QSA GLOBAL

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QSA GLOBAL, Inc.

Engineering Department

Technical Report

SENTRY Transport Package Tie-Down Analysis

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Engineering Approval:	[signature]	**Date:**	19 Jul 10

1.0 Purpose:

This report documents an analysis performed on the SENTRY transport package to the tie-down requirements of 10 CFR Part 71.45 (b).

2.0 SENTRY Transport Package Tie-Down Provisions:

The SENTRY transport package is equipped with four identical, multi-purpose Lifting/Tie-Down provisions located symmetrically around the package. The center of gravity (CG) is located approximately at the geometric center of the 780 pound maximum weight package.

The SENTRY tie-down provisions are a structural part of the package. However, they are designed to be intentionally removed without affecting the ability of the package to meet other requirements of 10 CFR Part 71.

Half of each tie-down provision is attached to the upper portion of the cylindrically shaped welded body by three high strength bolts, two on the top flat surface and one on the curved side surface of the body. The other half of the provision is attached to the body in the same manner, but with two bolts attached to the bottom and one attached to the side of the body. Refer to Figure 2.3. Materials used in construction of the tie-down provisions are shown in Table 2.1.

The upper and lower provision halves are connected together by a link plate attached to each half by a load pin. The two load pins are recruited when the package is tied-down using the link plate. It is not recommended to tie-down the package using the link plate, but this method still needs to meet the tie-down requirement of 10 CFR Part 71.45 (b).

The recommended tie-down method is to secure the package by looping high capacity straps or chains with or without a shackle through the large holes in the upper provisions and then staking the straps or chains to the vehicle down at about 45 degrees from horizontal.

There are two specific tie-down arrangements which will be analyzed separately. The first arrangement has the package oriented as shown in Figure 2.1. In this arrangement, the applied load, established by the requirements of 10 CFR Part 71, is taken by only one provision in the direction of vehicle travel. Another provision, 90 degrees from the vehicle direction, takes the load in the lateral direction. All four provisions share the load in the vertical direction.

The second arrangement has the package oriented as shown in Figure 2.2. In this arrangement, two provisions share the applied load in the direction of the vehicle. Two other provisions react to the load in the lateral direction, but one of these two provisions reacts to both the lateral and vehicle direction loads. All four provisions share the load in the vertical direction.

Security-Related Information Figure Withheld Under 10 CFR 2.390

Figure 2.1. Single Provision Arrangement.

Security-Related Information Figure
Withheld Under 10 CFR 2.390

Figure 2.2. Shared Provision Arrangement.

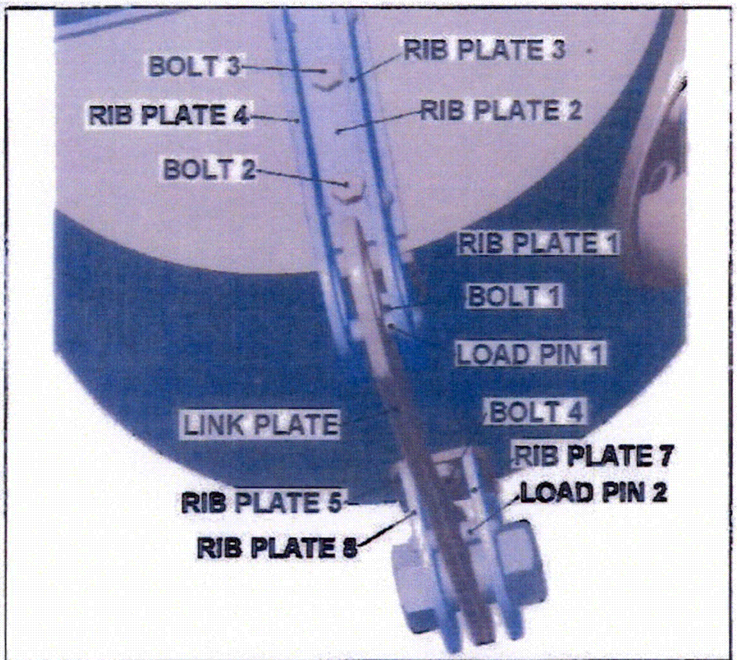


Figure 2.3. One of Four SENTRY Lifting & Tie-down Provisions

Table 2.1. Tie-Down Provision Materials List				
Component Name	Material	Condition	ASTM Spec	Minimum Yield Strength, psi
Rib Plate 1 thru 8	17-4 PH STN STL	H1025	A693	145,000
Link Plate	17-4 PH STN STL	H900	A693	170,000
Bolts 1 thru 8	17-4 PH STN STL	AH	F593	105,000
Load Pin 1 & 2	17-4 PH STN STL	H900	A693	170,000
Rivnuts 1 thru 8	316 STN STL	CW	A276	93,694

The rib assembly consists of two vertical parallel plates welded to a flat horizontal plate with two mounting holes and one perpendicular plate with one mounting hole. The vertical plates are separated by a gap to allow three hex bolts to be assembled between them attaching the rib assembly to the package. See Figures 2.4 & 2.5. The bolts pass through the mounting holes and mate into Rivnuts riveted into the cylindrical welded body of the transport package.

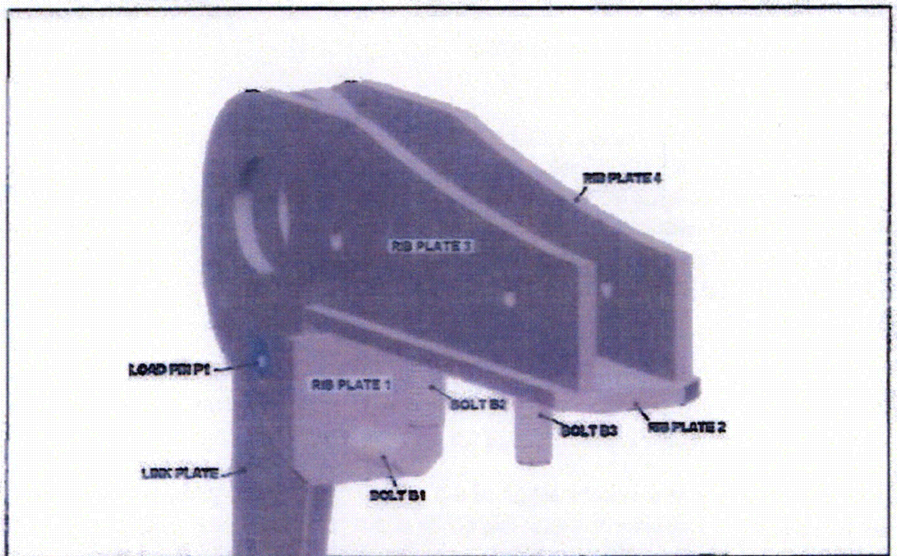


Figure 2.4. Tie-Down Rib Assembly Identification

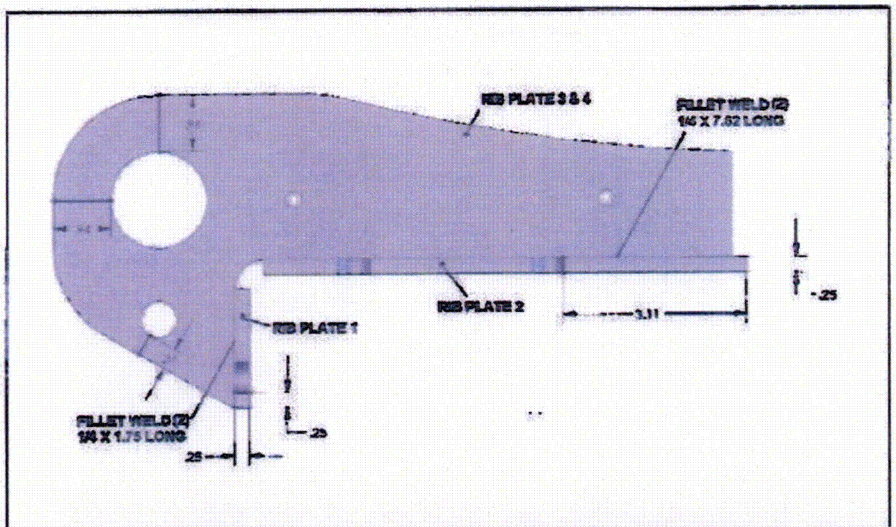


Figure 2.5. Tie-Down Rib Assembly Dimensions

3.0 Transport Tie-Down Requirement:

10 CFR Part 71.45 (b) Tie-down devices:

(1) If there is a system of tie-down devices that is a structural part of the package, the system must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of 2 times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of 5 times the weight of the package with its contents.

(2) Any other structural part of the package that could be used to tie down the package must be capable of being rendered inoperable for tying down the package during transport, or must be designed with strength equivalent to that required for tie-down devices.

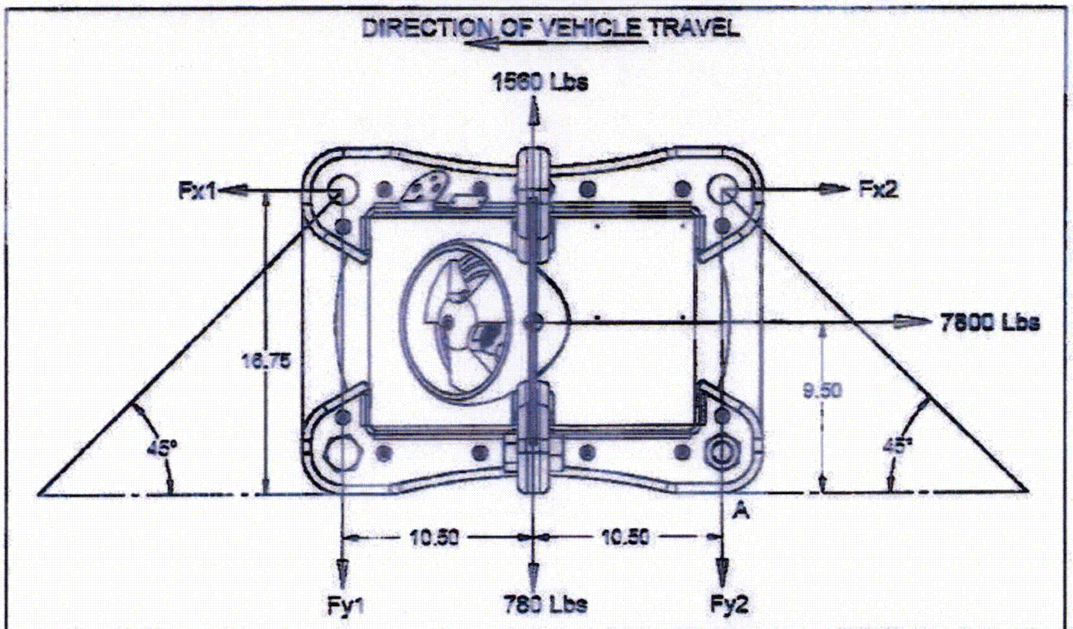
(3) Each tie-down device that is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this part.

4.0 General Assumptions:

1.0 Temperature range equal to -40 to +130 F.
2.0 No corrosion exists on the rib assembly and fastener components.
3.0 All 4 provisions are used in the tie-down analysis.

5.0 Analysis – Single Provision Tie-down by Rib Assembly:

Figure 5.1 Resolves the reaction forces in the upper tie-down provisions for a single provision arrangement with the load requirements applied per 10 CFR Part 71. Since the lateral direction loading (3900 Lbs) is less than the direction of vehicle loading (7800 Lbs), the worst case vehicle load value of 7800 lbs shall be used to determine the maximum reaction forces in the package.



$$F_{X2} = 0$$

$$+CCW \quad \Sigma M_A = 0 = 9.5(-7800) + 10.5(780) + 21(-F_{Y1}) + 16.75(F_{X1}) + 10.5(-1560) \quad : F_{Y1} = -2303$$

$$+UP \quad \Sigma F_Y = 0 = 1560 - F_{Y1} - F_{Y2} - 780 \quad : F_{Y2} = +1523$$

$$+LEFT \quad \Sigma F_X = 0 = F_{X1} - 7800 \quad : F_{X1} = +7800$$

Figure 5.1. Single Provision Force Diagram

The recommended tie-down angle for fixing the package to the bed of the vehicle is 45°. The largest reaction force found in Figure 5.1 is 7,800 Lbs in the horizontal direction. This force shall be used to determine the maximum tension force in the cable or chain from the upper provision to the vehicle bed at 45 degrees. Figure 5.2 shows the maximum tension force to be 11,031 lbs. The 11,031 tension force shall be used for the structural analysis shown in Figure 5.3.

