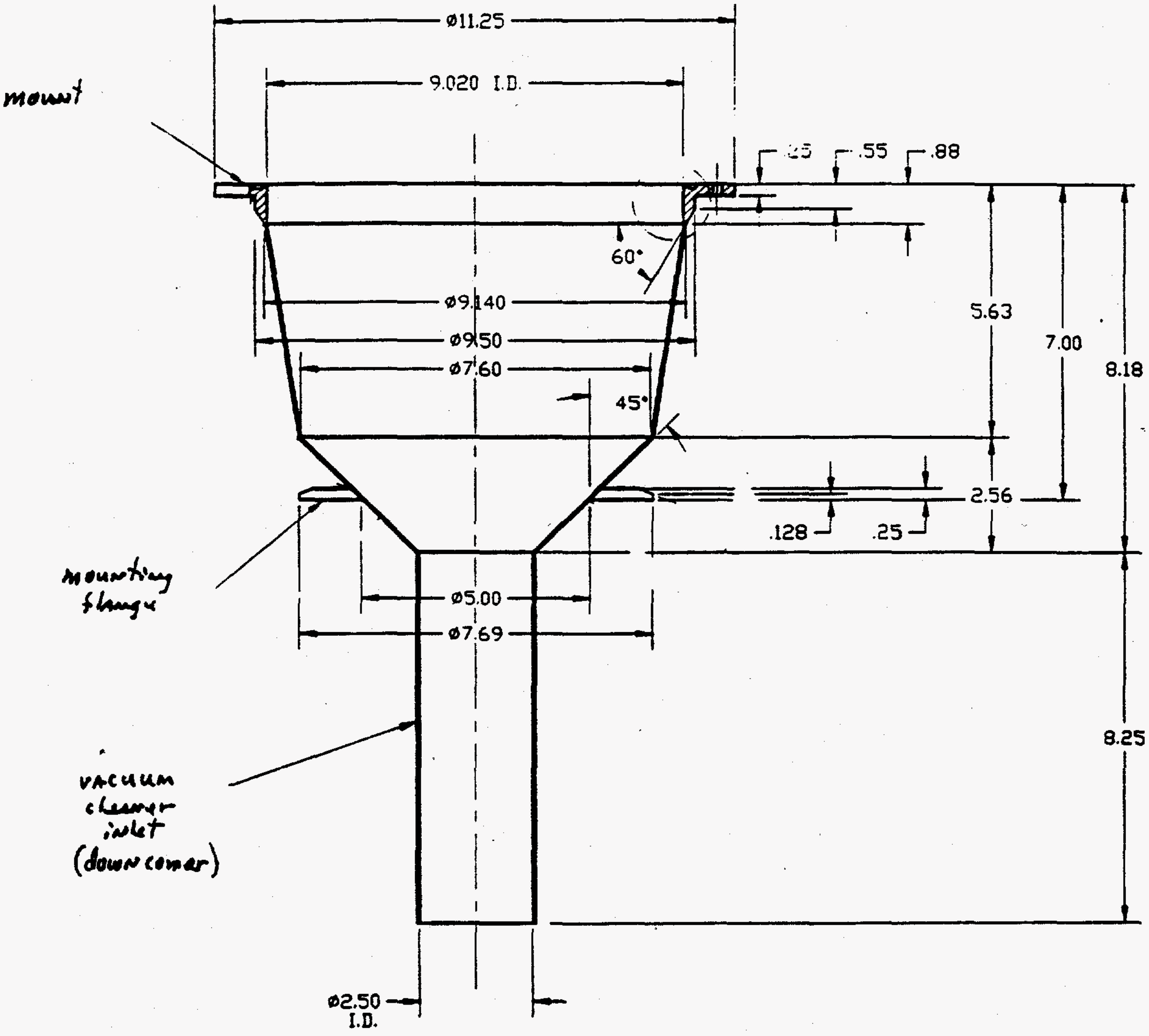


Fig. 4. Cyclone inner body.

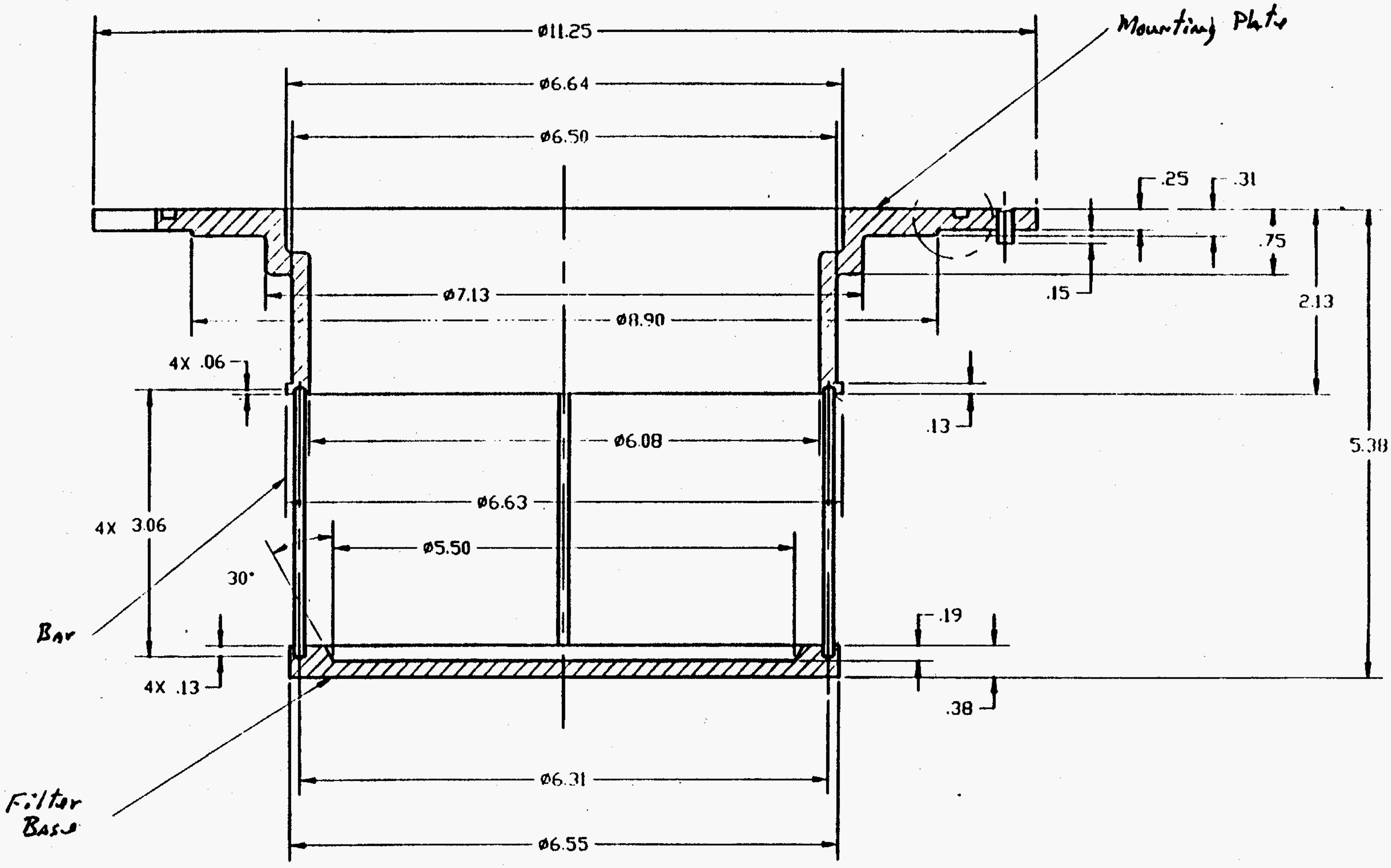


Fig. 5. Filter retainer.

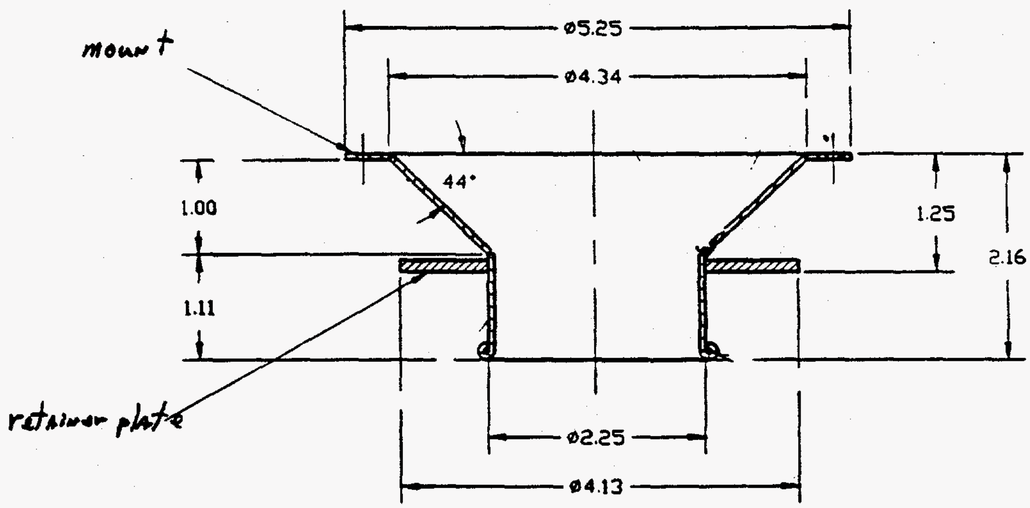
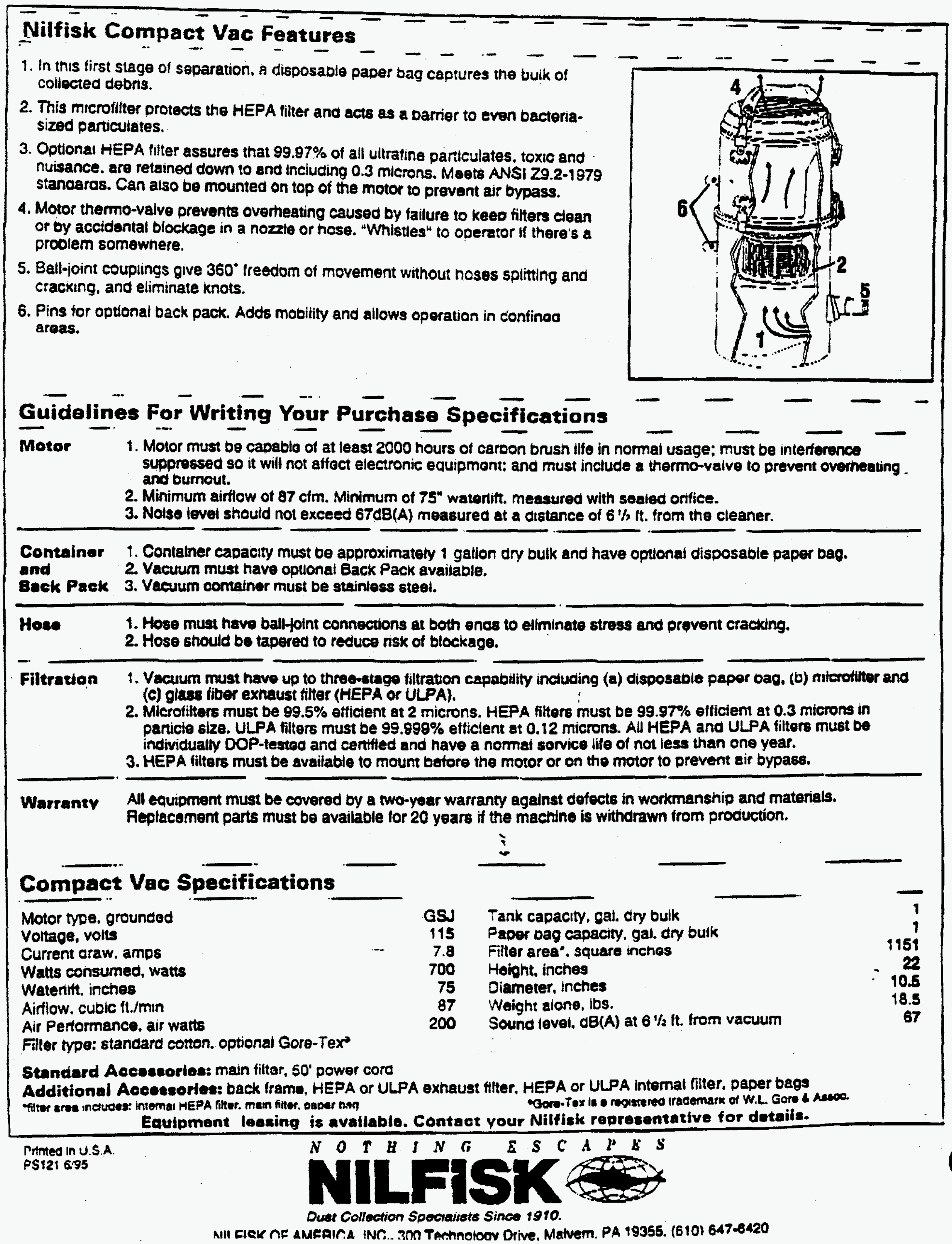


Fig. 6. Vacuum cleaner funnel.

Table 1. Motor features and specifications



Nilfisk Compact Vac Features

1. In this first stage of separation, a disposable paper bag captures the bulk of collected debris.
2. This microfilter protects the HEPA filter and acts as a barrier to even bacteria-sized particulates.
3. Optional HEPA filter assures that 99.97% of all ultrafine particulates, toxic and nuisance, are retained down to and including 0.3 microns. Meets ANSI Z9.2-1979 standards. Can also be mounted on top of the motor to prevent air bypass.
4. Motor thermo-valve prevents overheating caused by failure to keep filters clean or by accidental blockage in a nozzle or hose. "Whistles" to operator if there's a problem somewhere.
5. Ball-joint couplings give 360° freedom of movement without hoses splitting and cracking, and eliminate knots.
6. Pins for optional back pack. Adds mobility and allows operation in confined areas.

Guidelines For Writing Your Purchase Specifications

Motor
1. Motor must be capable of at least 2000 hours of carbon brush life in normal usage; must be interference suppressed so it will not affect electronic equipment; and must include a thermo-valve to prevent overheating and burnout.
2. Minimum airflow of 87 cfm. Minimum of 75" waterlift, measured with sealed orifice.
3. Noise level should not exceed 67dB(A) measured at a distance of 6 ½ ft. from the cleaner.

Container and Back Pack
1. Container capacity must be approximately 1 gallon dry bulk and have optional disposable paper bag.
2. Vacuum must have optional Back Pack available.
3. Vacuum container must be stainless steel.

Hose
1. Hose must have ball-joint connections at both ends to eliminate stress and prevent cracking.
2. Hose should be tapered to reduce risk of blockage.

Filtration
1. Vacuum must have up to three-stage filtration capability including (a) disposable paper bag, (b) microfilter and (c) glass fiber exhaust filter (HEPA or ULPA).
2. Microfilters must be 99.5% efficient at 2 microns. HEPA filters must be 99.97% efficient at 0.3 microns in particle size. ULPA filters must be 99.999% efficient at 0.12 microns. All HEPA and ULPA filters must be individually DOP-tested and certified and have a normal service life of not less than one year.
3. HEPA filters must be available to mount before the motor or on the motor to prevent air bypass.

Warranty
All equipment must be covered by a two-year warranty against defects in workmanship and materials. Replacement parts must be available for 20 years if the machine is withdrawn from production.

Compact Vac Specifications

Motor type, grounded	GSJ	Tank capacity, gal. dry bulk	1
Voltage, volts	115	Paper bag capacity, gal. dry bulk	1
Current draw, amps	7.8	Filter area*, square inches	1151
Watts consumed, watts	700	Height, inches	22
Waterlift, inches	75	Diameter, inches	10.5
Airflow, cubic ft./min	87	Weight alone, lbs.	18.5
Air Performance, air watts	200	Sound level, dB(A) at 6 ½ ft. from vacuum	67

Filter type: standard cotton, optional Gore-Tex*

Standard Accessories: main filter, 50' power cord

Additional Accessories: back frame, HEPA or ULPA exhaust filter, HEPA or ULPA internal filter, paper bags

*filter area includes: internal HEPA filter, main filter, paper bag

*Gore-Tex is a registered trademark of W.L. Gore & Assoc.

Equipment leasing is available. Contact your Nilfisk representative for details.

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NOTHING ESCAPES

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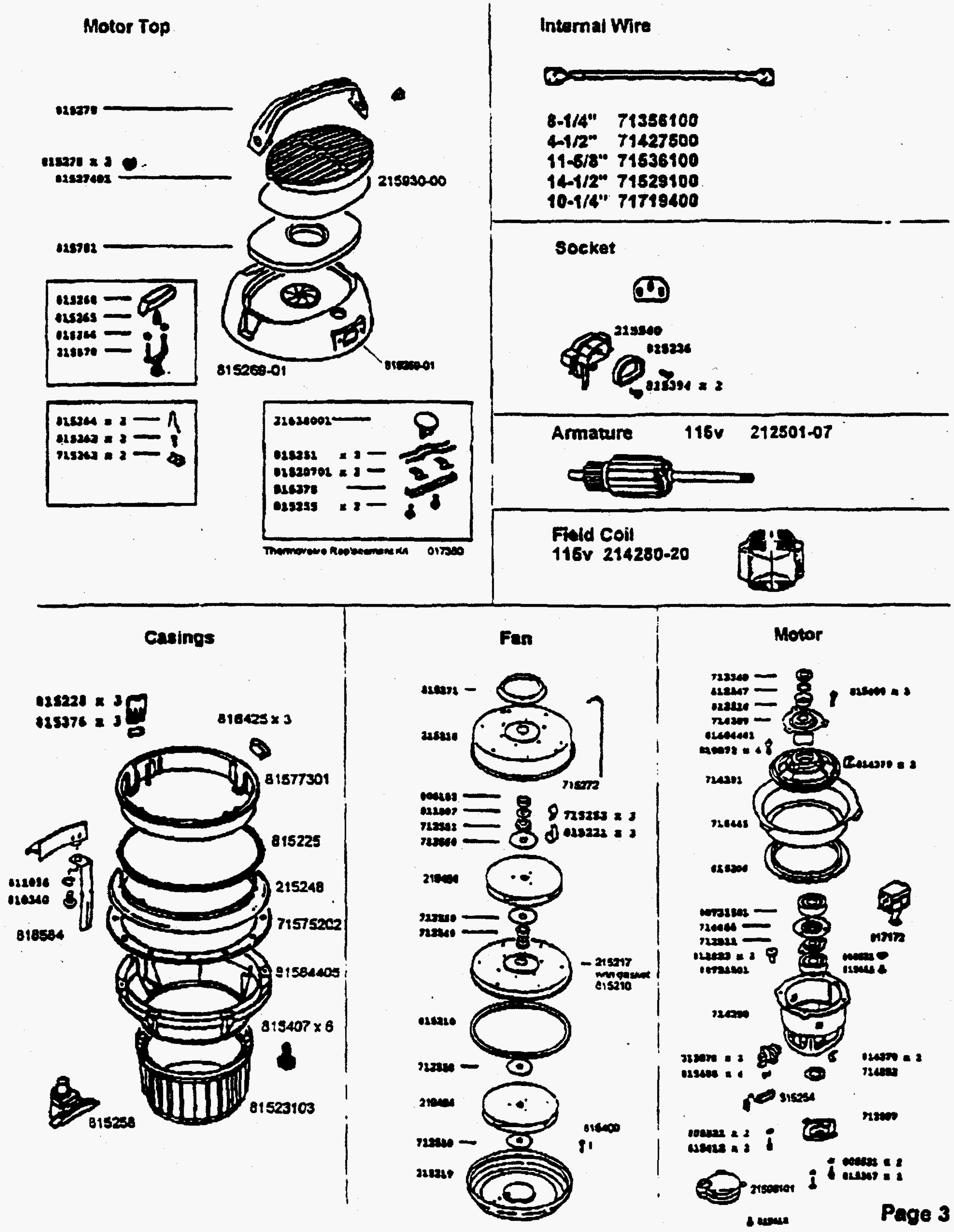
Table 2. Motor parts–GSJ



took the armature as 100% steel, the field coil as 100% steel, the fan assembly as 100% aluminum, and the motor assembly (the cast aluminum casing) as 100% aluminum. Using theoretical densities and the above weights, the material volume was calculated. The difference between the motor casing volume (9.0 in. ID cylinder × 6.75 in. height) and material volume was taken as the motor void volume subject to filling with liquid. The motor void volume was calculated to be 10.4 in.^{3} in the baseline case.

2.3 SYSTEM SUPPORT

The vacuum cleaner is mounted on a trolley, as shown in Fig. 2, or placed in a fixed geometry, such as a glove box. The trolley is an approximately 30-in.^{2} device with the vacuum cleaner placed in the center. The trolley base design provides protection to the cleaner and prevents inadvertent placement of the vacuum cleaner closer than 1 ft to other equipment. When in a fixed geometry, such as a glove box, curtain barriers or sides of the glove box control inadvertent placement of equipment close to the deposit bottle collection region. Thus, strong interaction controls can be used in a glove box fixed geometry.

The portable vacuum cleaner has a three-stage filtration system. Air flow is through a hose, through the cyclone portion of the vacuum cleaner body, and up through the downcomer. The air crosses a sock prefilter that surrounds a cylindrical HEPA filter. The air then flows through the motor and exhausts through a second HEPA filter. The DR Room glove box vacuum cleaner, on the other hand, has only the sock prefilter. The glove box HEPA filter system provides final filtration of the exhaust air.

As necessary, the deposit bottle and vacuum cleaner cyclone assembly are disconnected for cleaning and deposit bottle replacement.

3. VACUUM CLEANER MODEL

3.1 CALCULATIONAL METHOD

The SCALE computer program modules used in the criticality evaluations are part of the Standardized Computer Analysis for Licensing Evaluation (SCALE) code system. A summary description of the calculation procedure used in this analysis is essentially as described in ref. 4. The CSAS25 control sequence of SCALE was used for all computations. The CSAS25 control sequence activates the functional modules BONAMI-S, NITAWL-S , and KENO V.a. The control sequence and functional modules are summarized in the following paragraphs. The 27-group ENDF/B-IV cross-section library in SCALE-4.0 was used for all calculations.

The CSAS25 control sequence reads user-specific input data, which include the required cross-section library, specification for mixtures, information for resonance processing of nuclides (size, geometry, and temperature), and a detailed geometry model for KENO V.a. Physical and neutronics information, not supplied explicitly, but required by the functional modules (such as theoretical density, molecular weights, average resonance region background cross-sections), is supplied by the Standard Composition Library or calculated by the Materials Information Processor. The Standard Composition Library consists of a standard composition directory and table, an isotopic distribution directory and table, and a nuclide information table. These data were used to set up the input for BONAMI-S, NITAWL-S, and KENO V.a.

The 27-group ENDF/B-IV master cross-section library in SCALE is activated in the CSAS25 control sequence by specifying 27GROUPNDF4 (27GR) as the cross-section library name. The 27-group library is the broad companion library to the 218-group Criticality Safety Reference Library. The Criticality Safety Reference Library master library, which is based on the ENDF/B-IV data, was generated as a pseudo-problem-independent fine-group structure library for use in general criticality safety analysis and shipping cask calculations. The 27-group library was collapsed from the 218-group library using a characteristic fission- (1/E) - Maxwellian spectral flux shape. Explicit ENDF/B-IV resonance parameters are carried for resonance nuclides in both 27- and 218-group libraries. These resonance parameters are used by NITAWL-S in the CSAS25 control sequence for calculating problem-dependent, self-shielded resonance region cross sections.

BONAMI-S performs resonance shielding through the application of the Bondarenko shielding factor method. BONAMI-S reads the master format library and applies the Bondarenko correction to all nuclides that have Bondarenko data. Input data to BONAMI-S, set up by the CSAS25 control sequence, include information relating to the physical characteristics (composition of material, size, geometry, and temperature) of the system being calculated. BONAMI-S produces a Bondarenko-corrected master format library which is read by NITAWL-S.

For the 27-group master cross-section library used in this study, the primary purpose of the BONAMI functional module is to select the required material cross sections and to create a smaller master cross-section library to be processed by NITAWL. No data processing is performed in BONAMI for the 27-group cross-section library.

NITAWL-S applies the Nordheim Integral Treatment to perform neutron cross-section processing in the resonance energy range for nuclides that have ENDF/B resonance parameter data. This technique involves the numerical integration of ENDF/B resonance parameters using a calculated flux distribution, which is based on the calculated collision density across each resonance and subsequent weighting of the reaction cross-section to the desired broad group structure. Input data to NITAWL-S, automatically set up by the CSAS25 control sequence, include information relating to the physical and neutronic characteristics of the system being calculated. NITAWL-S uses these data to complete the processing of the problem-dependent master library from BONAMI-S. In the SCALE sequence, NITAWL-S assembles the group-to-group transfer arrays from elastic and inelastic scattering components, and performs other tasks to produce a problem-dependent, working cross-section library that than can be used by KENO V.a.

KENO V.a, a multigroup Monte Carlo computer code, is used to determine k_{eff} for multidimensional systems. The geometrical bodies allowed in KENO V.a for defining models include cuboids, spheres, and cylinders. KENO V.a has an enhanced geometry package that (1) allows arrays to be defined and positioned throughout the model, (2) includes a P_n-scattering treatment, (3) has an extended use of differential albedo reflection, (4) generates printer plots for checking the input model, (5) allows super grouping of energy-dependent data, (6) has a restart capability, and (7) defines origin specifications for cuboids, spheres, cylinders, hemicylinders, and hemispheres. For scoping calculations, the code used was SCALE version 4.3 for the PC, executed on a IBM clone pentium processor personal computer.

3.2 VACUUM CLEANER

3.2.1 Vacuum Cleaner Body Geometry

The vacuum cleaner is modeled using 18 cylindrical units stacked one on another. An overall drawing of the geometrical units comprising the model is shown in Fig. 7. Unless noted, the dimensions correspond closely with the "as built" drawings M1E703045 A169 through A177, Rev. 0, drawn in 1994. The units are assumed to be surrounded by either 1-in.- or 12-in.-thick water annuli according to the case for reflection. Beyond these annuli, an approximately 12-in. volume of water mist is assumed to model humid air conditions in all cases. Drawing MIE703045A599 contains the originals of Figs. 7 through 18.

Unit 1 is the lower-most section, and it consists of the 1-L polypropylene collection bottle 6.75 in. high (17.15 cm) with an inner radius of 1.75 in. (4.445 cm) and a wall thickness of 0.0625 in. (0.159 cm). The bottle's inner radius is slightly smaller than 1.75 in. due to wall thickness, but this value was taken for conservatism regarding criticality. The bottle material was modeled as poly(H_2O). The model and dimensions of the unit used in the computer code are shown in Fig. 8. The bottom of the bottle was ignored.

Unit 2 is the connector between the vacuum cleaner and the neck of the bottle. The bottle screws onto the female thread of the vacuum cleaner cyclone. The height of this cylinder was measured to be less than 1-5/8 in. (4.127 cm). The connector material was modeled as SS-304. The thickness is modeled as 0.0625 in. (0.159 cm). The outside diameter was measured to be 2.25 in. (5.71 cm), and this value was conservatively chosen as the inside diameter. This gives an inside radius of 1.125 in. (2.857 cm). The model is shown also in Fig. 8.

Units 3 through 6, shown in Fig. 9, are a 6-in.-high (15.24 cm) frustum of a cone of SS with an inside radius of 1.03 in. (2.616 cm) at the base and 2.43 in. (6.18 cm) inside radius at the top. The wall thickness is 0.059 in. (0.15 cm). The frustum is modeled as a series of pancakes stacked one on another. The radius of the pancake cylinder is the maximum radius of the section of the frustum it encompasses, as shown in Fig. 10. The actual geometry is depicted in solid line and the model is in dotted line. The first pancake is 1.38 in. (3.505 cm) in radius, which corresponds to the radius at the top of this section of the frustum. This is

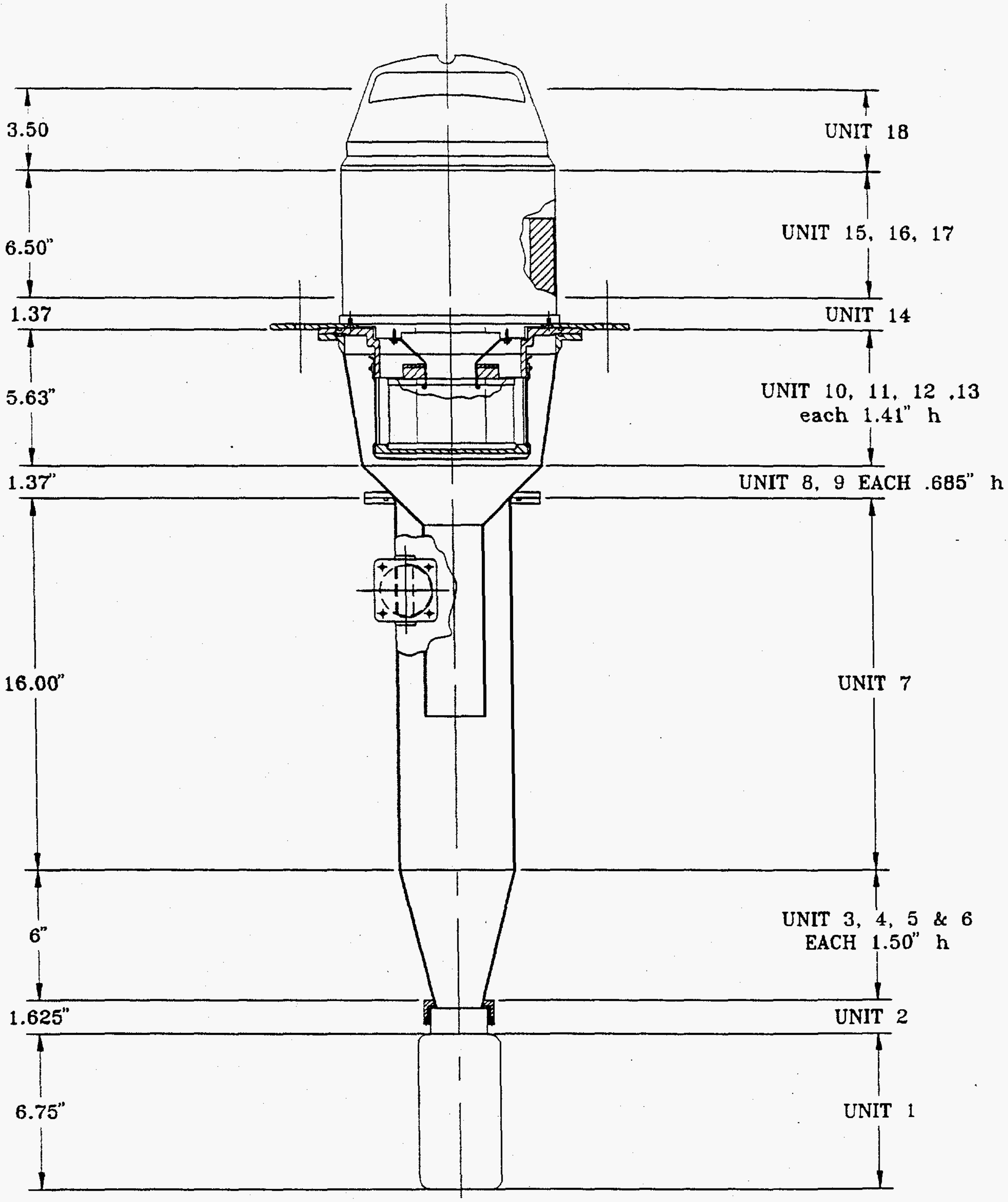
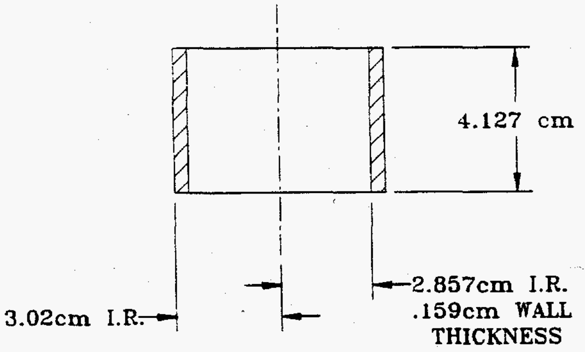
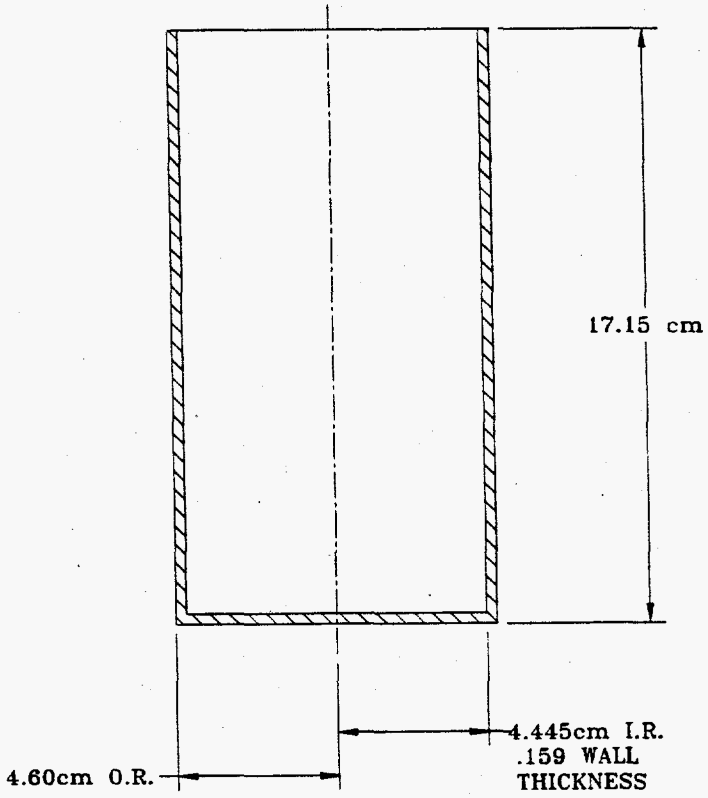


Fig. 7. Division of vacuum cleaner into cylindrical sections for modeling.



UNIT 2
CONNECTING
FITTING



UNIT 1
PLASTIC
BOTTLE

Fig. 8. Units 1 and 2: plastic bottle and connecting fitting.

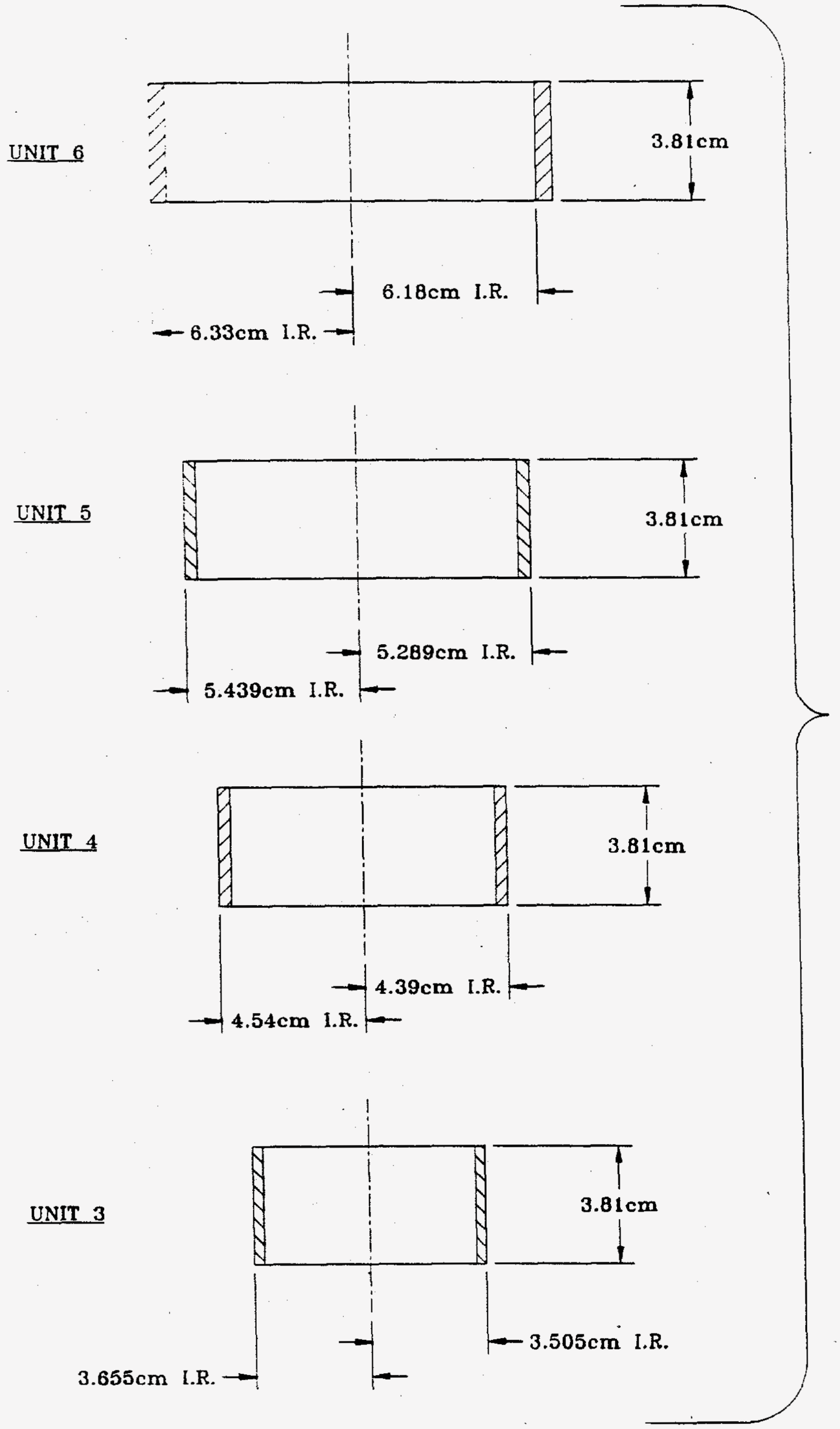


Fig. 9. Cone and frustum model of Units 3–6.

