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Design of Benign Matrix Drums for the Non-Destructive Assay Performance Demonstration Program for the National TRU Program

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Published September 1996

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1. INTRODUCTION

1.1 General

Regulatory compliance programs associated with the Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) Transuranic (TRU) Waste Characterization Program (the Program) require the collection of waste characterization data of known quality to support repository performance assessment, permitting, and associated activities. The WIPP Quality Assurance Program Plan (QAPP)[1] delineates data quality requirements and techniques necessary to produce data consistent with the data quality objectives (DQOs) of the Program. The QAPP utilizes performance based quality assurance objectives (QAOs) for the assessment of waste characterization facility analytical capability and compliance. The QAPP also requires each facility to participate in performance demonstration programs (PDPs) designed to produce objective method performance data used to support compliance assessment activities.

The DOE Carlsbad Area Office (CAO) is responsible for Program quality assurance plan development, implementation, and compliance verification at characterization facilities generating data for use in the Program. The non-destructive assay (NDA) PDP provides the CAO an objective means to appraise and document key waste NDA system performance parameters through the use of prescribed test apparatus, measurement routines, and analyses. Data generated in the PDP is used in the overall evaluation of TRU waste NDA system capability, performance, and reliability per QAPP criteria. The NDA PDP also provides a platform useful for ascertaining interlaboratory comparability of waste NDA characterization techniques employed complex wide. The NDA PDP does not contain provisions nor is intended to serve as a complete assessment and approval device but rather provides an independent source of information integral to method performance data evaluations and quality assurance audits.

The NDA PDP program is comprised of a series of tests conducted semi-annually at participating waste characterization facilities. Each individual semi-annual test is referred to as a cycle. Criteria for the acquisition, analysis, and reporting of waste NDA system performance data are specified in the Performance Demonstration Program Plan for Non-Destructive Assay for the TRU Waste Characterization Program document.[2] Blind audit samples, referred to as PDP samples, are devices used in the NDA PDP program to acquire waste NDA system performance data per defined measurement routines. As defined under the current NDA PDP Program Plan, a PDP sample consists of a DOT 17C 55-gallon PDP matrix drum configured with insertable radioactive standards, working reference materials (WRMs), as specified by the NDA PDP Program Coordinator. The particular manner in which the matrix drum and PDP standards(s) are combined is a function of the waste NDA system performance test objectives of a given cycle.

The WRMs utilized in sample preparation are specifically designed and prepared for use in the NDA PDP program. The design characteristics of the Phase I WRM set is addressed in the document, "Design of Phase I Radioactive Working Reference Materials for the Non-Destructive Assay Performance Demonstration Program for the National TRU Program".[3]

The sequence of NDA PDP cycles and the associated specification of PDP matrix drum/WRM sample configuration(s) is based on the concept of establishing a baseline waste NDA capability during the initial test cycle(s). PDP samples configured for subsequent cycles will be specified such that progressively more matrix/radioactive material variables and combinations thereof, derived from actual waste form configurations, will be represented and sequentially tested in a manner of incremental difficulty with respect to commonly employed waste NDA techniques. Hence, initial cycle PDP matrix drum(s) will be comprised of a relatively simple matrix elemental composition, density, and distribution with subsequent cycle designs possessing matrix attributes progressively more complex and realistic with respect to waste form configurations in the inventory.

Based on the incremental or phased performance testing concept, the design basis for the initial cycle PDP matrix drum(s) is founded in the need to determine the currently implemented waste NDA baseline capability. The design and specification of matrix drums for subsequent cycles must necessarily include considerations for the acquisition of information and performance data regarding NDA system functionality in the more difficult and realistic matrix/source configurations. Guidance on subsequent cycle PDP matrix drum design is derived from the eleven waste form configurations as defined in the WIPP TRU Waste Baseline Inventory Report.[4] It is the intent of the PDP Program Plan for NDA to develop matrix drum configurations which provide a reasonable test of the majority of waste forms in the DOE inventory through an appropriate representation of the various matrix attributes associated with the Baseline Inventory Report categories.

1.2 Purpose

The purpose of this document is to define per the PDP Program Plan, initial cycle benign matrix drum requirements, enumerate the associated specifications and document the final as-built design. The intent of the initial cycle PDP, the baseline capability determination cycles (cycle one and potentially cycle two), is to establish and document the waste NDA baseline capability presently implemented at participating waste characterization facilities. Participating facilities include those within the DOE complex and in the commercial sector. The baseline can be interpreted as that fundamental waste NDA capability necessary to perform accurate source mass calibrations and demonstrate the ability to assay radioactive material of a pre-specified nominal isotopic/chemical composition in waste forms characterized as non-interfering or benign. A benign simulated waste matrix refers to a material that inherently does not possess or has minimal properties with attributes known to interfere with or complicate the interpretation of commonly employed waste NDA measurements.

In order to acquire data regarding the baseline capability for the waste NDA of 55-gallon containerized wastes, devices are required to simulate a non-interfering waste form configuration. The devices identified for this function consist of two DOT 17C 55-gallon drums fitted with internal structures designed to accommodate the insertion of radioactive WRMs, hereafter referred to as PDP standards. One of the PDP matrix drums termed the zero matrix drum, contains only that internal structure required to insert and locate PDP standards with no additional matrix included. The second drum contains an expanded polyethylene foam material, the ETHAFOAM drum, possessing properties considered benign relative to commonly employed waste NDA techniques. Analyses used to assess the response characteristics of commonly employed waste NDA systems relative to the zero and ETHAFOAM PDP matrix drum configurations are also provided in this document. Such analyses are performed to evaluate the magnitude of bias induced by the specified configurations and ensure the concept of benign is maintained to the extent practicable.

A detailed documentation of the PDP matrix drum design is necessary as it is to serve as a consistent and accepted benchmark for waste NDA system performance and characterization facility intercomparisons. Hence statements regarding performance can be referenced to a specific, well defined and documented PDP matrix drum configuration. Knowledge of waste NDA system performance on the benign PDP type matrix also allows for extrapolations as appropriate to an expected performance for actual waste forms with similar properties. Properly documented PDP matrix drums aids the interpretation of such approximations and supports capability and compliance determinations performed by audit teams. Accurate documentation also supports efforts to resolve potential NDA system performance deficiencies which may exhibit themselves during PDP testing. This is particularly important in those instances where there may be some reason to suspect that noncompliance with PDP test scoring criteria may be an artifact of the PDP matrix drum versus an NDA system deficiency.

Although not explicitly stated, an inherent element of the PDP Plan is to provide a mechanism for characterization facilities to evaluate implemented techniques and refine or modify them based on experience acquired during test cycles. Hence, the documentation of the benign matrix drum design not only allows participating facilities to understand the manner in which they are being tested, but also permits capability self assessments with regard to the zero (base calibration) and ETHAFOAM type matrices.

Radioactive standards used in the preparation of PDP samples for testing are integral to the performance assessment process. The detailed PDP standard design is not addressed in this document although certain aspects of the design and configuration are considered in the specification and design of the PDP matrix drum(s). Such considerations include: (1) an evaluation of the interaction of radiations emitted from the PDP standard with the zero matrix internal support struucture and ETHAFOAM matrix materials; (2) the specification of internal support structure dimensions to accommodate insertion of the PDP standards into the matrix drum; and (3) specification of the internal support structure configuration such that desired radioactive material mass loadings can be achieved. Details concerning the radioactive PDP WRM design are found in reference 3. The scope of this document is confined to the design of the PDP drum radioactive standard internal support structure, the matrix type and the as installed configuration.

2. BENIGN MATRIX DRUM DESIGN REQUIREMENTS

2.1 Overview

The benign PDP matrix drum requirements delineated in this section are based primarily on the intent to determine the baseline 55-gallon containerized TRU waste NDA capability. The PDP matrix drum design must allow a ready interpretation and determination of waste NDA system performance without the complicating and convoluting effects of matrix attributes which result in or contribute to NDA technique interference. Therefore the design of the PDP matrix drum(s), the internal support structure, and selected matrix must be, to the extent practicable, non-interfering with respect to the introduction of bias in waste NDA techniques.

The term benign is used to designate a matrix possessing properties which are nominally non-interfering to waste NDA measurement techniques. Measurement interference sources are technique specific but include attributes such as; high matrix density, heterogeneous matrix distributions, matrix compositions containing high moderator/high Z element concentrations, etc. To the extent practicable the matrix drum design should not unduly bias one NDA modality over another due to the manner in which the matrix drum configuration manifests itself to the measurement system. To this end the PDP matrix drum configuration and composition detailed below is driven primarily by the intent to minimize the incorporation of matrix attributes known to interfere with fundamental waste NDA modalities, i.e. neutron and gamma based techniques.

2.2 Requirements

The PDP matrix drum design must provide a convenient means to externally introduce and locate PDP standards into the interior of a sealed 55-gallon PDP matrix drum. The design of this structure, termed the internal support structure, must allow for positioning of one or more standards at internal drum radii and vertical heights sufficient to produce radioactivity distributions useful in capability assessments. The insertion scheme and mechanism must allow for precise and reproducible positioning of the PDP standards. The design shall also accommodate a means to affix external tamper indicating devices which seal and provide a positive control over the installed PDP standard configuration during test series.

The internal support structure for PDP standard insertion and positioning shall also serve as a fixture allowing the installed benign matrix to be fastened with known orientation coordinates. The internal support structure design and materials must also be compatible with the benign matrix requirement, i.e. inherently minimize interferences with the various waste NDA techniques.

The matrix drum design must support the PDP Program objective of assessing NDA system capability in a consistent manner over all participating facilities and through time. In accordance with this, the matrix drum must include design provisions which ensure a stable, non-variable, and effectively inert simulated matrix. The selected matrix shall not necessitate periodic maintenance and/or inspections to validate its presence and configuration. The matrix material must be compatible with health and safety considerations such that it is not hazardous in nature necessitating handling and storage precautions, see Appendix A - ETHAFOAM Material Safety Data Sheet. The matrix material must allow consistency in fabrication and assembly such that there is no significant drum to drum configuration variation thereby supporting inter-comparisons among characterization facilities. The selected matrix material must be available, workable to support fabrication activities, and of reasonable cost.

The overall outside dimensions of the PDP matrix drum shall be compatible with the waste NDA assay system chambers and measurement mounting mechanisms of all identified characterization facility participants. Every attempt shall be made to fabricate the PDP matrix drum set identical in all respects. Where minor deviations due to a small proportion of installed waste NDA systems are present, modifications to the standard PDP matrix drum(s) will be performed for that particular system and documented as appropriate.

Considerations are to be taken regarding the design of the internal support structure and matrix insert material with respect to adjusting or retrofitting the installed matrix. Although not a hard requirement, it is desirable to have a matrix drum design which allows disassembly and reconfiguration to accommodate future testing objectives. It is imperative that such a design provide for an exact installation of each configuration should it be necessary to reconfigure to a previous specification. This feature is certainly desirable from a programmatic standpoint in that resources can be conserved by utilizing PDP matrix drums to test more than one matrix type or potentially radioactive PDP standard design.

The PDP drum(s) must be differentiable from those of the actual waste population introduced into the various waste characerization facilities or those used for special purposes such as instrument calibration. The PDP drums must be readily identifiable via a unique color, identical for all PDP drums fabricated for performance testing, and have a durable exterior alpha numeric identification and internal matrix code.

The matrix drum must be sufficiently robust in terms of physical integrity to accommodate mechanical stresses encountered during handling and transportation. Integrity of the internal support structure and matrix must be considered relative to a service period of at least 25 years.

A final consideration, specific to the benign matrix drum(s) is to endeavor to select the benign matrix such that a reasonable relationship to some subpopulation of the actual waste form inventory can be determined. Properties of the simulated benign matrix should resemble properties associated with waste forms which likewise can be categorized as benign. For example, it is useful if the density, distribution, and elemental composition of the PDP benign matrix can be identified as similar to or approximating matrix attributes associated with a given waste form subpopulation. The stipulation that an understandable correlation between the PDP benign matrix material and an actual waste form subpopulation places emphasis on the proper documentation of the benign matrix material properties and installed configuration. This type of information supports both audit evaluations and contributes to the incremental refinement of waste NDA performance demonstration methods. Careful consideration and documentation of the benign matrix drum(s) design also provides an experience base useful in ensuring proper design of the more complicated PDP matrix standards to be employed in later cycles where the intent is to simulate key waste matrix codes listed in the Baseline Inventory Report.

3. BENIGN PDP MATRIX DRUM SPECIFICATION AND DESIGN

For the purpose of establishing a baseline waste NDA capability, two benign matrix drums are specified as applicable for use in the initial PDP testing cycles, the zero and ETHAFOAM matrix drums. The drums used to fabricate the PDP matrix drums are DOT specification 17C (UN identification code - UN1A2/X) 55-gallon packaging drums.[5] The zero matrix drum contains a type II 90 mil rigid polyethylene liner surrounding the internal support structure which accommodates the insertion and positioning of PDP standards. No matrix material in included in the zero matrix drum. The ETHAFOAM drum is identical to the zero matrix drum with the exception of an installed ETHAFOAM matrix, an expanded polyethylene foam product.

The following subsections address the design of the internal support structure for the zero and ETHAFOAM PDP matrix drums. The ETHAFOAM matrix properties, configuration and internal support structure fastening method are delineated in section 4. Data for all internal support structure components is provided including the mass, geometry, and dimensions of each component in both tabular and illustration formats. Additionally, every practical effort has been made to acquire data on the elemental composition of the various matrix drum materials of fabrication such that unknowns are minimized with respect to potential NDA system interferences. This is of importance as it is the intent of the Performance Demonstration Program to control sources of uncertainty for the purpose of testing and evaluation.

3.1 Matrix/PDP Standard Internal Support Structure and Insert Fixtures

The internal support structure and insert fixtures are designed to provide for the convenient introduction and precise positioning of PDP standard(s) within the matrix drum. The insert fixtures house and secure the PDP standard(s) at given vertical heights for subsequent positioning within the PDP matrix drum. The insert fixtures are introduced into the matrix drum interior via fixed aluminum guides, integral components of the internal support structure, termed insert tubes. The vertical distribution of PDP radioactive standard(s) is configured by loading them into the insert fixture(s) and subsequently sliding the loaded insert fixture(s) into specified PDP drum insert tube(s) which determines the radial location(s) of the PDP standard(s) within the matrix drum. For the ETHAFOAM drum, the insert fixtures also accommodate ETHAFOAM matrix spacers which can be used to fill voids remaining between PDP standard(s) as mounted in an insert fixture. Filling the remaining space in an insert fixture with ETHAFOAM matrix spacers serves the purpose of ensuring ETHAFOAM matrix material exists in all drum volume elements excepting the location of the PDP standards. The internal support structure also serves as a framework to secure matrix materials, i.e. ETHAFOAM, within the drum interior. A three-dimensional view of the internal matrix/source support assembly, rigid 90-mil polyethylene liner attached, is illustrated in Figure 1 with elevation and plan views as shown in Figures 2 and 3, respectively.

It is a design requirement that the internal support structure be configured and fabricated in such a manner so as to minimize interaction with the characteristic radiations utilized for waste NDA measurements. In accordance with this requirement, aluminum (Type 6061), is used to fabricate the insert fixtures and to the extent practicable, components of the internal support structure. The mass and thickness of the aluminum 6061 components is also specified to minimize interaction with emitted radiations yet maintaining structural integrity sufficient to accommodate repetitive usage.

