Contract No:

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Disclaimer:

The Model 9977 Radioactive Material Packaging Primer

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The Model 9977 Packaging

The Model 9977 Packaging is a single containment drum style radioactive material (RAM) shipping container designed, tested and analyzed to meet the performance requirements of Title 10 the Code of Federal Regulations Part 71. A radioactive material shipping package, in combination with its contents, must perform three functions (please note that the performance criteria specified in the Code of Federal Regulations have alternate limits for normal operations and after accident conditions):

- Containment – The package must "contain" the radioactive material within it.
- Shielding – The packaging must limit its users and the public to radiation doses within specified limits.
- Subcriticality – The package must maintain its radioactive material as subcritical.

The design, features and functions of the Model 9977 Packaging are described in detail in its Safety Analysis Report for Packaging (SARP), SRNL document S-SARP-G-00001. Nominal Package weights and dimensions are listed in Table 1.

The Model 9977 Packaging, illustrated in Figures 1 and 2, consists of two basic assemblies or components, a radioactive material container (i.e. a "Containment Vessel") and a overpack assembly (i.e. the "Drum Overpack") that provides structural and thermal protection. The Containment Vessel has a 6-inch inside diameter and is referred to as a "6CV". The Drum Overpack Assembly consists of an overpack and a lid, which are assembled with eight sets of bolts and washers, and an internal set (Top and Bottom) of Load Distribution Fixtures. The Overpack and Lid contain thermal insulating and shock absorbing materials. The Load Distribution Fixtures act as impact protection for and are used to center the 6CV within the Overpack. The 6CV, illustrated in Figures 3 and 4, consists of a body (typically made from welded pips components) and a Closure Assembly. The Body and Closure Assembly mate with a double O-Ring seal system with a 10° conical sealing surface. The Closure Assembly consists of two major components, the Cone-Seal Plug and the Cone-Seal Nut. The Cone-Seal Plug incorporates the O-Rings and their Glands and the connections and gas pathways for testing the seal. The Cone-Seal Plug is used to apply the force that compresses the O-Rings and creates the seal between the Cone-Seal Plug and the 6CV Body.

Table 1 - Package Weights and Overall Dimensions

Nominal Drum Size (gallons)	**Drum Diameter** [a] (inches)	**Drum Height** (inches)	**Maximum Packaging Weight** (lb)	**Maximum Payload Weight** [b] (lb)	**Maximum Gross Weight** (lb)
35	18.35	36.1	250	100	350

a) Diameter of drum body (diameters of rim and rolling ring are 18.72 and 19.125 inches, respectively).
b) Payload is the weight of everything placed in the Containment Vessel (CV) (i.e., the radioactive material and all packing components).