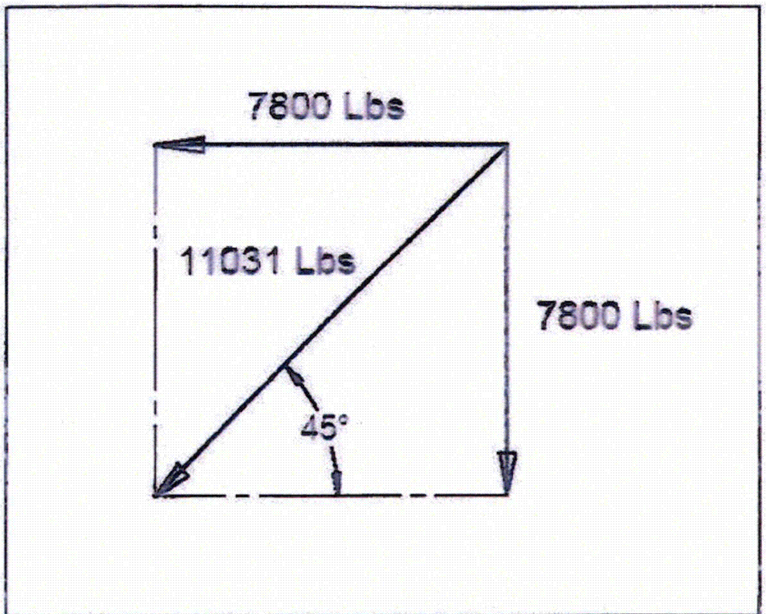


Figure 5.2. Single Provision Tension Force

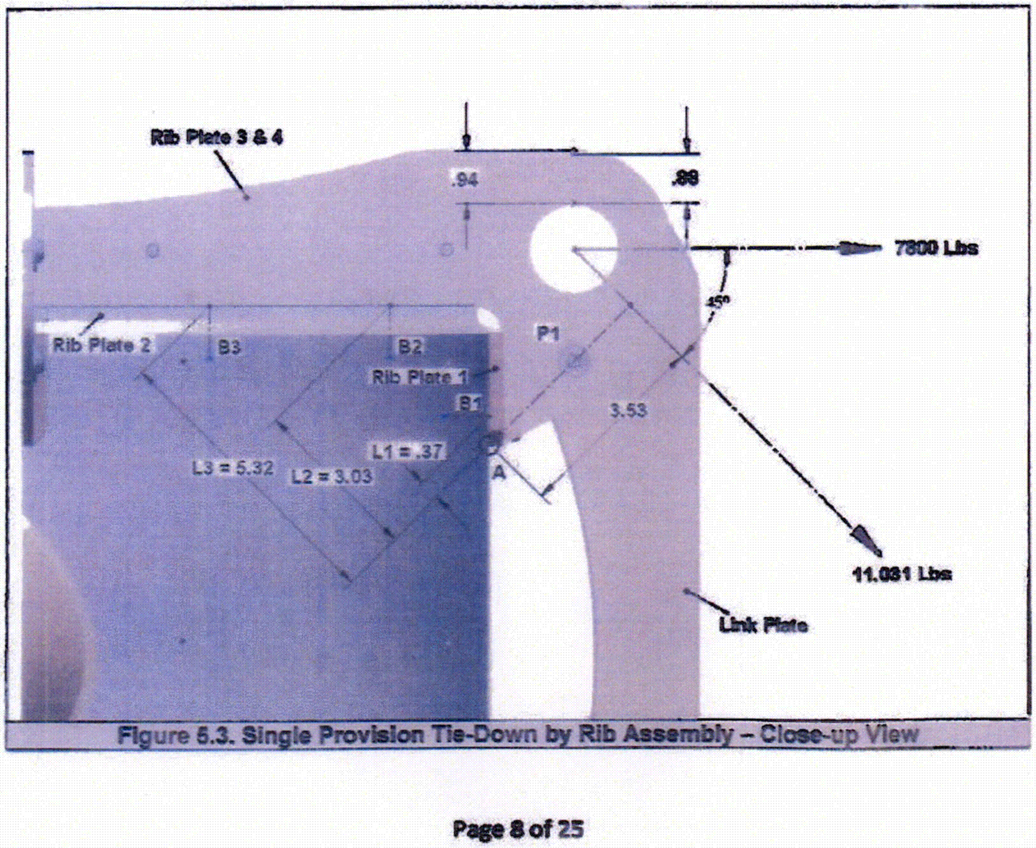


Figure 5.3. Single Provision Tie-Down by Rib Assembly – Close-up View

6.0 Results – Single Provision Tie-down by Rib Assembly:

Table 6.1 is a summary of the results of the tie-down analysis when securing the package by the rib assembly in the single provision arrangement. The table shows the calculated factor of safety for the "Bolt B3 Shear" failure is the worst case with a calculated factor of safety equal to 1. This is equal to the required factor of safety of 1. See Appendix A for the single provision tie-down by rib assembly calculations per failure mode.

Table 6.1. Summary of Single Tie-Down by Rib Analysis			
Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Rib Plates 3 & 4 Shear Tear-out	4	1	Pass
Rib Plate 2 Shear Tear-out	14		Pass
Rib Plate 2 Bearing Failure	2		Pass
Rib Plate 2 Tensile Failure	8		Pass
Bolt B3 Tensile Failure	2		Pass
Bolt B3 Shear Failure	1		Pass
Bolt B1 Thread Bearing Strip	4		Pass
Bolt B1 Thread Shear Strip	2		Pass
Rivnut at B1 Thread Shear Strip	2		Pass
Rib Plate Weld Shear – Horizontal	18		Pass
Rib Plate Weld Shear - Vertical	4		Pass
See Appendix A – Single Provision Tie-down by Rib Assembly Calculations			

7.0 Analysis – Single Provision Tie-Down by Link Plate:

The link plate is not recommended to be used as a tie-down provision. However, if the package is secured by the link plate, then it shall also meet the tie-down requirements of 10 CFR Part 71.45(b). Figure 7.1 shows the transport package secured by the link plate.

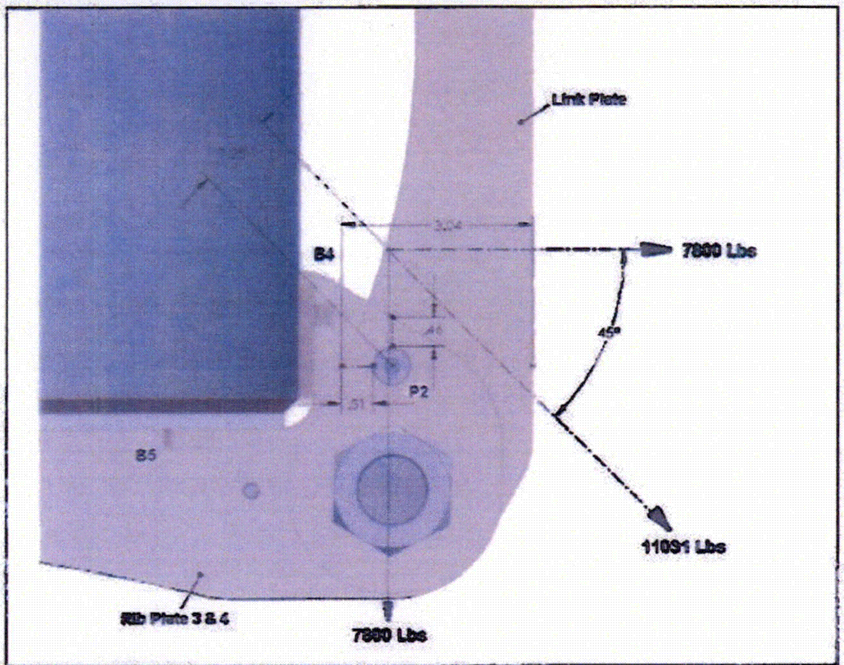


Figure 7.1. Single Provision Tie-Down by Link Plate – Close up

8.0 Results – Single Provision Tie-Down by Link Plate:

Table 8.1 is a summary of the results of the tie-down analysis when securing the package by the link plate in the single provision arrangement. The table shows the calculated factor of safety for the "Rib Plates 3 & 4 Bearing" failure mode is worst case with a calculated factor of safety equal to 3. This is 3 times the required factor of safety of 1. See Appendix B for the single provision tie-down by link plate calculations per failure mode.

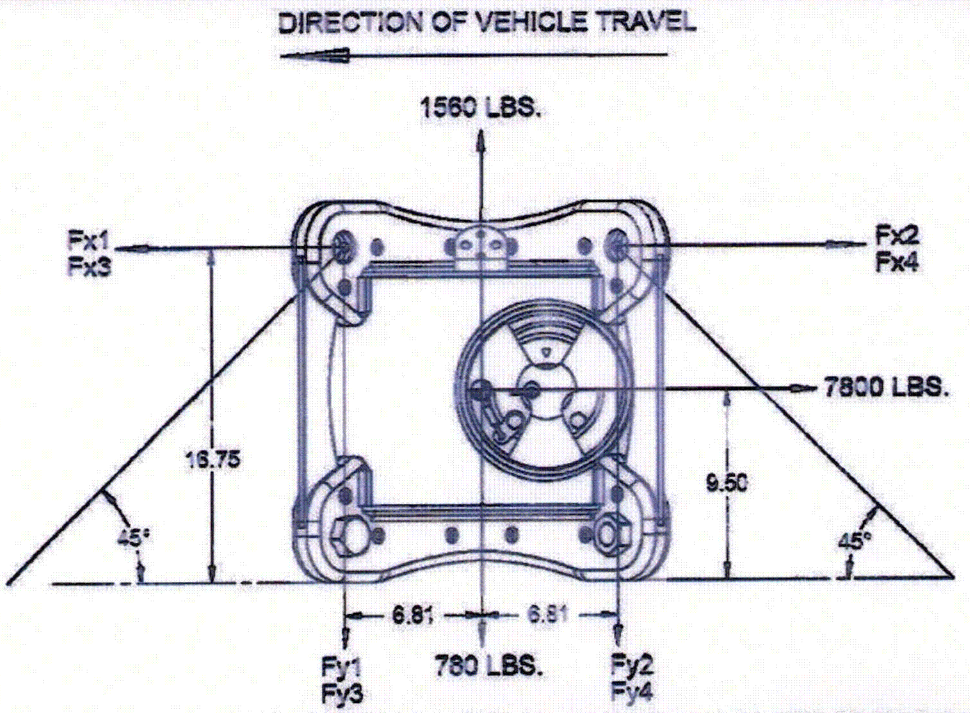
Table 8.1. Summary of Single Provision Tie-Down by Link Plate Analysis

Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Link Plate Tensile Failure - Midsection	15	1	Pass
Link Plate Shear Tear-out	6		Pass
Link Plate Bearing Failure	7		Pass
Link Plate Tensile Failure	28		Pass
Load Pin P1 or P2 Double Shear	12		Pass
Rib Plates 3 & 4 Shear Tear-out	3		Pass
Rib Plates 3 & 4 Bearing Failure	4		Pass
Rib Plates 3 & 4 Tensile Failure	15		Pass

See Appendix B – Single Provision Tie-down by Link Plate Calculations

9.0 Analysis – Shared Provision Tie-Down by Rib Assembly:

Figure 9.1 Resolves the reaction forces in the upper tie-down provisions for the shared provision arrangement with the load requirements applied per 10 CFR Part 71. Since the lateral direction loading (3900 Lbs) is less than the direction of vehicle loading (7800 Lbs), the worst case vehicle load value of 7800 lbs shall be used to determine the maximum reaction forces in the package. The calculated force for Fx1 is half the value shown since it is shared with Fx3. Similarly, the calculated forces for Fy1 and Fy2 are half the value shown since they are shared with Fy3 and Fy4 respectively.



$:F_{X2}, F_{X4} = 0$

+CCW $\Sigma M_A = 0 = 9.5(-7800) + 10.5(780) + 21(-F_{Y1}) + 16.75(F_{X1}) + 10.5(-1560)$ $:F_{Y1} = -2303/2$

$:F_{Y1}, F_{Y3} = -1152$

+ UP $\Sigma F_Y = 0 = 1560 - F_{Y2} - F_{Y1} - 780$ $:F_{Y2} = +1523/2$

$:F_{Y2}, F_{Y4} = +762$

+ LEFT $\Sigma F_X = 0 = F_{X1} - 7800$ $:F_{X1} = +7800/2$

$:F_{X1}, F_{X3} = +3900$

Figure 9.1. Shared Provision Force Diagram

The recommended tie-down angle for fixing the package to the bed of the vehicle is 45°. The largest reaction force found in Figure 9.1 is 3,900 Lbs in the horizontal direction. This force shall be used to determine the maximum tension force in the cable or chain from the upper provision to the vehicle bed. Figure 9.2 shows the maximum tension force to be 5515 lbs. The 5515 tension force shall be used for the structural analysis shown in Figure 9.3.