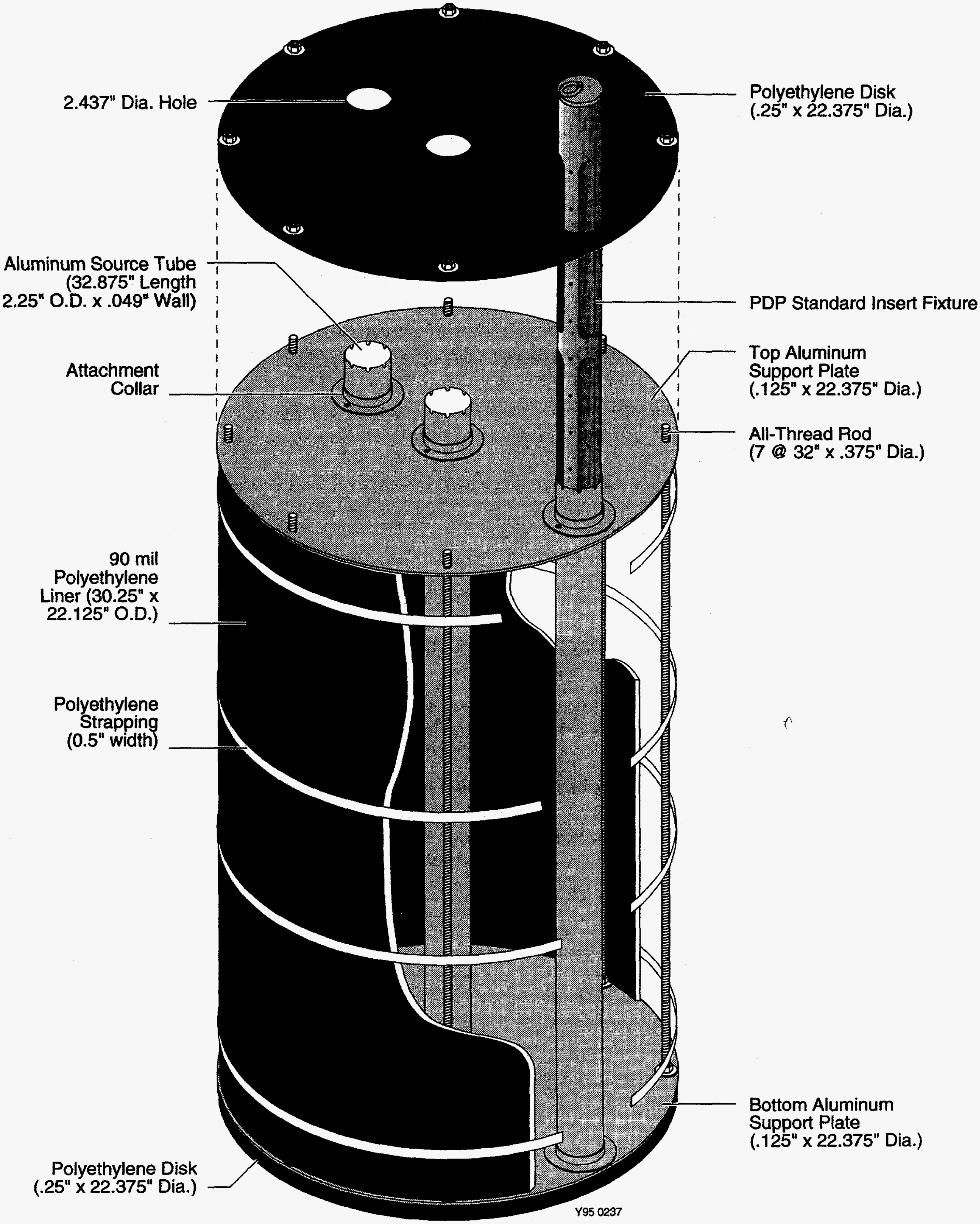

Figure 1. PDP matrix drum internals.

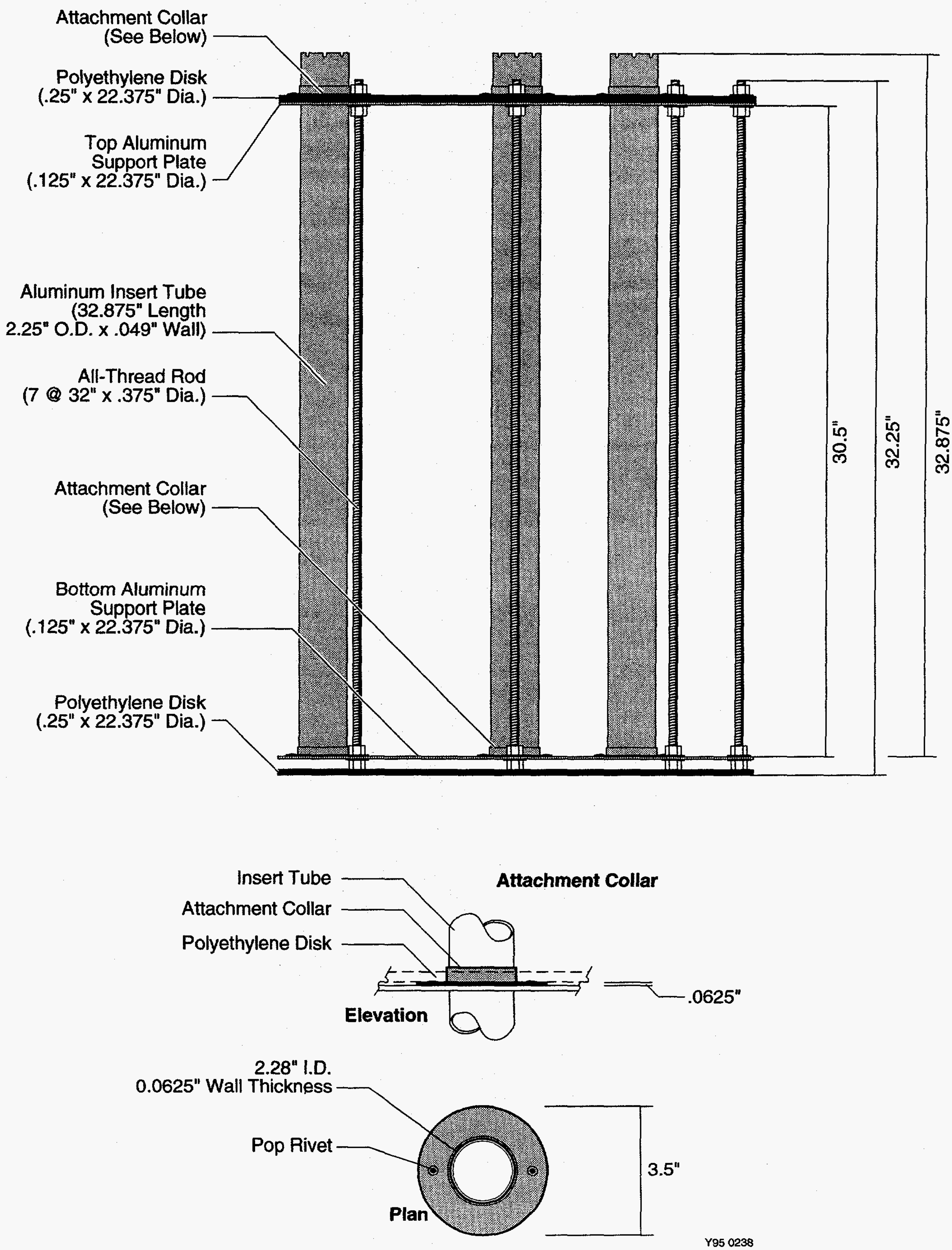

Figure 2. PDP matrix drum internal support structure (elevation).

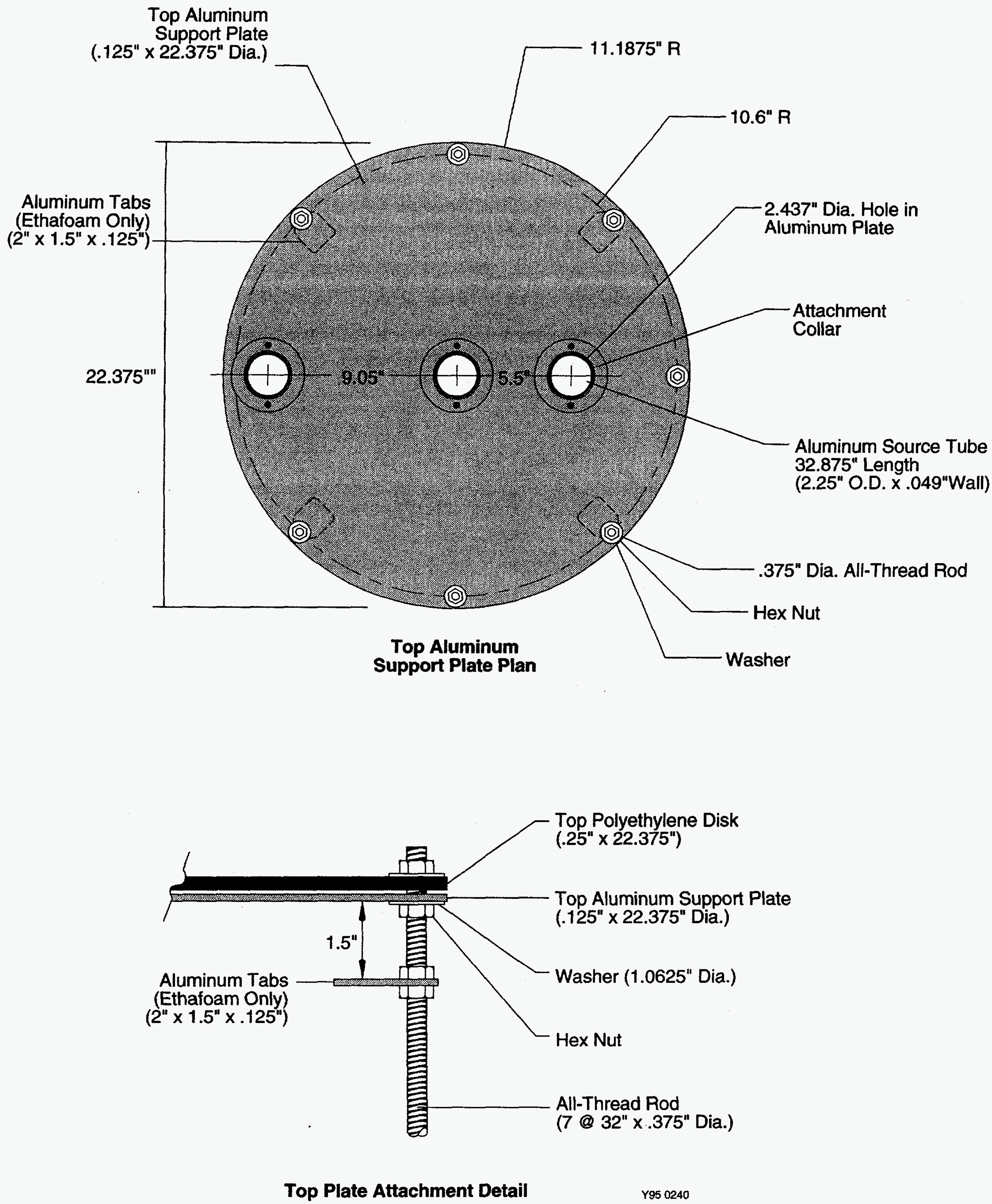

Figure 3. PDP matrix drum internal support structure (plan).

3.2 Internal Support Structure

The internal support structure consists of two aluminum support plates 0.125 in. thick with a 22.375 in. diameter connected by seven carbon steel allthread support rods 0.375 in. in diameter. The top aluminum plate contains three 2.437-in. diameter holes serving as penetrations for three insert tubes, 32.875-in long, 2.25-in O.D. with a 0.049-in wall. The insert tube diameter is a function of the PDP standard design and dimensions delineated in reference 3. Access to the drum interior is allowed through removal of the top plate should it be required that the installed matrix be reconfigured. A total of seven carbon steel allthread rods 32.0 in. long are used to fix the top and bottom aluminum plates parallel to each other at a 30.5-in. separation. Nuts and washers are positioned on the allthread rods to achieve the specified separation distance as illustrated in the Figure 2 elevation view. The aluminum plate/allthread rod configuration comprises the internal matrix/PDP standard support assembly, with the exception of the aluminum insert tubes.

The three aluminum insert tubes are fitted to the internal matrix support assembly as depicted in Figures 1, 2, and 3. The aluminum insert tubes run vertically through the drum volume at a length of 32.875 in., Figure 2. The insert tubes are notched at the top in 45-degree increments to allow specific angular orientations of the PDP standard insert fixture referenced to angular demarcations on the circumference of the drum exterior, Figure 4. The insert tubes are fitted to the internal support structure assembly by sliding them into the holes cut into the top aluminum support plate and positioning them as illustrated in Figures 2 and 3.

The fitted insert tube centers are at three different radii: 0.0 in. (the drum center), 5.5 in., and 9.05 inches. These particular radii were determined to be most efficacious for the pruposes of testing and minimizing complications to existing waste NDA systems. The insert tubes are fastened to the internal support assembly through the use of machined aluminum attachment collars (see Figure 5 and Figure 2 inset). Prior to fixing the insert tubes in place, all three are aligned such that the zero degree angular orientation of the insert tubes corresponds to the zero degree reference marked on the circumference of the drum, i.e. drum weld seam. Assembly is accomplished by fixing the bottom collar to the insert tube through the use of an aluminum-based epoxy compound such that the collar base is flush with the base of the tube. The collar is then pop-riveted to the bottom aluminum support plate, thereby securing the insert tube to the support structure assembly. The insert tube position is maintained vertical via the top aluminum support plate cutouts and by sliding an attachment collar onto the tube down to the top plate. Once the insert tube is in place the collar is pop riveted to the top aluminum support plate. The top aluminum collars are not epoxied to the insert tubes so that the top plate can be removed. Excepting the top and bottom polyethylene liner disks, the completed interanl support assembly is illustrated in Figure 2.

3.3 PDP Standard Insert Fixture

To precisely locate PDP standard(s) and/or matrix spacer(s) at specific vertical location(s) within the PDP matrix drum insert tube, insert fixtures are provided. There are three insert fixtures per drum, one for each internal support structure insert tube. Each insert fixture is fabricated from aluminum tube 2.125-in. O.D. by 32.375-in. length with a 0.065-in. wall, see Figure 6. The insert fixture tube diameter is based on the design and dimensions of the PDP standard addressed in reference 3. To minimize the total mass of structural material associated with the PDP matrix drum, the aluminum mass is reduced in the fixture tube by machining twelve lightening slots into each tube, four slots at three vertical locations. The

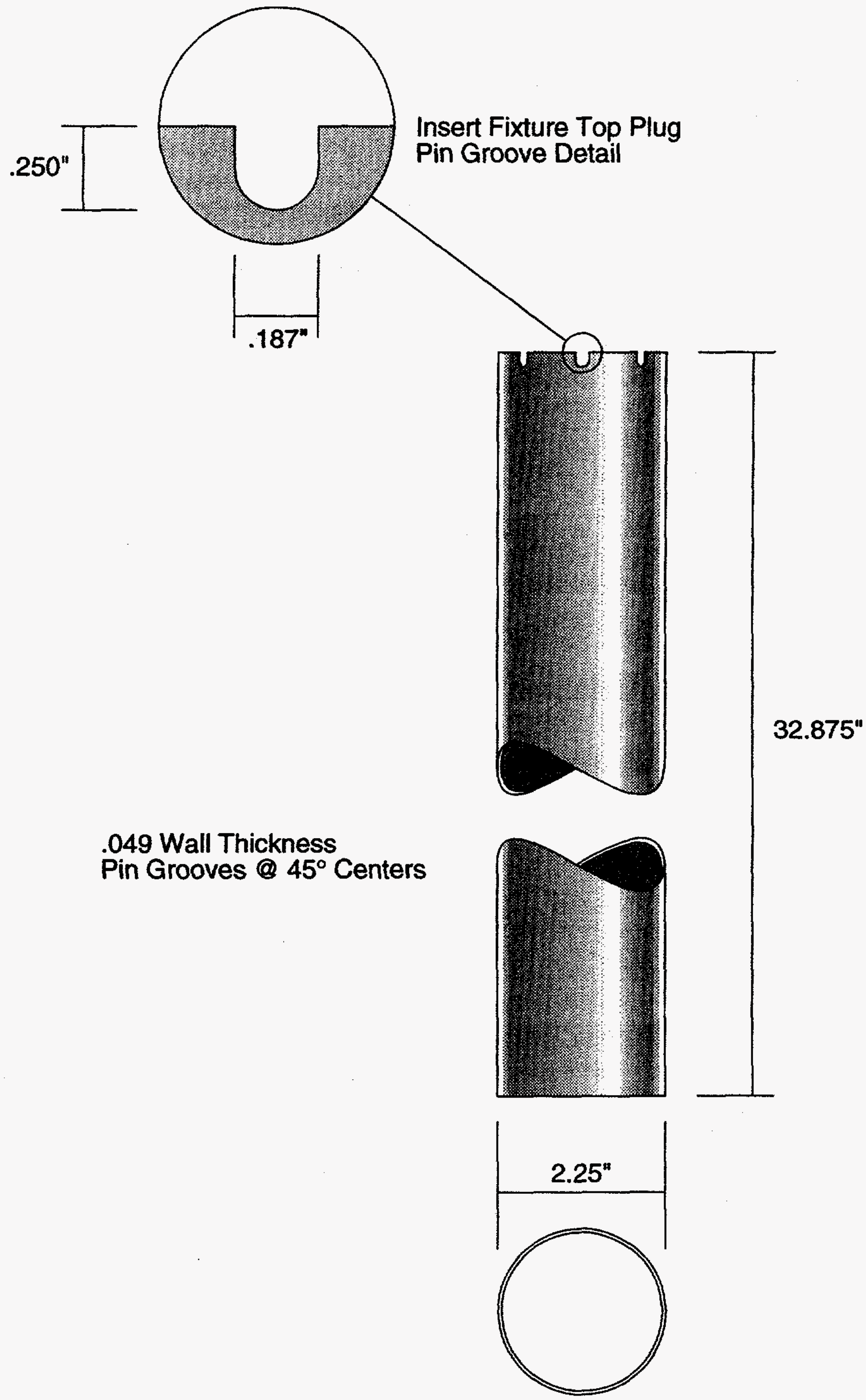

Figure 4. Internal support structure insert tube details.