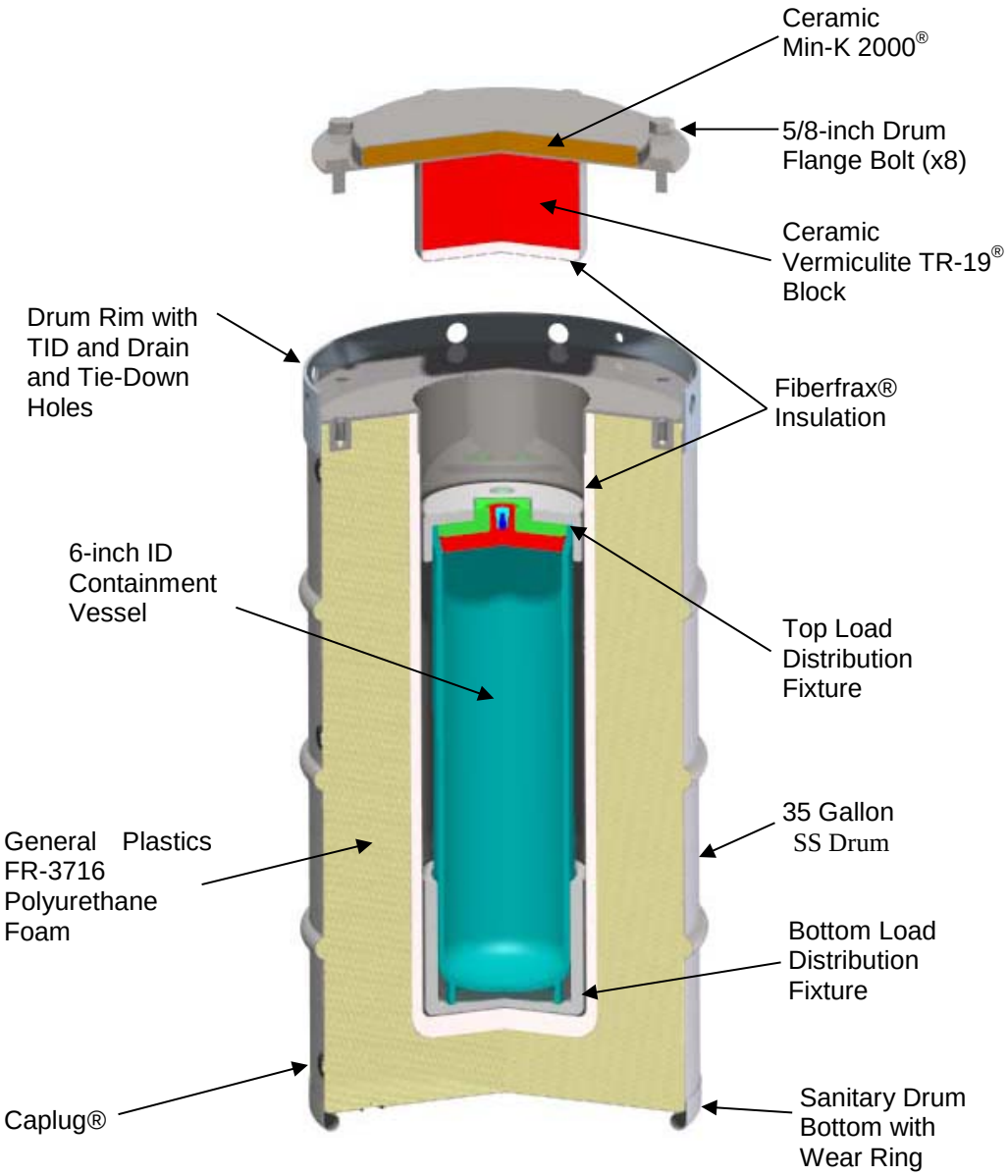

Figure 1 - 3-Dimensional Cut Away Illustration of the 9977

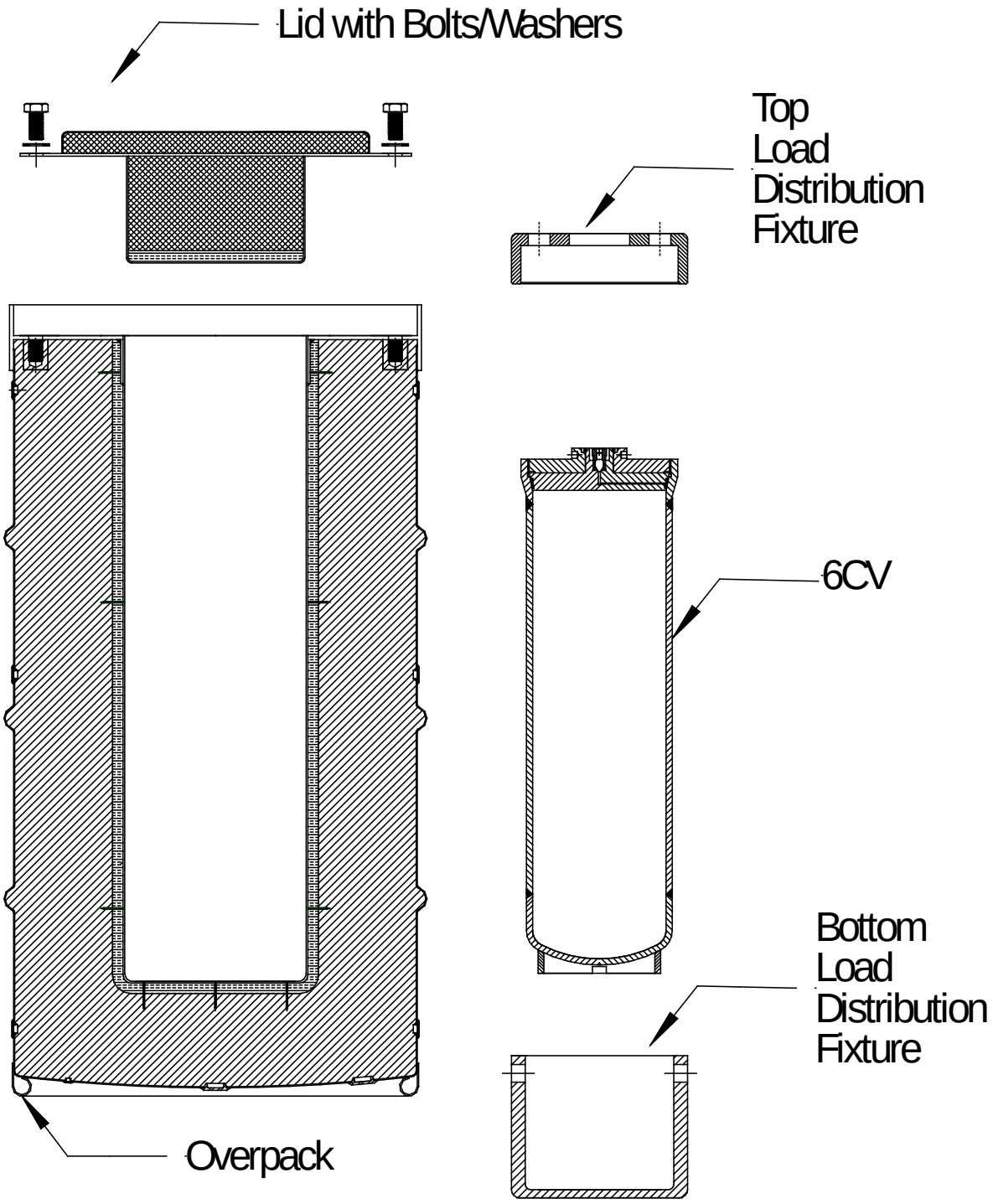

