44. 2025

ORNL-5408

MASTER

**Safety Analysis Report for Packaging (SARP)
of the Oak Ridge National Laboratory Garden
Carrier No. 2**

B. B. Klima
L. B. Shappert
R. D. Seagren
W. D. Box

NOTICE

**PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproofed from the best available
copy to permit the broadest possible avail-
ability.**

ORNL-5408
Dist. Category UC-71

Contract No. W-7405-eng-26

CHEMICAL TECHNOLOGY DIVISION
Pilot Plant Section

SAFETY ANALYSIS REPORT FOR PACKAGING (SARP) OF THE OAK RIDGE NATIONAL LABORATORY GARDEN CARRIER NO. 2

B. B. Klima*
L. B. Shappert
R. D. Seagren
W. D. Box

*Retired. Present address: Roane State Community College, Harriman, Tennessee.

Date Printed: April 1978

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. IT
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

107-10110-10111-10112-10113-10114-10115-10116-10117-10118-10119-10120-10121-10122-10123-10124-10125-10126-10127-10128-10129-10130-10131-10132-10133-10134-10135-10136-10137-10138-10139-10140-10141-10142-10143-10144-10145-10146-10147-10148-10149-10150-10151-10152-10153-10154-10155-10156-10157-10158-10159-10160-10161-10162-10163-10164-10165-10166-10167-10168-10169-10170-10171-10172-10173-10174-10175-10176-10177-10178-10179-10180-10181-10182-10183-10184-10185-10186-10187-10188-10189-10190-10191-10192-10193-10194-10195-10196-10197-10198-10199-10200-10201-10202-10203-10204-10205-10206-10207-10208-10209-10210-10211-10212-10213-10214-10215-10216-10217-10218-10219-10220-10221-10222-10223-10224-10225-10226-10227-10228-10229-10230-10231-10232-10233-10234-10235-10236-10237-10238-10239-10240-10241-10242-10243-10244-10245-10246-10247-10248-10249-10250-10251-10252-10253-10254-10255-10256-10257-10258-10259-10260-10261-10262-10263-10264-10265-10266-10267-10268-10269-10270-10271-10272-10273-10274-10275-10276-10277-10278-10279-10280-10281-10282-10283-10284-10285-10286-10287-10288-10289-10290-10291-10292-10293-10294-10295-10296-10297-10298-10299-10300-10301-10302-10303-10304-10305-10306-10307-10308-10309-10310-10311-10312-10313-10314-10315-10316-10317-10318-10319-10320-10321-10322-10323-10324-10325-10326-10327-10328-10329-10330-10331-10332-10333-10334-10335-10336-10337-10338-10339-10340-10341-10342-10343-10344-10345-10346-10347-10348-10349-10350-10351-10352-10353-10354-10355-10356-10357-10358-10359-10360-10361-10362-10363-10364-10365-10366-10367-10368-10369-10370-10371-10372-10373-10374-10375-10376-10377-10378-10379-10380-10381-10382-10383-10384-10385-10386-10387-10388-10389-10390-10391-10392-10393-10394-10395-10396-10397-10398-10399-10400-10401-10402-10403-10404-10405-10406-10407-10408-10409-10410-10411-10412-10413-10414-10415-10416-10417-10418-10419-10420-10421-10422-10423-10424-10425-10426-10427-10428-10429-10430-10431-10432-10433-10434-10435-10436-10437-10438-10439-10440-10441-10442-10443-10444-10445-10446-10447-10448-10449-10450-10451-10452-10453-10454-10455-10456-10457-10458-10459-10460-10461-10462-10463-10464-10465-10466-10467-10468-10469-10470-10471-10472-10473-10474-10475-10476-10477-10478-10479-10480-10481-10482-10483-10484-10485-10486-10487-10488-10489-10490-10491-10492-10493-10494-10495-10496-10497-10498-10499-10500-10501-10502-10503-10504-10505-10506-10507-10508-10509-10510-10511-10512-10513-10514-10515-10516-10517-10518-10519-10520-10521-10522-10523-10524-10525-10526-10527-10528-10529-10530-10531-10532-10533-10534-10535-10536-10537-10538-10539-10540-10541-10542-10543-10544-10545-10546-10547-10548-10549-10550-10551-10552-10553-10554-10555-10556-10557-10558-10559-10560-10561-10562-10563-10564-10565-10566-10567-10568-10569-10570-10571-10572-10573-10574-10575-10576-10577-10578-10579-10580-10581-10582-10583-10584-10585-10586-10587-10588-10589-10590-10591-10592-10593-10594-10595-10596-10597-10598-10599-10600-10601-10602-10603-10604-10605-10606-10607-10608-10609-10610-10611-10612-10613-10614-10615-10616-10617-10618-10619-10620-10621-10622-10623-10624-10625-10626-10627-10628-10629-10630-10631-10632-10633-10634-10635-10636-10637-10638-10639-10640-10641-10642-10643-10644-10645-10646-10647-10648-10649-10650-10651-10652-10653-10654-10655-10656-10657-10658-10659-10660-10661-10662-10663-10664-10665-10666-10667-10668-10669-10670-10671-10672-10673-10674-10675-10676-10677-10678-10679-10680-10681-10682-10683-10684-10685-10686-10687-10688-10689-10690-10691-10692-10693-10694-10695-10696-10697-10698-10699-10700-10701-10702-10703-10704-10705-10706-10707-10708-10709-10710-10711-10712-10713-10714-10715-10716-10717-10718-10719-10720-10721-10722-10723-10724-10725-10726-10727-10728-10729-10730-10731-10732-10733-10734-10735-10736-10737-10738-10739-10740-10741-10742-10743-10744-10745-10746-10747-10748-10749-10750-10751-10752-10753-10754-10755-10756-10757-10758-10759-10760-10761-10762-10763-10764-10765-10766-10767-10768-10769-10770-10771-10772-10773-10774-10775-10776-10777-10778-10779-10780-10781-10782-10783-10784-10785-10786-10787-10788-10789-10790-1079

TABLE OF CONTENTS

	Page
ABSTRACT	1
1. INTRODUCTION	1
1.1 Description of the Package	4
1.2 Contents of the Package	5
2. STRUCTURAL EVALUATION	6
2.1 Structural Design	6
2.2 Cask Weight	6
2.3 Mechanical Properties of Materials	6
3. GENERAL STANDARDS FOR ALL PACKAGES	10
3.1 Chemical and Galvanic Reactions	10
3.2 Package Closure	10
3.3 Package Lifting Devices	10
3.3.1 Garden Carrier No. 2 lifting trunnions	11
3.3.2 Fire shield lifting lug	16
3.3.3 Skid loops	20
3.4 Top Plug Lifting Device	23
3.5 Tie-down Device	26
3.5.1 Tie-down of Garden Carrier No. 2 to skid	26
3.5.2 Tie-down of fire shield to skid	32
3.5.3 Tie-down of fire shield to vehicle	37
4. STANDARDS FOR TYPE B AND LARGE QUANTITY PACKAGING	45
4.1 Load Resistance	45
4.1.1 Load resistance of Garden Carrier No. 2	46
4.1.2 Load resistance of the fire shield	49
4.2 External Pressure	49
5. COMPLIANCE WITH STANDARDS FOR NORMAL CONDITIONS OF TRANSPORT	52
5.1 Heat	52
5.1.1 Thermal properties of materials	52
5.1.2 Thermal model for transport of solids	52
5.1.3 Maximum temperatures	56
5.2 Cold	56
5.3 Pressure	58
5.4 Vibration	59
5.5 Water Spray	59

BLANK PAGE

	Page
5.6 Free Drop	59
5.7 Penetration	59
5.8 Compression	61
6. COMPLIANCE WITH STANDARDS FOR HYPOTHETICAL ACCIDENT CONDITIONS.....	61
6.1 Free Drop	61
6.1.1 Impact on top corner.....	62
6.1.2 Impact on side	62
6.1.3 Bolts holding drawers	62
6.1.4 Bolts holding top plug.....	67
6.2 Puncture.....	68
6.3 Thermal Evaluation	68
6.3.1 Hypothetical thermal accident conditions discussion.....	68
6.3.2 Thermal properties of materials.....	69
6.3.3 Thermal accident analysis.....	69
6.3.4 Temperatures as a result of the thermal accident analysis.....	69
6.3.5 Maximum internal pressures	70
6.4 Water Immersion	70
7. CONTAINMENT	71
7.1 Containment Requirements for Normal Conditions of Transport	76
7.2 Containment Requirements During the Hypothetical Accident	75
8. INNER CONTAINERS.....	75
8.1 Screw-Top Inner Container	75
8.1.1 Inner container wall thickness	77
8.1.2 Inner container bottom flat-head thickness	77
8.1.3 Inner container top head thickness	78
8.2 Thirty-foot Free-fall Test	78
9. CRITICALITY	79
9.1 Evaluation of a Single Package	79
10. SHIELDING EVALUATION	79
10.1 Discussion and Results	79
11. QUALITY ASSURANCE.....	79
11.1 Fabrication, Inspection and Acceptance Tests	79
11.2 Operating Procedures and Routine Inspections	80
11.3 Periodic Maintenance and Inspections	80

	Page
12. APPENDICES	81
12.1 Appendix A - Drawings.....	82
12.2 Appendix B - Approval Documents	97
12.3 Appendix C: Computer Program to Calculate Corner Drop Negative Acceleration Forces	106
12.4 Appendix D: Computer Program to Calculate Side Drop Negative Acceleration Forces	117
12.5 Appendix E : Report of Special Inspection of Garden Carrier No. 2.....	122
12.6 Appendix F : Operating Procedures Applicable to the Garden Carrier No. 2.....	125
13. REFERENCES	138

SAFETY ANALYSIS REPORT FOR PACKAGING (SARP) OF THE OAK RIDGE NATIONAL LABORATORY GARDEN CARRIER NO. 2

B. B. Klima, L. B. Shappert, R. D. Seagren, and W. D. Box

ABSTRACT

An analytical evaluation of the Oak Ridge National Laboratory Garden Carrier No. 2 was made to demonstrate its compliance with the regulations governing off-site radioactive material shipping packages. The evaluation encompassed five primary categories: structural integrity, thermal resistance, radiation shielding, nuclear criticality safety, and quality assurance. The results of the evaluation show that the cask complies with the applicable regulations.

1. INTRODUCTION

The ORNL Garden Carrier No. 2 was developed at the Oak Ridge National Laboratory. The design was analyzed in 1969¹ and reevaluated in 1975 to demonstrate compliance with the regulations. The results of the analyses are presented in Sects. 2 through 10 of this report. The package was inspected to ensure that it was built in accordance with the drawings presented in Appendix A.

The primary use of the container is to provide shielding, impact resistance, and thermal resistance for its contents during both normal transport and hypothetical accident conditions. The package is designed to ship large quantities of fissile and radioactive materials as solids. The package is authorized to be shipped by motor vehicle and rail. It complies with the Nuclear Regulatory Commission (NRC) regulations contained in the *Code of Federal Regulations*, Title 10, Part 71,² *DOE Manual* Chapter 0529,³ and all Immediate Action Directives (IAD) in effect as of this report date. The cask also complies with U. S. Department of Transportation regulations published in the *Code of Federal Regulations*, Title 49, Part 173.⁴

Calculations, engineering logic, and all related documents that demonstrate compliance with specifications are presented in subsequent sections of this report. Copies of the approval documents are reproduced in Appendix B.

The Garden Carrier No. 2 was fabricated and assigned the Department of Transportation Special Permit No. 6088. An interim certificate of compliance has been issued by the Atomic Energy Commission (see Appendix B). The cask, as it was used, is shown in Fig. 1, mounted and ready for shipment on its skid.

Previous analyses have indicated the need for a fire shield (see Fig. 2) to prevent the lead shielding from melting in the hypothetical accident sequence. This fire shield has been designed, and this analysis is based on its use.

BLANK PAGE

Fig. 1. Garden Carrier No. 2 (as originally used).

NOTE: BOTTOM END OF CASK LIFTING DEVICES RAISED TO ALLOW
SLIGHT DOORS TO BE SHOWN SHIFTED 90°.

Fig. 2. Section of Garden Carrier No. 2 with fire shield showing components.

1.1 Description of the Package

The ORNL Garden Carrier No. 2 (see Figs. 1 and 2) is a lead-filled 304L stainless steel weldment, cylindrical in shape, and measuring approximately 25 in. OD by 45 in. high. The inner cavity is 7.065 in. ID by 24 in. high. It provides approximately 8-3/16 in. of lead shielding. It has a 43-in.-OD by 51-11/16-in.-high fire shield that fits over the cask and is secured in place when the cask is shipped. The fire shield has a 1/2-in.-thick steel outer shell and a 3/16-in.-thick inner shell with the void filled with 2 in. of Kaowool*, a ceramic fiber insulation material. The assembly consists essentially of the following elements: cask body, cask top plug, two drawers, four cask closure plates, fire shield, and skid.

The cask body has an outside shell made from 1/2-in.-thick 304L stainless steel plate rolled to form a cylinder 25-3/16 in. in diameter. The bottom of the body is a 2-1/2-in.-thick 304L stainless steel plate. This plate forms the bottom of the stepped rectangular opening in which the two drawers slide. The sides of the drawer openings are 1-in.-thick plate while the top is 3/8 in. thick. The top plate is 1-1/2-in.-thick 304L stainless steel with a 10-in.-diam by 4-in.-deep offset for the top plug. The sides and bottom of the offset are made from 3/8-in. plate as is the central tube, which forms the wall of the inner cavity. The inner cavity is 7-1/16 in. ID by 24 in. long from the end of the top plug to the top of the drawers.

The body is welded to a 1-in.-thick base plate which is 32 in. in diameter. In addition, 14 triangular gussets, 1/2 in. thick by 3-3/8 in. on the side, are welded to the body and base plate and strengthen the base-plate flange. The 1-1/2-in. top plate of the body has two 2-in.-diam lead filling holes which are closed by 3/8 in.-thick plate welded after the lead filling. On the outside of the body and running vertically on each side are two lifting ribs. Each lifting rib has a 2-in.-diam lifting trunnion top and bottom.

The plug has a 1/2-in.-thick plate cylindrical outer wall. The top plate is 1-1/2 in. thick and the bottom is 3/8 in. thick. The 4-in. top plug extension is 9-15/16 in. in diameter. The lead was poured through two 2-in.-diam holes in the extension face. The plug is held on the body by 12 socket-head cap screws, each 3/4 in. in diam by 6 in. long (16NF-2). Each of the screw heads is recessed in the plug, and the body of the bolt passes through a stainless sleeve that is seal-welded top and bottom to the plug. The plug is sealed to the body by a 19-in.-OD by 18-1/2-in.-ID by 1/4-in.-diam neoprene "O"-ring recessed in a groove in the top of the body. The plug has a wire cable receptacle and an offset 1/2-in.-OD by 1/8 in.-wall-tubing interconnection to the center of the plug. The receptacle is for storing wire cable used to raise the inner container into and lower it out of the inner cavity. The receptacle is closed by a 1/2-in.-thick 304L stainless steel cover and is sealed by a 1/16-in.-thick neoprene gasket. The receptacle cover is held in place by six 1/4-in.-diam by 3/4-in.-long (20 NC-2) bolts. The plug has the following directive engraved on its top: "this cover must be on carrier and seal wired in place except when using top plug lifting lug." The top cover is fabricated from 1/8-in.-thick aluminum and is used to deny use of the plug lifting lug to lift the cask; it is held to the plug by two 3/4-in. by 1-in.-long (10 NC-2) hex-head head bolts, the heads of which are drilled for safety wires.

Two lead-filled drawers that overlap when closed are held in the closed position by eight 3/8-in. by 3/4-in. long (16 NC-2) hex-head cap screws in each drawer. The drawers each move back and forth on 14 cam rollers. The drawers are moved by an angle drive attached to the

---

*Product of Babcock Wilcox.

outside of the drawer which drives a screw (1-in. by 8 NC-2) on which the drive nut rides. The drive nut is held in place on the bottom of the drawer opening by two dowel-ended socket-head cap screws, each sealed by a stato-seal. Each of the drawers is covered during shipment by a stainless steel closure plate; this plate is secured by 20-1 2-in.- by 1-1 4-in.-long (13 NC-2) socket-head cap screws and sealed by a 1 16-in.-thick neoprene gasket.

The entrance to the bottom of the Garden Carrier through the base plate is sealed by a bottom closure plate held in place by eight 1 2-in.- by 1-in.-long (13 NC-2) hex-head cap screws and sealed by a 1 16-in.-thick neoprene gasket.

The Garden Carrier No. 2 is located and oriented on the skid by two locating pins. It is secured to the skid by eight 1-1 2-in.- by 3-1 2-in.-long (6 NC-2) socket-head cap screws made from 4140 annealed steel. Special 4140 annealed steel bolts are specified on the drawings; however, calculations prove that any steel bolt the proper size will be satisfactory.

The fire shield rests on a 1-in.-thick steel plate welded to the top of the skid. The fire shield has a 1 4-in.-thick inner shell which is welded to a ring which bolts to the plate mounted to the skid. Both the side inner shell and top (3 8 in. thick) are welded to a heavy steel ring at the top. Two inches of Kaowool insulation is applied to the outside of the inner plate, and it is held in place by clips secured on 6-in. centers. A 1 2-in. plate forms the outer shell of the fire shield.

An annular ring of maple wood fills the gap between the top of the Garden Carrier No. 2 and the fire shield. The clearance between the wood ring and the cask is 1 8 in. radially, but it contacts the cask vertically. Two maple pads are fastened to the inside of the fire shield in line with the drawer cover plates to prevent displacement of the drawers in the event of a catastrophic accident. A 1 8-in. clearance is found between the face of the drawer cover and the wooden pad. The fire shield has four lifting lugs, which are also used to tie the cask down to the vehicle by four cables. The skid is also tied to the vehicle with four tie-down cables fastened to the skid tie-down loops. The fire shield is oriented on the skid by two locating pins and secured by eight 1-1 2-in.- by 3-1 2-in.-long (6 NC-2) socket-head cap screws made from the same steel as used to bolt the cask to the skid.

The shipping skid is 5 ft by 5 ft by 6 in. high. The skid has four 1-1 2-in.-diam tie-down loops and has a 32-in.-diam plate matching the closure of the bottom of the cask. The skid has a Kaowool-insulated area directly under the cask. It also has a built-in locked tool box, which carries needed wrenches and other supplies.

The primary line of containment is the gasketed inner container. A secondary line of containment is considered to be the cask cavity that is sealed by five gasketed closures, three on the bottom and two at the top.

The Garden Carrier No. 2 weighs 8440 lb alone. The complete package, including the skid, fire shield, inner container, and contents, weighs 12,400 lb.

1.2 Contents of the Package

The ORNL Garden Carrier No. 2 is used to ship large quantities of fissile and radioactive materials (not otherwise specified) in the form of unirradiated or irradiated fuel elements, contained sections of fuel elements, solid fission products, and waste products. The maximum

thermal decay energy for shipments is 100 W. The fissile content is limited to not more than 500 g of ^{235}U , 350 g of ^{233}U or plutonium, or 350 of any combination thereof.

Solids are contained in a special inner container (see Sect. 8). Shipments are made as Fissile Class I and are authorized to be transported by motor vehicle and rail. Any shipment will be limited to a source strength such that the radiation levels will not exceed those specified in the DOT regulations.⁵

2. STRUCTURAL EVALUATION

The package complies with the structural requirements of the regulations (see Sects. 2 through 6). The calculations, test results, and engineering logic presented in the following sections demonstrate compliance with these performance criteria. The effects of both normal transport and specified accident conditions on the structural integrity of the package are considered.

2.1 Structural Design

The as-built drawings for the Garden Carrier No. 2 and all other applicable drawings are shown in Appendix A. The principal structural members of the cask are: (1) cask body, (2) top plug, and (3) two drawers. The welds of each of these fabricated pieces was checked by a dye-penetrant test and x-rayed. The weldment was then pressure-tested and filled with lead. Each member was filled slowly and the body heated at the time of filling. The heated zone of the cask body was raised as the level of the lead was raised so that (1) solidification was from the bottom, and (2) the solidifying metal was covered with molten metal until the top was reached. After finishing the filling operations, each hole was closed with a plug. When this was completed, the member was then machined to the required dimensions. The top plug and the drawers were similarly constructed.

2.2 Cask Weight

The weight of the package, its parts, and the contents are shown in Table 1.

2.3 Mechanical Properties of Materials

The mechanical properties of lead, carbon steel, and stainless steel are summarized in Table 2. The properties of the wood used in the fire shield are given in Table 3.

Table 1. Weight of components of Garden Carrier No. 2

Component	Weight (lb)
Cask body	6,530
Top plug	1,170
Drawer assembly (two drawers)	670
Drive unit covers	70
Skid	1,190
Fire shield	2,600
Inner container	40
Contents	<u>130</u>
Total	12,400

Table 2. Mechanical properties of lead, mild steel, and stainless steel

Properties	Symbol	Stainless steel 304L	Lead (solid)	Low carbon steel
<u>Static properties</u>				
Tensile yield stress, psi	σ_y	30×10^3 ^a	2000 ^b	30×10^3
Allowable shear stress, psi	τ_a	15×10^3 ^c	—	15×10^3 ^c
Ultimate shear strength, psi	τ_u	61×10^3 ^a	1825 ^b	45×10^3
Young's modulus, psi	E	30×10^6 ^a	2×10^6 ^b	29×10^6
Poisson's ratio	ν	0.3 ^b	0.40 ^b	—
Weight density, lb/in. ³	γ	0.283	0.41 ^b	0.283
Thermal expansion coefficient, °F ⁻¹	α	9.6×10^{-6}	16.3×10^{-6}	6.5×10^{-6}
Melting point		—	625°F ^b	—
<u>Dynamic properties</u>				
Specific energy, in.-lb/in. ³	S min	10×10^4 ^d		10×10^4 ^d
	S max	26×10^4 ^d		26×10^4 ^d

^aThe International Nickel Company, Inc., Mechanical and Physical Properties of Austenitic Chromium-Nickel Stainless Steel at Ambient Temperatures, 1963.