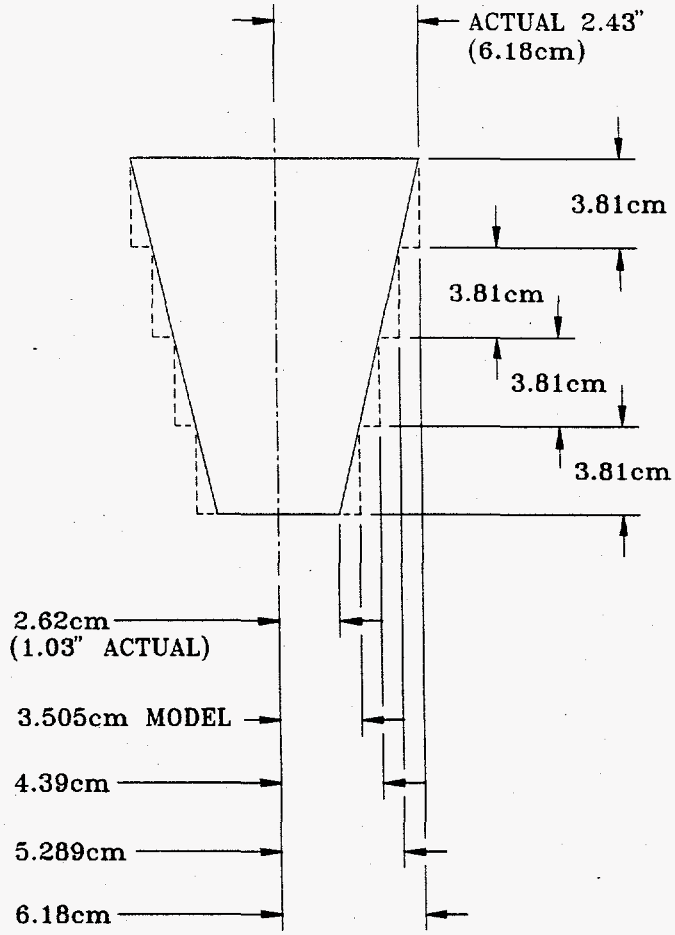


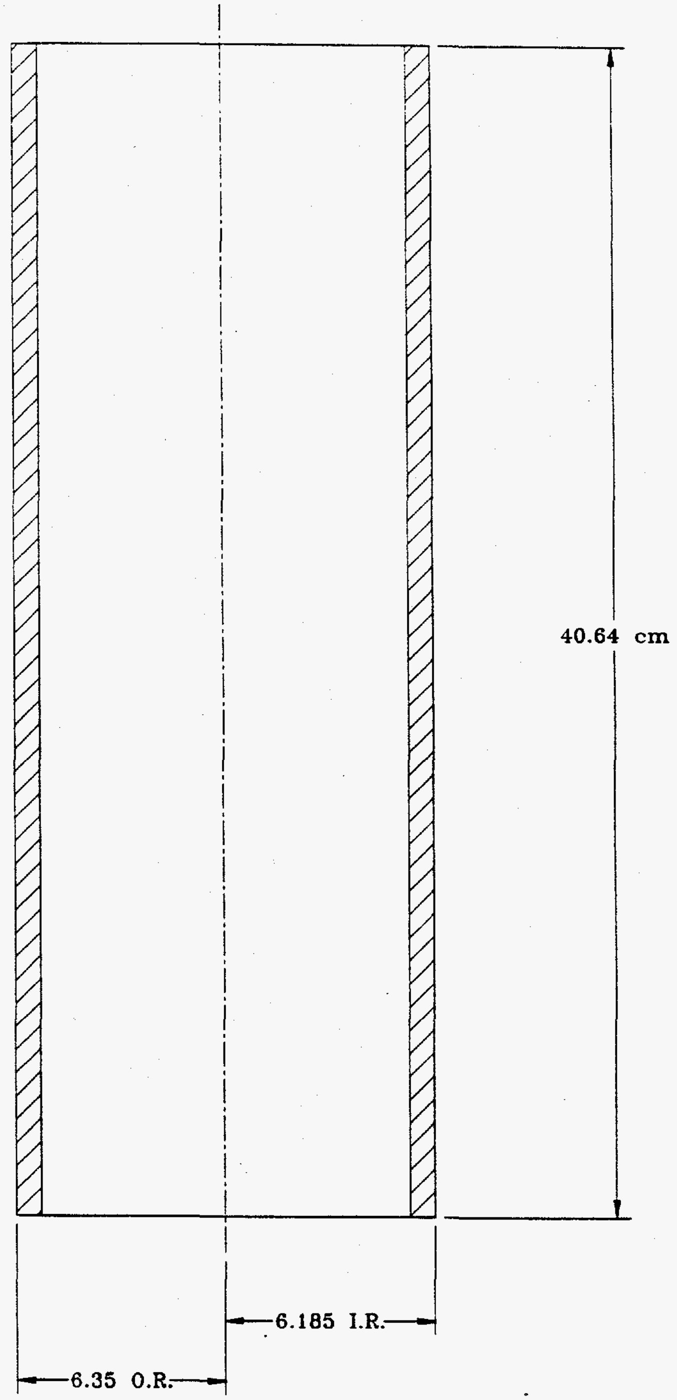
Fig. 10. Schematic of model and actual frustum, bottom of cyclone.

conservative since the actual radius of the bottom is 1.03 in. Each unit increments the radius by 0.35 in. (0.89 cm). The volume of each pancake exceeds the volume of the conical frustum it replaces at all points to make the volume of the solution greater than it is in reality and, therefore, conservative. Each pancake is 1.5 in. (3.81 cm) in height. This section consists of Units 3 through 6. As can be seen in Fig. 10, the bottoms of each model cylinder are not considered to be encased in SS but open to the water reflection volume. This should be a conservative assumption since the SS is a strong neutron absorber compared to water.

Unit 7, shown in Fig. 11, is modeled as a SS-304 cylinder of 2.435 in. internal radius (6.185 cm) and a wall thickness of 0.065 in. (0.165 cm). Although it contains a downcomer funnel made of steel, this part was omitted from the model, and instead, the space left vacant by its omission was replaced with uranyl fluoride solution. The steel downcomer absorbs neutrons and, therefore, this modeling is conservative. Its height is 16 in. (40.64 cm).

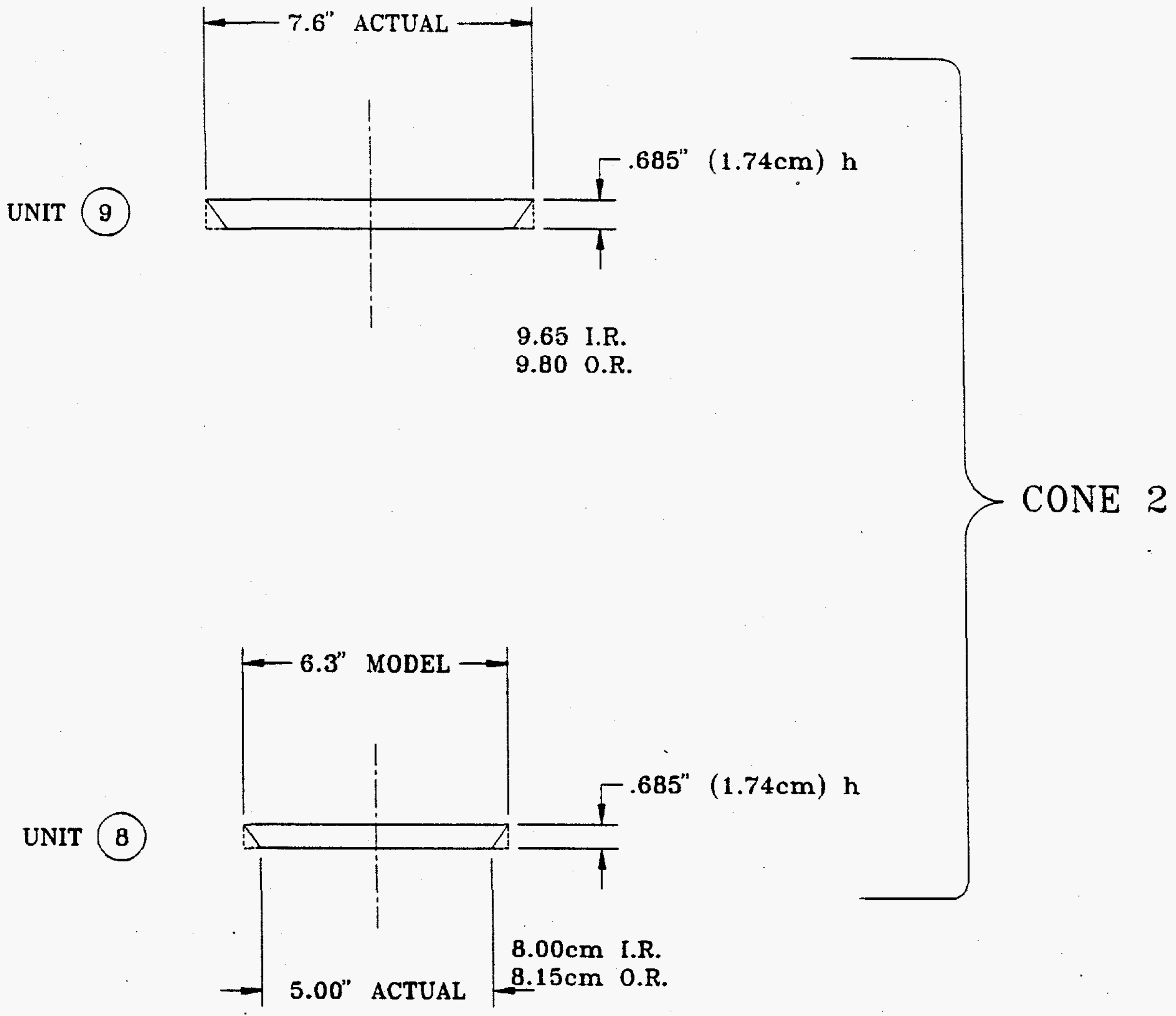
Units 8 and 9 (shown in Fig. 12) approximate a 1.37-in.-high (3.48 cm) SS-304 conical frustum. It was divided for modeling purposes into two pancakes (Units 8 and 9), each 0.685 in. (1.74 cm) high. The two units are 3.15 in. (8.00 cm) and 3.8 in. (9.65 cm) in internal radius, respectively. For Unit 8, this compares with a 2.5-in. (6.35 cm) internal radius of the bottom of the frustum. The 2.5-in. (6.35 cm) internal radius is, itself, a conservative assumption since it mates with a part which is 2.5 in. (6.35 cm) in outside radius. The wall thickness is 0.059 in. (0.15 cm). For Unit 9, the actual internal radius of the top of the part is 3.8 in. (9.65 cm). The two units together are at all points larger in diameter than the actual part. The solid lines in Fig. 12 depict the actual dimensions of the part and the dotted lines depict the model dimensions.

Units 10 through 13, as shown in Fig. 13, approximate a 5.63-in.-high (14.3 cm) SS-304 conical frustum. Although it contains a complicated geometry of internal parts, some of metal and some of plastic (like Units 8 and 9), it is modeled as a hollow metal cylinder filled with uranyl fluoride solution. This is consistent with earlier Y-12 and K-25 vacuum cleaner analyses.[5] This frustum is modeled as four pancake cylinders, as shown in Fig. 14. The actual inside diameter of the frustum is shown as the heavy line in this figure.



UNIT 7

Fig. 11. Unit 7: cyclone straight section.



SOLID LINES DEPICT ACTUAL PART
DIMENSIONS, DOTTED LINES ARE
MODELING DIMENSIONS

Fig. 12. Units 8 and 9: model of cyclone inner body frustum.

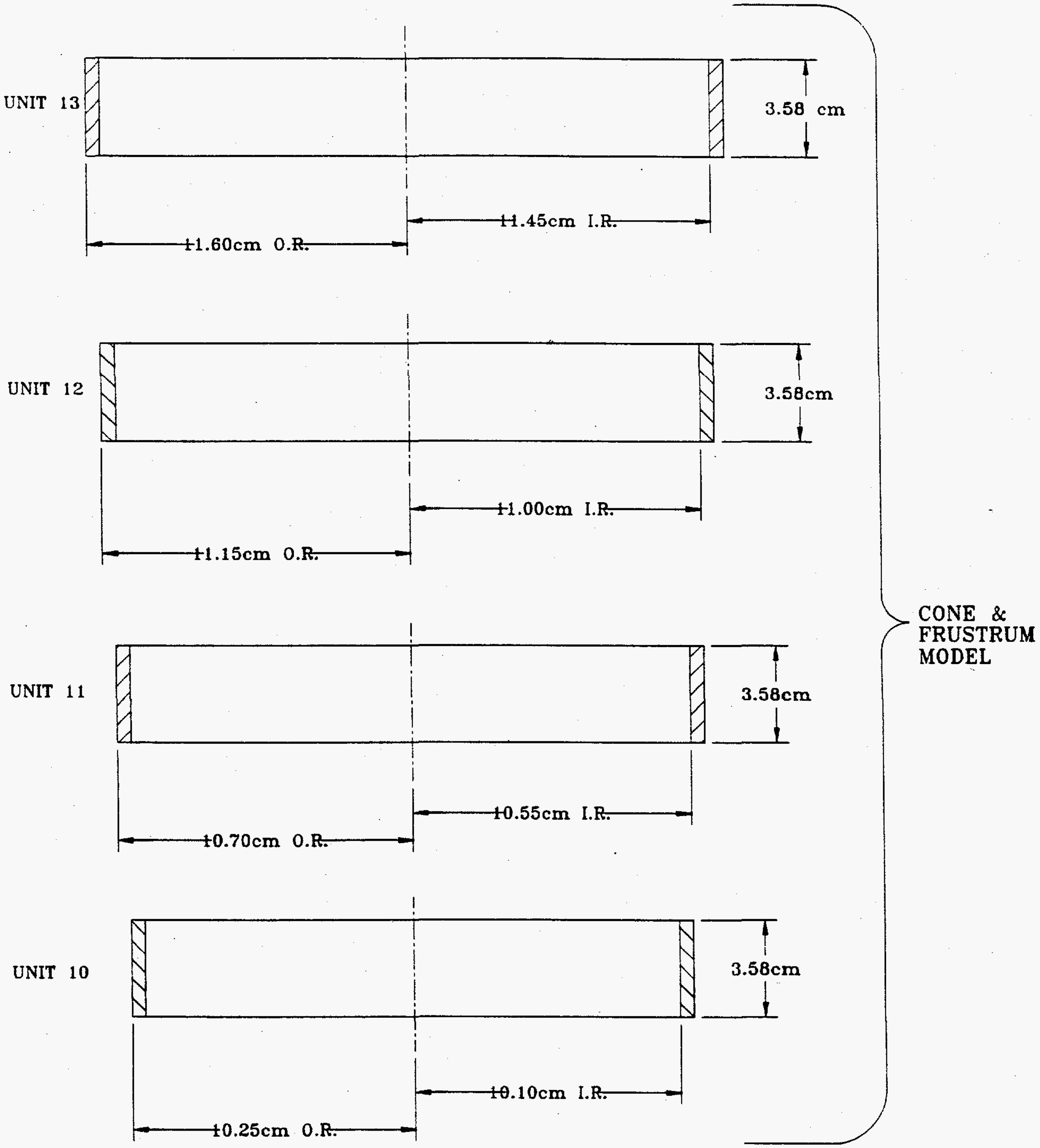


Fig. 13. Model of Units 10–13: upper frustum of cyclone inner body.

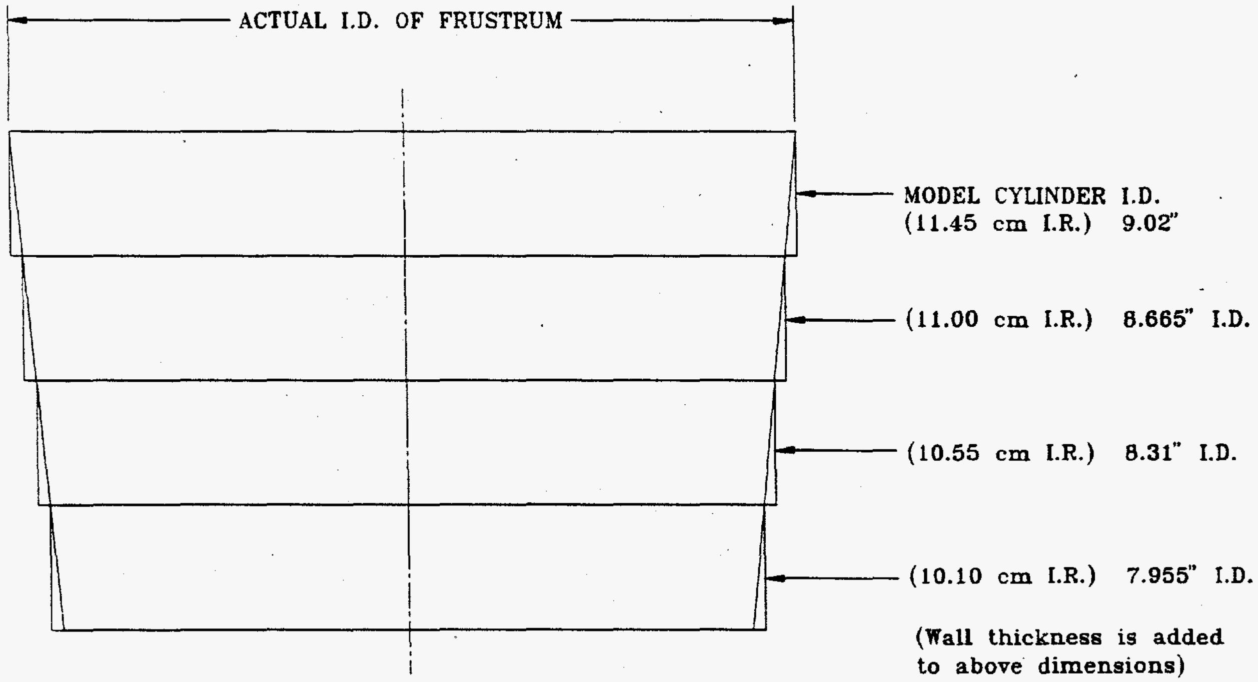


Fig. 14. Schematic of model and actual part, upper frustum of cyclone inner body.

Each unit is of a height of 1.41 in. (3.58 cm) and a 0.059-in. (0.15 cm) wall thickness. The base of Unit 10 has an internal radius of 3.98 in. (10.1 cm) which is larger than the actual internal radius of 3.8 in. (9.65 cm). Each unit increments the radius of the pancake by 0.1775 in. (0.45085 cm) until the internal radius of 4.51 in. (11.455 cm) at the top of the frustum.

Unit 14, shown in Fig. 15 as the "flange section", is a 1.37-in.-high (3.48 cm) cylinder 9 in. diam (22.9 cm) which covers the vacuum cleaner mounting plate, adaptor plate, and cyclone inner body flange sections. The total thickness of the flanges and plates was calculated to be 1.37 in. (3.48 cm) and, although this volume contains a quantity of steel, it was modeled as a 11.45-cm IR by 0.15-cm-thick SS-304 cylinder containing uranyl fluoride solution.

Unit 15, also shown in Fig. 15 and in detail in Fig. 16, is a 0.5-in.-tall (1.27 cm) cylinder with a void to a radius of 3.5 in. (8.89 cm), and then a plastic annulus from 8.89 cm to 4.51 in. (11.45 cm). No motor parts are in the model of this unit.

Unit 16, also shown in Fig. 15 and shown in detail in Fig. 17, consists of an inner cylinder to a radius of 1.75 in. (4.445 cm) which comprises the motor assembly. Then, an annular section begins between 4.445 cm and 3.5 in. (8.899 cm) which is modeled as uranyl fluoride solution. The next annulus from 8.89 cm to 11.45 cm is composed of plastic. A 0.059-in. (0.15 cm) SS cylinder then houses the assembly. The motor is assumed to consist of a reduced density of aluminum, iron, and/or copper mixed with UO_2F_2 solution as will be explained in Sect. 3.2.2. This unit is 3.63 in. (9.22 cm) high.

Unit 17, also shown in Fig. 15 and shown in detail in Fig. 17, consists of a cylinder, the first 1.75 in. (4.445 cm) of which is comprised of the motor assembly. The remaining annulus from 1.75 in. (4.445 cm) to 4.51 in. (11.45 cm) is void volume to be filled with solution. The motor is assumed to consist of a reduced density of aluminum, iron, and/or copper mixed with UO_2F_2 solution, as will be explained in Sect. 3.2.2. This unit is 2.37 in. (6.02 cm) high. The SS-304 wall thickness was 0.059 in (0.15 cm).

Unit 18, shown in Fig. 18, models the upper HEPA filter and casing. Data from the manufacturer indicate that the diameter of the HEPA container is 5 in. (12.7 cm), and the height is 3.5 in. (8.89 cm). The region is filled with uranyl fluoride solution for purposes of the model. A 0.059-in.-thick (0.15 cm) SS-304 wall was modeled.

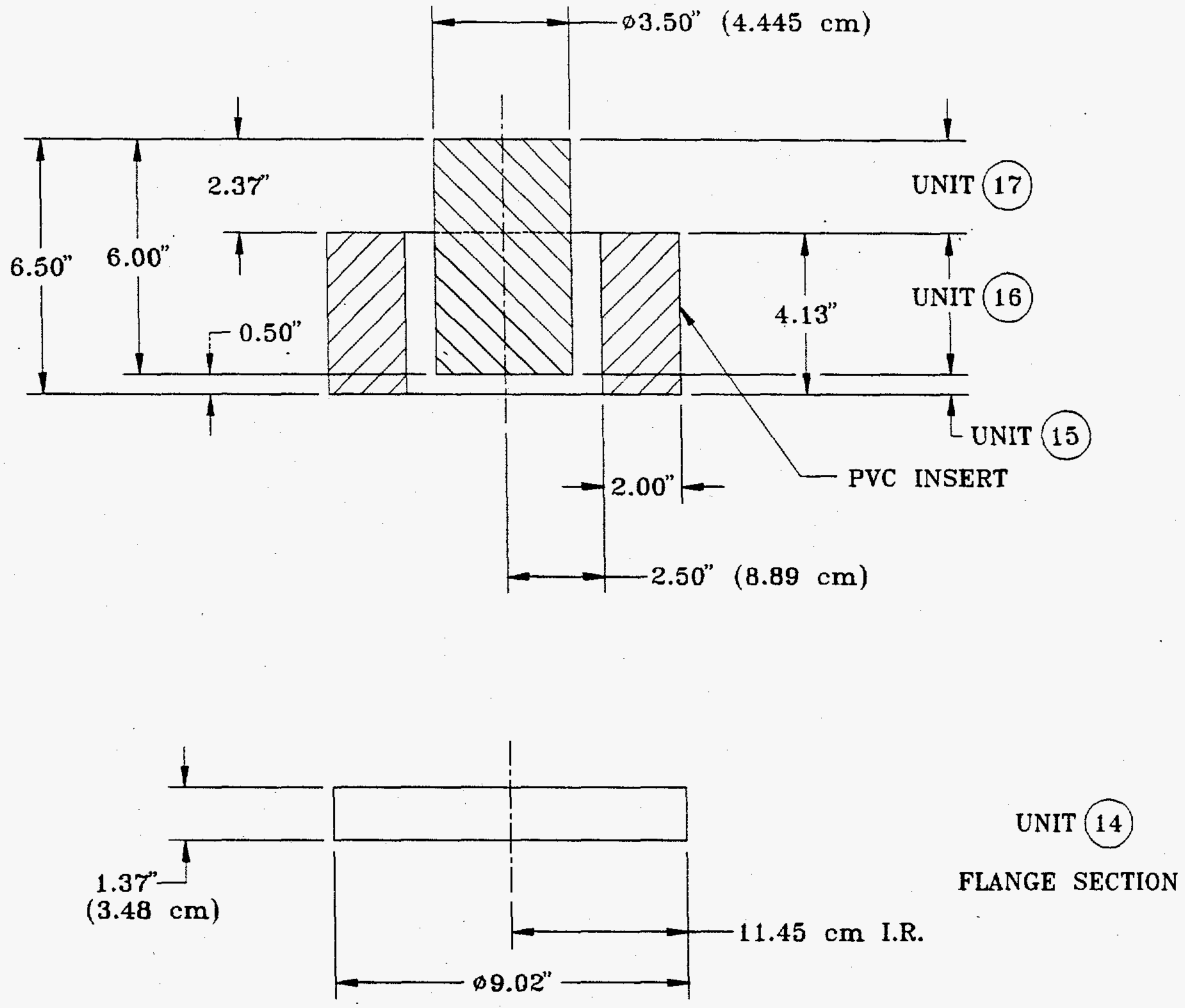


Fig. 15. Model of Units 14, 15, 16, and 17: flange section and motor assembly.

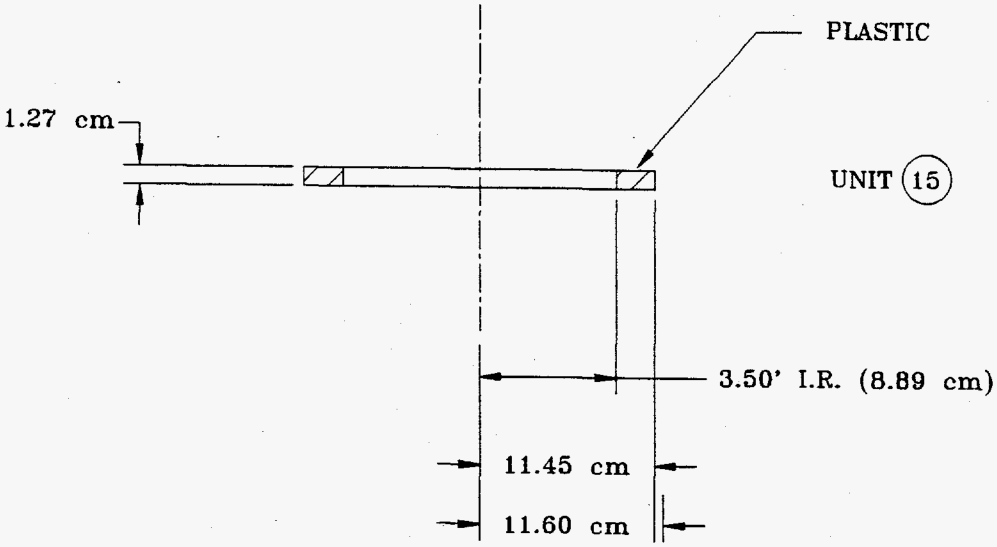


Fig. 16. Model of Unit 15: motor base assembly.

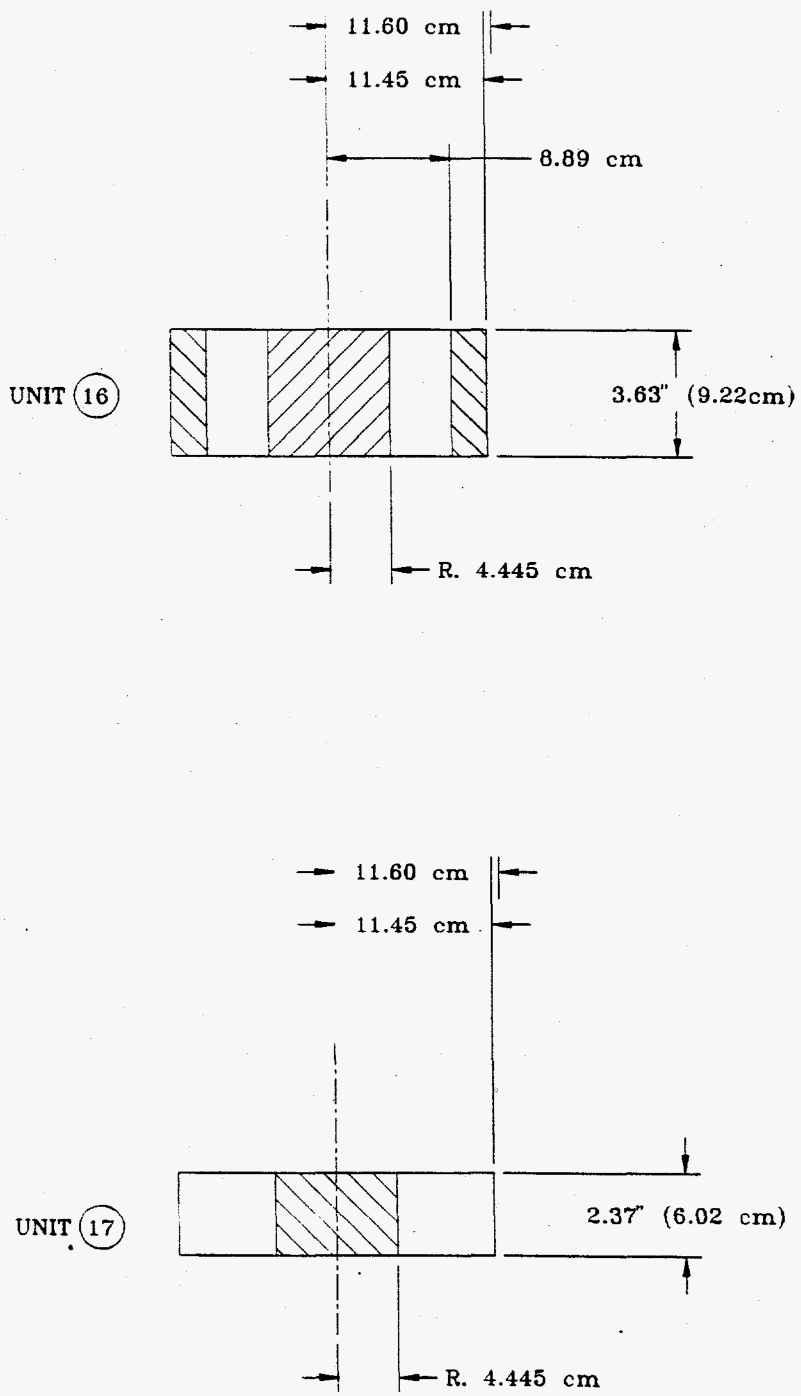


Fig. 17. Model of Units 16 and 17: motor assembly.

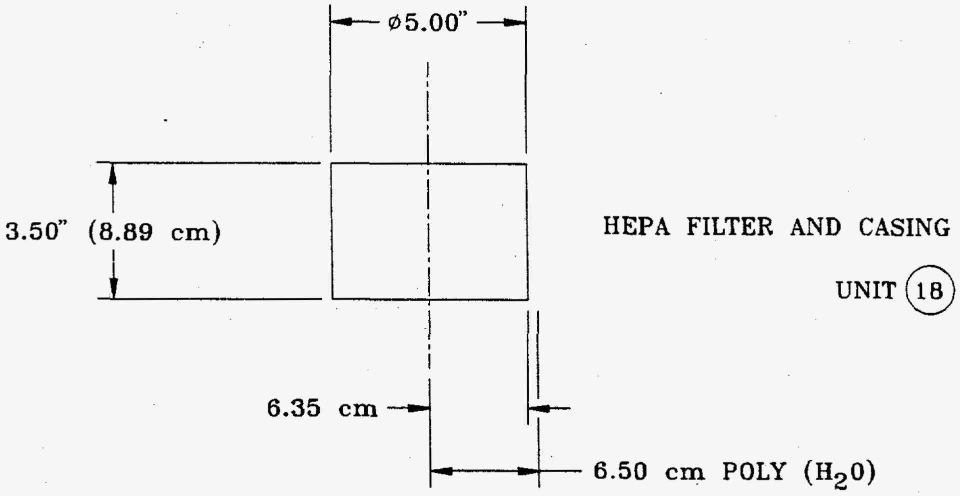


Fig. 18. Unit 18: HEPA filter and casing.

3.2.2 Vacuum Cleaner Motor Geometry and Materials

Units 15, 16, and 17 are a complicated section consisting of uranyl fluoride solution, a plastic annulus, and a central core which models the motor and fan assembly, as shown schematically in Fig. 15. Figure 15 shows the dimensions used in modeling. Also shown at the top of these two figures, but modeled in Unit 18, is the HEPA filter housing. As shown in Fig. 19, the motor/fan assembly begins at a diameter of 3.5 in. (8.89 cm) and expands to a 6.5-in.-diam (16.51 cm) at the point it mates approximately with the HEPA filter housing. The greatest uncertainty exists in the characteristics and geometry of the motor fan assembly. As indicated, the geometry is modeled only as a 3.5-in.-diam cylinder of 6-in. height. Although the upper section of the assembly slopes outward to a diameter of 6.5 in., the smaller diameter is assumed to exist throughout the length of the assembly, and the increased void volume resulting from this model is assumed to contain entirely uranyl fluoride solution. This is felt to be conservative because no information on the void volume of this section of the assembly is available. Figure 20 is a drawing that is made from measurements of a partially disassembled motor, Model GSJ-115, from Nilfisk of America. Figure 20 shows roughly the materials of construction of the parts of the motor and fan assembly. The motor is surrounded by a 0.0625-in.-thick (0.0159 cm) plastic cone as shown in Figs. 19 and 20. This plastic cone was omitted in this analysis and the space was filled with uranyl fluoride solution. At the base of this unit, there is a thin rubber gasket upon which the motor assembly rests in a vacuum cleaner as inspected at Machine Kinetics Corporation of Knoxville. This gasket space was also replaced with solution. The annular polyvinylchloride (PVC) plastic cylinder is modeled geometrically as it appears on the drawings—2 in. (5.08 cm) thickness, 4.13 in. (10.49 cm) high. It fits into the bottom of the motor/fan assembly section but was modeled as polyethylene, which is a lower neutron absorber than PVC. This plastic cylinder was placed there to occupy space which might otherwise fill with uranyl fluoride solution.

The steel wall of the vacuum cleaner was modeled as SS-304; the drawing specifies 300 series SS. Plastic parts are modeled using the Bonami library microscopic cross sections of hydrogen with a water thermal kernel in all of the plastic units. Although certain parts are believed to be PVC (rather than polyethylene), a conservative assumption is that they are polyethylene since it has a lower neutron absorbance cross section than PVC due to the

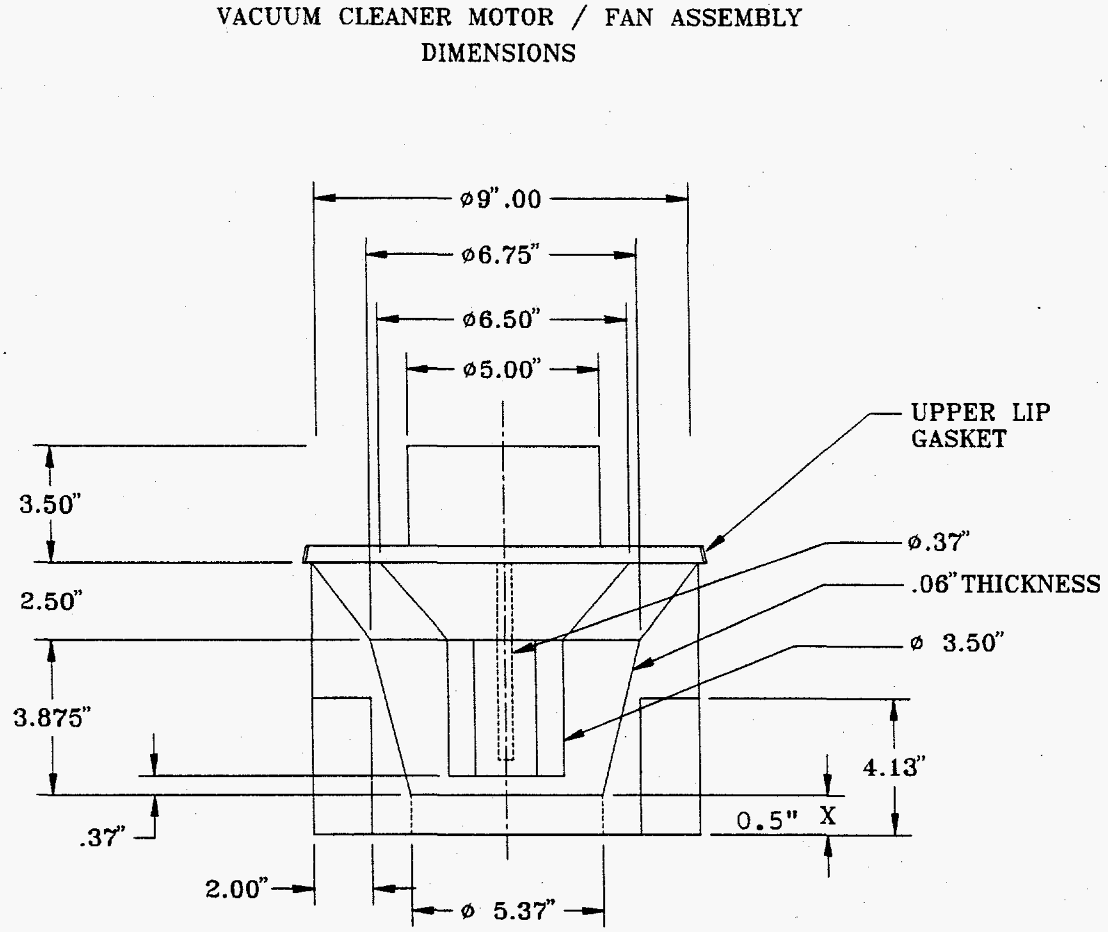


Fig. 19. Schematic of actual motor assembly approximate dimensions.

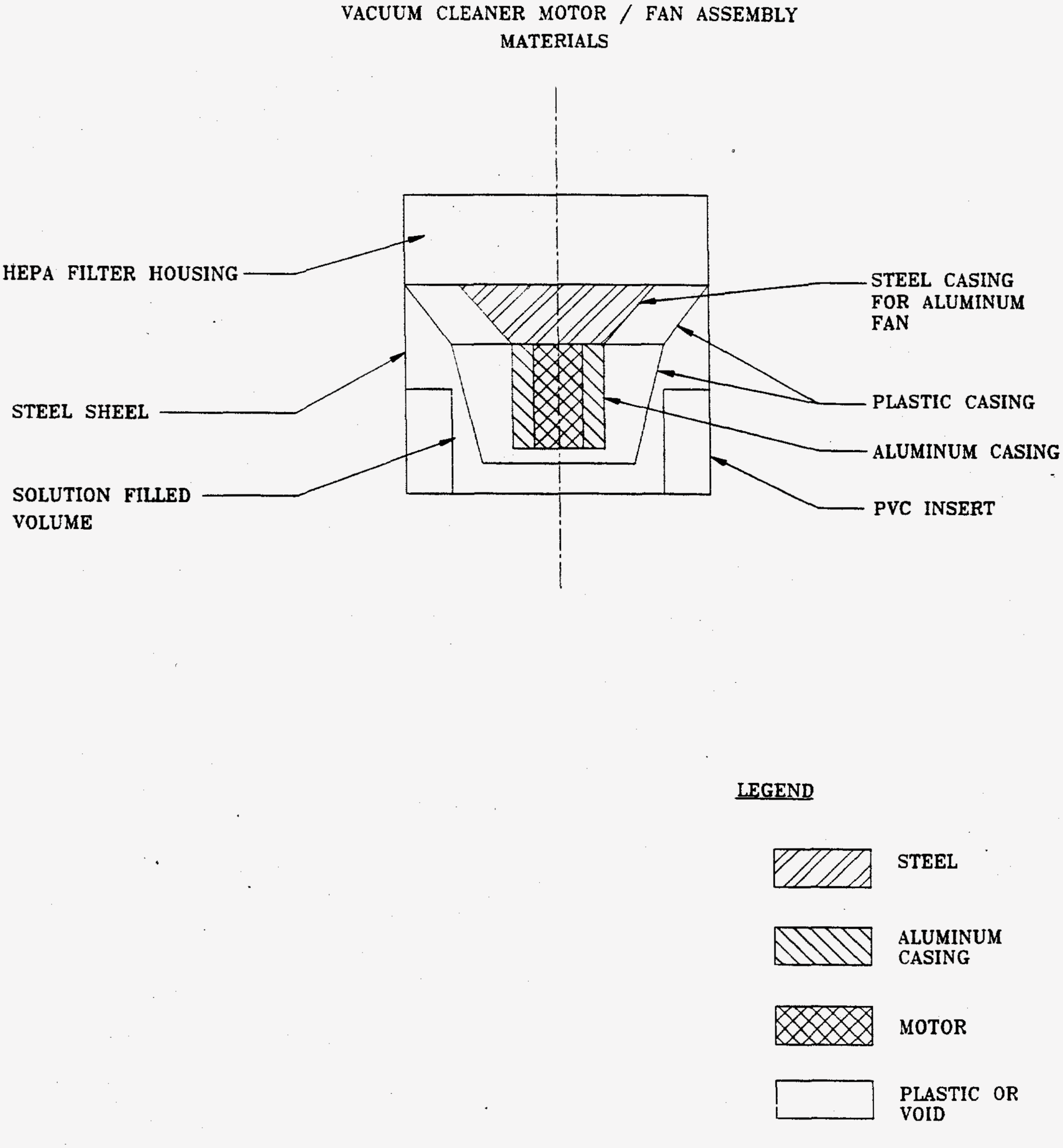


Fig. 20. Schematic of actual motor assembly materials based on Nilfisk parts.

chlorine in the PVC. Polyethylene has a comparable atomic density of hydrogen to polypropylene and the same model is used with both materials. The polypropylene material was modeled as poly(H_2O) according to the Bonami library of neutron cross sections.