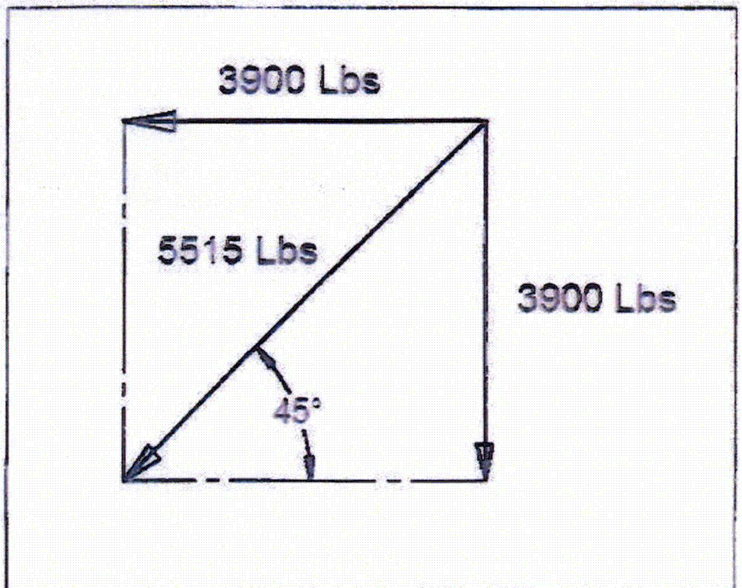


Figure 9.2. Shared Provision Tension Force

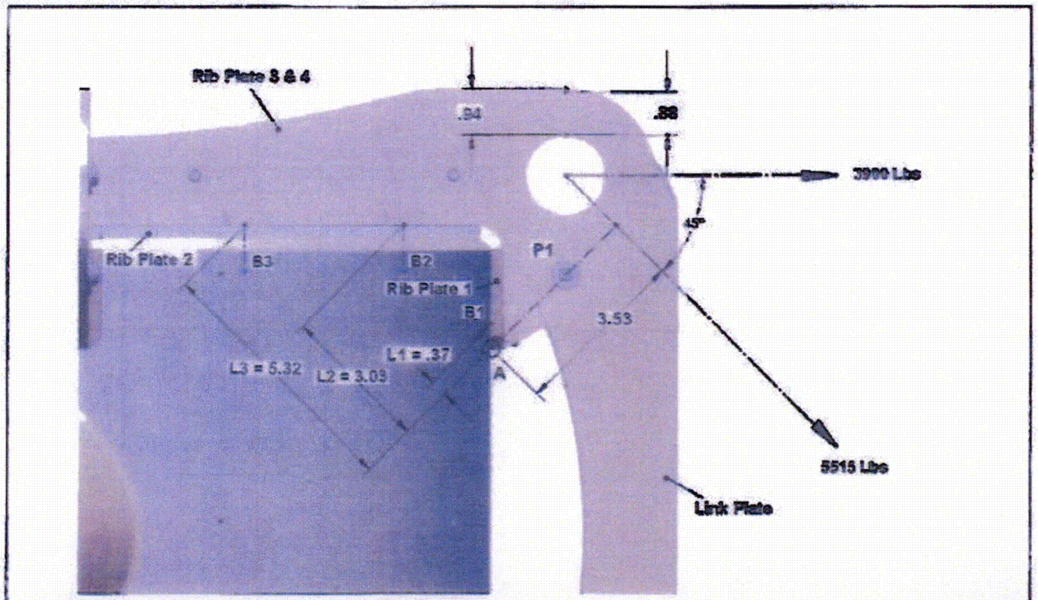


Figure 9.3. Shared Provision Tie-Down by Rib Assembly – Close-up View

10.0 Results – Shared Provision Tie-Down by Rib Assembly:

Table 10.1 is a summary of the results of the tie-down analysis when securing the package by the rib assembly in the shared provision arrangement. The table shows the calculated factor of safety for the "Bolt B3 Shear" failure is the worst case with a calculated factor of safety equal to 2. This is over 2 times the required factor of safety of 1. See Appendix C for the shared provision tie-down by rib assembly calculations per failure mode.

Table 10.1. Summary of Shared Provision Tie-Down by Rib Analysis

Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Rib Plates 3 & 4 Shear Tear-out	9	1	Pass
Rib Plate 2 Shear Tear-out	29		Pass
Rib Plate 2 Bearing Failure	4		Pass
Rib Plate 2 Tensile Failure	16		Pass
Bolt B3 Tensile Failure	3		Pass
Bolt B3 Shear Failure	2		Pass
Bolt B1 Thread Bearing Strip	9		Pass
Bolt B1 Thread Shear Strip	4		Pass
Rivnut at B1 Thread Shear Strip	4		Pass
Rib Plate Weld Shear – Horizontal	35		Pass
Rib Plate Weld Shear - Vertical	8		Pass

See Appendix C – Shared Provision Tie-down by Rib Assembly Calculations

11.0 Analysis – Shared Provision Tie-Down by Link Plate:

The link plate is not recommended to be used as a tie-down provision. However, if the package is secured by the link plate, then it shall also meet the tie-down requirements of 10 CFR Part 71.45(b). Figure 11.1 shows the transport package secured by the link plate.

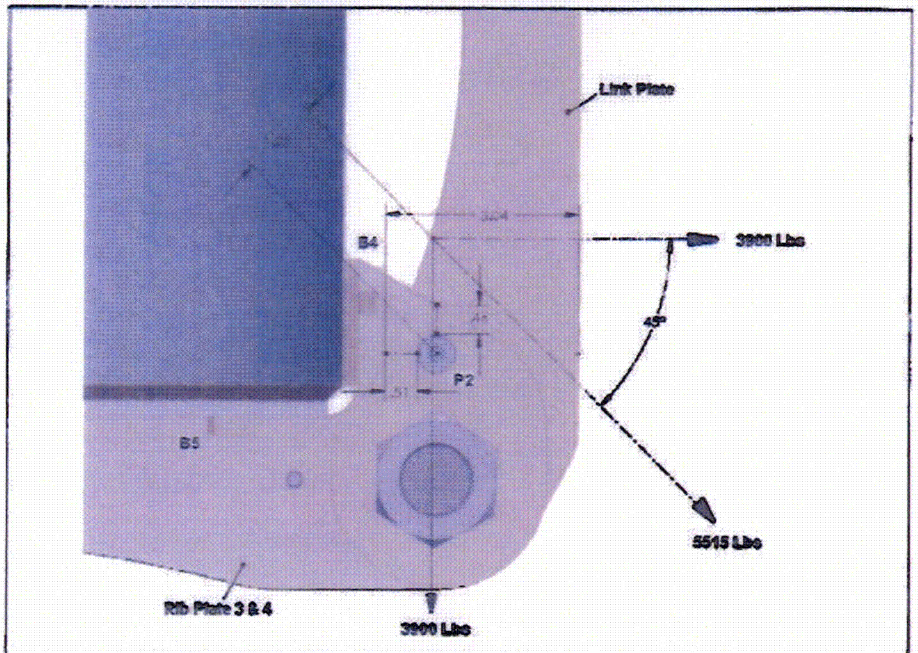


Figure 11.1. Shared Tie-Down by Link Plate – Close up

12.0 Results – Shared Provision Tie-Down by Link Plate:

Table 12.1 is a summary of the results of the tie-down analysis when securing the package by the link plate in the shared provision arrangement. The table shows the calculated factor of safety for the "Rib Plates 3 & 4 Bearing" failure mode is worst case with a calculated factor of safety equal to 6. This is 6 times the required factor of safety of 1. See Appendix D for the shared provision tie-down by link plate calculations per failure mode.

Table 12.1. Summary of Shared Provision Tie-Down by Link Plate Analysis

Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Link Plate Tensile Failure - Midsection	30	1	Pass
Link Plate Shear Tear-out	12		Pass
Link Plate Bearing Failure	14		Pass
Link Plate Tensile Failure	56		Pass
Load Pin P1 or P2 Double Shear	23		Pass
Rib Plates 3 & 4 Shear Tear-out	6		Pass
Rib Plates 3 & 4 Bearing Failure	8		Pass
Rib Plates 3 & 4 Tensile Failure	30		Pass

See Appendix D – Shared Provision Tie-down by Link Plate Calculations

13.0 Final Assessment:

The SENTRY transport package tied-down by either the rib assembly or the link plate meets the tie-down requirements of 10 CFR Part 71.45 (b). No failure mode was found to be less than 1 against yielding when securing the package by either one rib assembly or link plate.

If the tie-down provision were to fail due to excessive loading, the package is designed so that the failed provision would not impair the ability of the package to meet the other requirements of 10 CFR Part 71.

Appendix A – Single Provision Tie-Down by Rib Assembly Calculations

Determine Rib Plates 3&4 Shear Tear-out Failure

Rtfs =	16596	psi	= Tensile Stress = F/(2*L*t)
F =	7800	Lbf	= Applied Load = 10 x 780 Lbs
t =	0.250	in	= Plate thickness
L =	0.940	in	= Distance from hole to plate edge
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	4		= Factor of Safety = Ssr/Rtfs

Determine Rib Plate 2 Shear Tear out Failure

Rsts =	5016	psi	= Calc Shear Stress = F/(2*L*t)
F =	7800	Lbf	= Applied Load = 10 x 780 Lbs
t =	0.250	in	= Wall thickness
L =	3.110	in	= Distance from hole to edge
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	14		= Factor of Safety = Ssr/Rsts

Determine Rib Plate 2 Bearing Failure

Rbfs =	73934	psi	= Calc Bearing Stress = F/(d*t)
F =	7800	Lbf	= Applied Load = 10 x 780 Lbs
t =	0.250	in	= Plate thickness
d =	0.422	in	= Bolt minor diameter
Ysr =	145000	psi	= Allowable Yield Strength
Fs =	2		= Factor of Safety = Ysr/Rbfs

Determine Rib Plate 2 Tensile Failure

Rtfs =	18140	psi	= Tensile Stress = F/((w-d)*t)
F =	7800	Lbf	= Applied Load = 10 x 780 Lbs
t =	0.250	in	= Plate thickness
d =	0.530	in	= Hole diameter
w =	2.250	in	= Plate width
Ysr =	145000	psi	= Allowable Yield Strength
Fs =	8		= Factor of Safety = Ysr/Rtfs

Determine Bolt B3 Tensile Failure (Combined Stress)

B3ms=	62846	psi	=Max Tensile Stress on Bolt B3 = B3st/2 + Sqrt((B3st/2)^2 + Bss^2)
B3st =	38806	psi	= Calc Tensile Stress = Fp/A
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
Fp =	5506.6	Lbf	= Proportion of load on Bolt B3 = M*L3/SLx
A =	0.1419	in^2	= Bolt Stress Area
M =	38939	in-Lbf	= Moment = F*Lm
Lm =	3.530	in	= Moment Arm at point A
SLx =	37.620	in^2	= Bolt Distances Sumed (L1^2)+(L2^2)+(L3^2)
L3 =	5.320	in	= Bolt B3 Distance to Pivot Point A (See Figure 4 for L1, L2, & L3)
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	2		= Factor of Safety = Ysb/B3ms

Determine Bolt B3 Shear Failure (Combined Stress)

B3ss=	43443	psi	= Max Shear Stress on Bolt B3 = Sqrt ((B3st/2)^2 + Bss^2)
Bss =	38869	psi	= Calc Tensile Stress = Fn/A
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
Fn =	5516	Lbf	= Load shared by bolts B2 & B3 = F/2
A =	0.1419	in^2	= Bolt Stress Area
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	1		= Factor of Safety = Ssb/B3ss

Determine Bolt B1 Thread Bearing Failure

Btbs =	24255	psi	= Thread Bearing Stress = F/((PI/4)*(d^2-dr^2)*(h/p))
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
p =	0.077	in	= Thread pitch = 1/13
dr =	0.422	in	= Bolt root diameter
d =	0.500	in	= Bolt outer diameter
PI =	3.142	in	= Constant
h =	0.620	in	= Nut engagement
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	4		= Factor of Safety = Ssb/Btbs

Determine Bolt B1 Thread Shear Strip

Bts =	26841	psi	= Calc Shear Stress = F/(PI*dr*(h/2))
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
dr =	0.422	in	= Bolt root diameter
PI =	3.142	in	= Constant
h =	0.620	in	= Nut engagement
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	2		= Factor of Safety = Ssb/Bts