^bMetals Handbook, 8th ed., Vol. 1, Properties and Selection of Metals, American Society For Metals, Novelty, Ohio, 1961.

^c50% of tensile yield stress.

^dJ. H. Evans, Experimental Study of the Stress-Strain Properties of Cask Materials Under Specified Impact Conditions, USAEC publication CONF-740901-P1, 232-44 (1974).

Table 3. Properties of maple wood^a

Compressive strength, ultimate, with grain	7830 psi
Compressive strength elastic limit, with grain	5390 psi
Compressive strength elastic limit, across grain	1810 psi
Shear strength, with grain	2430 psi
Density	0.025 lb/in. ³

---

^aR. J. Roark, p. 417 (Table XIX) in Formulas for Stress and Strain, 4th ed., McGraw-Hill, New York, 1965.

3. GENERAL STANDARDS FOR ALL PACKAGES

The general standards for all packaging include the chemical and galvanic reactions of the materials composing the package, closure of the package, and the lifting and tie-down devices for the package.

3.1 Chemical and Galvanic Reactions

The package is fabricated from stainless steel and lead. The lead is completely encased in stainless steel so that any contents of the package would contact stainless steel rather than lead.

The fissile and radioactive contents of the package are housed in inner containers (see Sect. 8). Any liquid contents will be contained in polyethylene or stainless steel bottles inside these inner containers.

Experience and inspection have indicated no chemical, galvanic, or other reaction between the cladding and the containers, or between the containers and their contents.

3.2 Package Closure

The standards specify that the package shall be equipped with a positive closure that will prevent inadvertent opening.

The package, when shipped, is completely covered by the fire shield, which is fastened to the skid by eight 1-1/2-in. bolts. This fire shield prevents the cask from being inadvertently opened.

3.3 Package Lifting Devices

The regulations require that any system of lifting devices that is a structural part of the package shall be capable of supporting three times the weight of the loaded package without generating stress in any material of the package in excess of its yield strength.

The Garden Carrier No. 2 has three separate systems of lifting devices that can be used to lift the package: (1) the four lifting trunnions, which are a part of the cask itself and are used to handle the cask; (2) the four lugs located at the top of the fire shield, which are normally used to lift the fire shield and package and to tie the package to the vehicle; and (3) the four loops located on the skid, which are also used to tie the package to the vehicle. A fourth device, which is the top plug-lifting lug, will not be considered as a cask handling device since at all times, except when removing the top plug, it will be enclosed by a protective cover that is held in place by two wired and sealed bolts. It is necessary to demonstrate that the first three of these lifting systems are capable of meeting the requirements.

3.3.1 *Garden Carrier No. 2 lifting trunnions*

There are four 2-in.-diam lifting trunnions, one at each of the two lifting ribs located on the side of the cask. These trunnions and lifting ribs are shown in Fig. 3; the body of the cask has been filled with lead, but final machining has not been done. The lifting rib has a 3 4-in.-thick by 3-in.-wide outer plate. Normally two or all four of these lifting trunnions will be utilized at once. For computational purposes, use of the two top trunnions will be assumed.

The computational model used is shown in Fig. 4. The approach used to analyze this trunnion is similar to that for a propped beam. (See Ref. 6 for derivation of equations.)

The deflection, Δ , of the unrestrained end [see Fig. 4(a)] of the beam (2-in.-diam rod) is numerically equal to the elastic elongation of the 3 4-in. by 3-in. by 3-1/2-in. bar securing the end of the trunnion. An expression for the elongation of the bar, Δ , may be written as follows:

$$\Delta = -RL/AE = -R(3.5)/(2.25)(30 \times 10^6) = -5.19 \times 10^{-8} R \text{ in.} \quad (1)$$

where

R = reaction, lb.

L = length bar, 3.5 in..

A = area of bar, 2.25 in.².

E = modulus of elasticity (see Table 2), 30×10^6 .

The beam may be considered as two beams, loaded as shown in Fig. 4(b), and by the principle of superposition,

$$\Delta = \Delta_R - \Delta_P, \text{ with } \Delta \text{ being positive.} \quad (2)$$

As defined in the regulations, the cask lifting device must be capable of supporting three times the weight ($3W$) of the cask and its contents (See Table 1) without generating stresses in excess of the yield strength of the material. The total weight of the cask and contents is 8610 lb. The loading or force, P , is calculated:

$$P = FW/N = 3(8610)/2 = 12,915 \text{ lb.} \quad (3)$$

where

F = factor required by regulations, 3,

W = weight of carrier (see Table 1), 8610 lb.

N = number of trunnions used, 2.

ORNL PHOTO-96696-A

Fig. 3. Body of Garden Carrier No. 2 after it had been lead filled and prior to machining.

CRNL Des 69-173 A2
B-1

(a) CARRIER LIFTING TRUNNION COMPUTATIONAL MODEL

(b) BEAM SUPERPOSITION DIAGRAM

Fig. 4. Model of cask lifting trunnion and beam superposition diagram.

The deflection of the beam (Δ_P) at the end is given by

$$\Delta_P = 5PL^3/48EI. \quad (4)$$

The deflection due to the reaction, R, at the end of the beam may be calculated as follows:

$$\Delta_R = RL^3/3EI. \quad (5)$$

Substituting Eqs. (1), (4), and (5) into Eq. (2), it becomes

$$-5.19 \times 10^{-8} R = (RL^3/3EI) - (5PL^3/48EI). \quad (6)$$

The moment of inertia is computed by the following equation:

$$I = \pi r^4/4 = \pi/4 (1)^4 = \pi/4, \quad (7)$$

where

r = radius of trunnion, 1 in.

The value, R, may be determined by substituting the following values in Eq. (6):

$$\left[R(2.0)^3 / 3(30 \times 10^6) \pi / 4 \right] - \left[5(12,920)(2.0)^3 / 48(30 \times 10^6) \pi / 4 \right] + 5.19 \times 10^{-8} R = 0$$

$$R = 2770 \text{ lb.}$$

where

L = length trunnion, 2 in.

The shear (V) is calculated (see Fig. 4) as follows:

$$V = P - R = 12,920 - 2770 = 10,150 \text{ lb.} \quad (8)$$

The moment (M_r) is calculated (see Fig. 4) assuming $l = +$.

$$M_r = RL - P L/2 \quad (9)$$

$$= 2770 (2.0) - 12,920 (1.0)$$

$$= - 7380 \text{ lb.}$$

The load diagram for the cask lifting trunnion is shown in Fig. 5.

ORNL Dwg 68-11732 A2

Fig. 5. Load diagram for cask lifting trunnion.

The maximum bending stress, S_b , occurs at the point of maximum moment, $X = 0$, and is calculated as follows:

$$S_b = M_b c / I = 7380(1) / \pi / 4 = 9400 \text{ psi.} \quad (10)$$

where

c = distance from centroidal axis to extreme fiber, 1 in.

The maximum horizontal shearing stress, S_s , (maximum shearing stress) occurs in the length from $X = 0$ to $X = L/2$ at the neutral axis of the section where the bending stress is zero.

$$S_s = 4V/3A = 4(10,150) / 3(3.14) = 4310 \text{ psi.} \quad (11)$$

where

A = area of trunnion, 3.14 in.².

The stress in the lifting trunnion is less than the allowable stress (see Table 2), therefore, the lifting trunnion meets the requirements of the regulations.

Should the lifting trunnion fail due to excessive load, the mode of failure would be by bending; however, containment would not be lost nor would the ability of the package to meet other requirements be impaired.

3.3.2 Fire shield lifting lug

Four lifting lugs are located at the top of the fire shield (see Fig. 6), which could be used to lift the Garden Carrier No. 2. Probably two or all four of these lifting lugs would be used at one time to distribute the load during a lifting operation. This analysis, however, has postulated the use of only one lifting lug.

Each lifting lug is a 2-1/4-in.-thick mild steel bar with a 3.5-in.-diam hole in its center. Each lifting lug is welded to the fire shield by 30 in. of 5/8-in. fillet weld.

The following analysis is based on equations given by Roark⁷ that can be used to predict stress concentration factors found in the analysis of curved beams. For a value of $R/c = 4.0 / 2.25 = 1.80$, where R is the radius of curvature measured to the centroid of the section and c is defined below, a table supplied by Roark⁷ shows the following relationships:

$$k_t = 1.63 = S_t / S, \quad (12)$$

and

$$k_s = 0.70 = S_s / S, \quad (13)$$

Fig. 6. Fire shield lifting lug.

where

k = the stress concentration factor.

S_c = actual stress in extreme fiber on concave side.

S_u = actual stress in extreme fiber on convex side.

S = unit stress in corresponding fiber as computed by ordinary flexure formula for a straight beam.

$$S = Mc/I, \quad (14)$$

where

$$M = \text{maximum bending moment for beam with restrained ends} = F_{nr}L, \quad (15)$$

c = distance from centroidal axis to extreme fiber, 2.25 in.,

$$I = \text{moment of inertia, } bd^3/12, \text{ in.}^4. \quad (16)$$

L = length of beam, 8.0 in.,

$$F = \text{force, } 3\underline{W}, \text{ lb.} \quad (17)$$

$$F_{nr} = F(\sin 39.83^\circ), \text{ lb.} \quad (18)$$

$$F_{vp} = F(\cos 39.83^\circ), \text{ lb.} \quad (19)$$

$\underline{W}$ = Weight of package, 12,400 lb.

d = depth of beam, 4.5 in.,

b = width of beam, 2.5 in.

Substituting these values and the dimensions shown in Fig. 6,

$$F = 3(12,400) = 37,200 \text{ lb}$$

$$F_{nr} = 37,200 (0.640) = 23,800 \text{ lb}$$

$$F_{vp} = 37,200 (0.768) = 28,600 \text{ lb}$$

$$M = (23,800)(8.0)/8 = 23,800 \text{ in.-lb}$$

$$I = (2.5)(4.5)^3 / 12 = 18.98 \text{ in.}^4$$

$$S = (23,800)(2.25) / 18.98 = 2820 \text{ psi.}$$

Therefore, the stress on the extreme fibers is calculated by the following:

$$S_x = k_x S = (1.63)(2820) = 4600 \text{ psi.}$$

and

$$S_y = k_y S = (0.70)(2820) = 1980 \text{ psi.}$$

Thus the stresses in the extreme concave fiber and in the extreme convex fiber are less than the tensile yield strength of the mild steel material (see Table 2). Hence, the design meets the requirements.

The tension in the weld (σ_w) is determined by the following equation:

$$\sigma_w = F_{RP} / L(s) = 23,800 / 30(5.8) = 1270 \text{ psi.} \quad (20)$$

where

L = length of weld, 30 in.,

s = size of weld, 5.8 in.

The shear in the weld (τ_w) is determined

$$\tau_w = F_{RP} / w(s) = 23,800 / 30(5.8) = 1530 \text{ psi.} \quad (21)$$

The maximum stress in the weld is determined

$$\begin{aligned} \sigma_{max} &= \sigma_w / 2 \pm \left[(\sigma_w / 2)^2 + (\tau_w)^2 \right]^{1/2} = \\ 1270 / 2 \pm \left[(1270 / 2)^2 + (1530)^2 \right]^{1/2} &= 2290 \text{ psi.} \end{aligned} \quad (22)$$

The maximum stress in the weld is below the allowable levels (see Table 2).

Should the fire shield lifting lug fail due to excessive load, failure would be by bending; however, containment would not be lost, and the ability of the package to meet other requirements would not be impaired.

3.3.3 Skid loops

Four lifting loops are located on the skid (see Figs. 2 and 7) which could be used to lift the Garden Carrier No. 2. Since these lifting loops are well below the center of gravity, if they are used, all four will be needed simultaneously and equally loaded. These conditions will serve as the basis for this analysis.

Each lifting loop is a 1-1/2-in.-diam mild steel loop, as shown in Fig. 7.

The following analysis is based on equations given by Roark⁷ that can be used to predict stress concentration factors found in the analysis of curved beams. For a value of $R/c = 2.0/0.75 = 2.67$, where R is the radius of curvature measured to the centroid of the section and c is defined below, a table supplied by Roark⁷ shows the following:

$$k_i = 1.43 = S_i/S, \quad (23)$$

and

$$k_o = 0.76 = S_o/S, \quad (24)$$

where

k = the stress concentration factor,

S_i = actual stress in extreme fiber on concave side,

S_o = actual stress in extreme fiber on convex side,

S = unit stress in corresponding fiber as computed by ordinary flexure formula for a straight beam.

$$S = Mc/I, \quad (25)$$

where

$$M = \text{bending moment, } F_v L/8 \text{ in.-lb,} \quad (26)$$

c = distance from centroidal axis to extreme fiber, 0.75 in.,

$$I = \text{moment of inertia, } \pi r^4/4, \quad (27)$$

L = length of beam, 4.0 in.,

$$F_v = \text{force } 3W/4, \text{ lb,} \quad (28)$$

W = weight of package, 12,400 lb (see Table I),

r = radius of beam, 0.75 in.

Fig. 7. Skid lifting loop.

Substituting these values and the dimensions shown in Fig. 7.

$$M = (9300)(4.0)/8 = 4650 \text{ in.-lb.}$$

$$F_v = 3(12,400)/4 = 9300 \text{ lb.}$$

$$I = \pi(0.75)^4/4 = 0.249 \text{ in.}^4,$$

$$s = (4650)(0.75)/0.249 = 14,000 \text{ psi.}$$

Therefore,

$$S_c = k_s S = (1.43)(14,000) = 20,000 \text{ psi.}$$

and

$$S_o = k_o S = (0.76)(14,000) = 10,640 \text{ psi.}$$

Thus the stresses in the extreme concave fiber and in the extreme convex fiber of the skid lifting loops are less than the tensile yield strength of the mild steel material (see Table 2).

The tension in the weld is determined in the following manner:

$$\sigma_w = F_v/L(s) = 9300/9.42(0.5) = 1970 \text{ psi,} \quad (29)$$

where

L = length of weld, 9.42 in.

s = size of weld, 0.5 in.

The shear in the weld is determined by the equation:

$$\tau_w = F_v/Ls = 9300/9.42(0.5) = 1970 \text{ psi.} \quad (30)$$

The maximum shear in the weld is found by the following equation:

$$\sigma_{max} = \sigma_w/2 \left[(\sigma_w/2)^2 + (\tau_w)^2 \right]^{1/2} = 1970/2 \pm \left[(1970/2)^2 + (1970)^2 \right]^{1/2} = 3290 \text{ psi.} \quad (31)$$

The stresses in the weld are below the allowable levels (see Table 2). The skid lifting loops, therefore, meet the requirements of the regulations.

Should the skid lifting loop fail due to excessive load, the failure will be by bending; containment, however, would not be lost and the ability of the package to meet the other requirements would not be impaired.

3.4 Top Plug Lifting Device

If there is a system of lifting devices that is a structural part of the lid (top plug) only, the regulations require that this system shall be capable of supporting three times the weight of the lid (top plug) and any attachment without generating stress in any material of the lid in excess of its yield strength. It is further required that, unless rendered useless for lifting during transport of the package, the lid lifting or other system of lifting devices shall conform to the requirements for the package-lifting system.

The cask has one lid (top plug) lifting lug (see Fig. 8), and both the body of the top plug and the lifting lug are fabricated from 304L stainless steel. The lifting lug is located at the geometric center of the top plug.

The following analysis is based on equations given by Roark⁷ which can be used to predict stress concentration factors found in the analysis of curved beams. For a value of $R/c = 0.875/0.3125 = 2.80$, where R is the radius of curvature measured to the centroid of the section and c is defined below, a table supplied by Roark⁷ shows the following:

$$k_t = 1.34 = S_t/S, \quad (32)$$

and

$$k_o = 0.79 = S_o/S, \quad (33)$$

where

k = the stress concentration factor,

S_t = actual stress in extreme fiber on concave side,

S_o = actual stress in extreme fiber on convex side,

S = unit stress in corresponding fiber as computed by ordinary flexure formula for a straight beam.

$$S = Mc/I, \quad (34)$$

where

$$M = \text{bending moment, } F \cdot l/8, \text{ in.-lb,} \quad (35)$$

c = distance from centroidal axis to extreme fiber, 0.3125 in.,

$$I = \text{moment of inertia, } 8/12 \text{ in}^4, \quad (36)$$

L = length of beam, 1.375 in.,

$$F_v = \text{force, } 3W, \quad (37)$$

Fig. 8. Top plug lifting lug.

$\underline{W}$ = Weight of top plug, 1170 lb.

r = radius of beam, 0.75 in.

Substituting these values and the dimensions shown in Fig. 8.

$$F_c = 3(1170) = 3510 \text{ lb.}$$

$$M = (3510)(1.375) = 603 \text{ in.-lb.}$$

$$I = 2 \frac{1}{3} (1.0)(0.3125)^3 = 0.0203 \text{ in.}^4.$$

$$S = (603)(0.3125) / 0.0203 = 9300 \text{ psi.}$$

Therefore,

$$S_t = k_t S = (1.34)(9300) = 12,500 \text{ psi.}$$

and

$$S_o = k_o S = (0.79)(9300) = 7350 \text{ psi.}$$

Thus the stresses in the extreme concave fiber and in the extreme convex fiber of the top plug lifting lug are less than the tensile yield strength of the stainless steel material (see Table 2).

The tension in the weld is determined by the following:

$$\sigma_w = F_v / L(s) = 3510 / 6.00(0.25) = 2340 \text{ psi.} \quad (38)$$

where

L = length of weld, 6.00 in.,

s = size of weld, 0.25 in.

The shear in the weld is found by the equation:

$$\tau_w = F_v / L s = 3510 / 6.00(0.25) = 2340 \text{ psi.} \quad (39)$$

The maximum shear in the weld is determined by the equation:

$$\sigma_{max} = (\sigma_w / 2) \pm \left[(\sigma_w / 2)^2 + (\tau_w)^2 \right]^{1/2} = 2340 / 2 \pm \left[(2340 / 2)^2 + (2340)^2 \right]^{1/2} = 3790 \text{ psia.} \quad (40)$$

The stresses in the weld are below the allowable limits (see Table 2); therefore, the top plug lifting lug meets the requirements of the regulations.

Should the top plug lifting lug fail due to excessive load, the failure will be by bending; containment, however, would not be lost, and the ability of the package to meet the other requirements would not be impaired.

3.5 Tie-Down Device

The regulations require that if there is a system of tie-down devices which is a structural part of the package, this system must be capable of withstanding a static force applied to the center of gravity of the package with (1) a vertical component of two times the weight ($2W$) of the package and its contents, (2) a horizontal component along the direction of travel of ten times the weight ($10W$) of the package and its contents, and (3) a horizontal component in the transverse direction of five times the weight ($5W$) of the package and its contents. This applied load shall not generate stresses in any material of the package in excess of the yield strength of that material. In addition, any tie-down device that is a structural part of the package must be designed so that failure of the device under excessive load will not impair the ability of the package to meet other requirements of the regulations.

The Garden Carrier No. 2 is normally shipped bolted to its skid and enclosed in its fire shield as shown in Fig. 2. The overall plan for tying the package to the vehicle is shown in Fig. 9. Eight wire ropes tie the package to the vehicle: (1) four (Nos. 1, 2, 3, and 4) run from the skid tie-down loops to the vehicle, and (2) four (Nos. 5, 6, 7, and 8) run from the fire shield tie-down lugs to the vehicle.

To demonstrate the adequacy of the tie-downs, it will be demonstrated that: (1) the tie-down of the Garden Carrier to the skid is adequate, (2) the tie-down of the fire shield to the skid is adequate, and (3) the stresses imposed on the fire shield tie-down lug and its attachment to the fire shield are acceptable.

3.5.1 Tie-down of Garden Carrier No. 2 to skid

The Garden Carrier No. 2 is secured to its skid by means of eight 1-1/4-in.-diam bolts that have a specified material yield stress of 150,000 psi and are located as shown in Fig. 10.

To analyze this part of the tie-down system, the cask was considered as a cantilevered beam. At the plane of attachment, the cross section of the beam consists of the bolts loaded in tension and a strip, a , loaded in compression, as shown in Fig. 11. It is obvious that the maximum stress occurs at this plane. Since the geometry is circular, it is a computational advantage to combine the 5 and 10-W loads vectorially:

$$P = [(5W)^2 + (10W)^2]^{1/2} = 11.18W. \quad (41)$$

The line of action of P has been taken as the X axis, which is rotated from the direction of travel by an angle, α , as shown in Fig. 10, and is calculated below:

$$\alpha = \tan^{-1} 5/10 = 26.56^\circ. \quad (42)$$

ORNL DWG 75-4892
 R-1

Fig. 9. Tie-down plan of the Garden Carrier No. 2 to the vehicle.

Fig. 10. Bolting pattern and computational model for analysis of the tie-down system of the Garden Carrier No. 2 to its skid.

CERES. Desg 68-1735 AR

Fig. 11. Plan at attachment plane and stress diagram for the tie-down system when the cask or the fire shield is considered as a cantilevered beam.

The neutral axis, shown as the Y axis in Figs. 10 and 11, must first be located. Using methods of analysis previously developed.⁸

$$\Sigma b = (2r^3/A)\eta + rN\beta, \quad (43)$$

where

A = cross-sectional area of a bolt, 1.405 sq in.,⁹

$$\eta = + \sin^3 \theta/3 - \theta \cos \theta/2 + \sin 2\theta \cos \theta/4, \quad (44)$$

$$\beta = (1 - \cos \theta), \quad (45)$$

$$b = r - r'(1 - \cos \varphi) \text{ (see Table 4),} \quad (46)$$

N = number of effective bolts, 7,

r = radius base plate, 16 in.,

r' = centerline radius of bolt, in.