The masses of the armature, field coil, fan assembly, and motor assembly were provided by Nilfisk Corp. of America. Their dimensions and masses are shown in Appendix B. A KENO-code-generated map of the vacuum cleaner is shown in Appendix C.

3.3 BASELINE MODEL

The entire vacuum cleaner is modeled as a stack of the 18 units shown in Fig. 7 and described in the previous section. All sections not explicitly defined as being of a solid material in the model are assumed to be filled with uranyl fluoride solutions of various concentrations. The total volume was calculated to be 20 L. The volumes of the individual units (Units 1 through 18) are shown in Appendix D. A second calculation of the actual volume (less conservative from the point of view of calculating total critical masses) was performed. The resulting volume was 1910 cc and the calculations were performed with Math Cad are shown in Appendix E.

Baseline Case 1:

The motor section geometry and materials are subject to the most uncertainty and several sensitivity calculations around a baseline case were made. As a baseline case, the armature and field coils, composed of iron and copper, were taken to consist entirely of iron. Copper is a large neutron absorber and treating the armature and field coils as iron is conservative. All aluminum/iron parts are modeled as consisting of aluminum alone because iron is a better neutron absorber than aluminum. Iron was calculated to have an atomic density of 0.017 atoms/b·cm (based on a mass density of 7.86 g/cc) and aluminum to have a density of 0.0375 atoms/b·cm (based on a mass density of 2.7 g/cc). Calculations are shown in Appendix A. The total volume of the cylindrical section which models the motor fan assembly is 10.4 in.^{3} (945 cc). A void fraction of 18% was calculated based on a mass balance of motor parts. This void space is filled with uranyl fluoride solution as are other void sections of the vacuum cleaner. The calculations of densities are shown in Appendix A. KENO V.a calculations for 1-in. and 12-in. reflection were performed for uranium concentrations from 30 to 130 g/L.

Sensitivity calculations about the base case:

Sensitivity calculations were performed around the base case of motor materials composition. Physically, the void fraction inside the motor is fixed once an assumption about the materials of construction, their masses, and the motor volume is made. Case 2 considered iron/copper parts to be all copper; copper/aluminum parts were considered to be all aluminum. The sensitivity of the analysis was then examined for this change in composition. Case 3 mixture of 50% Fe, 50% Cu was considered also. Case 4 examined the motor as being entirely absent and its void filled with solution. KENO calculations for 1-in. and 12-in. reflection were performed. Table 3 shows the models and baseline cases which were tried.

3.4 DIFFERENCES BETWEEN CURRENT AND EARLIER MODELS

The present K-25 portable vacuum cleaner, per drawing M1E703045, has undergone several modifications from earlier versions used at Y-12. The present K-25 vacuum cleaner has eliminated a polypropylene disk located near the mounting plate. In the present analysis, this space left vacant by the disk was assumed to be filled with uranyl fluoride solution. The

Table 3. Composition of motor parts modeled in four cases

Model	Case 1, baseline	Case 2	Case 3	Case 4
Armature	100% Fe	100% Cu	50% Fe, 50% Cu	100% fissile solution
Field coil	100% Fe	100% Cu	50% Fe, 50% Cu	100% fissile solution
Fan assembly	100% Al	100% Al	100% Al	100% fissile solution
Motor assembly	100% Al	100% Al	100% Al	100% fissile solution
Fissile solution, fraction %	18	20	19	100%

present K-25 vacuum cleaner model includes a flange at the top of the cyclone which permits the removal of the cyclone to facilitate cleaning. The flange does not affect criticality safety calculations.

Unpublished K-25 Site analysis modeled the various frusta of cones by creating a complicated arrangement of layered disks which equaled the volume of the actual hardware. Different thicknesses of the SS steel wall were used and, in certain cases, these were much greater than the actual wall thickness. In the present model of the K-25 vacuum cleaner, cylinders are again layered one on another; however, the volume of the disks is adjusted so that it exceeds at all points the actual volume of the hardware. Although the sums of volumes in the earlier work are identical to that of the actual parts, the individual cylinders, on occasion, are smaller than the actual volumes and, on occasion, larger. The current model is more conservative since it assumes that at all points the modeled volume is greater than the actual volume. It is not clear why greater wall thicknesses than the actual hardware were chosen in the unpublished earlier analysis. Since the SS is a neutron absorber and a poor moderator, the present more realistic model of the wall thickness should also be more conservative.

This work gathered more information about the internal structure of the Nilfisk motor than was available in earlier analyses. Information on the weights of the four parts of the motor assembly was obtained from Nilfisk Corp. and is used in the present modeling. Where data were unavailable as, for example, in the compositions of the different parts, sensitivity calculations were made over the range of possible compositions. The dimensions of an actual plastic uranium collection bottle at the bottom were measured and input to the present model as indicated in Sect. 3.2.1.

Notable modeling assumptions:

1. Miscellaneous vacuum cleaner components (filters, motor housing, downcomer from filter/motor region into the cyclone, etc.) are not modeled in the KENO V.a calculations. Such components provide some neutron absorption and displace fissile solution. Thus, these components, if included, would lower reactivity and increase the calculated critical mass.

2. Plastic components were modeled as polyethylene rather than PVC. The chlorine in PVC should provide additional neutron poisoning.
3. Full flooding. The vacuum cleaner is filled with liquid to a height exceeding the top of the electric motor; the motor would cease functioning on flooding. It is not expected that the vacuum cleaner could draw liquid to a height above the hose inlet to the cyclone and the equipment below this height is safe geometry for UO_2F_2 solutions. Typically, administrative controls direct that the vacuum cleaner be used for collecting dry material only. Also, typically, the vacuum cleaner is designed to shed overhead water. For example, Fig. 1 shows a hat above the motor which is designed to prevent water from entering from above. Alternatively, the vacuum cleaner is placed in an enclosure, e.g., glove box, to protect it from sources of liquid.
4. Full reflection (12 in. water) establishes the minimum critical mass. Full reflection is unlikely in reality. There would be partial reflection from concrete, nearby structural equipment, air, and personnel.
5. Interaction effects are not modeled because the 12 in. of water reflection isolates the vacuum cleaner from other equipment in the model. Typically, the vacuum cleaner has physical barriers, e.g., sits on a trolley with stand-off bars, to prevent the vacuum cleaner from coming into contact with other fissile-containing equipment. Alternatively, the vacuum cleaner is placed in a fixed geometry, e.g., glove box, where spacing can be controlled among equipment.

4. ANALYSES

Calculations were conducted for and about the base case which modeled the vacuum cleaner geometries and materials of composition. The calculation base case uses realistic, though conservative, assumptions. Where there were uncertainties (e.g., the precise motor materials composition), bounding sensitivity calculations were performed.

4.1 RESULTS

Case 1. Baseline 100% iron motor parts

The baseline case considered the iron and copper motor parts (the armature and field coil) to consist only of iron. Aluminum and iron parts are assumed to consist only of aluminum, since aluminum is a low neutron absorber. The calculated k_{eff} are shown in Table 4. The k_{eff} chosen are the average k_{eff} which occurs for 103 generations run without skipping any generations. Values were obtained for uranium concentrations from 30 to 130 g/L at 1-in. and 12-in. water reflection. Graphs of these results are shown in Figs. 21 and 22 with error bars indicating the 2σ, 95% confidence interval of the data based on two standard deviations. With 12-in. reflection and a concentration of 70 g/L of uranium, k_{eff} plus two standard deviations approaches 0.95. With 1-in. reflection and a concentration of 100 g/L of uranium, k_{eff} plus two standard deviations approaches 0.95. The data at 1-in. reflection are a bit more scattered than those at 12-in. reflection. Note that k_{eff} is well below 1.0 for all 1-in. reflection

Table 4. Baseline case results: 100% iron motor parts

12-in. reflection				1-in. reflection			
g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$	g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$
30	0.7356	0.0082	0.7438	30	0.6807	0.009	0.6897
40	0.8061	0.008	0.8141	40	0.7495	0.0092	0.7587
50	0.8587	0.01	0.8687	50	0.7982	0.0094	0.8076
60	0.8999	0.01	0.9099	60	0.8455	0.0094	0.8549
70	0.9314	0.0094	0.9408	70	0.8682	0.0104	0.8786
80	0.958	0.0102	0.9682	80	0.8871	0.0118	0.8989
90	0.9868	0.0106	0.9974	90	0.903	0.0110	0.914
100	0.9989	0.0068	1.0057	100	0.9332	0.0108	0.944
110	1.0118	0.0108	1.0226	110	0.9353	0.0112	0.9465
120	1.0142	0.0108	1.025	120	0.9661	0.0118	0.9779
130	1.0439	0.0114	1.0553	130	0.9608	0.0116	0.9724

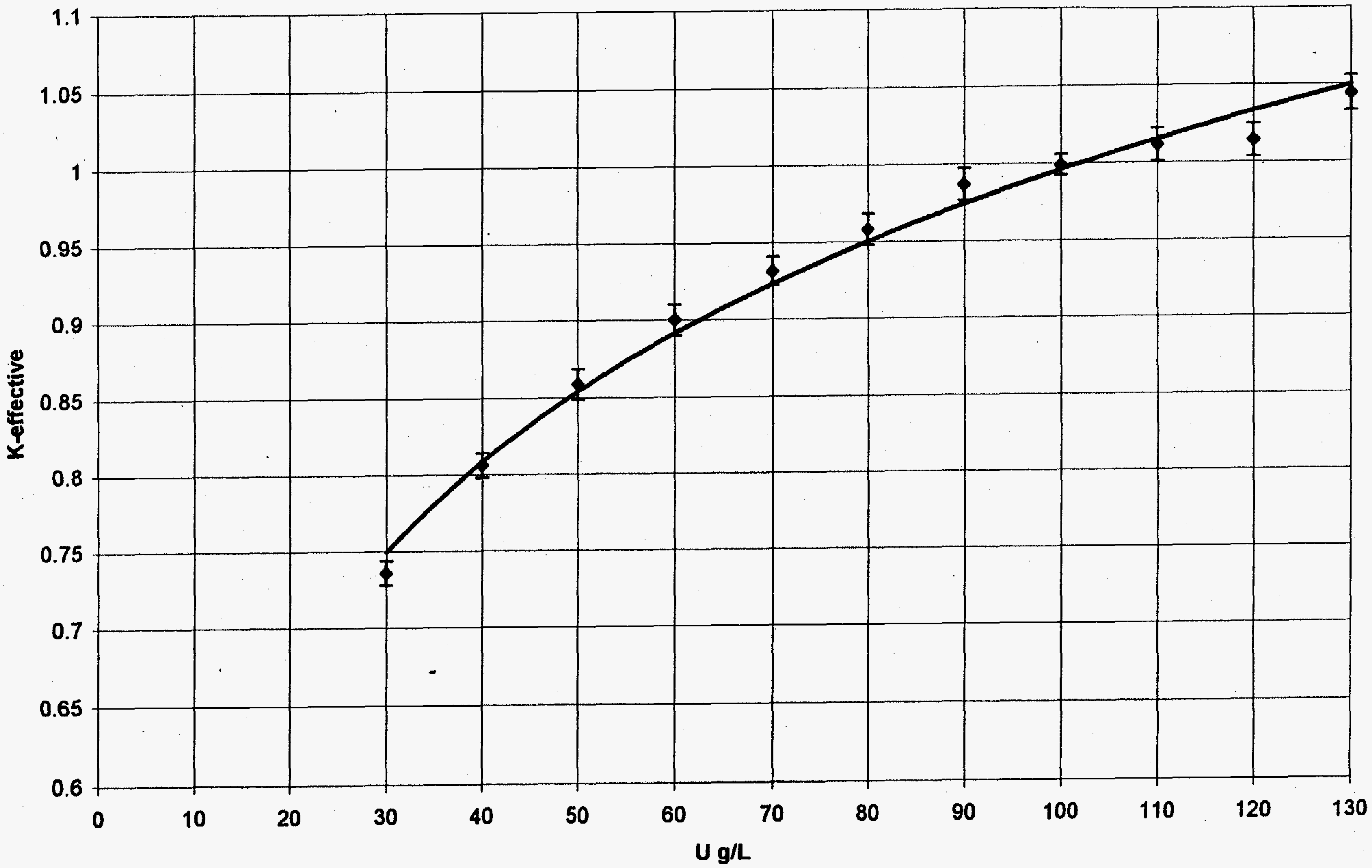


Fig. 21. Case 1, 12-in. reflection, 100% iron motor parts.

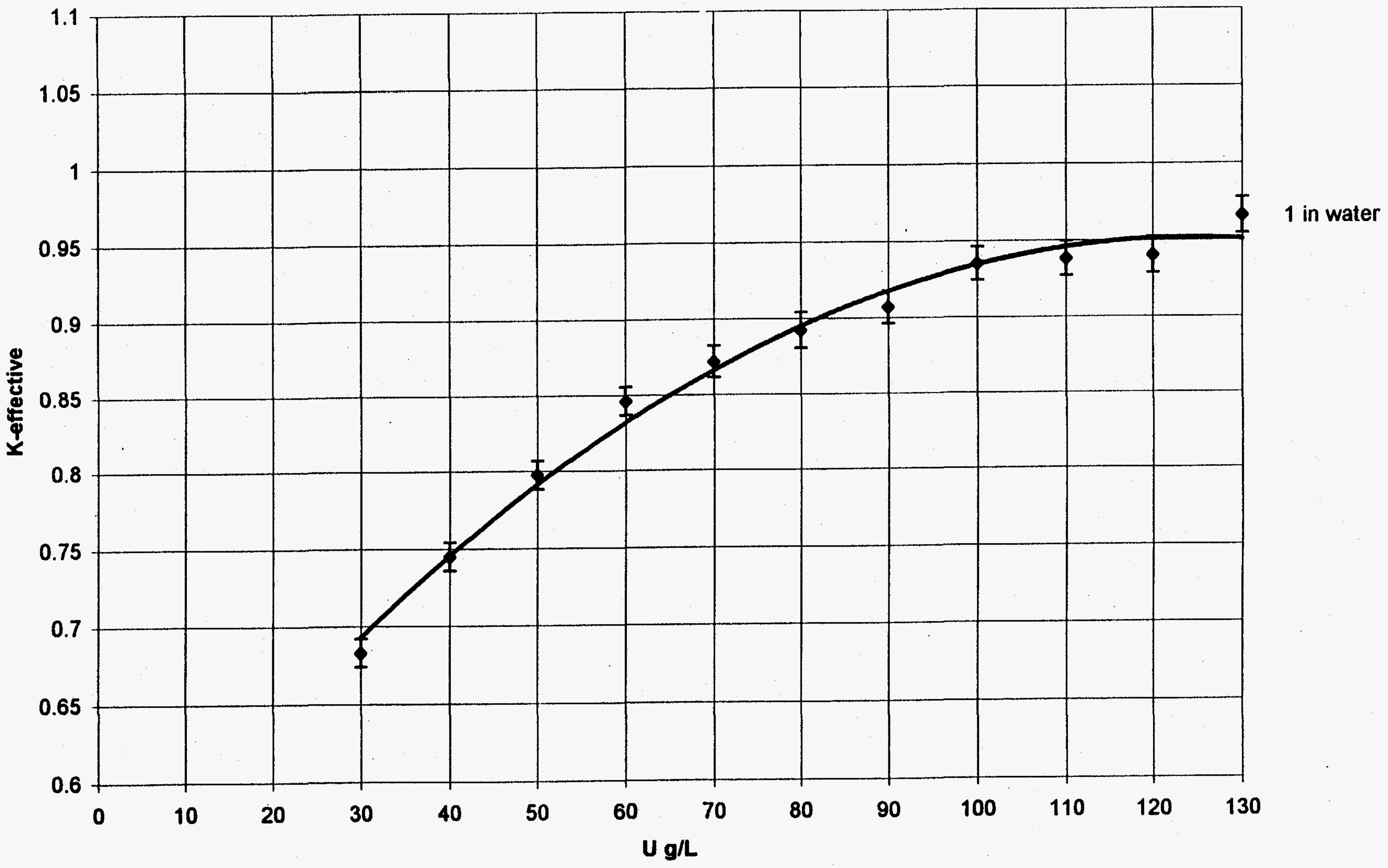


Fig. 22. Case 1, 1-in. reflection, 100% iron motor parts.

conditions, and below 0.95 for all but the 130 g/L condition. The fissile solution fraction in the motor region in Case 1 is 18%.

Case 2, 100% copper motor parts

For Case 2, iron and copper motor parts (the armature and the field coil) are modeled as consisting only of copper. Aluminum and iron motor parts are again assumed to consist only of aluminum since it is a low neutron absorber. Calculated k_{eff} are shown in aluminum, since it is a low neutron absorber. Calculated k_{eff} are shown in Table 5. The k_{eff} chosen is the average k_{eff} which occurs for 103 generations run. Values were obtained for uranium concentrations from 30 to 130 g/L at 1-in. and 12-in. water reflection. The graphs of these results are shown in Figs. 23 and 24, with error bars indicating the 95% confidence interval of the data based on two standard deviations. With 12-in. reflection, it again appears that at a concentration of 70 g/L of uranium k_{eff} approaches 0.95 within two standard deviations. With 1-in. reflection, it appears that at a concentration of 110 g/L of uranium k_{eff} exceeds 0.95 within two standard deviations. In this case, 100 g/L is below the 95% confidence interval of the data. The neutron absorbance cross section at 2200 m/s for ^{63}Cu is 3.79 b as compared with 2.63 b for ^{56}Fe so the lower k_{eff} in Case 2 is reasonable.

Table 5. Case 2, 100% copper motor parts

12-in. reflection				1-in. reflection			
g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$	g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$
30	0.7304	0.0078	0.7382	30	0.6713	0.0082	0.6795
40	0.8119	0.0078	0.8197	40	0.7531	0.01	0.7631
50	0.8594	0.0092	0.8686	50	0.8034	0.0106	0.814
60	0.903	0.01	0.913	60	0.8437	0.0098	0.8535
70	0.931	0.011	0.942	70	0.8641	0.0108	0.8749
80	0.9583	0.0098	0.9681	80	0.8852	0.011	0.8962
90	0.9895	0.0106	1.0001	90	0.9084	0.0124	0.9208
100	0.9983	0.0098	1.0081	100	0.9176	0.0116	0.9292
110	1.0207	0.011	1.0317	110	0.9445	0.0108	0.9553
120	1.0215	0.01	1.0315	120	0.9471	0.0114	0.9585
130	1.0348	0.0104	1.0452	130	0.9702	0.0102	0.9804

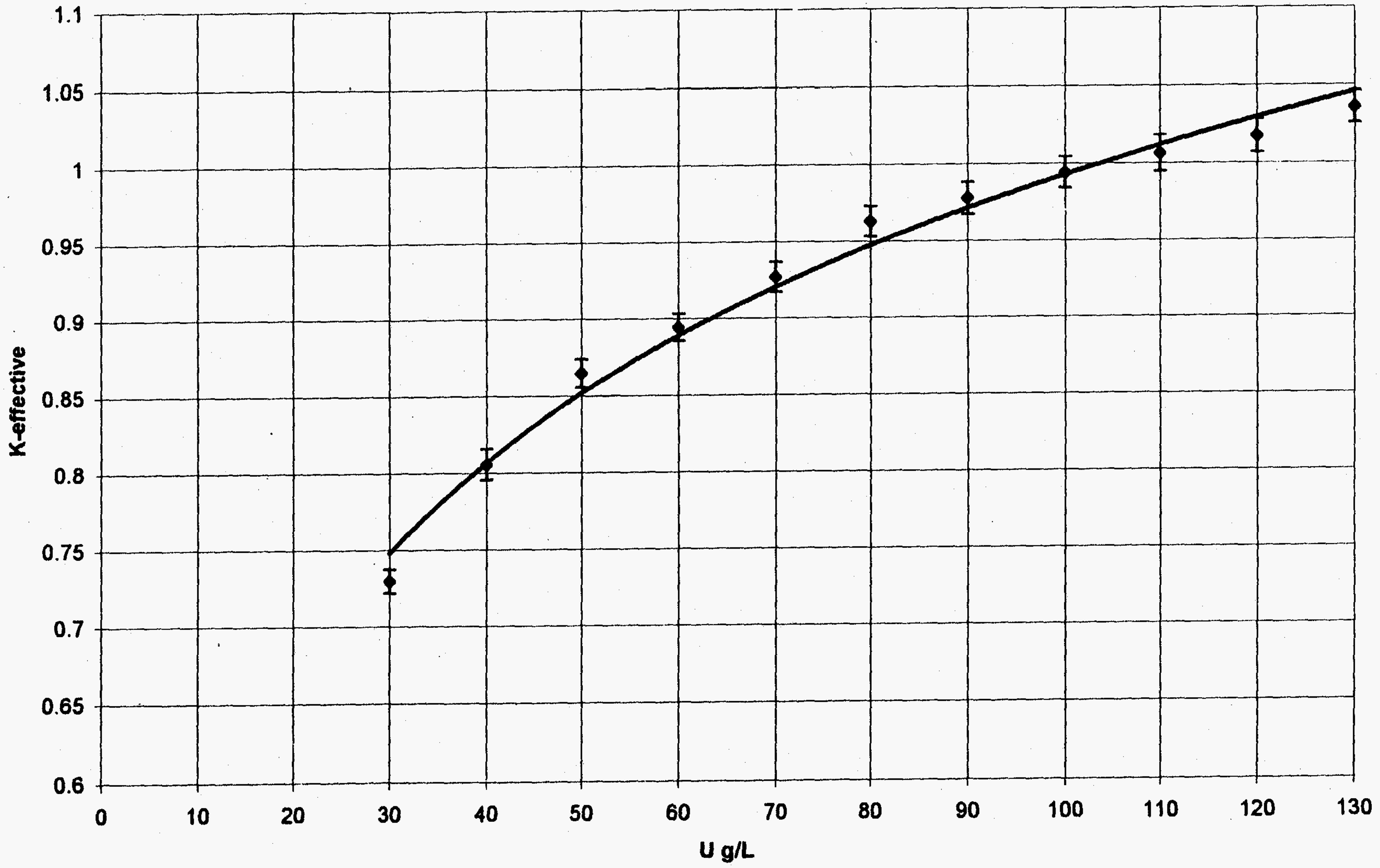


Fig. 23. Case 2, 12-in. reflection, 100% copper motor parts.

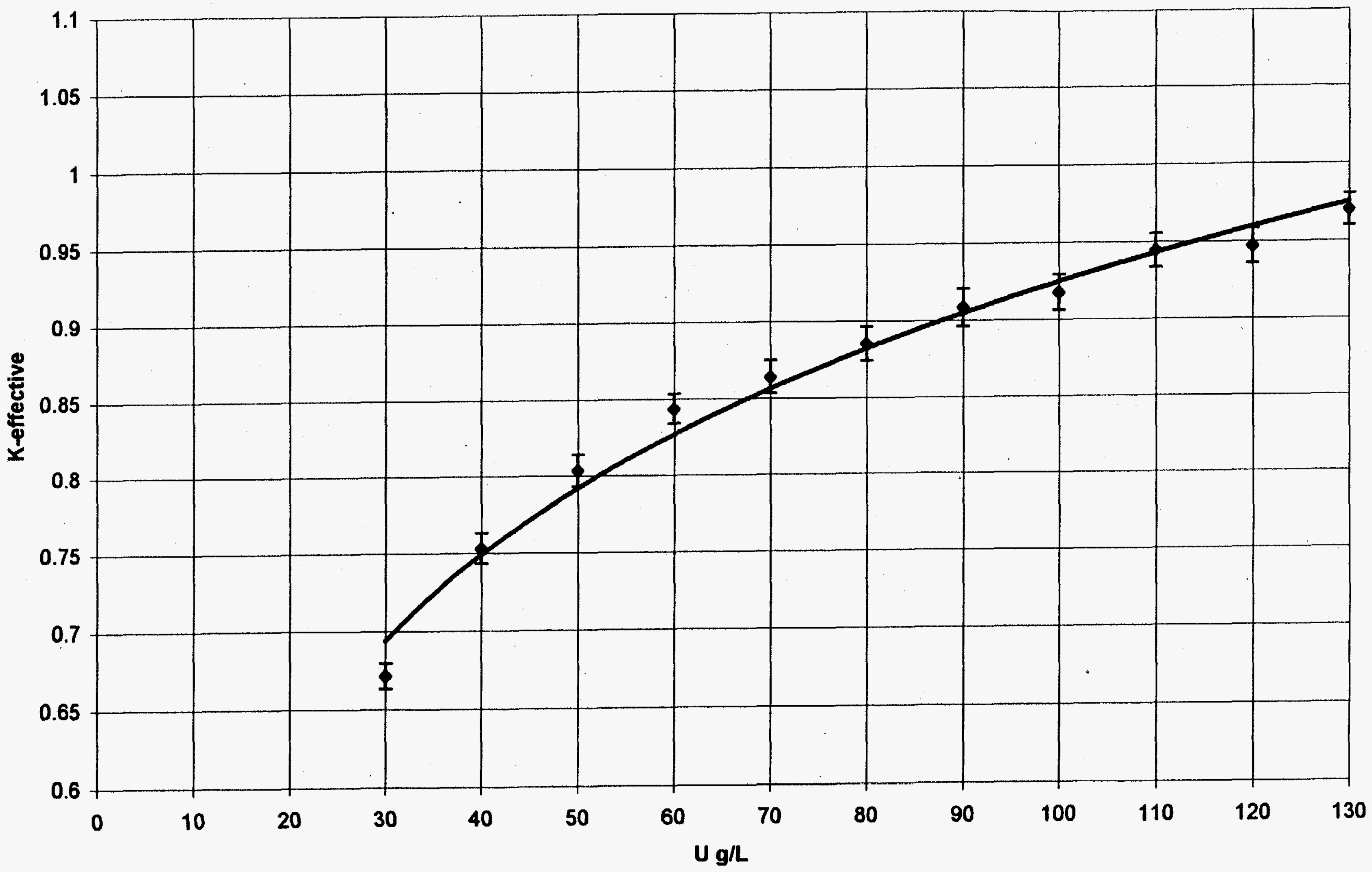


Fig. 24. Case 2, 1-in. reflection, 100% copper motor parts.

Case 3. 50% copper/50% iron parts

For Case 3, iron and copper motor parts (the armature and the field coil) are modeled as a 50:50 mixture of iron and copper. Again, aluminum and iron parts are assumed to consist only of aluminum, since it is a low neutron absorber. Calculated k_{eff} are shown in Table 6. The k_{eff} chosen is the average k_{eff} which occurs for 103 generations run. Values were obtained for uranium concentrations from 30 to 130 g/L at 1-in. and 12-in. water reflection. The graphs of these results are shown in Figs. 25 and 26, with error bars indicating the 95% confidence interval of the data based on two standard deviations. With 12-in. reflection, it again appears that at a concentration of 70 g/L of uranium k_{eff} does not reach 0.95 within two standard deviations. With 1-in. reflection, however, it appears that at a concentration of 110 g/L of uranium k_{eff} exceeds 0.95 within two standard deviations. In this case, 100 g/L is clearly below the 95% confidence interval of the data and may be a better figure to choose. The fissile solution fraction in the motor region is 19% in this case.

Table 6. Case 3, 50% copper/50% iron motor parts

12-in. reflection				1-in. reflection			
g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$	g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$
30	0.7259	0.0078	0.7345	30	0.6713	0.008	0.6793
40	0.8002	0.0082	0.8092	40	0.7531	0.0088	0.7619
50	0.8658	0.0096	0.8762	50	0.8034	0.0112	0.8146
60	0.9046	0.0086	0.9152	60	0.8437	0.01	0.8537
70	0.9294	0.0096	0.9386	70	0.8641	0.011	0.8751
80	0.9629	0.0108	0.9725	80	0.8852	0.0106	0.8958
90	0.9889	0.01	0.9997	90	0.9084	0.0122	0.9206
100	0.998	0.0116	1.0096	100	0.9176	0.0112	0.9288
110	1.0091	0.0104	1.0201	110	0.9445	0.012	0.9565
120	1.0234	0.0106	1.034	120	0.9471	0.0114	0.9585
130	1.0386	0.0114	1.0488	130	0.9702	0.0126	0.9828

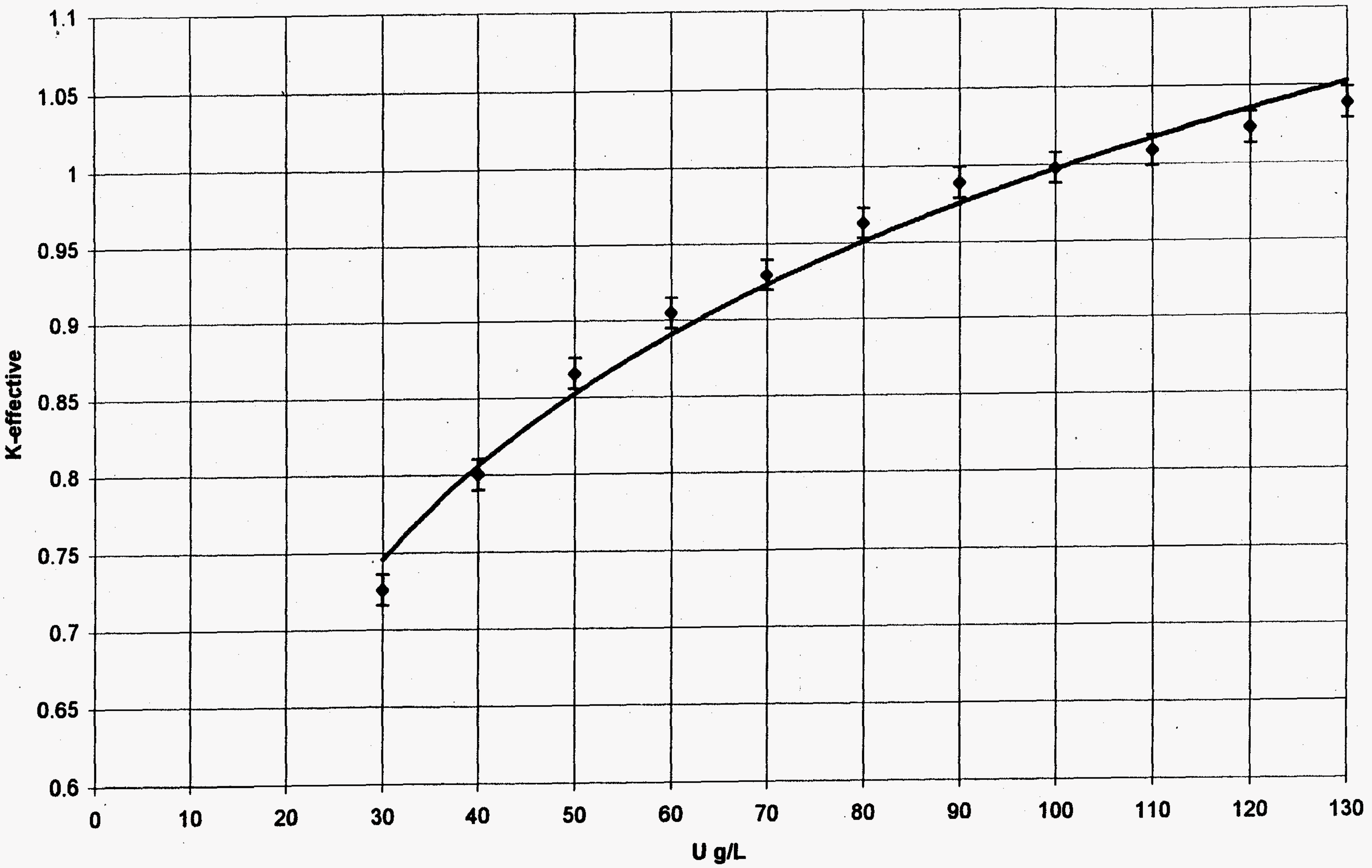


Fig. 25. Case 3, 12-in. reflection, 50% copper/50% iron motor parts.

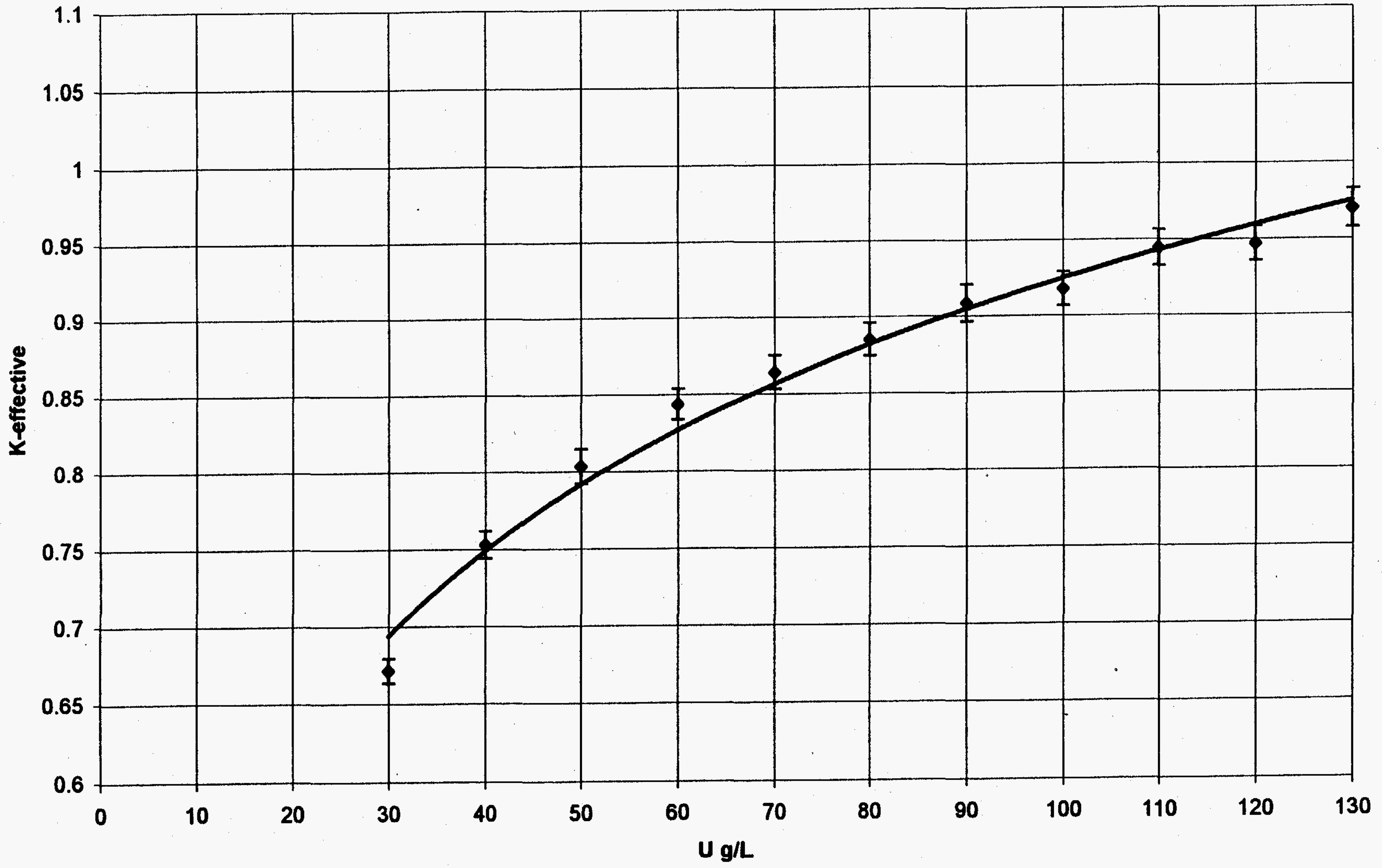


Fig. 26. Case 3, 1-in. reflection, 50% copper/50% iron motor parts.

Case 4, motor is entirely void

For Case 4, all iron, copper, and aluminum parts are removed from the motor assembly and the volume previously occupied by the motor is filled with fissile solution. This case is investigated for reasons of sensitivity analysis and does not represent a realistic case of motor geometry. The k_{eff} chosen is the average k_{eff} which occurs for 103 generations run. Values were obtained for uranium concentrations from 30 to 130 g/L at 1-in. and 12-in. water reflection. The numerical results are shown in Table 7. The graphs of these results are shown in Fig. 27 and 28, with error bars indicating the 95% confidence interval of the data based on two standard deviations. With 12-in. reflections, it appears that a concentration of 60 g/L of uranium k_{eff} approaches 0.95 within two standard deviations—not greatly different from the previous cases. With 1-in. reflection, it appears that at a concentration of 70 g/L of uranium k_{eff} is close to 0.95 within two standard deviations. This is quite a bit lower concentration than the previous cases and indicates that the unreflected case is much more sensitive to the changes in the fissile solution volume.