Y95 0246

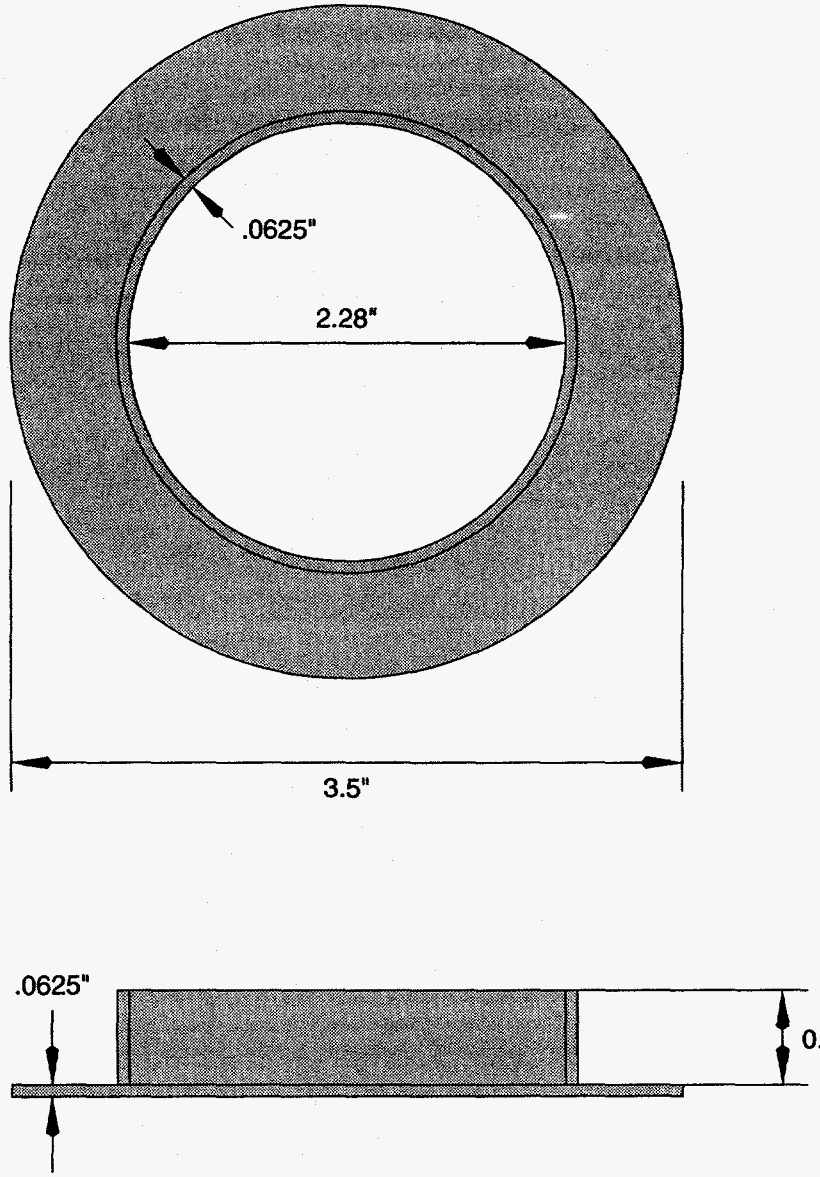

Figure 5. Aluminum attachment collar.

Y95 0239

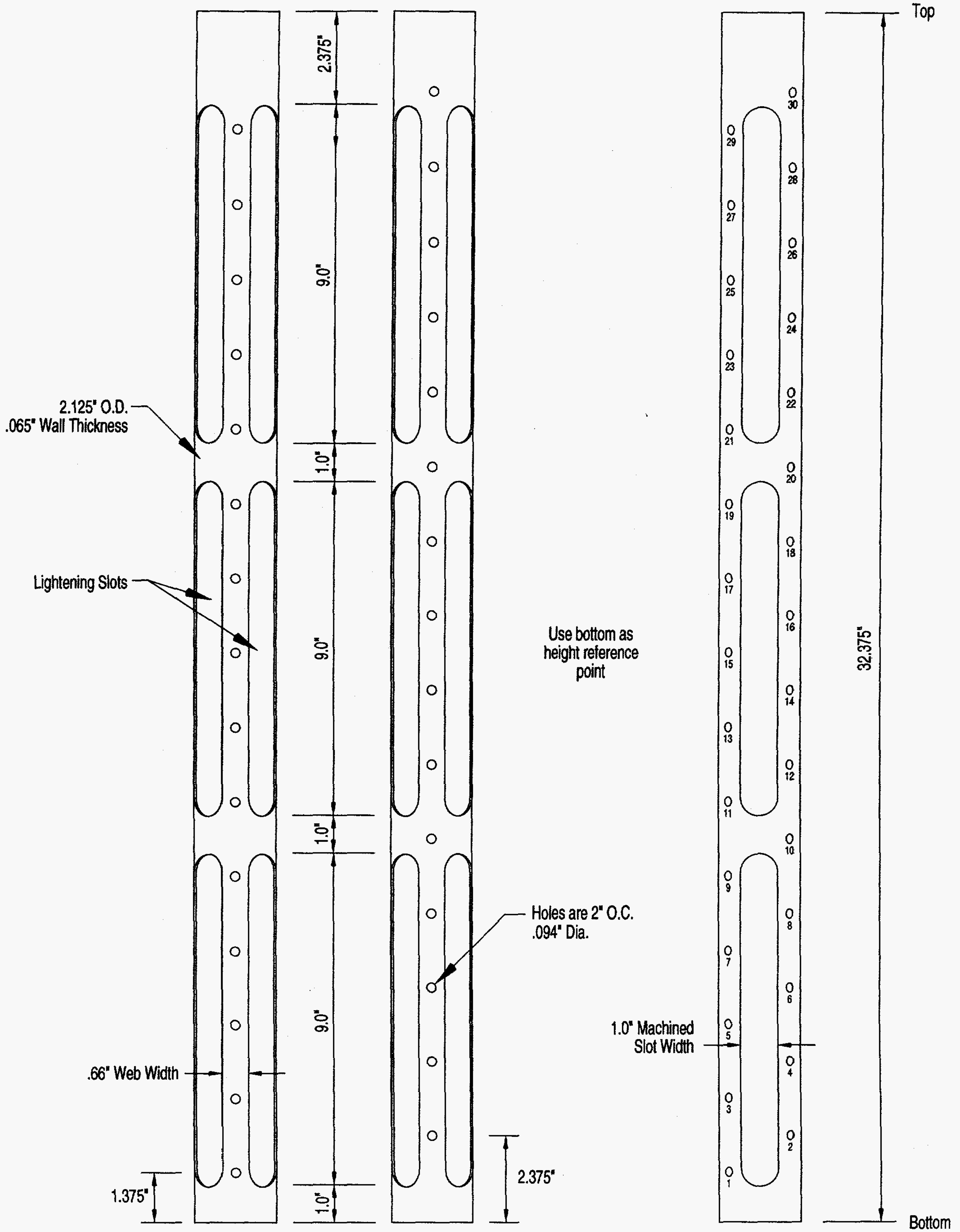

Figure 6. PDP standard insert fixture details.

Y95 0244

four lightening slots machined at a given tube height are each 1-in. wide with 9-in. high centers spaced equidistant around the circumference of the insert fixture tube. This configuration leaves four equally spaced vertical aluminum webs nominally 0.66-in wide. This four hole lightening cutout arrangement is repeated at two additional vertical locations separated by 1.0-in horizontal webs. The three sets of lightening holes, bottom, middle and top, are vertically centered at 5.5-in., 15.5-in. and 25.5-in. respectively relative to the fixture bottom edge, Figure 4. Solid tube is left at the bottom and top of the insert fixture 1.0-in. and 2.375-in. in length respectively.

The bottom of the insert fixture tube is capped with an aluminum disk 0.25-in. thick by 1.995-in. diameter. The aluminum bottom plug is fastened in place with two opposing pins, 0.125-in. diameter by 0.375-in. length, peened through the insert fixture tube wall and into the disk, see Figure 7. Excess pin material protruding past the outer surface of the insert fixture wall is filed and sanded flush with the surface to prevent binding during insertion into the support structure insert tube.

Insert fixture plunger rods are used to position PDP standard(s)/matrix spacer(s) at given vertical height(s) within the insert fixture, see Figure 8. Plunger rod hole sets, 0.094-in. diameter, are drilled on 2-in. vertical centers in two opposing webs starting at 1.375-in. from the insert fixture base, Figure 6. Plunger rod hole sets are also drilled into the remaining two opposing webs on 2-in. vertical centers with the first or lowest hole set starting at 2.375-in., vertically offset 1.0-in. from the alternate web set. Hence, hole sets are available in 1.0-in. increments oriented at 90 degrees with respect to a vertically adjacent hole set. A total of thirty hole sets in 1.0-in. increments ranging from 1.375-in. to 31.375-in. as referenced to the insert fixture base are provided.

The plunger rod consists of a section of aluminum tube 0.25-in. in diameter by 1.75-in. in length with a 0.065-in. wall. Each end of the rod is drilled and tapped for an 8-32 x 0.5-in. spring plunger, Figure 8 inset. The plunger rod snaps into horizontally opposed plunger holes, 0.094-in. diameter, between two vertical insert fixture webs bisecting the cylinder and providing a support on which the PDP standard(s) or matrix spacer(s) rest. Plunger extension through the insert fixture tube is adjusted to not exceed the exterior fixture tube surface eliminating interference or binding when installing the assembly into the support structure insert tube. Multiple plunger rods can be used to achieve various PDP standard/matrix spacer configurations. Plunger rods are removed through the use of a small tool, provided with the as delivered matrix drum set, by depressing either plunger allowing removal of the rod.

Once the PDP standard(s) and/or matrix spacer(s) are installed at desired locations within the insert fixture, the insert fixture cap is installed. The insert fixture cap is machined from 6061 aluminum round bar and is fitted with two 0.182-in. diameter by 0.350-in. copper coated carbon steel insert tube alignment pins, a top mounted ring (part of the TID mechanism), and two side opposed 1/4 20 x 0.750-in. spring plungers to secure the cap, see Figure 9. The insert fixture cap has three differing diameters yielding two machined shoulders. The cap bottom with the smallest diameter of 1.98-in. is dimensioned to slide 0.5-in. into the top of the insert fixture tube and contains two opposing spring plungers as the attachment mechanism. The plungers are adjusted such that the installed plunger rod does not protrude past the external insert fixture wall. The mid cylinder at a diameter of 2.125-in. contains two opposing Cu coated alignment pins for angular orientation of the fixture with respect to the PDP matrix drum. The top of the cap has a diameter of 2.25-in. and forms a 0.125-in. wide shoulder relative to the middle diameter cylinder which rests on the top of the insert tube supporting the installed insert fixture.

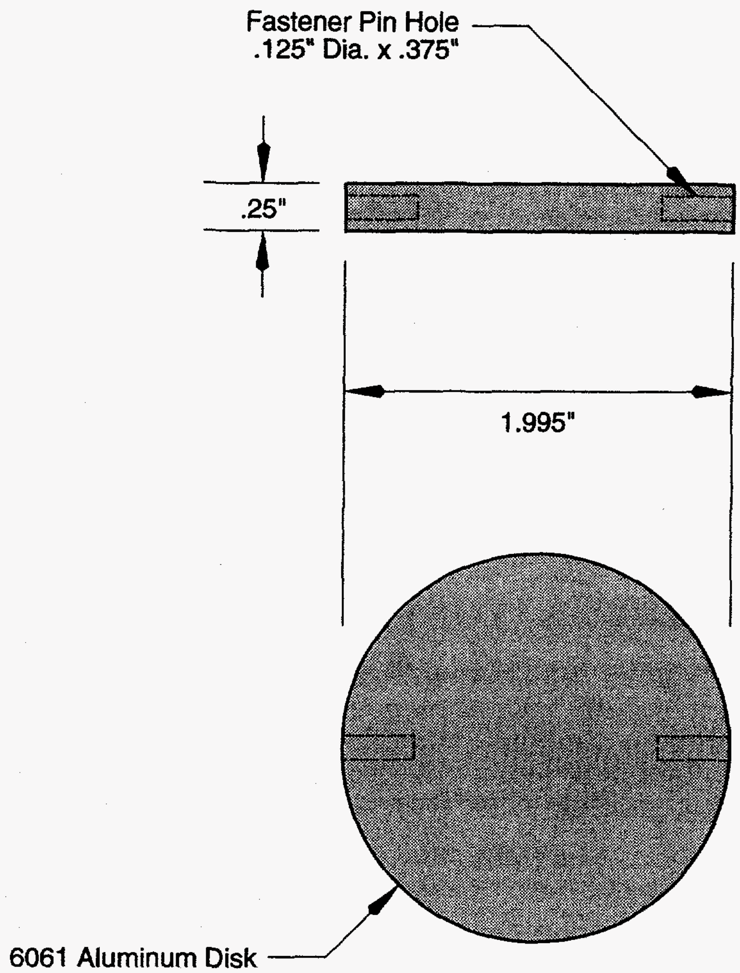

Figure 7. PDP standard insert fixture bottom plug.