Determine Rivnut at B1 Thread Shear Strip			
Nts =	22853	psi	= Calc Shear Stress = F/(Pi*dr*(h/2))
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
dr =	0.900	in	= Nut root diameter
Pi =	3.142	in	= Constant
h =	0.820	in	= Nut engagement
Ysn =	90435	psi	= Allowable Yield Strength
Ssn =	45217	psi	= Allowable Shear Strength = Ysn/2
Fs =	2		= Factor of Safety = Ssn/Nts

Determine Rib Plates 3&4 Weld Shear Failure - Horizontal			
Rws =	4095	psi	= Tensile Stress = F/(Lw*Tw)
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
hs =	0.250	in	= Weld Size
Lw =	15.240	in	= Total Weld Length - Horizontal Direction
Tw =	0.177	in	= Weld Throat Dimension = .7071*hs
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	18		= Factor of Safety = Ssr/Rws

Determine Rib Plates 3&4 Weld Shear Failure - Vertical			
Rws =	17829	psi	= Tensile Stress = F/(Lw*Tw)
F =	11031	Lbf	= Applied Load = 7800/ (sin45°)
hs =	0.250	in	= Weld Size
Lw =	3.500	in	= Total Weld Length - Vertical Direction
Tw =	0.177	in	= Weld Throat Dimension = .7071*hs
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	4		= Factor of Safety = Ssr/Rws

Appendix B – Single Provision Tie-Down by Link Plate Calculations

Determine Link Plate Tensile Failure at Midsection

Lts =	11278	psi	= Calc Tensile Stress = F/A
F =	7800	Lbf	= Applied load
X =	1.820	in	= Min Link Length
t =	0.380	in	= Link Plate thickness
A =	0.692	in^2	= Min Plate Stress Area = X*t
Ysl =	*170000*	psi	= Allowable Yield Strength
Fs =	15		= Factor of Safety = Ysl/Lts

Determine Link Plate Shear Tearout Failure

Lsts =	14230	psi	= Calc Shear Stress = Fn/(2*L*t)
F =	11031	Lbf	= Applied Load = 7800/(sin45°)
Fn =	5515.5	Lbf	= Load Shared by 2 ends = F/2
t =	0.380	in	= Link Plate thickness
L =	0.510	in	= Distance from hole to edge
Ysl =	*170000*	psi	= Allowable Yield Strength
Ssl =	85000	psi	= Allowable Shear Strength = Ysl/2
Fs =	6		= Factor of Safety = Ssl/Lsts

Determine Link Plate Bearing Failure

Lbfs =	25025	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	11031	Lbf	= Applied Load = 7800/(sin45°)
Fn =	5515.5	Lbf	= Load Shared by 2 ends = F/2
dp =	0.580	in	= Pin diameter
t =	0.380	in	= Link Plate thickness
Ysl =	*170000*	psi	= Allowable Yield Strength
Fs =	7		= Factor of Safety = Ysl/Lbfs

Determine Link Plate Tensile Failure

Ltfs =	6023	psi	= Tensile Stress = Fn/((w-d)*t)
F =	11031	Lbf	= Applied Load = 7800/(sin45°)
Fn =	5515.5	Lbf	= Load Shared by 2 ends = F/2
d =	0.630	in	= Hole diameter
t =	0.380	in	= Link Plate thickness
w =	3.040	in	= Link Plate width
Ysl =	*170000*	psi	= Allowable Yield Strength
Fs =	28		= Factor of Safety = Ysl/Ltfs

Determine Load Pin #1 Double Shear Failure

Pdss =	7381	psi	= Calc Tensile Stress = Fn/(A*2)
F =	7800	Lbf	= Applied load
Fn =	3900	Lbf	= Load Shared by 2 Pins = F/2
dp =	0.580	in	= Pin diameter
A =	0.264	in^2	= Pin Area = $Pi*(dp/2)^2$
Pi =	3.142	in	= Constant
Ysp =	*170000*	psi	= Allowable Yield Strength
Ssp =	85000	psi	= Allowable Shear Strength = Ysp/2
Fs =	12		= Factor of Safety = Ssp/Pdss

Determine Rib Plates 3 & 4 Shear Tearout Failure

Rsts =	23980	psi	= Calc Shear Stress = Fn/(2*L*t)
F =	11031	Lbf	= Applied Load = 7800/(sin45°)
Fn =	5515.5	Lbf	= Load Shared by 2 plates = F/2
t =	0.250	in	= Rib Plate thickness
L =	0.460	in	= Distance from hole to edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	3		= Factor of Safety = Ssr/Rsts

Determine Rib Plates 3 & 4 Bearing Failure

Rbfs =	38038	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	11031	Lbf	= Applied Load = 7800/(sin45°)
Fn =	5515.5	Lbf	= Load Shared by 2 plates = F/2
dp =	0.580	in	= Pin diameter
t =	0.250	in	= Rib Plate thickness
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	4		= Factor of Safety = Ysr/Rbfs

Determine Rib Plates 3 & 4 Tensile Failure

Rtfs =	9698	psi	= Tensile Stress = Fn/((w-(dp+dl))*t)
F =	11031	Lbf	= Applied Load = 7800/(sin45°)
Fn =	5515.5	Lbf	= Load Shared by 2 plates = F/2
dp =	0.630	in	= Pin hole diameter
t =	0.250	in	= Rib Plate thickness
w =	4.530	in	= Rib Plate width
dl =	1.625	in	= Large hole diameter
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	15		= Factor of Safety = Ysr/Rtfs

Appendix C – Shared Provision Tie-Down by Rib Assembly Calculations

Determine Rib Plates 3&4 Shear Tear-out Failure

Rtfs =	8298	psi	= Tensile Stress = F/(2*L*t)
F =	3900	Lbf	= Applied Load = (10 x 780 Lbs)/2
t =	0.250	in	= Plate thickness
L =	0.940	in	= Distance from hole to plate edge
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	9		= Factor of Safety = Ssr/Rtfs

Determine Rib Plate 2 Shear Tear out Failure

Rsts =	2508	psi	= Calc Shear Stress = F/(2*L*t)
F =	3900	Lbf	= Applied Load = (10 x 780 Lbs)/2
t =	0.250	in	= Wall thickness
L =	3.110	in	= Distance from hole to edge
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	29		= Factor of Safety = Ssr/Rsts

Determine Rib Plate 2 Bearing Failure

Rbfs =	36967	psi	= Calc Bearing Stress = F/(d*t)
F =	3900	Lbf	= Applied Load = (10 x 780 Lbs)/2
t =	0.250	in	= Plate thickness
d =	0.422	in	= Bolt minor diameter
Ysr =	145000	psi	= Allowable Yield Strength
Fs =	4		= Factor of Safety = Ysr/Rbfs

Determine Rib Plate 2 Tensile Failure

Rtfs =	9070	psi	= Tensile Stress = F/((w-d)*t)
F =	3900	Lbf	= Applied Load = (10 x 780 Lbs)/2
t =	0.250	in	= Plate thickness
d =	0.530	in	= Hole diameter
w =	2.250	in	= Plate width
Ysr =	145000	psi	= Allowable Yield Strength
Fs =	16		= Factor of Safety = Ysr/Rtfs

Determine Bolt B3 Tensile Failure (Combined Stress)

B3ms =	31420	psi	= Max Tensile Stress on Bolt B3 = B3st/2 + Sqrt((B3st/2)^2 + Bss^2)
B3st =	19401	psi	= Calc Tensile Stress = Fp/A
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fp =	2753.0	Lbf	= Proportion of load on Bolt B3 = M*L3/SLx
A =	0.1419	in^2	= Bolt Stress Area
M =	19468	in-Lbf	= Moment = F*Lm
Lm =	3.530	in	= Moment Arm at point A
SLx =	37.620	in^2	= Bolt Distances Sumed (L1^2)+(L2^2)+(L3^2)
L3 =	5.320	in	= Bolt B3 Distance to Pivot Point A (See Figure 4 for L1, L2, & L3)
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	3		= Factor of Safety = Ysb/B3ms

Determine Bolt B3 Shear Failure (Combined Stress)

B3ss =	21719	psi	= Max Shear Stress on Bolt B3 = Sqrt ((B3st/2)^2 + Bss^2)
Bss =	19435	psi	= Calc Tensile Stress = Fn/A
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2758	Lbf	= Load shared by bolts B2 & B3 = F/2
A =	0.1419	in^2	= Bolt Stress Area
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	2		= Factor of Safety = Ssb/B3ss

Determine Bolt B1 Thread Bearing Failure

Btbs =	12125	psi	= Thread Bearing Stress = F/[(PI/4)*(d^2-dr^2)*(h/p)]
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
p =	0.077	in	= Thread pitch = 1/13
dr =	0.422	in	= Bolt root diameter
d =	0.500	in	= Bolt outer diameter
PI =	3.142	in	= Constant
h =	0.620	in	= Nut engagement
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	9		= Factor of Safety = Ssb/Btbs

Determine Bolt B1 Thread Shear Strip

Bts =	13419	psi	= Calc Shear Stress = F/(PI*dr*(h/2))
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
dr =	0.422	in	= Bolt root diameter
PI =	3.142	in	= Constant
h =	0.620	in	= Nut engagement
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	4		= Factor of Safety = Ssb/Bts

Determine Rivnut at B1 Thread Shear Strip			
Nts =	11326	psi	= Calc Shear Stress = F/(PI*dr*(h/2))
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
dr =	0.500	in	= Nut root diameter
PI =	3.142	in	= Constant
h =	0.620	in	= Nut engagement
Ysn =	90435	psi	= Allowable Yield Strength
Ssn =	45217	psi	= Allowable Shear Strength = Ysn/2
Fs =	4		= Factor of Safety = Ssn/Nts

Determine Rib Plates 3&4 Weld Shear Failure - Horizontal			
Rws =	2047	psi	= Tensile Stress = F/(Lw*Tw)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
hs =	0.250	in	= Weld Size
Lw =	15.240	in	= Total Weld Length - Horizontal Direction
Tw =	0.177	in	= Weld Throat Dimension = .7071*hs
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	35		= Factor of Safety = Ssr/Rws

Determine Rib Plates 3&4 Weld Shear Failure - Vertical			
Rws =	8914	psi	= Tensile Stress = F/(Lw*Tw)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
hs =	0.250	in	= Weld Size
Lw =	3.500	in	= Total Weld Length - Vertical Direction
Tw =	0.177	in	= Weld Throat Dimension = .7071*hs
Ysr =	145000	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	8		= Factor of Safety = Ssr/Rws

Appendix D – Shared Provision Tie-Down by Link Plate Calculations

Determine Link Plate Tensile Failure at Midsection

Lts =	5639	psi	= Calc Tensile Stress = F/A
F =	3900	Lbf	= Applied load
X =	1.820	in	= Min Link Length
t =	0.380	in	= Link Plate thickness
A =	0.692	in^2	= Min Plate Stress Area = X*t
Ysl =	*170000*	psi	= Allowable Yield Strength
Fs =	30		= Factor of Safety = Ysl/Lts

Determine Link Plate Shear Tearout Failure

Lsts =	7114	psi	= Calc Shear Stress = Fn/(2*L*t)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2757.5	Lbf	= Load Shared by 2 ends = F/2
t =	0.380	in	= Link Plate thickness
L =	0.510	in	= Distance from hole to edge
Ysl =	*170000*	psi	= Allowable Yield Strength
Ssl =	85000	psi	= Allowable Shear Strength = Ysl/2
Fs =	12		= Factor of Safety = Ssl/Lsts

Determine Link Plate Bearing Failure

Lbfs =	12511	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2757.5	Lbf	= Load Shared by 2 ends = F/2
dp =	0.580	in	= Pin diameter
t =	0.380	in	= Link Plate thickness
Ysl =	*170000*	psi	= Allowable Yield Strength
Fs =	14		= Factor of Safety = Ysl/Lbfs

Determine Link Plate Tensile Failure

Ltfs =	3011	psi	= Tensile Stress = Fn/((w-d)*t)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2757.5	Lbf	= Load Shared by 2 ends = F/2
d =	0.630	in	= Hole diameter
t =	0.380	in	= Link Plate thickness
w =	3.040	in	= Link Plate width
Ysl =	*170000*	psi	= Allowable Yield Strength
Fs =	56		= Factor of Safety = Ysl/Ltfs

Determine Load Pin #1 Double Shear Failure			
Pdss =	3690	psi	= Calc Tensile Stress = Fn/(A*2)
F =	3900	Lbf	= Applied load
Fn =	1950	Lbf	= Load Shared by 2 Pins = F/2
dp =	0.580	in	= Pin diameter
A =	0.264	in^2	= Pin Area = PI*(dp/2)^2
PI =	3.142	in	= Constant
Ysp =	*170000*	psi	= Allowable Yield Strength
Ssp =	85000	psi	= Allowable Shear Strength = Ysp/2
Fs =	23		= Factor of Safety = Ssp/Pdss