Table 7. Case 4, all motor parts are replaced with fissile solution

12-in. reflection				1-in. reflection			
g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$	g U/L	k_{eff}	2σ	$k_{eff}+2\sigma$
30	0.7722	0.0082	0.7804	30	0.7214	0.009	0.7304
40	0.843	0.0086	0.8516	40	0.7972	0.01	0.8072
50	0.9085	0.01	0.9185	50	0.8469	0.0098	0.8567
60	0.9324	0.0102	0.9426	60	0.8886	0.0116	0.9002
70	0.9708	0.0104	0.9812	70	0.9155	0.0096	0.9251
80	1.0033	0.0104	1.0137	80	0.9408	0.0096	0.9504
90	1.0174	0.0112	1.0286	90	0.9507	0.011	0.9617
100	1.0303	0.0096	1.0399	100	0.9688	0.012	0.9808
110	1.0446	0.0112	1.0558	110	0.978	0.0108	0.9888
120	1.0533	0.012	1.0653	120	0.9981	0.0122	1.0103
130	1.0739	0.0054	1.0847	130	1.0103	0.0104	1.0207

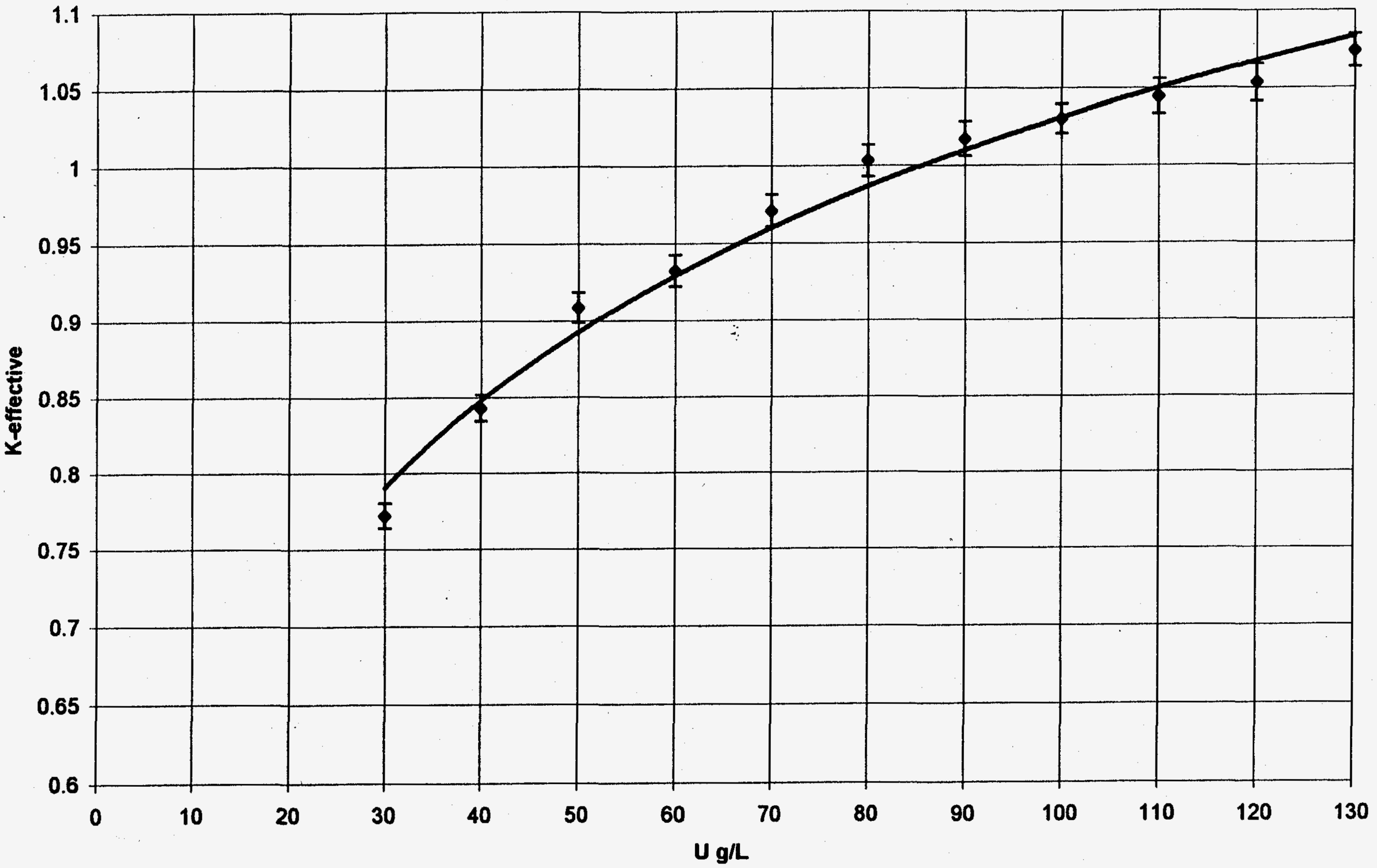


Fig. 27. Case 4, 12-in. reflection, motor parts replaced with fissile solution.

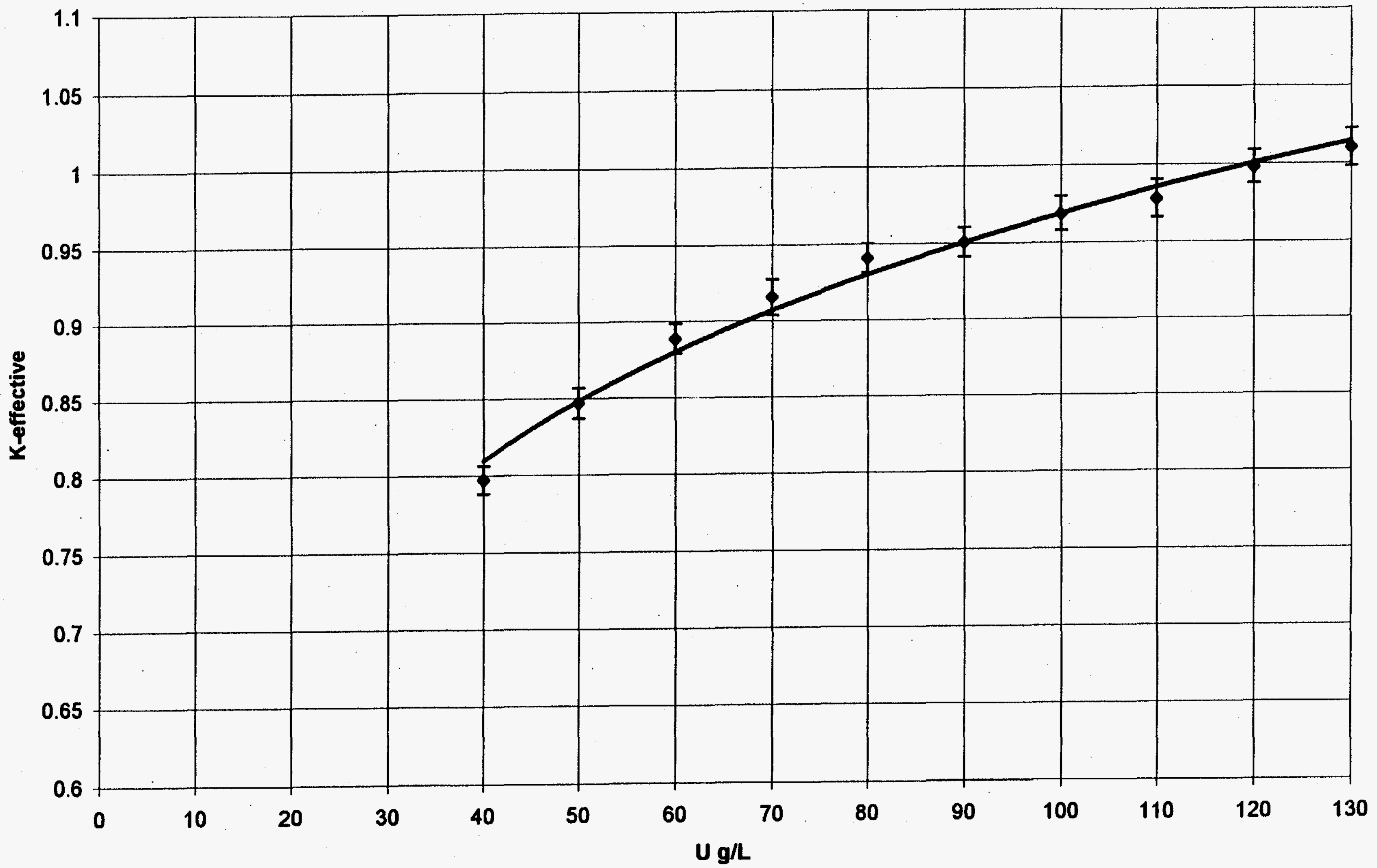


Fig. 28. Case 4, 1-in. reflection, motor parts replaced with fissile solution.

Sensitivity analyses were performed around baseline Case 1 (100% motor/fan parts constructed of iron) parameters using varying numbers of fission generations and a fixed number of 300 neutrons per generation with three generations skipped. The case of 12-in. reflection and 100 g/L was chosen, in particular, because it produced k_{eff} values which were very close to 1.0. The k_{eff} calculated versus number of generations is shown in Fig. 29 with 300 neutrons per generation. We see that the k_{eff}, in general, is fairly constant in value with an increasing number of generations; there is some scatter and a smooth curve is not generated. On the other hand, when the standard deviation, sigma, is plotted against the number of fission generations, as in Fig. 30, a very smooth curve is generated. The standard deviation diminishes asymptotically with an increasing number of generations.

A short analysis was also performed for a case in which the volume occupied by the HEPA filters and other parts was considered not as fissile solution but as volume which was unavailable to contain fissile solution. This analysis was performed for the following reasons. In Cases 1 through 4, the objective was to underestimate the volume occupied by the internal parts of the vacuum cleaner. The purpose there was to make a conservative estimate of the likelihood of a criticality occurring if all the parts of the machine became flooded. Critical concentrations were then calculated on the supposition that the entire machine was flooded. The mass of uranium in the vacuum cleaner was then estimated based on the vacuum cleaner volume. However, the case should be considered in which the mass calculated above is dissolved in solution that cannot reach all parts of the vacuum cleaner, i.e., in which the uranyl fluoride solution containing the above-calculated critical mass is contained in the minimum volume of vacuum cleaner that could be vacant. This involves making the most generous estimate of the occupied motor and filter volume, rather than the most conservative, as was done in Cases 1 through 4. The resulting void volume of the vacuum cleaner was reduced from 20.0 L to approximately 9.1 L. Therefore, the mass, 1400 g of uranium, which produced a k_{eff} of near 0.95 would now be confined to a volume of 9.1 L. The mass confined now to this volume would yield a concentration of 153 g/L of uranium. Criticality calculations were again performed assuming the volumes occupied by solution in Cases 1 through 4 now to be occupied by water, and the void volumes remaining to be

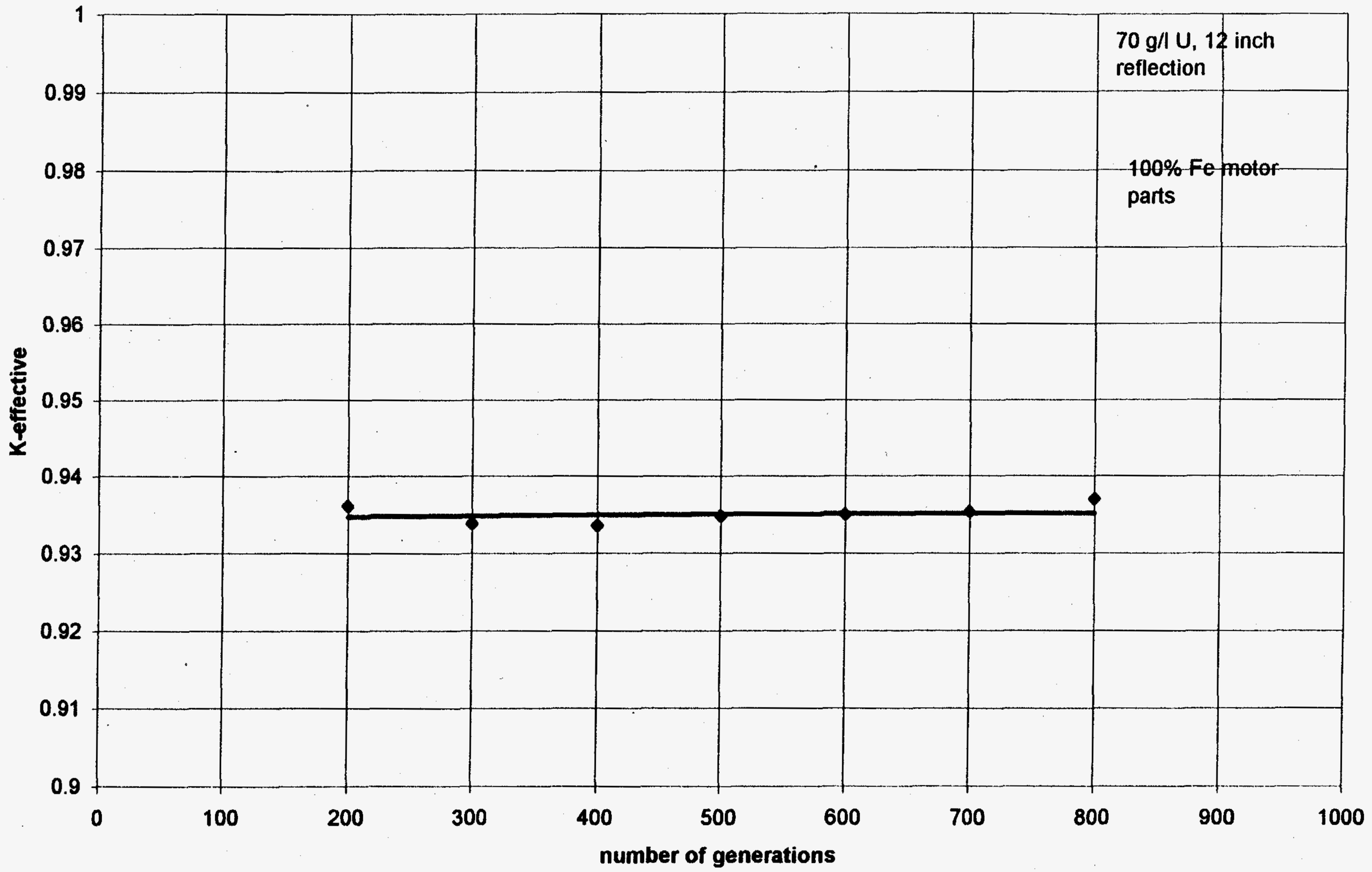


Fig. 29. K_{eff}, Case 1 vs number of generations, 300 neutrons per generation.

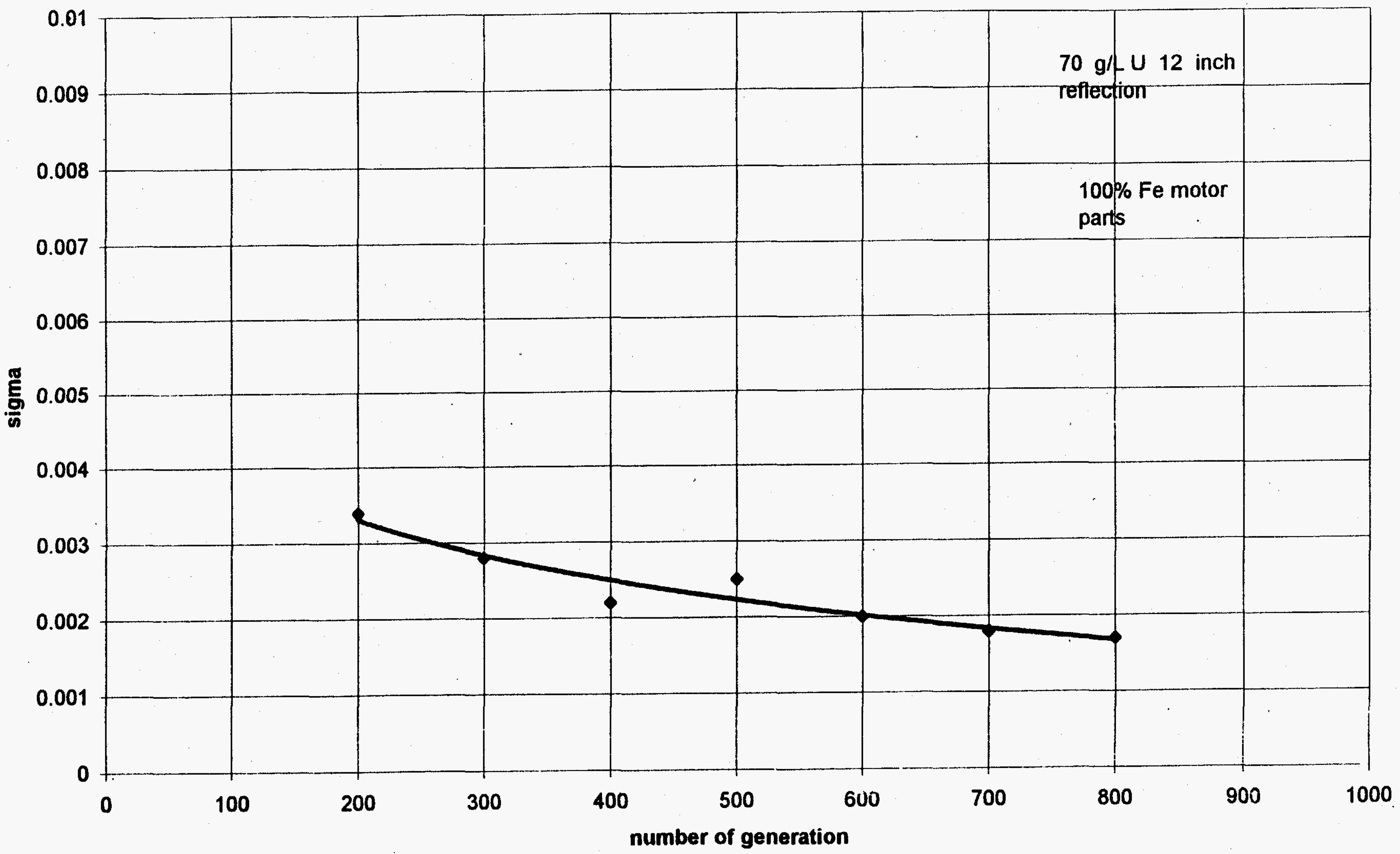


Fig. 30. Standard deviation vs number of generations, Case 1, 300 neutrons per generation.

occupied by uranium solution at 153 g/L. A k_{eff} of 0.9115 was calculated at 153 g/L. Therefore, the previous mass estimates of 1400 g at 100% enrichment should be conservative with regard to a criticality arising from this new hypothetical condition.

The effect in Case 1 at 12-in. water reflection on k_{eff} of diminishing the ^{235}U enrichment level to 20% was examined and the results are shown in Fig. 31 as a graph of k_{eff} vs total U concentration in g/L. It can be readily seen that k_{eff} does not approach 0.95 within 2σ until concentration of 700 g/L is reached, about 10 times greater than at 100% enrichment. The saturation concentration is approximately 1200 g U/L of UO_2F_2 in water according to the SCALE data library. This corresponds to a uranium mass of 28 kg. The results are shown in Table 8.

4.2 CONCLUSIONS

A detailed evaluation was made of the geometry, materials of construction, and conditions in which criticality would be produced of a Nilfisk Corp Model GSJ compact vacuum cleaner for a range of uranium concentration. Criticality calculations were performed for three different cases of motor and fan assembly construction at 100% enrichment. These three cases involved different assumptions about the materials of construction of the motor and fan assembly, since no firm information was available on the exact details of their composition. In Case 1, the baseline case, all parts (which according to the manufacturer could be composed of either iron or copper) were assumed to be composed entirely of iron. In Case 2, the opposite assumption was made that all parts which could be composed of iron or copper were actually composed entirely of copper. In Case 3, it was assumed that the parts were composed of 50% copper and 50% iron. A fourth case, in which the motor was hypothetically completely removed, was also considered. This fourth case was to evaluate the sensitivity of the calculations to the motor model. The conclusion was that there is not a significant reactivity effect due to the motor modeling. The motor model utilized in Case 1 is considered conservative and most appropriate for evaluating the safety of the vacuum cleaner.

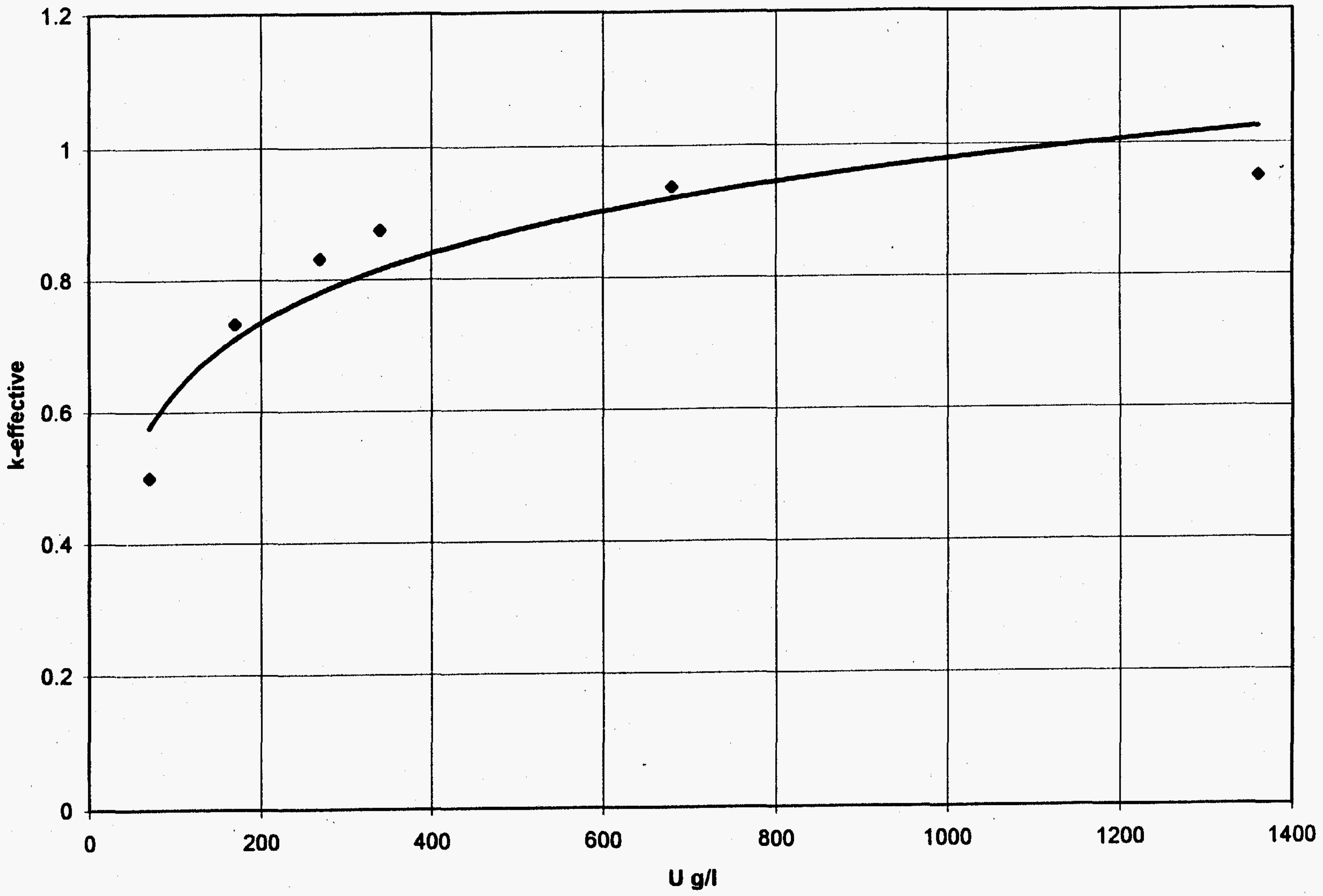


Fig. 31. K_{eff} vs total U g/L, 20% ^{235}U, 12-in. reflection.

Table 8. K_{eff} versus total uranium concentration, 20% enrichment

Baseline Case 1, 12-in. reflection	
Uranium, g/L	k_{eff}
70	0.5
270	0.8316
170	0.733
340	0.8748
680	0.9368
1360[a]	0.95

[a] Probably beyond saturation concentration for UO_2F_2.

The results of the criticality calculations for the three principal cases are shown in the Executive Summary for 12-in. water reflection and 70 g U/L and 1-in. nominal water reflection and 110 g U/L. In the case of 12-in. water reflection, a k_{eff} of less than 0.95 within two standard deviations is generated for the three principal cases of motor/fan assembly parts consisting of iron (Case 1), copper (Case 2), and a 50:50 iron/copper mixture (Case 3). This corresponds to a maximum mass of 1400 g of U at the 20-L volume that was calculated from the modeled geometry as described in Sect. 3 (compare actual volume, 19.1 L, Appendix E). In the case of 1-in. water reflection and 100 g U/L, the calculated k_{eff} is very close to 0.95 within two standard deviations in Case 1 and exceeds it in Cases 2 and 3. Therefore, a maximum concentration of 100 g/L or a total mass of 2000 g is recommended in this case. Figure 32 depicts the results of the baseline Case 1 calculations of k_{eff} vs uranium concentration at 1-in. and 12-in. water reflection along with a polynomial curve fit.

An analysis of the vacuum cleaner was made under the assumption that parts which were unlikely to contain solution did not contain any solution. This analysis assumed that the remaining volume of the machine was then filled with a uranyl nitrate solution of

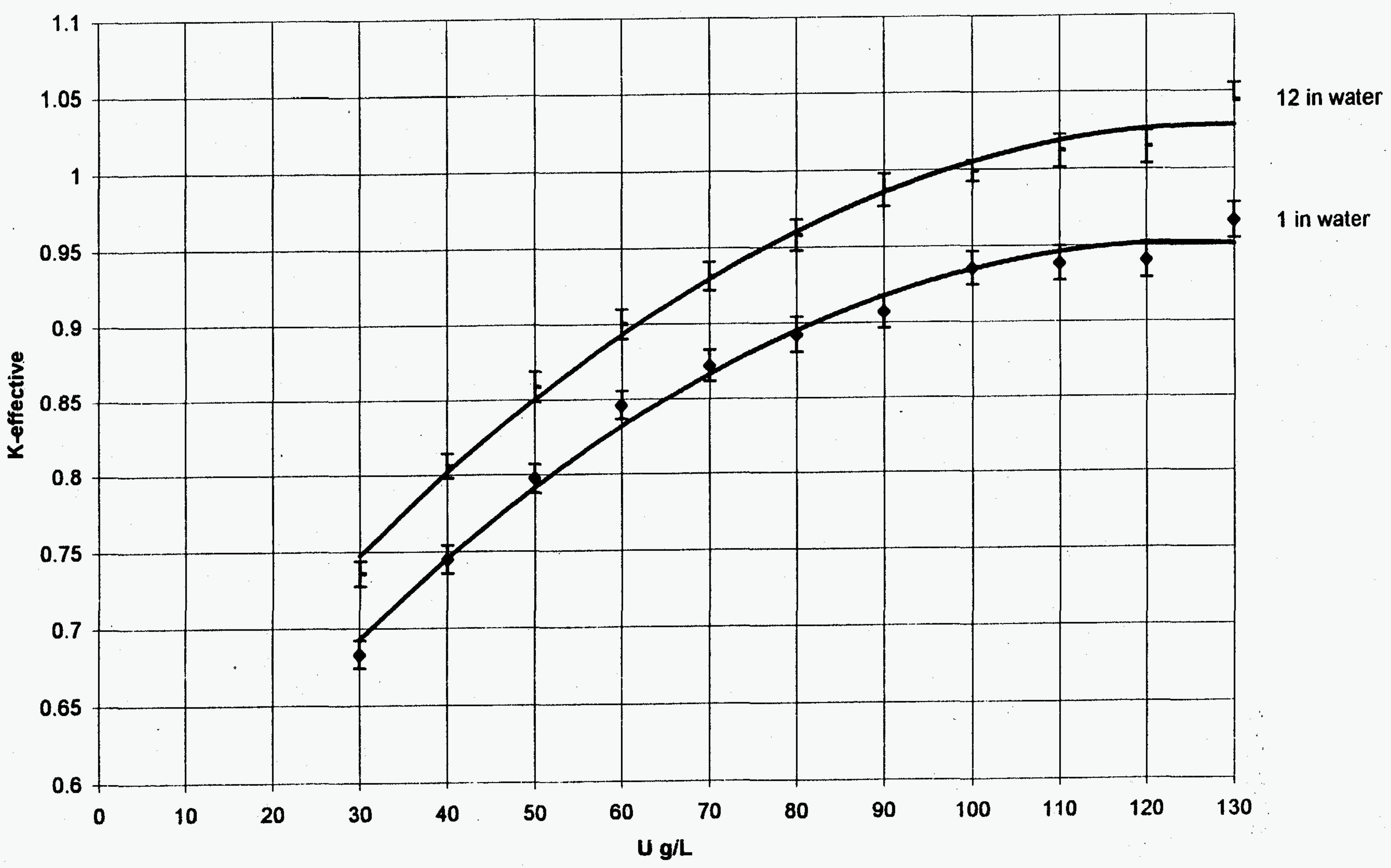


Fig. 32. Baseline Case 1 calculations of k_{eff} vs uranium concentration 1-in. and 12-in. water reflection.

correspondingly greater concentration. The k_{eff} generated at 1400 g total U mass was 0.9115, safely below 0.95.

An analysis of the k_{eff} at an enrichment of 20% ^{235}U revealed that in the baseline Case 1 at 12-in. reflection, k_{eff} did not exceed 0.95 at 680 g U/L (total) and appeared to reach 0.95 only near 1360 g U/L (total) (saturation is below 1300 g/L per KENO). A sample output from the baseline Case 1, 70 g U/L uranium, 12-in. reflection is provided in Appendix B.

5. CODE VALIDATION

Section 3.1 describes the calculational method. In summary, the SCALE computer code was used in this nuclear criticality evaluation. The CSAS25 control sequence of SCALE and the 27 energy group library, based on ENDF/B-IV cross section, were used for all computations. The CSAS25 control sequence activates modules BONAMI-S, NITAWL-S and KENO V.a. Scoping sensitivity calculations were done on a personal computer with an unvalidated version of SCALE-PC. Key calculations at critical conditions were done with a validated version of the SCALE 4.1 code and KENO V.a ran on the K-25 Site IBM 3090 main frame computer. Reference 6 documents the validation.

The SCALE 4.1/KENO V.a and SCALE 27 group cross sections were validated for the IBM 3090 (MK25B) mainframe at the Oak Ridge K-25 Site by comparing calculated predictions to 245 critical experiment results at $k_{eff} = 1.0$. The validation demonstrated the functionality and ability of the SCALE codes and cross section input data to accurately calculate critical experiments results. A statistical analysis was performed and a lower k_{eff} acceptance criteria of $k_{eff} + 2\sigma$ <0.9605 was established. That is, a calculated $k_{eff} + 2\sigma < 0.9605$ may be considered safely subcritical. Because of the broad range of enrichment and moderation considered in this analysis of the vacuum cleaner, an additional 1% margin was included for this work. Thus, a system with a calculated $k_{eff} + 2\sigma > 0.95$ is considered unsafe and may be critical. The SCALE mainframe and personal computer (PC) code results are shown together in Fig. 33. The calculated k_{eff} agree to within two standard deviations. Code validations were provided by running the PC source codes for Cases 1, 2,

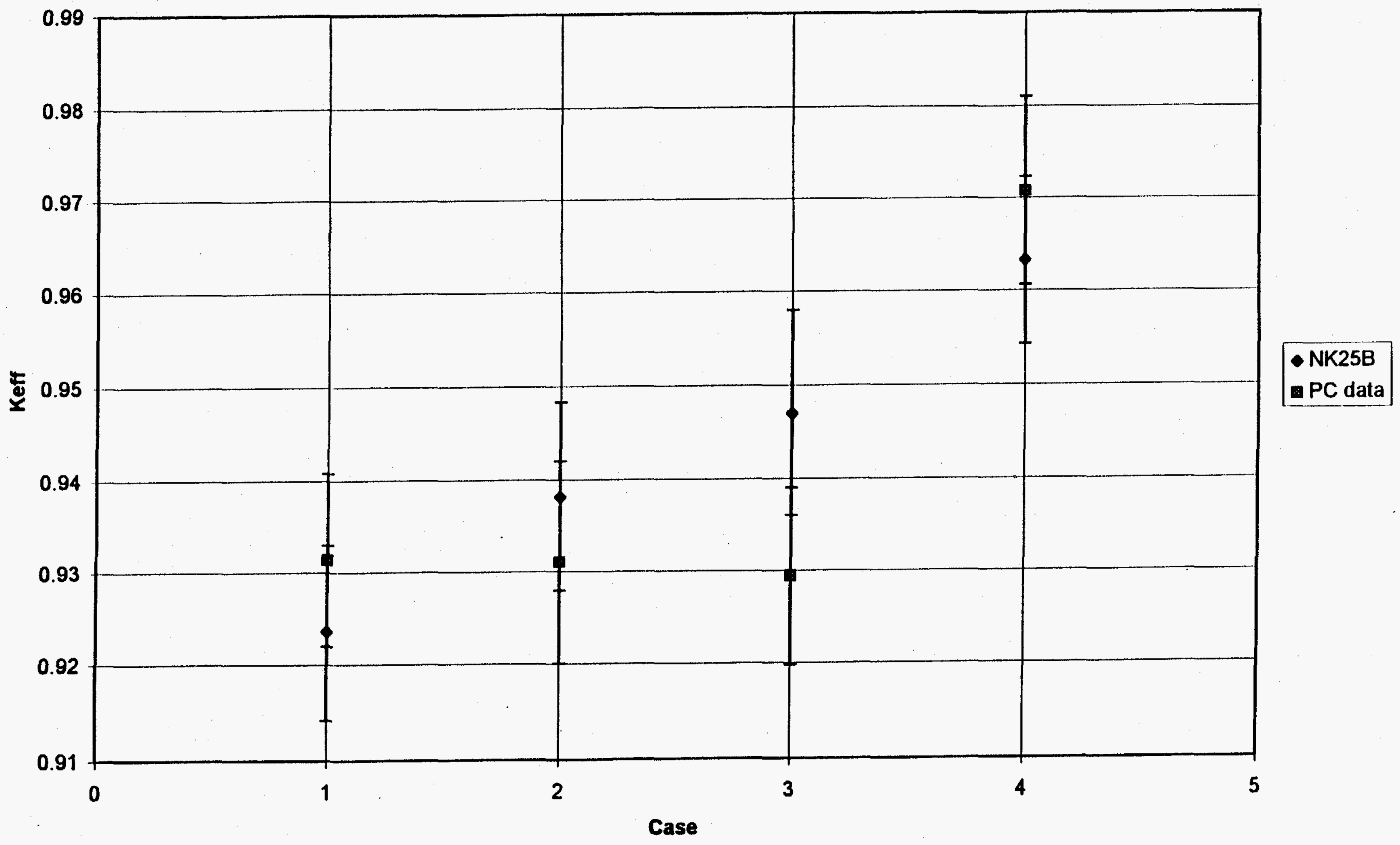


Fig. 33. Comparison of validated and PC k_{eff} results (error bars represent two sigma).

and 3 at fissile uranium concentrations of 70 g U/L on the NK25B validated mainframe computer. The results are contained in Table 9 and, as will be observed, fall in most cases near to within two sigma of the PC scoping calculations. This is further justification for the additional ≈1% safety margin taken on the k_{eff} acceptance criterium. There were minor errors in the codes executed in these cases, which have since been corrected, and should not affect the bias of the results.

Table 9. Comparison of validated and PC k_{eff} results

Case	Runs	NK25B data		PC data	
		k_{eff}	σ	k_{eff}	σ
1	C70R2	0.9236[a]	±0.0047	0.9314	±0.0047
2	C27R1	0.9381	±0.0051	0.9310	±0.0055
3	C37R1	0.9470	±0.0055	0.9294	±0.0048
4	C47RD	0.9633	±0.0045	0.9708	±0.0051

[a] There was a slight error in the densities of aluminum and iron in this calculation of the order of 3% and they were not recalculated.

6. REFERENCES

1. RISC Computer Code Collection, *SCALE-PC Modular Code System for Performing Criticality Safety Analyses for Licensing Evaluation, Version 4.1, Part 1*, CCC-619, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

2. Nilfisk of America, Inc., Malvern, Pennsylvania, Nilfisk Compact Vac Product Literature, March 1996.

3. Dimento, V., Nilfisk of America, Inc., Malvern, Pennsylvania, Facsimile Communication to J. Shor, July 22, 1996, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

4. Jordan, W. C., *Calculational Criticality Analyses of 10- and 20-MW* UF_6 *Freezer/Sublimer Vessels*, ORNL/CSD/TM-288, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 1993.

5. C. A. Sweet, "Criticality Safety Analysis of a Vacuum Cleaner for General High Enriched Uranium Cleanup Work," unpublished report, Lockheed Martin Energy Systems, Inc., July 28, 1993.

6. Lee, B. L., Jr. and D. M. D'Aquila, *Validation of Nuclear Criticality Safety Software and 27 Energy Group ENDF/B-IV Cross Section*, POEF-T-3636, Rev. 1, Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio (January 1996).

APPENDIX A. MODELING CALCULATIONS

APPENDIX A. MODELING CALCULATIONS

Nilfisk data:

1. Armature	1.25 lbs	567.5 g	Cu/Fe	Δ_{Fe} = 7.86 g
2. Field coil	2.00 lbs	908.0 g	Cu/Fe	Δ_{Cu} = 8.96 g
3. Fan assembly	1.25 lbs	567.5 g	A1	
4. Motor assembly	2.25 lbs	1021.0 g	A1/Fe	

Total motor volume: 6 in. × $1.75^2 \pi$ = 57.7 in.^{3} = 945 cc
h × $r^2\pi$

Case 1, Baseline

Assume Parts 1 and 2 are entirely of iron. Parts 3 and 4 are entirely of aluminum. Then, we have 1484 g of iron, 1589 g of aluminum. M.W. = 55.8, i.e., 189 cc of iron + 588 cc of aluminum = 777 total occupied volume and 168 cc void volume or ~18%.

Consider smeared densities:

Thus, rho molar of iron = 0.028; rho atom = 0.017 atoms/b·cm^2, and aluminum = 0.06228; rho atom = 0.0375 atoms/b·cm^2.

where, $6.022 \times \frac{10^{23}\ \text{atoms}}{\text{mole}}$ $\quad 1\times \frac{10^{-24}\ \text{b}}{\text{cm}^2}$

Case 2

Assume Parts 1 and 2 are all copper, Parts 3 and 4 are entirely aluminum. Then we have 1484 g of copper and 1589 g of aluminum.

Δ atomic Cu = 1484/63.54 · 945 (0.622) = 0.0148

Δ atomic Al = 0.0375 again

Volume of copper = 1484/8.96= 165 cc

Volume of aluminum = 588 cc

Total volume = 754 cc

Void volume = 191 cc or 20%

Case 3

50:50 mixture of copper and iron

Now, we have	742 g copper	82.8
	742 g iron	97.4
	1589 g aluminum	<u>588 cc</u>

Therefore, Δ atomic copper = 0.00744

Δ atomic iron = 0.0084

Δ atomic aluminum = 0.0375.

APPENDIX B. CRITICALITY SAFETY CALCULATION CHECK-OFF SHEET

APPENDIX B

CRITICALITY SAFETY CALCULATION CHECK-OFF SHEET

Problem: NCS Calculations for the K-25 Site Vacuum Cleaner K/ER-314
Computer: NK25B mainframe & PC Code: SCALE4.1 & SCALE-PC

ASSEMBLE INFORMATION (Check one and attach information)

☐ The information was submitted on a NCSA and the front bore two signatures.
☒ The information was gathered by ______ (analyst) and checked by W Curt Jordan (peer reviewer)
☐ A written statement of the problem to be analyzed exists between ______ (analyst) and others involved in design.

CHOOSE CONDITIONS TO CALCULATE (Attach NCSE form if available)

The normal and abnormal conditions to be calculated were chosen by ______ (analyst) with appropriate input from engineering, operations, etc.

The normal and abnormal conditions calculated were reviewed by W Curt Jordan (peer reviewer) with appropriate input from engineering, operations, etc.

DESIGN CALCULATIONAL MODEL (Attach Calculational Model Description)

The calculational model was designed by ______ (analyst)

The calculational model was reviewed by W Curt Jordan (peer reviewer), and it was found to be neither too conservative nor non-conservative.

PREPARE INPUT DATA (Attach Input Data)

The computer input data was prepared by ______ (analyst)

The computer input data was reviewed by W Curt Jordan (peer reviewer) and found to be correct and with the proper selection of computer program options.

COMPUTE

The computer program and cross-sections have been validated and this is documented in K/ER-314 (letter or report) (analyst)

The subcritical limit for this application is 1400 (analyst)

No changes have been authorized to the computer program or cross-sections without subsequent retesting or validation: the job was run on the correct computer; a routine check of the program and cross sections have been made within the last 100 days

______ (Criticality Safety Organization Manager)

INTERPRET RESULTS (Attach Results)

The results have been reviewed and checked by ______ (peer reviewer) who has determined that the answers were not misread, the calculations converged, there was representative sampling for Monte Carlo calculations, the method is validated, the range of validated applicability is not exceeded, and no conclusion is based on only one calculation.

COMMUNICATE CONCLUSIONS (Attach Conclusions)

The assumptions, results, bias, and conclusions of the calculational study are in writing and have been checked for logic and errors by

______ (Criticality Safety Organization Manager)

REVIEW (Attach Review)

Calculational studies which are not considered routine or which support a change in plant philosophy are to be reviewed externally.