Figure 2 - Exploded View of the 9977

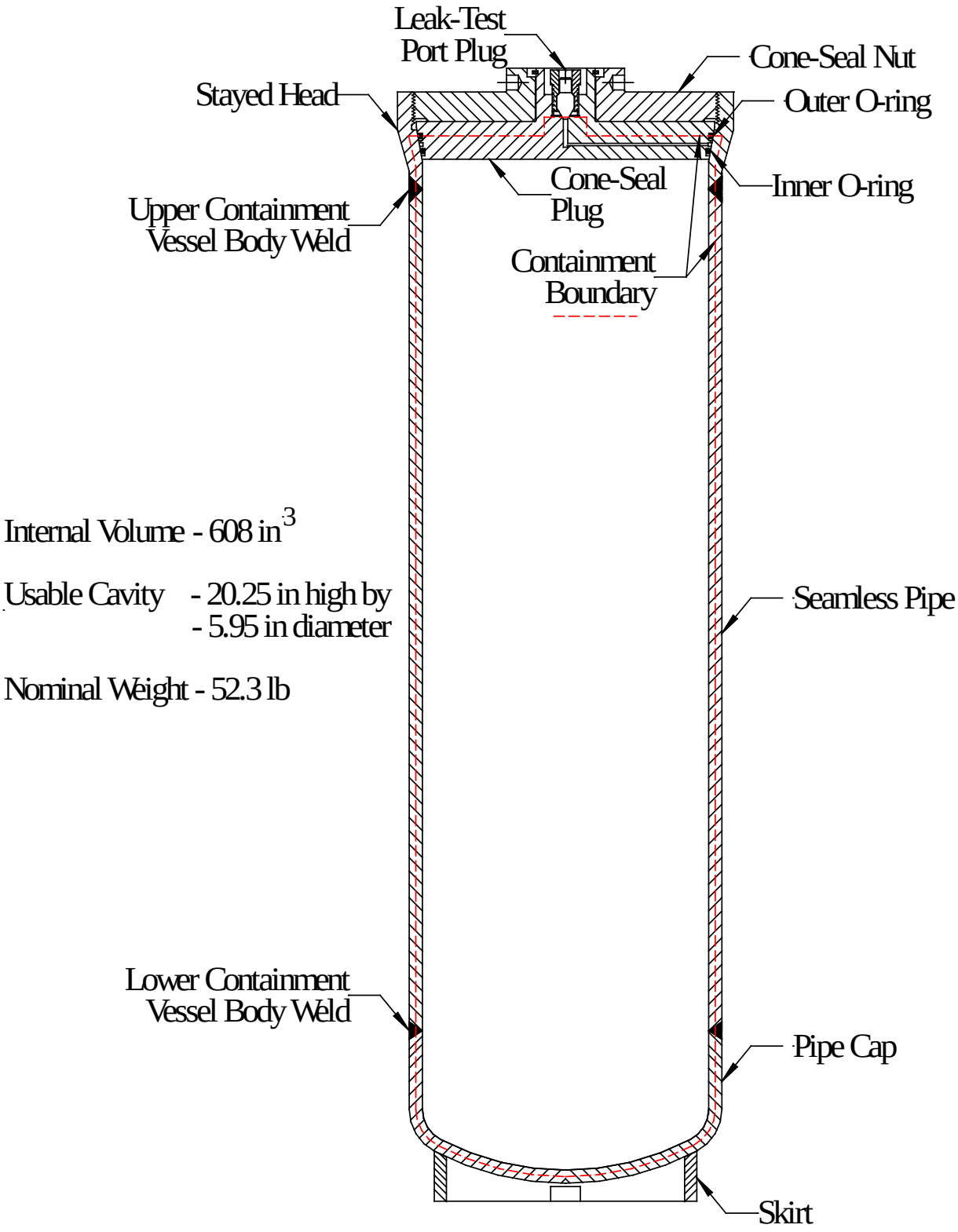

Figure 3 – The 6-Inch Containment Vessel (6CV)

