ENERCON Excellence—Every project. Every day.	CALCULATION COVER SHEET	CALC. NO. RTL-001-CALC-ST-0202
		REV. 0
		PAGE NO. 1 of 20

Title:	RT-100 Tie-Down Evaluation	**Client:**	Robatel Technologies, LLC
		Project:	RTL-001

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions that require confirmation? (If **YES**, Identify the assumptions) see Section 4	☒	☐
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, Identify the design verified calculation.) **Design Verified Calculation No.** ______	☐	☒
3	Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.** ______	☐	☒

Scope of Revision:

Initial Issue

Revision Impact on Results:

N/A

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☒ **Non-Safety Related** ☐

(Print Name and Sign)

Originator: Zhibo Wu [signature]	**Date:** 10-8-2012
Design Verifier: John Staples [signature]	**Date:** 8 OCT 2012
Approver: Curt Lindner [signature]	**Date:** 10/8/12

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		REV. 0
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CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0	8 Oct 2012	Initial Issue

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
1-20	0		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
1	1-4	0			
2	1-5	0			

ENERCON Excellence—Every project. Every day.	CALCULATION DESIGN VERIFICATION PLAN AND SUMMARY SHEET	CALC. NO. RTL-001-CALC-ST-0202 REV. 0 PAGE NO. 3 of 20

Calculation Design Verification Plan:

Calculation to be reviewed for correctness of inputs, design criteria, analytical methods, acceptance criteria and numerical accuracy.

Stated objectives and conclusions shall be confirmed to be reasonable and valid.

Any assumptions shall be clearly documented and confirmed to be appropriate and verified based on sound engineering principles and practices.

(Print Name and Sign for Approval – mark "N/A" if not required)

Approver: Curt Lindner [signature]	**Date:** 10/8/12

Calculation Design Verification Summary:

Calculation has been designated as **Safety Related** as noted on the cover sheet.

Calculation has been verified to be mathematically correct and performed in accordance with appropriate design inputs, assumptions, analytical methods, design criteria and acceptance criteria.

The conclusions developed in the calculation are reasonable, valid and consistent with the purpose and scope.

Assumptions are appropriate and correct.

Based On The Above Summary, The Calculation Is Determined To Be Acceptable.

(Print Name and Sign)

Design Verifier: John Staples [signature]	**Date:** 8 Oct 2012
Others:	**Date:**

ENCERCON Excellence—Every project. Every day.	CALCULATION DESIGN VERIFICATION CHECKLIST	CALC. NO.	RTL-001-CALC-ST-0202
		REV.	0
		PAGE NO.	4 of 20

Item	CHECKLIST ITEMS	Yes	No	N/A
1	**Design Inputs -** Were the design inputs correctly selected, referenced (latest revision), consistent with the design basis, and incorporated in the calculation?	X		
2	**Assumptions** - Were the assumptions reasonable and adequately described, justified and/or verified, and documented?	X		
3	**Quality Assurance** - Were the appropriate QA classification and requirements assigned to the calculation?	X		
4	**Codes, Standards, and Regulatory Requirements** - Were the applicable codes, standards, and regulatory requirements, including issue and addenda, properly identified and their requirements satisfied?	X		
5	**Construction and Operating Experience** - Have applicable construction and operating experience been considered?	X		
6	**Interfaces** - Have the design-interface requirements been satisfied, including interactions with other calculations?	X		
7	**Methods** - Was the calculation methodology appropriate and properly applied to satisfy the calculation objective?	X		
8	**Design Outputs** - Was the conclusion of the calculation clearly stated, did it correspond directly with the objectives, and are the results reasonable compared to the inputs?	X		
9	**Radiation Exposure** - Has the calculation properly considered radiation exposure to the public and plant personnel?			X
10	**Acceptance Criteria** - Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?	X		
11	**Computer Software**- Is a computer program or software used, and if so, are the requirements of CSP 3.02 met?			X

COMMENTS

(Print Name and Sign)

Design Verifier:	**John Staples** John Staples	**Date:** 8 Oct 2012
Others:		**Date:**

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1.0 Purpose and Scope

Robatel Technologies is designing the RT-100 transport cask, containing radioactive waste in the form of dewatered resins and filters. The RT-100 transport cask is required to meet the requirements of 10CFR Part 71 (Ref. 3.1). This calculation demonstrates that this package satisfies the requirements of 10CFR71.45 (Ref. 3.1) under the normal tie-down conditions. The NRC requirements in Reference 3.1 state that any tie-down attachment that is a structural part of the package must be designed to withstand transportation stresses with appropriate safety factors. The RT-100 package is designed with two tie-down arms, attached to the cask sidewall, for securing the assembled cask during transport. Failure of the tie-down mechanism under excessive load must not impair the ability of the cask to meet the requirements of Subpart E of Reference 3.1. Any other structural part 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 the tie-down attachments. The purpose of this calculation is to structurally qualify the fully-loaded RT-100 transport cask for the loadings associated with transport activities, including dead weight and payload weight with the appropriate dynamic factors, for the normal transport conditions.

2.0 Summary of Results and Conclusions

All structural members have a factor of safety of greater than 1.0 under the most adverse effects from the transport activities for the normal transport conditions. Based on tie-down arm thickness of 35 mm, the minimum factor of safety is 1.18 at the tie-down arms. Based on the dimensions shown on Figure 4, the minimum weld factor of safety is 1.57 at the tie-down plate to cask body weld **(see unverified Assumption 4.7).** For a minimum thickness of 32 mm, the factor of safety is reduced to 1.07 at the tie-down arm. Thus all welds and connections are qualified for the design loads. The failure of the structural tie-down devices under excessive loads does not impair the ability of the cask to meet the other regulatory requirements of the cask. The results of the analysis show that the RT-100 cask can withstand the required transport activities for the normal transport conditions. The shear stops shall be designed in accordance with all loads and requirements given in Section 7.3.1 (d). **Note: the latter statement is an unverified assumption as discussed in Section 4.3.**

Therefore, provided:

(a) shear stops, designed in accordance with Section 7.3.1.d are utilized during transportation; and,

(b) the tie-down plate dimensions are in accordance with Figure 4;

the members and welds of the RT-100 transport cask are adequate for their design function under the normal tie-down condition.

3.0 References

3.1 Nuclear Regulatory Commission, 10CFR Part 71, "Packaging and Transportation of Radioactive Material"

3.2 Drawings
   a. RT100-PE-1001-1, Rev. E, RT-100 General Assembly, Sheet 1
   b. RT100-PE-1001-2, Rev. E, RT-100 General Assembly, Sheet 2

3.3 Omer W. Blodgett, "Design of Welded Structures", 1966

3.4 ENERCON Calculation RTL-001-CALC-ST-0201 Rev. 0, "Lifting Evaluation"
3.5 ENERCON Calculation RTL-001-CALC-ST-0203 Rev. 0, "Bolting Evaluation"
3.6 ASME B&PV Code, Section II, 2007
3.7 ASME B&PV Code, Section III, 2007
3.8 ENERCON Calculation RTL-001-CALC-ST-0101 Rev. 0, "RT-100 Weight and Center of Gravity Calculation"
3.9 AISC Manual of Steel Construction, 7th edition
3.10 Hibbeler, R.C., Mechanics of Materials, 6th ed, 2005

4.0 Assumptions

4.1 The weight of the cask for the tie-down evaluation is considered as the total weight of the cask and the maximum payload. This assumption is acceptable without further evaluation.

4.2 The dimensions and properties of the Utility 4000A flatbed truck (see Appendix 1) will be utilized as a typical truck for determination of the cask tie-down configuration, as needed for evaluation. Minor variations between different flatbed transport trucks will not have a significant impact on the analysis results. This assumption is acceptable without further evaluation.