The analyst thinks these calculations (should/should not) be reviewed. (Circle one)

The peer reviewer thinks these calculations (should/[✓ should not]) be reviewed (Circle one) WCJ 1/2/97

The Criticality Safety Organization Manager thinks these calculations (should/should not) be reviewed. (Circle One)

NOTE: One or more "Should" votes requires the review.

APPENDIX C. KENO-CODE-GENERATED MAP OF VACUUM CLEANER

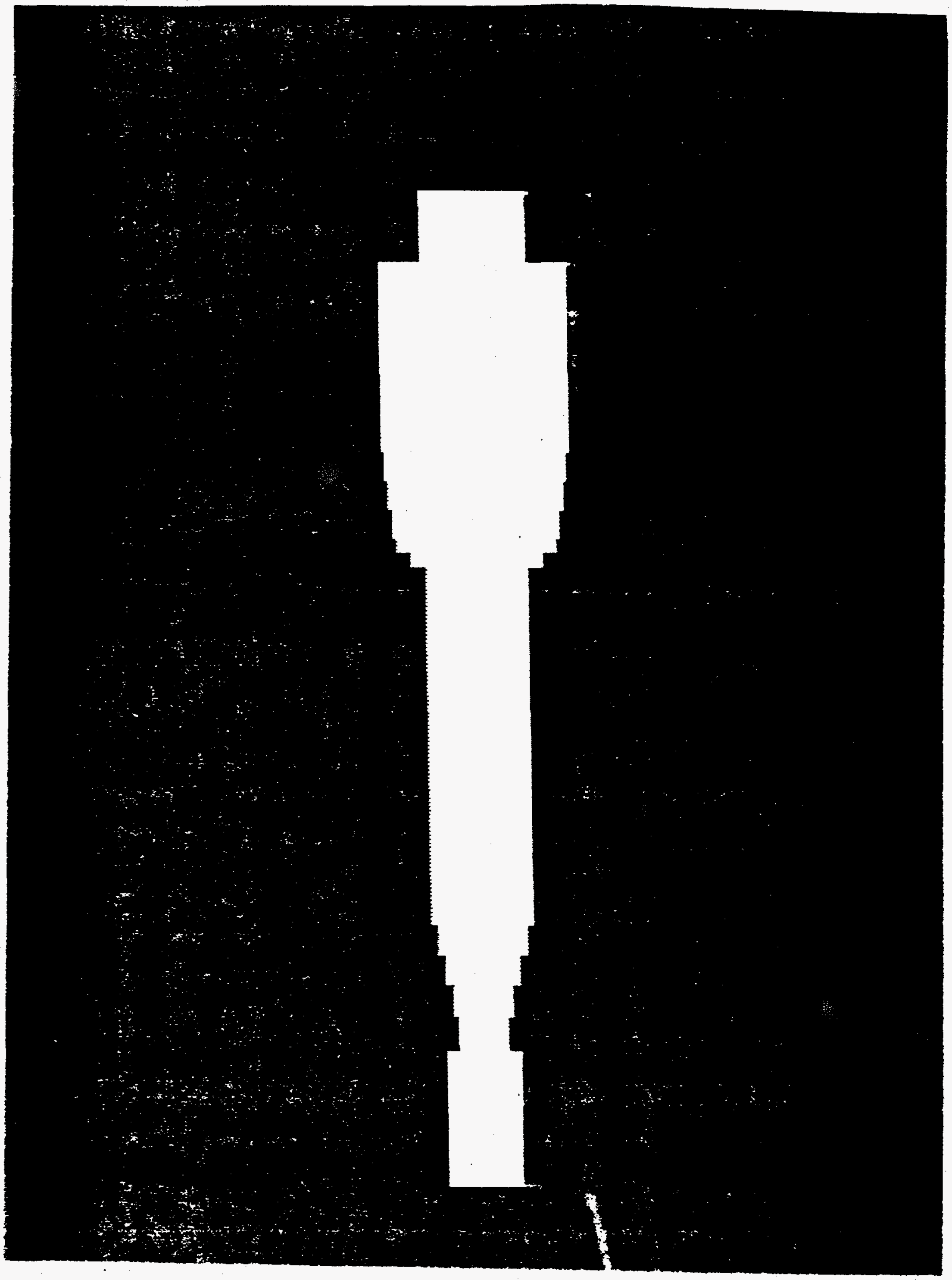


Fig. C-1. KENO-Code-generated map of vacuum cleaner.

APPENDIX D. VOLUMES OF UNITS 1 THROUGH 18, CALCULATED BY EXCEL AND KENO

Calculated volumes of individual units of model

Unit	Radius	Height	Volume
1	4.445	17.15	1,063.989
2	2.857	4.127	105.7754
3	3.505	3.81	146.9707
4	4.39	3.81	230.5598
5	5.289	3.81	334.6584
6	6.18	3.81	456.911
7	6.185	40.64	4,881.606
8	8	1.74	349.6704
9	9.65	1.74	508.7841
10	10.1	3.58	1,146.715
11	10.55	3.58	1,251.174
12	11	3.58	1,360.185
13	11.45	3.58	1,473.749
14	11.45	3.48	1,432.583
15	8.89	1.27	315.1642
16	8.89	9.22	1,716.032
17	11.45	6.02	2,104.722
18	6.35	8.89	1,125.586
Total			20,004.84

APPENDIX E. MATH CAD ESTIMATES OF ACTUAL VACUUM CLEANER MINIMUM VOLUME

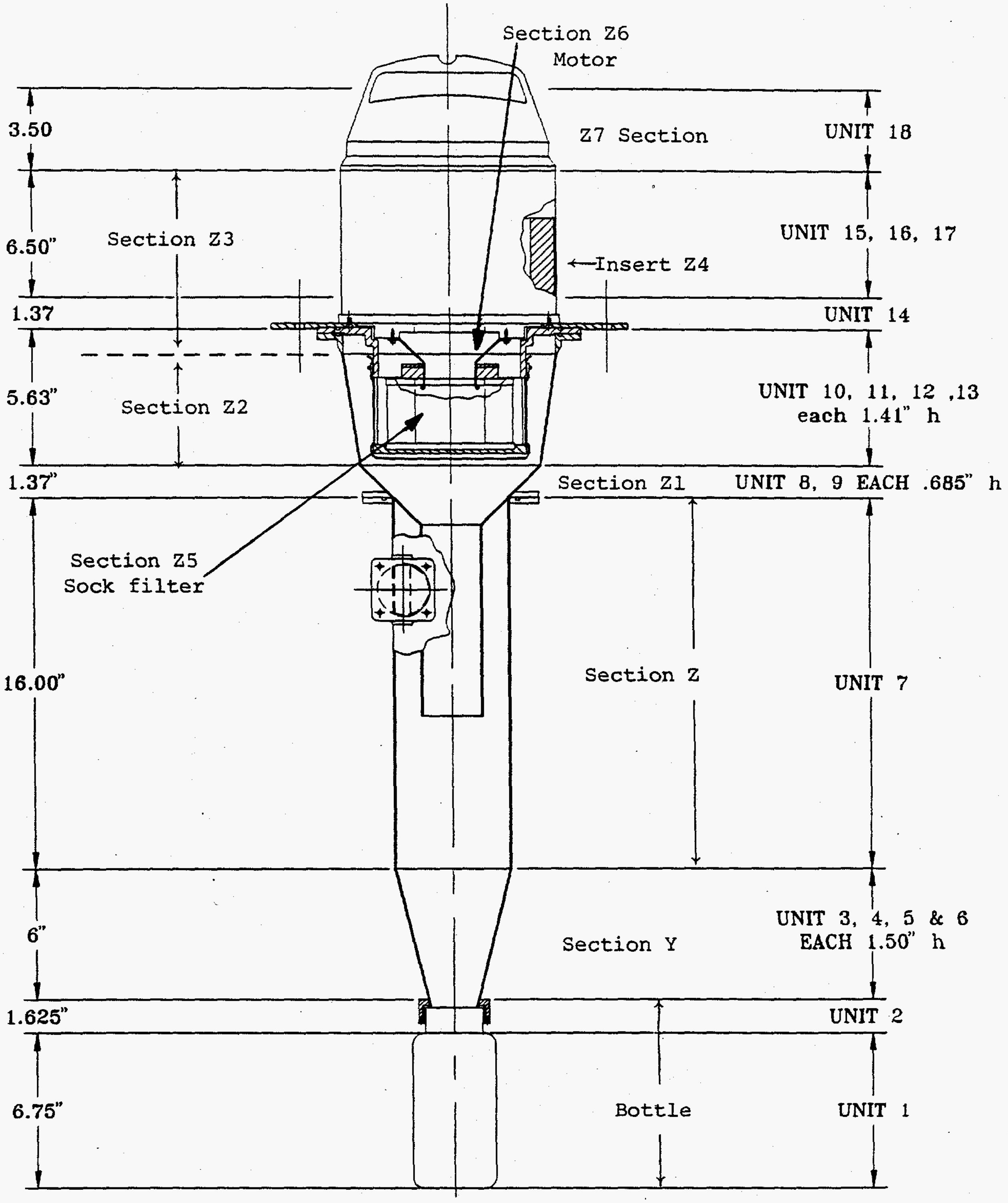


Fig. E.1. Division of vacuum cleaner into sections to calculate actual volumes.

Estimate of Minimum Volume of Actual Vacuum Cleaner

Section

$$y := \int_0^6 \left[\left(\frac{5 - 2.19}{6}\right)\cdot x + 1.08\right]^2 \cdot \pi \, dx$$

$y = 128.803$ **cubic inches**

$$z := \int_0^{16} \pi \cdot 2.5^2 \, dx$$

$z = 314.159$

$$z3 := \int_0^{.5 + 3.875 + 2.5} 4.01^2 \cdot \pi \, dx$$

$z3 = 347.305$ **uncorrected motor section volume**

$$z4 := \int_0^{4.13} \left(4.5^2 - 3.5^2\right)\cdot \pi \, dx$$ **plastic insert**

$z4 = 103.798$

Sock Filter $$z5 := \int_0^{5.38} 3.15^2 \cdot \pi \, dx$$ **included in volume**

$z5 = 167.708$

$$z1 := \int_0^{1.47} \left(\frac{7.6 - 2.5}{2.56}\cdot x + 2.5\right)^2 \cdot \pi \, dx$$

$z1 = 75.876$

$$z2 := \int_0^{4.75} \left(\frac{9.14 - 7.6}{4.75}\cdot x + 3.8\right)^2 \cdot \pi \, dx$$

$z2 = 314.605$

baseline case 1

$z6 := 47.4$ motor metal parts subtracted from total volume

$z7 := \frac{5^2}{4} \cdot \pi \cdot 3.5$ hepa filter included in volume

$T := (y + z + z1 + z2 + z3) - z4 - z6 + z7$

$T = 1.098 \cdot 10^3$

$T1 := 2.54^3 \cdot T + 1100$ 1100cc=volume of bottle

$T1 = 1.91 \cdot 10^4$ total vacuum cleaner volume, conservative estimate
in cubic centimeters

APPENDIX F. SAMPLE OF SCALE OUTPUT CASE 1, 70 g/L, 12-in. WATER REFLECTION

```
PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
 MODULE CSAS25   WILL BE CALLED
   PROBLEM  12.0 INCH H20 CONTACT REFLECTOR - 70 gU/1
   27GROUPNDF4 INFHOMMEDIUM
   SOLNUO2F2 1 70. 0. 1.0 293 92235 100.  END
   POLY(H2O) 2 1 END
   H2O 3 1 END
   FE  4 0 1.7E-2 END
   AL 4 0 3.75E-2  END
   SOLNUO2F2 4 70.  0.  .18 293 92235 100.  END
   H2O 5 3.425E-5 END
   MGCONCRETE 6 END
   SS304 7 END
   END COMP
   PROBLEM K12E100 18 CYLS IN A CUBOID ANNULUS - 70 G/L 12ff H20 REFL
   READ PARAN TME=200 NUB=YES PLT=YES FDN=YES RUN=YES END PARAM
   READ   GEOM
   UNIT  1
   CYLINDER 1   1  4.445   17.15     0.
   CYLINDER 2   1  4.604   17.15     0.
   CYLINDER 3   1  35.08    17.15   -30.48
   CUBOID    5  1    60. -60. 60. -60.  17.15  -30.48
   UNIT  2
   CYLINDER  1  1 2.857   4.127       0.
   CYLINDER  7  1 3.016    4.127       0.
   CYLINDER  3  1  33.49  4.127       0.
   CUBOID   5    1    60. -60. 60.  -60.   4.127  0.
   UNIT  3
   CYLINDER   1   1 3.505 3.81              0.
   CYLINDER   7   1 3.655   3.81            0.
   CYLINDER   3   1  34.13   3.81           0.
   CUBOID    5   1     60. -60. 60.  -60. 3.81    0.
   UNIT  4
   CYLINDER      1       1    4.39     3.81              0.
   CYLINDER      7       1    4.54     3.81        0.
   CYLINDER      3       1     35.02   3.81              0.
   CUBOID    5    1       60. -60. 60.  -60.     3.81    0.
   UNIT  5
   CYLINDER   1    1  5.289     3.81      0.
   CYLINDER   7  1 5.439   3.81      0.
   CYLINDER   3    1 35.91   3.81     0.
   CUBOID    5   1     60. -60. 60. -60. 3.81      0.
   UNIT  6
   CYLINDER    1       1  6.18        3.81  0.
   CYLINDER    7       1   6.33   3.81         0.
   CYLINDER    3       1   36.83  3.81   0.
   CUBOID     5    1      60. -60. 60. -60.  3.81  0.
   UNIT  7
   CYLINDER   1    1 6.185  40.64   0.
   CYLINDER   7  1 6.35  40.64   0.
   CYLINDER   3   1  36.665   40.64  0.
   CUBOID    5    1  60. -60. 60. -60.  40.64  0.
   UNIT  8
   CYLINDER   1     1  8.0 1.74   0.
   CYLINDER   7    1   8.15 1.74   0.
   CYLINDER   3  1   38.63  1.74   0.
   CUBOID  5  1  60. -60. 60. -60. 1.74   0.
   UNIT 9
   CYLINDER 1 1  9.65    1.74     0.
   CYLINDER 7 1  9.8    1.74     0.
   CYLINDER 3 1  40.28    1.74     0.
   CUBOID   5 1  60. -60. 60. -60.  1.74     0.
   UNIT  10
   CYLINDER    1   1 10.1  3.58  0.
   CYLINDER   7  1 10.25 3.58   0.
   CYLINDER  3  1 40.73 3.58   0.
   CUBOID   5   1  60. -60. 60.  -60.  3.58  0.
   UNIT  11
   CYLINDER  1 1 10.55 3.58     0.
   CYLINDER  7 1 10.7  3.58            0.
   CYLINDER  3 1 41.18  3.58  0.
   CUBOID    5  1        60. -60. 60. -60.  3.58 0.
   UNIT  12
   CYLINDER    1   1 11.       3.58                     0.
```

```
  CYLINDER    7    1 11.15 3.58   0.
  CYLINDER    3   1     41.63    3.58 0.
  CUBOID      5  1        60. -60. 60. -60.  3.58 0.
  UNIT 13
  CYLINDER    1          1         11.45   3.58    0.
  CYLINDER    7          1         11.6      3.58        0.
  CYLINDER    3          1          42.08 3.58    0.
  CUBOID   5  1       60. -60. 60. -60.  3.58 0.
  UNIT 14
  CYLINDER 1 1 11.45 3.48 0.0
  CYLINDER 7 1 11.60 3.48  0.0
  CYLINDER 3 1   42.08 3.48 0.0
  CUBOID   5 1  60. -60. 60. -60. 3.48  0.
  UNIT 15
  CYLINDER           1                  1 8.89 1.27  0.
  CYLINDER           2                  1 11.45   1.27   0.
  CYLINDER           3                  1 42.08   1.27   0.
  CUBOID   5         1                  60. -60. 60. -60. 1.27  0.
  UNIT 16
  CYLINDER           4                  1 4.445 9.22        0.
  CYLINDER           1                  1 8.89 9.22        0.
  CYLINDER           2                  1 11.45 9.22         0.
  CYLINDER           7                  1 11.60 9.22     0.
  CYLINDER           3                  1 42.08          9.22 0.
  CUBOID   5         1                     60. -60. 60. -60.    9.22 0.
  UNIT 17
  CYLINDER           4                     1 4.445 6.0198 0.
  CYLINDER           1                     1 11.45 6.0198 0.
  CYLINDER           7                     1 11.60   6.0198 0.
  CYLINDER           3                     1 42.0012 6.0198 0.
  CUBOID   5         1                     60. -60. 60. -60. 6.0198 0.
  UNIT 18
  CYLINDER           1                     1 6.35 8.89 0.
  CYLINDER           2                     1 6.5   8.89   0.
  CYLINDER           3                     1 36.98 8.89  0.
  CUBOID 5 1 60. -60. 60. -60. 8.89  0.
  GLOBAL
  UNIT 19
  COM='IDEFINES OVERALL COORDINATE SYSTEM '
  ARRAY 1 3*0
  CUBOID 5 1 120. 0. 120. 0. 190. 0.
  END GEOM
  READ ARRAY
  NUX=1 NUY=1 NUZ=18  FILL 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 END FILL
  END ARRAY
  END DATA

 SECONDARY MODULE 000008   HAS BEEN CALLED.

 MODULE 000008   IS FINISHED. COMPLETION CODE     0. CPU TIME USED    22.46 (SECONDS).

 SECONDARY MODULE 000002   HAS BEEN CALLED.

 MODULE 000002   IS FINISHED. COMPLETION CODE     0. CPU TIME USED    42.73 (SECONDS).

 SECONDARY MODULE 000009   HAS BEEN CALLED.

 MODULE 000009   IS FINISHED. COMPLETION CODE     0. CPU TIME USED   295.72 (SECONDS).

 MODULE CSAS25   IS FINISHED. COMPLETION CODE     0. CPU TIME USED   369.26 (SECONDS).

THE FOLLOWING DATA CARDS PRECEDE AN = CARD

 EXECUTION TERMINATED DUE TO ERRORS
```

```
   CCCCCCCCCCC     SSSSSSSSSSS      AAAAAAAAA      SSSSSSSSSSS     22222222222
5555555555555
  CCCCCCCCCCCCC   SSSSSSSSSSSSS    AAAAAAAAAAA    SSSSSSSSSSSSS   2222222222222
5555555555555
  CC         CC   SS         SS   AA         AA   SS         SS   22         22   55
  CC              SS              AA         AA   SS                         22   55
  CC              SS              AA         AA   SS                         22   55
  CC              SSSSSSSSSSSS    AAAAAAAAAAAAA   SSSSSSSSSSSS             22
555555555555
  CC               SSSSSSSSSSSS   AAAAAAAAAAAAA    SSSSSSSSSSSS          22
5555555555555
  CC                         SS   AA         AA              SS        22
55
  CC                         SS   AA         AA              SS      22
55
  CC         CC   SS         SS   AA         AA   SS         SS    22             55
55
  CCCCCCCCCCCCC   SSSSSSSSSSSSS   AA         AA   SSSSSSSSSSSSS   2222222222222
5555555555555
   CCCCCCCCCCC     SSSSSSSSSSS    AA         AA    SSSSSSSSSSS    2222222222222
55555555555


   SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS         SS   CC         CC   AA         AA   LL              EE
PP         PP   CC         CC
  SS              CC              AA         AA   LL              EE
PP         PP   CC
  SS              CC              AA         AA   LL              EE
PP         PP   CC
  SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       --------
-----   PPPPPPPPPPPP    CC
   SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       --------
-----   PPPPPPPPPPP     CC
             SS   CC              AA         AA   LL              EE
PP              CC
             SS   CC              AA         AA   LL              EE
PP              CC
  SS         SS   CC         CC   AA         AA   LL              EE
PP              CC         CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEE
PP              CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEE
PP               CCCCCCCCCCC


     0000000      88888888888                 //   33333333333       0000000
//   99999999999    666666666666
    000000000    8888888888888               //   3333333333333     000000000
//   9999999999999    6666666666666
   00       00   88         88              //    33         33    00       00
//    99        99    66
  00         00  88         88             //                33   00          00
//     99        99   66
  00         00  88         88            //                 33   00          00
//      99        99   66
  00         00   88888888888            //                333    00          00
//       9999999999999   66666666666
  00         00   88888888888           //                 333    00          00         //
999999999999   6666666666666
  00         00  88         88         //                    33   00          00        //
99   66     66
  00         00  88         88        //                     33   00          00       //
99   66     66
   00       00   88         88       //     33           33    00       00        //
99   66     66
    000000000    8888888888888      //          3333333333333     000000000         //
9999999999999   6666666666666
     0000000      88888888888      //            33333333333       0000000         //
999999999999     66666666666
```

```
   22222222222     22222222222                       0000000      7777777777777
22222222222          11
  2222222222222   2222222222222                     000000000     777777777777
2222222222222        111
  22         22   22         22         :::        00       00    77        77
:::       22          22       1111
             22              22         :::       00         00            77
:::                   22          11
             22              22         :::       00         00           77
:::                   22          11
           22              22                     00         00          77
22           11
         22              22                       00         00          77
22             11
       22              22               :::       00         00         77
:::            22                 11
     22              22                 :::       00         00         77
:::          22                   11
   22              22                   :::        00       00         77
:::        22                     11
  2222222222222   2222222222222                     000000000          77
2222222222222      11111111
  2222222222222   2222222222222                      0000000           77
2222222222222      11111111
```

```
   SSSSSSSSSSS     CCCCCCCCCCC       AAAAAAAAA      LL              EEEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC     AAAAAAAAAAA     LL              EEEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS           SS   CC            CC   AA          AA   LL              EE
PP           PP   CC            CC
  SS                CC                 AA          AA   LL              EE
PP           PP   CC
  SS                CC                 AA          AA   LL              EE
PP           PP   CC
  SSSSSSSSSSSS      CC                 AAAAAAAAAAAAA    LL              EEEEEEEEE        --------
-----   PPPPPPPPPPPP    CC
   SSSSSSSSSSSS     CC                 AAAAAAAAAAAAA    LL              EEEEEEEEE        --------
-----   PPPPPPPPPPP     CC
               SS   CC                 AA          AA   LL              EE
PP                CC
               SS   CC                 AA          AA   LL              EE
PP                CC
  SS           SS   CC            CC   AA          AA   LL              EE
PP                CC            CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA           AA   LLLLLLLLLLLL   EEEEEEEEEEEEE
PP                CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC    AA           AA   LLLLLLLLLLLL   EEEEEEEEEEEEE
PP                  CCCCCCCCCCC



**************************************************************************

**************************************************************************

**************************************************************************
                          *****
*****
                          *****                  PROGRAM VERIFICATION INFORMATION
*****
                          *****
*****
                          *****                 CODE SYSTEM:  SCALE-PC VERSION:  4.3
*****
                          *****
*****

**************************************************************************

**************************************************************************
                          *****
*****
                          *****
*****
                          *****             PROGRAM:  CSAS
*****
                          *****
*****
                          *****       CREATION DATE:  03-08-96
*****
                          *****
*****
                          *****              VOLUME:  DOS PART
*****
                          *****
*****
                          *****             LIBRARY:  C:\SCALE43\EXE
*****
                          *****
*****
                          *****
*****
                          *****     PRODUCTION CODE:  CSAS
*****
```

```
                        *****
*****
                        *****                  VERSION:  3.1
*****
                        *****
*****
                        *****                  JOBNAME:  SCALE-PC
*****
                        *****
*****
                        *****    DATE OF EXECUTION:  08/30/96
*****
                        *****
*****
                        *****    TIME OF EXECUTION:  22:07:21
*****
                        *****
*****
                        *****
*****
********************************************************************************
********************************************************************************
********************************************************************************
```

```
PROBLEM  12.0 INCH H20 CONTACT REFLECTOR - 100 GU/1


**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX             7 MIXTURES
MSC             9 COMPOSITION SPECIFICATIONS
IZM             1 MATERIAL ZONES
GE  INFHOMMEDIUM GEOMETRY
MORE            0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN            2 FUEL SOLUTIONS


**** PROBLEM COMPOSITION DESCRIPTION ****

SC  SOLNUO2F2     STANDARD COMPOSITION
MX              1 MIXTURE NO.
FD        70.0000 SOLUTION FUEL DENSITY
AML        0.0000 ACID MOLARITY
VF         1.0000 VOLUME FRACTION
TEMP        293.0 DEG KELVIN
SPG        1.0806 DEFAULT SPECIFIC GRAVITY
SC  UO2F2         STANDARD COMPOSITION
            92000       1.00 ATOM/MOLECULE
                                92235   100.000 WT%
             8016       2.00 ATOMS/MOLECULE
             9019       2.00 ATOMS/MOLECULE
SC  HFACID        STANDARD COMPOSITION
             1001       1.00 ATOM/MOLECULE
             9019       1.00 ATOM/MOLECULE
SC  H2O           STANDARD COMPOSITION
             1001       2.00 ATOMS/MOLECULE
             8016       1.00 ATOM/MOLECULE
END

SC  POLY(H2O)     STANDARD COMPOSITION
MX              2 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH       0.9230 THEORETICAL DENSITY
NEL             2 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
             1001       2.00 ATOMS/MOLECULE
             6012       1.00 ATOM/MOLECULE
END

SC  H2O           STANDARD COMPOSITION
MX              3 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH       0.9982 THEORETICAL DENSITY
NEL             2 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
             1001       2.00 ATOMS/MOLECULE
             8016       1.00 ATOM/MOLECULE
END

SC  FE            STANDARD COMPOSITION
MX              4 MIXTURE NO.
DEN    1.7000E-02 ATOMIC DENSITY
ROTH       7.8600 THEORETICAL DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
            26000       1.00 ATOM/MOLECULE
END

SC  AL            STANDARD COMPOSITION
MX              4 MIXTURE NO.
DEN    3.7500E-02 ATOMIC DENSITY
ROTH       2.7020 THEORETICAL DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
            13027       1.00 ATOM/MOLECULE
END

SC  SOLNUO2F2     STANDARD COMPOSITION
```

```
MX             4 MIXTURE NO.
FD       70.0000 SOLUTION FUEL DENSITY
AML       0.0000 ACID MOLARITY
VF        0.1800 VOLUME FRACTION
TEMP       293.0 DEG KELVIN
SPG       1.0806 DEFAULT SPECIFIC GRAVITY
SC  UO2F2        STANDARD COMPOSITION
           92000      1.00 ATOM/MOLECULE
                            92235   100.000 WT%
            8016      2.00 ATOMS/MOLECULE
            9019      2.00 ATOMS/MOLECULE
SC  HFACID       STANDARD COMPOSITION
            1001      1.00 ATOM/MOLECULE
            9019      1.00 ATOM/MOLECULE
SC  H2O          STANDARD COMPOSITION
            1001      2.00 ATOMS/MOLECULE
            8016      1.00 ATOM/MOLECULE
END

SC  H2O          STANDARD COMPOSITION
MX             5 MIXTURE NO.
VF        0.0000 VOLUME FRACTION
ROTH      0.9982 THEORETICAL DENSITY
NEL            2 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
            1001      2.00 ATOMS/MOLECULE
            8016      1.00 ATOM/MOLECULE
END

SC  MGCONCRETE   STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      2.1470 THEORETICAL DENSITY
NEL           14 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
           26000     0.559 WT%
            1001     0.332 WT%
            6012    10.532 WT%
            8016    49.943 WT%
           11023     0.141 WT%
           12000     9.420 WT%
           13027     0.786 WT%
           14000     4.210 WT%
           16000     0.248 WT%
           17000     0.052 WT%
           19000     0.945 WT%
           20000    22.632 WT%
           22000     0.149 WT%
           25055     0.051 WT%
END

SC  SS304        STANDARD COMPOSITION
MX             7 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      7.9200 THEORETICAL DENSITY
NEL            4 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
           24304    19.000 WT%
           25055     2.000 WT%
           26304    69.500 WT%
           28304     9.500 WT%
END

**** PROBLEM GEOMETRY ****


**** INFINITE HOMOGENEOUS MEDIUM ****
MFUEL          1 MIXTURE NO. OF THE INFINITE HOMOGENEOUS MEDIUM
```

```
***************************************************************************************
*************************
      ***
***
      ***                            PROBLEM  12.0 INCH H20 CONTACT REFLECTOR - 100
GU/1                        ***
      ***
***

***************************************************************************************
*************************

***************************************************************************************
*************************
      ***
***
      ***                              ********** DATA LIBRARY INFORMATION **********
***
      ***
***
      ***          UNIT                                                 VOLUME
***
      ***         NUMBER              DATA SET NAME                     NAME
UNIT FUNCTION                  ***
      ***         ------              -------------                     ----         ---
----------                  ***
      ***
***
      ***           89     C:\SCALE43\DATALIB\FT89F001
STANDARD COMPOSITION LIBRARY     ***
      ***
***
      ***           82     C:\SCALE43\DATALIB\FT82F001
CROSS SECTION LIBRARY            ***
      ***
***
      ***           11     C:\SCALE43\WORK\FT11F001
SHORT CROSS SECTION LIBRARY      ***
      ***
***
      ***           90     C:\SCALE43\WORK\FT90F001
INPUT DATA DIRECT ACCESS         ***
      ***
***

***************************************************************************************
*************************

***************************************************************************************
*************************
      ***
***
      ***
***
      ***                                    STANDARD COMPOSITION LIBRARY DATA
***
      ***                                    ---------------------------------
***
      ***
***
      ***             UNIT NUMBER  :  89
***
      ***
***
      ***             DATASET NAME :  C:\SCALE43\DATALIB\FT89F001
***
      ***
***
      ***             LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY
***
      ***                             637 STANDARD COMPOSITIONS, 490 NUCLIDES
***
      ***                             90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.
***
```

```
           ***
***
           ***            CREATION DATE:   6/30/95
***
           ***
***
           ***
***
           ***
***
           ***                                          CROSS SECTION LIBRARY DATA
***
           ***                                         ---------------------------
***
           ***
***
           ***            UNIT NUMBER  :  82
***
           ***
***
           ***            DATASET NAME :  C:\SCALE43\DATALIB\FT82F001
***
           ***
***
           ***            LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
***
           ***                               BASED ON ENDF-B VERSION 4 DATA
***
           ***                                  COMPILED FOR NRC     1/27/89
***
           ***                                     LAST UPDATED
08/12/94  ***
           ***                                        L.M.PETRIE   -   ORNL
***
           ***
***
           ***
***
           ***
***
           ***
***

*****************************************************************************************
**************************

*****************************************************************************************
**************************
                              ........   0 IO'S WERE USED BEFORE READING KENO V DATA
........
                              ........   0 IO'S WERE USED READING THE KENO V PARAMETER
DATA    ........

                              *************** DATA READING COMPLETED ***************
                              ........   0 IO'S WERE USED PREPARING THE KENO V INPUT
DATA    ........

                              ........   0 IO'S WERE USED LOADING THE KENO V DATA
........

                              ........   0 IO'S WERE USED LOADING THE DATA    ........
                              ........   0 IO'S WERE USED CHECKING THE KENO V GEOMETRY
DATA    ........
                              *****  RESTART DATA HAS BEEN WRITTEN ON UNIT 95  *****
                              ........   0 IO'S WERE USED WRITING THE KENO V - CSAS DATA
........

                              ........   0 IO'S WERE USED PROCESSING CSAS INPUT DATA
........
CONTROL MODULE CSAS25   IS COMPLETE.
```

```
  BBBBBBBBBBBB     OOOOOOOOOOO    NN           NN                     AAAAAAAAA     MM
MM  IIIIIIIIIIII     22222222222
  BBBBBBBBBBBBB   OOOOOOOOOOOOO   NNN          NN                    AAAAAAAAAAA    MMM
MMM  IIIIIIIIIIII    2222222222222
  BB          BB   OO          OO   NNNN         NN                  AA          AA   MMMM
MMMM       II             22         22
  BB          BB   OO          OO   NN NN        NN                  AA          AA   MM MM
MM MM       II                       22
  BB          BB   OO          OO   NN   NN      NN                  AA          AA   MM    MM
MM  MM        II                     22
  BBBBBBBBBBB    OO          OO   NN     NN    NN  -------------  AAAAAAAAAAAAA   MM
MMM   MM         II                 22
  BBBBBBBBBBB    OO          OO   NN      NN   NN  -------------  AAAAAAAAAAAAA   MM      M
MM       II               22
  BB          BB   OO          OO   NN        NN  NN                AA          AA   MM
MM       II             22
  BB          BB   OO          OO   NN         NN NN                AA          AA   MM
MM       II           22
  BB          BB   OO          OO   NN          NNNN                AA          AA   MM
MM       II         22
  BBBBBBBBBBBBB   OOOOOOOOOOOOO   NN           NNN                AA          AA   MM
MM  IIIIIIIIIIII    2222222222222
  BBBBBBBBBBB     OOOOOOOOOOO    NN            NN                AA          AA   MM
MM  IIIIIIIIIIII    2222222222222


   SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS          SS   CC          CC   AA          AA   LL              EE
PP          PP   CC          CC
  SS               CC                AA          AA   LL              EE
PP          PP   CC
  SS               CC                AA          AA   LL              EE
PP          PP   CC
  SSSSSSSSSSSS     CC                AAAAAAAAAAAAA   LL              EEEEEEEEE       --------
-----   PPPPPPPPPPPPP    CC
   SSSSSSSSSSSS   CC                AAAAAAAAAAAAA   LL              EEEEEEEEE       --------
-----   PPPPPPPPPPPP     CC
             SS   CC                AA          AA   LL              EE
PP               CC
             SS   CC                AA          AA   LL              EE
PP               CC
  SS          SS   CC          CC   AA          AA   LL              EE
PP               CC          CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA          AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP               CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC     AA          AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP                CCCCCCCCCCC


     0000000       88888888888             //    33333333333       0000000
//    99999999999      666666666666
    000000000     8888888888888           //   3333333333333     000000000
//    9999999999999    6666666666666
   00        00    88          88         //     33          33    00        00
//     99          99    66
  00          00   88          88        //                  33   00          00
//      99          99   66
  00          00   88          88       //                   33   00          00
//        99          99   66
  00          00   88888888888        //                  333    00          00
//        9999999999999   666666666666
  00          00   88888888888       //                   333    00          00         //
999999999999   6666666666666
  00          00   88          88     //                    33   00          00        //
99   66          66
  00          00   88          88    //                     33   00          00       //
99   66          66
   00        00    88          88   //          33          33    00        00       //
99   66          66
    000000000     8888888888888    //          3333333333333     000000000       //
9999999999999   6666666666666
```

```
     0000000     88888888888     //              33333333333       0000000        //
999999999999     66666666666


   22222222222     22222222222                      0000000      7777777777777
22222222222     88888888888
  2222222222222   2222222222222                    000000000     777777777777
2222222222222   8888888888888
  22          22    22          22          :::        00       00     77          77
:::       22          22    88          88
             22              22          :::       00         00                77
:::                  22    88          88
             22              22          :::       00         00               77
:::                  22    88          88
           22              22                      00         00              77
22      88888888888
         22              22                        00         00              77
22        88888888888
       22              22                ::: 00         00             77
:::            22          88          88
     22              22                  :::       00         00             77
:::          22            88          88
   22              22                    :::        00       00            77
:::        22              88          88
  2222222222222   2222222222222                     000000000          77
2222222222222   8888888888888
  2222222222222   2222222222222                      0000000           77
2222222222222    88888888888
```

```
   SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS         SS   CC         CC   AA         AA   LL              EE
PP          PP   CC          CC
  SS              CC              AA         AA   LL              EE
PP          PP   CC
  SS              CC              AA         AA   LL              EE
PP          PP   CC
  SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE        --------
-----   PPPPPPPPPPPPP    CC
   SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE        --------
-----   PPPPPPPPPPPP     CC
             SS   CC              AA         AA   LL              EE
PP               CC
             SS   CC              AA         AA   LL              EE
PP               CC
  SS         SS   CC         CC   AA         AA   LL              EE
PP               CC          CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP               CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP                CCCCCCCCCCC



*********************************************************************************

*********************************************************************************

*********************************************************************************
                         *****
*****
                         *****                    PROGRAM VERIFICATION INFORMATION
*****
                         *****
*****
                         *****                  CODE SYSTEM:   SCALE-PC VERSION:   4.3
*****
                         *****
*****

*********************************************************************************

*********************************************************************************
                         *****
*****
                         *****
*****
                         *****               PROGRAM:   000008
*****
                         *****
*****
                         *****         CREATION DATE:   09-15-95
*****
                         *****
*****
                         *****               VOLUME:    DOS PART
*****
                         *****
*****
                         *****               LIBRARY:   C:\SCALE43\EXE
*****
                         *****
*****
                         *****
*****
                         *****       PRODUCTION CODE:   BONAMI
*****
```

```
                        *****
*****
                        *****              VERSION:  3.0
*****
                        *****
*****
                        *****              JOBNAME:  SCALE-PC
*****
                        *****
*****
                        *****    DATE OF EXECUTION:  08/30/96
*****
                        *****
*****
                        *****    TIME OF EXECUTION:  22:07:28
*****
                        *****
*****
                        *****
*****
********************************************************************************
********************************************************************************
********************************************************************************
```

```
-1Q ARRAY HAS      1 ENTRIES.
 0Q ARRAY HAS      4 ENTRIES.
 1Q ARRAY HAS      6 ENTRIES.
 2Q ARRAY HAS      2 ENTRIES.
```

```
LOGICAL ASSIGNMENTS

MASTER LIBRARY   11
WORKING LIBRARY   0
SCRATCH FILE     18
NEW LIBRARY       1

P R O B L E M   D E S C R I P T I O N

IGR--GEOMETRY (0/1/2/3--INF MED/SLAB/CYL/SPHERE                    1

IZM--NUMBER OF ZONES OR MATERIAL REGIONS                           7

MS--MIXING TABLE LENGTH                                           34

IBL--SHIELDED CROSS SECTION EDIT OPTION (0/1--NO/YES)              0

IBR--BONDARENKO FACTOR EDIT OPTION (0/1--NO/YES)                   0

ISSOPT--DANCOFF FACTOR OPTION                                      0

CONVERGENCE CRITERION    1.00000E-03

GEOMETRY CORRECTION FACTOR FOR WIGNER RATIONAL APPROXIMATION  1.000E+00

        3Q ARRAY HAS     34 ENTRIES.

        4Q ARRAY HAS     34 ENTRIES.

        5Q ARRAY HAS     34 ENTRIES.

        6Q ARRAY HAS      7 ENTRIES.

        7Q ARRAY HAS      7 ENTRIES.

        8Q ARRAY HAS      7 ENTRIES.

        9Q ARRAY HAS      7 ENTRIES.

       10Q ARRAY HAS     34 ENTRIES.

       11Q ARRAY HAS      7 ENTRIES.

M I X I N G   T A B L E

ENTRY   MIXTURE   ISOTOPE   NUMBER DENSITY   NEW IDENTIFIER
   1       1        92235     1.79349E-04          1092235
   2       4        92235     3.22828E-05          4092235
   3       1         8016     3.34596E-02          1008016
   4       3         8016     3.33846E-02          3008016
   5       4         8016     6.02274E-03          4008016
   6       5         8016     1.14342E-06          5008016
   7       6         8016     4.03824E-02          6008016
   8       1         9019     3.58698E-04          1009019
   9       4         9019     6.45657E-05          4009019
  10       1         1001     6.62019E-02          1001001
  11       2         1001     7.93178E-02          2001001
  12       3         1001     6.67692E-02          3001001
  13       4         1001     1.19163E-02          4001001
  14       5         1001     2.28684E-06          5001001
  15       6         1001     4.25810E-03          6001001
  16       2         6012     3.96589E-02          2006012
  17       6         6012     1.13479E-02          6006012
  18       4        26000     1.70000E-02          4026000
  19       6        26000     1.29539E-04          6026000
  20       4        13027     3.75000E-02          4013027
  21       6        13027     3.76599E-04          6013027
  22       6        11023     7.93561E-05          6011023
  23       6        12000     5.01114E-03          6012000
  24       6        14000     1.93819E-03          6014000
  25       6        16000     1.00126E-04          6016000
  26       6        17000     1.90738E-05          6017000
  27       6        19000     3.12311E-04          6019000
  28       6        20000     7.30081E-03          6020000
  29       6        22000     4.01829E-05          6022000
  30       6        25055     1.20498E-05          6025055
```

```
  31      7       25055     1.73633E-03          7025055
  32      7       24304     1.74286E-02          7024304
  33      7       26304     5.93579E-02          7026304
  34      7       28304     7.72070E-03          7028304

GEOMETRY AND MATERIAL DESCRIPTION

ZONE   MIXTURE   OUTER DIMENSION   TEMPERATURE      EXTRA XS   TYPE (0/1--FUEL/MOD)
   1     1         1.00000E+00     2.93000E+02    0.00000E+00             0
   2     2         6.00000E+00     2.93000E+02    0.00000E+00             0
   3     3         1.10000E+01     2.93000E+02    0.00000E+00             0
   4     4         1.60000E+01     2.93000E+02    0.00000E+00             0
   5     5         2.10000E+01     2.93000E+02    0.00000E+00             0
   6     6         2.60000E+01     2.93000E+02    0.00000E+00             0
   7     7         3.10000E+01     2.93000E+02    0.00000E+00             0
     5178 LOCATIONS OF   100000 AVAILABLE ARE REQUIRED TO MAKE A NEW MASTER CONTAINING THE
SELF-SHIELDED VALUES

NO NUCLIDES IN YOUR PROBLEM HAVE BONDARENKO FACTOR DATA**BONAMI WILL COPY FROM LOGICAL 11
TO LOGICAL  1

COPY       1001    HYDROGEN         FROM LOG 11 TO LOG 18    BONDARENKO TRIGGER 0

COPY       1001    HYDROGEN         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       1001    HYDROGEN         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       1001    HYDROGEN         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       1001    HYDROGEN         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       1001    HYDROGEN         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       1001    HYDROGEN         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       6012    CARBON-12        FROM LOG 11 TO LOG 18    BONDARENKO TRIGGER 0

COPY       6012    CARBON-12        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       6012    CARBON-12        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       8016    OXYGEN-16        FROM LOG 11 TO LOG 18    BONDARENKO TRIGGER 0

COPY       8016    OXYGEN-16        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       8016    OXYGEN-16        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       8016    OXYGEN-16        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       8016    OXYGEN-16        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       8016    OXYGEN-16        FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       9019    FLUORINE         FROM LOG 11 TO LOG 18    BONDARENKO TRIGGER 0

COPY       9019    FLUORINE         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY       9019    FLUORINE         FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY      11023    SODIUM-23        FROM LOG 11 TO LOG  1    BONDARENKO TRIGGER 0

COPY      12000    MG 1280 218 GP 1 FROM LOG 11 TO LOG  1    BONDARENKO TRIGGER 0

COPY      13027    AL-27 1193 218 G FROM LOG 11 TO LOG 18    BONDARENKO TRIGGER 0

COPY      13027    AL-27 1193 218 G FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY      13027    AL-27 1193 218 G FROM LOG 18 TO LOG  1    BONDARENKO TRIGGER 0

COPY      14000     SILICON         FROM LOG 11 TO LOG  1    BONDARENKO TRIGGER 0

COPY      16000    SULFUR  LENDL MA FROM LOG 11 TO LOG  1    BONDARENKO TRIGGER 0

COPY      19000     POTASSIUM       FROM LOG 11 TO LOG  1    BONDARENKO TRIGGER 0

COPY      20000    CALCIUM ENDF/B-I FROM LOG 11 TO LOG  1    BONDARENKO TRIGGER 0
```

```
COPY     22000   TITANIUM         FROM LOG 11 TO LOG  1     BONDARENKO TRIGGER 0
COPY     24304  CR 1191 WT SS-30  FROM LOG 11 TO LOG  1     BONDARENKO TRIGGER 0
COPY     25055   MANGANESE-55     FROM LOG 11 TO LOG 18     BONDARENKO TRIGGER 0
COPY     25055   MANGANESE-55     FROM LOG 18 TO LOG  1     BONDARENKO TRIGGER 0
COPY     25055   MANGANESE-55     FROM LOG 18 TO LOG  1     BONDARENKO TRIGGER 0
COPY     26000   IRON             FROM LOG 11 TO LOG 18     BONDARENKO TRIGGER 0
COPY     26000   IRON             FROM LOG 18 TO LOG  1     BONDARENKO TRIGGER 0
COPY     26000   IRON             FROM LOG 18 TO LOG  1     BONDARENKO TRIGGER 0
COPY     26304  FE 1192 WT SS-30  FROM LOG 11 TO LOG  1     BONDARENKO TRIGGER 0
COPY     28304  NI 1190 WT SS-30  FROM LOG 11 TO LOG  1     BONDARENKO TRIGGER 0
COPY     92235   URANIUM-235      FROM LOG 11 TO LOG 18     BONDARENKO TRIGGER 0
COPY     92235   URANIUM-235      FROM LOG 18 TO LOG  1     BONDARENKO TRIGGER 0
COPY     92235   URANIUM-235      FROM LOG 18 TO LOG  1     BONDARENKO TRIGGER 0
COPY     17000  CHLORINE (MAT 11  FROM LOG 11 TO LOG  1     BONDARENKO TRIGGER 0
```

```
          SCALE 4.2 - 27 GROUP NEUTRON.GROUP LIBRARY
             BASED ON ENDF-B VERSION 4 DATA
                COMPILED FOR NRC     1/27/89
                   LAST UPDATED                                             08/12/94
                      L.M.PETRIE   -   ORNL
               TAPE ID                        4321          NUMBER OF NUCLIDES
34
               NUMBER OF NEUTRON GROUPS         27          NUMBER OF GAMMA GROUPS
0
               FIRST THERMAL GROUP              15          LOGICAL UNIT
1
                                      TABLE OF CONTENTS
        HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94       ID
1001001
        HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94       ID
2001001
        HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94       ID
3001001
        HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94       ID
4001001
        HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94       ID
5001001
        HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94       ID
6001001
        CARBON-12      ENDF/B-IV MAT 1274/THRM1065          UPDATED 08/12/94       ID
2006012
        CARBON-12      ENDF/B-IV MAT 1274/THRM1065          UPDATED 08/12/94       ID
6006012
        OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94       ID
1008016
        OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94       ID
3008016
        OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94       ID
4008016
        OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94       ID
5008016
        OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94       ID
6008016
        FLUORINE       ENDF/B-IV MAT 1277                   UPDATED 08/12/94       ID
1009019
        FLUORINE       ENDF/B-IV MAT 1277                   UPDATED 08/12/94       ID
4009019
        SODIUM-23      ENDF/B-IV MAT 1156                   UPDATED 08/12/94       ID
6011023
       MG 1280 218 GP 1/E*SIGT 040375(5)                    UPDATED 08/12/94       ID
6012000
       AL-27 1193 218 GP 040375(5)                          UPDATED 08/12/94       ID
4013027
       AL-27 1193 218 GP 040375(5)                          UPDATED 08/12/94       ID
6013027
        SILICON        ENDF/B-IV MAT 1194                   UPDATED 08/12/94       ID
6014000
       SULFUR  LENDL MAT 7020                               UPDATED 08/12/94       ID
6016000
        POTASSIUM      ENDF/B-IV MAT 1150                   UPDATED 08/12/94       ID
6019000
       CALCIUM ENDF/B-IV MAT 1195                           UPDATED 08/12/94       ID
6020000
        TITANIUM       ENDF/B-IV MAT 1286                   UPDATED 08/12/94       ID
6022000
       CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'     UPDATED 08/12/94       ID
7024304
        MANGANESE-55   ENDF/B-IV MAT 1197                   UPDATED 08/12/94       ID
6025055
        MANGANESE-55   ENDF/B-IV MAT 1197                   UPDATED 08/12/94       ID
7025055
        IRON           ENDF/B-IV MAT 1192                   UPDATED 08/12/94       ID
4026000
        IRON           ENDF/B-IV MAT 1192                   UPDATED 08/12/94       ID
6026000
       FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'     UPDATED 08/12/94       ID
7026304
       NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'     UPDATED 08/12/94       ID
7028304
        URANIUM-235    ENDF/B-IV MAT 1261                   UPDATED 08/12/94       ID
1092235
```

```
          URANIUM-235    ENDF/B-IV MAT 1261                        UPDATED 08/12/94        ID
4092235
         CHLORINE (MAT 1149 FROM VERSION IV) USING 1/SIGT WEIGHTIUPDATED 08/12/94        ID
6017000

          TAPE COPY USED      0 I/O'S, AND TOOK   12.90 SECONDS
```

```
                 NN          NN  IIIIIIIIIII    TTTTTTTTTTTT     AAAAAAAAA     WW
WW  LL
                 NNN         NN  IIIIIIIIIII    TTTTTTTTTTTT    AAAAAAAAAAA    WW
WW  LL
                 NNNN        NN      II             TT         AA        AA    WW
WW  LL
                 NN NN       NN      II             TT         AA        AA    WW
WW  LL
                 NN  NN      NN      II             TT         AA        AA    WW
WW  LL
                 NN   NN     NN      II             TT         AAAAAAAAAAAAA   WW     W
WW  LL
                 NN    NN    NN      II             TT         AAAAAAAAAAAAA   WW
WWW   WW  LL
                 NN     NN   NN      II             TT         AA        AA    WW   WW
WW  WW  LL
                 NN      NN NN       II             TT         AA        AA    WW WW
WW WW  LL
                 NN       NNNN       II             TT         AA        AA    WWWW
WWWW  LL
                 NN        NNN   IIIIIIIIIII        TT         AA        AA    WWW
WWW  LLLLLLLLLLLL
                 NN         NN   IIIIIIIIIII        TT         AA        AA    WW
WW  LLLLLLLLLLLL


   SSSSSSSSSSS    CCCCCCCCCCC     AAAAAAAAA    LL             EEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS  CCCCCCCCCCCCC   AAAAAAAAAAA   LL             EEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS        SS   CC        CC   AA        AA   LL             EE
PP         PP   CC         CC
  SS             CC             AA        AA   LL             EE
PP         PP   CC
  SS             CC             AA        AA   LL             EE
PP         PP   CC
  SSSSSSSSSSSS   CC             AAAAAAAAAAAAA  LL             EEEEEEEEE      --------
-----    PPPPPPPPPPPP    CC
   SSSSSSSSSSS   CC             AAAAAAAAAAAAA  LL             EEEEEEEEE      --------
-----    PPPPPPPPPPPP    CC
            SS   CC             AA        AA   LL             EE
PP             CC
            SS   CC             AA        AA   LL             EE
PP             CC
  SS        SS   CC        CC   AA        AA   LL             EE
PP             CC         CC
  SSSSSSSSSSSSS  CCCCCCCCCCCCC  AA        AA   LLLLLLLLLLLL   EEEEEEEEEEEEE
PP             CCCCCCCCCCCCC
   SSSSSSSSSSS    CCCCCCCCCCC   AA        AA   LLLLLLLLLLLL   EEEEEEEEEEEEE
PP              CCCCCCCCCCC


     0000000      88888888888             //   33333333333      0000000
//   99999999999     666666666666
    000000000     8888888888888          //   3333333333333    000000000
//   9999999999999   6666666666666
    00       00   88         88          //   33         33    00       00
//    99          99   66
   00         00  88         88         //               33   00         00
//      99        99   66
   00         00  88         88        //                33   00         00
//       99       99   66
   00         00   88888888888       //                333   00         00
//        9999999999999   66666666666
   00         00   88888888888      //                 333   00         00       //
999999999999   6666666666666
    00        00  88         88    //                    33   00         00      //
99   66          66
    00        00  88         88   //                     33   00         00     //
99   66          66
    00        00  88         88  //         33           33    00        00    //
99   66          66
     000000000    8888888888888  //          3333333333333    000000000       //
9999999999999   6666666666666
```

```
      0000000        88888888888      //            33333333333      0000000       //
999999999999     66666666666


    22222222222      22222222222                      0000000      7777777777777
5555555555555      0000000
   2222222222222    2222222222222                    000000000      777777777777
5555555555555     000000000
   22          22    22          22        :::     00         00    77          77
:::       55               00          00
               22                22        :::     00          00              77
:::       55              00          00
               22                22        :::     00          00             77
:::       55              00          00
             22                22                  00          00            77
555555555555     00           00
           22                22                    00          00            77
5555555555555    00           00
         22                22                :::   00          00           77
:::                     55    00          00
       22                   22                :::   00          00           77
:::                     55    00          00
     22                  22                  :::    00         00          77
:::       55             55     00         00
   2222222222222    2222222222222                    000000000           77
5555555555555     000000000
   2222222222222    2222222222222                     0000000            77
55555555555       0000000
```

```
   SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS          SS   CC          CC   AA          AA   LL              EE
PP          PP   CC          CC
  SS               CC                AA          AA   LL              EE
PP          PP   CC
  SS               CC                AA          AA   LL              EE
PP          PP   CC
  SSSSSSSSSSSS    CC                AAAAAAAAAAAAA   LL              EEEEEEEEE        --------
-----  PPPPPPPPPPPPP    CC
   SSSSSSSSSSSS   CC                AAAAAAAAAAAAA   LL              EEEEEEEEE        --------
-----  PPPPPPPPPPPP     CC
              SS   CC                AA          AA   LL              EE
PP               CC
              SS   CC                AA          AA   LL              EE
PP               CC
  SS          SS   CC          CC   AA          AA   LL              EE
PP               CC          CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA          AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP               CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC     AA          AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP                 CCCCCCCCCCC



*****************************************************************************

*****************************************************************************

*****************************************************************************
                        *****
*****
                        *****                      PROGRAM VERIFICATION INFORMATION
*****
                        *****
*****
                        *****                     CODE SYSTEM:   SCALE-PC VERSION:   4.3
*****
                        *****
*****

*****************************************************************************

*****************************************************************************
                        *****
*****
                        *****
*****
                        *****                PROGRAM:   000002
*****
                        *****
*****
                        *****          CREATION DATE:   09-28-95
*****
                        *****
*****
                        *****                 VOLUME:   DOS PART
*****
                        *****
*****
                        *****                LIBRARY:   C:\SCALE43\EXE
*****
                        *****
*****
                        *****
*****
                        *****        PRODUCTION CODE:   NITAWL
*****
```

```
                         *****
*****
                         *****              VERSION:   3.0
*****
                         *****
*****
                         *****              JOBNAME:   SCALE-PC
*****
                         *****
*****
                         *****    DATE OF EXECUTION:   08/30/96
*****
                         *****
*****
                         *****    TIME OF EXECUTION:   22:07:50
*****
                         *****
*****
                         *****
*****
**********************************************************************************
**********************************************************************************
**********************************************************************************
```

```
       -1Q ARRAY HAS      1 ENTRIES.

        0Q ARRAY HAS      9 ENTRIES.

        1Q ARRAY HAS     12 ENTRIES.

SELECT 34 NUCLIDES FROM THE MASTER  LIBRARY ON LOGICAL  1
        0 NUCLIDES FROM THE WORKING LIBRARY ON LOGICAL  2
        0 NUCLIDES FROM THE WORKING LIBRARY ON LOGICAL  3
          TO CREATE THE NEW WORKING LIBRARY ON LOGICAL  4

        7 RESONANCE CALCULATIONS HAVE BEEN REQUESTED
       -1 OUTPUT OPTION FOR AMPX FORMATTED CROSS SECTION DATA
     2001 MAXIMUM NUMBER OF RESONANCE MESH INTERVALS
        2 ORDER OF RESONANCE LEVEL PROCESSING

THE STORAGE ALLOCATED FOR THIS CASE IS    100000 WORDS

        2Q ARRAY HAS     34 ENTRIES.

        3Q ARRAY HAS    105 ENTRIES.

        4Q ARRAY HAS     34 ENTRIES.

 GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY
   TAPE IDENTIFICATION NUMBER                  4321
   NUMBER OF NUCLIDES ON TAPE                    34
   NUMBER OF NEUTRON ENERGY GROUPS               27
   FIRST THERMAL NEUTRON ENERGY GROUP            15
   NUMBER OF GAMMA ENERGY GROUPS                  0

   DIRECT ACCESS UNIT NUMBER  9 REQUIRES 118 BLOCKS OF LENGTH  1680 WORDS
 XSDRN TAPE   4321
                         SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
                            BASED ON ENDF-B VERSION 4 DATA
                               COMPILED FOR NRC     1/27/89
                                  LAST UPDATED
08/12/94
                                     L.M.PETRIE   -   ORNL

 NUCLIDES FROM XSDRN TAPE
    1     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94
1001001
    2     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94
2001001
    3     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94
3001001
    4     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94
4001001
    5     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94
5001001
    6     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94
6001001
    7     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED 08/12/94
2006012
    8     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED 08/12/94
6006012
    9     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED 08/12/94
1008016
   10     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED 08/12/94
3008016
   11     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED 08/12/94
4008016
   12     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED 08/12/94
5008016
   13     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED 08/12/94
6008016
   14     FLUORINE       ENDF/B-IV MAT 1277                    UPDATED 08/12/94
1009019
   15     FLUORINE       ENDF/B-IV MAT 1277                    UPDATED 08/12/94
4009019
   16     SODIUM-23      ENDF/B-IV MAT 1156                    UPDATED 08/12/94
6011023
```

```
   17    MG 1280 218 GP 1/E*SIGT 040375(5)                        UPDATED 08/12/94
6012000
   18    AL-27 1193 218 GP 040375(5)                              UPDATED 08/12/94
4013027
   19    AL-27 1193 218 GP 040375(5)                              UPDATED 08/12/94
6013027
   20     SILICON        ENDF/B-IV MAT 1194                       UPDATED 08/12/94
6014000
   21    SULFUR  LENDL MAT 7020                                   UPDATED 08/12/94
6016000
   22     POTASSIUM      ENDF/B-IV MAT 1150                       UPDATED 08/12/94
6019000
   23    CALCIUM ENDF/B-IV MAT 1195                               UPDATED 08/12/94
6020000
   24     TITANIUM       ENDF/B-IV MAT 1286                       UPDATED 08/12/94
6022000
   25    CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'         UPDATED 08/12/94
7024304
   26     MANGANESE-55   ENDF/B-IV MAT 1197                       UPDATED 08/12/94
6025055
   27     MANGANESE-55   ENDF/B-IV MAT 1197                       UPDATED 08/12/94
7025055
   28     IRON           ENDF/B-IV MAT 1192                       UPDATED 08/12/94
4026000
   29     IRON           ENDF/B-IV MAT 1192                       UPDATED 08/12/94
6026000
   30    FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'         UPDATED 08/12/94
7026304
   31    NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'         UPDATED 08/12/94
7028304
   32     URANIUM-235    ENDF/B-IV MAT 1261                       UPDATED 08/12/94
1092235
   33     URANIUM-235    ENDF/B-IV MAT 1261                       UPDATED 08/12/94
4092235
   34    CHLORINE (MAT 1149 FROM VERSION IV) USING 1/SIGT WEIGHTIUPDATED 08/12/94
6017000

 HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94   1001001
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94   2001001
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94   3001001
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94   4001001
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94   5001001
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED 08/12/94   6001001
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED 08/12/94   2006012
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00

 CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED 08/12/94   6006012
TEMPERATURE=   293.00
                                                          PROCESS NUMBER 1007 IS AT

TEMPERATURE=   293.00
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```
 OXYGEN-16      ENDF/B-IV MAT 1276                        UPDATED 08/12/94   1008016
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 OXYGEN-16      ENDF/B-IV MAT 1276                        UPDATED 08/12/94   3008016
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 OXYGEN-16      ENDF/B-IV MAT 1276                        UPDATED 08/12/94   4008016
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 OXYGEN-16      ENDF/B-IV MAT 1276                        UPDATED 08/12/94   5008016
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 OXYGEN-16      ENDF/B-IV MAT 1276                        UPDATED 08/12/94   6008016
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 FLUORINE       ENDF/B-IV MAT 1277                        UPDATED 08/12/94   1009019
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 FLUORINE       ENDF/B-IV MAT 1277                        UPDATED 08/12/94   4009019
TEMPERATURE=   293.00
                                                              PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 SODIUM-23      ENDF/B-IV MAT 1156                        UPDATED 08/12/94   6011023
TEMPERATURE=   293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)           =    22.792           TEMPERATURE(KELVIN)       =   293.000

POTENTIAL SCATTER SIGMA   =     3.530           LUMPED NUCLEAR DENSITY    = 7.9356068E-
05

SPIN FACTOR (G)           =    11.823           LUMP DIMENSION (A-BAR)    =
0.0000000E+00

INNER RADIUS              = 0.0000000E+00       DANCOFF CORRECTION (C)    =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1     =     1.008          SIGMA(PER ABSORBER ATOM)= 1.0935991E+03

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2     =    16.325          SIGMA(PER ABSORBER ATOM)= 3.2352876E+03

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS          RES FISS         RES SCAT
  7       -1.697674E-07    0.000000E+00    -8.342402E-07
  8        0.000000E+00    0.000000E+00     0.000000E+00
  9       -2.025277E-04    0.000000E+00    -2.082040E-01
 10       -1.011029E-03    0.000000E+00    -9.302186E-01

EXCESS RESONANCE INTEGRALS
```