Therefore,

$$\Sigma b = 125.96. \quad (47)$$

The value of θ was calculated to be 44.5°; the neutral axis located at a distance, a , from the edge of the baseplate and is calculated in the following manner:

$$a = r(1 - \cos \theta) = 16(1 - \cos 44.5^\circ) = 4.59 \text{ in.} \quad (48)$$

The moment of inertia of the section is computed by the following equation:⁸

$$\begin{aligned} I &= 2r \left[\theta/8 - \sin 4\theta/32 - 2 \cos \theta \sin^3 \theta/3 + \cos^2 \theta (\theta/2 - \sin 2\theta/4) \right] + A \Sigma b^2 \\ &= 2(16)^4 \left[0.777/8 - 0.03448/32 - 2(0.7132)(0.7010)^3/3 + (0.7132)^2 \right. \\ &\quad \left. (0.777/2 - .9998/4) \right] + 1.405 (1766.89) = 2841 \text{ in.}^4. \end{aligned} \quad (49)$$

The bending stress in the most distant bolt from the neutral axis is expressed by the following equation:

Table 4. Values of b , $\bar{b}$, and $\bar{b}^2$ for cask tie-down

Distance of bolt center from edge of baseplate ^a		b^a	$\bar{b}^b$	$\bar{b}^2$
$b_1 = 16 - 14 (\cos 3.44)$	=	2.03	—	—
$b_2 = 16 - 14.75 (\cos 45.67)$	=	5.69	1.10	1.21
$b_3 = 16 - 14 (\cos 56.56)$	=	8.28	3.69	13.62
$b_4 = 16 - 14.75 (\cos 81.21)$	=	13.74	9.15	83.72
$b_5 = 16 + 14.75 (\sin 8.79)$	=	18.26	13.67	186.87
$b_6 = 16 + 14 (\sin 33.44)$	=	23.71	19.12	365.57
$b_7 = 16 + 14.75 (\sin 44.33)$	=	26.31	21.72	471.76
$b_8 = 16 + 14 (\sin 86.56)$	=	29.97	25.38	644.14

^aSee Fig. 10.^bSee Fig. 11 ($\bar{b} = b - a$).

$$\begin{aligned}
 S_B &= PZb_n / I \\
 &= 11.18 (8610)(23.125)(25.38) / 2841 \\
 &= 19,900 \text{ psi.}
 \end{aligned}
 \tag{50}$$

The direct tensile stress distributed equally in all bolts is calculated by the following equation:

$$S_T = 2W / N_T A = 2(8610) / 8(1.405) = 1530 \text{ psi,} \tag{51}$$

where

N_T = total number of bolts, 8.

The shearing stress distributed equally in all bolts, neglecting friction, becomes the following:

$$S_s = P / N_T A = 11.18(8610) / 8(1.405) = 8560 \text{ psi.} \tag{52}$$

From Mohr's circle of stress, the maximum stress in the most stressed bolt will be expressed as follows:

$$\begin{aligned}
 S_{\text{max}} &= S_B + S_T / 2 \left[(S_B + S_T / 2)^2 + S_s^2 \right]^{1/2} \\
 &= 19,900 + 1530 / 2 + \left[(19,900 + 1530 / 2)^2 + (8560)^2 \right]^{1/2} \\
 &= 24,430 \text{ psi.}
 \end{aligned}
 \tag{53}$$

It is therefore concluded that the tie-down system of bolts of the Garden Carrier No. 2 to the skid exceeds the requirements of the regulations since the computed maximum stress is less than the yield stress (150,000 psi) of the bolting material specified on the drawing and also less than (30,000 psi) yield stress for mild steel; therefore, any socket-head bolt of the correct dimensions may be used for this purpose. Since the stress on the most stressed bolt is also below the yield strength for the 1-in.-thick 304L base plate, it will satisfy the requirements.

If any portion of the tie-down system of the Garden Carrier No. 2 to the skid should fail due to excessive load, containment would not be lost, and the ability of the package to meet the requirements would not be impaired.

3.5.2 Tie-down of fire shield to skid

The fire shield is secured to the skid with eight bolts of the same size and type as are used for the tie-down of the cask to the skid (see Sect. 3.5.1). The bolts are located on a 22-3/4-in.-radius bolt circle, as shown in Fig. 12.

Fig. 12. Bolting pattern and computational model for analysis of the tie-down system of the fire shield to the skid.

To analyze this part of the tie-down system, the fire shield was considered as a cantilevered beam. At the plane of attachment, the cross section of the beam consists of the bolts loaded in tension and a strip, a , loaded in compression, as shown in Fig. 11. It is obvious that the maximum stress occurs at this plane. Since the geometry is circular, it is a computational advantage to combine the 5- and 10- $\underline{W}$ loads vectorially:

$$P = \left[(5\underline{W})^2 + (10\underline{W})^2 \right]^{1/2} = 11.18\underline{W}. \quad (54)$$

The line of action of P has been taken as the X axis, which is rotated from the direction of travel by an angle, α , as shown in Fig. 12.

$$\alpha = \tan^{-1} 5/10 = 26.56^\circ. \quad (55)$$

The neutral axis, shown as the Y axis in Figs. 11 and 12 must first be located. Using methods of analysis previously developed,⁸

$$\Sigma b = 2r^3/A \eta + rN\beta, \quad (56)$$

where

A = cross-sectional area of a bolt, 1.405 sq in.,⁹

$$\eta = (+ \sin^3 \theta/3 - \theta \cos \theta/2 + \sin 2\theta \cos \theta/4), \quad (57)$$

$$\beta = (1 - \cos \theta), \quad (58)$$

$$b = r - r' (1 - \cos \varphi) \text{ (see Table 5),} \quad (59)$$

N = number of effective bolts, 7,

r = radius base plate, 24 in.,

r' = centerline radius of bolt, 22.75 in.

Therefore,

$$\Sigma b = 192.0. \quad (60)$$

The value of θ was calculated to be 38.3° , and the natural axis is located at a distance, a , from the edge of the plate where

$$a = r(1 - \cos \theta) = 24(1 - \cos 38.3^\circ) = 5.16 \text{ in.} \quad (61)$$

The moment of inertia of the section is calculated by the following:⁸

Table 5. Values of b , $\bar{b}$, and $\bar{b}^2$ for fire shield tie-down

Distance of bolt center from edge of baseplate ^a		b^a	$\bar{b}^b$	$\bar{b}^2$
$b_1 = 24 - 22.75 (\cos 8.44)$	=	1.50	—	—
$b_2 = 24 - 22.75 (\cos 36.56)$	=	5.72	0.56	0.3
$b_3 = 24 - 22.75 (\cos 53.44)$	=	10.45	5.29	28.0
$b_4 = 24 - 22.75 (\cos 81.56)$	=	20.66	15.50	240.3
$b_5 = 24 + 22.75 (\sin 8.44)$	=	27.34	22.18	492.0
$b_6 = 24 + 22.75 (\sin 36.56)$	=	37.55	32.39	1049.1
$b_7 = 24 + 22.75 (\sin 53.44)$	=	42.28	37.12	1377.9
$b_8 = 24 + 22.75 (\sin 81.56)$	=	46.50	41.34	1709.0

^aSee Fig. 12.^bSee Fig. 11 ($\bar{b} = b - a$).

$$\begin{aligned}
I &= 2r^4 \left[\frac{\theta}{8} - \frac{\sin 4\theta}{32} - 2 \cos \theta \frac{\sin^3 \theta}{3} + \cos^2 \theta \left(\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right) \right] \\
&+ A \Sigma \bar{b}^2 \\
&= 2(24)^4 \left[0.669/8 - 0.4506/32 - 2(0.7848)(0.6199)^3/3 \right. \\
&\quad \left. + (0.7848)^2 (0.669/2 - 0.9728/4) \right] + 1.405 (4896.5) = 7638 \text{ in.}^4.
\end{aligned} \tag{62}$$

The bending stress in the most distant bolt from the neutral axis is expressed as follows:

$$\begin{aligned}
S_b &= PZ_{bn}/I \\
&= 11.18(2600)(32.25)(41.34)/7638 \\
&= 5074 \text{ psi.}
\end{aligned}$$

The direct tensile stress distributed equally in all bolts is expressed by the following:

$$S_T = 2W/N_T A = 2(2600)/8(1.405) = 463 \text{ psi.} \tag{64}$$

where

N_T = total number of bolts, 8.

The shearing stress distributed equally in all bolts, neglecting friction, becomes

$$S_s = P/N_T A = 11.18(2600)/8(1.405) = 2586 \text{ psi.} \tag{65}$$

From Mohr's circle of stress, the maximum stress in the most stressed bolt becomes

$$\begin{aligned}
S_{max} &= S_b + S_T/2 \left[(S_b + S_T/2)^2 + S_s^2 \right]^{1/2} \\
&= 5074 + 463/2 + \left[(5074 + 463/2)^2 + (2586)^2 \right]^{1/2} \\
&= 6557 \text{ psi.}
\end{aligned} \tag{66}$$

It is therefore concluded that the tie-down system of bolts of the fire shield to the skid exceeds the requirements of the regulations because the computed maximum stress is less than the yield stress (150,000 psi) of the bolting material specified on the drawing and also less than the yield stress (30,000 psi) for mild steel; thus any socket-head bolt of the correct dimensions may be used for this purpose. Since the stress on the most stressed bolt is also below the yield strength for the 1-in.-thick 304L base plate, it will satisfy the requirements.

If any portion of the tie-down system of the fire shield to the skid should fail due to excessive load, containment would not be lost, and the ability of these packages to meet the requirements would not be impaired.

3.5.3 Tie-down of fire shield to vehicle

The wire rope (tension member) pulls directly on the tie-down lug (see Fig. 9). A 45° loading of the tie-down lug was chosen as a convenient angle (being in line with the lug). The force imposed on the tie-down lug is broken down into its components (vertical, F_z ; forward, F_x ; and transverse, F_y , loads). These loads are added and compared to the stress in the metal and the strength of the weld holding the tie-down lug to the fire shield. No credit is taken for the tie-down from the skid to the vehicle.

Vertical load application. The forces on the tie-down (F_z) resulting from the application of a vertical load applied to the center of gravity of two times the weight of the package are found by a summation of the vertical forces (see Fig. 13):

$$\Sigma F_v = 0, + = ? \quad (67)$$

$$\Sigma F_v = 0 = 2\underline{W} - \underline{W} - 4F_z$$

$$F_z = \underline{W} / 4 = 12,400 / 4 = 3100 \text{ lb.}$$

where

$$\underline{W} = \text{cask plus contents and skid weight (see Table 1); } 12,400 \text{ lb.}$$

The tension in the tension member from the $2\underline{W}$ load is

$$T_z = F_z (\sin 45^\circ) = 3100 (0.707) = 4380 \text{ lb.} \quad (68)$$

Forward load application. The forces on the tie-down (F_x) resulting from the application of a horizontal force applied to the center of gravity in the direction of travel of ten times the weight of the package are found by summing the horizontal forces (see Fig. 14):

$$\Sigma F_H = 0, + = - \quad (69)$$

$$\Sigma F_H = 0 = 10\underline{W} - 2F_x$$

$$F_x = 10\underline{W} / 2 = 10(12,400) / 2 = 62,000 \text{ lb.}$$

The tension in the tension member from the $10\underline{W}$ load is

$$T_x = F_x / (\cos 45^\circ)(\cos 45^\circ) = 62,000 / (0.707)(0.707) = 124,040 \text{ lb.} \quad (70)$$

ORNL DWG 75-4890
R-1

Fig. 13. Forces due to vertical thrust on Garden Carrier No. 2.

ORNL DWG. 75-4889 R-1

Fig. 14. Forces due to the forward thrust on Garden Carrier No. 2.

Transverse load application. The forces on the tie-down (F_y) resulting from the application of a horizontal force applied to the center of gravity transverse to the direction of travel of five times the weight of the package are found by a summation of the forces in the transverse direction (see Fig. 15):

$$\Sigma F_{TV} = 0, + = - \quad (71)$$

$$\Sigma F_{TV} = 0 = 5W - 2F_y$$

$$F_y = 5W/2 = 5(12,400)/2 = 31,000 \text{ lb.}$$

The tension in the tension member from the $5W$ transverse load is

$$T_y = F_y / (\cos 45^\circ)(\sin 45^\circ) = 31,000 / (0.707)(0.707) = 62,020 \text{ lb.} \quad (72)$$

Combined load application. The force produced for the forward (T_x), transverse (T_y), and vertical (T_z) applied loads may be added to determine the total tension in the tension member.

$$T_r = T_x + T_y + T_z = 124,040 + 62,020 + 4,380 = 190,440 \text{ lb.} \quad (73)$$

The horizontal and vertical components of the combined force (see Fig. 16) on the tie-down lug is found in the following manner:

For the horizontal,

$$F_{CH} = T_r \sin 45^\circ = 190,440 (0.707) = 134,600 \text{ lb.} \quad (74)$$

For the vertical,

$$F_{CV} = T_r \cos 45^\circ = 190,440 (0.707) = 134,600 \text{ lb.} \quad (75)$$

The tensile stress in the tie-down lug along plane A-A (see Fig. 16) is calculated as follows:

$$\sigma = F_{CH} / ht = 134,600 / 12.5(2.25) = 4,790 \text{ psi,} \quad (76)$$

where

h = depth of lifting lug, 12.5 in.

t = thickness of lifting lug, 2.25 in.

ORNL DWG. 75-489I
R-1

Fig. 15. Forces due to the transverse thrust on Garden Carrier No. 2.

The shear stress in the tie-down lug along plane A-A (see Fig. 16) is calculated as follows:

$$\tau = F_{CT} / hT = 134,600 / (12.5)(2.25) = 4,790 \text{ psi.} \quad (77)$$

The bending stress on the tie-down lug along plane A-A (see Fig. 16) is calculated as follows:

$$\sigma_b = MC / I = 774,000 (6.2) / 366 = 13,200 \text{ psi,} \quad (78)$$

where

$$M = F_{CT}a, \text{ in.-lb.} \quad (79)$$

a = distance edge to center of hole, 5.75 in.,

h = depth of section, 12.5 in.,

t = thickness of section, 2.2 in.,

$$C = \text{centroid distance from edge, } h/2 = 12.5/2 = 6.25 \text{ in.,} \quad (80)$$

$$I = 1/12 th^3, \text{ in.}^4. \quad (81)$$

$$M = 134,600 (5.75) = 774,000 \text{ in.-lb.}$$

$$I = 1/12 (2.25) (12.5)^3 = 366 \text{ in.}^4.$$

The bending stress in the curved beam is based on equations given by Roark⁷ which can be used to predict stress concentration factors found in the analysis of curved beams. For a value of $r/c = 4.00/2.25 = 1.8$, where r is the radius of curvature measured to the centroid of the section and c is defined below, a table supplied by Roark gives the following equations:

$$k_i = 1.63 = S_i / S \quad (82)$$

and

$$k_o = 0.70 = S_o / S, \quad (83)$$

where

k = the stress concentration factor,

S_i = actual stress in extreme fiber on concave side,

S_o = actual stress in extreme fiber on convex side,

S = unit stress in corresponding fiber as computed by ordinary flexure formula for a straight beam.

$$S = MC/I, \quad (84)$$

where

$$M = \text{maximum bending moment for beam with restrained ends, } F_{cu}L/8, \text{ in.-lb.} \quad (85)$$

C = distance from centroidal axis to extreme fiber, 2.25 in.,

$$I = \text{moment of inertia, } bc^3/12, \text{ in.}^4, \quad (86)$$

L = length of beam, 8.0 in.,

d = depth of beam, 4.5 in.,

b = width of beam, 2.25 in.

Substituting these values and the dimensions shown in Fig. 16,

$$M = (134,600)(8.0)/8.0 = 134,600 \text{ in.-lb.}$$

$$I = 2.25(4.5)^3/12 = 17.09 \text{ in.}^4,$$

$$S = (134,600)(2.25)/17.09 = 17,720 \text{ psi.}$$

Therefore, the stress on the extreme fibers along the plane F_{cv} (see Fig. 16) is found from the following equation:

$$S_s = k_s S = (1.63)(17,720) = 28,890 \text{ psi.}$$

and

$$S_o = k_o S = (0.70)(17,720) = 12,400 \text{ psi.}$$

Thus the bending stresses in the extreme concave fiber and in the extreme convex fiber are less than the tensile yield strength of the mild steel material (see Table 2). Hence the design meets the requirements.

The tensile stress in the weld (along plane CC Fig. 16) is calculated as follows:

$$\sigma_T = F_{TW} (im - jn) = 134,600 \left[(3.25)(13.5) - (2)(12.25) \right] = 6950 \text{ psi.} \quad (87)$$

The shear stress in the weld is determined as follows:

$$\tau = F_{CV} (im - jn) = 134,600 \left[(3.25)(13.5) - (2)(12.25) \right] = 6950 \text{ psi.} \quad (88)$$

The bending stress in the weld is calculated as follows:

$$\sigma_B = \pm MC / I = 302,850 \times 6.625 / 360 = 5570 \text{ psi.} \quad (89)$$

where

$$M = F_{CV}b = (134,600)(2.25) = 302,850 \text{ in.-lb} \quad (90)$$

$$C = m/2 = 13.25/2 = 6.625 \text{ in.} \quad (91)$$

$$I = (im^3 - jn^3) / 12 = \left[(3.25)(13.5)^3 - (2)(12.25)^3 \right] / 12 = 360 \text{ in.}^4. \quad (92)$$

The tie-down lugs are capable of resisting the tie-down loads and therefore meet the requirements of the regulations.

If the tie-down lug were to pull out of the fire shield or fail due to excessive loads, the failure would most likely be tension in the weld or bending of the tie-down lug; however, containment would not be lost, and the ability of the package to meet other requirements would not be impaired.

4. STANDARDS FOR TYPE B AND LARGE QUANTITY PACKAGING

The structural standards for large quantity packaging include load resistance of the packaging and the external pressure which the package must withstand. Compliance of the Garden Carrier No. 2 with these requirements is discussed in the following subsections.

4.1 Load Resistance

When regarded as a simple beam supported at its ends along any major axis, the container must be capable of withstanding a static load normal to and uniformly distributed along its

length that is equal to five times its fully loaded weight; it should not generate stress in any material of the cask in excess of the yield strength of that material.

Both the cask and the fire shield will be analyzed.

4.1.1 Load resistance of Garden Carrier No. 2

The cross section of the cask is composed of the outer stainless steel shell, the lead shielding, and the inner stainless steel shell, as shown in Fig. 17. Since these components are symmetrical about the same axis, the moment of inertia of the composite section is the sum of the equivalent moments of inertia of the individual components. For a thin shell, the moment of inertia, I_s , about its center is expressed by the following equation:

$$I_s = \pi r_m^3 t, \quad (93)$$

where

r_m = the mean radius of the thin shell, in.,

t = the thickness of the shell, in.

The moment of inertia of a hollow cylinder (I_{ph}), such as the lead shielding, becomes

$$I_{ph} = A (r_o^2 + r_i^2/4), \quad (94)$$

where

r_o = outside radius, in.,

r_i = inside radius, in.,

A = cross-sectional area, $\pi (r_o^2 - r_i^2)$, sq in. (95)

By the reinforced beam theory,¹⁰

$$\text{modulus of elasticity of steel/modulus of elasticity of lead} = n = 30 \times 10^6 / 2 \times 10^6 = 15, \quad (96)$$

and

$$n = \text{actual area of lead/equivalent area of steel} = A_{ph} / A_{ss}. \quad (97)$$

Fig. 17. The Garden Carrier No. 2 regarded as a simple beam and its equivalent cross section.

where

$$A_{ES} = A_{PB}/n = A_{PB}/15. \quad (98)$$

In order to convert the lead to equivalent steel, the following substitutions should be made in in Eq. (94):

$$I_{PB} = A_{PB}/15 (r_o^2 + r_i^2/4) = \pi/60 (r_o^4 - r_i^4).$$

The moment of inertia of the section is determined by adding the three moments of inertia as follows:

$$\begin{aligned} I &= \pi R_m^3 t_o + \pi/60 (r_o^4 - r_i^4) + \pi r_m^3 t_i \\ &= \pi (12.344)^3 (0.5) + \pi/60 [(12.094)^4 - (3.906)^4] + \pi (3.719)^3 (.375) \\ &= 4123 \text{ in.}^4, \end{aligned} \quad (99)$$

where

$$r_o = R_i \text{ (see Fig. 17),}$$

$$r_i = r_o \text{ (see Fig. 17).}$$

The maximum bending moment occurs at $L/2$ and can be determined from:

$$M_{max} = R_1 L/2 - \omega L^2/8 = 21,525 (46.25/2) - 931 (46.25)^2/8 = 249,000 \text{ in.-lb.} \quad (100)$$

where

$$\omega = \text{unit bending load in-lbs per lineal in.}$$

The maximum stress is the bending stress at $L/2$ and can be calculated in the following manner:

$$S_B = M_{max} R_o / I = 249,000(12.594)/4123 = 761 \text{ psi.} \quad (101)$$

The Garden Carrier No. 2 exceeds the requirements of the standards for load resistance.

4.1.2 Load resistance of the fire shield

The cross section of the fire shield area consists of two steel cylinders with insulation between them as shown in Fig. 18. Since the insulation has no strength, only the outer shell will be considered. For a thin shell, the moment of inertia, I , about its center is determined as follows:

$$I = \pi R_m^3 t_o \quad (102)$$

$$I = \pi(21.25)^3 (0.5),$$

$$I = 15.070 \text{ in.}^4,$$

where

R_m = the mean radius (see Fig. 18), 21.25 in.,

t_o = the thickness of the outer shell, 0.5 in.

The maximum bending moment occurs at $L/2$ and is calculated in the following manner:

$$M_{max} = R_1 L/2 - \omega l^2/8 = 31,000 (51.56)/2 - 1202(51.56)^2/8 = 399,750 \text{ in.-lb.} \quad (103)$$

The maximum stress is the bending stress at $L/2$ and is expressed in the following equation:

$$S_B = M_{max} R_o / I = 399,750(21.5) / 15,070 = 570 \text{ psi.} \quad (104)$$

The fire shield therefore exceeds the requirements of the standards for load resistance.

4.2 External Pressure

The regulations require that the design of the shipping package be adequate to ensure that the containment vessel will suffer no loss of contents if subjected to an external pressure of 25 psig.

Each opening of the Garden Carrier No. 2 is gasketed, and experience has demonstrated that the gaskets used, as they are applied, are suitable to an external pressure of over 25 psig. Primary reliance for containment is on the inner container, see Sect. 8. It is demonstrated that the outer shell of the Garden Carrier No. 2 is capable of withstanding more than 25 psig without damage by the following calculations based on the methods of the ASME Boiler and Pressure Vessel Code.¹¹

ORNL DWG 75-1045R-2

Fig. 18. The fire shield regarded as a simple beam and its equivalent cross section.