4.3 The truck used for transport of the RT100 cask will be specially designed for the cask tie-down configuration, including shear stops and integral support locations in line with the cask tie-down arms. The loads for the shear stops will be provided in this calculation for use in the design at a later date. For this calculation to be valid, these shear stops must be designed in accordance with all loads and requirements given in Section 7.43.1 (d). **This is an unverified assumption that requires verification.**

4.4 It is possible for the center of gravity of the payload to shift ±10% of the interior dimensions of the cask containment (Ref. 3.8). The payload is significantly lighter than the fully loaded cask. Therefore, this shift has no significant effect on the tie-down conditions since the change in payload location will have an inconsequential effect of the center of gravity of the fully-assembled, loaded cask, resulting in a maximum change of less than 4cm in the overall center of gravity, which is approximately a 2.5% change (Ref. 3.8). Only the overall center of gravity location is used for this calculation. This assumption is acceptable without further evaluation.

4.5 The slight asymmetry in the tie-down arm design which enables the cables or chains from opposite arms to clear one another is ignored. Instead average dimensions are utilized. This assumption is acceptable without further evaluation.

4.6 A sliding friction coefficient of $\mu=0.05$ is assumed for a metal cask on a metal bed in open vehicles. This assumption is conservative and requires no further evaluation.

4.7 The tie-down plate dimensions are in accordance with Figure 4. **This is an unverified assumption that requires verification.**

There are no additional unverified assumptions in this calculation. Other design assumptions used, if any, will be noted and referenced as needed in the body of the calculation.

5.0 Design Inputs

5.1 The total weight of the fully assembled cask is 33930kg (Ref. 3.2.a).
5.2 The maximum payload weight is 15,000 lbs, or 6,803.9 kg (see Appendix 2). Conservatively, a value of 7,060kg will be used for the evaluation.
5.3 Per 10CFR71.45(b) (Ref. 3.1), any tie-down attachment that is a structural part of the package 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 and its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package and its contents and a horizontal component in the transverse direction of 5 times the weight of the package and its contents. These factors will therefore be used in determining the resultant loads on the tie-down arms from the restrained package during transport.
5.4 The material properties used for the cask shell and the tie-down arms shall be as given in Table 1, unless noted otherwise. The allowable value used are for the 50°C (Ref 3.1, 71.43 (g)).
5.5 A value of 9.81 m/s^2 will be used for the gravitational acceleration.
5.6 A value of 0.3 will be used for the Poisson's Ratio of all stainless steel in accordance with Table NF-2 of Reference 3.6.

Material	Temp. (°C)	Strength (MPa)		
		Yield (S_y)	Ultimate (S_u)	Membrane Allowable (S_m)
X2CRNI19.11 (ASTM A240 Type 304/304L dual certified) (Cask Body)(1)(2)	-29	206.8	517.1	137.9
	20	206.8	517.1	137.9
	50	199.3	511.0	137.9
	100	170.2	485.6	137.9
	150	154.2	456.1	137.7
	200	143.7	442.5	129.0
	250	135.4	437.9	122.0
X2CRNIMON22.5.3 (ASTM SA-240/UNS No. S31803) (Tie-Down Arms)(1)	-29	448.2	620.5	258.6
	20	448.2	620.5	258.6
	50	437.2	620.5	258.6
	100	395.1	617.9	257.1
	150	369.9	598.0	246.6
	200	354.4	577.5	236.7
	250	344.0	565.0	-

Notes:

1. Material properties are taken from ASME B&PV Code, Section II, Part D (Ref. 3.6) by interpolation.
2. Cask material is being procured as dual-certified SA-240 Type 304/304L.

6.0 Methodology

The RT-100 transport cask will be a safety-related structure in accordance with 10CFR Part 71 (Ref. 3.1). The cask consists of a stainless steel containment structure with a lead shielding panel between the inner and outer cask walls, ductile stainless steel and foam upper and lower impact limiters, a pair of concentric, removable stainless steel cask lids and a pair of stainless steel tie-down arms on opposite sides of the cask body (Ref. 3.2). Per Section 5.3, safety factors of 2, 10 and 5 will be used in the vertical and horizontal directions for determining the weight of the assembled cask for transport restraint.

The evaluation of the RT-100 cask tie-down arms and outer shell is provided in this document to show that they meet all of the applicable requirements of 10CFR71.45 (Ref. 3.1) for the combined weight of the assembled cask and the payload. The tie-down arms, with a total of four attachment points, are designed to resist the combination of loads in the three orthogonal directions. An evaluation is provided to demonstrate that failure of the tie-down arms under excessive load will not impair the cask's ability to meet the other applicable requirements of Reference 3.1 (see Section 7.5).

7.0 Calculations

NOTE: In many cases, calculations are made using exact values, not the rounded numbers shown. Therefore, in certain situations, the numbers displayed may not be capable of providing the final solution. Using exact numbers, however, provides the most accurate solution possible.

7.1 Load Calculation

See Section 5.0 (Design Inputs) of this calculation for a list of all applicable loads and safety factors and Section 6.0 (Methodology) for the applicable methodology and restraint conditions. The detailed calculation of loads follows.

Package Loads

Gravitational Acceleration:	$g = 9.81\ m/s^2$
Cask Mass:	Mc = 33930 kg (section 5.1)
Payload Mass:	Mp = 7060 kg (section 5.2)
Total Mass:	M = Mc + Mp = 40990 kg, use 42000 kg
Total Weight:	W = Mg = 412.02 kN
Vertical Dynamic Factor	$d_v = 2$ (Section 5.3)
Axial Dynamic Factor	$d_a = 10$ (Section 5.3)
Transversel Dynamic Factor	$d_L = 5$ (Section 5.3)

Vertical Load, $P_v = M \times g \times d_v = 42000 \times 9.81 \times 2 \times \frac{1\ kN}{1000\ N} =$ 824.0 kN

Axial Load, $P_a = M \times g \times d_a = 42000 \times 9.81 \times 10 \times \frac{1\ kN}{1000\ N} =$ 4120.2 kN

Transverse Load, $P_L = M \times g \times d_L = 42000 \times 9.81 \times 5 \times \frac{1\ kN}{1000\ N} =$ 2060.1 kN

7.2 Lifting Pocket Tie-Down Evaluation

Per 10CFR71.45(b) (Ref. 3.1), any structural part of the package, other than those components designated and designed for restraint activities, that could be used to restrain the package must be capable of being rendered inoperable for restraining the package during transport, or must be designed with strength equivalent to that required for tie-down attachments. The lifting pockets can be rendered inoperable through the use of padlocks on the lifting eyes provided in each of the lifting pockets (Refs. 3.2 and 3.4). All lifting devices for secondary lifts (i.e., for lifting the impact limiters separately from the assembled package) will be removed from the package during transport (Refs. 3.2 and 3.4). The lifting pockets will not be used for restraining the load during transport and therefore do not need to be designed for the restraint loads. The lifting pockets are acceptable without further evaluation.

7.3 Tie-Down Devices Evaluation

The cask will be restrained by the use of two tie-down arms on the cask sidewalls, on opposite sides of the cask body, with two attachment eyes on each tie-down arm (Ref.3.2). The assembled cask will be attached to the flatbed truck with straps or cables attached to the tie-down arm attachment eyes. The cask tie-down load will be considered as the total weight of the fully-assembled cask, including the payload, with the required dynamic factors applied to the three orthogonal load directions. Four shear stops prevent movement of the base of the package. (See Assumption 4.3)

The geometric configuration of the tie-down system was selected such that:
(1) The resultant tie-down arm tensile loads are tangent to the cask surface in order to minimize the effects of out-of-plane stresses in the cask shell. (See Figure 2 & 3 for determination of the tie-down geometry).
(2) The shear stops loads are transferred to the cask surface via compression in the lower impact limiter.