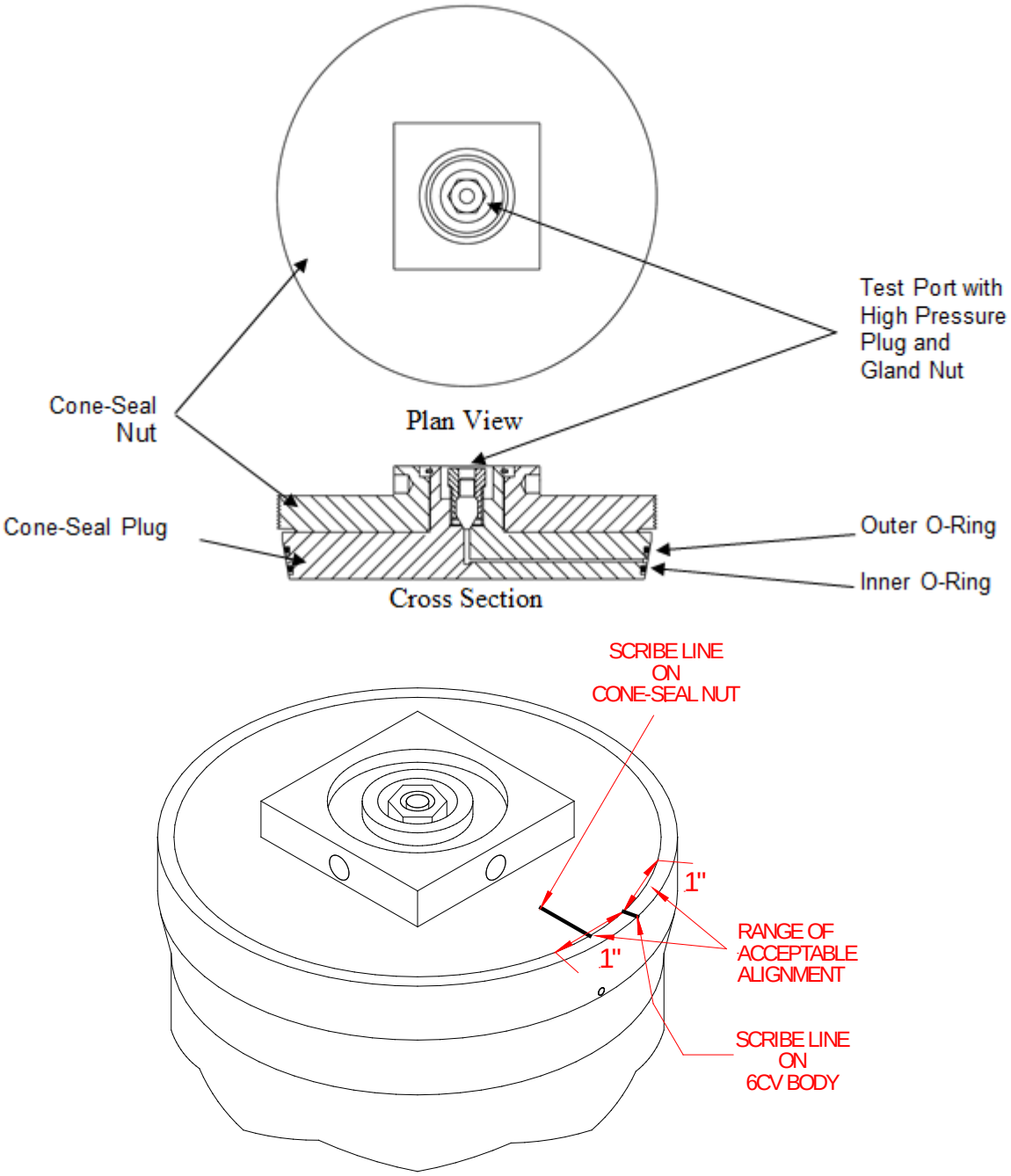

Figure 4 - Views of a 6CV Closure Assembly

The 9977 Drum Design

The drum design meets the performance requirements of 49 CFR 178 for an open head drum, but is modified with a bolted-flange closure. The closure does not incorporate a gasket. The drum body is a closed unit consisting of a shell, top deck plate, reinforcing rim (vertical flange) and a liner assembly. The volume between the liner assembly and drum shell is filled with shock-absorbing thermal-insulating materials. The drum shell and liner are fabricated of 18-guage Type 304L stainless steel (SS). The drum shell incorporates a drum bottom with a radiused edge that is butt welded to the side wall. The drum bottom includes a rolled wear ring, 0.060-inch thick by ¾-inch inside diameter (ID), attached by welds external to the drum shell. The drum's top deck plate is fabricated of $^{3}/_{16}$-inch thick Type 304L SS plate. The top portion of the drum incorporates a $^{3}/_{16}$-inch thick rim that reinforces the drum head and protects both the closure lid and the bolts during accident events. The rim includes eight 1-inch diameter drain holes that are qualified as package lifting and tie-down points. Drum construction details are shown on drawings R-R2-G-00017 and R-R2-G-00018. As applicable, the drum is designed, analyzed and fabricated in accordance with Section III, Subsection NF of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC).

Four ¾-inch diameter vent holes are drilled at locations around the drum, approximately 90° apart and at each of three elevations, for a total of twelve vent holes along the drum sidewall. Five additional holes, two 1-inch diameter fill holes and three ¼-inch diameter vent holes, are located on the drum bottom. All of the holes are covered with Caplug® fusible plastic plugs. During a fire event, the plugs combust or melt, allowing the drum to vent gases generated by intumescing foam insulation. The vent holes ensure that the drum cannot be ruptured by gas pressure.

The drum closure lid is fabricated from ⅛-inch thick Type 304L SS Plate. Eight ⅝-inch by 1¼-inch long heavy hex-head bolts with ⅝-inch plain, narrow Type B washers secure the lid to the top deck plate of the drum body. The closure lid incorporates chambers above and below the Lid Plate filled with shock-absorbing thermal-insulating materials. The Lid Top and Lid Bottom chambers are fabricated of 18-guage and 14-guage Type 304L SS, respectively. The top of the Lid Top is approximately 0.275 inch below the top surface of the drum-head reinforcing rim. The Lid Bottom chamber reinforces the Lid Plate and provides additional thermal protection and shock absorption for the 6CV during accident events. The Lid Top chamber also reinforces the Lid Plate, adds thermal protection to the contents, and prevents the closure lid from shearing away from the bolts during HAC events.

Four ¼-inch diameter holes through the Lid Plate allow the Lid Top and Lid Bottom volumes to exchange gases and equilibrate pressure. The Lid Top chamber is vented by four ¼-inch diameter holes also covered with Caplug® fusible plastic plugs. The Caplugs® prevent water from entering the lid through the vent holes under normal conditions. In a fire event, the plugs combust or melt, allowing the lid to vent heated air from the Lid Top and Lid Bottom chambers.

To simplify the drum closure, the threaded inserts that receive the closure bolts are welded to the underside of the drum's top deck plate. During installation, the bolts are tightened to a torque value of 45 (±5) ft-lb. The bolt heads are drilled through with a ⅛-inch hole to receive Tamper Indicating Devices. Details are shown on Drawing R-R1-G-00020.

The 9977 Drum Design Insulation

Two layers of insulation material fill the volume between the drum liner and shell. First, two ½-inch thick blankets of Fiberfrax® insulation are wrapped around and attached to the sides and bottom of the liner. The Fiberfrax® is backed on both sides with fiberglass cloth held in place by fiberglass thread stitched longitudinally at 4-inch intervals. The fiberglass cloth gives the Fiberfrax® composite both mechanical strength and wear resistance and helps retard gas flow during a fire event. The remaining volume between the Fiberfrax® and the drum wall is filled with General Plastics FR-3716 polyurethane foam (also known as Last-A-Foam®), poured through fill holes in the drum bottom and foamed in place. The nominal densities of Fiberfrax® and FR-3716 foam are 7-to-10 lb/ft^3 and 16 lb/ft^3, respectively. The combined thickness of the two insulators is approximately 4.95 inches radially (i.e., between the liner and the drum shell) and approximately 4.52 inches axially (i.e., between the liner bottom and drum bottom). Details are shown in Figures 1 and 2 and Drawings R-R1-G-0020, R-R2-G-0017, and R-R2-G-0019.

The closure lid incorporates two chambers of insulation. The Lid Top chamber contains a 1-inch thick, 14-inch diameter disk of Thermal Ceramics Min-K 2000® insulation. The Lid Bottom chamber contains a rigid disk of Thermal Ceramics TR-19® Block insulation, 4.3-inch thick by 8-inch diameter. When installed, the TR-19® disk compresses two 8-inch diameter by ½-inch thick blankets of Fiberfrax® insulation to a total thickness of ½ inch. The total axial thickness of both the insulators is approximately 5.75 inches. Details are shown in Figures 1 and 2 and Drawing R-R2-G-00018.