Y95 0249

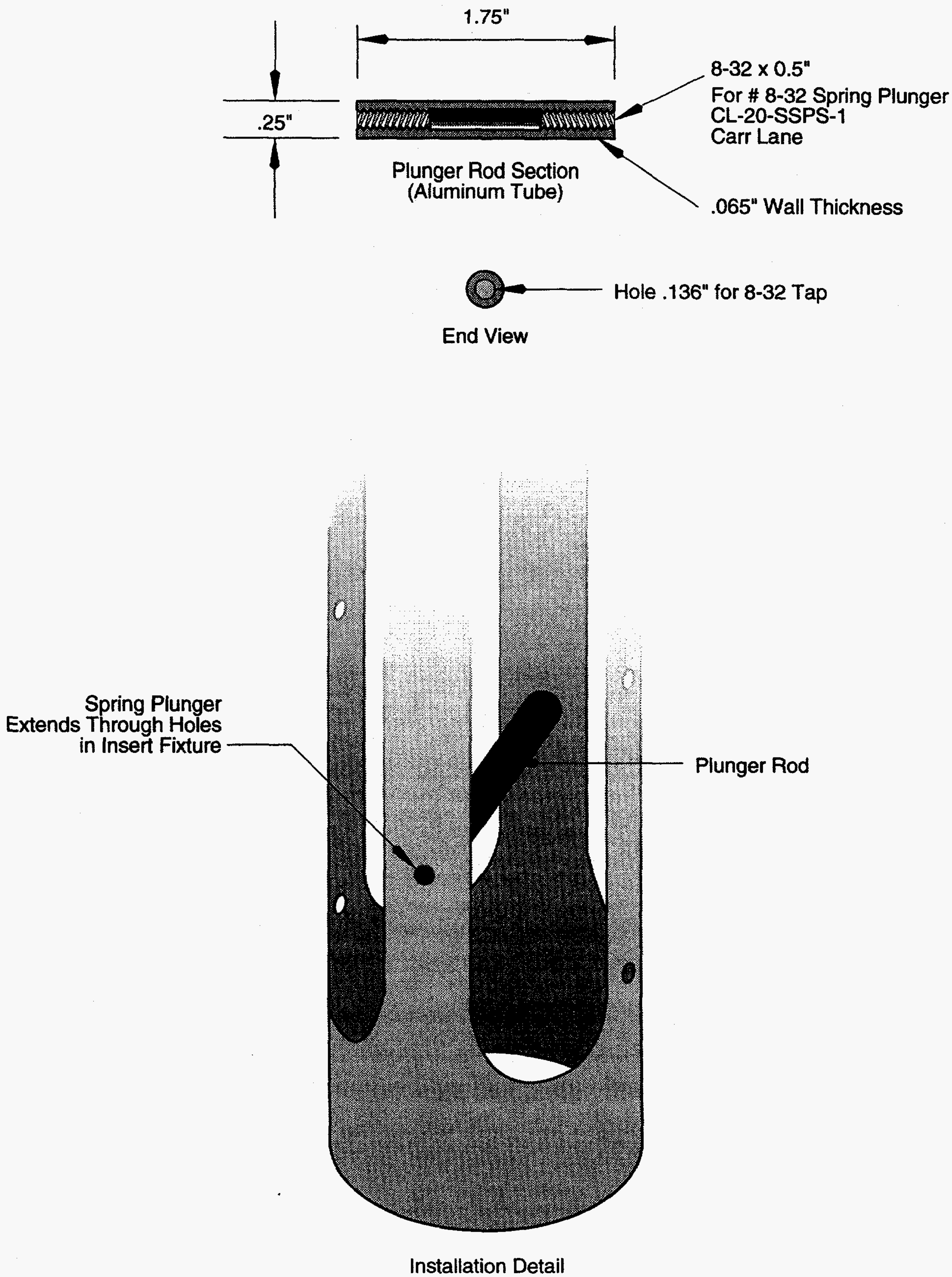

Figure 8. Insert fixture plunger rod details.

Y95 0245

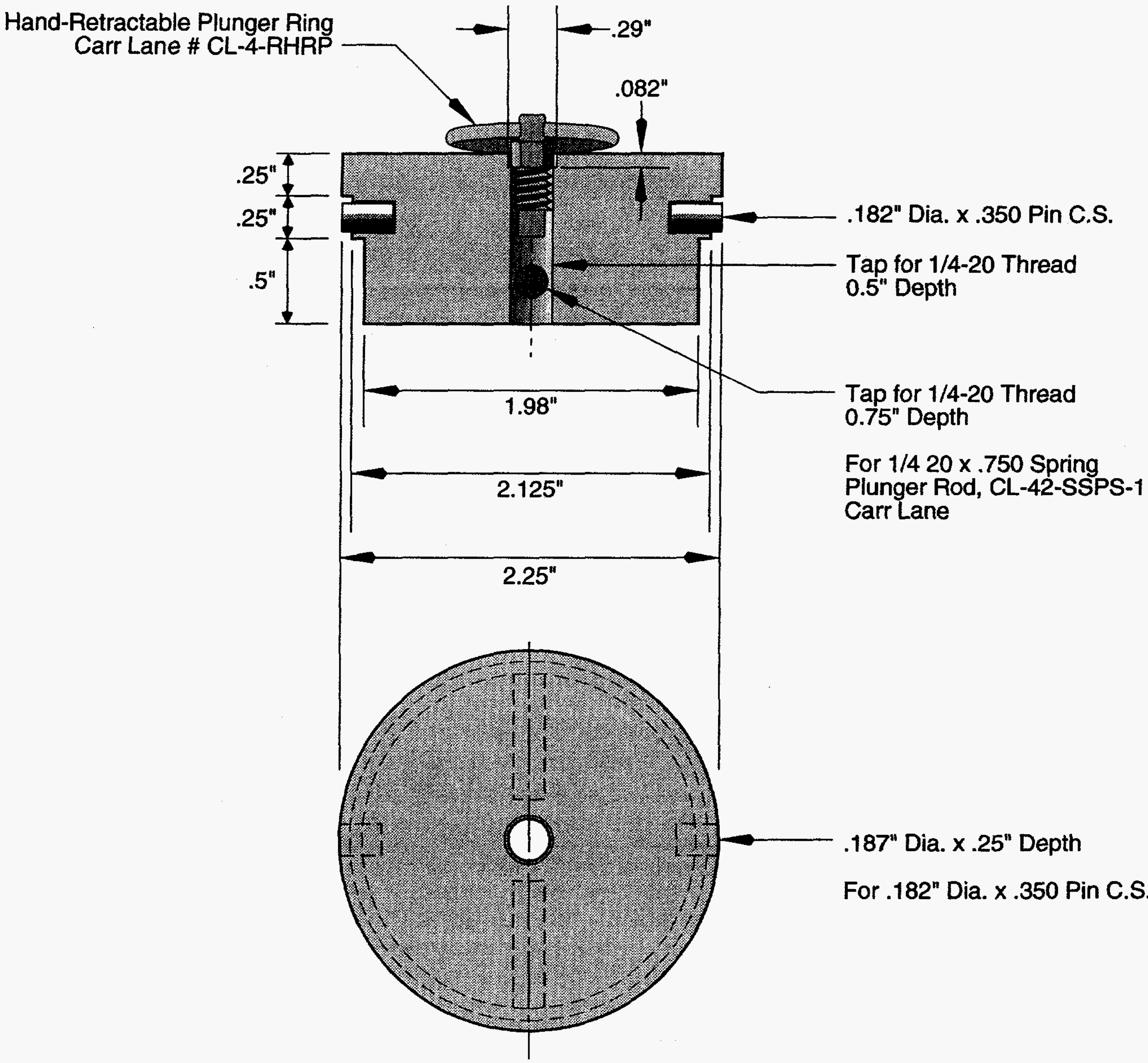

Figure 9. Insert fixture top plug.

Y95 0247

The cap is attached to the insert fixture tube by depressing one of the spring plungers (via supplied plunger depression tool) against the interior of the insert fixture tube top and aligning the opposing spring plunger with the locking slot machined into the tube top. The locking slot is L-shaped, 0.125-in. wide, vertical depth of 0.312-in. relative to the top of the insert fixture and a horizontal run of 0.312-in. relative to the machined vertical slot. The cap is pressed down and rotated into the machined locking slot until the opposite plunger rod snaps into its respective hole. Once the cap is snapped into place the entire fixture can be supported by the cap, see Figure 10 inset. The assembled insert fixture, Figure 10, is then placed into an internal support structure insert tube where the two insert fixture cap alignment pins rest in a set of grooves machined into the top of the insert tube at 45 degree increments. The cap has a demarcation line allowing the user to position the insert fixture at a given angular orientation circumferentially marked from 0 to 360 degrees in increments of 90 degrees on the PDP drum lid immediately adjacent to the insert tube penetration. The insert tube demarcations are keyed to external drum angular demarcations located around the drum circumference in 22.5 degree increments. This angular demarcation arrangement allows for the quantification of system response as a function of position in the drum cylindrical coordinate system. It also is intended to provide a means to account for angular dependencies associated with the orientation of an asymmetrically configured radioactive standard.

Two insert fixture cap configurations have been produced for the PDP program. The standard configuration is shown in Figure 9. A modification to the standard configuration was made to accommodate the tight vertical tolerance of the Los Alamos National Laboratory neutron assay system and is shown in Figure 11.

3.4 Internal Support Structure/Insert Fixture Component Itemization

A list of the various support structure components discussed above is provided in Table 1. Table 2 contains an itemization of the standard drum matrix/insert fixture components and associated masses. The number of each component and total associated mass is tabulated. The elemental composition of these materials is provided in Section 3.4. The data contained in this section is provided to support radiation transport modeling and waste NDA system response interpretations.

Table 1. PDP matrix drum internal support structure component itemization/data.

Component description	Number of items	Mass (g)
Top and bottom aluminum plate	2 plates	2,008.0/plate
Seamless aluminum insert tubes	3 tubes	364.0/tube 1,092.0/(3 tubes)
Aluminum insert tube attachment collars	2 collars/tube 6 collars total	23.2/collar 139.2/(6 collars)
⅜" carbon steel allthread rod	7 rods	346.3/rod 2,424.1/(7 rods)
Carbon steel nuts and washers for ⅜" allthread rod	4 nuts/(⅜" rod) 4 washers/(⅜" rod)	6.6/nut 6.5/washer

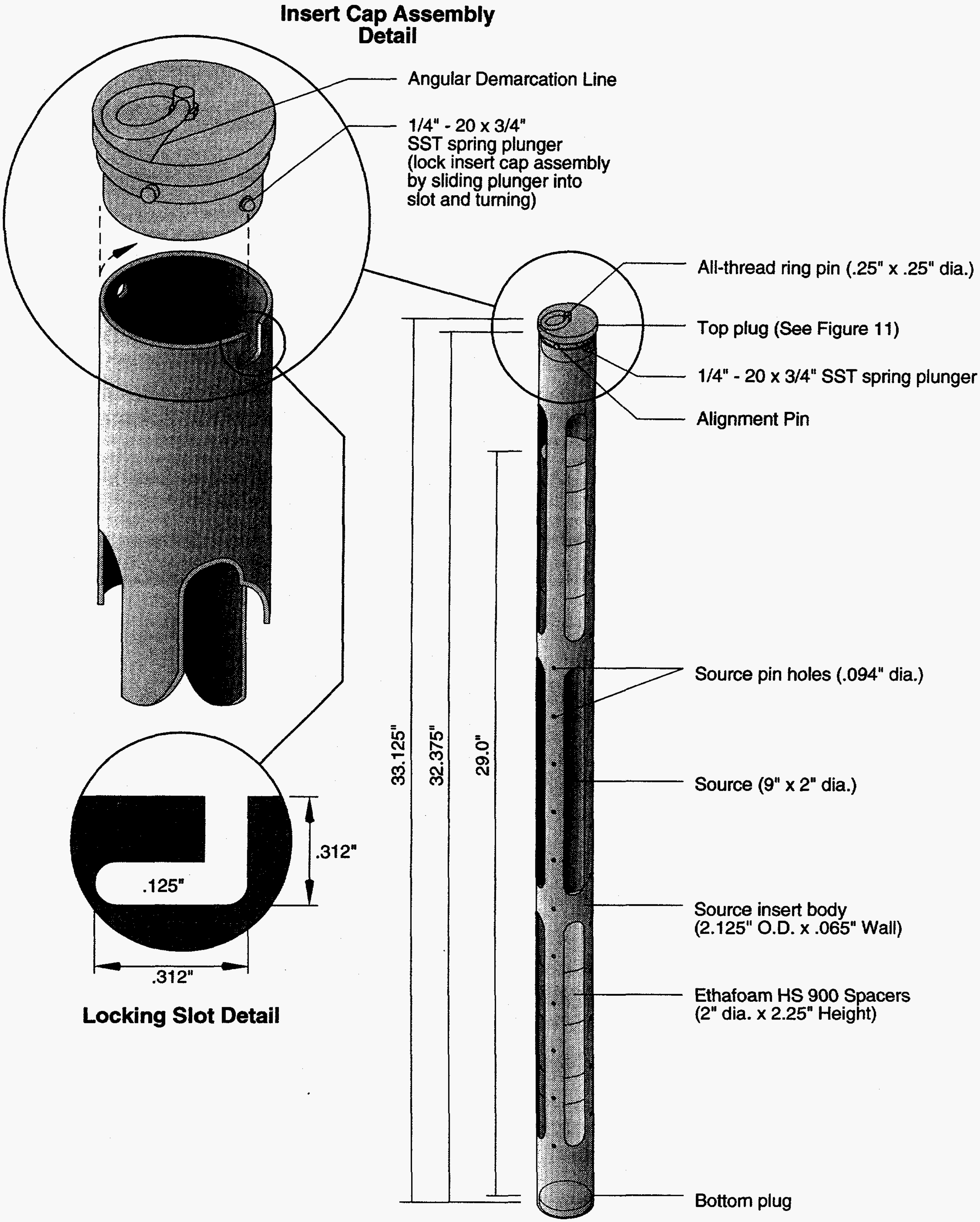

Figure 10. PDP matrix drum insert fixture.

Y95 0306

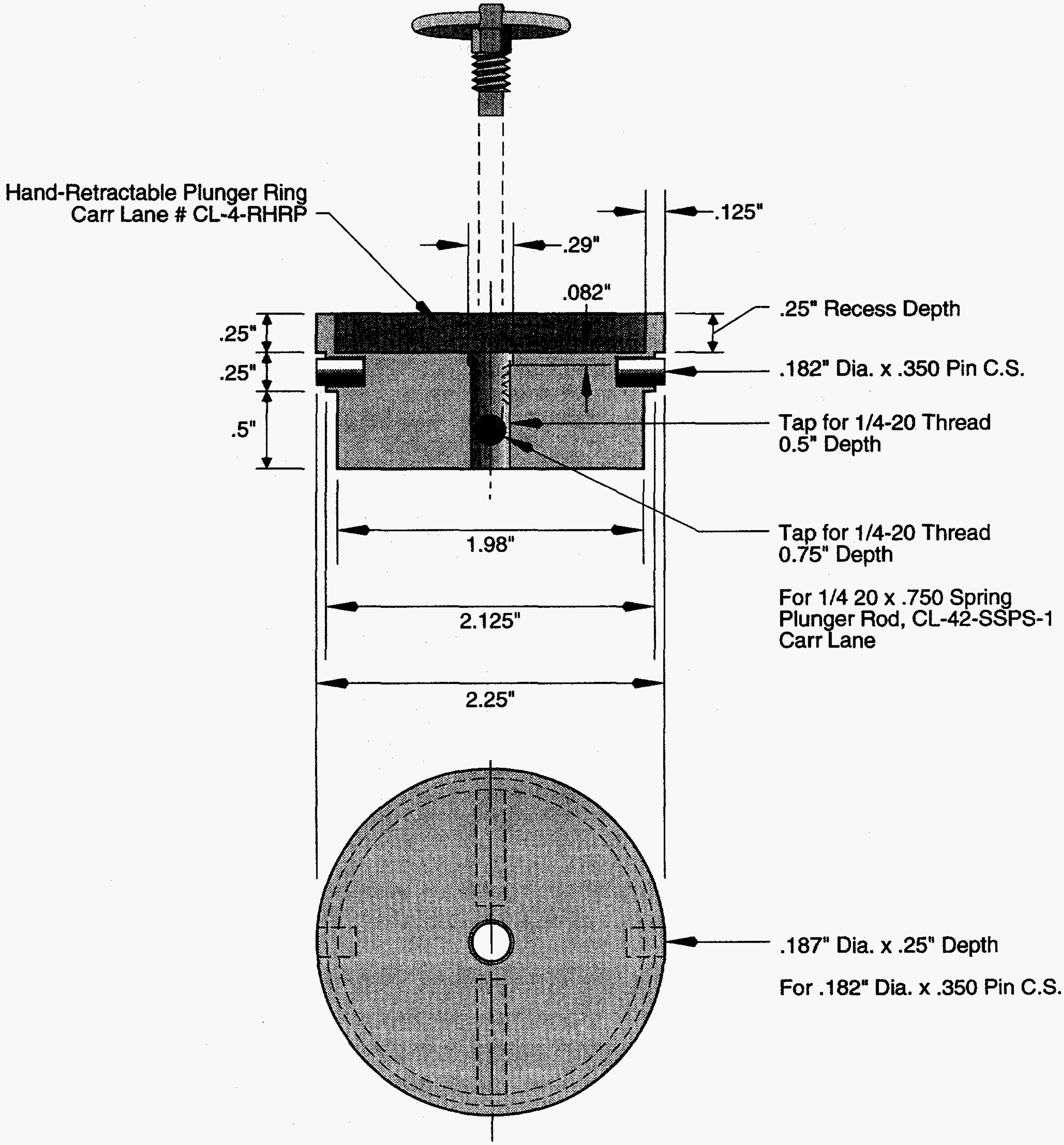

Figure 11. Insert fixture top plug (Los Alamos).