7.3.1 Tie-Down Forces

The analytical model for determining the loads required to prevent rotation and translation of the package due to the applied loads is shown in Figure 3. The shear stop forces at the bottom of the package are represented by the orthogonal components of a single force vector, S, making an angle of γ with the global y-axis (see Figure 3).

The stresses in the members are determined by considering the component loads (10W, 5W, and 2W) individually and superimposing the results. A detailed force analysis is conducted using the dimensions and notations shown in Fig. 2 & 3, and other terms are defined below:

W: weight of cask, kN
Tx: tensile force in member 2 and 3 resulting from 5W load, kN
Ty: tensile force in member 1 and 2 resulting from 10W load, kN
Tz: tensile force in each member resulting from 2W load, kN
$T_{1,2,3,4}$: total tensile force in subscripted member, kN
Fx: total force in the x direction resulting from 5W load, kN
Fy: total force in the y direction resulting from 10W load, kN
L: Effective length of tie-down arm, i.e. distance between tie-down tangent point and center of tie-down attachment eye, mm

Note: Per Assumption 4.5, the slight asymmetry in the tie-down arm is ignored and average dimensions are used.

(a). Considering only the 10W load, in the –Y direction, and summing moments about the axis y=-R:

$$\sum M_X = 0 \Rightarrow 2Ty\left(c/L \times (y'\text{-}b + R) + b/L \times z'\right) = 10Wd$$

Solving for Ty: $Ty = \dfrac{10Wd}{2\left(c/L \times (y'\text{-}b + R) + b/L \times z'\right)}$

$$= \frac{10 \times 412.02 \times 1648}{2\left(297.92/605 \times (1093.9 - 391.31 + 1293.5) + 391.31/605 \times 1726.92\right)} = 1616.77 \text{ kN}$$

(b). Considering only the 5W load, in the X direction, and summing moments about the axis x=R:

$$\sum M_Y = 0 \Rightarrow 2Tx\left(c/L \times (R - a - x') + a/L \times z'\right) = 5Wd$$

Solving for Tx $\Rightarrow Tx = \dfrac{5Wd}{2\left(c/L \times (R - a - x') + a/L \times z'\right)}$

$$= \frac{5 \times 412.02 \times 1648}{2\left(297.92/605 \times (1293.5 - 352.34 - 427.96) + 352.34/605 \times 1726.92\right)} = 1348.92 \text{ kN}$$

(c). Considering only the 2W load, in the Z direction, and summing up vertical force:

$$\sum F_Z = 0 \Rightarrow 4Tz(c/L) = 2W$$

Solving for Tz $\Rightarrow Tz = \dfrac{2W}{4(c/L)} = \dfrac{2 \times 412.02}{4(297.92/605)} = 418.36$ kN

The force in the most loaded member, which is member 2 in this case,

$$T_{max} = Tx + Ty + Tz + Ti$$

where Ti is the initial member tension that can be estimated or measured. Ti will be neglected except for its effect on the member. T_{max} can be in any member since the regulations do not specify the directions of the forces but only the line of action.

$$T_{max} = Tx + Ty + Tz = 1348.92 + 1616.77 + 418.36 = 3384.05 \text{ kN}$$

(d). Then to balance the force in the X direction:

$$\sum F_X = 0 \Rightarrow 2Tx(a/L) + Fxx = 5W$$

solving for Fxx $\Rightarrow Fxx = 5W - 2Tx(a / L)$

$$\Rightarrow Fxx = 5 \times 412.02 - 2 \times 1348.92 \times \frac{352.34}{605} = 488.93 \text{ kN}$$

To balance the force in the Y direction:

$$\sum F_Y = 0 \Rightarrow 2Ty(b/L) + Fyy = 10W$$

solving for Fyy $\Rightarrow Fyy = 10W - 2Ty(b/L)$

$$\Rightarrow Fyy = 10 \times 412.02 - 2 \times 1616.77 \times \frac{391.31}{605} = 2028.74 \text{ kN}$$

Summation of the force in the Z direction, noting from above that $4Tz(c/L) - 2W = 0$

$$Fn = 2Tx(c/L) + 2Ty(c/L) + 4Tz(c/L) - 2W \Rightarrow Fn = 2Tx(c/L) + 2Ty(c/L)$$

$$\Rightarrow Fn = 2 \times 1348.92 \times \frac{297.92}{605} + 2 \times 1616.77 \times \frac{297.92}{605} = 2920.75 \text{ kN}$$

Now, the friction force can be determined as: $F_f = \mu Fn = 2\mu(Tx(c/L) + Ty(c/L))$

where μ=0.05 for a metal cask on a metal bed in open vehicles.

$$F_f = \mu Fn = 0.05 \times 2920.75 = 146.04 \text{ kN}$$

The force Fxx and Fyy are the resultant force of the friction force and the resistance of the shear stop. Since there are 2 shear stops in action, the design loads for each shear stop are.

$$Sx = (Fxx - F_f \sin\gamma)/2 = (488.93 - 146.04 \sin 26.6^\circ)/2 = 211.81 \text{ kN}$$

$$Sy = (Fyy - F_f \cos\gamma)/2 = (2028.74 - 146.04 \cos 26.6^\circ)/2 = 949.06 \text{ kN}$$

where γ is the direction of the vectorial resultant of the 10W and 5W loads as measured from the Y axis, i.e. $\gamma = a\tan(5/10) = 26.6^\circ$

7.3.2 Tie-down arm evaluation

The tie-down arm is shown on Ref. 3.2.b section A-A. The maximum tie-down arm load of 3384.05 kN was determined in Section 7.3.1 above.

Stress for the tie-down arm and its connection to the exterior cask shell are shown as follows:

Tension on net section at hole:

$\sigma_{allow} = \sigma_y = 437.2$ MPa @ 50°C, see Table 1

$$A_{net} = 2(200 - 90)25 + (260 - 90)35 = 11450 mm^2$$

$$\sigma_{net} = \frac{3384.05 \times 10^3}{11450 \times 10^{-6}} = 295.55 MPa$$

$$Factor\ of\ safety = \frac{\sigma_{allow}}{\sigma_{net}} = \frac{437.2}{295.55} = 1.48$$

Contact bearing at lifting hole:

$\sigma_{allow} = 1.35\sigma_y = 590.2$ MPa (Ref. 3.9)

$$A_{brg} = 90(2 \times 25 + 35) = 7650 mm^2$$

$$\sigma_{brg} = \frac{3384.05 \times 10^3}{7650 \times 10^{-6}} = 442.36 MPa$$

$$Factor\ of\ safety = \frac{\sigma_{allow}}{\sigma_{brg}} = \frac{590.2}{442.36} = 1.33$$

Edge tear out:

Based on the maximum-distortion-energy theory for a ductile material in pure shear (Ref. 3.10),

$\tau_{allow} = 0.6\sigma_y = 262.32$ MPa

$A = 2(2 \times 110 \times 25 + 110 \times 35) = 18700 mm^2$

$$\tau = \frac{3384.05 \times 10^3}{18700 \times 10^{-6}} = 180.97 MPa$$

$$Factor\ of\ safety = \frac{\tau_{allow}}{\tau} = \frac{262.32}{180.97} = 1.45$$

Arm Tension:

$\sigma_{allow} = \sigma_y = 437.2$ MPa

$A_{arm} = 260 \times 35 = 9100 mm^2$

$$\sigma_{arm} = \frac{3384.05 \times 10^3}{9100 \times 10^{-6}} = 371.87 MPa$$

$$Factor\ of\ safety = \frac{\sigma_{allow}}{\sigma_{arm}} = \frac{437.2}{371.87} = 1.18$$