The 6CV Containment Vessel Design

The 9977 6CV design is discussed in detail in SARP Chapter 1 Section 1.2.1.3 and is summarized below.

The 9977 6CV, illustrated in Figure 3, has a nominal ID of six inches. The 6CV is a stainless steel pressure vessel designed, analyzed and fabricated in accordance with Section III, Subsection NB of the ASME Code, with design conditions of 800 psig at 300 °F. The 6CV main body is fabricated from 6-inch, Schedule 40, seamless, Type 304L SS pipe. A standard Schedule 40 Type 304L SS pipe cap is welded to the pipe segment to form a blind end. A stayed head is machined from a 7½-inch diameter by 2¼-inch long Type 304L SS bar and welded to the open end of the pipe segment, completing the vessel body weldment. The head is machined to include 6½-12UNS-2B internal threads and an internal cone-seal surface with a 32-micro-inch finish. Both vessel body joints are Category B full-penetration circumferential welds. A support skirt to stand the 6CV vertically is formed from a short segment of 5-inch, Schedule 40 Type 304L SS pipe welded to the convex side of the cap. Two rectangular notches milled into the bottom edge of the skirt (180° apart) can engage a rectangular key to prevent vessel rotation during removal and installation of the closure assembly.

The 6CV Closure Assembly consists of a Type 304L SS Cone-Seal Plug, shaped in part like a truncated cone, and a threaded Cone-Seal Nut made from Nitronic 60 SS. The two Closure Assembly components rotate freely relative to one another and are coupled by a snap-ring that also ensures unseating of the closure seal during disassembly. As the Cone-Seal Nut is threaded into the stayed head of the vessel, the Cone-Seal Plug is thrust axially against the corresponding cone-seal surface of the vessel. Both internal and external sealing surfaces are machined to the

same angles, surface finishes, and with matching diameters so that they mate with essentially zero clearance. The Cone-Seal Nut and the Containment Vessel body are made from dissimilar materials. Two O-ring grooves (outer and inner) are machined in the face of the external Cone-Seal Plug. Viton® GLT/GLT-S O-rings fit into these grooves to complete the leaktight closure assembly.

For operator safety, a 0.094-inch diameter vent hole is located in the stayed head region of the vessel wall, between the threads and the internal sealing surface. The vent hole is clocked 90° from the notches in the vessel support skirt. Unscrewing the Cone-Seal Nut a few turns will unseat the Cone-Seal Plug from the internal cone-seal surface and route any pressurized gases from the CV through the vent hole.

A leak-test port is incorporated into the Cone-Seal Plug and connected by a drilled radial passage to the annular volume between the two O-ring grooves in the Cone-Seal Plug. The leak-test port provides a means of verifying proper assembly of the vessel closure and is itself closed by the Leak-Test Port Plug. The vessel containment boundary is formed by the vessel body weldment, the Cone-Seal Plug, the Cone-Seal Port Plug, and the Outer O-ring.

The internal volume of a closed 6CV is approximately 608 cubic inches. The nominal assembly weight is 52.3 lb and nominal overall length is 24.03 inches. The usable cavity of the 6CV is a minimum of 20.25 inches deep with a minimum diameter of 5.95 inches. Details are shown in Drawing R-R2-G-00042. Table 2 list the materials of construction for the 9977 6CV.

Table 2 – Material Specifications for the 9977 6CV

Component	Material Specification
CV Weldment (b)	
- Stayed Head - Bar	ASME SA-479 Grade 304L
- Pipe – 6-inch Sch 40	ASME SA-312 Grade TP-304L, seamless
- Pipe – 5-inch Sch 40	ASME SA-312 Grade TP-304L
- Pipe Cap – 6-inch Std Wt	ASME SA-403 Grade 304L, WP-W
Cone-Seal Plug (c)	ASME SA-479 304L SS
Cone-Seal Nut (c)	ARMCO Nitronic 60 SS SA-479 UNS-S21800 annealed
O-Ring (e)	AS-568-252, Viton GLT/GLT-S, Parker V0835-75/VM835-75
Retaining Ring (e)	Waldes TRUARC #5108-125
Leak-Test Port Plug (e)	PPI No. P-110-034-60, 316/316L SS
Gland Nut (e)	PPI No. P-130-246-60, 410 SS

Note:

Gen 9977 6CV differences from the 9975 SCV are highlighted with grey shading

a Drawing Number R-R2-G-00042

b Drawing Number R-R3-F-0016

c Drawing Number R-R4-F-0054D

d Drawing Number R-R4-F-0054B

e Drawing Number R-R2-F-0018

C. Dimensions & Features

Dimensions and other features for the 9977 6CV are listed in Table 3 (Cone Seal Nut), Table 4 (Cone Seal Plug), and Table 5 (CV Body Weldment).

Table 3 – Dimensions of the 9977 6CV Cone-Seal Nut

Item *	Dimension/Specification
N1	2.50” Square
N2	1.63”
N3	1.28”
N4	0.30”
N5	0.18”
N6	0.50”
N7	1.130”
N8	6½” - 12UNS – 2A threads
N9	0.06” × 45°
N10	0.31” Drill × .25” deep – 4 holes
N11	6.0”
N12	0.06”
N13	0.03” R
N14	0.03” R