Determine Rib Plates 3 & 4 Shear Tearout Failure			
Rsts =	11989	psi	= Calc Shear Stress = Fn/(2*L*t)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2757.5	Lbf	= Load Shared by 2 plates = F/2
t =	0.250	in	= Rib Plate thickness
L =	0.460	in	= Distance from hole to edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	6		= Factor of Safety = Ssr/Rsts

Determine Rib Plates 3 & 4 Bearing Failure			
Rbfs =	19017	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2757.5	Lbf	= Load Shared by 2 plates = F/2
dp =	0.580	in	= Pin diameter
t =	0.250	in	= Rib Plate thickness
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	8		= Factor of Safety = Ysr/Rbfs

Determine Rib Plates 3 & 4 Tensile Failure			
Rtfs =	4848	psi	= Tensile Stress = Fn/[(w-(dp+dl))*t)
F =	5515	Lbf	= Applied Load = 3900/ (sin45°)
Fn =	2757.5	Lbf	= Load Shared by 2 plates = F/2
dp =	0.630	in	= Pin hole diameter
t =	0.250	in	= Rib Plate thickness
w =	4.530	in	= Rib Plate width
dl =	1.625	in	= Large hole diameter
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	30		= Factor of Safety = Ysr/Rtfs

2.12.11 Test Plan 195 dated 30 June 2010

QSA GLOBAL	Document Number **F-E-1808-1** **Test Plan Cover Sheet**	Revision 0

TEST PLAN 195

SENTRY TRANSPORT PACKAGE
STANDARD CONFIGURATION
Type (B) Transport Tests

Originator	S. Gemi	Date: 25 June 2010

APPROVALS		
Engineering	S. Gemi	Date: 25 June 2010
Regulatory	L. Ricker	Date: 30 Jun 2010
Quality Assurance	C. Roughan	Date: 30 Jun 2010

TEST PLAN 195

SENTRY TRANSPORT PACKAGE
STANDARD CONFIGURATION
TYPE (B) TRANSPORT TESTS

JUNE 2010

Contents

Test Plan No. 195

Section 1 Introduction

A review of the results of Test plan 180 report #2 raised the need to perform another drop test sequence on a test specimen built to the special configuration of the SENTRY transport package. The special configuration is identical to the standard configuration but without the plastic inserts assembled into the handling rib assemblies.

The additional testing involves dropping a test specimen in the orientation with the rear plate access port faces down towards the drop pad. This orientation does not provide much impact absorption with the handling ribs attached. The drop test height shall be adjusted higher than 10 CFR Part 71 drop height requirements to give the test specimen the impact energy equivalent to a SENTRY transport package built to the maximum specified weight of 780 Lbs. This test specimen built to the special configuration in the specified orientation at the adjusted height is the worst case test condition for the SENTRY transport package built to the standard configuration.

This plan will test the SENTRY transport package in the special standard configuration to the test requirements for Type B(U)-96 packages as described in the Code of Federal Regulations, 10 CFR Part 71, revised as of March 31, 1999. The test plan also covers the criteria stated in the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Series No.6 1985 Edition (As Amended 1990).

This document describes the test specimen, testing equipment, testing scenario, justifies the package orientation and provides test worksheets to record key steps in the testing sequence.

<u>Roles and Responsibilities</u>

- **Engineering** executes the tests according to the test plan and summarizes the test results.
- **Regulatory Affairs** monitors the tests and reviews test reports for compliance with regulatory requirements.
- **Quality Assurance** oversees test execution and test report generation to assure compliance with the QSA Global Quality Assurance Program.
- **Engineering, Regulatory Affairs** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71 and IAEA TS-R-1 1996.

Section 2 Transport Package Description

The SENTRY transport package is a family of packages, consisting of 2 different model numbers. Model 860 refers to the SENTRY projector series and Model 867 refers to the SENTRY source changer.

The Model 860 SENTRY Projector series is further broken down into 2 projectors types defined by their rated capacity for cobalt-60, the SENTRY 330 and SENTRY 110 projectors. Each projector type is available in either a standard or basic transport package configuration. The standard configuration will most likely be the most commonly used version of the transport package. The basic configuration is the same as the standard configuration but without the array of removable handling rib assemblies.

The Model 867 SENTRY source changer is rated at 330 curies of cobalt-60. Similar to the projectors, the source changer is available in both a standard and basic configuration.

Figure 2.1.is a schematic overview of the SENTRY transport package configuration tree.

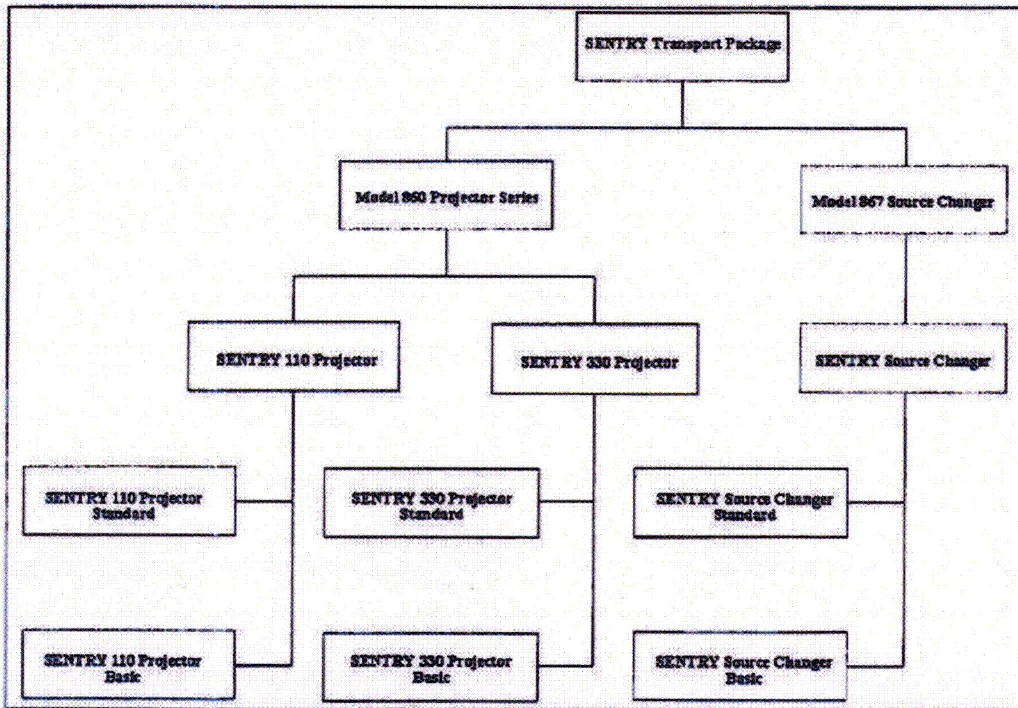


Figure 2.1. SENTRY Transport Package Configuration Tree.

Table 2.1 is a reference table comparing the various SENTRY transport package configurations.

Table 2.1. SENTRY Transport Package Configurations.						
Configuration	Handling Ribs	Active Source Wire Assembly	Active Source Capsule	Max. Package Weight (Lbs.)	Refer to Figure	Source Capacity (Curies of Co60)
** SENTRY 330 Projector – Standard	Yes	42465-9 & 42465-10	60011 & 60012	780	2.2	330
SENTRY 330 Projector – Basic	No	42465-9 & 42465-10	60011 & 60012	700	2.3	330
SENTRY 110 Projector – Standard	Yes	42465-8	60011	580	2.2	110
SENTRY 110 Projector – Basic	No	42465-8	60011	500	2.3	110
SENTRY Source Changer – Standard	Yes	42465-8, 42465-9 & 42465-10	60011 & 60012	780	2.2	330
SENTRY Source Changer - Basic	No	42465-8, 42465-9 & 42465-10	60011 & 60012	700	2.3	330

** Indicates configuration but without plastic inserts to be tested in this test plan.

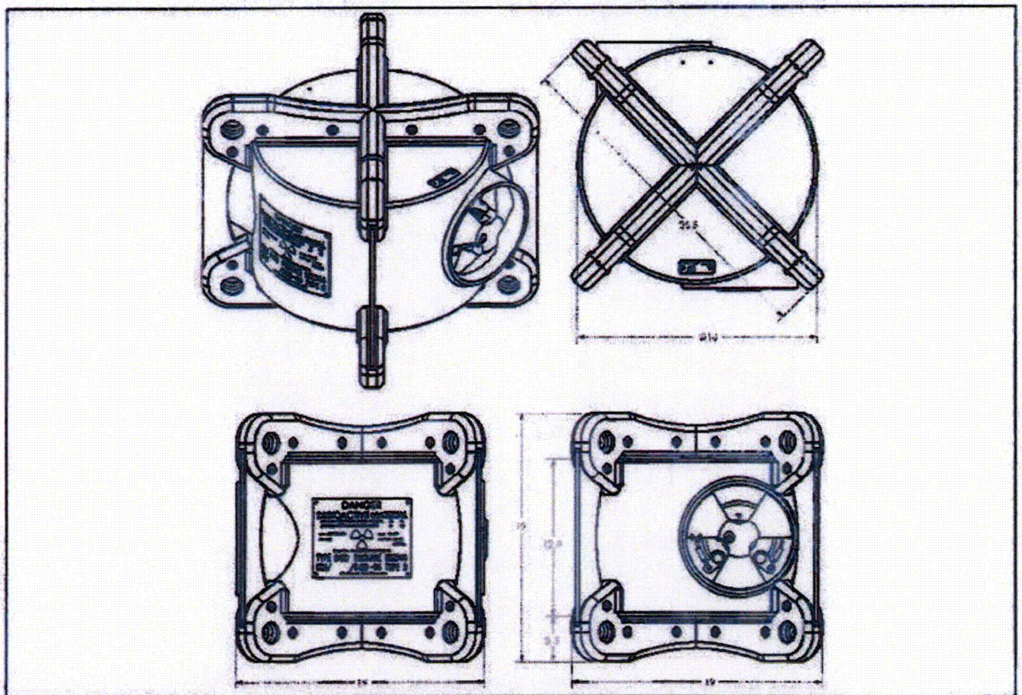


Figure 2.2. SENTRY Transport Package Standard Configuration.

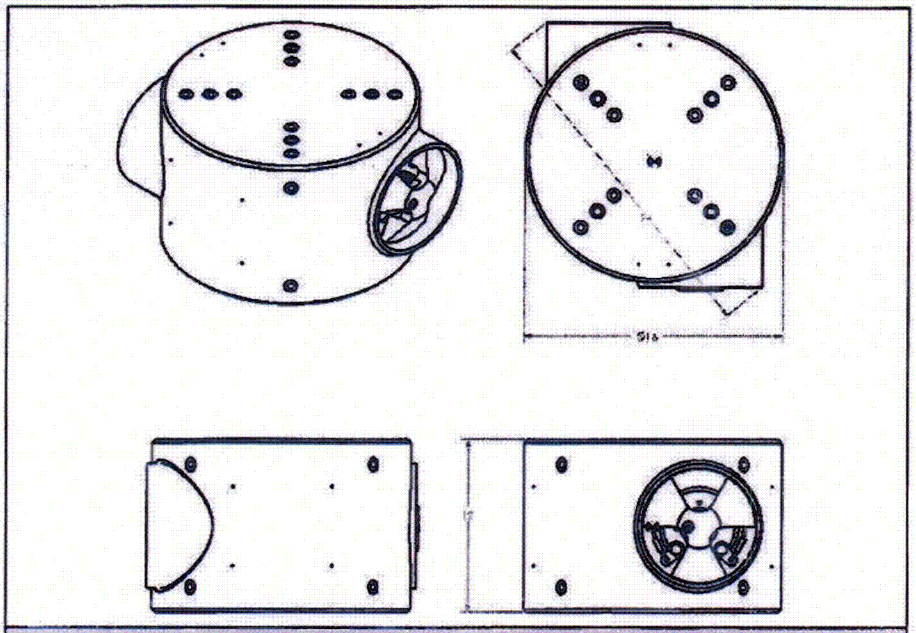


Figure 2.3. SENTRY Transport Package Basic Configuration.