The capability of the outer shell (disregarding the lead backup material) to withstand external pressure (Paragraph UG-28)¹¹ is calculated as follows:

$$L/d_o = 44.25/25.188 = 1.76, \quad (105)$$

$$D_o/t = 25.188/0.500 = 50.4, \quad (106)$$

where

L = inside length of cask, 44.25 in.,

d_o = outside diameter of cylindrical shell, 25.188 in.,

t = shell plate thickness, 0.500 in.,

and the maximum allowable working pressure (P_a) at a maximum temperature of 400° F is the following:

$$P_a = B/d_o t = 6200/50.4 = 123 \text{ psi}, \quad (107)$$

where $B = 6200$ from Fig. UHA-28.3 Appendix V.¹¹

The capability of the flat top of the cask (disregarding the lead backup material) to withstand external pressure (with reference to Paragraph UG-34¹¹) is calculated in the following manner:

$$P = St^2 d^2 C = 11,000(1.5)^2 (25.188)^2 (0.25) = 24,750/158.6 = 156 \text{ psi}. \quad (108)$$

where

P = design pressure, psi,

S = maximum allowable stress value, 11,000 psi (at 400° F),

t = plate thickness, 1.5 in.,

d = inside diameter head, 25.188 in.,

C = constant, 0.25.

Since the maximum allowable working pressure on the shell and head of the cask exceeds 25 psig, it is concluded that the carrier exceeds the requirements of the structural standards for external pressure.

5. COMPLIANCE WITH STANDARDS FOR NORMAL CONDITIONS OF TRANSPORT

The regulations stipulate that a single package must be able to withstand the normal conditions of transport without substantially reducing the effectiveness of the package and without releasing radioactive material from the containment vessel. The contents of the container are limited so that the package will contain no gases or vapors that could reduce the effectiveness of the packaging. No circulating coolant other than atmospheric air is used, and no mechanical cooling device is required or provided. The Garden Carrier No. 2 and its inner containers are designed so that the contents will not be vented to the atmosphere under normal conditions of transport. These normal conditions include the effects of heat, cold, pressure, free drop, and penetrations.

5.1 Heat

The package must be able to withstand direct sunlight at an ambient temperature of 130°F in still air without reducing the effectiveness of the packaging. The regulations¹² set forth by DOT further stipulate that the temperature of any accessible surface of the fully loaded shipping package shipped by common carrier shall not exceed 122°F or being transported on a sole-use vehicle shall not exceed 180°F when the package is in the shade in still air at ambient temperature. For this later evaluation, ambient temperature was assumed to be 100°F. A modified version of HEATING-3¹³ computer program was used to compute the steady-state temperature distribution in the cask and its contents under the specified conditions.

5.1.1 *Thermal properties of materials*

The thermal properties of materials used to compute the temperature distribution are listed in Table 6.

Thermal properties of Kaowool insulation was obtained from the manufacturer, Babcock and Wilcox. Thermal properties of all other materials were determined from standard texts.

5.1.2 *Thermal model for transport of solids*

The model used for the heat-transfer computations for solids shipment is illustrated in Fig. 19. The contents were modeled as a homogeneous cylinder occupying 25% of the available cavity volume. The thermal conductivity of the source was assumed to be ten times the thermal conductivity of water (see Table 6). This will provide a relatively uniform temperature distribution over a small section of the inner container which is similar to what might be encountered in shipping large pieces of source material. A thermal conductivity more nearly typical of metal, powders, etc. would give truer source temperatures but would not affect the container, cask, or fire-shield temperatures. Physical properties of stainless steel and the maximum decay heat load of 100 W, uniformly distributed, were used for the contents.

Table 6. Material properties of materials of construction
used in thermal analysis

Material	Temperature (°F)	Thermal conductivity (Btu/hr-ft-°F)	Density (lb/in. ³)	Heat capacity (Btu/lb-°F)	Latent heat (Btu/lb)	
Lead	32.0	20.10	0.4109	0.031	11.3	
	212.0	19.00				
	392.0	18.00				
	572.0	18.00				
	621.3					
SST 304	32.0	8.50	0.2824	0.12		
	260.3	9.80				
	440.3	10.60				
	620.3	11.40				
	752			0.135		
	800.3	12.20				
	980.3	13.00				
	1160.0	13.80				
Kaowool (insulation)	400.0	0.0250	3.47 x 10 ⁻³	0.255		
	600.0	0.0375				
	800.0	0.0517				
	1000.0	0.0692				
	1200.0	0.0833				
	1400.0	0.1100				
	1600.0	0.1367				
Aluminum	32.0	117.00	9.78 x 10 ⁻²	0.2106		
	212.0	119.00		0.2225		
	392.0	124.00		0.2344		
	572.0	133.00		0.2463		
	752.0	144.0		0.2582		
	932.0	155.0		0.2702		
	1112.0			0.2821		

Table 6. (continued)

Material	Temperature (°F)	Thermal conductivity (Btu/hr-ft°f)	Density (lb/in. ³)	Heat capacity (Btu/lb-°f)	Latent heat (Btu/lb)
Air	32.0	0.014	4.69 x 10 ⁻⁵	0.240	
	100.0	0.015	4.11 x 10 ⁻⁵	0.240	
	200.0	0.017	3.47 x 10 ⁻⁵	0.241	
	300.0	0.019	3.01 x 10 ⁻⁵	0.243	
	400.0	0.021	2.66 x 10 ⁻⁵	0.245	
	500.0	0.023	2.38 x 10 ⁻⁵	0.247	
	600.0	0.025	2.16 x 10 ⁻⁵	0.250	
	700.0	0.027	1.97 x 10 ⁻⁵	0.253	
	800.0	0.029	1.82 x 10 ⁻⁵	0.256	
	900.0	0.030	1.68 x 10 ⁻⁵	0.259	
	1000.0	0.032	1.57 x 10 ⁻⁵	0.262	
Polyethylene	1500.0	0.040	1.17 x 10 ⁻⁵	0.276	
	0.0	2.868	3.38 x 10 ⁻²	0.550	
	32.0	3.19			
	100.0	3.63	3.61 x 10 ⁻²	1.000	
	200.0	3.93			
	300.0	3.95			
	420.0	3.76			
	620.0	2.75			
Source					

The sliding doors were modeled as a cylinder of lead encased in stainless steel. Internal air gaps associated with the door arrangement were incorporated into a single air gap external to the steel cylinder, Region 34 in the HEATING-3 model, Fig. 19. The bottom of the cask was assumed to be insulated because insulation material will be secured in the skid.

It was determined that natural convection, in addition to radiation and conduction, was a significant mode of heat transfer in the interior air gaps represented by Regions 12, 19, 34, 36, 43, 47, 52, and 56 in the HEATING-3 model. Natural convection was neglected in the remaining internal air gaps, leaving radiation and conduction as the only modes of heat transfer across these air gaps. Internal convection is assumed to be significant if the Rayleigh number $[Ra = (p^2 g \beta C_p / \mu k)(\Delta T L^3)]$ based on the gap size, L , is greater than 1000.

In calculating the steady-state temperatures for the 130°F environment in direct sunlight, it was assumed that 144 Btu/hr-ft² was incident upon the projected area of the cask. This projected area, 18.75 ft², is the maximum area that could be exposed to direct sunlight at any time regardless of the position of the cask to the sun. The fraction of the incident solar flux that is absorbed by the cask is equal to the absorptivity of the outer surface of the cask, estimated to be 0.6. The total energy absorbed was assumed to be evenly distributed over the actual area of the top and sides of the cask. The bottom of the cask was assumed to be insulated. For an absorptivity of 0.6, the net flux absorbed over the actual noninsulated surface area is 26.5 Btu/hr-ft².

5.1.3 Maximum temperatures

Calculated temperatures at points of interest within the cask are presented in Table 7 for the 130°F environment in direct sunlight as well as for the 100°F environment in shade. The calculations are for the solids shipment with the decay heat load being 100 W. The maximum accessible surface temperature for the 100°F environment was calculated to be 114°F, less than the limit of 122°F specified by applicable regulations. Since all temperatures are below both the melting point of lead and the temperature at which polyethylene is damaged, calculations for the liquid load, which has only a 20-W heat source (maximum), were not made. Since the temperatures are well within the operating limits of the gaskets and seals, the integrity of the cask and its inner container will be unaffected by these thermal boundary conditions. Therefore, the container complies with the regulations.

5.2 Cold

The shipping package must be able to withstand an ambient temperature of -40°F in still air and shade.

Taking $T_1 = -40^\circ\text{F}$ (420°R) and assuming no internal heat load, the final or maximum pressure (P_2) in any cavity sealed at a pressure of 14.7 psia and a temperature of 70°F (530°R) is:

$$P_2 = (P_1 T_2) / T_1 = 11.65 \text{ psia.} \quad (109)$$

Table 7. Maximum selected temperature for solid
shipment thermal analysis

Node number ^a	Environment	
	100°F shade	130°F direct sunlight
10	103	155
130	124	181
156	124	181
186	124	181
192	102	152
226	125	181
301	125	181
485	135	190
546	126	181
552	103	152
564	129	183
689	129	183
696	104	153
777	130	184

^aSee Fig. 19.

The resulting pressure differential is less than the 25 psig differential pressure investigated in Sect. 4.2. A temperature of -40°F is within the operating temperature range of the seals and the 300 series stainless steel cladding, structural components, and fasteners which make up the cask. Brittle fracture of these components under the stipulated cold condition is not likely because the temperatures of these components are above their ductile-to-brittle transition temperatures. The fire shield and skid, made of mild steel, are not considered a part of the containment.

The preceding considerations indicate that the stipulated cold conditions will not reduce the effectiveness of the packaging, and that the container conforms to the requirements for the cold condition of normal transport.

5.3 Pressure

The regulations for normal conditions of transport specify that the package should be able to withstand an atmospheric pressure of 0.5 times the standard atmospheric pressure, with the resulting pressure being 7.3 psia.

When the model is under full heat load, trapped air in the cavity will expand and exert internal pressures. Assuming assembly at 70°F and 14.7 psia, the resulting pressure of any trapped air is:

$$P_2 = (P_1 T_2) / T_1 = (14.7)(650) / 530 = 18.0 \text{ psia (3.3 psig)}. \quad (110)$$

where

P_1 = assembly pressure, 14.7 psia,

T_2 = temperature under heat load, 650°R (190°F),

T_1 = assembly temperature, 530°R , (70°F).

The cask and its gasketed seals will be able to withstand this pressure without damage or reduction in effectiveness of the packaging, and the container conforms to the requirements for the reduced pressure condition of normal transport.

The pressure increases in the internal air gaps were estimated using ideal gas law, assuming constant volume, a sealing temperature, T_1 , of 70°F (530°R), and a sealing pressure, P_1 , of 14.7 psia. The final pressure, P_2 , can be expressed in terms of the final temperature, T_2 , and the initial conditions, P_1 and T_1 , as

$$P_2 = P_1(T_2/T_1).$$

The internal pressures associated with the internal air gaps for the 100°F shade

environment, for the 130°F direct sunlight environment, are presented in Table 8 for a decay heat load of 100 W.

5.4 Vibration

The package is of welded construction, and therefore vibrations received in transit are not expected to affect its integrity. In addition, the cask, which was built several years ago, has operated in the transportation environment and has suffered no ill effects as a result of the vibrations that were encountered.

5.5 Water Spray

The containment capabilities of the Garden Carrier No. 2 are not compromised by water spray, since all external surfaces of the fire shield are of steel and the cask is made of stainless steel. The closure seal is impervious to water.

5.6 Free Drop

The regulations for normal conditions of transport require that a package weighing between 10,000 and 20,000 lb be capable of withstanding a free drop through a distance of 3 ft onto a flat, essentially unyielding, horizontal surface, striking the surface in a position in which maximum damage is expected to result. A free drop of the Garden Carrier No. 2 through a distance of 3 ft is expected to produce only minor denting of the outside steel shell of the cask itself. If the package were dropped 3 ft and minor repairable external damage did occur, the effectiveness of the package would not be reduced. (See the analysis of the 30-ft free-fall, Sect. 6.1).

5.7 Penetration

The regulations for normal conditions of transport stipulate that the package must be capable of withstanding the impact of the hemispherical end of a vertical steel cylinder that weighs 13 lb, has a 1-1/4-in.-diam, and is dropped from a height of 40 in., normally onto the exposed surface of the package that is expected to be the most vulnerable to puncture.

The outer shell of the fire shield is 1/2 in.-thick steel. Tests conducted on 1/2 in. thick stainless steel have shown that the damage produced by the 13-lb steel cylinder being dropped through a distance of 40 in. will be negligible and the effectiveness of the fire shield will not be reduced.

Table 8. Pressures in internal air gaps for 100-W load

Region ^a	Description	100°F Environment		130°F Environment	
		T _{air} (°F)	Pressure (psig)	T _{air} (°F)	Pressure (psig)
4	Between side of lead fill and outer shell top plug	124	1.51	181	5.02
9	Between top of lead and shell of body	126	1.55	182	5.05
10	Between bottom of lead and top plug shell	126	1.55	183	5.08
12	Between top of inner container and bottom of top plug	130	1.68	187	5.19
15	Between side of lead and shell of body	127	1.58	182	5.05
19	Between side of inner container and side of inner cavity	140	1.93	190	5.27
30	Between drawer at center	131	1.69	185	5.13
34	Between drawer and drawer closure plate	128	1.61	182	5.05
36	Between drawer and bottom closure plate	129	1.64	183	5.08
43	Between side of base plate and fire shield	119	1.37	171	4.74
47	Between side of carrier and inner shell of fire shield	121	1.41	178	4.94
52	Between top of carrier and inner shell of fire shield	120	1.39	178	4.94
56	Inside inner container	149	2.18	202	5.60

^aSee Fig. 19.

5.8 Compression

Since the Garden Carrier No. 2 weighs over 10,000 lb, this section of the regulations does not apply.

6. COMPLIANCE WITH STANDARDS FOR HYPOTHETICAL ACCIDENT CONDITIONS

The standards for the hypothetical accident conditions stipulate that a container used for the shipment of large quantities of fissile or radioactive material shall be designed and constructed in such a manner and its contents limited so that, if it is subjected to the specified free drop, puncture, thermal, and water immersion conditions, the following standards will be met:

- (1) The reduction in shielding would not be sufficient to increase the external radiation dose rate to more than 1000 mR/hr at a distance of 3 ft from the outside surface of the package.
- (2) No radioactive material would be released from the package except for gases containing total radioactivity not to exceed 0.1% of the total radioactivity of the contents of the package.
- (3) The contents would remain subcritical.

6.1 Free Drop

The first in the sequence of hypothetical accident conditions to which the cask must be subjected is a free drop through a distance of 30 ft onto a flat, essentially unyielding, horizontal surface, striking the surface in a position in which the maximum damage is expected to occur.

The Garden Carrier No. 2 is covered by the fire shield before being shipped. Damage to the package will be evaluated by assuming it impacts the unyielding surface with the following impact orientations and conditions:

1. A corner drop will be made on the fire shield.
2. A side drop will be made on the fire shield.
3. Using the negative accelerations determined by the corner and side drops, the ability of the bolts to restrain the top plug and the drawer will be demonstrated.

6.1.1 *Impact on top corner*

A computational analysis (see Appendix C) was applied to a simplified cylindrical cask model to estimate the deformation resulting from a 30-ft corner drop (see Fig. 20) with its line of action through the center of gravity. Results shown in Table 9 indicate by using specific energies of steel that vary from 100,000 to 260,000 in.-lb/in.³, the deformation would vary from 2 to 1.4 in.; this deformation would occur primarily in the steel because of the large bending area between the steel, the wood distributor ring, and the carrier.

6.1.2 *Impact on side*

A computational analysis (see Appendix D) was applied to a simplified cylindrical cask model to estimate the deformation resulting from its impact on the side such that the edge of the skid and the top corner of the fire shield hit the immovable surface simultaneously (see Fig. 21). Some of the impact forces will be dissipated in bending the skid; however, the bending of the skid elements is being disregarded and all of the energy is assumed to deform the fire shield. The skid edge is a 6-in. by 6-in.-wide flange which has a 0.269-in.-thick flange. Results shown in Table 10 indicate that the deformation would vary between 1.4 to 1.0 in. when using specific energies of steel that vary from 100,000 to 260,000 in.-lb/in.³.

6.1.3 *Bolts holding drawers*

A side drop in which the axis of the drawers would be vertical would place the bolts securing these drawers under the greatest strain.

Each drawer is restrained during transit by eight 3/8-in. by 3/4-in. long (16 NC-2) hex-head stainless steel cap screws which hold the face of the drawer onto the cask body. In addition, the drawer movement is restrained by two 13/32-in.-diam dowel ends on the stainless steel socket-head cap screws which hold the drive nut on the screw. After the two dowel ends are sheared off and the eight screws fail, the line of containment for the drawer would be a gasketed cover secure by twenty 1/2-in.- by 1-1/4-in.-long (13 NC-2) socket-head stainless steel cap screws.

Using the largest negative acceleration in Table 10 and applying it to the weight of the drawer, the force, F_p , is determined as follows:

$$F_p = W_d \times g = 335 \times 1046 = 350,410 \text{ lb.} \quad (111)$$

where

W_d = weight of drawer, 335 lb,

g = negative acceleration, 1046.

Fig. 20. Deformation geometry for corner impact orientation of Garden Carrier No. 2 in its fire shield.

Table 9. Impact on top corner - maximum negative acceleration and deformation resulting from high and low values of specific energy in steel

Specific energy (in.-lb/in. ³)	Maximum deformation corner drop (in.)	Maximum negative acceleration (g)
100,000	1.96	474
260,000	1.37	724

Table 10. Impact on side - maximum negative acceleration and deformation resulting from high and low values of specific energy in steel

Specific energy (in.-lb/in. ³)	Maximum deformation corner drop (in.)	Maximum negative acceleration (g)
100,000	1.36	693
260,000	0.95	1046

DETAIL "A-A"

Fig. 21. Deformation geometry for side impact orientation of Garden Carrier No. 2 in its fire shield.

The force, F_p , is applied to the cask in a direction of the drop. The component F_B of that force applied along the axis of the bolts and the drawer is found as follows:

$$F_B = F_p \cos \theta = 350,410 (0.987) = 346,000 \text{ lb.} \quad (112)$$

where

θ = angle between axis of bolts and drawers and impact surface, 9.19° .

The force which the eight 3/8-in. cap screws will resist, F_s , is found as follows:

$$F_s = NS_u = 8(12,000) = 96,000 \text{ lb.} \quad (113)$$

where

N = number of screws, 8,

S_u = peak force for 3/8-in. cap screws,¹⁴ 12,000 lb.

The force which the two dowel ends will shear, F_d , is found as follows:

$$F_d = N\pi d^2/4 \tau_u = 2\pi(13/32)^2 (61,000) 4 = 15,800 \text{ lb.} \quad (114)$$

where

N = number of dowels, 2,

d = diameter of dowel ends, 13/31 in.

The force that the twenty 1/2-in. socket-head screws will resist, F_H , is found as follows:

$$F_H = NS_u = 20(18,300) = 366,000 \text{ lb } [>346,000 \text{ lb, see Eq. (112)}], \quad (115)$$

where

N = number of screws, 20,

S_u = yield force for 1/2-in. screws,¹⁴ 18,300 lb.

The twenty socket-head cap screws that hold the drawer cover plate will, therefore, retain the drawer in the cavity. As a safeguard, a wood filler block is located on the inside of the fire shield in front of each of the two drawer closures (1/8-in. clearance).

If the bolts on the drawer closure were to break, containment would not be lost, since the primary line of containment is the inner container. The ability of the cask to meet the other

requirements would not be altered.

6.1.4 Bolts holding top plug

A drop on the top of the cask (fire shield) would certainly drive the top plug more firmly into the top of the cask, probably deforming the walls of the top plug extension into its recess such that it would be very difficult to remove.

A corner drop will be used to demonstrate the behavior of the twelve 3/4-in. bolts holding the top plug to cask.

Using the largest deceleration in Table 9 and applying it to the weight of the top plug and the contents of the cask, the force, F_p , is determined as follows:

$$F_p = W_p \times g = 1340 (724) = 970,160 \text{ lb.} \quad (116)$$

W_p = weight of top plug plus cask content (see Table 1), 1340 lb,

g = deceleration, 724.

The force, F_p , is applied to the cask in the direction of the drop. The component, F_θ , of that force applied along the axis of the bolt and plug is found as follows:

$$F_\theta = F_p \cos \theta = 970,160 (0.768) = 745,100 \text{ lb.} \quad (117)$$

where

θ = angle between axis of bolts and impact surface, 39.83° .

The maximum force which the twelve 3/4-in. stainless steel bolts can resist before breakage is found as follows:

$$F_R = NS_u = 12(37,500) = 450,000 \text{ lb.} \quad (118)$$

where

N = number of bolts, 12,

S_u = peak force for 3/4-in. cap screws,¹⁴ 37,500 lb.

A wooden block is placed in contact between the top of the cask and the inside of the fire shield. This block will absorb the energy of the top plug and will prevent the bolts from stretching to the point of breakage. This is shown as follows:

$$F_B = A \sigma_e = 430(5390) = 2,320,000 \text{ lb.} \quad (119)$$

where

A = area of wood, 430 in.²,

σ_e = compressive strength elastic limit (see Table 3), 5390 psi.

Therefore, although the bolts are stressed beyond their yield strength, the wooden block will prevent their being stretched to the breaking point. Additionally, the wooden block will absorb the residual energy of the impact, and the fire shield will prevent the loss of the top plug shielding should the bolts fail.

6.2 Puncture

The second in the sequence of hypothetical accident conditions to which the cask must be subjected is a free drop through a distance of 40 in. to strike (in a position in which maximum damage is expected) the top end of a vertical mild steel bar mounted on an essentially unyielding horizontal surface. The mild steel bar shall have a diameter of 6 in., with the top horizontal and its edge rounded to a radius of not more than 1 4 in.; the bar shall be of such length that it will cause maximum damage to the cask, but not less than 8 in. long. The long axis of this bar shall be normal to the surface of the cask upon impact.