7.3.2 Tie-down arm weld stresses

The stresses in the welds attaching the main arm of the tie-down arm to the cask body plates are found by applying the loads from the attachment arms to the weld around the perimeter of the plates. The maximum load on the tie-down arm welds will be the sum of the loads in two connecting arms. Thus, from inspection of Fig. 3, the maximum tie-down arm load is

$F = 2Tx + Ty + 2Tz = 2 \times 1348.92 + 1616.77 + 2 \times 418.36 = 5151.32$ kN, and

Weld axial load: $Fx = F\frac{b}{L} = 5151.32 \times \frac{391.31}{605} = 3331.88$ kN

Weld vertical load: $Fy = F\frac{c}{L} = 5151.32 \times \frac{297.92}{605} = 2536.63$ kN

Weld transverse load: $Fz = F\frac{a}{L} = 5151.32 \times \frac{352.34}{605} = 3000.04$ kN

Arm tensile strength: 437.2 MPa (Table 1)
Cask tensile strength: 199.3 MPa (Table 1)
Weld tensile strength: 450 MPa, weld between tie-down arm and plate (Appendix 2 pg 3 & 4)
420 MPa, weld between tie-down plate and cask (Appendix 2 pg 3 & 5)

The weld length, b, is :
b = r*(44°+40°)*π/180 = 1050*(44°+40°)*π/180 = 1539.38 mm

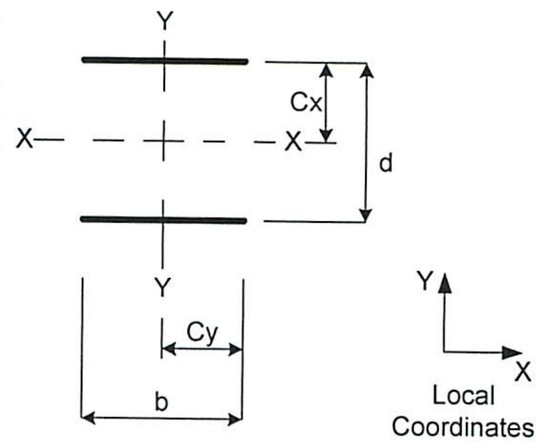
The weld height, d, for weld between tie-down plate and cask body is (Figure 4, and Assumption 4.7):

d = 620-410*tan29.5° = 388.03 mm

FILLET WELD EVALUATION:

DESCRIPTION: (joint, loading, members, etc.)

Weld Between Tie-Down Arm and Plate
See Reference 3.2 for weld information



WELD PROPERTIES ARE AS FOLLOWS:

b =	1.539	m
d =	0.26	m
Cy = b/2 =	0.77	m
Cx = d/2 =	0.13	m
Aw = 2b =	3.08	m
Sx = bd =	0.40	m^3 / m
Sy = $b^2/3$ =	0.79	m^3 / m
Jw = $b(3d^2 + b^2)/6$ =	0.66	m^4 / m

WELD (EXX) STRENGTH = Fw =	450.0	MPa	Weld size =	0.022	m
BASE METAL STRENGTH (FY) =	437.2	MPa	Thickness =	0.022	m

(Smaller of weld size or base metal thickness)

LOADING AT CENTER OF PATTERN: (using local coordinate previously defined)

Fx =	3331.88	kN	Mx =	0	kN-m
Fy =	2536.63	kN	My =	0	kN-m
Fz =	3000.04	kN	Mz =	0	kN-m

WELD STRESS IS AS FOLLOWS:

$$ft = \frac{Fz}{Aw} + \frac{Mx}{Sx} + \frac{My}{Sy} = 974.67 \text{ kN/m} \qquad fvy = \frac{Fy}{Aw} + \frac{Mz(Cy)}{Jw} = 824.12 \text{ kN/m}$$

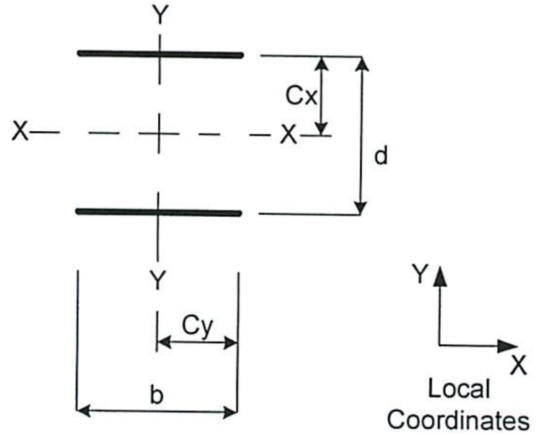
$$fvx = \frac{Fx}{Aw} + \frac{Mz(Cx)}{Jw} = 1082.48 \text{ kN/m} \qquad fw = (ft^2 + fvx^2 + fvy^2)^{1/2} = 1673.59 \text{ kN/m}$$

Weld Allowable Stress = 0.6(Fw)(Weld Size)0.7071(1C 4200 MPa
Base Metal Shear Allowable = 0.6(FY) Thick(1000) = 5771 MPa
FS FOR WELD METAL STRESS = **2.510** > 1.0 WELD STRESS IS O.K.
FS FOR BASE METAL SHEAR = **3.448** > 1.0 BASE METAL SHEAR IS O.K.

FILLET WELD EVALUATION:

DESCRIPTION: (joint, loading, members, etc.)

Weld Between Tie-down Plate and Cask Body
See Reference 3.2 for weld information



WELD PROPERTIES ARE AS FOLLOWS:

b =	1.539	m
d =	0.388	m
Cy = b/2 =	0.77	m
Cx = d/2 =	0.19	m
Aw = 2b =	3.08	m
Sx = bd =	0.60	m^3 / m
Sy = $b^2/3$ =	0.79	m^3 / m
Jw = $b(3d^2 + b^2)/6$ =	0.72	m^4 / m

WELD (EXX) STRENGTH = Fw = 420.0 MPa — Weld size = 0.022 m
BASE METAL STRENGTH (FY)= 199.3 MPa — Thickness = 0.022 m
(Smaller of weld size or base metal thickness)

LOADING AT CENTER OF PATTERN: (using local coordinate previously defined)

Fx =	3331.88	kN	Mx =	0	kN-m
Fy =	2536.63	kN	My =	0	kN-m
Fz =	3000.04	kN	Mz =	0	kN-m

WELD STRESS IS AS FOLLOWS:

$$ft = \frac{Fz}{Aw} + \frac{Mx}{Sx} + \frac{My}{Sy} = 974.67 \text{ kN/m} \qquad fvy = \frac{Fy}{Aw} + \frac{Mz(Cy)}{Jw} = 824.12 \text{ kN/m}$$

$$fvx = \frac{Fx}{Aw} + \frac{Mz(Cx)}{Jw} = 1082.48 \text{ kN/m} \qquad fw = (ft^2 + fvx^2 + fvy^2)^{1/2} = 1673.59 \text{ kN/m}$$

Weld Allowable Stress = 0.6(Fw)(Weld Size)0.7071(1C 3920 MPa
Base Metal Shear Allowable = 0.6(FY) Thick(1000) = 2631 MPa
FS FOR WELD METAL STRESS = **2.342** > 1.0 WELD STRESS IS O.K.
FS FOR BASE METAL SHEAR = **1.572** > 1.0 BASE METAL SHEAR IS O.K.

7.4 Shear Stop Load Evaluation

The base of the cask will be restrained against movement in the axial and transverse directions through the use of shear stops welded to the top of the specially designed flatbed truck (see Figure 1). These shear stops will be designed and evaluated as part of the flatbed truck and are not considered here.