Y95 0248

Table 2. PDP matrix drum insert fixture component itemization/data.

Component description	Number of items	Mass (g)
insert tube top Al mounting plug with alignment pins	1 plug/fixture 3 fixture/drum	106/plug
insert fixture Al tube with lightening holes	3 fixture/drum	283.8/fixture
insert fixture Al bottom plug	1 plug/fixture 3 fixture/drum	41.7/plug
spring plunger (top mounting plug)	2 plunger/plug	2.79/plunger
top mounting plug TID ring	1TID ring/plug 3 plug/drum	3.9/TID ring
plunger rod assembly		
supplied plunger rods	15 rod/drum	2.53/rod
spring plunger (rod)	2 spring plunger/rod	1.04/spring plunger

3.5 Internal Support Structure/Insert Fixture Composition Data

The elemental composition of the materials comprising the internal support structure and insert fixture itemized in Section 3.3 are provided in this section. The composition data were acquired from several sources, including analyses supplied by the material vendor, consultation with individuals involved in materials science, and applicable references.[6] Standard specifications were provided by the American Society for Testing and Materials (ASTM), the American Metallurgy Society (AMS), and the American Society of Mechanical Engineers (ASME).

The preferred source of elemental composition/chemical data is controlled vendor-based analyses acquired during the material production process. Unfortunately, such quality assurance requirement data accompanies procured stock at a significant cost and is therefore available only on certain items. In lieu of such detailed analyses, it is possible to track material compositions based on the standard specification number designations marked on the stock. Thus, elemental composition data can be acquired from the manufacturing, material properties, and chemical requirement data contained in such standards. The data contained in the elemental composition tables are sufficient to allow a reasonable representation of the various materials in radiation transport models and support interpretation of measurement data response as a function of material type.

Provided in Tables 3 through 5 are the element(s), the respective weight percents, and the atom densities associated with the materials used to fabricate the components of the internal structure/insert fixtures. The weight percent data can typically be obtained from more than one data source. Therefore, weight percent data are tabulated for all such sources, allowing the user to individually select or average the values as desired for subsequent response interpretation and/or computation purposes. Also provided are vendor and/or ASTM standard material specification references.

Table 3. Seamless drawn tube and sheet aluminum alloy 6061-T6 elemental composition: $\rho = 2.71$ g/cm^3 (insert tubes and top/bottom support plates).

Element	Atomic weight	Weight %[a] (vendor)[b,c] {ASTM Specs}[d,e,f]	Atoms/cm^3 (units of 10^{24})
Mg	24.305	1.0 (0.8 - 1.2) {0.8 - 1.2}	6.716E-04
Al	26.9815	96.625 (97.16) {96.53}	5.850E-02
Si	28.086	0.6 (0.4 - 0.8) {0.40 - 0.8}	3.487E-04
Ti	47.90	0.15 (0.0 - 0.15) {0.15}	5.116E-05
Cr	51.996	0.25 (0.04 - 0.35) {0.04 - 0.35}	7.855E-05
Mn	54.938	0.15 (0.0 - 0.15) {0.15}	4.461E-05
Fe	55.847	0.7 (0.0 - 0.7) {0.7}	2.048E-04
Cu	63.546	0.275 (0.15 - 0.4) {0.15 - 0.40}	7.070E-05
Zn	65.37	0.25 (0.0 - 0.25) {0.25}	6.248E-05

Table 3. (continued).

Element	Atomic weight	Weight %[a] (vendor)[b,c] {ASTM Specs}[d,e,f]	Atoms/cm^3 (units of 10^{24})
Other	—	— (0.05 ea - 0.15 tot) {0.05 ea - 0.15 tot}	—

a. Reference 6.

b. Chemical composition limits as per vendor, ALCOA, Lafayette, IN; specification - WW-T-700/6F2, AMS 4082L, ASTM B210-92A (seamless drawn tube).

c. Chemical composition limits as per vendor, Kaiser Aluminum, Spokane, WA; specification - AMS4027_Rev K, ASTM B209_Rev92 AM. (sheet aluminum alloy).

d. Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes, ASTM Designation: B 210-92a, Annual Book of ASTM Standards, Vol. 03.05. (seamless drawn tube).

e. Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate, ASTM Designation: B209-92a, Annual Book of ASTM Standards, Vol. 11.01. (sheet aluminum alloy).

Table 4. Rod aluminum alloy 6061-T65110 elemental composition: $\rho = 2.71$ g/cm^3, (aluminum insert tube collars and insert fixture top/bottom plugs).

Element	Atomic weight	Weight %[a] (ASTM B-211-93)[b]	Atoms/cm^3 (units of 10^{24})
Mg	24.305	1.0 (0.8 - 1.2)	6.716 E-04
Al	26.9815	96.625 (97.16)	5.845 E-02
Si	28.086	0.6 (0.4 - 0.8)	3.487 E-04
Ti	47.90	0.15 (0.15)	5.111 E-05
Cr	51.996	0.25 (0.04 - 0.35)	7.855 E-05
Mn	54.938	0.15 (0.15)	4.457 E-05
Fe	55.847	0.7 (0.7)	2.046 E-04
Cu	63.546	0.275 (0.15 - 0.40)	7.063 E-05
Zn	65.37	0.25 (0.25)	6.242 E-05
other		— (0.05 ea - 0.15 max)	

a. Reference 6.

b. Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire, ASTM Designation: B211-93.

Table 5. Allthread support rod and nut/washer elemental composition - $\rho = 7.83\ g/cm^3$.

Element	Atomic weight	Weight % {ASTM A575-86a}[a]	Atoms/cm³ (units of 10^{24})
C	12.011	{0.17 - 0.24}[b]	7.853 E-04
P	30.9738	{0.04 max}	6.090 E-05
S	32.06	{0.05 max}	7.355 E-05
Mn	54.938	{0.25 - 0.60}	3.648 E-04
Fe	55.847	{99.29}[c]	8.385 E-02

a. Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades, ASTM designation A575-86a, Annual Book of ASTM Standards, Vol 01.05, grade designation M1020, ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys.

b. Estimated at 0.20 wt %.

c. Balance of the mass attributed to Fe using the estimated C value[a], P and S max values and the Mn midrange value.

4. ETHAFOAM as a Benign Matrix

4.1 Material Properties

The benign matrix drum has been specified to consist of a matrix that is uniform in distribution and possesses an elemental composition and density considered nominally non-interfering relative to waste NDA measurement techniques. In terms of existing NDA instrumentation capabilities, this requires that the matrix have a low density and not contain significant high Z element and/or neutron absorber/high moderator atom densities. The selected matrix must also comply with the requirements as delineated in section 2.2. Several materials have been investigated as to their properties with respect to the stated requirements. One of the more important is matrix density which must not be of a value that will result in significant neutron interaction and gamma attenuation effects. Of equal importance is the elemental composition and distribution of the matrix. The matrix cannot be comprised of elements in sufficient concentration to contribute significantly to radiation absorption, moderation, and attenuation. These matrix properties must be balanced against the requirement that the material be readily obtainable and workable in regards to fabrication considerations.

A reasonable low density non-interfering matrix candidate is a brand name product called ETHAFOAM HS-900[a], a plank polyethylene plastic foam, density is 0.15 g/cm^3, manufactured by the DOW Chemical Company. ETHAFOAM products are described as tough, closed-cell materials that are energy-absorbent, resilient, lightweight, moisture- and chemical-resistant, usable over a wide temperature ranges, and easy to fabricate. The appearance is that of a milky white solid. The product is typically utilized in protective packaging applications.

As indicated, the elemental composition of the selected matrix is an important factor when considering a non-interfering matrix type. Vendor supplied information regarding the production of ETHAFOAM HS-900 includes the use of blowing agents such as difluoroethane, which are stated to be fugitive and leave the product after manufacture, see Appendix A - Material Safety Data Sheet. Concern over residual elemental contaminants in the polyethylene base, which may represent sources of NDA system bias, prompted an independent analysis of the ETHAFOAM elemental composition. A sample of the ETHAFOAM HS-900 material was acquired from DOW Chemical and analyzed at the INEL. The analysis performed used the inductively coupled plasma mass spectrometry (ICPMS) technique. The ICPMS analysis yielded semi-quantitative data sufficient for purposes of verifying the presence of elements with high interaction cross sections. The ICPMS analysis technique is sensitive to all elements of concern except chlorine. A combustion analysis technique was also used to establish the weight fractions of hydrogen, carbon, nitrogen, and sulfur.

A tabulation of the measured concentrations in parts per million for those elements detected in the ETHAFOAM sample via the ICPMS analysis are shown in Table 6. The results of the ICPMS analysis indicate no detected interfering type elements in concentrations that would be considered interfering to existing NDA techniques. Although no quantitative data regarding the chlorine concentration resulted from the analyses, there were no qualitative indications of its presence. An additional analysis of the

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a. Mention of specific products or manufacturers in this document implies neither endorsement or preference nor disapproval by the U.S. Government, any of its agencies, or Lockheed Martin Idaho Technologies Company, of the use of a specific product for any purpose.

Table 6. ETHAFOAM HS-900 elemental analysis data.

Inductively coupled plasma mass spectrometry			
< 100 ppm	< 50 ppm	< 10 ppm	< 1 ppm (nominal detection limit)
P	S	Na	All other elements of concern
K	Ca	Mg	
	Br	Fe	
		I	
CHNS combustion analysis (nominal wt%)			
C	H	N	S
86	14	Trace (<1%)	Not detected

ETHAFOAM sample using x-ray fluorescence is being performed to verify this claim. Included in Table 6 are the results of the combustion analysis procedure (CHNS analysis) for hydrogen, carbon, nitrogen, and sulfur in units of weight percent.

4.2 PDP ETHAFOAM Matrix Drum Configuration

The ETHAFOAM HS-900 polyethylene plastic foam is available in plank form with nominal dimensions of 2.25-in. thick by 24-in. wide by 108-in. long. The ETHAFOAM sheet material is sized into discs, 20.75-in. diameter, through the use of a foam/rubber cutting device. Three holes are also cut into each disc at the radii of the internal support structure insert tubes. The sized ETHAFOAM discs are positioned within the internal support structure by stacking one upon the other until a total of thirteen discs have been installed resulting in nominal uniform fill height of 29-inches. The set of thirteen ETHAFOAM discs are secured as a single unit through the use of four aluminum tabs mounted to every other allthread support rod. The aluminum tabs are positioned on the allthread rod via the use of nuts and washers on both the top and bottom side of the tab. To ensure the thirteen ETHAFOAM discs are firmly secured within the internal support structure, the washer/nut fastener sets are used to force the top disc into the twelve below resulting in a tight immobile stack. The aluminum securing tabs can be reached through the removal of the top aluminum support plate thereby allowing disassembly of the drum if desired. Figure 12 shows a three-dimensional view of the assembled ETHAFOAM low density polyethylene matrix. The installed mass of the ETHAFOAM matrix is provided in Table 7.

The completed ETHAFOAM matrix/internal support structure assembly is fitted with the cylinder portion of a 90-mil rigid polyethylene liner for the purpose of reproducing the liner associated with the majority of actual waste drums. As the internal support structure outside dimensions are not exactly those of the internal dimensions of a 90-mil rigid liner, the liner bottom is cut out, and the cylinder side, 30.375 in. high, weighing approximately 5,000 g, is sliced open vertically and fitted over the internal support structure assembly. The 90-mil liner cylinder is secured in place using 0.5-in. wide polyethylene strapping, Figure 12. The elemental composition data for the 90-mil rigid liner is tabulated in Table 8.

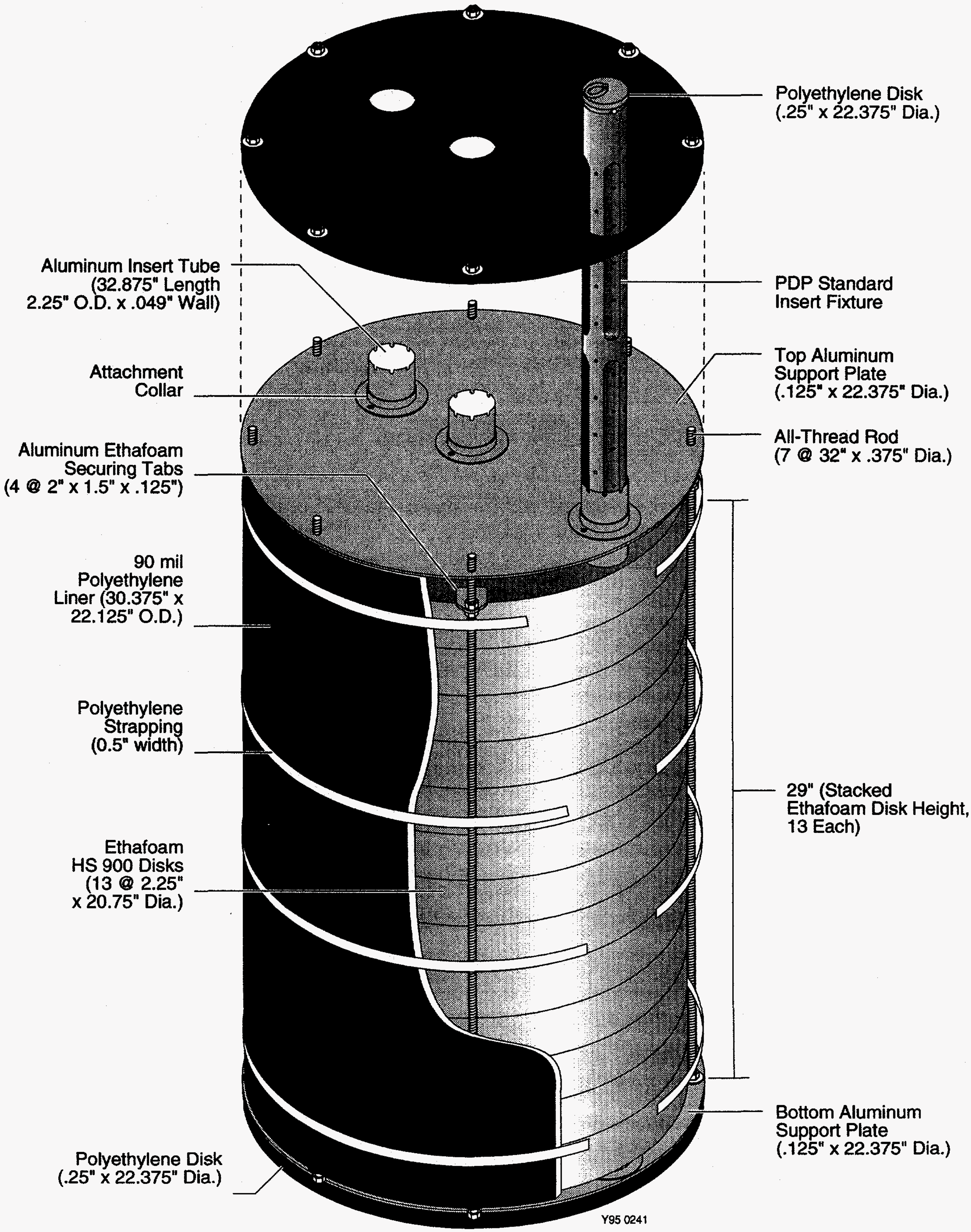

Figure 12. PDP ETHAFOAM matrix drum.