* Item Call-outs as indicated in Figure 5

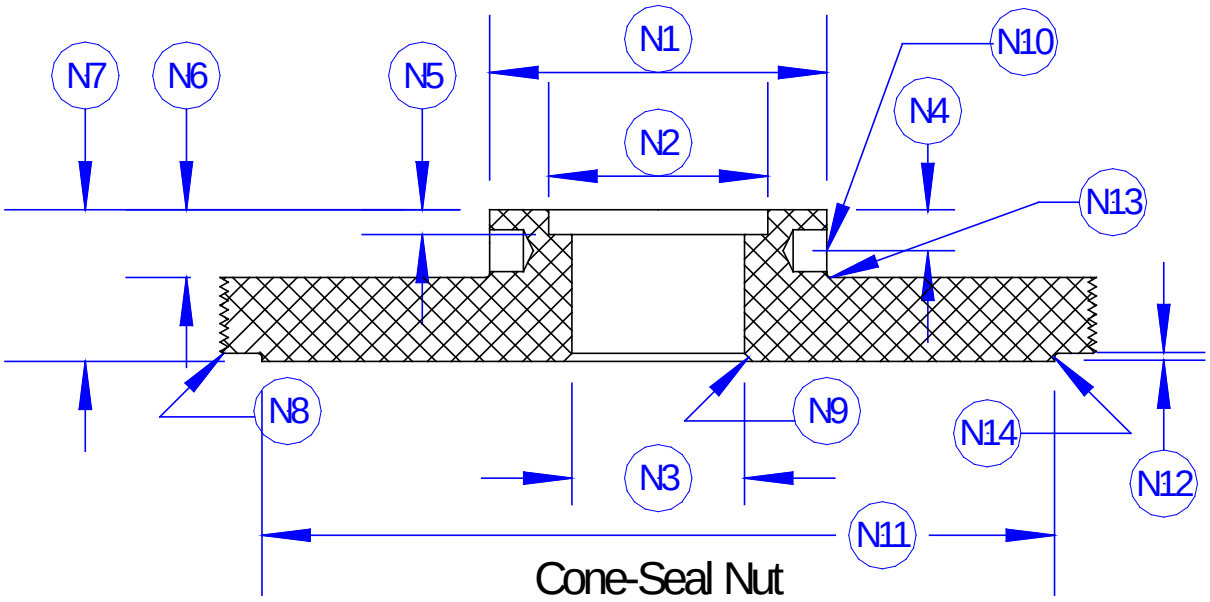

Figure 5 – Identification of Dimensions of the Cone-Seal Nut

Table 4 – Dimensions of the 9977 6CV Cone-Seal Plug

Item *	Dimension/Specification
P1 – Q4	10° ± 30’ on each side.
P2	6.310 ± 0.005”
P3	1.25”
P4	1.176”
P5	0.90”
P6	0.44”
P7	0.44”
P8	R 0.03”
P9	0.75”
P10	0.056”
P11	1.70”
P12 – Q8	0.086”
P13 – Q9	0.086”
P14	0.094” diameter drill
P15	1.88”
P16	0.56”
P17	0.06”
P18	32 a.a.micro-inches finish
P19 – Q12	32 a.a.micro-inches finish
P20 – Q7	60°
P21	0.187”
P22 – Q7	0.094” diameter Drill
P23 – Q6	32 a.a.micro-inches finish
P24	9/16 – 16UNF-2B threads
P25	0.20”
P26	0.41”
P27 – Q11	0.150”/0.155”
P28	0.53”
P29 – Q12	0.150”/0.155”
P30	0.63