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                       RESOLVED

ABSORPTION            9.69555E-02
FISSION               0.00000E+00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

MG 1280 218 GP 1/E*SIGT 040375(5)                        UPDATED 08/12/94    6012000
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

AL-27 1193 218 GP 040375(5)                              UPDATED 08/12/94    4013027
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

AL-27 1193 218 GP 040375(5)                              UPDATED 08/12/94    6013027
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

 SILICON          ENDF/B-IV MAT 1194                     UPDATED 08/12/94    6014000
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=      0.00

SULFUR  LENDL MAT 7020                                   UPDATED 08/12/94    6016000
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=      0.00

 POTASSIUM        ENDF/B-IV MAT 1150                     UPDATED 08/12/94    6019000
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=      0.00

CALCIUM ENDF/B-IV MAT 1195                               UPDATED 08/12/94    6020000
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

 TITANIUM         ENDF/B-IV MAT 1286                     UPDATED 08/12/94    6022000
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=      0.00

CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'         UPDATED 08/12/94    7024304
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

 MANGANESE-55     ENDF/B-IV MAT 1197                     UPDATED 08/12/94    6025055
TEMPERATURE=    293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)           =    54.466            TEMPERATURE(KELVIN)        =   293.000

POTENTIAL SCATTER SIGMA   =     2.590            LUMPED NUCLEAR DENSITY     = 1.2049777E-
05

SPIN FACTOR (G)           =    14.448            LUMP DIMENSION (A-BAR)     =
0.0000000E+00

INNER RADIUS              = 0.0000000E+00        DANCOFF CORRECTION (C)     =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1     =      1.008           SIGMA(PER ABSORBER ATOM)= 7.2021025E+03

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.
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MASS OF MODERATOR-2     =     16.328              SIGMA(PER ABSORBER ATOM)= 2.1326717E+04

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP         RES ABS          RES FISS          RES SCAT
  8      -7.584859E-06    0.000000E+00    -4.388205E-03
  9      -2.174919E-05    0.000000E+00    -1.963177E-02
 10      -1.112325E-02    0.000000E+00    -5.566122E-01
 11      -8.937288E-02    0.000000E+00    -4.057405E+00

EXCESS RESONANCE INTEGRALS

                    RESOLVED

ABSORPTION       9.09709E+00
FISSION          0.00000E+00
                                                         PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 MANGANESE-55    ENDF/B-IV MAT 1197                   UPDATED 08/12/94    7025055
TEMPERATURE=   293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)          =    54.466              TEMPERATURE(KELVIN)        =   293.000

POTENTIAL SCATTER SIGMA  =     2.590              LUMPED NUCLEAR DENSITY     = 1.7363295E-
03

SPIN FACTOR (G)          =    14.448              LUMP DIMENSION (A-BAR)     =
0.0000000E+00

INNER RADIUS             = 0.0000000E+00          DANCOFF CORRECTION (C)     =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1     =     55.845              SIGMA(PER ABSORBER ATOM)= 3.4663022E+02

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2     =     55.925              SIGMA(PER ABSORBER ATOM)= 1.2557598E+02

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP         RES ABS          RES FISS          RES SCAT
  8      -5.518788E-04    0.000000E+00    -3.944190E-01
  9      -2.797993E-03    0.000000E+00    -2.293471E+00
 10      -3.291452E-01    0.000000E+00    -3.820862E+01
 11      -2.680562E+00    0.000000E+00    -1.159996E+02

EXCESS RESONANCE INTEGRALS

                    RESOLVED

ABSORPTION       3.33719E+00
FISSION          0.00000E+00
                                                         PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

 IRON            ENDF/B-IV MAT 1192                   UPDATED 08/12/94    4026000
TEMPERATURE=   293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE
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```
MASS NUMBER (A)           =    55.365             TEMPERATURE(KELVIN)        =   293.000

POTENTIAL SCATTER SIGMA   =     2.659             LUMPED NUCLEAR DENSITY     = 1.7000001E-
02

SPIN FACTOR (G)           =     0.748             LUMP DIMENSION (A-BAR)     =
0.0000000E+00

INNER RADIUS              = 0.0000000E+00         DANCOFF CORRECTION (C)     =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1    =     1.008            SIGMA(PER ABSORBER ATOM)= 1.4286198E+01

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2    =    22.298            SIGMA(PER ABSORBER ATOM)= 4.3837705E+00

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP         RES ABS         RES FISS          RES SCAT
  8       -5.400211E-04    0.000000E+00    -1.303678E+00
  9       -3.998998E-04    0.000000E+00    -1.905708E-01
 10        2.853071E-08    0.000000E+00    -2.581987E-06

EXCESS RESONANCE INTEGRALS

                      RESOLVED

ABSORPTION         2.11414E-02
FISSION            0.00000E+00
                                                    PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

 IRON             ENDF/B-IV MAT 1192                UPDATED 08/12/94    6026000
TEMPERATURE=    293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)           =    55.365             TEMPERATURE(KELVIN)        =   293.000

POTENTIAL SCATTER SIGMA   =     2.659             LUMPED NUCLEAR DENSITY     = 1.2953907E-
04

SPIN FACTOR (G)           =     0.748             LUMP DIMENSION (A-BAR)     =
0.0000000E+00

INNER RADIUS              = 0.0000000E+00         DANCOFF CORRECTION (C)     =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1    =     1.008            SIGMA(PER ABSORBER ATOM)= 6.6994250E+02

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2    =    16.270            SIGMA(PER ABSORBER ATOM)= 1.9740624E+03

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP         RES ABS         RES FISS          RES SCAT
  8       -1.379277E-05    0.000000E+00    -2.653044E-02
  9       -5.431981E-06    0.000000E+00    -2.347404E-03
 10        2.148488E-09    0.000000E+00    -2.730928E-07
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EXCESS RESONANCE INTEGRALS

                        RESOLVED

ABSORPTION             2.33052E-02
FISSION                0.00000E+00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'          UPDATED 08/12/94    7026304
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'          UPDATED 08/12/94    7028304
TEMPERATURE=    293.00
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

 URANIUM-235    ENDF/B-IV MAT 1261                         UPDATED 08/12/94    1092235
TEMPERATURE=    293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)            =   233.025             TEMPERATURE(KELVIN)        =   293.000

POTENTIAL SCATTER SIGMA  =     11.500              LUMPED NUCLEAR DENSITY     = 1.7934914E-
04

SPIN FACTOR (G)            = 15171.100             LUMP DIMENSION (A-BAR)     =
0.0000000E+00

INNER RADIUS               = 0.0000000E+00         DANCOFF CORRECTION (C)     =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1     =      1.008            SIGMA(PER ABSORBER ATOM)= 7.5230469E+03

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2     =     16.016            SIGMA(PER ABSORBER ATOM)= 7.3244318E+02

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP          RES ABS          RES FISS          RES SCAT
 12       -9.044416E-01    -5.549288E-01    -2.391155E-02
 13       -3.145243E+00    -1.546129E+00    -7.353358E-02
 14       -2.226849E+00    -1.339141E+00    -1.698238E-02
 15       -1.228059E-04    -9.337281E-05     6.295855E-07

EXCESS RESONANCE INTEGRALS

                        RESOLVED

ABSORPTION             2.21088E+02
FISSION                1.31466E+02
                                                             PROCESS NUMBER 1007 IS AT
TEMPERATURE=    293.00

 URANIUM-235    ENDF/B-IV MAT 1261                         UPDATED 08/12/94    4092235
TEMPERATURE=    293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS  0.0000E+00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)            =   233.025             TEMPERATURE(KELVIN)        =   293.000
```

```
POTENTIAL SCATTER SIGMA  =    11.500            LUMPED NUCLEAR DENSITY    = 3.2282845E-
05

SPIN FACTOR (G)          = 15171.100            LUMP DIMENSION (A-BAR)    =
0.0000000E+00

INNER RADIUS             = 0.0000000E+00        DANCOFF CORRECTION (C)    =
0.0000000E+00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1    =     1.008            SIGMA(PER ABSORBER ATOM)= 7.5230474E+03

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2    =    38.504            SIGMA(PER ABSORBER ATOM)= 7.6364658E+03

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS         RES FISS        RES SCAT
 12      -5.092921E-01   -3.125200E-01   -1.243320E-02
 13      -1.847332E+00   -9.110399E-01   -3.932169E-02
 14      -1.357982E+00   -8.222151E-01   -7.465982E-03
 15      -1.181174E-04   -8.954299E-05    7.257908E-07

EXCESS RESONANCE INTEGRALS

                    RESOLVED

ABSORPTION         2.24002E+02
FISSION            1.33058E+02
                                                      PROCESS NUMBER 1007 IS AT
TEMPERATURE=   293.00

CHLORINE (MAT 1149 FROM VERSION IV) USING 1/SIGT WEIGHTIUPDATED 08/12/94    6017000
TEMPERATURE=   293.00
                                                      PROCESS NUMBER 1007 IS AT
TEMPERATURE=   300.00
```

```
      THIS XSDRN WORKING TAPE WAS CREATED 08/30/96 AT 22:07:52
      THE TITLE OF THE PARENT CASE IS AS FOLLOWS
      SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
         BASED ON ENDF-B VERSION 4 DATA
            COMPILED FOR NRC     1/27/89
          TAPE ID                            4321        NUMBER OF NUCLIDES
34
          NUMBER OF NEUTRON GROUPS             27        NUMBER OF GAMMA GROUPS
0
          FIRST THERMAL GROUP                  15        LOGICAL UNIT
4
                                         TABLE OF CONTENTS
         HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94        ID
1001001
         HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94        ID
2001001
         HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94        ID
3001001
         HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94        ID
4001001
         HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94        ID
5001001
         HYDROGEN       ENDF/B-IV MAT 1269/THRM1002          UPDATED 08/12/94        ID
6001001
         CARBON-12      ENDF/B-IV MAT 1274/THRM1065          UPDATED 08/12/94        ID
2006012
         CARBON-12      ENDF/B-IV MAT 1274/THRM1065          UPDATED 08/12/94        ID
6006012
         OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94        ID
1008016
         OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94        ID
3008016
         OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94        ID
4008016
         OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94        ID
5008016
         OXYGEN-16      ENDF/B-IV MAT 1276                   UPDATED 08/12/94        ID
6008016
         FLUORINE       ENDF/B-IV MAT 1277                   UPDATED 08/12/94        ID
1009019
         FLUORINE       ENDF/B-IV MAT 1277                   UPDATED 08/12/94        ID
4009019
         SODIUM-23      ENDF/B-IV MAT 1156                   UPDATED 08/12/94        ID
6011023
        MG 1280 218 GP 1/E*SIGT 040375(5)                    UPDATED 08/12/94        ID
6012000
        AL-27 1193 218 GP 040375(5)                          UPDATED 08/12/94        ID
4013027
        AL-27 1193 218 GP 040375(5)                          UPDATED 08/12/94        ID
6013027
         SILICON        ENDF/B-IV MAT 1194                   UPDATED 08/12/94        ID
6014000
        SULFUR  LENDL MAT 7020                               UPDATED 08/12/94        ID
6016000
         POTASSIUM      ENDF/B-IV MAT 1150                   UPDATED 08/12/94        ID
6019000
        CALCIUM ENDF/B-IV MAT 1195                           UPDATED 08/12/94        ID
6020000
         TITANIUM       ENDF/B-IV MAT 1286                   UPDATED 08/12/94        ID
6022000
        CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'     UPDATED 08/12/94        ID
7024304
         MANGANESE-55   ENDF/B-IV MAT 1197                   UPDATED 08/12/94        ID
6025055
         MANGANESE-55   ENDF/B-IV MAT 1197                   UPDATED 08/12/94        ID
7025055
         IRON           ENDF/B-IV MAT 1192                   UPDATED 08/12/94        ID
4026000
         IRON           ENDF/B-IV MAT 1192                   UPDATED 08/12/94        ID
6026000
        FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'     UPDATED 08/12/94        ID
7026304
        NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'     UPDATED 08/12/94        ID
7028304
         URANIUM-235    ENDF/B-IV MAT 1261                   UPDATED 08/12/94        ID
1092235
```

```
              URANIUM-235     ENDF/B-IV MAT 1261                       UPDATED 08/12/94        ID
       4092235
             CHLORINE (MAT 1149 FROM VERSION IV) USING 1/SIGT WEIGHTIUPDATED 08/12/94        ID
       6017000

               TAPE COPY USED       0 I/O'S, AND TOOK     9.44 SECONDS
```

```
                  KK           KK  EEEEEEEEEEEEE  NN          NN   OOOOOOOOOOO
VV            VV
                  KK          KK   EEEEEEEEEEEEE  NNN         NN  OOOOOOOOOOOOO
VV            VV
                  KK         KK    EE             NNNN        NN  OO          OO
VV            VV
                  KK        KK     EE             NN NN       NN  OO          OO
VV            VV
                  KK       KK      EE             NN  NN      NN  OO          OO
VV            VV
                  KKKKKKKK         EEEEEEEEE      NN   NN     NN  OO          OO     --------
-----    VV         VV
                  KKKKKKKK         EEEEEEEEE      NN    NN    NN  OO          OO     --------
-----     VV      VV
                  KK       KK      EE             NN     NN   NN  OO          OO
VV       VV
                  KK        KK     EE             NN      NN NN   OO          OO
VV    VV
                  KK         KK    EE             NN       NNNN   OO          OO
VV VV
                  KK          KK   EEEEEEEEEEEEE  NN        NNN   OOOOOOOOOOOOO
VVV
                  KK           KK  EEEEEEEEEEEEE  NN         NN    OOOOOOOOOOO
V


   SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA      LL              EEEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AAAAAAAAAAA      LL              EEEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS          SS  CC          CC  AA          AA   LL              EE
PP          PP   CC          CC
  SS              CC              AA          AA   LL              EE
PP          PP   CC
  SS              CC              AA          AA   LL              EE
PP          PP   CC
  SSSSSSSSSSSS    CC              AAAAAAAAAAAAA    LL              EEEEEEEEE          --------
-----    PPPPPPPPPPPPP    CC
   SSSSSSSSSSSS   CC              AAAAAAAAAAAAA    LL              EEEEEEEEE          --------
-----    PPPPPPPPPPPP     CC
              SS  CC              AA          AA   LL              EE
PP               CC
              SS  CC              AA          AA   LL              EE
PP               CC
  SS          SS  CC          CC  AA          AA   LL              EE
PP               CC          CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA          AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP               CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC    AA          AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP                CCCCCCCCCCC


     0000000       88888888888               //   33333333333      0000000
//   99999999999     666666666666
    000000000     8888888888888             //   3333333333333    000000000
//   9999999999999   666666666666
   00         00   88          88          //    33          33    00         00
//    99          99   66
  00          00   88          88         //                 33   00          00
//     99           99   66
  00          00   88          88        //                  33   00          00
//       99           99   66
  00          00   88888888888          //                 333    00          00
//        9999999999999   666666666666
  00          00   88888888888         //                  333    00          00          //
999999999999   6666666666666
  00          00   88          88     //                     33   00          00         //
99   66          66
  00          00   88          88    //                      33   00          00        //
99   66          66
   00         00   88          88   //        33           33    00         00        //
99   66          66
    000000000     8888888888888   //          3333333333333    000000000          //
9999999999999   666666666666
```

```
     0000000       88888888888      //              33333333333       0000000        //
999999999999     66666666666


   22222222222     22222222222                        0000000       88888888888
33333333333     33333333333
  2222222222222   2222222222222                      000000000     8888888888888
3333333333333   3333333333333
  22         22   22         22          :::        00       00    88          88
:::       33          33   33          33
             22              22          :::       00         00   88          88
:::                   33               33
             22              22          :::       00         00   88          88
:::                   33               33
           22              22                      00         00    88888888888
333             333
         22              22                        00         00    88888888888
333             333
       22              22                :::       00         00   88          88
:::                   33               33
     22              22                  :::       00         00   88          88
:::                   33               33
   22              22                    :::        00       00    88          88
:::       33          33   33          33
  2222222222222   2222222222222                      000000000     8888888888888
3333333333333   3333333333333
  2222222222222   2222222222222                       0000000       88888888888
33333333333     33333333333
```

```
   SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE
PPPPPPPPPPPP     CCCCCCCCCCC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE
PPPPPPPPPPPPP   CCCCCCCCCCCCC
  SS         SS   CC         CC    AA         AA    LL              EE
PP         PP   CC         CC
  SS              CC               AA         AA    LL              EE
PP         PP   CC
  SS              CC               AA         AA    LL              EE
PP         PP   CC
  SSSSSSSSSSSS    CC               AAAAAAAAAAAAA    LL              EEEEEEEEE        --------
-----   PPPPPPPPPPPPP   CC
   SSSSSSSSSSSS   CC               AAAAAAAAAAAAA    LL              EEEEEEEEE        --------
-----   PPPPPPPPPPP     CC
             SS   CC               AA         AA    LL              EE
PP              CC
             SS   CC               AA         AA    LL              EE
PP              CC
  SS         SS   CC         CC    AA         AA    LL              EE
PP              CC         CC
  SSSSSSSSSSSSS   CCCCCCCCCCCCC    AA         AA    LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP              CCCCCCCCCCCCC
   SSSSSSSSSSS     CCCCCCCCCCC     AA         AA    LLLLLLLLLLLLL   EEEEEEEEEEEEE
PP               CCCCCCCCCCC



********************************************************************************

********************************************************************************

********************************************************************************
                        *****
*****
                        *****                       PROGRAM VERIFICATION INFORMATION
*****
                        *****
*****
                        *****                      CODE SYSTEM:   SCALE-PC VERSION:   4.3
*****
                        *****
*****

********************************************************************************

********************************************************************************
                        *****
*****
                        *****
*****
                        *****                  PROGRAM:  000009
*****
                        *****
*****
                        *****            CREATION DATE:  03-08-96
*****
                        *****
*****
                        *****                   VOLUME:   DOS PART
*****
                        *****
*****
                        *****                  LIBRARY:  C:\SCALE43\EXE
*****
                        *****
*****
                        *****
*****
                        *****          PRODUCTION CODE:  KENOVA
*****
```