The garden Carrier No. 2 fire shield is fabricated with an outer shell of 0.5-in. steel and an inner shell of 3/8-in. steel at the top and 1/4 in. on the side. The gap between the outer and inner shells is filled with Kaowool insulation, a soft material that is assumed to provide no support for the outer shell during the puncture portion of the hypothetical accident. A shipping container with a similar type construction was tested, and the drop onto the piston did not puncture the outer shell. The package that was tested¹⁹ had a 3 16-in.-thick outer shell and weighed 3,800 lb. The Garden Carrier No. 2 has a 1 2-in.-thick outer shell and weighs 12,400 lb, which has a comparable weight to the outer shell ratio. It can, therefore, be assumed that the Garden Carrier No. 2 will also pass the puncture test.

6.3 Thermal Evaluation

6.3.1 Hypothetical thermal accident condition discussion

The third in the sequence of hypothetical accident conditions specified by the regulations to which the cask must be subjected is exposure for 30 min within a source of radiant heat having a temperature of 1475°F and an emissivity coefficient of 0.9, or equivalent. For calculational purposes, it shall be assumed that the package has an absorption coefficient of

0.8. The package shall not be cooled artificially until after the 30-min test period and the temperature at the center of the package has begun to fall, or until 3 hr following the test period.

A modified version of the computer program, HEATING-3,¹³ was used to determine the temperature distribution when exposed to these thermal environments.

It was assumed that the cask was loaded with the maximum permissible decay heat load of 100 W for shipment of solids. The temperature distribution from the 100°F ambient condition for the 100-W internal heat load was input as the initial temperature distribution for the accident (fire) calculations.

The damage from the free drop and puncture portions of the hypothetical accident would not adversely affect the performance of the container in the hypothetical thermal accident. Hence the undamaged configuration was assumed.

6.3.2 *Thermal properties of materials*

The thermal properties of materials used to compute the temperature distribution under steady-state and transient conditions are listed in Table 6 (see Sect. 5.1.1).

6.3.3 *Thermal accident analysis*

The computational model previously used and described in Sect. 5.1.2, representing half of the container, was also used for the thermal accident analysis. The HEATING-3 computer program was used to determine the temperature distribution in the container that would result from the prescribed 30-min thermal exposure. The material constants given in Table 6 were used in the calculations; a description of the treatment of heat transfer across the gaps is given in Sect. 5.1.2. The steady-state temperature distribution computed for the heat condition of normal transport (100°F ambient shade with 100-W source) was taken as the starting point. A 100-W internal heat generation was used for the transient analysis. The case for liquids with a 20-W internal generation rate was not investigated, since the 100-W case is conservative, and all temperatures were found to be satisfactory.

6.3.4 *Temperatures as result of the thermal accident analysis*

Cask temperatures were followed for 3 hr after the conclusion of the fire, since regulations specify that the cask cannot be artificially cooled prior to this time unless the temperature in the center of the cask has begun to fall.

A plot of the temperatures in three different areas of the cask was made for the duration of the run and are presented. Figure 22 shows how the temperature varies from the side. The temperature for node 552 (see Fig. 19), which is located on the outside surface of the fire shield approximately half way up the side, responds to the fire condition, heating up to 1375°F and cooling down rapidly. The temperatures on the outside of the body of the carrier (node

TEMPERATURE MONITOR FOR NODES 485, 546, 552, AND 564

Fig. 22. Temperatures on various points through the side of the Garden Carrier No. 2 shipping assembly as determined during and after the thermal accident conditions.

546), the interior of the lead fill (node 564), and the gasket of the inner container (node 485) were at essentially the same temperatures, 166°F, at the end of 3 hr (see Fig. 23). The temperatures at the top of the assembly (see Fig. 23) show a maximum temperature in the lead (node 226) and the outside of the carrier (node 130) of approximately 155°F at the end of 3 hr. The temperatures in the drawer and drawer closure gasket are shown in Fig. 24. These temperatures are approximately 180° at the end of 3 hr.

The maximum centerline temperature remained at approximately 184°F throughout the 30-min test period and rose to approximately 220°F at the end of the 3-hr cool down (the maximum cask temperature was 230°F). With no artificial cooling, the maximum centerline temperature rose to 230°F after 5 hr of cool down which was also the maximum cask temperature.

The temperatures of that magnitude (230°F max) will have no deleterious effects on any of the gaskets nor on a polyethylene bottle used inside the inner container.

Consequently, if the cask is subjected to the high-temperature thermal environment, it is capable of withstanding it with no loss of contents and, therefore, meets this part of the regulations.

6.3.5 *Maximum internal pressures*

The maximum pressures associated with the internal air gaps as a result of the thermal accident were estimated (see Table 11) using the same ideal relatives as before (see Sect. 5.3).

Maximum internal pressures of this magnitude (5.3 psig) will have no deleterious effect on the shipping cask.

6.4 Water Immersion

The fourth in the sequence of hypothetical accident conditions to which the cask must be subjected is immersion in water in such a manner that all portions of the package are under at least 3 ft of water for a period of not less than 8 hr.

The gaskets of the cask and the inner container will not have been damaged. The integrity of the cask and the inner containers after the 30-ft free-fall and fire test should be inviolate. The moderation afforded by the water is not determined (see Sect. 9).

7. CONTAINMENT

The radioactive material shipped in the Garden Carrier No. 2 is contained inside an inner container. The test and evaluation of the inner containers is described in Sect. 8.

TEMPERATURE MONITOR FOR NODES 10, 130, AND 226

Fig. 23. Temperatures at various points at the top of the Garden Carrier No. 2 shipping assembly as determined during and after the thermal accident conditions.

TEMPERATURE MONITOR FOR NODES 689, 696, AND 777

Fig. 24. Temperatures at various points near the bottom side of the Garden Carrier No. 2 shipping assembly as determined during and after the thermal accident conditions.

Table 1. Pressures in internal air gaps for 100-W load

Region ^a	Description	1475°F Fire	
		T _{air} (°F)	Pressure (psig)
12	Between top of inner container and bottom of top plug	165	4.58
19	Between side of inner container and side of inner cavity	184	5.11
30	Between drawers at center	190	5.27
34	Between drawers and drawer closure plate	187	5.19
36	Between drawer and bottom closure plate	192	5.33
43	Between side of base plate and fire shield	184	5.11
47	Between side of carrier and inner shell of fire shield	160	4.44
52	Between top of carrier and inner shell of fire shield	162	4.49
56	Inside inner container	188	5.22

^aSee Fig. 19.

7.1 Containment Requirements for Normal Conditions of Transport

The inner containers will withstand pressures and temperatures in excess of those encountered in normal transport. Section 5.3 indicates that the maximum normal operating pressure encountered in normal transport will be 5.6 psig at 202°F (see Table 8). Under these conditions, no release of radioactive material, loss of coolant (air), or contamination of coolant should occur.

7.2 Containment Requirements During the Hypothetical Accident

The inner containers will withstand pressures and temperatures in excess of those encountered in the hypothetical accident. It is shown in Sect. 8 that the maximum operating pressure during the hypothetical accident conditions will be 10.5 psig at 230°F.

8. INNER CONTAINERS

A 2R pipe cap container and a screwed-top inner container (Fig. 25) have been approved for use with the Garden Carrier No. 2. These containers may be used for solids shipments.

Fabrication of these containers will be in accordance with ORNL Quality Assurance Procedures for Quality Level III fabrication. Applicable approved ORNL procedures will be used for welding. All welds will be appropriately inspected in accordance with approved ORNL weld inspection procedures. Containers shall be leak tested using bubble techniques or helium leak-detection methods.

8.1 Screw-Top Inner Container

The screw-top inner container, shown in Fig. 25 has a maximum length of 23-5/8 in. The container needs to be made only as long as necessary to contain the material inside it. The neoprene "O"-ring gaskets will not be damaged by the thermal test (see Sect. 6.3.4).

Since the nature of the radioactive contents of the inner container in the cask are either solids or liquids, the inner container vessel pressure that will develop due to the expansion of the contained gases, plus the vapor pressure of the liquid (water) at the maximum temperature, will be assumed to be "the most severe anticipated case." A pressure of 10.5 psig will result [see Eq. (120)]. It is demonstrated below that the screw-top inner container meets the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code.¹¹ It is demonstrated that the screw top inner container is capable of a maximum internal pressure of 59 psig.

ORNL DWG 75-4899

Fig. 25. Screwed-top inner container.

8.1.1 Inner container wall thickness

From Paragraph UG-27,¹¹ the minimum wall thickness for the cylindrical portion of the inner container is determined by

$$t = Pr SE - 0.6P, \quad (120)$$

where

P = pressure, 10.5 psig.

r = inside radius of shell, 3.3125 in.,

S = design stress, 7800 psi (Table UHA-23),¹¹

E = joint efficiency, 1.0.

The minimum allowable wall thickness

$$t = (10.5)(3.3125) \left[7800(1.0) - 0.6(10.5) \right] = 0.004 \text{ in.}$$

The wall thickness of the cylindrical portion of the screw-top inner container is 0.125 in., which exceeds the requirements of the ASME Code.

Substituting the wall thickness (0.125 in.) in the above equation (No. 120) and solving for P, the pressure for which the inner container wall is capable of withstanding is 288 psig.

8.1.2 Inner container bottom flat head thickness

From Paragraph UG-34,¹¹ the minimum thickness of the bottom flat head of the inner container is determined by

$$t = d (CP S)^{1/2}, \quad (121)$$

where

d = diameter inside, 6.625 in.,

C = design constant, 0.3 in.,

P = pressure, 10.5 psig.

S = design stress, 7800 psi (see Table UHA-23),¹¹

$$t = 6.625 (0.3(10.5 \cdot 7800))^{1/2} = 0.133 \text{ in.}$$

The bottom flat head of the screw-top inner container is 3.8 in. thick and meets the requirements of the ASME Code.

Substituting the bottom flat-head thickness (3.8 in.) in the above equation (121) and solving for P, the pressure which the inner container bottom is capable of withstanding is 83 psig.

8.1.3 Inner container top head thickness

From Paragraph UG-34,¹¹ the minimum thickness of the screw top head of the inner container is determined by

$$t = d (C P S)^{1/2}, \quad (122)$$

where

d = diameter inside, 6.625 in.,

C = design constant, 0.75,

P = pressure, 10.5 psig,

S = design stress, 7800 psi (see Table UHA-23),¹¹

$$t = 6.625 \left[(0.75)(10.5) \cdot 7800 \right]^{1/2} = 0.211 \text{ in.}$$

The screw-top head of the screw-top inner container is 1.2 in. thick and exceeds the requirements of the ASME Code.

Substituting the top head thickness (1.2 in.) in the above equation (122) and solving for P, the pressure which the inner container top is capable of withstanding is 59 psig.

8.2 Thirty-foot Free-fall Test

Two containers of the same type as described above were fabricated and tested¹⁶ by the 30-ft free drop on a corner and flat on the bottom. No damage was sustained by either the container or the containment; therefore, no damage should be expected for these inner containers.

Liquid-filled polyethylene bottles inside these containers have survived the 30-ft drop without loss of contents.

9. CRITICALITY

The analysis for the single container given below is shown to be adequate for an infinite array of similar containers.

9.1 Evaluation of a Single Package

A criticality analysis has been made (see Nuclear Safety Review 776 in Appendix B).

Since the quantity of fissile isotopes carried is below all minimum critical masses for these isotopes under optimum moderation and reflection, and since the cask effectively isolates the contents from neutron interaction with packages of similar design, unlimited numbers could be stacked with no criticality problem occurring. Thus the package is adequate for Fissile Class I shipments.

10. SHIELDING EVALUATION

10.1 Discussion and Results

The cavity in the Garden Carrier No. 2 is surrounded by a 0.375-in.-thick stainless steel inner shell and a 0.50-in.-thick outer stainless steel shell. The shielding cavity between the two is filled with lead that is 8-3/16 in. thick. In addition, the cask contents are limited to a source strength that will not exceed the allowable radiation dose limits of the DOT regulations.⁵

The conditions of normal transport and the hypothetical accident produce minor deformation of the fire shield and essentially no loss of shielding (see Sects. 5 and 6). Any slight increase in the dose rate will be below the permissible limits.

11. QUALITY ASSURANCE

11.1 Fabrication, Inspection, and Acceptance Tests

The fabrication of this cask was performed in the Oak Ridge National Laboratory Shops in accordance with normal shop fabrication procedures. Material was specified on the original drawings as "304L SST." Material was withdrawn from stores stock. The cask was inspected by ORNL Shop Inspection personnel for conformance to the drawings, quality of workmanship, and compliance with welding requirements when fabricated. In the opinion of the inspecting personnel, the weldments were made in accordance with the drawings and specifications. This is further supported by the fact that the cask has operated for six years without failures or loss of effectiveness. An inspection of the cask was made to verify its integrity (see Appendix E). The routine operating inspection procedures specify periodic weld

inspections to verify weld integrity.

11.2 Operating Procedures and Routine Inspections

The Chemical Technology Division has established operating and routine inspection procedures and standard checklists to ensure that all shipments are safe and that they comply with ERDA regulations, as well as all ORNL procedures and regulations. A copy of typical procedures and checklists are presented in Appendix F. The completed records are kept in Bldg. 4500N, Room A-16.

11.3 Periodic Maintenance and Inspections

Biennial inspections and inspections before each shipment will be made as outlined in Appendix F. Maintenance will be performed when inspections indicate damage. The completed records are kept in Bldg. 4500N, Room A-16.

12. APPENDIXES

12.1 Appendix A - Drawings

	<u>Page No.</u>
Garden Carrier No. 2 Assembly M-11332-EM-010-E-4	83
Garden Carrier No. 2 Detail Sheet No. 1 M-11332-EM-011-E-3	84
Garden Carrier No. 2 Detail Sheet No. 2 M-11332-EM-012-E-2	85
Garden Carrier No. 2 Detail Sheet No. 3 M-11332-EM-013-E-0	86
Garden Carrier No. 2 Detail Sheet No. 4 M-11332-EM-014-E-2	87
Garden Carrier No. 2 Detail Sheet No. 5 M-11332-EM-015-E-1	88
Garden Carrier No. 2 Detail Sheet No. 6 M-11332-EM-016-E-0	89
Garden Carrier No. 2 Detail Sheet No. 7 M-11332-EM-017-D-0	90
Garden Carrier No. 2 Assembly and Skid M-11332-EM-018-E-4	91
Garden Carrier No. 2 Screwed Top Inner Container M-11332-EM-019-D-0	92
Garden Carrier No. 2 Flanged Inner Container M-11332-EM-020-E-4	93
Garden Carrier No. 2 Shipping Skid M-12124-CB-043-D-2	94
Garden Carrier No. 2 M-12166-CD-037-D-2	95
Garden Carrier No. 2 Fire Shield Assembly and Details M-12166-CD-043-E-1	96

BLANK PAGE

BLANK PAGE

APPROVED FOR CONSTRUCTION:

BLANK PAGE

① Drive Unit Cover
Mtl. 304 SS
1 REVISED
Scale 1"=1"

⑩ Top Cover
Mtl. 304 SS
1 REVISED
Scale 1"=1"

② Bottom Cover Plate
Mtl. 304 SS
1 REVISED
Scale 1"=1"

③ Bottom Cover Plate Gasket
Mtl. Neoprene
1 REVISED
Scale 1"=1"

④ Drive Unit Cover 2358
Mtl. Neoprene
2 REVISED
Scale 1"=1"

GENERAL SPECIFICATIONS	
1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.	2. ALL DIMENSIONS ARE TO BE TAKEN FROM THE EXTERIOR SURFACE UNLESS OTHERWISE SPECIFIED.
3. ALL DIMENSIONS ARE TO BE TAKEN FROM THE CENTERLINE UNLESS OTHERWISE SPECIFIED.	4. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.
5. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.	6. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.
7. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.	8. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.
9. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.	10. ALL DIMENSIONS ARE TO BE TAKEN FROM THE SURFACE UNLESS OTHERWISE SPECIFIED.

BLANK PAGE

BLANK PAGE

NOTE:
All Joints To Be Continuous Welded
To Prevent Contamination From
Air Flowing To Be P.S. 13 MET-400 201 E

SECTION A-A

⑦ TURBINE
MATERIAL 304L SS
EQUIPPED
SCALE 1"=1"

⑧ FILLER BLOCK
MATERIAL 304L SS
EQUIPPED
SCALE 1"=1"

⑨ DRIVE NUT
MATERIAL 177PH SS
EQUIPPED
SCALE 1"=1"

⑪ TURBINE YOKES
MATERIAL 304L SS
EQUIPPED
SCALE 1"=1"

BOLT & NUT
MATERIAL 304L SS
EQUIPPED
SCALE 1"=1"

⑫ FLANGE BUSHING
MATERIAL TITAN
EQUIPPED
SCALE 1"=1"

⑬ SPECIAL SPECIFICATIONS
1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. ALL DIMENSIONS ARE TO BE HOLDING DIMENSIONS UNLESS OTHERWISE SPECIFIED.
3. ALL DIMENSIONS ARE TO BE HOLDING DIMENSIONS UNLESS OTHERWISE SPECIFIED.
4. ALL DIMENSIONS ARE TO BE HOLDING DIMENSIONS UNLESS OTHERWISE SPECIFIED.
5. ALL DIMENSIONS ARE TO BE HOLDING DIMENSIONS UNLESS OTHERWISE SPECIFIED.

BLANK PAGE

PARTS LIST			
PART	QTY	DESCRIPTION	UNIT

⑦ TRUNNION
MATERIAL: 304L SST
FINISH: POLISHED
SCALE: 1"=1"

⑧ DRIVE SCREW
MATERIAL: 316 SST
FINISH: POLISHED
SCALE: 1"=1"

⑨ DRIVE NUT
MATERIAL: 316 SST
FINISH: POLISHED
SCALE: 1"=1"

⑩ SCREW
MATERIAL: 316 SST
FINISH: POLISHED
SCALE: 1"=1"

⑪ FLANGED BUSHING
MATERIAL: 316L SST
FINISH: POLISHED
SCALE: 1"=1"

GENERAL SPECIFICATIONS		MATERIALS		FINISHES		TOLERANCES		ASSEMBLY	
1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.		2. ALL DIMENSIONS ARE TO BE HOLD TO THE CLOSEST TOLERANCE PERMITTED BY THE MANUFACTURING PROCESS.		3. ALL DIMENSIONS ARE TO BE HOLD TO THE CLOSEST TOLERANCE PERMITTED BY THE MANUFACTURING PROCESS.		4. ALL DIMENSIONS ARE TO BE HOLD TO THE CLOSEST TOLERANCE PERMITTED BY THE MANUFACTURING PROCESS.		5. ALL DIMENSIONS ARE TO BE HOLD TO THE CLOSEST TOLERANCE PERMITTED BY THE MANUFACTURING PROCESS.	

Assembly Drawing For Sub-Assembly		Drawing No. 1000000000	
Drawing Title: GED CASE		Drawing No. 1000000000	
Drawing Date: 11/15/2010		Drawing No. 1000000000	
Drawing By: GED CASE		Drawing No. 1000000000	
Drawing Check: GED CASE		Drawing No. 1000000000	
Drawing Appr: GED CASE		Drawing No. 1000000000	
Drawing Rev: 1		Drawing No. 1000000000	

APPROVED FOR CONSTRUCTION

BLANK PAGE

Top View

Note "A"
AP Assembly Of Doors Parts 3 B 55
The Gap Between Doors Must Be
3/8" See Assembly Drawing E-10-00 E

② MAIN BODY
MAY 1955

REVISION	DATE	BY	CHKD
1	11-15-55	W. J. B.	W. J. B.
2	11-15-55	W. J. B.	W. J. B.
3	11-15-55	W. J. B.	W. J. B.
4	11-15-55	W. J. B.	W. J. B.
5	11-15-55	W. J. B.	W. J. B.
6	11-15-55	W. J. B.	W. J. B.
7	11-15-55	W. J. B.	W. J. B.
8	11-15-55	W. J. B.	W. J. B.
9	11-15-55	W. J. B.	W. J. B.
10	11-15-55	W. J. B.	W. J. B.

BLANK PAGE

BLANK PAGE

SECTION B-B

SECTION A-A

BLANK PAGE

BLANK PAGE

SECTION C-C
TWO MILLIMONE

B. 4" Dia. Drill Thru / Top
40" - 100" / 1" C. Bar / 15" Dia
1" Dia. Dr. / 4" Radius

TYPICAL ROLLER ASSEMBLY
Scale 1" = 1'

FRONT CORNER DETAIL

1. The design of the structure shall be in accordance with the requirements of the American Institute of Steel Construction, Inc. (AISC) and the American Concrete Institute (ACI). 2. The design of the structure shall be in accordance with the requirements of the American Institute of Steel Construction, Inc. (AISC) and the American Concrete Institute (ACI). 3. The design of the structure shall be in accordance with the requirements of the American Institute of Steel Construction, Inc. (AISC) and the American Concrete Institute (ACI).	4. The design of the structure shall be in accordance with the requirements of the American Institute of Steel Construction, Inc. (AISC) and the American Concrete Institute (ACI). 5. The design of the structure shall be in accordance with the requirements of the American Institute of Steel Construction, Inc. (AISC) and the American Concrete Institute (ACI). 6. The design of the structure shall be in accordance with the requirements of the American Institute of Steel Construction, Inc. (AISC) and the American Concrete Institute (ACI).

BLANK PAGE

BLANK PAGE

20 RIGHT HAND DOOR
MAYL 301557
2 Required
Scale 1"=1'

3 LEFT HAND
MAYL 301557
2 Required
Scale 1"=1'

TYPICAL DETAIL
FOR DOORS
Scale 1"=1'

22 DRIVE BURNING
MAYL 301557
2 Required
Scale 1"=1'

23 DRIVE BURNING
MAYL 301557
2 Required
Scale 1"=1'

NOTE: A
All assembly With Main Body Part 12
This Gap Between Doors Parts 1 & 2
Must Be 1/4" See Fig 2-1-10

GENERAL SPECIFICATIONS	DETAILS
1. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.	1. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.
2. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.	2. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.
3. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.	3. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.
4. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.	4. All work shall be done in accordance with the specifications of the Department of the Interior, Bureau of Reclamation, and the Bureau of Indian Affairs.
 