7.5 Failure of Cask Tie-Down Arms Under Excessive Loads

The smallest tie-down arms factor of safety is 1.18 against tie-down arm tension. Therefore, under excessive loading, the failure of the tie-down arms will occur by necking of the tie-down arm. This will not impair the package's ability to meet other regulatory requirements since the tie-down arms are welded to a plate that is in turn welded to the cask body. Damage to the tie-down arm will not damage any component integral to the cask body and will therefore not compromise the cask body shell.

8.0 Figures

Figure 1 - Cask to Flatbed Configuration Sketch (see Appendix 1)

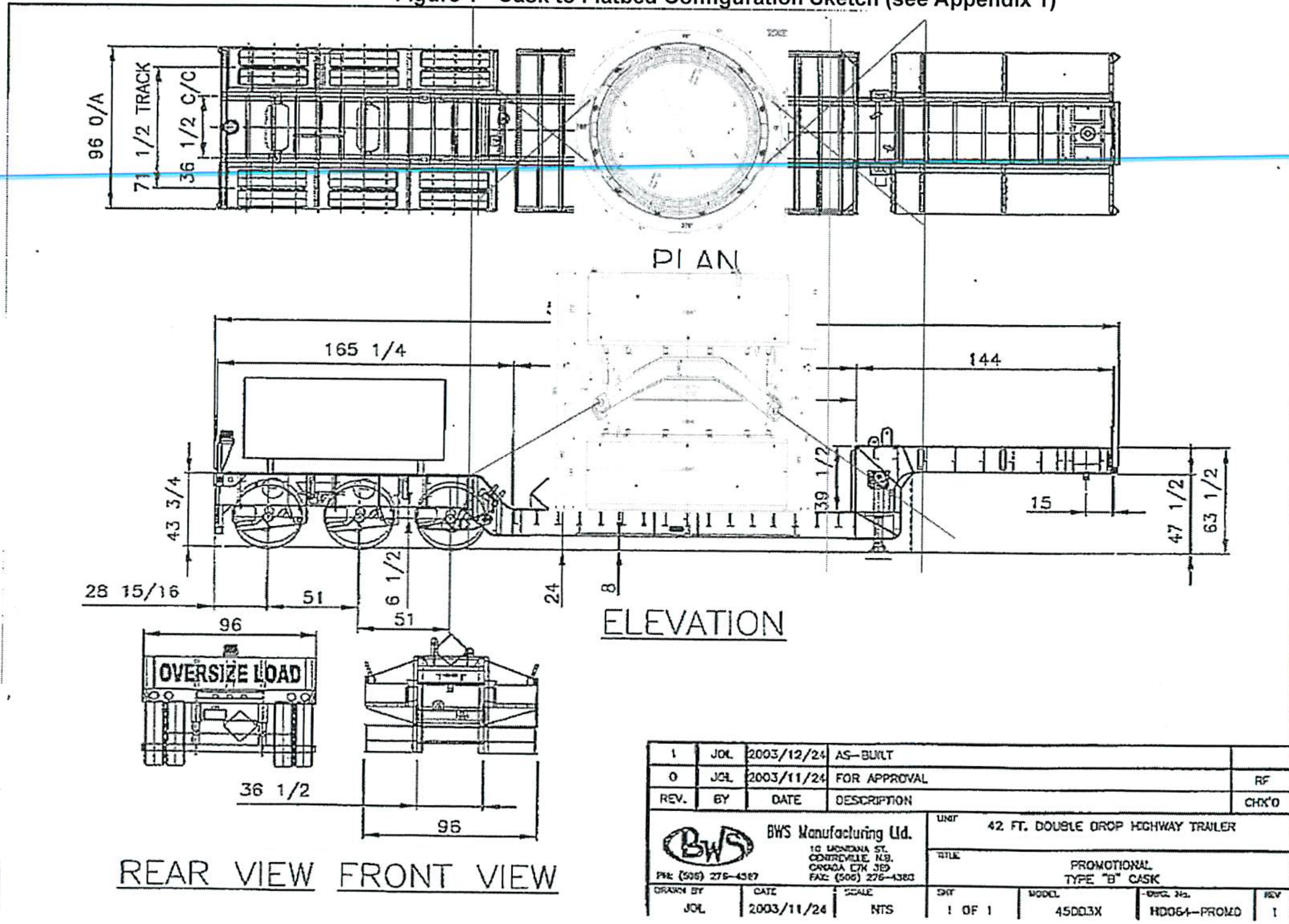


Figure 2. Tie-Down Arm Geometry

Unit: mm
R = impace limiter radius = 2587/2
r = cask radius = (2040+60)/2
d = cask C.G. elev. = 1648
t = avg. tie-down eye elev. = 1429
L = total length from the tangent point of the tie-down arm (to the cask body) to the tie-down eye
x' = avg. tie-down eye X axis offset
y' = avg. tie-down eye Y axis offset
z' = cask tangent elev.
a = L cosθ sinϕ
b = L cosθ cosϕ
c = L sinθ

weight	412.02	KN
R	1293.5	mm
r	1050	mm
d	1648	mm
t	1429	mm
L	605	mm
θ	0.514872	rad
ϕ	0.733038	rad
a	352.3409	mm
b	391.3142	mm
c	297.9163	mm
x'	427.9612	mm
y'	1093.901	mm
z'	1726.916	mm