```
                        *****
*****
                        *****                  VERSION:  3.1
*****
                        *****
*****
                        *****                  JOBNAME:  SCALE-PC
*****
                        *****
*****
                        *****        DATE OF EXECUTION:  08/30/96
*****
                        *****
*****
                        *****        TIME OF EXECUTION:  22:08:33
*****
                        *****
*****
                        *****
*****
********************************************************************************
********************************************************************************
********************************************************************************
```

```
*****************************************************************************************************
*************************
       ***
***
       ***                                 PROBLEM K12ELOQ 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL            ***
       ***
***

*****************************************************************************************************
*************************
       ***                                  ******      NUMERIC PARAMETERS       ******
***
       ***
***
       ***
***
       ***                      TME         MAXIMUM PROBLEM TIME (MIN)
200.00                   ***
       ***
***
       ***                      TBA         TIME PER GENERATION (MIN)
0.50                    ***
       ***
***
       ***                      GEN         NUMBER OF GENERATIONS
103                    ***
       ***
***
       ***                      NPG         NUMBER PER GENERATION
300                    ***
       ***
***
       ***                      NSK         NUMBER OF GENERATIONS TO BE SKIPPED
3                     ***
       ***
***
       ***                      BEG         BEGINNING GENERATION NUMBER
1                     ***
       ***
***
       ***                      RES         GENERATIONS BETWEEN CHECKPOINTS
0                     ***
       ***
***
       ***                      X1D         NUMBER OF EXTRA 1-D CROSS SECTIONS
1                     ***
       ***
***
       ***                      NBK         NEUTRON BANK SIZE
325                    ***
       ***
***
       ***                      XNB         EXTRA POSITIONS IN NEUTRON BANK
0                     ***
       ***
***
       ***                      NFB         FISSION BANK SIZE
300                    ***
       ***
***
       ***                      XFB         EXTRA POSITIONS IN FISSION BANK
0                     ***
       ***
***
       ***                      WTA         DEFAULT VALUE OF WEIGHT AVERAGE
0.5000                   ***
       ***
***
       ***                      WTH         WEIGHT HIGH FOR SPLITTING
3.0000                   ***
       ***
***
```

```
          ***                        WTL        WEIGHT LOW FOR RUSSIAN ROULETTE
0.3333                    ***
          ***
***
          ***                        RND        STARTING RANDOM NUMBER
BB827100001                   ***
          ***
***
          ***                        NB8        NUMBER OF D.A. BLOCKS ON UNIT  8
200                     ***
          ***
***
          ***                        NL8        LENGTH OF D.A. BLOCKS ON UNIT  8
512                     ***
          ***
***
          ***                        ADJ        MODE OF CALCULATION
FORWARD                    ***
          ***
***
          ***                                   INPUT DATA WRITTEN ON RESTART UNIT
NO                     ***
          ***
***
          ***                                   BINARY DATA INTERFACE
YES                     ***
          ***
***
          ***
***

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**************************

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```

```
**********************************************************************************************
**************************
       ***
***
       ***                                      PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL              ***
       ***
***

**********************************************************************************************
**************************
       ***                                ******      LOGICAL PARAMETERS        ******
***
       ***
***
       ***  RUN  EXECUTE PROBLEM AFTER CHECKING DATA    YES             PLT  PLOT PICTURE
MAP(S)                     YES ***
       ***
***
       ***  FLX  COMPUTE FLUX                            NO             FDN  COMPUTE
FISSION DENSITIES                YES ***
       ***
***
       ***  SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION    NO             NUB  COMPUTE NU-BAR
& AVG FISSION GROUP       YES ***
       ***
***
       ***  MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER     NO             MKP  COMPUTE MATRIX
K-EFF BY UNIT LOCATION    NO ***
       ***
***
       ***  CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER   NO             CKP  COMPUTE
COFACTOR K-EFF BY UNIT LOCATION  NO ***
       ***
***
       ***  FMU  PRINT FISS PROD MATRIX BY UNIT NUMBER   NO             FMP  PRINT FISS
PROD MATRIX BY UNIT LOCATION  NO ***
       ***
***
       ***  MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER     NO             MKA  COMPUTE MATRIX
K-EFF BY ARRAY NUMBER      NO ***
       ***
***
       ***  CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER   NO             CKA  COMPUTE
COFACTOR K-EFF BY ARRAY NUMBER   NO ***
       ***
***
       ***  FMH  PRINT FISS PROD MATRIX BY HOLE NUMBER   NO             FMA  PRINT FISS
PROD MATRIX BY ARRAY NUMBER   NO ***
       ***
***
       ***  HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL    NO             HAL  COLLECT MATRIX
BY HIGHEST ARRAY LEVEL    NO ***
       ***
***
       ***  AMX  PRINT ALL MIXED CROSS SECTIONS          NO             FAR  PRINT FIS. AND
ABS. BY REGION            NO ***
       ***
***
       ***  XS1  PRINT 1-D MIXTURE X-SECTIONS            NO             GAS  PRINT FAR BY
GROUP                        NO ***
       ***
***
       ***  XS2  PRINT 2-D MIXTURE X-SECTIONS            NO             PAX  PRINT XSEC-
ALBEDO CORRELATION TABLES     NO ***
       ***
***
       ***  XAP  PRINT MIXTURE ANGLES & PROBABILITIES    NO             PWT  PRINT WEIGHT
AVERAGE ARRAY                NO ***
       ***
***
```

```
       ***  PKI  PRINT FISSION SPECTRUM                    NO            PGM  PRINT INPUT
GEOMETRY                     NO ***
       ***
***
       ***  P1D  PRINT EXTRA 1-D CROSS SECTIONS            NO            BUG  PRINT DEBUG
INFORMATION                  NO ***
       ***
***
       ***                                                               TRK  PRINT TRACKING
INFORMATION               NO ***
       ***
***
       ***
***

******************************************************************************************
**************************

******************************************************************************************
**************************

******************************************************************************************
**************************
                                             PARAMETER INPUT COMPLETED

                               ........    0 IO'S WERE USED READING THE PARAMETER DATA
........

                              *************** DATA READING COMPLETED ***************
```

```
*******************************************************************************************
**************************
       ***
***
       ***                            PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL                ***
       ***
***

*******************************************************************************************
**************************

*******************************************************************************************
**************************
       ***
***
       ***          UNIT                                                   VOLUME
***
       ***         NUMBER                  DATA SET NAME                    NAME
UNIT FUNCTION                     ***
       ***         ------                  -------------                    ----        ---
----------                     ***
       ***
***
       ***      XSC  14      C:\SCALE43\WORK\FT14F001
MIXED CROSS SECTIONS              ***
       ***
***
       ***      ALB  79      C:\SCALE43\DATALIB\FT79F001
INPUT ALBEDOS                     ***
       ***
***
       ***      WTS  80      C:\SCALE43\DATALIB\FT80F001
INPUT WEIGHTS                     ***
       ***
***
       ***      SKT  16       UNKNOWN
WRITE SCRATCH DATA                ***
       ***
***
       ***      BIN  95      C:\SCALE43\WORK\FT95F001
BINARY INPUT DATA                 ***
       ***
***
       ***      RST  95      C:\SCALE43\WORK\FT95F001
READ RESTART DATA                 ***
       ***
***
       ***      LIB   4      C:\SCALE43\WORK\FT04F001
INPUT AMPX WORKING LIBRARY        ***
       ***
***
       ***            8      C:\SCALE43\WORK\FT08F001
INPUT DATA DIRECT ACCESS          ***
       ***
***
       ***            9       UNKNOWN
SUPER GROUPED DIRECT ACCESS       ***
       ***
***
       ***           10       UNKNOWN
XSEC MIXING DIRECT ACCESS         ***
       ***
***

*******************************************************************************************
**************************
                                   ........    0 IO'S WERE USED PREPARING INPUT DATA
........


                                   CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT
4
```

```
                              PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL

                                        MIXING TABLE

                                  NUMBER OF SCATTERING ANGLES =  2
                                CROSS SECTION MESSAGE THRESHOLD =3.0E-05


MIXTURE =       1           DENSITY(G/CC) =  1.0805
   NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA        AWT              NUCLIDE TITLE
   1001001  6.62019E-02   1.02517E-01    1001      1.0077       HYDROGEN         ENDF/B-IV MAT
1269/THRM1002               UPDATED 08/12/94
   1008016  3.34596E-02   8.22228E-01    8016     15.9904       OXYGEN-16        ENDF/B-IV MAT
1276                        UPDATED 08/12/94
   1009019  3.58698E-04   1.04726E-02    9019     18.9982       FLUORINE         ENDF/B-IV MAT
1277                        UPDATED 08/12/94
   1092235  1.79349E-04   6.47830E-02   92235    235.0441       URANIUM-235      ENDF/B-IV MAT
1261                        UPDATED 08/12/94

MIXTURE =       2           DENSITY(G/CC) = 0.92299
   NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA        AWT              NUCLIDE TITLE
   2001001  7.93178E-02   1.43793E-01    1001      1.0077       HYDROGEN         ENDF/B-IV MAT
1269/THRM1002               UPDATED 08/12/94
   2006012  3.96589E-02   8.56207E-01    6000     12.0001       CARBON-12        ENDF/B-IV MAT
1274/THRM1065               UPDATED 08/12/94

MIXTURE =       3           DENSITY(G/CC) = 0.99817
   NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA        AWT              NUCLIDE TITLE
   3001001  6.67692E-02   1.11927E-01    1001      1.0077       HYDROGEN         ENDF/B-IV MAT
1269/THRM1002               UPDATED 08/12/94
   3008016  3.33846E-02   8.88074E-01    8016     15.9904       OXYGEN-16        ENDF/B-IV MAT
1276                        UPDATED 08/12/94

MIXTURE =       4           DENSITY(G/CC) =  3.4511
   NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA        AWT              NUCLIDE TITLE
   4001001  1.19163E-02   5.77758E-03    1001      1.0077       HYDROGEN         ENDF/B-IV MAT
1269/THRM1002               UPDATED 08/12/94
   4008016  6.02274E-03   4.63386E-02    8016     15.9904       OXYGEN-16        ENDF/B-IV MAT
1276                        UPDATED 08/12/94
   4009019  6.45657E-05   5.90208E-04    9019     18.9982       FLUORINE         ENDF/B-IV MAT
1277                        UPDATED 08/12/94
   4013027  3.75000E-02   4.86847E-01   13027     26.9818     AL-27 1193 218 GP 040375(5)
UPDATED 08/12/94
   4026000  1.70000E-02   4.56796E-01   26000     55.8447       IRON             ENDF/B-IV MAT
1192                        UPDATED 08/12/94
   4092235  3.22828E-05   3.65100E-03   92235    235.0441       URANIUM-235      ENDF/B-IV MAT
1261                        UPDATED 08/12/94

MIXTURE =       5           DENSITY(G/CC) = 0.34187E-04
   NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA        AWT              NUCLIDE TITLE
   5001001  2.28684E-06   1.11927E-01    1001      1.0077       HYDROGEN         ENDF/B-IV MAT
1269/THRM1002               UPDATED 08/12/94
   5008016  1.14342E-06   8.88074E-01    8016     15.9904       OXYGEN-16        ENDF/B-IV MAT
1276                        UPDATED 08/12/94

MIXTURE =       6           DENSITY(G/CC) =  2.1470
   NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA        AWT              NUCLIDE TITLE
   6001001  4.25810E-03   3.31854E-03    1001      1.0077       HYDROGEN         ENDF/B-IV MAT
1269/THRM1002               UPDATED 08/12/94
   6006012  1.13479E-02   1.05322E-01    6000     12.0001       CARBON-12        ENDF/B-IV MAT
1274/THRM1065               UPDATED 08/12/94
   6008016  4.03824E-02   4.99424E-01    8016     15.9904       OXYGEN-16        ENDF/B-IV MAT
1276                        UPDATED 08/12/94
   6011023  7.93561E-05   1.41100E-03   11023     22.9895       SODIUM-23        ENDF/B-IV MAT
1156                        UPDATED 08/12/94
   6012000  5.01114E-03   9.41991E-02   12000     24.3048     MG 1280 218 GP 1/E*SIGT
040375(5)                             UPDATED 08/12/94
   6013027  3.76599E-04   7.85902E-03   13027     26.9818     AL-27 1193 218 GP 040375(5)
UPDATED 08/12/94
   6014000  1.93819E-03   4.21011E-02   14000     28.0853       SILICON          ENDF/B-IV MAT
1194                        UPDATED 08/12/94
   6016000  1.00126E-04   2.48300E-03   16000     32.0634     SULFUR  LENDL MAT 7020
UPDATED 08/12/94
   6017000  1.90738E-05   5.23001E-04   17000     35.4526     CHLORINE (MAT 1149 FROM
VERSION IV) USING 1/SIGT WEIGHTIUPDATED 08/12/94
```

```
   6019000   3.12311E-04  9.44503E-03   19000     39.1019       POTASSIUM       ENDF/B-IV MAT
1150                       UPDATED 08/12/94
   6020000   7.30081E-03  2.26319E-01   20000     40.0803     CALCIUM ENDF/B-IV MAT 1195
UPDATED 08/12/94
   6022000   4.01829E-05  1.48802E-03   22000     47.8793       TITANIUM        ENDF/B-IV MAT
1286                       UPDATED 08/12/94
   6025055   1.20498E-05  5.12000E-04   25055     54.9379       MANGANESE-55    ENDF/B-IV MAT
1197                       UPDATED 08/12/94
   6026000   1.29539E-04  5.59502E-03   26000     55.8447       IRON            ENDF/B-IV MAT
1192                       UPDATED 08/12/94

MIXTURE =       7         DENSITY(G/CC) =   7.9200
   NUCLIDE    ATOM-DENS.   WGT. FRAC.     ZA        AWT               NUCLIDE TITLE
   7024304   1.74286E-02  1.90000E-01   24000     51.9957     CR 1191 WT SS-304(1/EST) P-3
293K SP=5+4(42375)'         UPDATED 08/12/94
   7025055   1.73633E-03  1.99999E-02   25055     54.9379       MANGANESE-55    ENDF/B-IV MAT
1197                       UPDATED 08/12/94
   7026304   5.93579E-02  6.95000E-01   26000     55.8447     FE 1192 WT SS-304(1/EST) P-3
293K SP=5+4(42375)'         UPDATED 08/12/94
   7028304   7.72070E-03  9.50001E-02   28000     58.6872     NI 1190 WT SS-304(1/EST) P-3
293K SP=5+4(42375)'         UPDATED 08/12/94


                               1001001     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002
UPDATED 08/12/94
                               2001001     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002
UPDATED 08/12/94
                               3001001     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002
UPDATED 08/12/94
                               4001001     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002
UPDATED 08/12/94
                               5001001     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002
UPDATED 08/12/94
                               6001001     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002
UPDATED 08/12/94
                               2006012     CARBON-12       ENDF/B-IV MAT 1274/THRM1065
UPDATED 08/12/94
                               6006012     CARBON-12       ENDF/B-IV MAT 1274/THRM1065
UPDATED 08/12/94
                               1008016     OXYGEN-16       ENDF/B-IV MAT 1276
UPDATED 08/12/94
                               3008016     OXYGEN-16       ENDF/B-IV MAT 1276
UPDATED 08/12/94
                               4008016     OXYGEN-16       ENDF/B-IV MAT 1276
UPDATED 08/12/94
                               5008016     OXYGEN-16       ENDF/B-IV MAT 1276
UPDATED 08/12/94
                               6008016     OXYGEN-16       ENDF/B-IV MAT 1276
UPDATED 08/12/94
                               1009019     FLUORINE        ENDF/B-IV MAT 1277
UPDATED 08/12/94
                               4009019     FLUORINE        ENDF/B-IV MAT 1277
UPDATED 08/12/94
                               6011023     SODIUM-23       ENDF/B-IV MAT 1156
UPDATED 08/12/94
                               6012000    MG 1280 218 GP 1/E*SIGT 040375(5)
UPDATED 08/12/94
                               4013027    AL-27 1193 218 GP 040375(5)
UPDATED 08/12/94
                               6013027    AL-27 1193 218 GP 040375(5)
UPDATED 08/12/94
                               6014000     SILICON         ENDF/B-IV MAT 1194
UPDATED 08/12/94
                               6016000    SULFUR  LENDL MAT 7020
UPDATED 08/12/94
                               6019000     POTASSIUM       ENDF/B-IV MAT 1150
UPDATED 08/12/94
                               6020000    CALCIUM ENDF/B-IV MAT 1195
UPDATED 08/12/94
                               6022000     TITANIUM        ENDF/B-IV MAT 1286
UPDATED 08/12/94
                               7024304    CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
UPDATED 08/12/94
                               6025055     MANGANESE-55    ENDF/B-IV MAT 1197
UPDATED 08/12/94
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                                   7025055     MANGANESE-55   ENDF/B-IV MAT 1197
UPDATED 08/12/94
                                   4026000      IRON          ENDF/B-IV MAT 1192
UPDATED 08/12/94
                                   6026000      IRON          ENDF/B-IV MAT 1192
UPDATED 08/12/94
                                   7026304     FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
UPDATED 08/12/94
                                   7028304     NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
UPDATED 08/12/94
                                   1092235      URANIUM-235   ENDF/B-IV MAT 1261
UPDATED 08/12/94
                                   4092235      URANIUM-235   ENDF/B-IV MAT 1261
UPDATED 08/12/94
                                   6017000     CHLORINE (MAT 1149 FROM VERSION IV) USING 1/SIGT
WEIGHTIUPDATED 08/12/94

KENO MESSAGE NUMBER K5-222        1 TRANSFERS FOR MIXTURE     1 WERE CORRECTED FOR BAD
MOMENTS.

KENO MESSAGE NUMBER K5-222        1 TRANSFERS FOR MIXTURE     4 WERE CORRECTED FOR BAD
MOMENTS.

KENO MESSAGE NUMBER K5-222        1 TRANSFERS FOR MIXTURE     3 WERE CORRECTED FOR BAD
MOMENTS.

KENO MESSAGE NUMBER K5-222        2 TRANSFERS FOR MIXTURE     5 WERE CORRECTED FOR BAD
MOMENTS.

KENO MESSAGE NUMBER K5-222        2 TRANSFERS FOR MIXTURE     6 WERE CORRECTED FOR BAD
MOMENTS.

KENO MESSAGE NUMBER K5-222        1 TRANSFERS FOR MIXTURE     2 WERE CORRECTED FOR BAD
MOMENTS.

                                ........    0 IO'S WERE USED MIXING CROSS-SECTIONS
........

                                 1-D CROSS SECTION ARRAY ID NUMBERS
                                    1  2002  1452    27    18  1018

                                ........    0 IO'S WERE USED PREPARING THE CROSS SECTIONS
........
```

```
*********************************************************************************************
*********
            ***
***
            ***         PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H2O
REFL             ***
            ***
***

*********************************************************************************************
*********

*********************************************************************************************
*********
            ***
***
            ***                          ****** ADDITIONAL INFORMATION ******
***
            ***
***
            ***  NUMBER OF ENERGY GROUPS                27        USE LATTICE GEOMETRY
YES  ***
            ***
***
            ***  NO. OF FISSION SPECTRUM SOURCE GROUP  1        GLOBAL ARRAY NUMBER
1  ***
            ***
***
            ***  NO. OF SCATTERING ANGLES IN XSECS      2        NUMBER OF UNITS IN THE
GLOBAL X DIR.      1  ***
            ***
***
            ***  ENTRIES/NEUTRON IN THE NEUTRON BANK  16        NUMBER OF UNITS IN THE
GLOBAL Y DIR.      1  ***
            ***
***
            ***  ENTRIES/NEUTRON IN THE FISSION BANK   9        NUMBER OF UNITS IN THE
GLOBAL Z DIR.     18  ***
            ***
***
            ***  NUMBER OF MIXTURES USED                6        USE A GLOBAL REFLECTOR
YES  ***
            ***
***
            ***  NUMBER OF BIAS ID'S USED               1        USE NESTED HOLES
NO  ***
            ***
***
            ***  NUMBER OF DIFFERENTIAL ALBEDOS USED   0        NUMBER OF HOLES
0  ***
            ***
***
            ***  TOTAL INPUT GEOMETRY REGIONS          77        MAXIMUM HOLE NESTING LEVEL
0  ***
            ***
***
            ***  NUMBER OF GEOMETRY REGIONS USED       77        USE NESTED ARRAYS
NO  ***
            ***
***
            ***  LARGEST GEOMETRY UNIT NUMBER          19        NUMBER OF ARRAYS USED
1  ***
            ***
***
            ***  LARGEST ARRAY NUMBER                   1        MAXIMUM ARRAY NESTING
LEVEL              1  ***
            ***
***
            ***
***
            ***  +X BOUNDARY CONDITION            VACUUM        -X BOUNDARY CONDITION
VACUUM  ***
            ***
***
```

```
                  ***  +Y BOUNDARY CONDITION            VACUUM       -Y BOUNDARY CONDITION
VACUUM   ***
                  ***
***
                  ***  +Z BOUNDARY CONDITION            VACUUM       -Z BOUNDARY CONDITION
VACUUM   ***
                  ***
***

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*****************************************************************************************
****
                      ***
***
                      ***          PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF
H20 REFL               ***
                      ***
***

*****************************************************************************************
****

*****************************************************************************************
****
                      ***
***
                      ***                     ****** SPACE AND SUPERGROUP INFORMATION ******
***
                      ***
***
                      ***      100000 WORDS IS THE TOTAL SPACE AVAILABLE.
***
                      ***
***
                      ***       10225 WORDS WERE USED FOR NON-SUPERGROUP STORAGE.
***
                      ***
***
                      ***       89775 WORDS OF STORAGE ARE AVAILABLE FOR SUPERGROUPED DATA.
***
                      ***
***
                      ***       99751 WORDS OF STORAGE ARE AVAILABLE FOR CONSTRUCTING THE
SUPERGROUPS.              ***
                      ***
***
                      ***       89715 WORDS OF STORAGE ARE AVAILABLE TO EACH SUPERGROUP.
***
                      ***
***
                      ***         879 WORDS ARE NEEDED FOR THE LARGEST GROUP.
***
                      ***
***
                      ***       11320 WORDS OF STORAGE IS SUFFICIENT TO RUN THIS PROBLEM.
***
                      ***
***
                      ***       22074 WORDS OF STORAGE WILL ALLOW THE PROBLEM TO RUN WITH ONE
SUPERGROUP.           ***
                      ***
***
                      ***       22176 WORDS OF STORAGE WILL BE USED TO RUN THIS PROBLEM.
***
                      ***
***

*****************************************************************************************
****

*****************************************************************************************
****
                      ***
***
                      ***                  STARTING      ENDING       XSEC       ALBEDO
TOTAL                  ***
                      ***    SUPERGROUP      GROUP        GROUP      LENGTH      LENGTH
LENGTH                 ***
                      ***
***
                      ***
***
                      ***         1            1           27         2441          0
11789                 ***
```

```
                    ***
***
************************************************************************************************
****
                                    ........    0 IO'S WERE USED IN SUPERGROUPING    ........
                                    ........    0 IO'S WERE USED LOADING THE DATA    ........
```

```
                                         PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H2O REFL

                 MEDIA BIAS      GEOMETRY DESCRIPTION FOR THOSE UNITS UTILIZED IN THIS
PROBLEM
REGION            NUM   ID

                                                   -----   UNIT    1   -----

  1 CYLINDER          1  1  RADIUS =  4.4450     +Z =  17.150     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  2 CYLINDER          2  1  RADIUS =  4.6040     +Z =  17.150     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  3 CYLINDER          3  1  RADIUS =  35.080     +Z =  17.150     -Z = -30.480
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  4 CUBOID            5  1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000     +Z =  17.150     -Z = -30.480

                                                   -----   UNIT    2   -----

  1 CYLINDER          1  1  RADIUS =  2.8570     +Z =  4.1270     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  2 CYLINDER          7  1  RADIUS =  3.0160     +Z =  4.1270     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  3 CYLINDER          3  1  RADIUS =  33.490     +Z =  4.1270     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  4 CUBOID            5  1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000     +Z =  4.1270     -Z = 0.00000

                                                   -----   UNIT    3   -----

  1 CYLINDER          1  1  RADIUS =  3.5050     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  2 CYLINDER          7  1  RADIUS =  3.6550     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  3 CYLINDER          3  1  RADIUS =  34.130     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  4 CUBOID            5  1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000     +Z =  3.8100     -Z = 0.00000

                                                   -----   UNIT    4   -----

  1 CYLINDER          1  1  RADIUS =  4.3900     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  2 CYLINDER          7  1  RADIUS =  4.5400     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  3 CYLINDER          3  1  RADIUS =  35.020     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  4 CUBOID            5  1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000     +Z =  3.8100     -Z = 0.00000

                                                   -----   UNIT    5   -----

  1 CYLINDER          1  1  RADIUS =  5.2890     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  2 CYLINDER          7  1  RADIUS =  5.4390     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000
```

```
  3 CYLINDER          3  1  RADIUS =  35.910     +Z =  3.8100     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  4 CUBOID            5  1      +X =  60.000    -X = -60.000     +Y =  60.000     -Y = -
60.000     +Z =  3.8100     -Z = 0.00000
```

```
                                      PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL

                      MEDIA BIAS       GEOMETRY DESCRIPTION FOR THOSE UNITS UTILIZED IN THIS
PROBLEM
REGION                 NUM   ID


                                                       -----   UNIT     6    -----

  1 CYLINDER             1   1  RADIUS =  6.1800      +Z =  3.8100      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  2 CYLINDER             7   1  RADIUS =  6.3300      +Z =  3.8100      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  3 CYLINDER             3   1  RADIUS =  36.830      +Z =  3.8100      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  4 CUBOID               5   1      +X =  60.000      -X = -60.000      +Y =  60.000      -Y = -
60.000      +Z =  3.8100      -Z = 0.00000


                                                       -----   UNIT     7    -----

  1 CYLINDER             1   1  RADIUS =  6.1850      +Z =  40.640      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  2 CYLINDER             7   1  RADIUS =  6.3500      +Z =  40.640      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  3 CYLINDER             3   1  RADIUS =  36.665      +Z =  40.640      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  4 CUBOID               5   1      +X =  60.000      -X = -60.000      +Y =  60.000      -Y = -
60.000      +Z =  40.640      -Z = 0.00000


                                                       -----   UNIT     8    -----

  1 CYLINDER             1   1  RADIUS =  8.0000      +Z =  1.7400      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  2 CYLINDER             7   1  RADIUS =  8.1500      +Z =  1.7400      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  3 CYLINDER             3   1  RADIUS =  38.630      +Z =  1.7400      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  4 CUBOID               5   1      +X =  60.000      -X = -60.000      +Y =  60.000      -Y = -
60.000      +Z =  1.7400      -Z = 0.00000


                                                       -----   UNIT     9    -----

  1 CYLINDER             1   1  RADIUS =  9.6500      +Z =  1.7400      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  2 CYLINDER             7   1  RADIUS =  9.8000      +Z =  1.7400      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  3 CYLINDER             3   1  RADIUS =  40.280      +Z =  1.7400      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  4 CUBOID               5   1      +X =  60.000      -X = -60.000      +Y =  60.000      -Y = -
60.000      +Z =  1.7400      -Z = 0.00000


                                                       -----   UNIT    10    -----

  1 CYLINDER             1   1  RADIUS =  10.100      +Z =  3.5800      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000

  2 CYLINDER             7   1  RADIUS =  10.250      +Z =  3.5800      -Z = 0.00000
CENTERLINE IS AT   X = 0.00000       Y = 0.00000
```

```
 3 CYLINDER          3  1  RADIUS =  40.730      +Z =  3.5800      -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

 4 CUBOID            5  1      +X =  60.000      -X = -60.000      +Y =  60.000      -Y = -
60.000      +Z =  3.5800      -Z = 0.00000
```

```
                                     PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL

                  MEDIA BIAS     GEOMETRY DESCRIPTION FOR THOSE UNITS UTILIZED IN THIS
PROBLEM
REGION             NUM   ID

                                                         -----   UNIT    11    -----

  1 CYLINDER          1   1  RADIUS =  10.550     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          7   1  RADIUS =  10.700     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          3   1  RADIUS =  41.180     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CUBOID            5   1       +X =  60.000    -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  3.5800      -Z = 0.00000

                                                         -----   UNIT    12    -----

  1 CYLINDER          1   1  RADIUS =  11.000     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          7   1  RADIUS =  11.150     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          3   1  RADIUS =  41.630     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CUBOID            5   1       +X =  60.000    -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  3.5800      -Z = 0.00000

                                                         -----   UNIT    13    -----

  1 CYLINDER          1   1  RADIUS =  11.450     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          7   1  RADIUS =  11.600     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          3   1  RADIUS =  42.080     +Z =  3.5800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CUBOID            5   1       +X =  60.000    -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  3.5800      -Z = 0.00000

                                                         -----   UNIT    14    -----

  1 CYLINDER          1   1  RADIUS =  11.450     +Z =  3.4800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          7   1  RADIUS =  11.600     +Z =  3.4800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          3   1  RADIUS =  42.080     +Z =  3.4800     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CUBOID            5   1       +X =  60.000    -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  3.4800      -Z = 0.00000

                                                         -----   UNIT    15    -----

  1 CYLINDER          1   1  RADIUS =  8.8900     +Z =  1.2700     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          2   1  RADIUS =  11.450     +Z =  1.2700     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000
```

```
  3 CYLINDER          3  1  RADIUS =  42.080     +Z =  1.2700     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000      Y = 0.00000

  4 CUBOID            5  1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000     +Z =  1.2700     -Z = 0.00000
```

```
                                       PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL

                   MEDIA BIAS      GEOMETRY DESCRIPTION FOR THOSE UNITS UTILIZED IN THIS
PROBLEM
REGION              NUM   ID


                                                  -----   UNIT    16    -----

  1 CYLINDER          4   1  RADIUS =  4.4450     +Z =  9.2200     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          1   1  RADIUS =  8.8900     +Z =  9.2200     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          2   1  RADIUS =  11.450     +Z =  9.2200     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CYLINDER          7   1  RADIUS =  11.600     +Z =  9.2200     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  5 CYLINDER          3   1  RADIUS =  42.080     +Z =  9.2200     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  6 CUBOID            5   1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  9.2200     -Z = 0.00000


                                                  -----   UNIT    17    -----

  1 CYLINDER          4   1  RADIUS =  4.4450     +Z =  6.0198     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          1   1  RADIUS =  11.450     +Z =  6.0198     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          7   1  RADIUS =  11.600     +Z =  6.0198     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CYLINDER          3   1  RADIUS =  42.001     +Z =  6.0198     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  5 CUBOID            5   1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  6.0198     -Z = 0.00000


                                                  -----   UNIT    18    -----

  1 CYLINDER          1   1  RADIUS =  6.3500     +Z =  8.8900     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  2 CYLINDER          2   1  RADIUS =  6.5000     +Z =  8.8900     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  3 CYLINDER          3   1  RADIUS =  36.980     +Z =  8.8900     -Z = 0.00000
CENTERLINE IS AT  X = 0.00000       Y = 0.00000

  4 CUBOID            5   1      +X =  60.000     -X = -60.000     +Y =  60.000     -Y = -
60.000      +Z =  8.8900     -Z = 0.00000

                                          *******************   GLOBAL
*******************
                                          -----   UNIT    19   EXTERNAL TO LATTICE  1   ----
-

IDEFINES OVERALL COORDINATE SYSTEM

  1 ARRAY NUMBER      1          +X =  120.00     -X = 0.00000     +Y =  120.00     -Y =
0.00000      +Z =  154.32     -Z = 0.00000

  2 CUBOID            5   1      +X =  120.00     -X = 0.00000     +Y =  120.00     -Y =
0.00000      +Z =  190.00     -Z = 0.00000
```

```
                              PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H20
REFL
                         -------  UNIT ORIENTATION DESCRIPTION FOR ARRAY   1          -------

Z LAYER   1, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  1
Z LAYER   2, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  2
Z LAYER   3, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  3
Z LAYER   4, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  4
Z LAYER   5, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  5
Z LAYER   6, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  6
Z LAYER   7, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  7
Z LAYER   8, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  8
Z LAYER   9, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  9
Z LAYER  10, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP
  10
```

```
                         PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H20
REFL

                 ------- UNIT ORIENTATION DESCRIPTION FOR ARRAY   1 (CONT.) -------

Z LAYER  11, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 11
Z LAYER  12, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 12
Z LAYER  13, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 13
Z LAYER  14, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 14
Z LAYER  15, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 15
Z LAYER  16, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 16
Z LAYER  17, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 17
Z LAYER  18, X COLUMN   1 TO   1 LEFT TO RIGHT   Y ROW   1 TO   1  BOTTOM TO TOP

 18
```

```
                              PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100
G/L 12FF H20 REFL
                              VOLUMES FOR THOSE UNITS UTILIZED IN  THIS PROBLEM

                                         GEOMETRY
CUMULATIVE
                      UNIT    REGION      REGION           VOLUME
VOLUME

                       1        1           1         1.06453E+03 CM**3
1.06453E+03 CM**3
                                2           2         7.75197E+01 CM**3
1.14205E+03 CM**3
                                3           3         1.82999E+05 CM**3
1.84141E+05 CM**3
                                4           4         5.01731E+05 CM**3
6.85872E+05 CM**3

                       2        1           5         1.05829E+02 CM**3
1.05829E+02 CM**3
                                2           6         1.21071E+01 CM**3
1.17936E+02 CM**3
                                3           7         1.44237E+04 CM**3
1.45417E+04 CM**3
                                4           8         4.48871E+04 CM**3
5.94288E+04 CM**3

                       3        1           9         1.47045E+02 CM**3
1.47045E+02 CM**3
                                2          10         1.28552E+01 CM**3
1.59900E+02 CM**3
                                3          11         1.37828E+04 CM**3
1.39427E+04 CM**3
                                4          12         4.09213E+04 CM**3
5.48640E+04 CM**3

                       4        1          13         2.30677E+02 CM**3
2.30677E+02 CM**3
                                2          14         1.60331E+01 CM**3
2.46710E+02 CM**3
                                3          15         1.44327E+04 CM**3
1.46794E+04 CM**3
                                4          16         4.01846E+04 CM**3
5.48640E+04 CM**3

                       5        1          17         3.34828E+02 CM**3
3.34828E+02 CM**3
                                2          18         1.92613E+01 CM**3
3.54089E+02 CM**3
                                3          19         1.50809E+04 CM**3
1.54350E+04 CM**3
                                4          20         3.94290E+04 CM**3
5.48640E+04 CM**3

                       6        1          21         4.57143E+02 CM**3
4.57143E+02 CM**3
                                2          22         2.24607E+01 CM**3
4.79603E+02 CM**3
                                3          23         1.57564E+04 CM**3
1.62360E+04 CM**3
                                4          24         3.86280E+04 CM**3
5.48640E+04 CM**3

                       7        1          25         4.88408E+03 CM**3
4.88408E+03 CM**3
                                2          26         2.64065E+02 CM**3
5.14815E+03 CM**3
                                3          27         1.66487E+05 CM**3
1.71635E+05 CM**3
                                4          28         4.13581E+05 CM**3
5.85216E+05 CM**3

                       8        1          29         3.49848E+02 CM**3
3.49848E+02 CM**3
                                2          30         1.32422E+01 CM**3
3.63090E+02 CM**3
```

```
                                 3        31         7.79425E+03 CM**3
8.15734E+03 CM**3
                                 4        32         1.68987E+04 CM**3
2.50560E+04 CM**3

                        9        1        33         5.09042E+02 CM**3
5.09042E+02 CM**3
                                 2        34         1.59482E+01 CM**3
5.24990E+02 CM**3
                                 3        35         8.34408E+03 CM**3
8.86907E+03 CM**3
                                 4        36         1.61869E+04 CM**3
2.50560E+04 CM**3

                        10       1        37         1.14730E+03 CM**3
1.14730E+03 CM**3
                                 2        38         3.43311E+01 CM**3
1.18163E+03 CM**3
                                 3        39         1.74762E+04 CM**3
1.86579E+04 CM**3
                                 4        40         3.28941E+04 CM**3
5.15520E+04 CM**3

                        11       1        41         1.25181E+03 CM**3
1.25181E+03 CM**3
                                 2        42         3.58494E+01 CM**3
1.28766E+03 CM**3
                                 3        43         1.77848E+04 CM**3
1.90724E+04 CM**3
                                 4        44         3.24796E+04 CM**3
5.15520E+04 CM**3

                        12       1        45         1.36088E+03 CM**3
1.36088E+03 CM**3
                                 2        46         3.73677E+01 CM**3
1.39824E+03 CM**3
                                 3        47         1.80933E+04 CM**3
1.94915E+04 CM**3
                                 4        48         3.20605E+04 CM**3
5.15520E+04 CM**3

                        13       1        49         1.47450E+03 CM**3
1.47450E+03 CM**3
                                 2        50         3.88864E+01 CM**3
1.51338E+03 CM**3
                                 3        51         1.84018E+04 CM**3
1.99152E+04 CM**3
                                 4        52         3.16368E+04 CM**3
5.15520E+04 CM**3

                        14       1        53         1.43331E+03 CM**3
1.43331E+03 CM**3
                                 2        54         3.78002E+01 CM**3
1.47111E+03 CM**3
                                 3        55         1.78878E+04 CM**3
1.93589E+04 CM**3
                                 4        56         3.07531E+04 CM**3
5.01120E+04 CM**3

                        15       1        57         3.15324E+02 CM**3
3.15324E+02 CM**3
                                 2        58         2.07752E+02 CM**3
5.23076E+02 CM**3
                                 3        59         6.54181E+03 CM**3
7.06488E+03 CM**3
                                 4        60         1.12231E+04 CM**3
1.82880E+04 CM**3

                        16       1        61         5.72301E+02 CM**3
5.72301E+02 CM**3
                                 2        62         1.71690E+03 CM**3
2.28920E+03 CM**3
                                 3        63         1.50824E+03 CM**3
3.79745E+03 CM**3
                                 4        64         1.00149E+02 CM**3
3.89760E+03 CM**3
```

```
                          5        65        4.73924E+04 CM**3
5.12900E+04 CM**3
                          6        66        8.14780E+04 CM**3
1.32768E+05 CM**3

                 17       1        67        3.73659E+02 CM**3
3.73659E+02 CM**3
                          2        68        2.10572E+03 CM**3
2.47938E+03 CM**3
                          3        69        6.53877E+01 CM**3
2.54477E+03 CM**3
                          4        70        3.08175E+04 CM**3
3.33623E+04 CM**3
                          5        71        5.33229E+04 CM**3
8.66851E+04 CM**3

                 18       1        72        1.12616E+03 CM**3
1.12616E+03 CM**3
                          2        73        5.38328E+01 CM**3
1.17999E+03 CM**3
                          3        74        3.70132E+04 CM**3
3.81931E+04 CM**3
                          4        75        8.98229E+04 CM**3
1.28016E+05 CM**3

                 SURROUNDING GEOMETRY VOLUMES -  GEOMETRY REGION     76 IS AN ARRAY
PLACEMENT BOUNDARY REGION

                 19       1        76        2.22216E+06 CM**3
2.22216E+06 CM**3
                          2        77        5.13838E+05 CM**3
2.73600E+06 CM**3


                             UNIT     USES   REGION    MIXTURE        TOTAL
VOLUME

                              1        1       1          1
1.06453E+03 CM**3
                                               2          2
7.75197E+01 CM**3
                                               3          3
1.82999E+05 CM**3
                                               4          5
5.01731E+05 CM**3

                              2        1       1          1
1.05829E+02 CM**3
                                               2          7
1.21071E+01 CM**3
                                               3          3
1.44237E+04 CM**3
                                               4          5
4.48871E+04 CM**3

                              3        1       1          1
1.47045E+02 CM**3
                                               2          7
1.28552E+01 CM**3
                                               3          3
1.37828E+04 CM**3
                                               4          5
4.09213E+04 CM**3

                              4        1       1          1
2.30677E+02 CM**3
                                               2          7
1.60331E+01 CM**3
                                               3          3
1.44327E+04 CM**3
                                               4          5
4.01846E+04 CM**3

                              5        1       1          1
3.34828E+02 CM**3
```

```
                                                        2          7
1.92613E+01 CM**3
                                                        3          3
1.50809E+04 CM**3
                                                        4          5
3.94290E+04 CM**3

                                        6       1       1          1
4.57143E+02 CM**3
                                                        2          7
2.24607E+01 CM**3
                                                        3          3
1.57564E+04 CM**3
                                                        4          5
3.86280E+04 CM**3

                                        7       1       1          1
4.88408E+03 CM**3
                                                        2          7
2.64065E+02 CM**3
                                                        3          3
1.66487E+05 CM**3
                                                        4          5
4.13581E+05 CM**3

                                        8       1       1          1
3.49848E+02 CM**3
                                                        2          7
1.32422E+01 CM**3
                                                        3          3
7.79425E+03 CM**3
                                                        4          5
1.68987E+04 CM**3

                                        9       1       1          1
5.09042E+02 CM**3
                                                        2          7
1.59482E+01 CM**3
                                                        3          3
8.34408E+03 CM**3
                                                        4          5
1.61869E+04 CM**3

                                       10       1       1          1
1.14730E+03 CM**3
                                                        2          7
3.43311E+01 CM**3
                                                        3          3
1.74762E+04 CM**3
                                                        4          5
3.28941E+04 CM**3

                                       11       1       1          1
1.25181E+03 CM**3
                                                        2          7
3.58494E+01 CM**3
                                                        3          3
1.77848E+04 CM**3
                                                        4          5
3.24796E+04 CM**3

                                       12       1       1          1
1.36088E+03 CM**3
                                                        2          7
3.73677E+01 CM**3
                                                        3          3
1.80933E+04 CM**3
                                                        4          5
3.20605E+04 CM**3

                                       13       1       1          1
1.47450E+03 CM**3
                                                        2          7
3.88864E+01 CM**3
                                                        3          3
1.84018E+04 CM**3
```

```
                                                          4                5
3.16368E+04  CM**3

                                      14        1         1                1
1.43331E+03  CM**3
                                                          2                7
3.78002E+01  CM**3
                                                          3                3
1.78878E+04  CM**3
                                                          4                5
3.07531E+04  CM**3

                                      15        1         1                1
3.15324E+02  CM**3
                                                          2                2
2.07752E+02  CM**3
                                                          3                3
6.54181E+03  CM**3
                                                          4                5
1.12231E+04  CM**3

                                      16        1         1                4
5.72301E+02  CM**3
                                                          2                1
1.71690E+03  CM**3
                                                          3                2
1.50824E+03  CM**3
                                                          4                7
1.00149E+02  CM**3
                                                          5                3
4.73924E+04  CM**3
                                                          6                5
8.14780E+04  CM**3

                                      17        1         1                4
3.73659E+02  CM**3
                                                          2                1
2.10572E+03  CM**3
                                                          3                7
6.53877E+01  CM**3
                                                          4                3
3.08175E+04  CM**3
                                                          5                5
5.33229E+04  CM**3

                                      18        1         1                1
1.12616E+03  CM**3
                                                          2                2
5.38328E+01  CM**3
                                                          3                3
3.70132E+04  CM**3
                                                          4                5
8.98229E+04  CM**3

                                      19        1         1
2.22216E+06  CM**3
                                                          2                5
5.13838E+05  CM**3


                                                  TOTAL MIXTURE VOLUMES
                                              MIXTURE          TOTAL VOLUME
MASS(G)
                                                 1          2.00149E+04  CM**3
2.16267E+04
                                                 2          1.84735E+03  CM**3
1.70508E+03
                                                 3          6.50509E+05  CM**3
6.49320E+05
                                                 4          9.45960E+02  CM**3
3.26461E+03
                                                 5          2.06196E+06  CM**3
7.04929E+01
                                                 7          7.25744E+02  CM**3
5.74790E+03
```

```
**********************************************************************************************
**************************
       ***
***
       ***                                                 BIASING INFORMATION
***
       ***
***
       ***     A DEFAULT WEIGHT OF    0.500 WILL BE USED FOR ALL BIAS ID'S.
***
       ***
***

**********************************************************************************************
**************************
                                  ........    0 IO'S WERE USED IN KENO-V BEFORE TRACKING
........

                                  ........ 0.22150 MINUTES WERE USED PROCESSING DATA.
........

VOLUME FRACTION OF FISSILE MATERIAL IN THE CORE= 9.43265E-03

START TYPE 0 WAS USED.

THE NEUTRONS WERE STARTED WITH A FLAT DISTRIBUTION IN A CUBOID DEFINED BY:
                        +X= 1.20000E+02  -X= 0.00000E+00  +Y= 1.20000E+02  -Y= 0.00000E+00
+Z= 1.54317E+02  -Z= 0.00000E+00
THE FLAG TO START NEUTRONS IN THE REFLECTOR WAS TURNED OFF

0.09450 MINUTES WERE REQUIRED FOR STARTING.   TOTAL ELAPSED TIME IS 0.32000 MINUTES.
```

```
PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H2O REFL

                        GENERATION     ELAPSED TIME        AVERAGE          AVG K-EFF
MATRIX             MATRIX K-EFF
     GENERATION     K-EFFECTIVE         MINUTES          K-EFFECTIVE        DEVIATION        K-
EFFECTIVE           DEVIATION
KENO MESSAGE NUMBER K5-132      WARNING....ONLY  299 INDEPENDENT FISSION POINTS WERE
GENERATED
              1      8.40679E-01     3.64333E-01     1.00000E+00      0.00000E+00
0.00000E+00          0.00000E+00
KENO MESSAGE NUMBER K5-132      WARNING....ONLY  270 INDEPENDENT FISSION POINTS WERE
GENERATED
              2      7.69348E-01     4.11833E-01     1.00000E+00      0.00000E+00
0.00000E+00          0.00000E+00
              3      8.81244E-01     4.54000E-01     8.81244E-01      0.00000E+00
0.00000E+00          0.00000E+00
              4      9.42993E-01     4.93333E-01     9.12118E-01      3.08746E-02
0.00000E+00          0.00000E+00
              5      8.92263E-01     5.39167E-01     9.05500E-01      1.90145E-02
0.00000E+00          0.00000E+00
              6      8.63004E-01     5.84000E-01     8.94876E-01      1.71361E-02
0.00000E+00          0.00000E+00
              7      9.02710E-01     6.28833E-01     8.96443E-01      1.33657E-02
0.00000E+00          0.00000E+00
              8      1.03145E+00     6.71833E-01     9.18944E-01      2.50080E-02
0.00000E+00          0.00000E+00
              9      9.58121E-01     7.16667E-01     9.24540E-01      2.18640E-02
0.00000E+00          0.00000E+00
             10      9.36590E-01     7.58833E-01     9.26047E-01      1.89946E-02
0.00000E+00          0.00000E+00
             11      9.63494E-01     8.00000E-01     9.30207E-01      1.72607E-02
0.00000E+00          0.00000E+00
             12      9.56961E-01     8.44833E-01     9.32883E-01      1.56685E-02
0.00000E+00          0.00000E+00
             13      9.14207E-01     8.89833E-01     9.31185E-01      1.42740E-02
0.00000E+00          0.00000E+00
             14      9.51945E-01     9.35500E-01     9.32915E-01      1.31447E-02
0.00000E+00          0.00000E+00
             15      9.76000E-01     9.79500E-01     9.36229E-01      1.25374E-02
0.00000E+00          0.00000E+00
             16      8.00616E-01     1.02883E+00     9.26543E-01      1.51183E-02
0.00000E+00          0.00000E+00
             17      8.58850E-01     1.07567E+00     9.22030E-01      1.47802E-02
0.00000E+00          0.00000E+00
             18      9.92300E-01     1.11400E+00     9.26422E-01      1.45064E-02
0.00000E+00          0.00000E+00
             19      9.22572E-01     1.15433E+00     9.26195E-01      1.36283E-02
0.00000E+00          0.00000E+00
             20      8.59732E-01     1.20100E+00     9.22503E-01      1.33689E-02
0.00000E+00          0.00000E+00
             21      9.73557E-01     1.24683E+00     9.25190E-01      1.29280E-02
0.00000E+00          0.00000E+00
             22      9.82220E-01     1.28700E+00     9.28041E-01      1.25917E-02
0.00000E+00          0.00000E+00
             23      9.05303E-01     1.33367E+00     9.26959E-01      1.20260E-02
0.00000E+00          0.00000E+00
             24      1.00970E+00     1.37400E+00     9.30719E-01      1.20673E-02
0.00000E+00          0.00000E+00
             25      9.04199E-01     1.42433E+00     9.29566E-01      1.15882E-02
0.00000E+00          0.00000E+00
             26      9.48770E-01     1.46650E+00     9.30367E-01      1.11237E-02
0.00000E+00          0.00000E+00
             27      8.30857E-01     1.51500E+00     9.26386E-01      1.13878E-02
0.00000E+00          0.00000E+00
             28      9.20443E-01     1.55900E+00     9.26158E-01      1.09434E-02
0.00000E+00          0.00000E+00
             29      9.73936E-01     1.60283E+00     9.27927E-01      1.06779E-02
0.00000E+00          0.00000E+00
             30      9.09946E-01     1.64583E+00     9.27285E-01      1.03095E-02
0.00000E+00          0.00000E+00
             31      9.16268E-01     1.68900E+00     9.26905E-01      9.95494E-03
0.00000E+00          0.00000E+00
             32      9.49573E-01     1.73567E+00     9.27661E-01      9.64702E-03
0.00000E+00          0.00000E+00
             33      9.78290E-01     1.78050E+00     9.29294E-01      9.47249E-03
0.00000E+00          0.00000E+00
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          34      9.61561E-01      1.82617E+00      9.30302E-01      9.22696E-03
 0.00000E+00      0.00000E+00
          35      9.43113E-01      1.87383E+00      9.30690E-01      8.95141E-03
 0.00000E+00      0.00000E+00
          36      9.81764E-01      1.91683E+00      9.32193E-01      8.81311E-03
 0.00000E+00      0.00000E+00
          37      9.77347E-01      1.95900E+00      9.33483E-01      8.65431E-03
 0.00000E+00      0.00000E+00
          38      9.10226E-01      2.00650E+00      9.32837E-01      8.43525E-03
 0.00000E+00      0.00000E+00
          39      8.46691E-01      2.05417E+00      9.30508E-01      8.52807E-03
 0.00000E+00      0.00000E+00
          40      8.90012E-01      2.10083E+00      9.29443E-01      8.36875E-03
 0.00000E+00      0.00000E+00
          41      9.44349E-01      2.14483E+00      9.29825E-01      8.16029E-03
 0.00000E+00      0.00000E+00
          42      9.52331E-01      2.19050E+00      9.30388E-01      7.97355E-03
 0.00000E+00      0.00000E+00
          43      9.12439E-01      2.23633E+00      9.29950E-01      7.78895E-03
 0.00000E+00      0.00000E+00
          44      9.10956E-01      2.28300E+00      9.29498E-01      7.61468E-03
 0.00000E+00      0.00000E+00
          45      9.24223E-01      2.32600E+00      9.29375E-01      7.43650E-03
 0.00000E+00      0.00000E+00
          46      9.84137E-01      2.36550E+00      9.30620E-01      7.37135E-03
 0.00000E+00      0.00000E+00
          47      9.32272E-01      2.41400E+00      9.30656E-01      7.20577E-03
 0.00000E+00      0.00000E+00
          48      9.07521E-01      2.45783E+00      9.30153E-01      7.06531E-03
 0.00000E+00      0.00000E+00
          49      1.00720E+00      2.50267E+00      9.31793E-01      7.10506E-03
 0.00000E+00      0.00000E+00
          50      9.10082E-01      2.54483E+00      9.31340E-01      6.97015E-03
 0.00000E+00      0.00000E+00
          51      8.93321E-01      2.58967E+00      9.30564E-01      6.87037E-03
 0.00000E+00      0.00000E+00
          52      9.19406E-01      2.63550E+00      9.30341E-01      6.73526E-03
 0.00000E+00      0.00000E+00
          53      9.01864E-01      2.68300E+00      9.29783E-01      6.62545E-03
 0.00000E+00      0.00000E+00
          54      8.50000E-01      2.73067E+00      9.28249E-01      6.67550E-03
 0.00000E+00      0.00000E+00
          55      9.80486E-01      2.77183E+00      9.29234E-01      6.62209E-03
 0.00000E+00      0.00000E+00
          56      9.10251E-01      2.81483E+00      9.28883E-01      6.50781E-03
 0.00000E+00      0.00000E+00
          57      9.62094E-01      2.85517E+00      9.29487E-01      6.41686E-03
 0.00000E+00      0.00000E+00
          58      9.50098E-01      2.89817E+00      9.29855E-01      6.31197E-03
 0.00000E+00      0.00000E+00
          59      9.06746E-01      2.94583E+00      9.29449E-01      6.21349E-03
 0.00000E+00      0.00000E+00
          60      9.57345E-01      2.98883E+00      9.29930E-01      6.12434E-03
 0.00000E+00      0.00000E+00
          61      9.56170E-01      3.03367E+00      9.30375E-01      6.03604E-03
 0.00000E+00      0.00000E+00
          62      9.06277E-01      3.07850E+00      9.29973E-01      5.94817E-03
 0.00000E+00      0.00000E+00
          63      9.03276E-01      3.12150E+00      9.29536E-01      5.86619E-03
 0.00000E+00      0.00000E+00
          64      9.54427E-01      3.16650E+00      9.29937E-01      5.78475E-03
 0.00000E+00      0.00000E+00
          65      9.58690E-01      3.21133E+00      9.30393E-01      5.71045E-03
 0.00000E+00      0.00000E+00
          66      8.82497E-01      3.25517E+00      9.29645E-01      5.67013E-03
 0.00000E+00      0.00000E+00
          67      9.84573E-01      3.30100E+00      9.30490E-01      5.64581E-03
 0.00000E+00      0.00000E+00
          68      9.11503E-01      3.34317E+00      9.30202E-01      5.56705E-03
 0.00000E+00      0.00000E+00
          69      9.66710E-01      3.38617E+00      9.30747E-01      5.51034E-03
 0.00000E+00      0.00000E+00
          70      9.96421E-01      3.43183E+00      9.31713E-01      5.51394E-03
 0.00000E+00      0.00000E+00
          71      8.44103E-01      3.47767E+00      9.30443E-01      5.57982E-03
 0.00000E+00      0.00000E+00
```