Table 7. ETHAFOAM HS-900 matrix data.

Component description	Number of items	Mass (g)
ETHAFOAM HS-900 Plank Polyethylene Plastic Foam	13 discs/drum	1760/disc 24640/drum

Table 8. Polyethylene drum liner 90 mil, $\rho = 1.00\ g/cm^3$.

Element	Atomic weight	Weight %[a]	Atoms/cm^3 (units of 10^{24})
H	1.00797	14.011	7.999 E-02
C	12.011	85.989	4.118 E-02
Other[b]			

a. Chemical composition - polyethylene 97.5%, carbon black (C - 2.5 wt%)

b. Impurities: oxides of calcium, silicon, iron, and zinc per scanning electron microscopy performed on random liner sample at the INEL, 6/93.

The 90-mil rigid liner bottom is reproduced by placing a 0.25-in. thick, 22.375-in. diameter, 1,548-g polyethylene plate in the drum bottom below the bottom aluminum support plate. Cutouts have been made in a similar top polyethylene plate, 1,050-g, to accept the insert tube penetrations and simulate the liner lid. Elemental composition data for the top and bottom liner lids is found in Table 9. The polyethylene liner lid is placed on top of the top aluminum support plate and fastened with washer/nut assemblies. The entire assembly is then lowered into a DOT 17C 55-gallon drum with the weld seam used as a reference for zero degrees as per the angular demarcations. The zero degree weld seam reference is always aligned with the 9.05-in. radius insert tube, i.e. tube number 3, as per Figure 13. The drum lid is then fitted to the top and fastened with the drum locking ring and the lock ring bolt secured in place. The weight of the completely assembled ETHAFOAM and zero matrix drums are 67.6 and 43 kg, respectively. The exterior dimensions of the assembled PDP ETHAFOAM and empty matrix drums are as illustrated in Figure 14 with the exception of the Los Alamos PDP drum set which has a lower overall height due modification of the insert fixture top plug.

In order to validate the integrity of an assembled PDP ETHAFOAM matrix drum, digital radiography images were acquired after transportation of the palletized assembly. An ETHAFOAM matrix drum completely packaged for delivery to a participating facility was transported over road approximately 55 miles to the location of the Digital Radiography and Computed Tomography project locted at the Idaho State University where digital radiography images could be acquired. This simple test allows a quick assessment of whether shifting or failure of internal components occurs due to the rigors of transportation. The images were also used to verify that the as installed disc stack configuration was as intended, i.e., a compressed and immobilized stack of thirteen discs, yielding an ETHAFOAM matrix distribution of uniform density.

Table 9. High-density polyethylene liner (top & bottom lid), $\rho = 0.955$ g/cm^3.

Element	Atomic weight	Weight % (vendor)[a]	Atoms/cm^3 (units of 10^{24})
H	1.00797	14.011	7.995 E-02
C	12.011	85.989	4.118 E-02
Other[b]			

a. Chemical composition - estimate polyethylene 97.5%, carbon black 2.5 wt%, (actual composition proprietary), Poly-Hi Solidur Corp., PA.

b. Impurities: oxides of aluminum, silicon, sulfur, calcium, titanium, chromium, iron, zinc, and lead per scanning electron microscopy performed on random sample at the INEL, 6/93.

Radiographic imaging instrumentation consisted of a gadolidium oxysulfide scintillator screen 42"wide x 61" lens coupled to a digital CCD (charge coupled device) camera. The image was acquired with a fan beam collimator with a fifteen degree half angle and a 3 mm vertical opening using a 420 keV x-ray source. The shutter on the camera was opened and the source scanned vertically in a continuous fashion over the drum height, scan time approximately four minutes. Data suitable for 3D tomographic reconstruction was also collected using a cone beam collimator with the 420 KeV source. Several reconstructions were performed to assess certain components of the matrix drum. The acquired images indicated no movement of the internal components during transportation and a uniform ETHAFOAM disc set with no significant inter-disc gaps. One of the acquired radiograph images is shown in Figure 15 demonstrating the desired ETHAFOAM configuration and no shifting of internal components due to shipping.

4.3 ETHAFOAM PDP Drum Configuration Radiation Transport - Scoping Calculations

Selection of a material for use as a benign matrix can be based on first principles, i.e. low density, uniform density, low Z elemental composition, etc. Although a material considered benign with respect to implemented waste NDA techniques can be reasonably identified in this manner, there is nevertheless a potential that an unsuspected system bias may arise due to material properties and/or the installation configuration. Unknown bias elements may result in unquantifiable system response anomalies complicating the assessment of performance and compliance. In an attempt to identify unsuspected instrumental bias sources, Monte Carlo Neutron Photon (MCNP) analyses of the transport of characteristic radiations in the ETHAFOAM and zero matrix PDP drum configurations have been performed. MCNP models were developed to quantify the transport characteristics for nominal passive neutron and passive gamma waste NDA apparatus using energy spectra and characteristic radiation signatures associated with low burnup plutonium. Active thermal neutron interrogation analyses were not performed on the empty and ethafoam matrix drums due to limitations of the MCNP model available at the time.

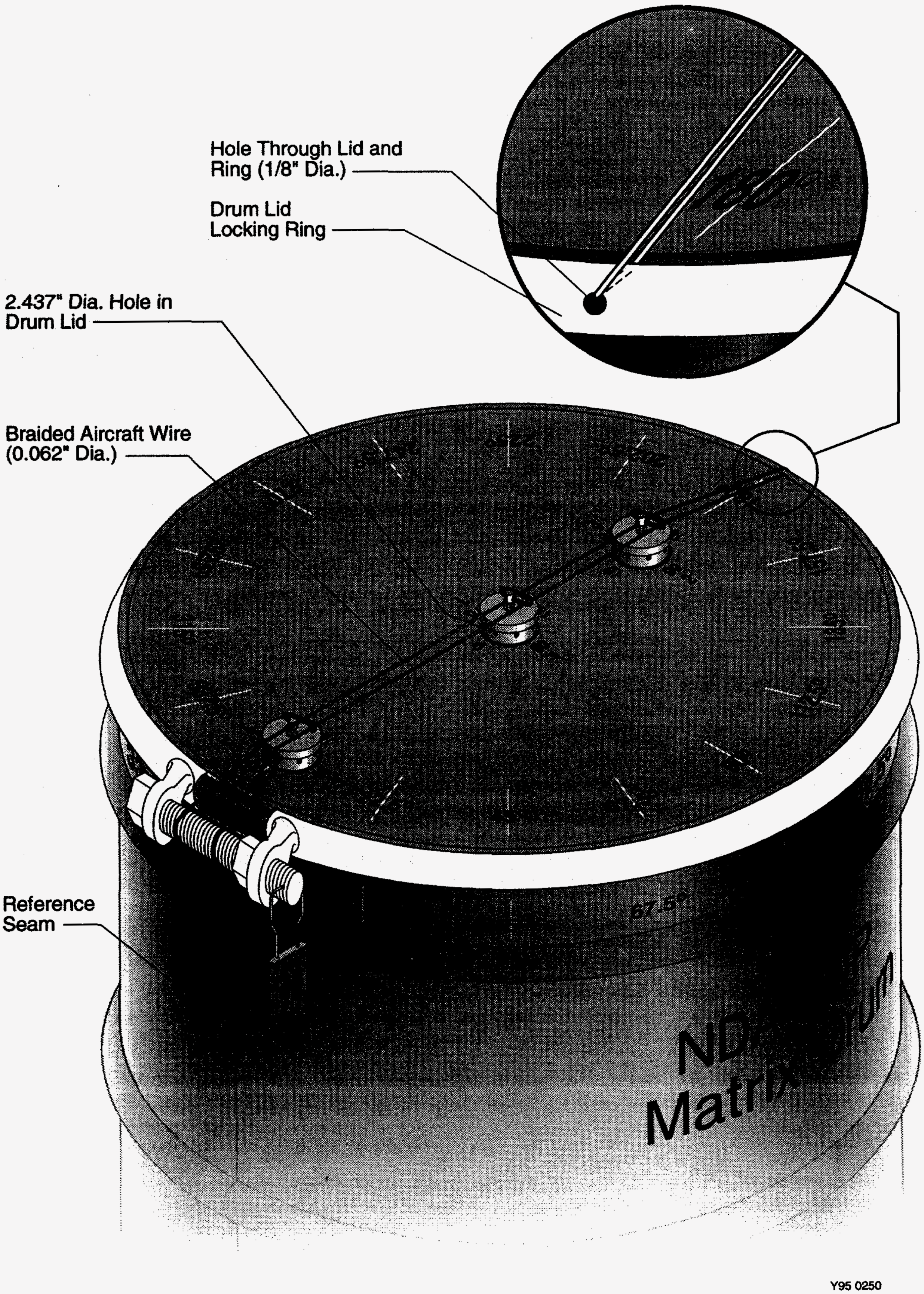

Figure 13. Prepared PDP sample with TID in place.

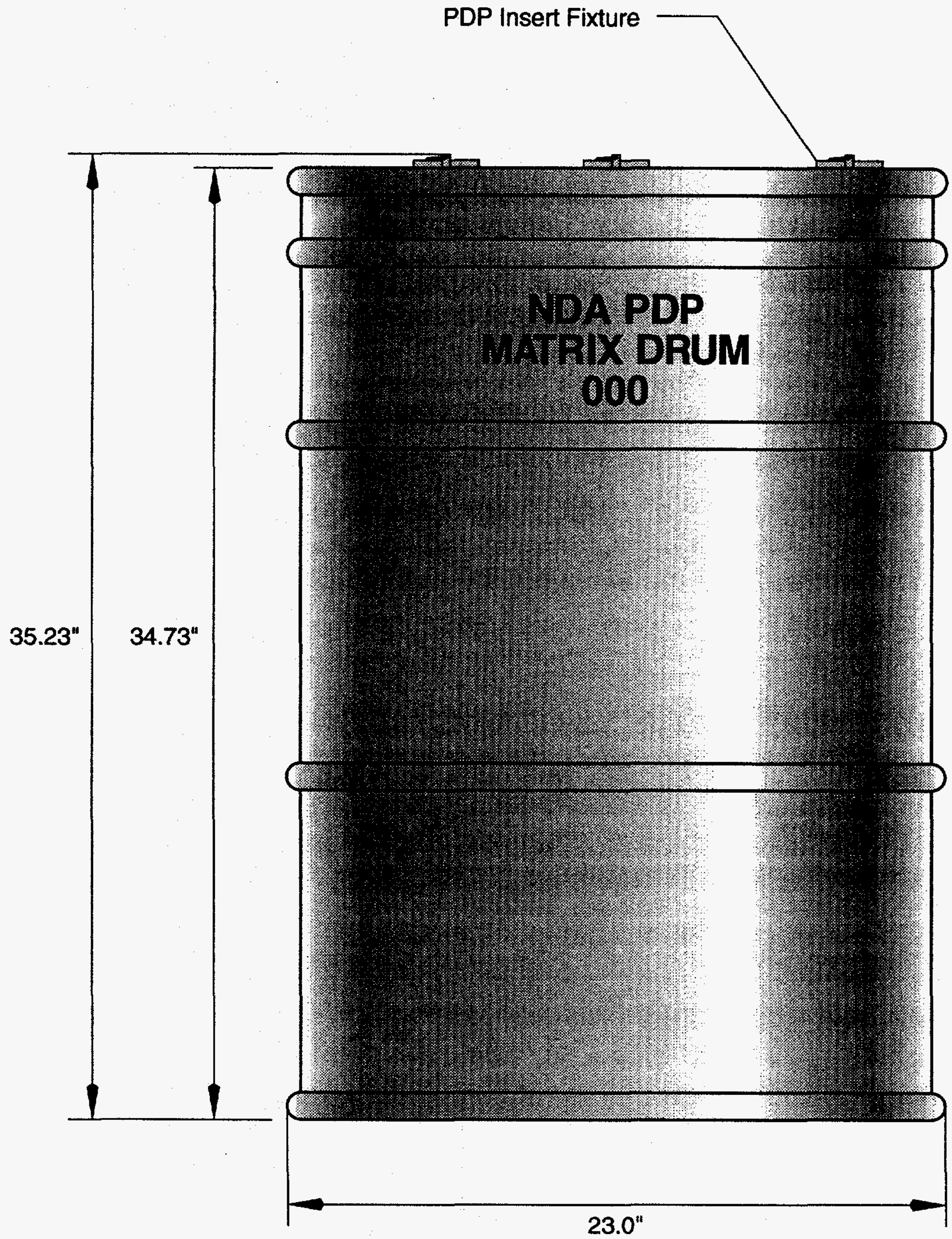

Figure 14. Exterior PDP drum dimensions (nominal).

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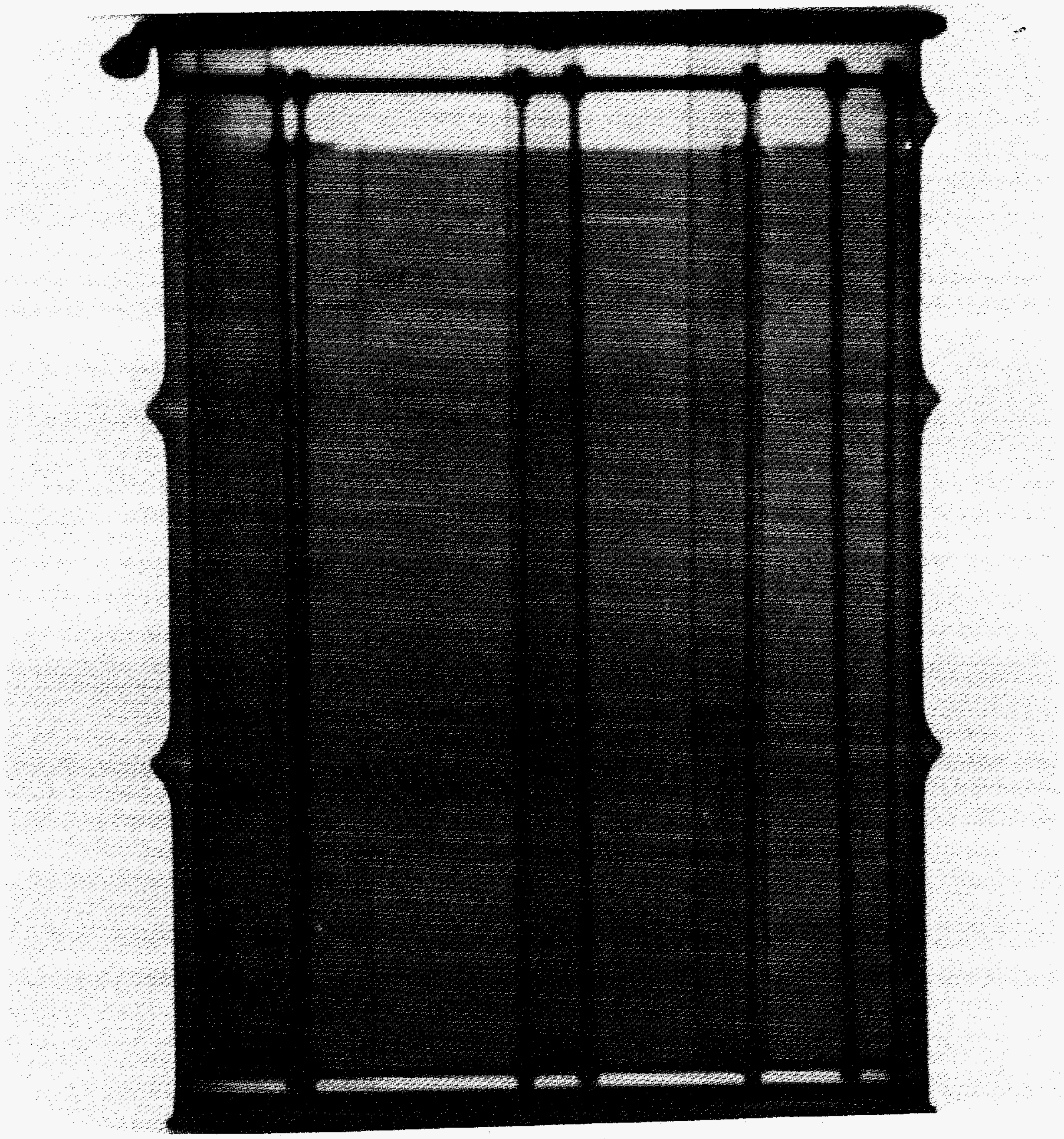

Figure 15. PDP ETHAFOAM radiography image.