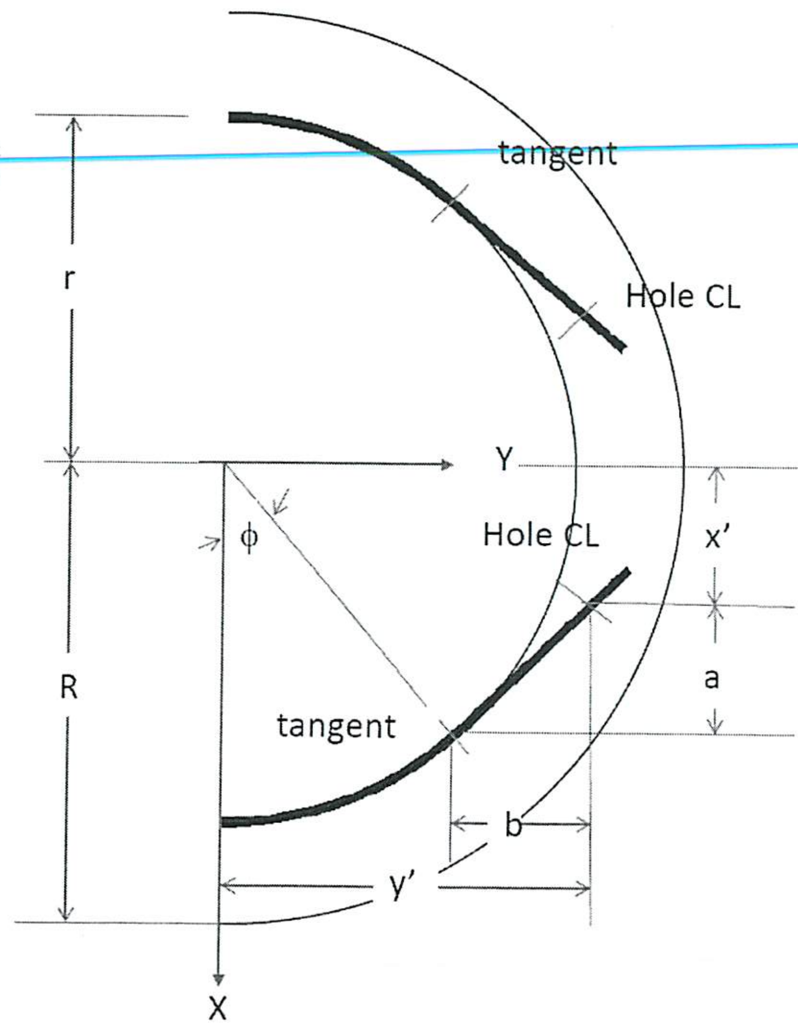


Figure 3. Tie-Down Free Body Diagram

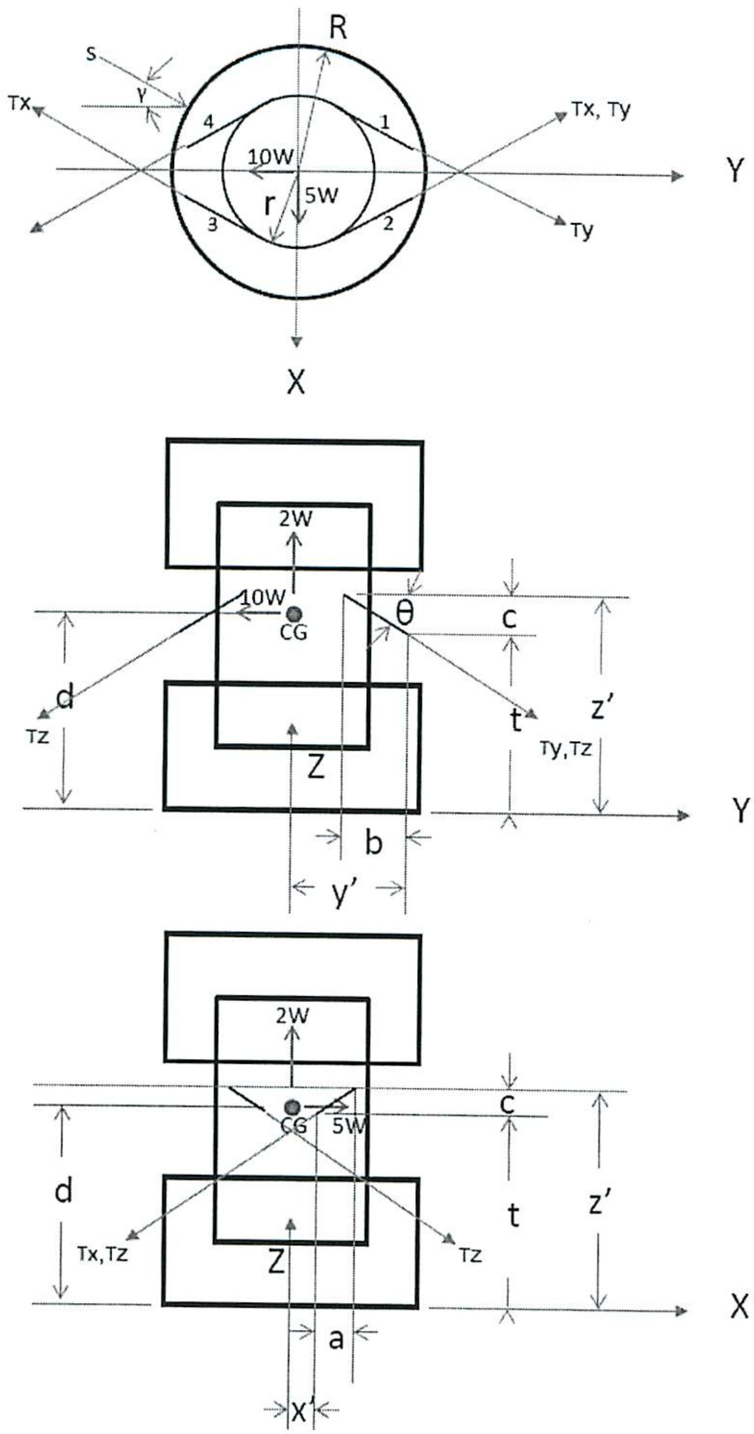
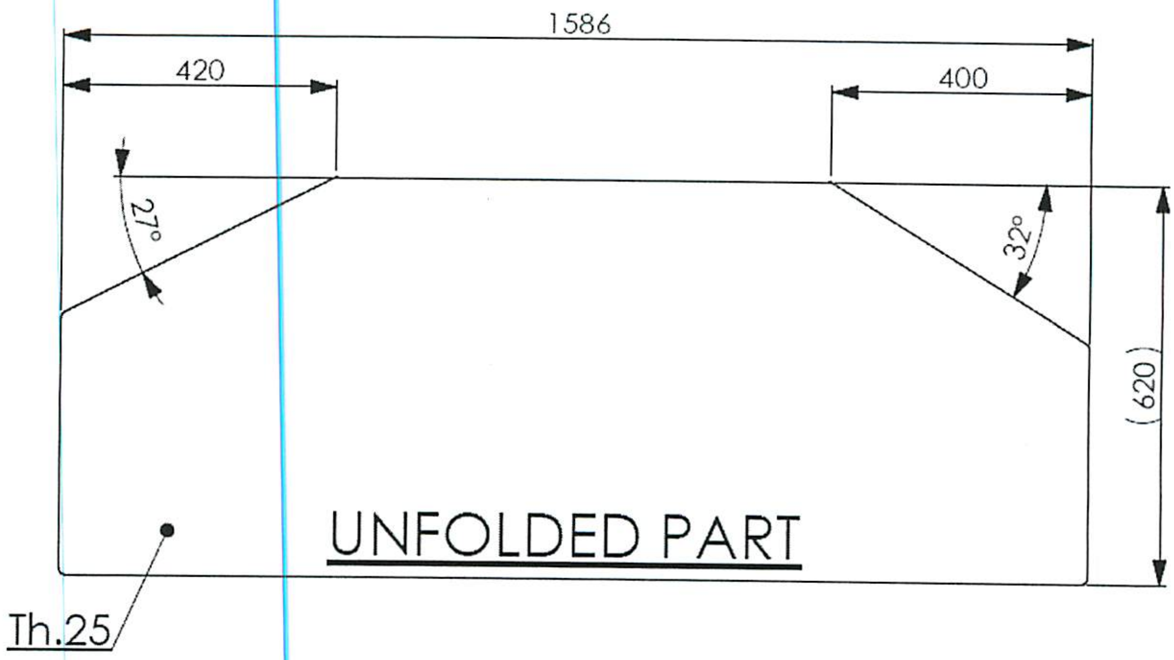


Figure 4. Tie-Down Plate Detail



Appendix 1

Utility 4000A Flatbed Truck Dimensions and Properties

Dealer Locator   Used Trailers

Zip, City & State or Dealer Name   Sub

RESOURCES PARTS SERVICE COMPANY

PRESS ROOM

4000A™

Features Options Specifications Gallery

PRINT

Conduit	UTM Black Enamel Finish with Primer Undercoat on all Steel Show-Surfaces, Aluminum Parts in Natural Finish. Black Rust Preventative Coating on Crossmembers, Undercarriage and Inboard Surface on Main Beams
Cross Members	3" Steel I-Beam Crossmembers on 16" Center Line Full Length
Fixed Air Ride Suspension Location	Suspension Location at 30-1/2" Center Line to Rear
Floor Type	1-1/8" Extruded Aluminum Flat Top Floor with 4 Hardwood Nail Strips
Front Subframe Assembly Finish	1/4" Steel Approach Plate
Hendrickson Air Ride Systems with Integral Axes	Hendrickson AANT 23K Intraax Air Ride
Hub Piloted System with Outboard Drums	Outboard Cast Drums for 16-1/2" x 7" Brakes
Kingpin Type	1/2" x 4" 80,000 PSI Bottom Flange
Main Harness	UTM Moisture Resistant 6-Wire Cable Harness with Internal Ground and 7-Way Plug
Oil Seals	Stemco® Guardian® HP Oil Seal. (Guardian HP or Discover Seal Required for Stemco 5-Year Platinum Performance Warranty)
Outriggers	3 Aluminum Tube Outriggers Each Side
Payload Capacity	80,000 lbs. Payload Capacity
Pipe Spools	Extruded Aluminum on 24" Center Line Centered between Pockets (Meets "Trailer Cargo Anchoring Device" Requirement)
Rubber Dock Bumpers on Rear Rail	(2) 3-1/2" Rubber Bumpers Mounted on Rear Rail
Side Rail	Extruded Aluminum Side Rail with Integral Track on Roadside and Curbside for Sliding Winches
Stop/Tail/Turn Light Configuration	Grote 4" L.E.D. Stop/Tail/Turn Lights
Top Flange	Hat Section 80,000 PSI Top Flange

Purchasing
- Request a Quote
- Find a Dealer

Downloads
- Brochure - Flatbed
- Data Sheet
- Sales Sheet

Warranty

Every trailer manufactured and sold by Utility Trailer Manufacturing Company is backed by a 5-year warranty policy.