BLANK PAGE

BLANK PAGE

(16) Top Plug Detail
MATL 300 SERIES SS 3 LEAD
1 REQUIRED

GENERAL SPECIFICATIONS	TOLERANCES UNLESS OTHERWISE SPECIFIED
1. UNLESS OTHERWISE SPECIFIED 2. TYPE, GRADE, OR FINISH OF MATERIALS, MAY BE CHANGED BY SUBSTITUTION 3. FINISHED SURFACE FINISH SHALL NOT EXCEED OVER 100-1000	FINISHES UNLESS OTHERWISE SPECIFIED FINISHES DECIMALS ANGLES SCALE

BLANK PAGE

TER. PLUG DETAIL
MATH: 300 SERIES SST & LEAD
REQUIRED

Assembly Details Page Single		Form CO-200	
Garden Carrier No. 2 Assembly		Rev. 10-22-72	
REFERENCE NUMBER		NO.	
See BOM BATTERY LAYOUT PROVIDED BY DAVID CARBIDE CORPORATION ONE HUNTER TERRACE			
C.T.D. CASE		4500	
GARDEN CARRIER NO. 2 DETAIL SHEET NO. 7			
DATE		BY	
10-1-73		W. E. Hines	
M	11332	EM	017
			0

APPROVED FOR CONSTRUCTION

BLANK PAGE

BLANK PAGE

BLANK PAGE

GENERAL NOTES

1-347 St. St. May Be Subst.
2-Tube (s) May Be Fabricated
3-Roll Tag (s) To Diameter
4-Weld Joints 1/2 To Be
Helium Leak Test. Wt.
5-After Fabrication The
According With DOT
6-D Ring Material To Be
Type 2-185
7-Quality Level III.

Top View

Elevation

Bottom

1/2" Drill - 1/2" Deep
2-Holes

Cap Detail

THREAD	MA
60000	Max
5.9888	Max
5.9778	Max
5.9657	Max
5.9537	Max

Flange Detail

Groove De

Each Container Shall Be
Marked (Stamps) With Radioactive
Material Tag As Shown
2' x 2 1/2' x 1/4" Thick Plate And
Weld To The Container.

WARNING: CAP-60 HAS
RADIOACTIVE MATERIAL.
PROPERTY OF
CERAMIC RESEARCH
CORP. DO NOT USE
OR REUSE. PLEASE RETURN.

Tag Detail

SPES	No	INSPE	DATE	BY	REMARKS
WPS-345	1	RT			
"	2	RT			
"	3	V			
"	4	V			
"	5	V			

NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, IS MADE
THAT THE USE OF INFORMATION OR ANY INFORMATION, APPLICABLE
METHODS OR PROCEDURES IN THIS DOCUMENT MAY NOT CAUSE
HARMFUL RESULTS OF DAMAGE. NO LIABILITY IS ASSUMED WITH RESPECT TO
THE USE OF, OR FOR DAMAGE RESULTING FROM THE USE OF, ANY
INFORMATION, APPLICABLE, METHOD OR PROCEDURE DESCRIBED IN THIS
DOCUMENT. THE DRAWINGS AND DATA ARE AVAILABLE FOR INFORMATION
TO BE USED FOR OTHER PURPOSES, AND ARE
TO BE RETURNED UPON REQUEST OF THE INFORMATION CONTROLLER.

TRAVERSE UNLESS
OTHERWISE SPECIFIED:
FRACTIONS a
DECIMALS a
ANGLES a
SCALE 1/2" = 1" Unless Noted

BLANK PAGE

GENERAL NOTES

- 1-307 St. Steel May Be Substituted For 304L St. Steel
- 2-Tube (a) May Be Fabricated From $\frac{1}{8}$ " Thick Plate
- 3-Roll Tag (B) To Diameter Of Outside Of Container
- 4-Weld Joints 1/8" To Be Tested After Fabrication By Medium Leak Test-Weld Joints 1/8" And Small Inspection
- 5-After Fabrication The Container Will Be Cleaned In Accordance With ROT STD #5-1, 2, 3
- 6-Ring Material To Be Neoprene Or Silastic 32 Or 33 Size 2-765
- 7-Quality Level III.

Cap Detail**THREAD TABLE 6-12 PITCH**

Male		Female	
6.0000	Max. Major Diam	6.0000	Min. Major Diam
5.9998	Min. " "	5.9998	Max. Minor Diam
5.9778	Max. Minor Diam	5.9788	Max. " "
5.9997	Max. Pitch Diam	5.9957	Min. Pitch Diam
5.9371	Min. " "	5.9347	Max. " "

MATERIAL LIST

Qty	Description	Mat'l
1	Cable 1/8" x 8" LUCHE No 22-03-5085	100 St. Steel
1	Cap 6.628" x 1/8"	304L St. Steel
1	Flange 6.628" x 1/8"	" "
1	Tube 6.628" x 0.075" x 5.06" x 22" Lg	" "
1	Plate 6.628" x 1/8"	" "
1	Ring 6.628" x 0.075" x 5.06" x 22" Lg	304L St. Steel
1	Ring 6.628" x 0.075" x 5.06" x 22" Lg	304L St. Steel
1	Plate 6.628" x 1/8"	" "

Groove Detail

This Drawing Supersedes Dwg M-11332-EM-019-DR3

Flange Detail **Tag Detail**

Garden Carrier No 2 Assembly		EM-019-E
REFERENCE DRAWINGS		REVISION
GAS RING REMOVAL LAYOUT DESIGNED BY UNION CARBIDE CORPORATION GAS RING REMOVAL		
GARDEN CARRIER No 2 SCREW TOP INNER CONTAINER		
DATE	APPROVED	APPROVED
1/1/68	1/1/68	1/1/68
M 11332	EM 019	D

APPROVED FOR CONSTRUCTION

BLANK PAGE

VIEW A-A "O" RING GLAND
& CAN CONSTRUCTION
Scale: 2"=1"

- Notes:**
1. O Ring Material To Be Neoprene Or Silastic
  2. $\frac{3}{8}$ -24 UNF = $\frac{7}{8}$ Long Hex Head Bolt (Dried Head For Safety Wire)
Thread Length $\frac{5}{8}$ Long Minimum
Material: 4150 Or 150,000 Minimum
Yield Strength Order Number Of Bolts
Required For Shipping Cans To Be Fabricated
  3. Each Container Shall Be Marked With Radioactive Material Tag As Shown. 2" x 2" Plate And Weld To The Container.
  4. Design As Shown Is Satisfactory For Containing Material Within The Garden Carrier No 2 Dwg. N-11332-EM-0. Length Of Can May Be Changed As Required
  5. Stress Relief Completed Container
  6. All Material 304L Stainless Steel.
  7. Weld Specification In Accordance With WPS-302, Insp. Met. WK-201 Sch. F.
  8. Threads Shall Be Chased To Standard Smooth Finish. Clean And Lubricate With
  9. Glue Gasket In Groove.
  10. QL-3

VIEW B-B LIFTING RING
Scale: 2" = 1"

Not To Scale

THE REPRESENTATION OF PROPERTY INTERESTS OF INDIVIDUALS IS MADE FOR THE USE OR ENCLOSURE OF ANY INFORMATION APPROPRIATE METHOD OF PROPERTY ENCLOSURES OF THESE INDIVIDUALS MAY NOT INCLUDE PRIVATE RIGHTS OF OTHERS. NO LIABILITY IS ASSIGNED WITH RESPECT TO THE USE OF, OR THE METHODS RELATING FROM THE USE OF, ANY INFORMATION, APPROPRIATE METHOD OF PROPERTY ENCLOSURES OF THESE INDIVIDUALS, OR ANY OTHER INFORMATION AVAILABLE FOR INFORMATION TO OTHERS AND NOT TO BE USED FOR OTHER PURPOSES, AND ARE TO BE DELETED FROM REPORTS OF THE INFORMATION CONTAINED

GENERAL SPECIFICATIONS

UNLESS OTHERWISE SPECIFIED:

1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR
3. MACHINED SURFACE FINISH SHALL NOT EXCEED:
(ASA B46.1-1987) ✓

BLANK PAGE

**VIEW A-A 'O' RING GLAND
& CAN CONSTRUCTION**
Scale: 2"=1"

- Notes:**
1. "O" Ring Material To Be Neoprene Or Silastic.
  2. 1/4"-24 UNF x 1/8" Long Hex Head Bolt (Drilled Head for Safety Wire) Thread Length 5/8" Long Minimum Material: A30 Or 150,000 Minimum Yield Strength. Order Number Of Bolts Required For Shipping Cans To Be Fabricated.

3. Each Container Shall Be Marked With Radioactive Material Tag As Shown. 2"x2 1/2"x 1/2" The Photo And Weld To The Container.

4. Design As Shown Is Satisfactory For Containing Material Within The Garden Carrier No 2 Dwg. M 11332-EM 010-E Length Of Can May Be Changed As Req'd.

5. Stress Relieve Completed Container.
6. All Material 304L Stainless Steel.

7. Weld Specification In Accordance With Spec. WPS-302, Insp. Met. WR-201 Sch. F.

8. Threads Shall Be Chased With Standard Tap To Ensure Smooth Finish. Clean, And Lubricate With Molykote.

9. Glue Gasket In Groove.

10. QLS

VIEW B-B LIFTING RING
Scale: 2"=1"

PARTS LIST			
PART	QTY	REQD	DESCRIPTION

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

STOCK SIZE		MATERIAL	

||
||
||

BLANK PAGE

SECTION B-B
SCALE: 1/2" = 1'

FISSILE RADIOACTIVE MATERIAL
DOT SP 5936
ORNL-BS11-174 WEIGHT 11,600 LBS

RETURN TO
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

FILL WITH YELLOW SHAPEL

DETAIL ITEM 25

LOCATE AND WELD ON FRONT & TOP OF "I" BEAM CENTER DRY HOLE CHARGER ONLY

RELAYED 2" x 2" WROUGH STEEL BUTT WELDED - TACK WELD PING. 1 RELAYED MEET

NOTES

FABRICATE SKID FROM MILD STEEL. ALL JOINTS SHALL BE CONTINUOUSLY WELDED FULL PENETRATION. PAINT COMPLETED ASSEMBLY WITH 1 COAT OF CHROME PRIMER & 2 COATS OF GRAY MACHINE ENAMEL.

SECTION A-A
SCALE: 1/2" = 1'

SHIPPING SKID DETAIL
SCALE: NOTED

SECTION C-C
SCALE: 1/2" = 1'

NO.	REVISIONS	DATE	APPD.	APPD.
1	GENERAL (PINS, BOLTS, RING)	10/1/54	WML	
2	CHANGED BOLT TO NUT SEE C.C. NO. 1	11/1/54	WML	
3	ADDED IDENTIFICATION PLATE	11/1/54	WML	
4	ADDED 2 HOLES IN SHIPPING SKID	11/1/54	WML	
5	REMOVED Dwg. 0-689-D ADDED Dwg. EM-051-D REMOVED FREE SHIELD & PAW ADDED PAGE R. SHIPPING SKID	6-15-56	WML	
6	ADDED NOTES	11/1/54	WML	

SECTION C-C
SCALE: 1/2" = 1'

- NOTES**
1. Maintain and use discretion to avoid excess build-up of rebar.
  2. This drawing is intended for fabrication in our shop and is not to be used elsewhere.
  3. Remove A Section Of The Bottom Plate 10" From E. Of Skid Weld All Around. Patch C (SEE Dwg. 0-687-0600) Replace Existing Plate

BLANK PAGE

FISSILE RADIOACTIVE MATERIAL
DOT SP 5936
ORNL-8511-174 WEIGHT 11,600 LBS

RETURN TO
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

FILL WITH YELLOW DRAPEL

DETAIL ITEM (20)

LOCATE AND WELD ON FRONT & TOP OF
1" BREAK CENTER
DRY HOLE CHARGER ONLY

HEAVY WELDED STEEL
F HINGED - THEN
PINS & RELOCATE HANG

P.B.

FROM WELD STEEL
ALL BE CONTINUOUSLY
INSULATION. PAINT
HEAVILY WITH 1 COAT OF
& 2 COATS OF GRAY

L. COMPARTMENTS

16" DRILL 2 HOLES
ALIGNMENT PIN 2 PLACES

Garden Carrier No. 2 Screw Top Inner Container	CD-086-B
Fire Shield Assembly & Details G.C. No. 2	CD-063-2
Garden Carrier Assembly & Shield Assembly	EM-018-E EM-051-D
REFERENCE DRAWINGS	DWG. NO.
PRFP CHEMICAL DEVELOPMENT	NO. 3597
GARDEN CARRIER NO. 2 / DRY HOLE CHARGER	
SHIPPING SKID - FIRE SHIELD & PAN	

1. Manufacture must use discretion to avoid excess build-up of rebar.

2. This drawing is intended for fabrication in one step and is not to be cut outside for field.

3. Remove A Section Of The Bottom Plate 12" x 18", Place Two Plates 6" x 18" x 1/2" Thick 6" From E. Of Side Weld All Around, Pack Cavity With 4 Thickness Of Insulation (3A, Mx 01-267-0600) Replace Existing Plate And Weld All Around.

LEAVE OR DIMENSIONS UNLESS OTHERWISE SPECIFIED:

FRACTIONS 1/2"

DECIMALS 1/16"

ANGLES 1/4"

SCALE NOTED

REVISIONS	APPROVED	DATE
1. R.C. 1/1/64	J.M. 1/1/64	1/1/64
2. R.C. 1/1/64	J.M. 1/1/64	1/1/64
3. R.C. 1/1/64	J.M. 1/1/64	1/1/64
4. R.C. 1/1/64	J.M. 1/1/64	1/1/64
5. R.C. 1/1/64	J.M. 1/1/64	1/1/64
 

M-12124-CB-043-2-5

BLANK PAGE

BLANK PAGE

BLANK PAGE

[illegible] [illegible]

DETAIL ITEM ⑬
2009.1.1

ASSEMBLY
June 1961

DETAIL ITEM ③

[illegible]

BLANK PAGE

NOTES:

1. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
2. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
3. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
4. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
5. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
6. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
7. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
8. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
9. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3
10. From 3 Cap. with other 2 in Base Plate. In the manufacture to be placed on 3' Center vertically Every 10' From 100' to the Top. On the 100' Cap in the Center and Two Rows One Row 6" Every 30' And One Row 12" Every 30' Total Cap 3

DETAIL ITEM ①

DETAIL ITEM ⑮

DETAIL ITEM ⑯

Support to Structure

DETAIL ITEM ⑰

WELD NOTES:

WELD	DESCRIPTION	WELD	DESCRIPTION
 
18	Cap	18	Cap
19	Base Plate	19	Base Plate
20	Cap	20	Cap

PARTS LIST

ITEM	QTY	DESCRIPTION	UNIT	REMARKS
1	1	Base Plate	1	Base Plate
2	1	Cap	1	Cap
3	1	Base Plate	1	Base Plate
4	1	Cap	1	Cap
5	1	Base Plate	1	Base Plate
6	1	Cap	1	Cap
7	1	Base Plate	1	Base Plate
8	1	Cap	1	Cap
9	1	Base Plate	1	Base Plate
10	1	Cap	1	Cap
11	1	Base Plate	1	Base Plate
12	1	Cap	1	Cap
13	1	Base Plate	1	Base Plate
14	1	Cap	1	Cap
15	1	Base Plate	1	Base Plate
16	1	Cap	1	Cap
17	1	Base Plate	1	Base Plate
18	1	Cap	1	Cap
19	1	Base Plate	1	Base Plate
20	1	Cap	1	Cap

ASSEMBLY
Base Plate

Approved for Construction	Approved for Construction
Approved for Construction	Approved for Construction
Approved for Construction	Approved for Construction
Approved for Construction	Approved for Construction

ASSEMBLY & DETAILS	ASSEMBLY & DETAILS
GARDEN CARRIER NO. 2	GARDEN CARRIER NO. 2
1977	1977
1977	1977

APPROVED FOR CONSTRUCTION

BLANK PAGE

12.2 Appendix B - Approval Documents

	<u>Page No.</u>
Department of Transportation Special Permit No. 6088 dated Oct. 1, 1969	98
First Revision DOT Special Permit No. 6088 dated Aug. 5, 1971	101
Interim AEC Certificate of Compliance AEC-OR USA 6088/BLF dated Sept. 21, 1973	102
ORNL Nuclear Safety Review NSR 742 dated June 17, 1974	103
Letter of Approval of SARP after Review by ORNL Transportation Committee, E. M. King to R. D. Seagren dated Nov. 30, 1977.	105

BLANK PAGE

DEPARTMENT OF TRANSPORTATION
HAZARDOUS MATERIALS REGULATIONS BOARD
WASHINGTON, D.C. 20590

SPECIAL PERMIT NO. 6088

This special permit is issued pursuant to 49 CFR 170.15 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of the August 11, 1969, petition by Oak Ridge National Laboratory, Oak Ridge, Tennessee.

1. Shipments of fissile and large quantities of radioactive materials, n.o.s., are hereby authorized in the packaging as described in this special permit. This packaging, when constructed and assembled as prescribed herein, with the contents as authorized herein meets the standards prescribed in the DOT regulations, Sections 173.395(c)(2), 173.396(c)(3), and 173.398(c). Shipments must be in accordance with the provisions of the U. S. Atomic Energy Commission (USAEC), Oak Ridge Operations Office approval number 69-014 dated August 4, 1969, and as further provided for herein.
2. Each shipper, under this permit, other than the petitioner named above, shall register his identity with this Board prior to his first shipment, and shall have a copy of this permit in his possession before making any shipment.
3. The packaging authorized by this permit consists of lead-filled, steel cask weldment, which is a right cylinder approximately 25" in diameter by 49" high, weighing about 8500 pounds, with a 7" diameter by 24" deep cavity. Approximately 8 3/16" of lead shielding is provided. Contents are loaded within DOT Specification 2R or equivalent inner containment. The package is identified as the Garden Carrier Number 2 Shipping Cask, and is described on Oak Ridge National Laboratory's drawing number M-12166-CD-037-D and in the attachment to the USAEC Certification.
4. The contents of each package authorized by this permit consist of fissile and large quantities of radioactive material n.o.s., in the form of unirradiated and irradiated fuel elements and contained sections of fuel elements with solid and liquid mixed fission products, or waste products. Liquids will be contained in primary polyethylene or stainless steel bottles within

the DOT Specification 2R containment vessel. The maximum thermal decay energy of the contents is 100 watts. The fissile content is limited to not more than 500 grams of uranium-235, 350 grams of uranium-233 or plutonium, or 350 grams of any combination thereof.

5. The packaging authorized by this permit meets the requirements for shipment as Fissile Class I. The transport index must be assigned based on external radiation levels.

6. The outside of each package must be plainly and durably marked "DOT SP 6088", in connection with and in addition to the other markings and labels prescribed by the DOT regulations. Each shipping paper issued in connection with shipments made under this permit must bear the notation "DOT SPECIAL PERMIT NO. 6088", in connection with the commodity description thereon.

7. Each package must have its gross weight plainly and durably marked on the outside of the package.

8. This permit authorizes shipments only by motor vehicle, and rail.

9. The shipper is required to furnish an experience report to this Board before expiration of the permit and when any amendment is requested. This report must include the approximate number of packages shipped, and the number of packages involved in any loss of contents. The modes of transportation used for these shipments must also be shown.

10. Prior to each shipment authorized by this permit, the shipper shall notify the consignee of the dates of shipment and expected arrival. The shipper shall notify each consignee of any special loading/unloading instructions prior to his first shipment.

11. Any incident involving loss of contents of the package must be reported to this Board at the earliest feasible moment following the incident.

Continuation of SP 6088

Page 3

12. This permit does not relieve the shipper or carrier from compliance with any requirement of the DOT regulations, except as specifically provided for herein.

13. This permit expires September 30, 1971, and may be revoked for cause at any time.

Issued at Washington, D.C.:

W. R. Fiste
For the Administrator
Federal Highway Administration

25 September 1969
(Date)

Mac E. Rogers
For the Administrator
Federal Railroad Administration

OCT - 1 1969
(Date)

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U.S. Department of Transportation, Washington, D.C. 20590. Attention: Special Permits.

Dist: a, d, e, h, i

DEPARTMENT OF TRANSPORTATION
HAZARDOUS MATERIALS REGULATIONS BOARD
WASHINGTON, D.C. 20590

SPECIAL PERMIT NO. 6088
FIRST REVISION

Pursuant to 49 CFR 170.15 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of the July 22, 1971, petition by the Oak Ridge National Laboratory, Oak Ridge, Tennessee:

Special Permit No. 6088 is hereby amended by revising paragraph (13) to read as follows:

"13. This permit expires on September 30, 1973."

All other terms of this permit, as revised, remain unchanged. The complete permit currently in effect consists of the original issue and the First Revision.

Issued at Washington, D.C.:

J. R. Fiste
For the Administrator
Federal Highway Administration

2 AUG 1971
(DATE)

Mac E. Rogers
For the Administrator
Federal Railroad Administration

AUG 5 1971
(DATE)

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U.S. Department of Transportation, Washington, D.C. 20590.
Attention: Special Permits.

Dist: a, c, e, h, i
U.S. Atomic Energy Commission, Richland, Washington

Form AEC-418
(9-72)
AECM 5201

U.S. ATOMIC ENERGY COMMISSION
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1a. Number AEC OR	USA 6083/BLF	1b. Revision No. 0	1c. Page No. 1	1d. Total No. Pages 1

2. Authority

This certificate is issued pursuant to Sections 172.394, 172.395, and 172.396 of the Department of Transportation Hazardous Materials Regulations as amended (49 CFR 170-199 and 14 CFR 192), and AEC Manual Chapters 5201 and 0529.