Neutron transport analyses have been performed utilizing the three dimensional MCNP SWEPP Assay System (SAS) model[7]. The SAS is a standard passive active neutron drum counting system installed at the INEL SWEPP waste characterization facility. The analysis yields a passive detection efficiency for the twelve detector packages in the SAS waste assay system. Models of the two benign matrix configurations, the uniform ETHAFOAM matrix and the empty 55 gallon drum cases were constructed for the computations. The matrix/radioactive source drum fill height used is 85% equivalent to 29-in. which for the ETHAFOAM matrix results in approximately 55 pounds of polyethylene at a density of 0.15 g/cm^3. The composition of ETHAFOAM used in the analysis is that of polyethylene tabulated in Table 6. The trace elements, < 1000 ppm were not included in the model as their concentrations have no measureable effect on the response of the SAS system. No matrix is included in the model for the empty drum case, only a distributed source in a void throughout the 85% drum fill height. The radioactive source composition and distribution specified in the model corresponds to the criteria of a benign configuration, i.e., it is of a low total mass, 0.66 grams low burnup Pu, and is uniformly distributed through the 85% fill height region in both the ETHAFOAM and empty cases.

The SAS system response analysis is comprised primarily of computing a matrix dependent correction factor for the empty drum and ETHAFOAM matrix using the MCNP SAS system model. Obtained from the MCNP computation is efficiency, i.e., detected counts per neutron born in the matrix, and the detection system time dependence in the form of a normalized die-away function computation per matrix/source configuration for both the shielded and system detection packages. This data is computed for the empty drum (without 90 mil liner) 85% fill height uniform source distribution, the empty zero matrix PDP drum (with 90 mil liner) 85% fill height uniform source distribution and the 85% fill height ETHAFOAM PDP matrix configuration possessing the same uniform source distribution. Of primary interest in the analysis is to determine the magnitude of the correction factor which must be applied to the PDP matrix drum configurations. Correction factors for the shielded (Cd covered detector packages) and system (bare detectors plus Cd covered detector packages) passive mode measure are embedded in the following expression for the real coincidence counts per fission per the coincidence counting theory delineated in reference 8.

$$r = \frac{\lambda_{sf} N_{240} \epsilon^2 (1 - 2S\delta t)}{1 + ST^*} \sum_{v=1} G_v v(v-1) \int_0^{\infty} dt \eta(t) \int_{t+t_d}^{t+t_d+T} dt' \eta(t')$$

where the various terms of the equation are as follows: $\lambda_{sf} N_{240}$ represents the spontaneous fission rate, ϵ^2 is the squared drum configuration specific passive efficiency, $1 - 2S\delta t$ and $1 + ST^*$ are count loss correction terms, $\sum_{v=1} G_v v(v-1)$ average number of neutrons per fission over the weighted statistical distribution of G_v, and $\int_0^{\infty} dt \eta(t) \int_{t+t_d}^{t+t_d+T} dt' \eta(t')$ is a term accounting for the coincidence count per fission time dependency specific to the die-away function of the matrix of interest. The product of the squared matrix configuration dependent efficiency and double time integral time terms accounts for those response variables necessary to derive the passive system matrix correction factor. The MCNP based passive system correction factor is arrived at by taking the ratio of the empty drum (without liner) squared efficiency by double time integral product to that computed for the zero (with liner) and ETHAFOAM PDP matrices. The MCNP-based correction factors for the shielded and system empty drum configuration with liner are 1.24 and 1.12 respectively. For the case of the ETHAFOAM matrix configuration, the MCNP based passive mode correction factors for the shielded and system detector sets are 3.12 and 2.33 respectively. The configuration dependent efficiencies and double time integrals used to determine these ratios are tabulated in Table 10.

The MCNP computed bias estimate associated with the passive system for the zero matrix (with liner) PDP drum can be defended as benign, i.e. correction factors less than 25%. The same MCNP computed ETHAFOAM induced bias is not necessarily benign for the passive neutron mode for the SWEPP SAS system drum counter configuration from the standpoint of the moderating properties of the ETHAFOAM configuration.

A performance evalaution was also performed for a standard gamma type waste NDA system, segmented gamma scanner (SGS), to assess the magnitude of bias induced by the zero and ETHAFOAM matrix drum configurations.[9] The analysis was performed at LANL by the NIS-5 group using a code called TCNDA. The TCNDA code contains modules for modeling the response of general transmission corrected gamma-ray assay and photon computerized tomography instrument. SGS configuration and acquisition parameters, typical of SGS instruments employed in the complex, were utilized in the response prediction code for the zero matrix and ETHAFOAM matrices. The phase I PDP WRM radioactive standards were also modeled in the code versus using a uniformly distributed source as was done with the MCNP neutron analyses. A parametric evaluation was performed using 1-in. and 4-in. diameter WRMs distributed in various combinations of one to nine through three radii and three vertical drum positions. The bias interval endpoints predicted via the parametric SGS response modeling exercise were (-6% to 19%) and (-22% to 38%) for the zero matrix and ETHAFOAM matrix respectively. For the 2-in. PDP WRM, it was estimated that the response would result in bias ranges decrease somewhat on the order of (-3% to 15%) and (-17% to 32%) for the zero matrix and ETHAFOAM respectively. The bias ranges determined as a result of the evaluation are primarily a function of the WRM diameter and poistion within the PDP matrix drums.[9] Both the bias magnitude and lack of significant interference via the PDP matrix configurations allows a general asssessment that the empty and ETHAFOAM PDP drum configurations are benign with respect to the nominal SGS system.

Table 10. MCNP-computed passive neutron PDP matrix drum response data - 85% fill height.[7]

	Passive Detection System	
Drum Configuration	Shielded	System
Empty drum efficiency (no liner)	0.0299	0.1281
Empty drum time integral (no liner)	0.2842	0.3724
Empty drum efficiency (with liner)	0.0271	0.1261
Empty drum time integral (with liner)	0.2802	0.3446
ETHAFOAM efficiency	0.0169	0.101
ETHAFOAM time integral	0.2847	0.2575

Based on the scoping analyses discussed above, it is concluded that the magnitude of bias resulting from the empty and ETHAFOAM PDP drum configuration for the typical SGS gamma type system is acceptable relative to the definition and intent of benign. A similar conclusion is reached for the passive neutron type system when used with the zero matrix PDP drum configuration. There is considerably more passive neutron assay system response bias associated with the ETHAFOAM configuration. The increased passive neutron system bias is due primarily to the concentration of hydrogen and lack of absorbing type elements such as chlorine. Hence the ETHAFOAM cannot be termed benign as per the definition, but is considered manageable by existing techniques and NDA analysis routines.

5. PDP MATRIX DRUM PERFORMANCE TEST CONTROL MECHANISM

A requirement for the PDP matrix drums is that a means to seal and secure the prepared PDP sample for the duration of the performance testing sequence be provided. To accomodate this requirement, plunger rings have been affixed to the top of each insert fixture top plug. The three insert fixtures are secured in place for testing through the use of 0.062 steel braded aircraft wire and a 0.125-in. hole drilled through the 55 gallon drum body top rib at 180 degrees as per the circumferential angular drum demarcations, the drum lid side at 180 degrees, and the drum lid bolted lock ring also at 180 degrees, see Figure 12. The braded aircraft wire is initially installed by producing a loop in one end through the use of an aluminum cable sleeve which is subsequently crimped in place. The loop is slipped over the 0.625-in. diameter lock ring bolt positioned in the unthreaded drop bolt lug and the other end of the wire is threaded through the installed insert fixture rings, the alinged hole which passees through the top drum rib, the drum lid side, and the lock ring and then back through the insert fixture top plug rings. At this point another loop is created using a aluminum cable sleeve. This second loop is slipped over the end of the lock ring bolt thereby providing a means to secure all three insert fixtures in place. The size of the loop and crimped cable sleeve is small enough to pass through the insert fixture top plug rings allowing access to and removal of the insert fixtures. The loops will not fit through the 0.125-in. hole drilled through the drum, drum lid, and lock ring after the initial attachment of the wire to the PDP matrix drum. Hence the wire can be removed from the insert fixtures but physically ties the drum, drum lid and lock ring together.

To prepare a PDP matrix sample for testing, lock ring bolt is unthreaded, the braded wire is removed from the three insert fixture top cap rings, and the insert fixtures are removed for configuration with PDP standard(s)/matrix spacer(s) per specification. The lock ring is then aligned and the lock ring bolt partially installed through the unthreaded bolt lug. The braded wire loops are passed through the three insert fixture top plug rings and both ends looped over the lock ring bolt. The lock ring bolt is then threaded into the threaded lock ring bolt housing and tightened with the steel lock nut. The hole present in the end of the lock bolt which protrudes past the threaded lock ring bolt lug after installation is used to affix a serialized tamper indicating device (TID). The metal ring of a serialized TID is fitted through the hole thereby preventing removal of the bolt in this configuration will destroy the TID. An illustration of the completed PDP sample with the security configuration and TID in place is provided in Figure 13.

6. EXTERIOR PDP MATRIX DRUM APPEARANCE AND TRANSPORTATION

6.1 Exterior Appearance

The color selected for all PDP matrix drums is a dark blue, Sherwin Williams Fleet Color Blue #4819. To protect against surface scratches occurring as a result of handling, a catalyst, brand name Polasol Urethane hardener - catalyst #B6V241, is added as a paint hardener. The various PDP matrix drums are identifiable via alpha-numeric markings stenciled in black in two separate locations 180 degrees apart immediately under the top drum rib as illustrated in Figure 14. The drum is identified with the text, "NDA PDP Matrix Drum" under which is a three digit matrix code.

6.2 Drum Transportation

Eqiupment used to prepare the completed PDP matrix drum for transportation consists of a wood pallet and an aluminum protective housing for the insert fixtures and insert tubes. The aluminum protective housing contains packaging material fit tightly to the insert fixture/insert tubes, which penetrate approximately 0.5-in. above the surface of the top drum rib. The drum is fastened to the pallet through the use of 0.5-in. wide metal strapping which passes through strap restraining clips located on the top mounted aluminum protective housing. The pallet is designed for standard forklift trucks and pallet jacks. The palletized PDP matrix drum prepared for shipment is illustrated in Figure 16. Pallet dimensions are shown in Figure 17. The aluminum protective housing also serves as a platform for attaching shipping labels and may be re-used for subsequent transportation. The entire palletized assembly is wrapped with a cellophane material to prevent surface damage during shipping. The as delivered PDP matrix drum components are delineated in Table 11 below.

Table 11. As-delivered PDP matrix drum components.

Palletized ETHAFOAM Matrix Drum		Palletized Zero Matrix Drum	
ETHAFOAM matrix drum	1 each	Zero matrix drum	1 each
insert tube protective housing	1 each	insert tube protective housing	1 each
ETHAFOAM insert fixture matrix spacers	8 each	insert fixture (installed)	3 each
spring plunger rods	15 each	shipping pallet	1 each
sample prep tool, pencil scribe	1 each	sample prep tool, pencil scribe	1 each
insert fixture (installed)	3 each		
ETHAFOAM matrix spacers installed in insert fixture, 13 ea	39 each		
shipping pallet	1 each		

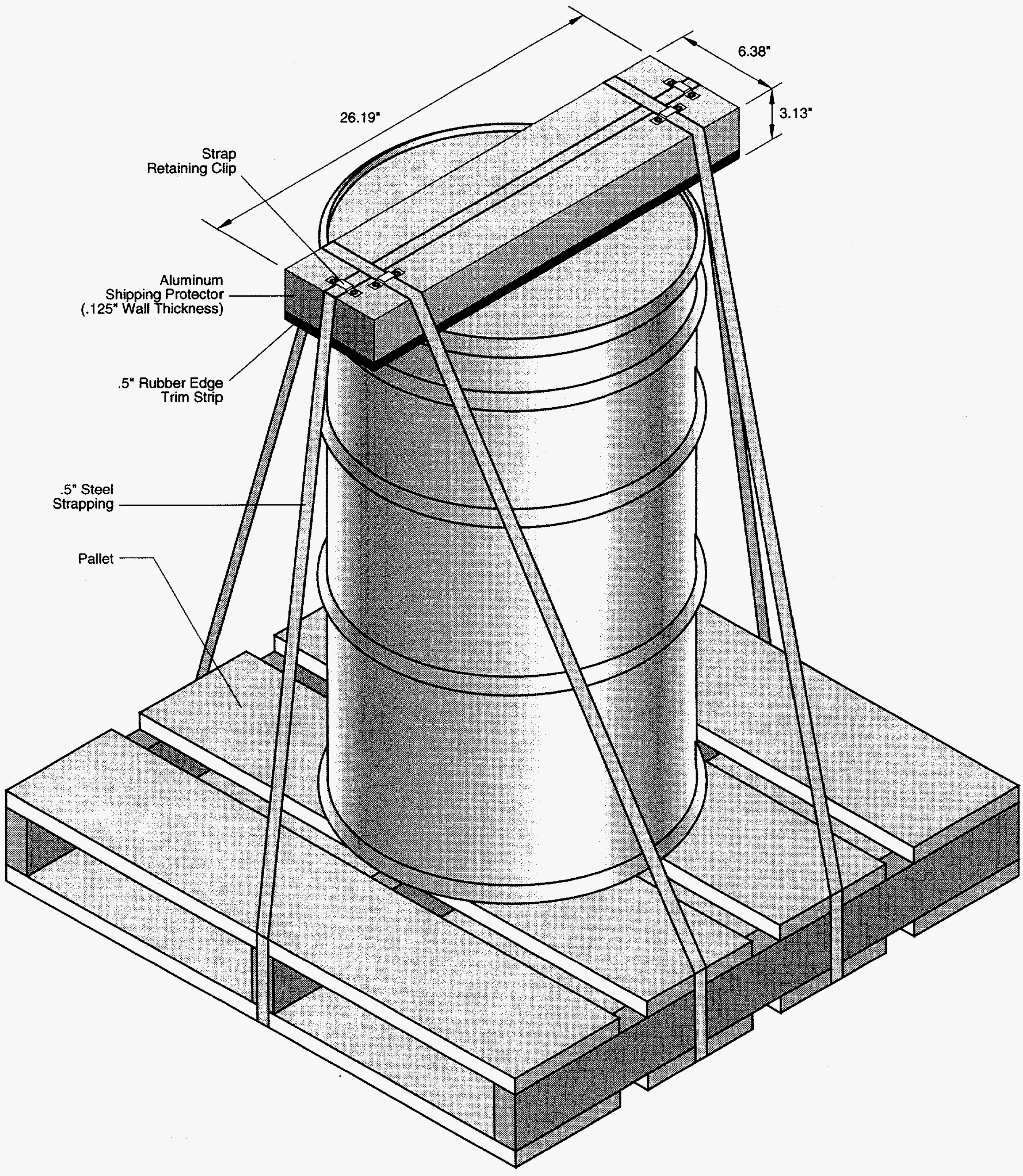

Figure 16. PDP matrix drum transportation package.