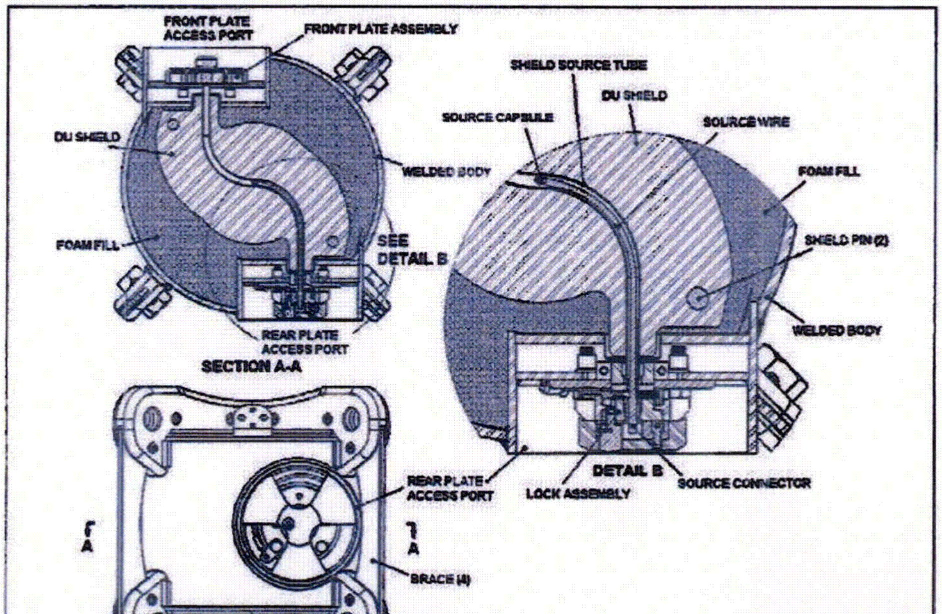


Figure 2.4. SENTRY Transport Package Common Components

All configurations include a depleted uranium shield completely encased and fully supported in a cylindrically shaped, stainless steel, welded body (See Figure 2.4). The welded body, also called the shell, includes two, tube shaped, access ports integrally welded on opposite sides of the main body. A twin set of shield mounting bars, one on each side of the shield, are welded to the back plate of each access port tube. Heavy duty,

titanium, shield pins pass through the shield and into both shield mounting bars. This creates two positive shield attachment points to the welded body.

The shield source tube ends are also inserted into holes in each of the access port back plates. In addition to this, the shield is captured and centrally located between the top and bottom endplates. This combination of shield securing features provide for a robust shield support system within the welded body.

The inner cavity of the welded body, around the shield, is filled with polyurethane foam. The foam prevents contamination to and from the depleted uranium shield. Previous thermal tests have shown charred polyurethane foam will inhibit the flow of oxygen to the shield and prevent oxidation from occurring during a fire as long as the foam remains confined. This is shown on QSA Global test plan results number 70.

Previous tests have also shown the charred foam will not support the shield at temperatures at or above 800°C. Therefore, the SENTRY relies primarily on the shield support system inside the welded body to hold the shield in place during the thermal test where temperatures reach 800°C.

A titanium source tube, cast into the center of the shield, provides a conduit for the source wire assembly within the shield. The source tube of the SENTRY projector allows the source assembly to pass through the shield. However, the source tube of the SENTRY source changer has a stop to prevent the source assembly from passing through the center of the container. The source capsule is located close to the most shielded location at the center of the shield in all transport configurations.

The two opposing access ports provide a protected mounting space for both the rear-plate and front-plate assemblies. The front-plate assembly is used only on the projector configurations. The source changer configuration uses a rear-plate assembly in each access port.

In all configurations, the rear-plate assembly locks, secures, and locates the source wire assembly to an ideally shielded position within the package. A redundant fastening system attaches the rear-plate to the welded body. The primary attachment method of the fastening system is achieved by four, high strength, stainless steel, hex head bolts, BLT015, threaded into stainless steel rivet nuts assembled into the welded body. The rivet nuts facilitate repair in the event the threads are damaged in the future. An alternate configuration consists of using a threaded stainless steel ring with multiple tapped holes instead of using the rivet nuts. The ring can be rotated to use a different set of tapped holes in the event the initial set becomes damaged.

The secondary method of attachment is by a single stainless steel tamperproof button head screw. This screw reduces and limits unauthorized access to the source. The tertiary method of attachment is provided by two, stainless steel, retaining pins (projectors) or set screws (changer) assembled to the rear-plate. The pins or set screws enter the welded body through a horizontal slot in the mounting plate. The rear-plate is rotated 90 degrees to prevent the pins or set screws from passing back out through the mounting plate where no slot exists. This keeps the rear-plate from separating from the welded body in the event the primary and secondary attachment methods are compromised. The recessed location of the rear-plate mounting surface within the access port tube provides additional restraint preventing rotation and translation on the rear-plate. This effect requires only one screw or bolt to keep the source secured to the shield in the welded body.

There are three rear-plate assembly designs used in the SENTRY transport package. All three designs use the same basic rear-plate assembly concept but the projector and source changer configurations differ in the way the source wire assembly is locked to the package.

Except for the SENTRY 110 projector rear-plate being 0.31 inches thinner than the SENTRY 330 rear-plate, both projector configurations use the same rear-plate assembly. The difference in rear-plate thickness is to allow for the difference in length of the dedicated source wire assemblies used in each projector.

All SENTRY configurations use a selector ring to change and indicate the safety state of the package. When the selector ring is rotated to the "LOCK" position, it securely holds the source wire assembly in place for transport. The selector ring retainer allows the selector ring to rotate and keeps it attached to the rear-plate

assembly. The selector ring retainer also provides the housing for the critical spring-loaded locking components and is attached to the rear-plate by 4 stainless steel socket head cap screws.

The projector configurations use the round ball feature of the connector to capture the source wire assembly between two spring-loaded locking components, the sleeve and lock slide, of the rear-plate assembly to secure the source wire assembly to the package.

The source changer configuration uses two spring-loaded fork shaped locking pins to hold the helical wrap feature of the Teleflex wire or cable to secure the source wire assembly to the package. The source changer cannot use the same source wire securing mechanism as the projectors because of two reasons.

1. The source changer accommodates two different length source wire assemblies.
2. The source changer requires the source to enter and exit from the same rear-plate assembly.

A sealed, special form, stainless steel, source capsule contains the radioactive contents of the package. The source capsule and a stainless steel connector are independently swaged to each end of a flexible stainless steel wire or cable to form the source wire assembly.

A dust cover over the source wire connector prevents access to the source assembly until a keyed plunger lock is actuated and the cover removed. This dust cover is in place during transport.

The front-plate assembly of the projector does not hold the source assembly but instead blocks access into or out of the source tube cavity from the end opposite the rear-plate access port.

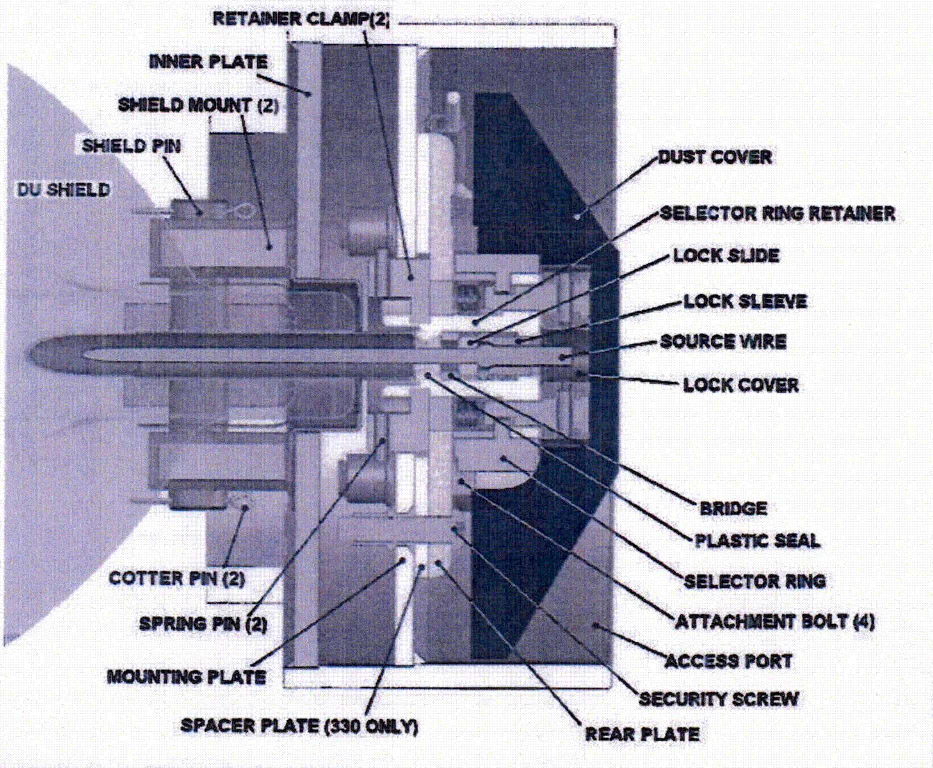


Figure 2.5. SENTRY Projector(s) Rear-plate Assembly with source wire secured

Figure 2.5 shows the rear-plate assembly end of the projector version of the SENTRY transport package. The SENTRY 110 rear-plate is thinner than the SENTRY 330 rear-plate by 0.31 inches to account for the

difference in source wire lengths. Except for the shield and the rear-plate thickness, all other components are identical in both projectors.

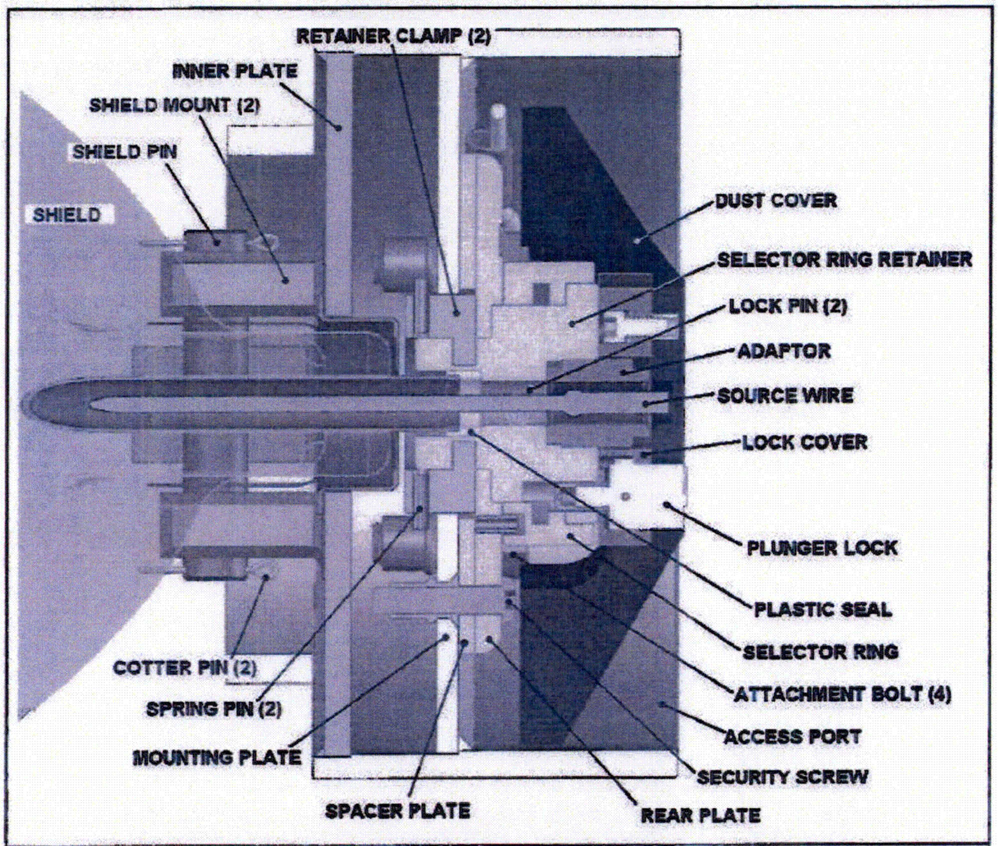


Figure 2.6. SENTRY Source Changer Rear-plate Assembly with source wire secured

Figure 2.6 shows the rear-plate assembly end of the source changer version of the SENTRY transport package. The source changer rear-plate is essentially the same thickness as the SENTRY 330 projector rear-plate. Many of the source changer rear-plate components differ from the projector version, but the rear-plate fastening system is identical.

Section 3 Regulatory Compliance

The main purpose of this test plan is to demonstrate that the SENTRY projector/transport package complies with the Type B(U)-96 transport package test requirements of 10 CFR 71 and IAEA TS-R-1 1996.

3.1 *Normal Transport Condition Tests*

The **water spray preconditioning** (10 CFR 71.71 (c) (6)), the **compression test** (10 CFR 71.71 (c) (9)), and the **penetration test** (10 CFR 71.71 (c) (10)) were all addressed under test plan 180 report #1.