3. CONDITIONS

3a. This certificate is issued on the basis of SAFETY ANALYSIS REPORT FC-1: PACKAGING (SARP)

(1) Prepared by
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee 37830

(2) Number Letter of Request
(H. E. Ramsey)

(3) Date Published
July 6, 1969

3b. The packaging described in the SARP and further described in item 4 below, when constructed and assembled as prescribed in the SARP, with the contents as authorized herein, meets the standards prescribed in DOT regulations.

3c. The outside of each package must be plainly and durably marked with the letters and number shown in item 1a. on this form in accordance with the standards for markings in paragraph 173.24(b) of 49 CFR 173.

3d. This certificate does not relieve the consignor from compliance with any requirements of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies.

3e. Each user of packages approved under this certificate shall register his name and address with the issuing office.

4. Description of Packaging and Authorized Contents, Reservations, and References.

- A. The packaging consists of a lead-filled, steel cask weldment, which is a right cylinder approximately 25" O.D. x 49" high with a 7" I.D. x 24" deep cavity. Lead shielding approximately 8-3/16" thick is provided. The top opening is closed by a stainless steel clad lead shield. The bottom opening has two stainless steel clad lead shielded opposing stepped sliding drawers. All openings are sealed with neoprene gaskets. Contents are loaded within DOT Specification 2R or equivalent inner containment. The gross weight is approximately 8500 lb.
- B. The authorized contents of each package consists of fissile and large quantities of radioactive materials, N.O.S., in the form of unirradiated and irradiated fuel elements and contained sections of fuel elements with solid and liquid mixed fission products, or waste products. Liquids will be contained in primary polyethylene or stainless steel bottles within the DOT Specification 2R Containment vessel. The maximum thermal decay energy for solid nonfissile radioisotopes is 100 watts and for liquid nonfissile radioisotopes is 11.5 watts. The fissile content is limited to not more than 500 g of ^{235}U , 350 g of ^{233}U or Pu , or 350 g of any combination thereof.
- C. Shipments are authorized as Fissile Class I. The Transport Index is assigned on the basis of external radiation levels.
- D. Shipments are authorized by motor vehicle and rail.

TO BE COMPLETED BY AEC

5a. Address for AEC Approving Official U.S. Atomic Energy Commission P.O. Box E Oak Ridge, Tennessee 37830	5b. Signature for AEC Approving Official
	5c. Name and Title for AEC Approving Official William H. Travis, Director Safety & Environmental Control Division
	6. Expiration Date (if appropriate) ? Date September 21, 1972

REQUEST FOR NUCLEAR SAFETY REVIEW

This request covers operations with fissile material in a control area and/or fissile material transfers that originate within the control area. The control area supervisor shall complete the blocks below and describe the process and/or operations to be performed, emphasizing the provisions for nuclear criticality safety on the reverse side of this page. This request shall be approved by the Radiation Control Officers of the originating Division and the Division(s) to which fissile material will be transferred.

ORIG.	
CRITICALITY COMMITTEE	
NSR 742	
EXPIRATION DATE	July, 1979

TITLE, CONTROL AREA, AND SUMMARY OF BASIC CONTROL PARAMETERS

(To be completed by the Control Area Supervisor)

TITLE (FOR REFERENCE PURPOSES)		DATE OF REQUEST	DATE REVIEW REQUESTED
Garden Carrier No. 2		5/1/74	5/15/74
CONTROL AREA	CODE NO.	BUILDING ROOM	DIVISION
		4500B	Chem. Tech.
TYPE AND FORM OF MATERIAL	Unirradiated or irradiated fuel elements and contained sections of fuel element, solid and liquid mixed fission products plus fissionable material		
ISOTOPIC ENRICHMENT (WT. %)	Natural to fully enriched		
QUANTITY OF FISSILE ISOTOPES	PER ISOLATED BATCH OR UNIT Maximum 500 g ^{235}U , 350 g ^{233}U or Pu, or 350 g of any combination		
	TOTAL IN CONTROL AREA		
	TOTAL TO BE PROCESSED		
Concentration or Density of Fissile Material			
Spacing of Fissile Units	Class I Large Quantity Shipment use		
Proximity and Type of Neutron Reflectors or Adjacent Fissile Material			
Limit on Moderation			
Limit on Neutron Absorbers			
Limit on Volume or Dimensions of Containers	8.1875 in. lead shielded cask 25-3/16 in. OD x 46-1/8 in. high, 7.065 in. ID x 24 in. deep, right cylinder		
THIS REQUEST MODIFIES, REPLACES NSR NO.			
replaces NSR 395 which expires 5/15/74			

RECOMMENDATIONS

(To be completed by the Criticality Committee)

This endorsement is based on our present understanding of the operation (whether acquired verbally or in writing) and is subject to review and cancellation.

The 9-in.-thick lead-steel shield surrounding the fissile material, effectively isolates the limited quantity of fissile payload, thus eliminating effective interaction between similar, adjacent casks. The requirements of Fissile Class I are therefore met for this cask when loaded as described in this NSR. The proposed loadings are approved.

 J. P. Nichols
 Chairman, Criticality Committee
 6/17/74

PROVISIONS FOR NUCLEAR CRITICALITY SAFETY

(To be completed by the Control Area Supervisor)

Provisions for nuclear criticality safety shall be described below in accordance with Appendices II and III of the AEC Manual Chapter 0530. This shall include brief descriptions of the process and/or all operations to be performed, plans and procedures for the operations for nuclear criticality safety, and the basic control parameters. Please attach 11 copies of referenced drawings and documents.

The SARP for the Carden Carrier No. 2 is in process of preparation. This document will be included as an appendix.

The masses of fissionable isotopes are the same as previously requested and approved on Nuclear Request Nos. 331, 365, and 375.

ORNL
CRITICALITY COMMITTEE
NSR 742

EXPIRATION DATE
July, 1978 1979

RADIATION CONTROL OFFICER	DIVISION	CON. AREA SUPERVISOR	BUILDING
RADIATION CONTROL OFFICER	DIVISION	RADIATION CONTROL OFFICER	DIVISION

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

November 30, 1977

TC 75-6

To: R. D. Seagren
From: Transportation Committee
Subject: SARP of the ORNL Garden Carrier No. 2 --
Draft

The Committee has reviewed the subject draft dated November 10, 1977. Attached are comments made by individual members of the Committee for changes needed or suggested. The SARP is approved for technical content and approach -- with the expectation that you will make a positive response to the comments. (If you have any question concerning the comments, please contact the individual making the comments.)

E. M. King, Chairman
Transportation Committee

EMK:bb

cc: Transportation Committee
G. H. Burger
J. A. Cox

12.3 Appendix C: Computer Program to Calculate Corner Drop Negative Acceleration Forces

Program 1001 Cask Derivation of Equations

When a cask constructed of a single, ideally plastic material impacts on its top corner, the major portion of the kinetic energy will be dissipated through displacement of material in the impact area. An ideally plastic material is a material that has a constant stress for all values of strain.

The expression

$$dU = S dV, \quad (C-1)$$

where

S = the quantity of energy required to displace a unit volume of material;

V = the displaced volume of material and can be used as a basis for determining the effect of the top-corner impact. (The lack of an accurate numerical value of S necessitates a conservative estimation of its value.);

U = the kinetic energy.

With reference to the computational diagram illustrated in Fig. C.1, it may be said that

$$dV = 1/2 XY dZ. \quad (C-2)$$

By trigonometry,

$$X = r(\cos B - \cos A). \quad (C-3)$$

$$Y = X \tan \alpha = \tan \alpha \ r(\cos B - \cos A). \quad (C-4)$$

$$dZ = r \cos dB. \quad (C-5)$$

It follows that,

$$dU = SXYdZ/2. \quad (C-6)$$

ORNL DWG 75-93

Fig. C.1. Model for corner drop calculations.

and

$$U = \Sigma dU = \Sigma SXYdZ \quad 2. \quad (C-7)$$

This expression can be readily solved using the computer. A value for the angle, A , can be assumed and B incremented from $-A$ to A or from 0 to A if the result is multiplied by two and the energy required for the assumed deformation is computed. A is started small, incremented, and the energy required is compared with the cask's potential energy. In this manner, a calculated impact history is produced. The program also computes other variables using the expressions below. The maximum deformation, Δ , is found in the following manner:

$$\Delta = \sin \alpha (1 - \cos A) (r). \quad (C-8)$$

The applied force, F , $F = dU/d\Delta$, and the acceleration, a , was computed from the following equation:

$$a = F/Wg. \quad (C-9)$$

The velocity at any increment is found from the following kinetic energy principle:

$$\Delta KE = U = (M/2)(V_o^2 - V^2) \quad , \quad (C-10)$$

or

$$V = (V_o^2 - 2U/M)^{1/2} = \left[(2g/W)(Wh - U) \right]^{1/2} \quad (C-10a)$$

where

V_o = initial velocity,

M = cask mass,

W = weight,

h = drop height,

g = gravitational constant.

The time is computed from the relationship:

$$a = dV/dt, \quad (C-11)$$

or

$$dt = dV/a, \quad (C-11a)$$

and summary techniques.

The computer program is given and the results for specific energies of 100,000 and 260,000 in.-lb in.³ are given. The plots of the negative accelerations versus deformation are given in Figs. C.2 and C.3.

Fig. C.2. Plot of negative acceleration vs deformation at a specific energy of 100,000 in.-lb/in.³ for steel for the 30-ft corner drop.

Fig. C.3. Plot of negative acceleration vs deformation at a specific energy of 260,000 in.-lb/in.³ for steel for the 30-ft side drop.

OPTS,L,E,C.

C PROGRAM NUMBER 1001-CASE
C MADE OF A HOMOGENEOUS MATERIAL / AN IDEAL STRESS-STRAIN RELATIONSHIP
C IMPACTING AN UNYIELDING SURFACE. THE CASE IMPACTS ON ITS CORNER
C THIS PROGRAM COMPUTES THE RESPONSE OF A CASE HAVING RIGHT CYLINDRICAL
C GEOMETRY.
C BY JOHN SWANS P.E., GENERAL ENGINEERING DIVISION, CAR RIDGE NATIONAL LAB.

GLOSSARY OF NOTATION

C R=RADIUS OF CASE
C C=CASE LENGTH
C S=YIELD STRESS OR FLOW PRESSURE
C W=CASE WEIGHT
C H=DROP HEIGHT
C O=ANGLE AT WHICH CASE IMPACTS
C U=ENERGY
C F=FORCE
C T=TIME
C AG=ACCELERATION
C UT-TOTAL ENERGY
C V=VELOCITY
C X=DEFORMATION
C AB=ANGLE IN CONTACT / THE SURFACE

1 DIMENSION V(1000),AV(1000),P(1000),U(1000),T(1000),AG(1000),
1 X(1000),AG(1000)
P=3.141592654
S=0.0
AVA = 0.0

C INPUT MATERIAL CONSTANT

C INPUT CASE GEOMETRY

1010 POPRAT(1H,30X)
W=1200.
R=21.5
C=51.5625
O=ATAN(2.*P/C)
DO 90 NN=1,2
N=48
IF(NN.EQ.2) N=360.
DO 90 N=1,2
S=100000.
IF(NN.EQ.2) S=260000.

C INPUT TEST CONDITION

C INPUT ANGLE INCREMENTS

30 AB=.01
AB=.01
WRITE (51,1002)
WRITE (51,1002)
WRITE (51,1010)
WRITE (51,1002)
WRITE (51,1002)

C ZERO SUBSCRIPTED VARIABLES

DO 10 I=1,1000
AV(I)=0.0
AG(I)=0.0
V(I)=0.0
X(I)=0.0

```

      C(1) = 0.0
      F(1) = 0.0
      U(1) = 0.0
      AP(1) = 0.0
14 CONTINUE
C 17 NO NONSUBSCRIPTED VARIABLES
      TA = 0.0
      AT = 0.0
      A = 0.0
      AB = 0.0
      TX = 0.0
      B = 0.0
      XB = 0.0
      XA = 0.0
      UT = 0.0
      VV = SQRT((64.0*W)/12.)
      DO 1 I = 1, 1000
        AB = 0.0
C  INCREMENT ANGLE A
        9 A = A + AA
          CB = COS(A)
          B = 0.0
          AT = 0.0
          SUMU = 0.0
10 DO 2 J = 1, 1000
C  INCREMENT ANGLE B
          B = B + BB
          CB = COS(B)
C  CALCULATE VOLUME DISPLACED
11 CC = (CB - CA)
          BY = (TAN(O) * B) * CC
          BX = B * CC
12 BZ = B * CB * BB
          BU = BY * BX + BZ * B
C  CALCULATE ENERGY ABSORBED
          SUMU = SUMU + BU
C  CALCULATE AREA
13 BA = 2.0 * BX * BZ / COS(O)
          AP = AP + BA
          IF (B .GE. A) GO TO 3
        2 CONTINUE
        1 U(I) = SUMU
          AP(I) = AP
C  CALCULATE FORCE
          F(I) = AP(I) * S
C  CALCULATE VELOCITY
          IF (U(I) .GE. UT) GO TO 16
          5 VA = SQRT((64. / (12. * W)) * (UT - U(I)))
16 IF (U(I) .GE. UT) VA = 0.0
C  CALCULATE ACCELERATION
          AC(I) = F(I) / U
C  CALCULATE DEFORMATION
          XA = (TAN(O) * COS(O) * B * (1. - CA))
          X(I) = XA
C  CALCULATE TIME
          TX = (XA - XH) / ((VV + VA) * G.)
        7 TA = TA + TX

```

```

      T(I) = TA* 1000.
      IX=XA
6     V(I) = VA
8     VV=VA
      AN(I) = A* 57.3
      IF (U(I).GE.UT) GO TO 4
1     CONTINUE
4     CONTINUE
C     OUTPUT-WRITE LOOP
      K=I
      WRITE (51,1002)
      WRITE (51,1004)
1004  FORMAT (1H, 9X,37BCASK GEOMETRY AND MATERIAL PROPERTIES)
      WRITE (51,1002)
      WRITE (51,1005)
1005  FORMAT (1H, 4X,6HRADIUS,8X,6HLENGTH,10X,6HWRIGHT,6X,
1       15HSPECIFIC ENERGY)
      WRITE (51,1006)
1006  FORMAT (1H, 4X,6HINCHES,8X,6HINCHES,10X,6HPOUNDS,8X
1       13HLB-IN/CU. IN.)
      WRITE (51,1002)
1002  FORMAT (1H0)
      WRITE (51,1007) P,C,W,S
1007  FORMAT (F11.3,F14.3,F16.1,F18.1)
      WRITE (51,1002)
      WRITE (51,1000)
1000  FORMAT (1H.,4X,11HDEFORMATION,4X,8HVELOCITY,7X,4HTIME,13X,5HFORCE,
1       10X,6HENERGY,5X,12HACCELERATION)
      WRITE (51,1001)
1001  FORMAT (1H, 6X,6HINCHES,7X,8HFT./SEC.,4X,12HHILLISECONDS,8X,
1       6HPOUNDS,10X,6HIB-IN.,10X,3HX G)
      WRITE (51,1002)
      DO 15 I=1,K
      WRITE (51,1003) X(I),V(I),T(I),F(I),U(I),AG(I)
1003  FORMAT (1H ,F14.4, F13.2, F16.5, F15.2, F16.2, F12.2)
15     CONTINUE
      CALL QWIKPL(X,AG,K,'LINEAR','J.H.IVANS')
20     CONTINUE
90     CONTINUE
      STOP
      END

```

CASK GEOMETRY AND MATERIAL PROPERTIES

RADIUS INCHES	LENGTH INCHES	WEIGHT POUNDS	SPECIFIC ENERGY LB-IN/CU. IN.

21.500	51.563	12400.0	100000.0

DEFORMATION INCHES	VELOCITY FT./SEC.	TIME MILLISECONDS	FORCE POUNDS	ENERGY LB-IN.	ACCELERATION G

0.0007	43.82	0.00131	0.0	0.0	0.0
0.0028	43.82	0.00524	180.59	0.19	0.01
0.0062	43.82	0.01178	782.36	1.84	0.06
0.0110	43.82	0.02095	2045.61	8.66	0.16
0.0172	43.82	0.03273	4211.11	28.04	0.34
0.0248	43.82	0.04712	7517.73	72.42	0.61
0.0337	43.82	0.06413	12205.85	160.63	0.98
0.0440	43.82	0.08376	18513.43	219.11	1.49
0.0557	43.81	0.10599	26678.64	583.25	2.15
0.0688	43.81	0.13083	36939.02	998.72	2.98
0.0832	43.81	0.15828	49531.50	1622.69	3.99
0.0990	43.81	0.18834	64690.68	2525.06	5.22
0.1162	43.80	0.22100	82651.81	3789.82	6.67
0.1347	43.79	0.25626	103647.31	5516.10	8.36
0.1546	43.78	0.29413	127910.50	7819.70	10.32
0.1759	43.76	0.33460	155671.75	10833.94	12.55
0.1985	43.75	0.37768	187158.81	14710.74	15.09
0.2225	43.72	0.42336	222602.69	19622.75	17.95
0.2478	43.69	0.47165	262225.81	25762.69	21.15
0.2745	43.65	0.52257	306257.13	33346.75	24.70
0.3025	43.61	0.57610	354914.94	42613.16	28.62
0.3319	43.55	0.63228	408424.38	53825.81	32.94
0.3626	43.49	0.69110	467002.00	67272.81	37.66
0.3947	43.41	0.75260	530864.19	83269.31	42.81
0.4281	43.31	0.81679	600226.94	102158.38	48.41
0.4628	43.20	0.88370	675303.88	124310.38	54.46
0.4989	43.07	0.95337	756302.63	150125.38	60.99
0.5363	42.93	1.02583	843431.44	180032.94	68.02
0.5750	42.75	1.10114	936897.44	214495.44	75.56
0.6150	42.55	1.17936	1036903.75	254005.56	83.62
0.6564	42.32	1.26056	1143649.00	299088.38	92.23
0.6990	42.06	1.34481	1257331.00	350202.50	101.40
0.7430	41.77	1.43223	1378145.00	408241.00	111.14
0.7883	41.43	1.52292	1506282.00	473531.13	121.47
0.8348	41.05	1.61703	1641928.00	546836.19	132.41
0.8827	40.61	1.71471	1785272.00	628852.44	143.97
0.9318	40.13	1.81617	1936500.00	720317.75	156.17
0.9823	39.58	1.92163	2095785.00	822002.38	169.01
1.0340	38.96	2.03137	2263310.00	934715.88	182.52
1.0870	38.27	2.14572	2439247.00	1059301.00	196.71
1.1412	37.49	2.26509	2623764.00	1196644.00	211.59
1.1968	36.61	2.38997	2817025.00	1347679.00	227.18
1.2535	35.62	2.52096	3019197.00	1513353.00	243.48
1.3116	34.51	2.65885	3230432.00	1694679.00	260.52
1.3708	33.26	2.80463	3450895.00	1892692.00	278.30
1.4313	31.83	2.95959	3680737.00	2108471.00	296.83
1.4931	30.20	3.12549	3920089.00	2343130.00	316.14
1.5561	28.33	3.30480	4169120.00	2597844.00	336.22
1.6202	26.15	3.50117	4427960.00	2873792.00	357.69
1.6857	23.57	3.72042	4696740.00	3172221.00	378.77
1.7523	20.42	3.97281	4975604.00	3494405.00	401.26
1.8201	16.36	4.28012	5264640.00	3841655.00	424.57
1.8891	10.34	4.71089	5564448.00	4215338.00	448.71
1.9593	0.0	5.04227	5873884.00	4616831.00	473.70

PLOT CALL OUTSIDE LIMITS X=0.0

Y=-.11602 02

IPEW= 3

CASE GEOMETRY AND MATERIAL PROPERTIES

RADIUS INCHES	LENGTH INCHES	WEIGHT POUNDS	SPECIFIC ENERGY LB-IN/CU. IN.
21.509	51.563	12400.0	260000.0

DEFORMATION INCHES	VELOCITY FT./SEC.	TIME MILLISECONDS	FORCE POUNDS	ENERGY LB-IN.	ACCELERATION G
0.0007	43.82	0.00131	0.0	0.0	0.0
0.0020	43.82	0.00524	469.53	0.48	0.04
0.0062	43.82	0.01178	2034.14	4.79	0.16
0.0110	43.82	0.02095	5318.58	22.51	0.43
0.0172	43.82	0.03273	10948.89	72.09	0.88
0.0248	43.82	0.04712	19546.11	188.30	1.58
0.0337	43.82	0.06413	31735.21	417.65	2.56
0.0440	43.81	0.08376	48134.93	829.68	3.88
0.0557	43.81	0.10599	69364.44	1516.46	5.59
0.0688	43.81	0.13084	96041.44	2596.67	7.75
0.0832	43.80	0.15830	120781.00	4219.00	10.39
0.0990	43.79	0.18836	160195.75	6565.14	13.56
0.1162	43.77	0.22104	214094.69	9853.51	17.33
0.1347	43.75	0.25634	265483.00	14341.88	21.73
0.1546	43.72	0.29425	332567.31	20331.24	26.82
0.1759	43.68	0.33479	404746.63	28168.24	32.64
0.1985	43.63	0.37794	486613.06	38247.98	39.24
0.2225	43.57	0.42379	578767.13	51019.18	46.67
0.2478	43.49	0.47228	681787.13	66982.94	54.98
0.2745	43.39	0.52346	796268.56	86701.25	64.22
0.3025	43.27	0.57737	922778.81	110793.94	74.42
0.3319	43.13	0.63404	1061903.00	139946.69	85.64
0.3626	42.95	0.69353	1214205.00	174909.44	97.92
0.3947	42.74	0.75589	1380247.00	216500.56	111.31
0.4281	42.49	0.82120	1560590.00	265611.81	125.85
0.4628	42.20	0.88955	1755790.00	323207.63	141.60
0.4989	41.86	0.96105	1966386.00	390326.88	158.58
0.5363	41.46	1.03585	2192921.00	468087.06	176.85
0.5750	40.99	1.11411	2435933.00	557689.25	196.45
0.6150	40.45	1.19604	2695949.00	660415.38	217.42
0.6564	39.82	1.28191	2973488.00	777631.31	239.80
0.6990	39.09	1.37201	3269060.00	910787.63	263.63
0.7435	38.26	1.46675	3583177.00	1061426.00	288.97
0.7883	37.29	1.56663	3916334.00	1231175.00	315.83
0.8348	36.17	1.67228	4269013.00	1421767.00	344.28
0.8827	34.88	1.78454	4641707.00	1635006.00	374.33
0.9318	33.38	1.90454	5034901.00	1872815.00	406.04
0.9823	31.64	2.03382	5449042.00	2137196.00	439.44
1.0340	29.58	2.17463	5884606.00	2430248.00	474.56
1.0870	27.12	2.33040	6342042.00	2754180.00	511.45
1.1412	24.17	2.50688	6821786.00	3111285.00	550.14
1.1968	20.32	2.71509	7324266.00	3503973.00	590.67
1.2535	15.09	2.98233	7849912.00	3934738.00	633.06
1.3116	4.99	3.46410	8399123.00	4406183.00	677.35
1.3708	0.0	5.44514	8972328.00	4921018.00	723.57

PLOT CALL OUTSIDE LIMITS   X=0.0   Y=-.11002 02   IPEH= 3

IEC002I STOP 00000

12.4 Appendix D: Computer Program to Calculate Side Drop Negative Acceleration Forces

The computer program was the same as derived in Appendix C, however, the program was changed to reflect the change in the angle of impact. The angle, α , in Fig. C-1 was 63° for the side drop.