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           72      9.72037E-01      3.52067E+00      9.31038E-01      5.53154E-03
  0.00000E+00      0.00000E+00
           73      8.54520E-01      3.56733E+00      9.29960E-01      5.55855E-03
  0.00000E+00      0.00000E+00
           74      9.53675E-01      3.61683E+00      9.30289E-01      5.49069E-03
  0.00000E+00      0.00000E+00
           75      9.00844E-01      3.66167E+00      9.29886E-01      5.42996E-03
  0.00000E+00      0.00000E+00
           76      9.51456E-01      3.70567E+00      9.30177E-01      5.36400E-03
  0.00000E+00      0.00000E+00
           77      9.22897E-01      3.75417E+00      9.30080E-01      5.29289E-03
  0.00000E+00      0.00000E+00
           78      9.55999E-01      3.79717E+00      9.30421E-01      5.23390E-03
  0.00000E+00      0.00000E+00
           79      9.55721E-01      3.84300E+00      9.30750E-01      5.17592E-03
  0.00000E+00      0.00000E+00
           80      9.05932E-01      3.88500E+00      9.30432E-01      5.11903E-03
  0.00000E+00      0.00000E+00
           81      8.97176E-01      3.93350E+00      9.30011E-01      5.07132E-03
  0.00000E+00      0.00000E+00
           82      9.93124E-01      3.97467E+00      9.30800E-01      5.06929E-03
  0.00000E+00      0.00000E+00
           83      9.03353E-01      4.01967E+00      9.30461E-01      5.01777E-03
  0.00000E+00      0.00000E+00
           84      8.96965E-01      4.06533E+00      9.30052E-01      4.97300E-03
  0.00000E+00      0.00000E+00
           85      9.73655E-01      4.10833E+00      9.30578E-01      4.94073E-03
  0.00000E+00      0.00000E+00
           86      8.98091E-01      4.15233E+00      9.30191E-01      4.89685E-03
  0.00000E+00      0.00000E+00
           87      8.98869E-01      4.19717E+00      9.29822E-01      4.85291E-03
  0.00000E+00      0.00000E+00
           88      8.94481E-01      4.24300E+00      9.29412E-01      4.81372E-03
  0.00000E+00      0.00000E+00
           89      9.61341E-01      4.28867E+00      9.29779E-01      4.77221E-03
  0.00000E+00      0.00000E+00
           90      9.61289E-01      4.33000E+00      9.30137E-01      4.73123E-03
  0.00000E+00      0.00000E+00
           91      9.37258E-01      4.37567E+00      9.30217E-01      4.67846E-03
  0.00000E+00      0.00000E+00
           92      1.01139E+00      4.41683E+00      9.31119E-01      4.71329E-03
  0.00000E+00      0.00000E+00
           93      8.87354E-01      4.46083E+00      9.30638E-01      4.68595E-03
  0.00000E+00      0.00000E+00
           94      9.02889E-01      4.50750E+00      9.30336E-01      4.64454E-03
  0.00000E+00      0.00000E+00
           95      8.46400E-01      4.55417E+00      9.29433E-01      4.68214E-03
  0.00000E+00      0.00000E+00
           96      8.87012E-01      4.60000E+00      9.28982E-01      4.65399E-03
  0.00000E+00      0.00000E+00
           97      9.70471E-01      4.64383E+00      9.29419E-01      4.62541E-03
  0.00000E+00      0.00000E+00
           98      8.69497E-01      4.68783E+00      9.28795E-01      4.61934E-03
  0.00000E+00      0.00000E+00
           99      8.90907E-01      4.73367E+00      9.28404E-01      4.58812E-03
  0.00000E+00      0.00000E+00
          100      9.86637E-01      4.77750E+00      9.28998E-01      4.57978E-03
  0.00000E+00      0.00000E+00
          101      9.33507E-01      4.82067E+00      9.29044E-01      4.53351E-03
  0.00000E+00      0.00000E+00
          102      1.00264E+00      4.86183E+00      9.29780E-01      4.54789E-03
  0.00000E+00      0.00000E+00
          103      1.04497E+00      4.90200E+00      9.30920E-01      4.64484E-03
  0.00000E+00      0.00000E+00

 KENO MESSAGE NUMBER K5-123        EXECUTION TERMINATED DUE TO COMPLETION OF THE
 SPECIFIED NUMBER OF GENERATIONS.
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                                             PROBLEM K12ELOO 18 CYLS IN A CUBOID
ANNULUS - 100 G/L 12FF H20 REFL

LIFETIME =  1.97001E-04 + OR -  1.61236E-06            GENERATION TIME =  6.39673E-05 +
OR -  5.88273E-07
NU BAR   =  2.41927E+00 + OR -  9.83954E-06       AVERAGE FISSION GROUP =  2.44696E+01 +
OR -  4.33824E-03
                         ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION =  3.20547E-02 +
OR -  1.49297E-04

NO. OF INITIAL
 GENERATIONS      AVERAGE                            67 PER CENT           95 PER CENT
99 PER CENT      NUMBER OF
  SKIPPED       K-EFFECTIVE     DEVIATION    CONFIDENCE INTERVAL   CONFIDENCE INTERVAL
CONFIDENCE INTERVAL  HISTORIES

      3           0.93142   + OR - 0.00466    0.92675 TO 0.93608    0.92209 TO 0.94075
0.91742 TO 0.94541      30000

      4           0.93130   + OR - 0.00471    0.92659 TO 0.93601    0.92188 TO 0.94072
0.91717 TO 0.94543      29700

      5           0.93170   + OR - 0.00474    0.92696 TO 0.93644    0.92222 TO 0.94118
0.91747 TO 0.94592      29400

      6           0.93241   + OR - 0.00474    0.92767 TO 0.93714    0.92293 TO 0.94188
0.91820 TO 0.94662      29100

      7           0.93272   + OR - 0.00478    0.92794 TO 0.93749    0.92316 TO 0.94227
0.91839 TO 0.94705      28800

      8           0.93168   + OR - 0.00471    0.92697 TO 0.93639    0.92225 TO 0.94110
0.91754 TO 0.94581      28500

      9           0.93140   + OR - 0.00475    0.92664 TO 0.93615    0.92189 TO 0.94090
0.91714 TO 0.94566      28200

     10           0.93134   + OR - 0.00480    0.92654 TO 0.93614    0.92173 TO 0.94095
0.91693 TO 0.94575      27900

     11           0.93099   + OR - 0.00484    0.92615 TO 0.93583    0.92130 TO 0.94068
0.91646 TO 0.94552      27600

     12           0.93070   + OR - 0.00489    0.92582 TO 0.93559    0.92093 TO 0.94048
0.91604 TO 0.94537      27300

     17           0.93247   + OR - 0.00483    0.92764 TO 0.93730    0.92281 TO 0.94213
0.91798 TO 0.94697      25800

     22           0.93163   + OR - 0.00493    0.92670 TO 0.93656    0.92177 TO 0.94149
0.91684 TO 0.94642      24300

     27           0.93241   + OR - 0.00495    0.92747 TO 0.93736    0.92252 TO 0.94230
0.91758 TO 0.94725      22800

     32           0.93230   + OR - 0.00524    0.92706 TO 0.93754    0.92182 TO 0.94278
0.91658 TO 0.94802      21300

     37           0.92956   + OR - 0.00547    0.92409 TO 0.93503    0.91862 TO 0.94050
0.91315 TO 0.94598      19800

     42           0.93127   + OR - 0.00569    0.92557 TO 0.93696    0.91988 TO 0.94266
0.91418 TO 0.94835      18300

     47           0.93113   + OR - 0.00611    0.92502 TO 0.93725    0.91891 TO 0.94336
0.91279 TO 0.94947      16800

     52           0.93149   + OR - 0.00647    0.92502 TO 0.93796    0.91855 TO 0.94443
0.91208 TO 0.95090      15300

     57           0.93263   + OR - 0.00679    0.92585 TO 0.93942    0.91906 TO 0.94621
0.91227 TO 0.95300      13800

     62           0.93231   + OR - 0.00751    0.92480 TO 0.93982    0.91728 TO 0.94733
0.90977 TO 0.95484      12300
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     67          0.93170   + OR - 0.00823     0.92347 TO 0.93992     0.91524 TO 0.94815
0.90702 TO 0.95638       10800

     72          0.93066   + OR - 0.00868     0.92197 TO 0.93934     0.91329 TO 0.94802
0.90461 TO 0.95670       9300

     77          0.93334   + OR - 0.00978     0.92356 TO 0.94313     0.91378 TO 0.95291
0.90399 TO 0.96269       7800

     82          0.93138   + OR - 0.01149     0.91989 TO 0.94287     0.90839 TO 0.95437
0.89690 TO 0.96586       6300

     87          0.93675   + OR - 0.01430     0.92245 TO 0.95106     0.90815 TO 0.96536
0.89384 TO 0.97966       4800

     92          0.92930   + OR - 0.01905     0.91025 TO 0.94835     0.89119 TO 0.96740
0.87214 TO 0.98645       3300
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                                                PROBLEM K12EL00 18 CYLS IN A CUBOID
ANNULUS - 100 G/L 12FF H20 REFL

NO. OF INITIAL
 GENERATIONS      AVERAGE                                 67 PER CENT            95 PER CENT
99 PER CENT      NUMBER OF
   SKIPPED      K-EFFECTIVE       DEVIATION     CONFIDENCE INTERVAL   CONFIDENCE INTERVAL
CONFIDENCE INTERVAL  HISTORIES

     97           0.95469   + OR - 0.02784      0.92686 TO 0.98253    0.89902 TO 1.01037
0.87118 TO 1.03820       1800
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                          PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H20
REFL

                      PLOT OF AVERAGE K-EFFECTIVE BY GENERATION RUN.
     THE LINE REPRESENTS K-EFF = 0.9314 + OR -  0.0047 WHICH OCCURS FOR   103 GENERATIONS
RUN.

                            0.8994                   0.9212                    0.9430
     |-------------------------|-------------------------|-------------------------|--------
-----------------
     |
   5 +                I                             *                |             I
     |                          *                         I          |
     |      I                   *                  I                 |
     |                       I                                 *     |
I
     |                                   I                           |*
I
  10 +                                        I                      |*
I
     |                                               I               |     *
I
     |                                                    I          |       *
I
     |                                                   I           |     *
I
     |                                                      I        |      *
I
  15 +                                                          I    |          *
I
     |                                          I                  *|                I
     |                                     I                 *       |          I
     |                                           I                *  |              I
     |                                           I               *   |             I
  20 +                                       I               *       |        I
     |                                          I               *    |          I
     |                                              I              *|             I
     |                                             I              * |           I
     |                                                  I            | *             I
  25 +                                                 I             |*            I
     |                                                  I            |*             I
     |                                             I             *   |         I
     |                                             I            *    |        I
     |                                                I           * |          I
  30 +                                               I           *   |         I
     |                                               I           *   |        I
     |                                                I           * |        I
     |                                                   I           *          I
     |                                                    I          |*          I
  35 +                                                     I         |*          I
     |                                                       I       |  *         I
     |                                                        I      |   *         I
     |                                                        I      |   *        I
     |                                                     I         |*         I
  40 +                                                    I         *|        I
     |                                                    I          *        I
     |                                                     I         *         I
     |                                                     I         *        I
     |                                                     I        *|       I
  45 +                                                     I        *|       I
     |                                                      I        |*       I
     |                                                      I        |*       I
     |                                                      I        *       I
     |                                                        I      | *       I
  50 +                                                       I       |*       I
     |                                                      I        *       I
     |                                                      I        *       I
     |                                                      I       *|      I
     |                                                    I        * |    I
  55 +                                                     I        *|     I
     |                                                     I       * |     I
     |                                                      I       *|     I
     |                                                      I       *|      I
     |                                                      I       *|     I
  60 +                                                      I       *|      I
     |                                                       I       *      I
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    |                                                        I      *     I
    |                                                       I      *|     I
    |                                                        I     *|     I
 65 +                                                        I      *      I
    |                                                        I     *|     I
    |                                                         I     *      I
    |                                                        I      *     I
    |                                                         I     *      I
 70 +                                                          I    |*      I
    |                                                        I      *     I
    |                                                         I     |*     I
    |                                                        I     *|     I
    |                                                        I      *     I
 75 +                                                        I     *|     I
    |                                                        I      *     I
    |                                                        I     *|     I
    |                                                         I     *     I
    |                                                         I     *     I
 80 +                                                         I     *     I
    |                                                        I     *|    I
    |                                                         I     *     I
    |                                                         I     *     I
    |                                                         I    *|    I
 85 +                                                         I     *     I
    |                                                         I    *|    I
    |                                                        I     *|    I
    |                                                        I     *|   I
    |                                                        I     *|   I
 90 +                                                         I    *|    I
    |                                                         I    *|    I
    |                                                          I    |*     I
    |                                                          I    *    I
    |                                                         I     *    I
 95 +                                                        I     *|   I
    |                                                        I    * |  I
    |                                                        I     *|   I
    |                                                       I     * |  I
    |                                                       I    *  |  I
100 +                                                        I    * |  I
    |                                                        I    * |  I
    |                                                         I    *|   I
    |                                                          I    *     I
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                          PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H20
REFL

                      PLOT OF AVERAGE K-EFFECTIVE BY GENERATION SKIPPED.
     THE LINE REPRESENTS K-EFF = 0.9314 + OR -  0.0047 WHICH OCCURS FOR      3 GENERATIONS
SKIPPED.

                           0.9293                   0.9765                   1.0238
     |-------------------------|------------------------|------------------------|--------
----------------
     |
     |                       I  * I
   5 +                       I  * I
     |                        I *  I
     |                        I *  I
     |                       I  * I
     |                       I  * I
  10 +                       I  * I
     |                       I *| I
     |                       I *| I
     |                       I *| I
     |                       I *| I
  15 +                      I  *| I
     |                       I  * I
     |                        I *  I
     |                       I  * I
     |                       I  * I
  20 +                        I *  I
     |                       I  *  I
     |                       I  * I
     |                       I  *  I
     |                       I *| I
  25 +                       I  * I
     |                       I *| I
     |                        I *  I
     |                        I *  I
     |                       I  *  I
  30 +                       I  *  I
     |                       I  *  I
     |                       I  *  I
     |                       I  *  I
     |                       I  * I
  35 +                       I *| I
     |                      I  *| I
     |                      I  *| I
     |                      I  *| I
     |                       I *| I
  40 +                       I  *  I
     |                       I  *  I
     |                       I  *  I
     |                       I  *  I
     |                       I  *  I
  45 +                       I  *  I
     |                      I  *|  I
     |                      I  *|  I
     |                      I   *  I
     |                      I  *| I
  50 +                      I  *| I
     |                      I   *  I
     |                      I   *  I
     |                       I  *  I
     |                       I  |*  I
  55 +                       I  *   I
     |                       I  |*  I
     |                       I  *   I
     |                      I   *   I
     |                       I  *   I
  60 +                      I   *   I
     |                      I   *   I
     |                      I   *   I
     |                      I   *    I
     |                      I   *   I
  65 +                      I   *   I
     |                      I   |*   I
     |                     I    *   I
     |                      I   *    I
```

```
     |                    I    *   I
  70 +                   I    *|  I
     |                    I    *   I
     |                    I   *|   I
     |                     I   |*   I
     |                     I   *    I
  75 +                     I   |*    I
     |                    I    *    I
     |                    I    |*    I
     |                    I    *     I
     |                   I     *    I
  80 +                   I     *     I
     |                    I    |*     I
     |                   I     *     I
     |                   I     *      I
     |                    I    |*      I
  85 +                  I      *      I
     |                   I     |*      I
     |                    I    | *       I
     |                     I   |   *       I
     |                    I    |  *        I
  90 +                  I      | *        I
     |                 I       | *         I
     |             I          *|        I
     |               I         |*          I
     |                I        |  *           I
  95 +                      I  |        *          I
     |                         |I           *            I
     |                      I  |           *              I
     |                         |      I             *            I
     |                         |                  I            *          I
 100 +                         |              I                 *               I
     |                         |                                   I          *
I
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                                    PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H20
REFL

SKIPPING  3 GENERATIONS

GROUP  FISSION  UNIT   REGION    FISSIONS      PERCENT        ABSORPTIONS    PERCENT
LEAKAGE        PERCENT
      FRACTION                                 DEVIATION                     DEVIATION
DEVIATION

  1      0.0001                 1.38516E-04    4.9927         1.02367E-03    4.7025
9.32637E-04     20.3911

  2      0.0007                 6.41353E-04    1.6418         2.31068E-03    1.4757
2.75062E-03     11.0975

  3      0.0008                 7.32413E-04    1.2381         3.04464E-04    1.2725
2.43928E-03     10.6308

  4      0.0004                 4.15506E-04    1.4276         1.75359E-04    1.3559
1.11730E-03     17.3510

  5      0.0006                 5.46048E-04    0.9861         2.43112E-04    0.9993
1.09283E-03     16.1131

  6      0.0008                 7.29110E-04    0.8745         3.52803E-04    0.8678
1.62312E-03     14.9251

  7      0.0008                 7.57809E-04    0.7819         4.05854E-04    0.8018
1.61970E-03     13.7985

  8      0.0009                 7.98035E-04    0.8952         4.98513E-04    0.8707
1.08879E-03     18.8428

  9      0.0012                 1.13614E-03    0.8260         7.35305E-04    0.8207
7.23960E-04     19.9918

 10      0.0026                 2.41171E-03    0.9272         1.66312E-03    0.9834
6.62748E-04     22.4802

 11      0.0058                 5.37179E-03    0.9169         3.65609E-03    0.8740
7.62338E-04     20.3652

 12      0.0083                 7.72067E-03    1.0451         5.32538E-03    0.9960
3.27969E-04     30.1567

 13      0.0085                 7.87888E-03    1.0131         6.57084E-03    0.9462
4.53410E-04     28.7600

 14      0.0074                 6.87615E-03    0.8894         6.36980E-03    0.7779
4.83402E-04     23.9318

 15      0.0013                 1.23748E-03    1.2069         1.89739E-03    1.1886
3.25383E-04     33.3452

 16      0.0009                 8.31031E-04    1.8166         1.20143E-03    1.6508
1.94447E-04     39.8076

 17      0.0015                 1.38444E-03    2.2528         1.16692E-03    1.9387
1.32284E-04     49.2372

 18      0.0020                 1.85841E-03    2.4892         1.29436E-03    2.2312
1.29843E-04     49.2431

 19      0.0023                 2.16343E-03    2.0312         1.73475E-03    1.8152
0.00000E+00      0.0000

 20      0.0102                 9.47906E-03    1.1192         7.56427E-03    1.0798
3.91654E-04     27.2197

 21      0.0058                 5.43050E-03    1.7652         3.91235E-03    1.6027
3.13039E-05    100.0000

 22      0.0156                 1.45580E-02    1.5120         1.07984E-02    1.2486
1.63761E-04     42.2980
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 23      0.0778                     7.24426E-02      0.8162       7.03042E-02      0.4822
1.24241E-03    11.6771

 24      0.2146                     1.99876E-01      0.6094       2.11042E-01      0.3019
1.99271E-03    10.0616

 25      0.2095                     1.95168E-01      0.5552       2.09042E-01      0.3021
1.36848E-03    10.5527

 26      0.2941                     2.73926E-01      0.6282       2.97683E-01      0.2891
1.37597E-03    13.1247

 27      0.1255                     1.16909E-01      0.7524       1.28642E-01      0.4076
1.58461E-04    30.9500

SYSTEM TOTAL =                      9.31417E-01      0.5008       9.75918E-01      0.2050
2.35848E-02     4.3346

ELAPSED TIME   4.90383 MINUTES

RANDOM NUMBER=        3F266CB7DC6
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                                      PROBLEM K12ELOO 18 CYLS IN A CUBOID
ANNULUS - 100 G/L 12FF H20 REFL

                                          **** FISSION DENSITIES ****

                                   FISSION      PERCENT           TOTAL
                   UNIT  REGION    DENSITY      DEVIATION        FISSIONS

                    1      1      3.742E-08      96.08          3.983E-05
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    2      1      8.190E-08      99.70          8.667E-06
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    3      1      9.215E-09      95.62          1.355E-06
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    4      1      1.369E-07      57.51          3.159E-05
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    5      1      5.275E-07      50.93          1.766E-04
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    6      1      3.681E-07      43.06          1.683E-04
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    7      1      1.500E-05       2.99          7.326E-02
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    8      1      6.963E-05       3.76          2.436E-02
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                    9      1      7.448E-05       3.07          3.791E-02
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                   10      1      7.966E-05       2.20          9.139E-02
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                   11      1      9.250E-05       2.01          1.158E-01
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                   12      1      9.454E-05       1.71          1.287E-01
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                   13      1      9.038E-05       1.73          1.333E-01
                           2      0.000E+00       0.00          0.000E+00
                           3      0.000E+00       0.00          0.000E+00
                           4      0.000E+00       0.00          0.000E+00

                   14      1      8.233E-05       1.71          1.180E-01
                           2      0.000E+00       0.00          0.000E+00
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                                        3     0.000E+00      0.00            0.000E+00
                                        4     0.000E+00      0.00            0.000E+00

                                 15     1     7.945E-05      3.14            2.505E-02
                                        2     0.000E+00      0.00            0.000E+00
                                        3     0.000E+00      0.00            0.000E+00
                                        4     0.000E+00      0.00            0.000E+00

                                 16     1     7.252E-06      4.78            4.150E-03
                                        2     5.586E-05      2.37            9.590E-02
                                        3     0.000E+00      0.00            0.000E+00
                                        4     0.000E+00      0.00            0.000E+00
                                        5     0.000E+00      0.00            0.000E+00
                                        6     0.000E+00      0.00            0.000E+00

                                 17     1     4.401E-06      6.36            1.645E-03
                                        2     2.929E-05      3.04            6.168E-02
                                        3     0.000E+00      0.00            0.000E+00
                                        4     0.000E+00      0.00            0.000E+00
                                        5     0.000E+00      0.00            0.000E+00

                                 18     1     1.768E-05      5.49            1.991E-02
                                        2     0.000E+00      0.00            0.000E+00
                                        3     0.000E+00      0.00            0.000E+00
                                        4     0.000E+00      0.00            0.000E+00
               GLOBAL UNIT

                                 19     1     0.000E+00      0.00            0.000E+00
                                        2     0.000E+00      0.00            0.000E+00
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PROBLEM K12ELOO 18 CYLS IN A CUBOID ANNULUS - 100 G/L 12FF H20 REFL
                               FREQUENCY FOR GENERATIONS    4 TO  103
0.7813 TO 0.8044     *
0.8044 TO 0.8275
0.8275 TO 0.8506     *****
0.8506 TO 0.8737     *****
0.8737 TO 0.8968     ********
0.8968 TO 0.9199     **************************
0.9199 TO 0.9430     ********
0.9430 TO 0.9661     ***********************
0.9661 TO 0.9892     ***************
0.9892 TO 1.0123     *******
1.0123 TO 1.0354     *
1.0354 TO 1.0584     *

                               FREQUENCY FOR GENERATIONS   29 TO  103
0.7813 TO 0.8044
0.8044 TO 0.8275
0.8275 TO 0.8506     ****
0.8506 TO 0.8737     **
0.8737 TO 0.8968     *******
0.8968 TO 0.9199     **********************
0.9199 TO 0.9430     *****
0.9430 TO 0.9661     *****************
0.9661 TO 0.9892     ************
0.9892 TO 1.0123     *****
1.0123 TO 1.0354
1.0354 TO 1.0584     *

                               FREQUENCY FOR GENERATIONS   54 TO  103
0.7813 TO 0.8044
0.8044 TO 0.8275
0.8275 TO 0.8506     ***
0.8506 TO 0.8737     **
0.8737 TO 0.8968     *****
0.8968 TO 0.9199     *************
0.9199 TO 0.9430     ***
0.9430 TO 0.9661     ************
0.9661 TO 0.9892     *******
0.9892 TO 1.0123     ****
1.0123 TO 1.0354
1.0354 TO 1.0584     *

                               FREQUENCY FOR GENERATIONS   79 TO  103
0.7813 TO 0.8044
0.8044 TO 0.8275
0.8275 TO 0.8506     *
0.8506 TO 0.8737     *
0.8737 TO 0.8968     ****
0.8968 TO 0.9199     *******
0.9199 TO 0.9430     **
0.9430 TO 0.9661     ***
0.9661 TO 0.9892     ***
0.9892 TO 1.0123     ***
1.0123 TO 1.0354
1.0354 TO 1.0584     *


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          CONGRATULATIONS!  YOU HAVE  SUCCESSFULLY TRAVERSED THE PERILOUS PATH THROUGH
KENO V IN    4.90483 MINUTES

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