The **1.2 meter free drop test** per 10 CFR 71.71 (c) (7) was addressed under test plan 180 report #1 & 2. A test specimen dropped in the same orientation as planned for this test was dropped from 32.2 feet twice without a change in the safety performance of the package. All components important to safety remained intact and functional after the first drop. The radiation dose levels were below 200-mR/hr on the surface of the package after all tests. Therefore, there is no need to perform the 1.2 meter again before the 9 meter drop test.

3.2 *Hypothetical Accident Condition Tests*

The **crush test** (10 CFR 71.73 (c) (2)) and the **immersion test** (10 CFR 71.73 (c) (6)) were both addressed under test plan 180 report #1.

The SENTRY transport package shall be subjected to the 9 **meter free drop test** (10 CFR 71.73 (c) (1), and then the **puncture test** (10 CFR 71.73 (c) (3).

The **thermal test** (10 CFR 71.73 (c) (4)) will most likely be assessed and not performed. The assessment will be based on the examination of the damage to the test specimen after the puncture test. Experience from thermal testing the Model 660 & Model 680 transport packages has shown the shield will oxidize and diminish its ability to protect only when the adjacent foam fill is allowed to combust and then fall away from the shield. Charred foam seems to provide enough thermal insulation to prevent the shield from oxidizing as long as the charred foam remains in place. Any damage producing an unintentional opening in the shell or welded body would need to be assessed to determine whether the transport package would pass or fail the thermal test.

3.3 Free Drop Height Adjustment

Assume air friction is negligible for an object dropped from 30 feet. The kinetic energy of the dropped package just before impact is equal to the total potential energy just before the package began to drop. The potential energy (PE) is simply equal to the weight (W) of the package multiplied by the height (H) of the package just before it was dropped.

PE = W x H

In this equation, the weight (W) is directly proportional to the height (H). Therefore, a lighter package can be dropped from a higher drop height in order to produce equivalent impact energy for a heavier package dropped at a lower drop height. The following example calculates the adjusted 30-foot free drop height for a SENTRY 330 Standard test specimen built lighter than the maximum allowable package weight for this configuration.

Drop #1: The maximum package weight is 780 pounds and the free drop height requirement is 30 feet.

PE (1) = 780 x 30 = 23400 Lbs-Ft

Drop #2: Say, the actual test specimen weight is 734 pounds and adjusted free drop height is unknown, H.

PE (2) = PE (1) = 23400 Lbs-Ft = 743 Lbs x H feet

H = 31.5 feet = 31 feet 6 inches

The actual adjusted drop heights for the 30-foot free drop and puncture drop tests is to be determined once the test specimen is weighed and just before the test.

The adjusted heights will provide impact energy equal to or greater than the maximum transport package weight if dropped at the 10 CFR Part 71 specified drop heights (30 feet free drop and 1 meter puncture).

Section 4 Discussion on System Failure Modes of Interest

The tests of this plan attempt to cause failure or malfunction to critical safety components and/or systems needed to protect against elevated dose levels during and after a hypothetical accident as described in 10CFR part 71. The critical safety components and/or systems of the SENTRY transport package are the shield, the rear plate assembly, the rear plate attachment hardware, and the location of the source assembly within the shield.

Possible failure modes of interest for this test are as follows:

- Fracture of the depleted uranium (DU) shield causing failure to provide sufficient shielding.
- Damage to the welded body enough to shift in the shield location relative to the shielded source assembly causing unacceptable dose levels around the package.
- Damage to the rear plate lock assembly enough to remove the source assembly from its shielded location
- Failure of the rear plate attachment hardware to keep the rear plate lock assembly with source assembly attached to the package.

4.1 Pass Criteria

To confirm the package meets the normal conditions of transport requirements, the test specimen shall be considered passing the test if it does not show any signs of loss or dispersal of its radioactive or simulated contents and also does not show a substantial reduction in the effectiveness of the packaging.

To confirm the package meets the hypothetical accident condition requirements, the test specimen shall be considered passing the test if it also does not show an increase in external surface radiation levels above 1-R/hr at 1 meter (40 inches) from the packages external surface after the hypothetical accident condition tests.

Section 5 Assessment of Package Conformance

5.1 *Hypothetical Accident Conditions (71.51 (a)(2))*

There should be no escape of radioactive materials greater than A_2 in one week and no external dose rate greater than 1 R/hr at 1m from the external surface with the maximum radioactive contents which the package is designed to carry.

5.2 *Transport Package Contents*

The SENTRY transport package is designed to carry a special form cobalt-60 source capsule. Containment of the radioactive source is tested at manufacture. The source capsule design has been certified in accordance with the performance requirements for special form as specified in 10 CFR Part 71 and IAEA TS-R-1 1996.

This test plan therefore does not discuss/specify tests associated with the containment of the radioactive source. The purpose of the tests is to demonstrate that the source remains shielded within the limits specified by the regulations.

Since source integrity has been demonstrated through special form testing, a simulated source will be used during testing of the package. The radiation levels after testing will be measured by replacing the simulated source with an active source. The post-test measurements will be compared with pre-test measurements to verify the source has not shifted within the shield.

Section 6 Construction and Condition of Test Specimens

The SENTRY transport package test specimens shall be constructed in accordance with QSA Global engineering drawings and Quality Assurance Program. The drawings and quality program accurately represent the intended design along with methods for manufacturing and verifying the finished product.

Figure 6.1 is a picture of the test specimen. Figure 6.2 is a picture of the SENTRY transport package standard configuration. Notice they are the same package except for the yellow plastic inserts and attaching hardware.

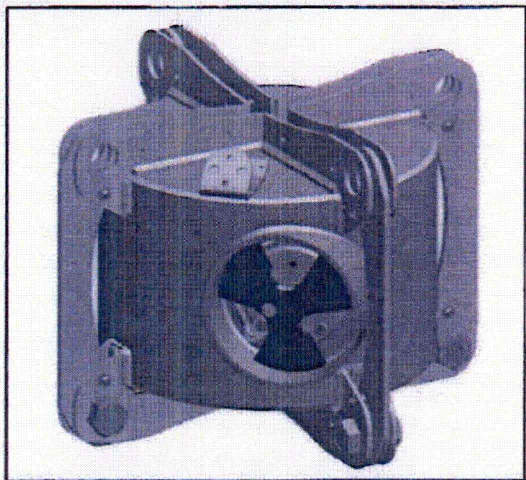


Figure 6.1. Test Specimen – SENTRY Transport Package Special Configuration.

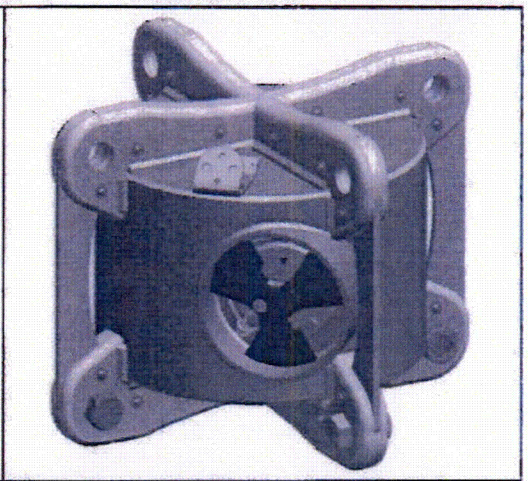


Figure 6.2. For reference - SENTRY Transport Package Standard Configuration.

Table 6.1 Test specimen build documentation and identification.

Table 6.1. Test Specimen Manufacturing Documentation and Identification			
Test Specimen Configuration	Drawing Number	TMI	Serial Number(s)
SENTRY 330 Projector – Special Standard	TP86000-330X	199	TP180D

6.1 Test Specimen Justification

The SENTRY 330 transport package – Standard configuration is the heaviest package of all the SENTRY transport packages. The maximum weight of the package in this configuration is 780 pounds. The array of handling rib assemblies attached to the welded body increases the weight by 80 pounds more than the Basic configuration. The handling ribs, when present, provide protection and substantial impact energy absorption to the package in all but a few free drop orientations. The few unprotected orientations can be narrowed down to one worst case orientation with the handling ribs attached. This worst case orientation shall be tested in this plan. The SENTRY 330 projector – special standard configuration, with handling ribs but without the plastic inserts, shall be used for assessing compliance to the free drop testing requirements of 10 CFR Part 71 and IAEA TS-R-1 1996 for all SENTRY transport packages built to the standard configuration.

6.2 Structural Materials of Test Specimen

The structural materials of all SENTRY transport packages are Ti-6Al-4V titanium, 304/304L and 17-4 PH stainless steel. The shielding materials are U-0.75% Ti depleted uranium and tungsten. Fasteners needed to attach the rear plate assembly to the welded body are type 17-4 PH stainless steel. Materials used in the non-safety related components are 300 series stainless steel, brass, copper, plastic, and rubber.

6.3 Temperature Conditions

The fracture toughness (strength and ductility) of the primary structural material, 304/304 L stainless steel, does not change enough within the temperature range of minus 40°F to plus 100°F to affect the results of the tests in this plan. Depleted uranium is a relatively less ductile material than the stainless steel but also does not appear to have a ductile to brittle transition temperature within this range.

Test plan/report 79 shows the compressive impact strength of the polyurethane foam changes very little between minus 40°F to plus 100°F. This change in compressive strength is not expected to affect the results of the tests in this plan. The foam fill limits the shields movement during the impact of the drop test. However, the shield relies primarily on the welded stainless steel structure and the titanium pins to keep it secure and in place during impact.

Therefore, all test specimens will be dropped at ambient temperature since a temperature within minus 40°F to plus 100°F is not expected to change the results of the tests.

6.4 Pressure Conditions

Except for the source capsule, the transport package is open to the atmosphere and therefore in equilibrium with the outside pressure of the package. The internal operating pressure of the containment system, namely the source capsule, has been tested to withstand the pressure range of 3.5 PSI absolute to 20 PSI absolute. The tests will therefore be performed at atmospheric pressure.

6.5 Vibration Conditions

Vibration normally occurring in transport will be addressed under test plan 178, ISO/ANSI performance testing, and is not expected to adversely affect the structural aspects of the transport package. The rear plate assembly fastening system however could possibly be affected by transport vibration. These fasteners are preloaded or stretched within the materials proportional limit by a specified torque applied during assembly. The assembly preload is designed to withstand dynamic forces and vibration normal to transport.

Section 7 Material and Equipment List

The equipment list worksheets in Section 9 identify the equipment required, with additional space to list other necessary equipment and measuring instruments needed to perform the tests. Additional materials and equipment used to facilitate the tests will be listed as needed.

Section 8 Test Procedure

All test specimens must follow the planned sequence presented below. Any change to the planned drop orientations shall require a documented justification and description for the new orientation.

8.1 Test Sequence

1. Test specimen preparation and inspection.
2. 9m free drop test.
3. Puncture test.
4. Test inspection.
5. Thermal assessment.
6. Final test assessment.

8.2 Test Specimen Preparation and Inspection

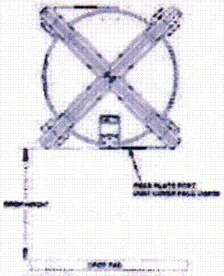
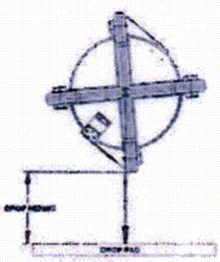
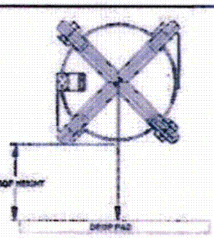
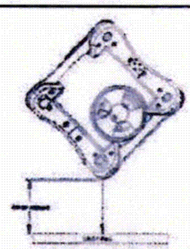
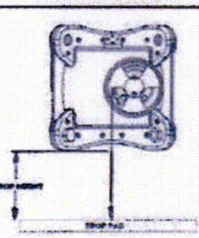
1. Manufacture the SENTRY test specimen per table 6.1.
2. Inspect the test specimens to ensure that:
   - All fabrication and inspection records are documented in accordance with the QSA Global Quality Assurance Program.
   - The test specimens comply with the requirements of the drawing.
3. Perform and record the radiation profile in accordance with QSA Global Work Instruction WI-Q-1806.
4. Engineering, Regulatory Affairs and Quality Assurance will jointly verify that the test specimens comply with the drawings and the QSA Global Quality Assurance Program.
5. Measure the location of the simulated source.
6. Prepare the test specimens for transport.

8.3 9m Free Drop Tests per 10 CFR 71.73(c) (1)

The 9 meter free drop test shall demonstrate compliance to the hypothetical accident sequence.