The results for specific energies for stainless steel of 100,000 and 260,000 in.-lb in.³ are given. The plots of the negative accelerations vs deformation are given in Figs. D-1 and D.2.

CASK GEOMETRY AND MATERIAL PROPERTIES

RADIUS INCHES	LENGTH INCHES	WEIGHT POUNDS	SPECIFIC ENERGY LB-IN/CH. IN.		
21.500	51.563	12400.0	100000.0		
DEFORMATION INCHES	VELOCITY FT./SEC.	TIME MILLISECONDS	FORCE POUNDS	ENERGY LB-IN.	ACCELERATION X G
0.0011	43.02	0.00202	0.0	0.0	0.0
0.0042	43.02	0.00007	860.95	1.30	0.07
0.0096	43.02	0.01016	3764.55	13.68	0.30
0.0170	43.02	0.03229	9842.97	64.20	0.79
0.0265	43.02	0.05045	20262.05	207.94	1.63
0.0382	43.02	0.07263	36173.57	537.14	2.92
0.0520	43.01	0.09006	50731.67	1191.36	4.74
0.0679	43.01	0.12911	89002.25	2366.72	7.10
0.0859	43.00	0.16339	120371.00	4325.00	10.35
0.1060	43.70	0.20170	177741.56	7407.10	14.33
0.1283	43.76	0.24405	238333.30	12034.98	19.22
0.1526	43.73	0.29045	311275.94	10727.54	25.10
0.1791	43.60	0.34091	397700.30	24107.03	32.07
0.2077	43.62	0.39540	490725.00	40911.19	40.22
0.2383	43.53	0.45409	615475.50	57996.29	49.64
0.2711	43.42	0.51690	749056.50	80351.63	60.41
0.3060	43.20	0.58391	900564.94	109104.69	72.63
0.3429	43.10	0.65521	1071113.00	145535.31	86.30
0.3819	42.87	0.73090	1261771.00	191073.31	101.76
0.4231	42.59	0.81111	1473638.00	247321.69	118.00
0.4663	42.24	0.89600	1707766.00	316047.69	137.72
0.5116	41.01	0.98579	1965235.00	399200.25	158.49
0.5589	41.30	1.08075	2247699.00	490941.63	191.22
0.6083	40.67	1.18123	2554302.00	617503.69	206.00
0.6598	39.93	1.28769	2888143.00	757677.19	232.91
0.7133	39.03	1.40059	3249394.00	921972.94	262.05
0.7689	37.96	1.52103	3639141.00	1113431.00	293.40
0.8266	36.60	1.64971	4050300.00	1335245.00	327.29
0.8862	35.15	1.78815	4508116.00	1590839.00	363.56
0.9480	33.31	1.93837	4989310.00	1883860.00	402.36
1.0117	31.00	2.10333	5502952.00	2218236.00	443.79
1.0774	28.33	2.28701	6049960.00	2598073.00	487.90
1.1452	24.85	2.50019	6631209.00	3027703.00	534.70
1.2150	20.23	2.75012	7247053.00	3512022.00	584.50
1.2868	13.25	3.11537	7900575.00	4055697.00	637.14
1.3605	0.0	4.04319	8590316.00	4663900.00	692.77
PLOT CALL OUTSIDE LIMITS		X=0.0	Y=-.1100E 02	IPEN= 3	

CASK GEOMETRY AND MATERIAL PROPERTIES

RADIUS INCHES	LENGTH INCHES	WEIGHT POUNDS	SPECIFIC ENERGY LB-IN/CH. IN.		
21.500	51.563	12800.0	260000.0		
DEFORMATION INCHES	VELOCITY FT./SEC.	TIME MILLISECONDS	FORCE POUNDS	ENERGY LB-IN.	ACCELERATION G
0.0011	43.82	0.00202	0.0	0.0	0.0
0.0047	43.82	0.00807	2259.27	3.60	0.18
0.0096	43.82	0.01816	9787.82	35.56	0.79
0.0170	43.82	0.03229	25591.73	166.92	2.06
0.0265	43.82	0.05085	52683.41	540.64	4.25
0.0382	43.81	0.07264	94051.25	1396.57	7.58
0.0520	43.80	0.09806	152702.31	3097.54	12.31
0.0679	43.79	0.12912	231613.88	6153.46	18.68
0.0859	43.76	0.16342	333764.69	11247.08	26.92
0.1060	43.72	0.20178	462128.19	19250.68	37.27
0.1283	43.66	0.24420	619666.88	31290.95	49.97
0.1526	43.58	0.29073	809317.44	48691.63	65.27
0.1791	43.46	0.34140	1034021.00	73080.25	83.34
0.2077	43.29	0.39628	1296687.00	106368.88	104.57
0.2383	43.07	0.45546	1600236.00	150790.00	129.05
0.2711	42.78	0.51908	1947546.00	208914.50	157.06
0.3060	42.40	0.58728	2341468.00	283672.63	188.83
0.3429	41.92	0.66032	2784894.00	378392.44	224.59
0.3819	41.31	0.73850	3280604.00	496791.25	264.56
0.4231	40.54	0.82225	3831459.00	643037.38	308.99
0.4663	39.58	0.91212	4440193.00	821724.56	358.08
0.5116	38.33	1.00892	5109613.00	1037942.38	412.07
0.5589	36.91	1.11374	5842458.00	1297248.00	471.17
0.6083	35.06	1.22819	6641394.00	1605712.00	535.60
0.6598	32.75	1.35471	7509174.00	1969953.00	605.58
0.7133	29.82	1.49732	8448424.00	2397123.00	681.32
0.7685	25.98	1.66337	9461768.00	2894923.00	763.05
0.8266	20.66	1.86933	10551788.00	3471645.00	850.95
0.8862	11.87	2.17503	11721101.00	4136194.00	945.25
0.9480	0.0	3.04118	12972229.00	4898078.00	1046.15
PLOT CALL OUTSIDE LIMITS		X=0.0	Y=-.11002 02	IP=3	
INC002I STOP 00000					

Fig. D.1. Plot of negative acceleration vs deformation at specific energy of 100,000 in.-lb/in.³ for steel for the 30-ft side drop.

Fig. D.2. Plot of negative acceleration vs deformation at specific energy at 260,000 in.-lb/in.³ for steel for the 30-ft side drop.

12.5 Appendix E: Report of Special Inspection of Garden Carrier No. 2

The Garden Carrier No. 2 was constructed before quality assurance records were maintained at the ORNL shops. A thorough inspection was made of the cask and the letter report on that inspection is included in this appendix.

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

December 21, 1973

TO: B. B. Klima

SUBJECT: Inspection of shipping cask - Garden Carrier #2
Work Order A-3043C-AA Inspection Request 10927

This inspection was performed to verify the integrity of this shipping cask.

The cask was surveyed by ORNL Health Physics and found to be free of radioactive contamination.

Visual Inspection

This cask conforms to the characteristics of Drawing M-11332-EM-010-E Rev. 2.

The cask is properly identified by stamped lettering.

No structural defects were observed in the cask or shipping pallet.

Lifting attachments are adequate and of sound construction.

Liquid Penetrant Examination

All accessible welds and lifting attachments were examined with liquid penetrant in accordance with ORNL Standard NDE-30, Technique 1, "Color Contrast solvent-removable" and were found to be satisfactory.

Leak Test

A vacuum test was made on the assembled cask. The internal cavity was evacuated to 250 microns pressure. Pressure rise test indicated a return to atmospheric pressure in approximately 15 minutes.

Material Identification

Thickness measurements were made of the lead containing assemblies. These thicknesses are in accordance with drawing specifications. All accessible parts were examined with a thermoelectric comparator and determined to have been fabricated from 300 series stainless steel.

These inspections and tests indicate good quality materials and welds.

It is our opinion that the integrity of this cask is of equal quality to comparable shipping casks currently being fabricated.

INSPECTION ENGINEERING DEPARTMENT

O. J. Smith

OJS:pg

cc: J. R. McGuffey
J. N. Robinson
C. R. Starlin
IR-10927

12.6 Appendix F: Operating Procedures Applicable to the Garden Carrier No. 2

The operating procedures* can vary from shipment to shipment depending upon the following: (1) the cell or place from which the contents are picked up or discharged into; (2) the type of inner container (whether or not it must be unloaded remotely using manipulators); (3) the design of the discharge hole (horizontal or vertical), and other contingencies. The operating procedures included are typical and more general. More detailed procedures will be developed to cover the specific contingencies.

<u>Procedure No.</u>	<u>Procedure Title</u>	<u>Page No.</u>
GC2-1	Operating procedure to load bagged inner container in empty carrier	126
GC2-2	Operating procedure to unload cask into hot cell or storage well, Bldg. 3597	129
GC2-10	Polyethylene Bottle Pressure Test	133
GC2-11	Test of Flanged Inner Container	135
GC2-12	Test of Screwed Top Inner Container	136
GC2-13	Inspection of Garden Carrier No. 2	137

---

* Operating procedures prepared by J. H. Goode, ORNL.

Procedure GC2-1

Page 1 of 3

Date _____

Garden Carrier No. 2
AEC-OR-USA-6088/BLF

OPERATING PROCEDURE TO LOAD BAGGED INNER CONTAINER IN EMPTY CARRIER

1. Upon arrival (at discharge site) of Garden Carrier No.2, have Health Physics representative survey fire shield, skid, and vehicle for alpha and beta-gamma radiation and transferable contamination.

	α d/m/100 cm ²		β -- γ		Inspector	Date
	Probe <300	Smear <30	Probe	Smear		
Fire shield						
Skid						
Vehicle						

Is decontamination necessary? _____

Decontamination completed. _____

2. Remove fire shield and cask from skid using large hex key wrench located in tool box on skid to loosen socket-head cap screws. Store bolts for reuse. Inspect bolts for defect. If bolts are reusable, stow in safe place. _____
If need replacement, record number and type of bolts used. _____
3. Raise cask and set it on firm supports (wood blocks) to permit access to and removal of the cover from the bottom discharge hole. Inspect bolts. _____ Necessary to replace bolts. _____
Bolts replaced (type number). _____
Inspect gasket seating surface. _____ Surface ok. _____
Needs rework. _____ Surface repaired. _____
Stow bolts, gasket, and cover for reuse. _____
4. Remove socket-head cap screws if the top plug is to be lifted to expose the cavity. The top plug may be lifted by eye-bolts inserted

Procedure GC2-1

Page 2 of 3

Date _____

into the bolt holes for the aluminum cover or by using a clevis or shackle through the lid lifting lug. _____

Monitor for radiation contamination as cover is being raised. _____

_____ Decontamination necessary. _____

Completed. _____

Inspect bolts. _____ Necessary to replace bolts. _____

Bolts replaced (type number). _____

Store bolts for reuse. _____

Check condition of "O"-ring gasket (neoprene 1/4-in.-diam by 18-1/2-in. ID x 19-in. OD) on body of cask. _____

"O"-ring gasket needs replacement. _____

"O"-ring gasket replaced. _____

5. To load empty inner container, place container in a remotely removable plastic bag.

Through the Top

- 5a. Remove wire rope hole cover. Insert nylon cord or braided stainless steel cable through hole at bottom of receptacle and attach it to lifting ring on inner container lid. Place bagged container in cask cavity, and carefully replace the top plug of cask to prevent cutting the cord or cable or damaging gasket.

Insert and tighten 12 socket-head cap screws holding plug in place.

_____ Coil excess string inside receptacle. (Be sure string is tied so it cannot slip down hole. Replace receptacle gasket and cover plate. _____

Insert and tighten six socket head cap screws. _____

Through the Bottom

- 5b. (Do not remove the top plug.)

Remove bottom closure (see 4 above). _____

Remove drawer cover bolts. _____

Remove drawer covers. _____

Procedure GC2-1

Page 3 of 3

Date _____

Remove drawer bolts. _____

Store bolts and covers for reuse. _____

Remove wire rope hole cover bolts. _____

Remove wire rope hole cover plate. _____

Open drawers (check for radiation contamination). _____

Decontamination necessary. _____ Completed. _____

Insert nylon cord or braided stainless wire cable through hole and attach it to lifting ring on inner container lid. _____

Pull bagged inner container into cavity. _____

Close drawers. _____ Secure drawers with bolts. _____

Coil excess nylon cord or braided stainless wire cable inside receptacle. _____

Be sure string is knotted so it cannot slip down hole. Replace receptacle gasket cover. _____

Replace receptacle cover plate. _____

Insert and tighten six socket-head cap screws. _____

Replace drawer cover plates gasket and cover plates. _____

Inspect gaskets. _____ Need replacement. _____

Replaced. _____

Insert and tighten drawer cover plate bolts. _____

Replace bottom cover and gasket. _____

Insert and tighten bottom cover bolts. _____

Procedure GC2-2

Page 1 of 4

Date _____

Garden Carrier No. 2

AEC-OR-USA-6088/BLF

OPERATING PROCEDURE TO UNLOAD CASK INTO HOT CELL
OR STORAGE WELL, BLDG. 3597

1. Upon arrival (at discharge site) of Garden Carrier No. 2, have Health Physics representative survey fire shield, skid, and vehicle for alpha and beta-gamma radiation and transferable contamination.

	α d/m/100 cm ²		$\beta - \gamma$		Inspector	Date
	Probe <300	Smear <30	Probe	Smear		
Fire shield						
Skid						
Vehicle						

Is decontamination necessary? _____

Decontamination completed. _____

2. Remove fire shield and cask from skid using large hex key wrench located in tool box on skid to loosen socket-head cap screws. Store bolts for reuse. Inspect bolts for defects. If bolts are reusable, stow in safe place. _____
If need replacement, record number and type of bolts used. _____
3. Raise cask and set it on firm supports (wood blocks) to permit access to and removal of the cover from the bottom discharge hole. Inspect bolts. _____ Necessary to replace bolts. _____
Bolts replaced (type number). _____
Inspect gasket seating surface. _____ Surface ok. _____
Needs rework. _____ Surface repaired. _____
Stow bolts, gasket, and cover for reuse. _____
4. Position cask over hole into hot cell or storage well at Bldg. 3597. _____

5. Prepare cask for discharge of contents.

Remove drawer cover bolts. _____

Remove drawer covers. _____

Remove drawer bolts. _____

Store drawer bolts and covers with bolts and gaskets for reuse. _____

Remove string hole cover plate bolts. _____

Remove string hole cover and gasket. _____

Store string hole bolts, cover, and gasket for reuse. _____

Apply tension to string to lift inner container from the drawers. _____

Open drawers. _____

Open cell or storage well closure. _____

Lower inner container into cell or storage well. _____

Monitor (Health Physics) passage of contents into cell. _____

If inner container is to be retrieved, proceed. However, if inner container is to be left in cell or storage well, the string may be elected to be dropped into the container. _____

Retrieve the string. _____

Empty or fill inner container. _____

Raise inner container into the cask with string. _____

Monitor passage of inner container into cask. _____

Close drawers. _____

Lower inner container onto drawers. _____

Coil excess string in string hole. _____

String hole:

Inspect gasket seating surface body. _____

Inspect gasket seating surface flange. _____

Inspect gasket. _____

Gasket needs replacement. _____ Replaced _____

Seating surface needs refinishing. _____

Refinished. _____

Procedure GC2-2

Page 3 or 4

Date _____

Install gasket. _____ Install cover. _____

Install and tighten bolts. _____

Doors:

Door bolts installed. _____

Door Covers:

Inspect right gasket seating surface body. _____

Inspect left gasket seating surface body. _____

Inspect right gasket seating surface flange. _____

Inspect left gasket seating surface flange. _____

Gasket needs replacement. _____ Replaced. _____

Seating surface needs refinishing. _____

Refinished. _____

Install door cover gasket and door. _____

Install and tighten door cover bolts. _____

Inspect bottom cover gasket. _____

Inspect bottom cover gasket seating surface on cask. _____

Inspect bottom cover gasket seating surface on cover. _____

Gasket needs replacement. _____ Replaced. _____

Gasket seating surface needs refinishing. _____

Refinished. _____

Install bottom cover and gasket. _____

Install and tighten bottom cover bolts. _____

6. Survey cask for radiation and contamination on all surfaces. _____

	α d/m/100 cm ²		$\beta - \gamma$		Inspector	Date
	Probe <300	Smear <30	Probe	Smear		
Shipping cask						

Is decontamination necessary? _____

Decontamination completed. _____

7. Lifting cask on shipping skid. _____
8. Secure cask to shipping skid with bolts; tighten them. _____

Procedure GC2-2

Page 4 of 4

Date _____

9. Place fire shield over cask. _____
 Insert and tighten bolts on fire shield. _____
10. Replace tools in tool box. _____
 Lock tool box. _____
11. Survey assembly for radiation and contamination on all surfaces.

	α d/m/100 cm ²		β γ		Inspector	Date
	Probe <300	Smear <30	Probe	Smear		
Fire shield						
Skid						

Cask is ready for transmittal to shipping.

Procedure GC2-10

Page 1 of 2

Date _____

Garden Carrier No. 2

Test Procedure

GC2-10 Polyethylene Bottle Pressure Test

1. Inspect bottle for flaws.
2. Check "O"-ring (Viton - Fluorelastomer or approved equivalent).
3. Close with special cap. (180 in.-lbs. torque)
4. Pressurize to 25 psig using air.
5. Shut off air supply.
6. Submerge bottle in water and examine for leaks.

Frequency: Before use. (No container is used more than once.)

Record data on attached Table.

Procedure GC2-11

Date _____

Garden Carrier No. 2

Test Procedure^{*}GC2-11 Test of flanged inner container for
(drawing M-11332-EM-020-D)

1. Inner container fabricated in accordance with drawing.
_____

2. Inner container assigned a serial number and so identified.
_____

3. Bubble test 25 psig. _____

Container approved for use _____

Date _____

_____
^{*}Test annually or on putting new container in service.

Procedure GC2-12

Date _____

Garden Carrier No. 2

Test Procedure^{*}

GC2-12 Test of screwed top inner container
(drawing M-11332-EM-019-0)

1. Inner container fabricated in accordance with drawing.
_____
2. Inner container assigned a serial number and so identified.
_____
3. Bubble test at 25 psig. _____

_____
^{*}Test before each shipment.

Procedure GC2-13

Date _____

Garden Carrier No. 2

Test Procedure *

GC2-13 Test of Garden Carrier No. 2

1. Dye penetrant test all accessible welds and lifting attachments in accordance with ORNL-Standard NDE-30.
Technique 1. "Color Contrast Solvent Removable"

-
2. Apply vacuum test to assembled cask. Evacuate to 250 microns. If pressure rise to atmospheric is less than 15 minutes, gaskets should be replaced or leakage source investigated.

initial vacuum _____ microns

final vacuum _____

elapsed time _____

Cask is acceptable to use

---

* Test biennially.

13. REFERENCES

1. B. B. Klima, Analysis of the Oak Ridge National Laboratory Garden Carrier No. 2, ORNL/TM-2531 (September 1969).
2. Code of Federal Regulations, Title 10, Chapter 1 (May 1975).
3. ERDA Manual, Chapter 0529 (June 14, 1973).
4. Code of Federal Regulations, Title 49, Part 173.
5. Code of Federal Regulations, Title 49, Part 173, Paragraph 173.393(j).
6. J. H. Evans, Analysis of the Oak Ridge National Laboratory Dry Hole Charger Shipping Cask, ORNL/TM-2302 (December 1965).
7. R. J. Roark, Formulas for Stress and Strain, 4th ed., McGraw-Hill, New York, 1965.
8. J. H. Evans, Structural Analysis of Shipping Casks, Vol. 7, Cask Tie-Down Design Manual, ORNL/TM-1312, Vol. 7 (May 1969).
9. E. Oberg and F. D. Jones, p. 1110 in Machinery's Handbook, 16th ed., The Industrial Press, New York, 1959.
10. F. L. Singer, pp. 329-46 in Strength of Materials, Harper, New York, 1951.
11. ASME Boiler and Pressure Vessel Code, Sect. VIII, "Rules for Construction of Vessels," Division I, American Society of Mechanical Engineers, New York, 1974.
12. Code of Federal Regulations, Title 49, Part 173, Paragraph 173.393(e)(2).
13. W. D. Turner and M. Siman-Tov, HEATING-3, An IBM 360 Heat Conduction Program, ORNL/TM-3208 (February 1971).
14. D. D. Cannon, Structural Analysis of Shipping Casks, Vol. 12, Energy Absorption Characteristics of Stainless Steel Bolts Under Impact Loadings, ORNL/TM-1312, Vol. 12, p. 55 (1972).
15. J. H. Evans, Safety Analysis Report for Packaging Lawrence Livermore Laboratory Shipping Container, ORNL/TM-4905 (December 1975).
16. B. B. Klima and L. B. Shappert, Safety Analysis Report Packaging ORNL Shipping Cask D-38, ORNL/TM-4485 (in preparation).