New Trailers: Dry Vans, Reefers, Flatbeds, Tautliner

Used Trailers

Dealer Locator

Resources: Why Utility?, Testing, Request a Quote, Photos & Videos, Downloads

Parts: Specials, Line Card

Service: Pre-Delivery Inspection, Service Bulletins, Warranty Certificate

Company: About Us, History, Sustainability, Careers, Contact Us

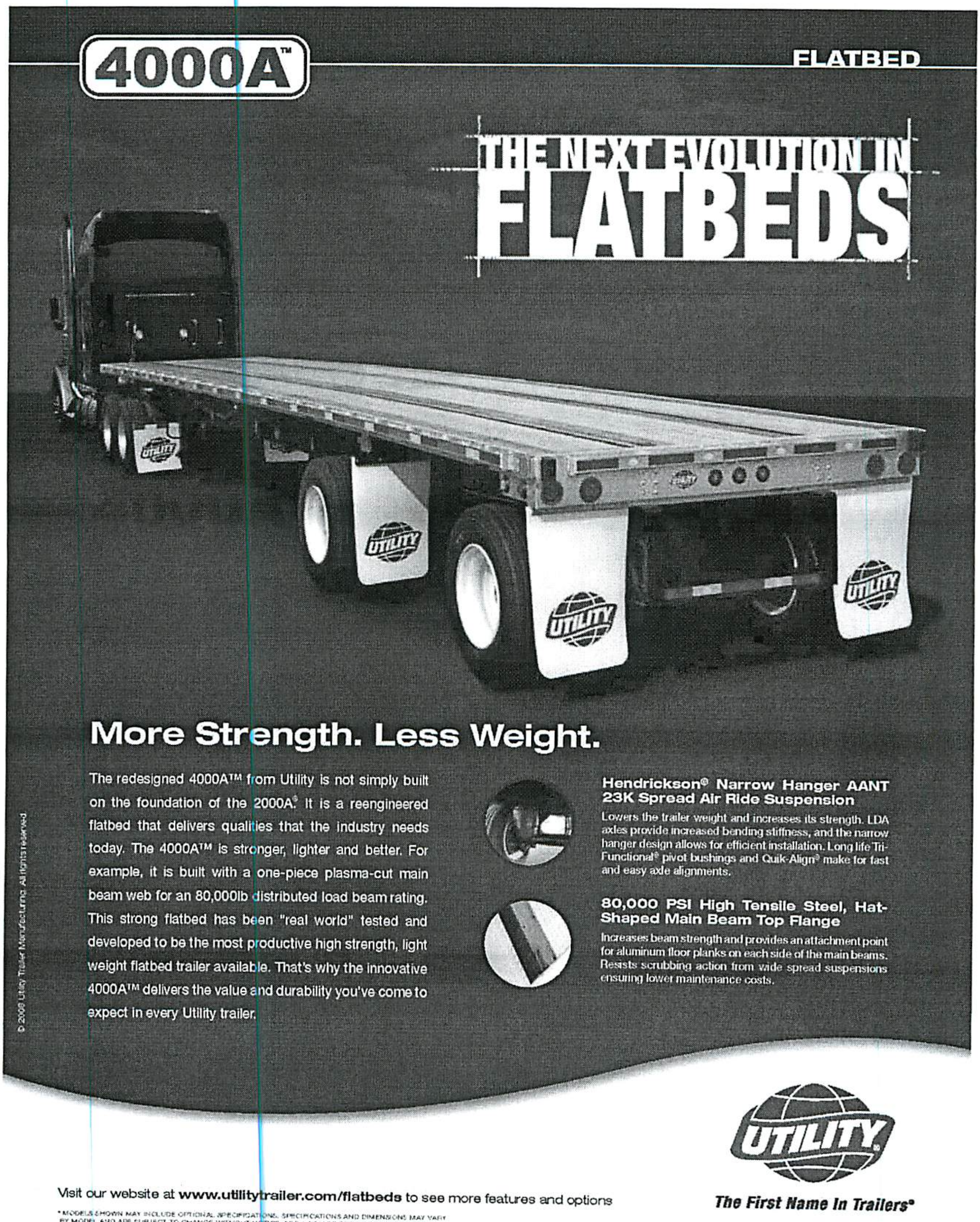
Press Room: Press Releases, In The Media, Events, Utilitopics

Join Mailing List:

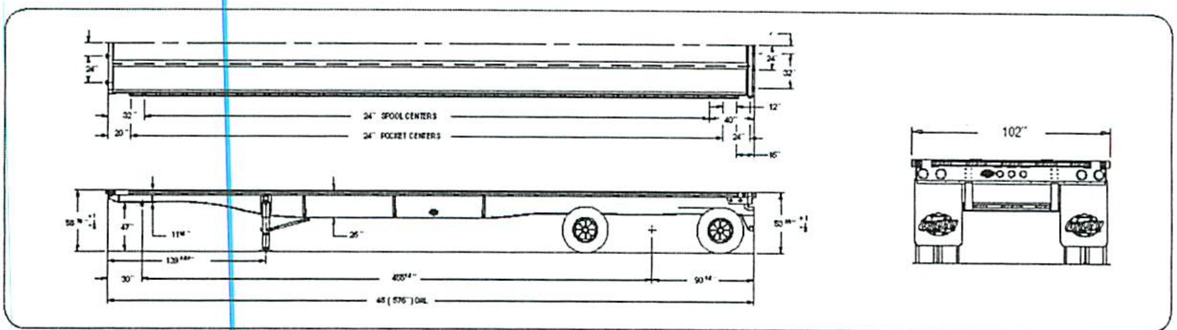
Your Email Address   SIGNUP

Find Us On:

Home | Privacy Policy | Site Disclaimer | Contact


4000A™
FLATBED
THE NEXT EVOLUTION IN
FLATBEDS
UTILITY
More Strength. Less Weight.
The redesigned 4000A™ from Utility is not simply built on the foundation of the 2000A® It is a reengineered flatbed that delivers qualities that the industry needs today. The 4000A™ is stronger, lighter and better. For example, it is built with a one-piece plasma-cut main beam web for an 80,000lb distributed load beam rating. This strong flatbed has been "real world" tested and developed to be the most productive high strength, light weight flatbed trailer available. That's why the innovative 4000A™ delivers the value and durability you've come to expect in every Utility trailer.
Hendrickson® Narrow Hanger AANT 23K Spread Air Ride Suspension
Lowers the trailer weight and increases its strength. LDA axles provide increased bending stiffness, and the narrow hanger design allows for efficient installation. Long life Tri-Functional® pivot bushings and Quik-Align® make for fast and easy axle alignments.
80,000 PSI High Tensile Steel, Hat-Shaped Main Beam Top Flange
Increases beam strength and provides an attachment point for aluminum floor planks on each side of the main beams. Resists scrubbing action from wide spread suspensions ensuring lower maintenance costs.
© 2008 Utility Trailer Manufacturing. All rights reserved
UTILITY
The First Name In Trailers®
Visit our website at www.utilitytrailer.com/flatbeds to see more features and options
* MODELS SHOWN MAY INCLUDE OPTIONAL SPECIFICATIONS. SPECIFICATIONS AND DIMENSIONS MAY VARY BY MODEL AND ARE SUBJECT TO CHANGE WITHOUT NOTICE. SEE A DEALER FOR MORE INFORMATION

4000A Our Standard Features Exceed Industry Standards



6,500 lbs. Working Load Limit Rated Pipe Spools
Utility's standard heavy wall thickness, robotically welded pipe spools surpass D.O.T. requirements for load securement points.