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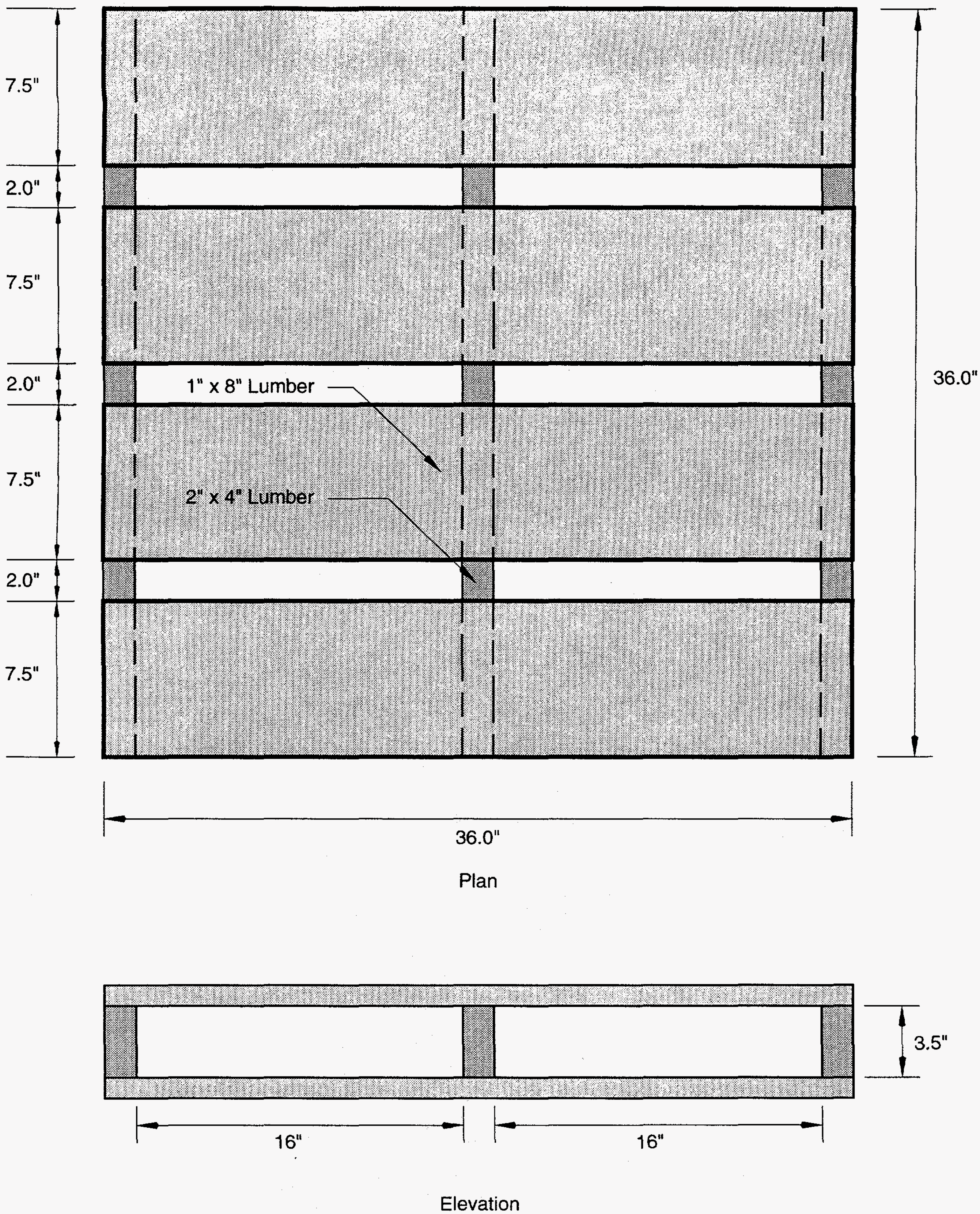

Figure 17. PDP matrix drum pallet construction.

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Appendix A

Material Safety Data Sheet

Material Safety Data Sheet

The Dow Chemical Company
Midland, Michigan 48674
Emergency 517-636-4400

1. CHEMICAL PRODUCT & COMPANY IDENTIFICATION

24-Hour Emergency Phone Number: 517-636-4400

Product: ETHAFOAM (R) HS-900 BRAND PLANK POLYETHYLENE PLASTIC FOAM

Product Code: 29390

Effective Date: 02/03/94 Date Printed: 05/20/94 MSD: 004901

The Dow Chemical Company, Midland, MI 48674

Customer Information Center: 800-258-2436

2. COMPOSITION/INFORMATION ON INGREDIENTS

Polyethylene	CAS# 009002-88-4	88-100%
Chlorodifluoroethane* (HCFC-142b)	CAS# 000075-68-3	0- 8%
Difluoroethane (HFC-152a)*	CAS# 000075-37-6	0- 6%
Stearyl stearamide	CAS# 013276-08-9	0- 2%
Color concentrate in polyethylene		0- 2%

*Blowing agents are fugitive and leave product after manufacture. HCFC-142b has been eliminated from current production. It is listed here to allow for turnover of inventory. Product containing HCFC-142b may be identified by "EA/MP" included as part of the product identification on the product label or ink-jet printed on the side of the board.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

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************************************************************************
*Milky white or colored solid.  Poses little or no immediate hazard.   *
*Toxic fumes are releasedin fire situation.  Appearance:  Cellular     *
*solid plastic foam .  Odor:  No odor.                                 *
*                                                                      *
*                  EMERGENCY PHONE NUMBER  517-636-4400                *
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POTENTIAL HEALTH EFFECTS (See Section 11 for toxicological data.)

(Continued on page 2)

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EYE: Solid or dust may cause irritation or corneal injury due to mechanical action. Fumes/vapors released during thermal operations such as hot-wire cutting may cause eye irritation and respiratory irritation.

SKIN CONTACT: Essentially nonirritating to skin. Mechanical injury only.

SKIN ABSORPTION: Skin absorption is unlikely due to physical properties.

INGESTION: Ingestion is unlikely due to physical state. Physical injury only. May cause choking if swallowed.

INHALATION: Dust may cause irritation to upper respiratory tract and lungs. Fumes/vapors generated during thermal operations such as hot wire cutting may cause eye and respiratory irritation. Signs and symptoms of excessive exposure may be anesthetic or narcotic effects. Excessive exposure may increase sensitivity to epinephrine and increase myocardial irritability (irregular heartbeats). (chlorodifluoroethane, difluoroethane) Signs and symptoms of excessive exposure may be central nervous system effects. In animals, excessive exposure to chlorodifluoroethane has caused low blood pressure, respiratory stimulation and chest tightness (bronchoconstriction). Blowing agents are fugitive and leave the product within several months after manufacture. Concentrations of the blowing agent(s) anticipated incidental to proper industrial handling are expected to be very low--well below concentrations which produce the acute inhalation effects listed above for the blowing agent(s) and well below guidelines.

SYSTEMIC (OTHER TARGET ORGAN) EFFECTS: Repeated exposure to dusts may cause respiratory effects and possible kidney effects. In animals, excessive exposure to chlorodifluoroethane has caused low blood pressure, respiratory stimulation and chest tightness (bronchoconstriction).

CANCER INFORMATION: Did not cause cancer in long-term animal studies. (chlorodifluoroethane, difluoroethane)

TERATOLOGY (BIRTH DEFECTS): Birth defects are unlikely.

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Exposures having no adverse effects on the mother should have no effects on the fetus. (chlorodifluoroethane, difluoroethane)

MUTAGENICITY (EFFECTS ON GENETIC MATERIAL): Results of chlorodifluoroethane mutagenicity tests in animals have been negative. Has been shown to be negative in some in-vitro ('test tube') mutagenicity tests and positive in others. (chlorodifluoroethane, difluoroethane)

4. FIRST AID

EYES: Flush eyes with plenty of water; mechanical effects only.

SKIN: Wash off in flowing water or shower.

INGESTION: No adverse effects anticipated by this route of exposure.

INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, oxygen should be administered by qualified personnel. Call a physician or transport to a medical facility.

NOTE TO PHYSICIAN: Exposure may increase "myocardial irritability". Do not administer sympathomimetic drugs unless absolutely necessary. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES
FLASH POINT: <-58F (difluoroethane)
METHOD USED: TOC

FLAMMABILTY LIMITS
LFL: 3.9% by volume (difluoroethane)
UFL: 16.9% by volume (difluoroethane)

FIRE & EXPLOSION HAZARDS: Avoid dense smoke.

EXTINGUISHING MEDIA: Water fog

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FIRE-FIGHTING EQUIPMENT: Wear self-contained, positive pressure breathing apparatus.

6. ACCIDENTAL RELEASE MEASURES (See Section 15 for Regulatory Information)

ACTION TO TAKE FOR SPILLS/LEAKS: Pick up and handle as any other inert material.

7. HANDLING AND STORAGE

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Practice reasonable care and cleanliness as a common sense safety precaution when handling this product.

Note: When large quantities of this product are stored or fabricated, small quantities of the blowing agent which is used to produce the foam may be released. Combustion products of this blowing agent may tend to accelerate corrosion of heaters and boilers. Corrosion can eventually create holes in the combustion chamber leading to the release of combustion gases and carbon monoxide, which would endanger the health of persons in the area. Heating equipment should be inspected regularly during every heating season to check for pinholes or larger defects in the combustion chamber.

WARNING: This polyethylene foam is combustible and should not be exposed to flame or other ignition sources. The burning characteristics vary significantly with the amount of material present and other combustion conditions. Large quantities of foam as might be found in storage or work areas, can burn rapidly with intense heat and produce dense smoke. Under normal combustion conditions, carbon monoxide is generated. Additional toxic substances may be released under less than full combustion conditions. In fire fighting situations, dense smoke should be avoided and positive pressure, self-contained breathing apparatus used.

WARNING: In order to prevent buildup of combustible vapors, do not store large quantities of this product in unventilated

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spaces. Transport bulk shipments of this product in ventilated vehicles.

WARNING: To prevent the potential of fire or explosion, do not weld or apply intense heat to closed airtight containers which contain this material or which contains parts fabricated of this material. Open airtight containers bearing this material in a well-ventilated area away from sparks, flames, or other ignition sources.

WARNING: Fabrication methods which involve cutting into the foam will release blowing agent remaining in the cells. Provide adequate ventilation to assure localized blowing agent concentratons in release areas are maintained below the lower flammability limit.

WARNING: Exercise appropriate caution when using this product in applications involving exposure to children. Choking and/ or swallowing of foam by small children may occur.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

VENTILATION: Provide general and/or local exhaust ventilation to control airborne levels below the exposure guidelines.

PERSONAL PROTECTIVE EQUIPMENT

EYE PROTECTION: Use safety glasses. If there is a potential for exposure to particles which could cause mechanical injury to the eye, wear chemical goggles. If vapor exposure causes eye discomfort, use a full-face respirator.

SKIN PROTECTION: No precautions other than clean body-covering clothing should be needed.

RESPIRATORY PROTECTION: Atmospheric levels should be maintained below the exposure guideline. When respiratory protection is required for certain operations, use an approved air-purifying respirator. In dusty atmospheres, use an approved dust respirator.

EXPOSURE GUIDELINE(S): 1-chloro-1, 1-difluoroethane (HCFC 142b: Dow IHG and AIHA WEEL are 1000 ppm, TWA.

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1,1-difluoroethane (HFC-152a): AIHA WEEL is 1000 ppm TWA.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE: Cellular solid plastic foam.
ODOR: No odor.
VAPOR PRESSURE: Not applicable
VAPOR DENSITY: Not applicable
BOILING POINT: Not applicable
SOLUBILITY IN WATER/MISCIBILITY: Insoluble
SPECIFIC GRAVITY/DENSITY: 0.056 - 0.080

10. STABILITY AND REACTIVITY

STABILITY: (CONDITIONS TO AVOID) Avoid fire and temperatures over 625F, 329C.

INCOMPATIBILITY: (SPECIFIC MATERIALS TO AVOID) Strong oxidizing agents.

HAZARDOUS DECOMPOSITION PRODUCTS: Under normal combustion conditions carbon monoxide is generated. Additional toxic substances may be released under less than full combustion conditions.

HAZARDOUS POLYMERIZATION: Will not occur.

11. TOXICOLOGICAL INFORMATION (See Section 3 for Potential Health Effects. For detailed toxicological data, write or call the address or non-emergency number shown in Section 1)

12. ECOLOGICAL INFORMATION (For detailed Ecological data, write or call the address or non-emergency number shown in Section 1)

No bioconcentration is expected because of the relatively high molecular weight (MW greater than 1000). In the terrestrial environment, material is expected to remain in the soil. In the aquatic environment, material is expected to float.

DEGRADATION & TRANSFORMATION: This water insoluble polymeric solid is expected to be inert in the environment. Surface photodegrada-

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tion is expected with exposure to sunlight. No appreciable biodegradation is expected.

ECOTOXICOLOGY: Not expected to be acutely toxic.

13. DISPOSAL CONSIDERATIONS (See Section 15 for Regulatory Information)

DISPOSAL METHOD: Reuse, recycle, or bury in an approved landfill. Follow all local, state, and federal requirements for disposal.

14. TRANSPORT INFORMATION

DEPARTMENT OF TRANSPORTATION (D.O.T.):

This product is not regulated by D.O.T. when shipped domestically by land.

CANADIAN TDG INFORMATION:

This product is not regulated by TDG when shipped domestically by land.

15. REGULATORY INFORMATION (Not meant to be all-inclusive--selected regulations represented)

NOTICE: The information herein is presented in good faith and believed to be accurate as of the effective date shown above. However, no warranty, express or implied is given. Regulatory requirements are subject to change and may differ from one location to another; it is the buyer's responsibility to ensure that its activities comply with federal, state or provincial, and local laws. The following specific information is made for the purpose of complying with numerous federal, state or provincial, and local laws and regulations. See other sections for health and safety information.

U.S. REGULATIONS

SARA 313 INFORMATION: This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372:

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Product Code: 29390

Effective Date: 02/03/94 Date Printed: 05/20/94 MSD: 004901

REGULATORY INFORMATION (CONTINUED)

CHEMICAL NAME	CAS NUMBER	CONCENTRATION
CHLORODIFLUOROETHANE	000075-68-3	<8 %

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA "Hazard Categories" promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

Not to have met any hazard category

STATE RIGHT-TO-KNOW: The following product components are cited on certain state lists as mentioned. Non-listed components may be shown in the composition section of the MSDS.

CHEMICAL NAME	CAS NUMBER	LIST
1,1-DIFLUOROETHANE	000075-37-6	NJ3
CHLORODIFLUOROETHANE	000075-68-3	PA1 NJ3

NJ3=New Jersey Workplace Hazardous Substance (present at greater than or equal to 1.0%).
PA1=Pennsylvania Hazardous Substance (present at greater than or equal to 1.0%).

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) RATINGS:

Health	0
Flammability	1
Reactivity	0

CANADIAN REGULATOINS

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REGULATORY INFORMATION (CONTINUED)

WHMIS INFORMATION: The Canadian Workplace Hazardous Materials Information System (WHMIS) Classification for this product is:

This product is not a "Controlled Product" under WHMIS.

16. OTHER INFORMATION

MSDS STATUS: Revised Section 7.

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The Information Herein Is Given In Good Faith, But No Warranty, Express Or Implied, Is Made. Consult The Dow Chemical Company For Further Information.