* Item Call-outs as indicated in Figure 6

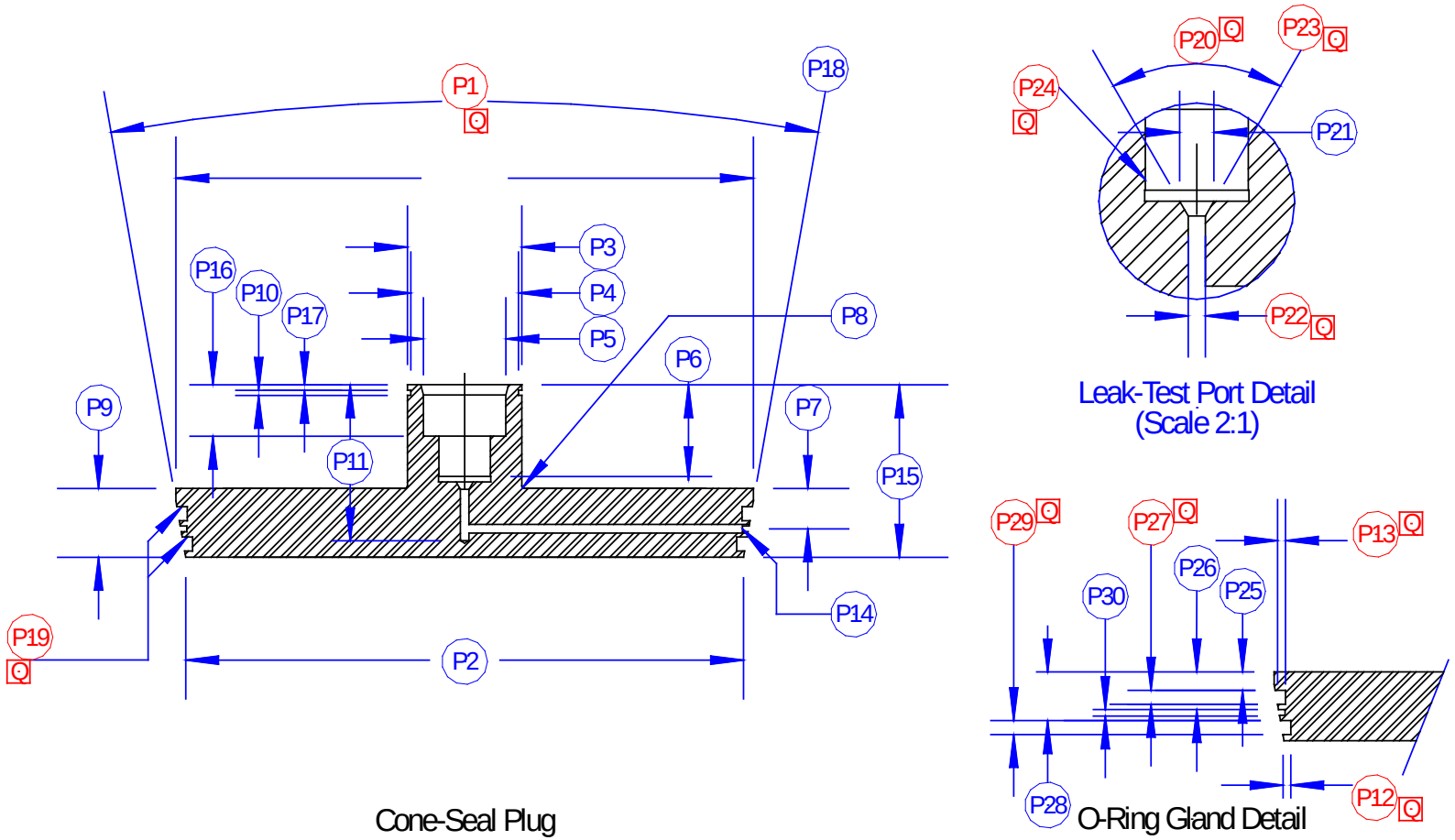

Figure 6 – Identification of Dimensions of the Cone-Seal Plug

Table 5 – Dimensions of the 9977 6CV Weldment

Item *	Dimension/Specification
W1 – Q2	10° ± 30’ on each side.
W2	7.12”
W3 – Q1	6.300”/6.310”
W4 – Q4	32 a.a.micro-inches finish
W5	15°
W6	0.68”
W7	0.094” Diameter
W8	0.12” × 6.520” dia. Thread relief
W9	0.75”
W10	2.00”
W11	1.62”
W12	6.065” Ref.
W13	6.625” Ref.
W14	23.50”
W15	0.31”
W16	0.63”
W17	5.047”
W18	5.563”
W19	6½” – 12UNS – 2B threads
W20	23.12
W21	0.38+/-.015”

* Item Call-outs as indicated in Figure 7

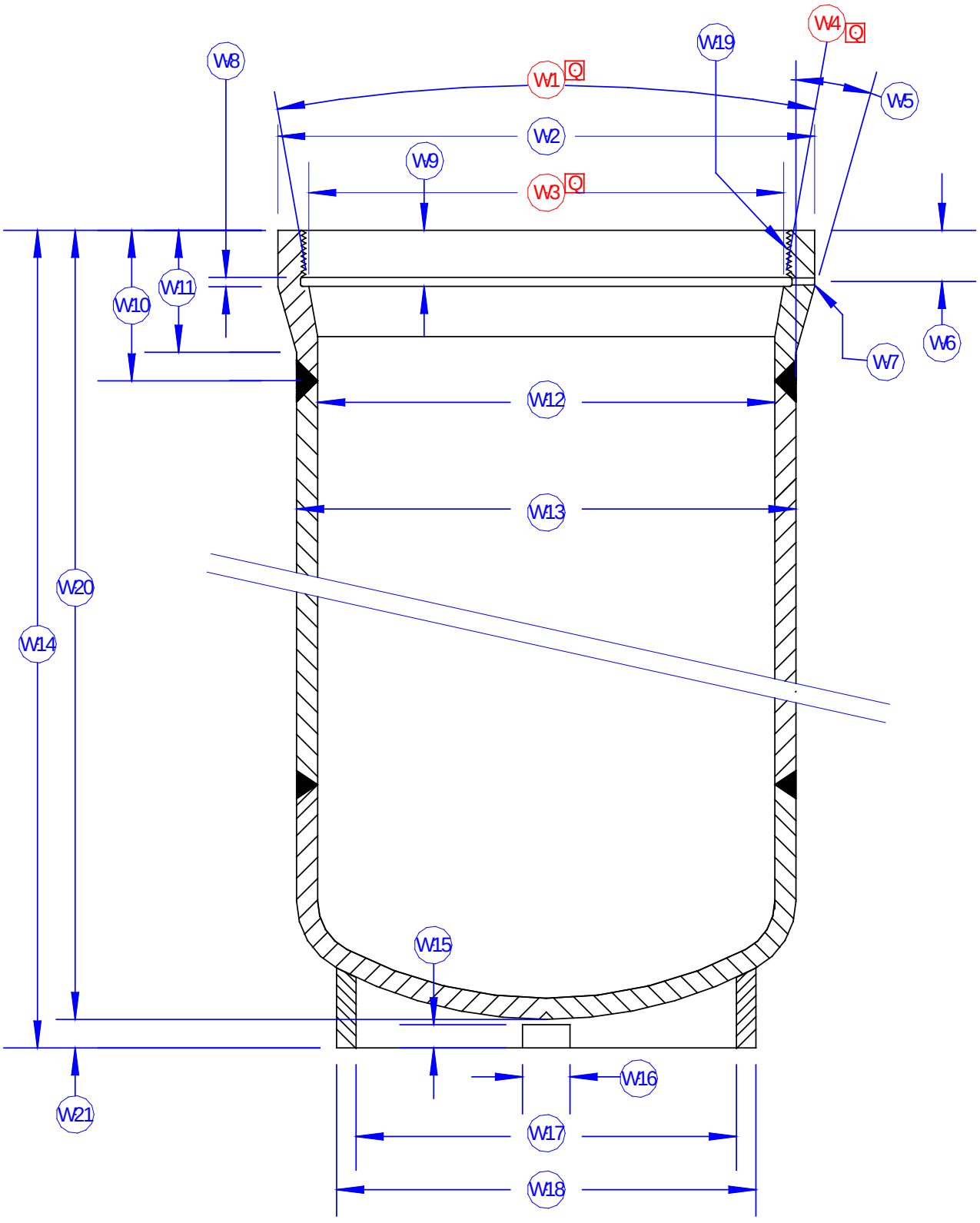

Figure 7 – Identification of Dimensions of the Containment Vessel Weldment

D. Fabrication methodologies

The fabrication method for the 9977 6CV is listed below. The 6CV is fabricated in accordance with ASME B&PVC Section III.