One-Piece Plasma-Cut Main Beam Webs
For strength and durability, Utility flatbeds feature camber-shaped one-piece main beam webs. Our computer controlled plasma cutter creates the cambered shape into the main beam web with absolute accuracy. Utility main beams typically maintain more of their original shape when loaded.

100% Plug-in Connectors
Utility's modular wiring harness features 100% plug-in connectors with internal ground wiring for reliable, easy-to-maintain lighting throughout the trailer.

Integral Winch Track Both Sides
Nothing increases versatility and load security like Utility's integral winch track. With sliding winches, there will always be a winch where it's needed.

Durable Outrigger Attachments
Absorbs load, rather than resisting it, resulting in a longer outrigger attachment life

Higher Quality Paint Process for Lower Life Cycle Costs
For more protection against rust and corrosion, all main beam surfaces are shot blasted prior to painting with a two-part primer and two-part urethane top coat. Interior surfaces of the main beams are painted with a durable rust preventative coating for lower maintenance costs.

Additional Standard Features

Aluminum Front Rail
For lower tare weight and high strength, the aluminum front rail provides protection, ease of maintenance, and durability.

Front Stainless Steel Corners
Stainless steel corners and top plates protect against impact damage and provide additional strength, easier maintenance, and increased durability.

Durable Suspension Design
Optimized suspension structure designed to minimize fatigue cracking of the main beams and suspension components for extended frame life.

Microencapsulated Adhesive on All Floor Screws
Better and stronger connections, reducing maintenance.

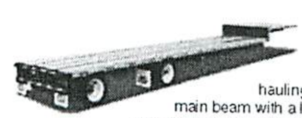
Side Rails are Mechanically Fastened
This allows stress to flex the connection without the fatigue associated with rigid welded joints.

Contoured Beam at Rear for Proper Axle Loading
This design optimizes load distribution between the axles and extends suspension life.

Rear Corners Designed for High Impact Loads
The dock impact is distributed into the entire side rail, resulting in longer rear rail life.

Our Full Line of Flatbeds

All Steel
Designed and engineered for heavy-duty use, the Utility 2000S® All Steel flatbed features thick, rear corner impact plates to protect against dock damage and a tapered front approach plate.



Drop Deck
Utility's heavy-duty, light weight dual axle drop deck, is specifically designed for hauling heavy or awkward loads. Features include a main beam with a large radius in the drop area to allow stress to flow through the entire structure. Utility's unique one-piece continuous bottom flange and 3/16" thick rear buckplate give the trailer additional strength.

Appendix 2

Cask Design Input Email

Johnathon McFarland

From: Curt Lindner [clindner@robateltech.com]
Sent: Friday, July 06, 2012 4:04 PM
To: John Staples; Johnathon McFarland
Subject: RT-100 - Maximum Payload and Gross Weights

For the purposes of preparing the lifting, tie-down and bolting analyses, consider a maximum payload weight as 15000 lbs (6820 kg) and a maximum total weight of 41,000 kg (90,200 lbs). These values bound the sum of the maximum gross weight in the procurement agreement and the maximum cask weight of 34054 kg (74,920 lbs) per Robatel drawing RT-100 PE 1001-1, Rev. C.

Curt Lindner
Lead Engineer, Advanced Analysis
ENERCON Excellence—Every project. Every day. FEDERAL SERVICES, INC.
clindner@enercon.com
office: 770-497-8818 x237
cell: 678-362-7110

From: C.Dane - ROBATEL
To: John Staples
Cc: Curt Lindner; Zhibo Wu
Subject: RE: Tie down
Date: Wednesday, September 26, 2012 3:08:15 AM

Hi John,

Find attached the filler metal procurement procedure.
Unfortunately, it is still only in French.
But you can see the filler metal that will be used in tables in chapter 9.2.2.
The material anticipated is E308LT0-4 for the weld of the tie down support plate and the outer shell.

The filler metal is E2209T0-4 for the weld between the tie down support plate and the tie down arms (for S31803 material together)

No more thickness modification is allowed and the weld can't be more than 17 mm.

A table of the allowables is in chapter 9.2.4

Regards

Chris

FLUXINOX 22.9.3L

OERLIKON

Cored Wires
Stainless and Heat resistant steels

Fluxinox 22.9.3L is an alloyed rutile flux cored wire, suitable for the joining and cladding of corrosion resistant ferritic-austenitic duplex-steels. The weld metal consists of about 30% ferrite and 70% austenite and is particularly resistant to pitting, crevice corrosion and stress corrosion cracking in chloride and hydrogen sulphide bearing media. Principal applications include the construction of chemical plants and offshore installations, for operating temperatures up to 250 °C.

Classification	
AWS	A5.22: E2209T0-4 / E2209T0-1
EN	12073: T 22 9 3 N L R M 3 / T 22 9 3 N L R C 3

Approvals	Grades
TÜV	
UDT	

see Appendix, Classification Society Approvals, for details pag. 521

Analysis of all-weld metal (Typical values in %)

C	Mn	Si	P	S	Cr	Ni	Mo	Nb	Cu	N	Ferrite
≤ 0.04	1.20	0.70	-	-	22	9	3	-	-	0.10	35-45

All-weld metal Mechanical Properties

Heat Treatment	Yield Strength N/mm²	Tensile Strength N/mm²	Elongation A5 (%)	Impact Energy ISO - V (J) - 60 °C	Hardness
As Welded	≥ 450	≥ 690	≥ 20	≥ 32	-

Gas test: Acc. To EN 439: M21(Arcal 21-Atal 6)

Shielding Gas: Acc. To EN 439: M21(Arcal21-Atal6) or C1(Arcal 2)

Materials

1.4462 (X2CrNiMoN22-5-3)

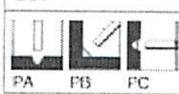
UNS S31803 - S31500 - S31200 - S32304

Storage

Keep dry and avoid condensation

Current condition and welding position

DC+



Packaging data: K300 kg. 16

Diameters	1,2	1,6				

In-Flux Sterling® 308L*
flat & horizontal

AWS E308LT0-4/-1
(Dual classified as EXXXTX-1
for CO2 gas shielding)

Description

An austenitic stainless steel deposit with low carbon used for joining common austenitic stainless steels such as Types 301, 302, 304, 304L, CF-8, and CF-3. Approvals and conformances: AWS Spec A5.22, ASME SFA5.22

Typical Deposit Analysis %

C	0.04
Mn	1.10
Si	0.70
Cr	19.60
Ni	9.50
Fe	Bal.

Typical Properties as Welded

Tensile Strength	85,000 psi
Yield Strength	61,000 psi
Elongation in 2"	43%
DeLong Ferrite Number	10

** U.S. Patent No. 4449031