The 9 meter (30 foot) drop heights are minimum heights. The actual or adjusted free drop heights shall be recorded on the test data sheet.

8.3.1 9 Meter Free Drop Test Orientation Justification

Drop Orientation Target	Drop Orientation Diagram	Justification
Extended face of rear plate access port		Rib assemblies provide little impact absorption. Relatively flat face of access port increases stopping rate resulting in high impact loads to components important to safety. This is the most vulnerable orientation for the standard configuration.
Extended edge of the rear plate access port		Rib assembly and brace provides substantial impact absorption at the point of impact. Rib and brace deforms upon impact reducing deformation to access port and rear plate. Not the most vulnerable orientation for the standard configuration.
Curved side surface of welded body at the seam weld		Curved surface allows impact absorbing deformation to welded body decreasing stopping rate. Test Results of Test Plan 180 showed minor damage to this area when dropped twice from 32 feet. Not the most vulnerable orientation for the standard configuration.
Curved edge of the welded body directly on the seam weld		Rib assemblies provide substantial impact absorption. Curved edge of welded body protected by handling ribs. Not the most vulnerable orientation for the standard configuration.
Bottom or top surface of welded body		Rib assemblies provide substantial impact absorption. Bottom and top surface protected by handling ribs. Not the most vulnerable orientation for the standard configuration.

8.3.2 9m Free Drop Test Set-up

1. Orient the test specimen on the drop pad.
2. Photograph the set-up.
3. Measure and record the ambient temperature.
4. Raise the test package to the drop height and in its orientation over the drop pad.
5. Start the video recorder.
6. Drop the test specimen.
7. Stop the video recorder.
8. Record and photograph the damage to the test specimen.

8.3.3 9m Free Drop Test Orientation

Figure 8.3.3 shows the package orientation for the 9 meter drop. This drop orientation attempts to shift the shield enough to break the source wire and/or remove the rear-plate by damaging the attachment bolts. The impact surface is on the extended face of the dust cover and rim of the rear-plate access port.

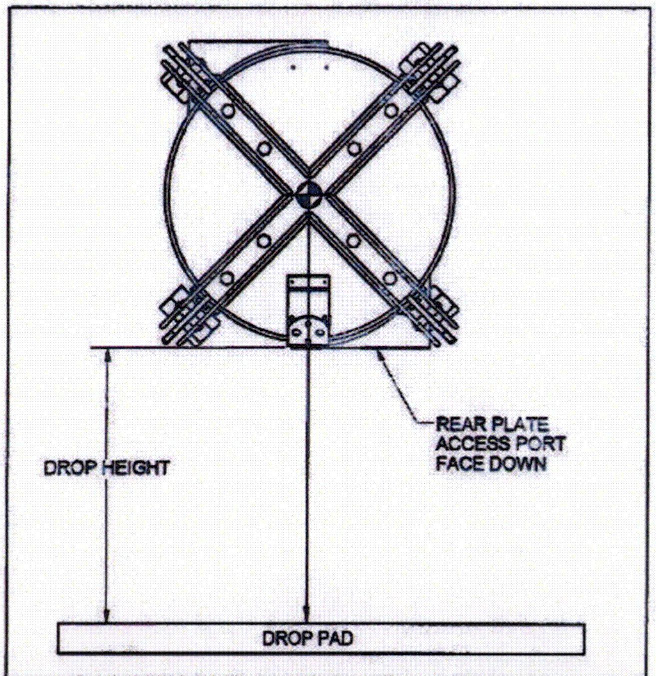


Figure 8.3.3: 9 Meter Free Drop Orientation

8.3.4 9m Free Drop Test Assessment

Upon completion of each test, **Engineering, Regulatory Affairs** and **Quality Assurance** team members will jointly take the following actions:

- Review the test execution to ensure that each test was performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan.
- Make a preliminary evaluation of the specimens relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996.
- Assess the damage to each specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of each specimen after the 9m free drop test to determine what changes, if any, are necessary in package orientation in the puncture test to achieve maximum damage.

8.4 Puncture Test per 10 CFR 71.73(c) (3)

The package is dropped from 1m (40") or an adjusted height onto the puncture billet. This test uses the 12" high puncture billet. The billet meets the minimum height (8") required in 10 CFR 71.73(c) (3). The specimen has no projections or overhanging members longer than 12" which could act as impact absorbers, allowing the billet to cause the maximum damage to the specimen. The billet is to be bolted to the drop surface used in the drop tests.

The puncture drop height shall be adjusted based on the maximum weight of the package and shall be recorded on the test data sheet.

8.4.1 Puncture Test Orientation

Figure 8.4.1 shows the package orientation for the puncture drop. This drop orientation attempts to damage the lock assembly on the rear plate and/or remove the rear-plate by damaging the attachment bolts. The impact surface is the dust cover inside the rear-plate access port.

If the orientation needs to be changed, the new orientation must be documented and approved with a justification describing how it would be a worst condition than the planned orientation.

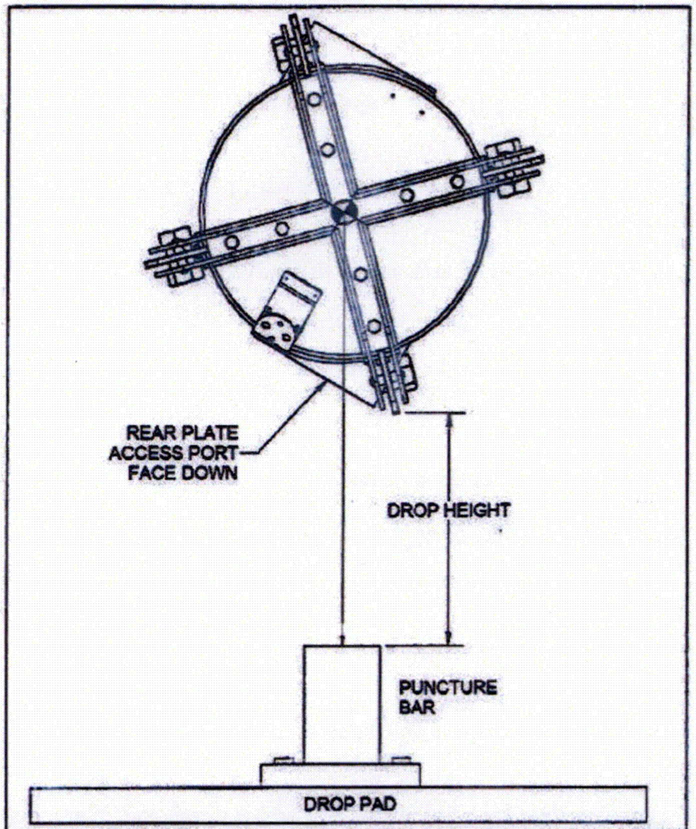


Figure 8.4.1: Puncture Drop Orientation

8.4.2 Puncture Test Set-up

1. Orientation the test specimen over the puncture billet.
2. Photograph the set-up.
3. Measure and record the ambient temperature.
4. Raise the test specimen to the drop height and in its orientation over the puncture billet.
5. Start the video recorder.
6. Drop the test specimen.
7. Stop the video recorder.
8. Record and photograph the damage to the test specimen.

8.4.3 Puncture Test Assessment

Upon completion of the test, **Engineering, Regulatory Affairs** and **Quality Assurance** team members will jointly take the following actions:

- Review the test execution to ensure that the tests were performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan.

- Make a preliminary evaluation of each specimen relative to the requirements of 10 CFR 71 and IAEA TS-R-1 1996.

8.5 Post Test Inspection

Perform the test inspection after the puncture test.

1. Measure and record the damage to the test specimen.
2. Measure the location of the simulated source.
3. Remove and assess the condition of the simulated source.
4. Reassemble the packages using a representative active source, making sure that the source location and the package configuration are the same as they were immediately after the puncture test.
5. Measure and record a radiation profile of each test specimen in accordance with QSA Global Work Instruction WI-Q-1806.
6. Assess the significance of any change in radiation at the surface and at one meter from the packages.
7. Determine whether it is necessary to radiograph the test specimens for inspection of hidden component damage or failure.
8. Record any damage or failure found in radiograph of the test specimens, if performed.

8.6 Thermal Test Assessment per 10 CFR 71.73(c) (4)

The test specimen shall be assessed to determine whether the test specimen will pass the thermal test.

The assessment will be based on the examination of the damage to the test specimen after the puncture test. Experience from thermal testing the Model 660 & Model 680 transport packages has shown the shield will oxidize and diminish its ability to protect only when the adjacent foam fill is allowed to combust and then fall away from the shield. Charred foam seems to provide enough thermal insulation to prevent the shield from oxidizing as long as the charred foam remains in place. Any damage producing an unintentional opening in the shell or welded body would need to be assessed to determine whether the transport package would pass or fail the thermal test.

Engineering, Regulatory Affairs, and **Quality Assurance** team members will make a final assessment of each test specimen and jointly determine whether the specimens meet the requirements of 10 CFR 71 and IAEA TS-R-1 1996.

8.7 Test Specimen Storage

Place the test specimens in an appropriate container, if necessary and store. Written management approval is needed to dispose of any test specimen of this test plan. If the specimens are disposed of, then include a copy of the signed disposal approval in the SENTRY design history file.

Section 9 Worksheets

Use the following worksheets for executing the tests of section 8. Record the information onto copies of these worksheets for each test performed.

Attach a copy of the relevant inspection report or calibration certificate after the range and accuracy of the equipment has been verified.

Test Specimen & Equipment List

Test Specimen & Equipment Documentation					
Test Specimen					
Configuration	**Drawing Number**	**Serial Number**	**Attach IIR**	**Attach NCR**	**Attach Route Cards**

Tools & Equipment		
Tool Description	**Enter the Model and Serial Number Mark NA when not used.**	**Attach Inspection Report or Calibration Certificate**
Drop Surface, Drawing No. T10740	**S/N 001**	**Yes**
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificates.		
Signature	**Print Name**	**Date**
Engineering:		
Regulatory:		
Quality Assurance:		

Free Drop & Puncture Test Checklist

Test:		
Test Location:		
Step	**Data**	
1. Record test specimen serial number:		
2. Record the test specimen weight:		
3. Record the ambient temperature (°C):		Instrument S/N:
4. Identify set-up orientation figure:		
5. Record drop height.		
6. Photograph set-up in at least two perpendicular planes.		
7. Begin video recording of the test so that impact is recorded.		
8. Release the test specimen.		
9. Stop the video recorder. Ensure the point of impact and orientation specified in the plan has been achieved.		
10. Record the damage to the test specimen. Use a separate sheet and attach, if needed.		
11. Record location of simulated source, if possible.		
12. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach.		
Test witnessed by (Signature)	**Print Name**	**Date**
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Free Drop & Puncture Test Data Sheet

Test Specimen Serial No.:	Test:
Test Date:	Test Time:
Describe drop orientation and drop height:	
Describe impact (location, rotation, etc.):	
Describe on-site inspection (damage, broken parts, etc.):	
On-site test assessment: • Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1 1996, and this test plan? **Yes or No.** • Does the test specimen meet the requirements of 10 CFR 71 and IAEA TS-R-1 1996 for this test? **Yes or No.** • Any changes to subsequent drop orientations needed to achieve maximum damage? **Yes or No.** If yes, then identify and justify. • Did sufficient damage occur at or on the rear-plate attachment area to warrant further drop testing the SENTRY 110 Projector – Basic configuration because of its thinner rear-plate? **Yes or No.** • Should testing continue with this test specimen? **Yes or No.** If yes, next test: ____________________ • Will the test specimen pass the thermal test based on the accumulated damage assessment? **Yes or No** **Engineering:** **Regulatory:** **QA:**	
Describe any post-test disassembly and inspection:	
Describe any change in source position (if possible):	
Describe results of radiography (if performed):	
Completed by:	Date:

Test Inspection Data Sheet

Test Specimen Serial No.:	Last Test Performed:
Describe and measure (if appropriate) any damage, signs of permanent strain, deformation and/or broken parts.	
Describe the condition of the simulated source wire assembly.	
Reassemble the package using a representative active source, making sure that the source position and the package configuration is the same as they were immediately after the last test. Measure and record a radiation profile of each test specimen in accordance with QSA Global Work Instruction WI-Q-1806.	
Compare the pre-test dose levels with post-test dose levels at the surface of the package and at 1 meter from the surface of the package.	
Is a radiograph required to inspect for hidden component damage or failure? If radiography is performed, describe any damage or failures found.	
Completed by:	Date:

*There is no page 29. RB 30 Aug 2010

2.12.12 Test Plan Report 195 dated 21 July 2010