- The 9977 6CV fabrication is in accordance with ASME B&PVC Section III, Division 1, Subsection NB.
- Stainless Steel materials to be in accordance with ASME B&PVC, Section III, Division 1, Subsection NB-2000.
- Welds using filler material shall be made using filler material in accordance with ASME B&PVC, Section III, Div 1, Subsection NB-2400.
- Welding Procedures and Welders shall be qualified in accordance with ASME B&PVC Section IX.
- Welding and Fabrication shall be in accordance with ASME B&PVC Section III, Div. 1, Subsection NB-4000.

E. Acceptance Testing and Inspections

Acceptance testing and inspections are listed below for the 9977 6CV which uses ASME B&PVC Section III, Divivion1 as a starting point.

- All welds shall be inspection is accordance with ASME B&PVC Section III, Div. 1, Subsection NB-5000. Both the drawing and NB-5000 require liquid penetrant examination of root and final passes.
- External threads must pass Class 2A Tolerance Go-No Go ring Gauge.
- Internal threads must pass Class 2B Tolerance Go-No Go ring Gauge.
- The specified dimensions and finishes to be provided after welding.
- Features marked with a Q have quality requirements defined in S-SARP-G-00001.
- A 5.95 inch dia right circular cylinder 20.25 inches long shall fit in the internal cavity of each assembled and sealed CV.
- Closure Torque is 100 ft-lb (+20 / -0 ft-lbs).
- The CV shall be hydrostatic tested in accordance with ASME B&PVC Section III, Div. I, Article NB-6200, with test pressure at 1235 psig.
- Certification of O-ring material, size, and date of manufacture shall be furnished by the vendor with each new O-ring. O-rings shall be individually wrapped to prevent damage in shipment and shall be labeled to ensure traceability. Spare part Viton® GLT or GLT-S O-rings shall be received and stored by the Shipper in accordance with SAE ARP5316 and the Parker O-ring Handbook.

E. Operational Photographs

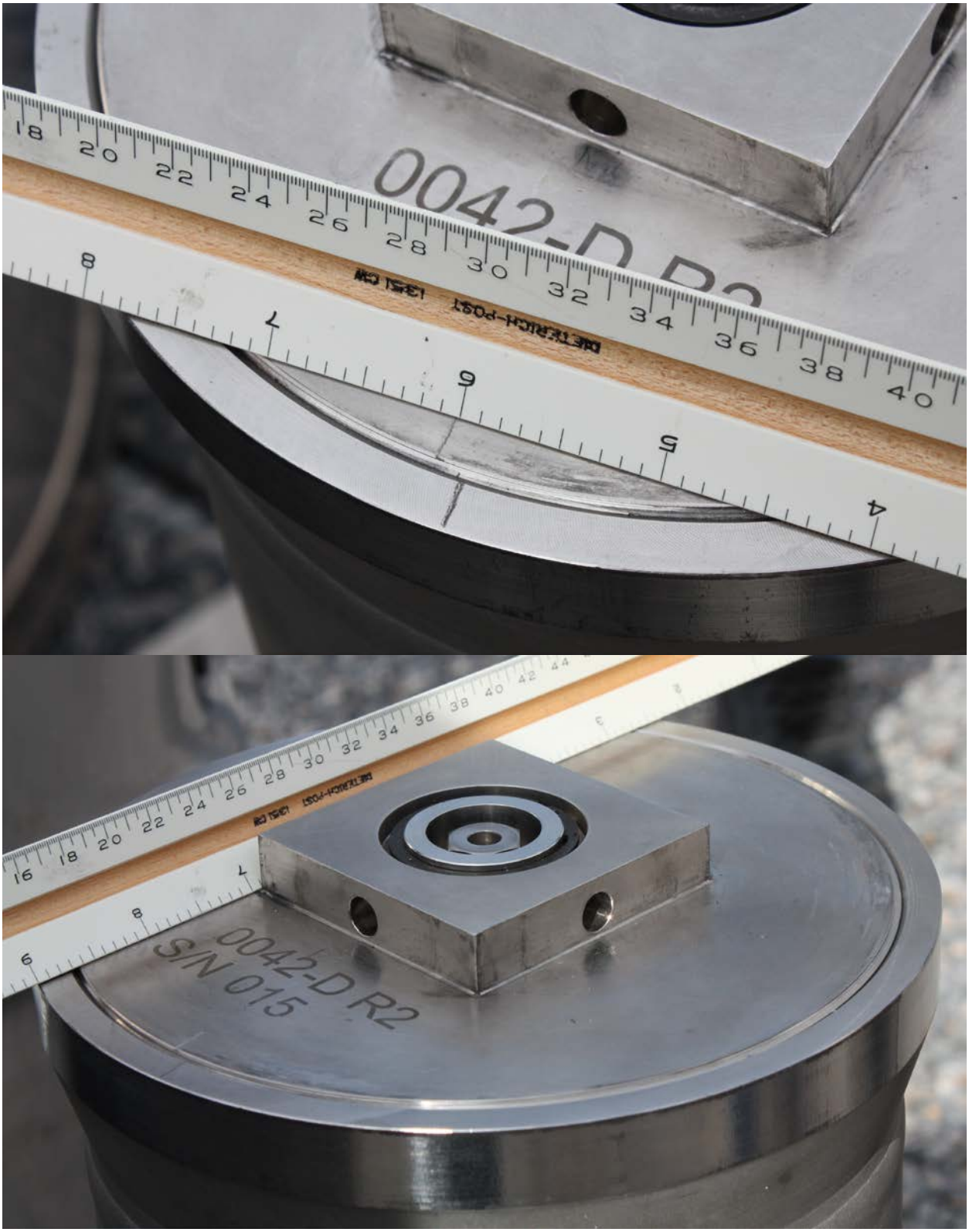

Figure 8 – Properly Closed 6CV

Figure 9 – 6CV Reported as “Loose”

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