RTL-001-CALC-ST-0101 Rev 0_Redacted

| ENERCON<br>*Excellence — Every project. Every day.* | CALCULATION COVER SHEET | **CALC. NO.** RTL-001-CALC-ST-0101<br>**REV.** 0<br>**PAGE NO.** 1 of 12 |
|---|---|---|

| **Title:** | RT-100 Weight and Center of Gravity Calculation | **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) ______ | ☐ | ☒ |
| 2 | Does this calculation serve as an "Alternate Calculation"? (If **YES**, Identify the design verified calculation.)<br>**Design Verified Calculation No.** ______ | ☐ | ☒ |
| 3 | Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.)<br>**Superseded Calculation No.**______ | ☐ | ☒ |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:** Natalie George *Natalie A. George* | **Date:** 9-12-2012 |
| **Design Verifier:** John McFarland *John Staples for John McFarland per email 8/29/2012 8:22 PM* | **Date:** 9-12-2012 |
| **Approver:** John Staples *John F Staples* | **Date:** 9-12-2012 |

| ENERCON<br>Excellence—Every project. Every day. | CALCULATION<br>REVISION STATUS SHEET | CALC. NO. | RTL-001-CALC-ST-0101 |
|---|---|---|---|
| | | REV. | 0 |
| | | PAGE NO. | 2 of 12 |

## CALCULATION REVISION STATUS

| REVISION | DATE | DESCRIPTION |
|---|---|---|
| 0 | 9-12-2012 | Initial Issue |

## PAGE REVISION STATUS

| PAGE NO. | REVISION | PAGE NO. | REVISION |
|---|---|---|---|
| 1-12 | 0 | | |

## APPENDIX REVISION STATUS

| APPENDIX NO. | PAGE NO. | REVISION NO. | APPENDIX NO. | PAGE NO. | REVISION NO. |
|---|---|---|---|---|---|
| A | A1-A2 | 0 | | | |
| B | B1-B16 | 0 | | | |
| C | C1-C2 | 0 | | | |

<table>
<tr><td rowspan="3">ENERCON<br>Excellence—Every project. Every day</td><td rowspan="3">CALCULATION<br>DESIGN VERIFICATION<br>PLAN AND SUMMARY SHEET</td><td>CALC. NO. RTL-001-CALC-ST-0101</td></tr>
<tr><td>REV. 0</td></tr>
<tr><td>PAGE NO. 3 of 12</td></tr>
</table>

**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:** John Staples *John F. Staples* | **Date:** 9-12-2012 |

**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 McFarland *John Staples for John McFarland per email 8/29/2012 1:22 pm* | **Date:** 9-12-2012 |
| **Others:** | **Date:** |

| 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 McFarland John Staples for John McFarland per email 8/29/2012 8:22 pm | **Date:** 9-12-2012 |
| **Others:** John Staples (review of ANSYS outputs) | **Date:** 9-12-2012 |

## Table of Contents

## 1.0 Purpose and Scope

Robatel Technologies is designing the RT-100 transport cask to transport 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). The purpose of this calculation is to determine the detailed cask component and assembly weights and to derive the location of the center of gravity locations for the components and assemblies of the RT-100 transport cask. Weights and center of gravity locations will be determined for fully assembled unloaded and loaded conditions.

## 2.0 Summary of Results and Conclusions

Table 2.1 gives the weights and center of gravity locations for the itemized components. Weights and center of gravity locations were determined using the ANSYS computer program (See Appendix B for output). The center of gravity locations are based on a coordinate system located at the bottom, center of the lower impact limiter, with (+y) as vertical up and (x) and (z) in perpendicular horizontal directions. See Section 7.0 for example center of gravity location calculation.

Table 2.2 gives the weights and center of gravity locations for the itemized assemblies, including the fully assembled cask. Weights and center of gravity locations for the assemblies and unloaded fully assembled cask were determined using the ANSYS computer program (See Appendix B for output). The center of gravity location for the loaded, fully assembled cask is calculated in Section 7.0. The center of gravity locations are based on a coordinate system located at the bottom, center of the lower impact limiter, with (+y) as vertical up and (x) and (z) in perpendicular horizontal directions.

Proprietary Information Content Withheld Under 10 CFR 2.390

**Table 2.2 - Assembly Weights and Center of Gravity Locations**

| Assembly | ANSYS Component Name | Weight (kg) | Center of Gravity, y-dir (m) | Center of Gravity, x, z-dir (m) |
|---|---|---|---|---|
| Lower Impact Limiter | BIL | 2401 | 0.5161 | 0 |
| Cask Body | CASK | 24472 | 1.4458 | 0 |
| Primary Lid w/ bolts | PLID | 3668 | 2.7161 | 0 |
| Secondary Lid w/ bolts | SLID | 865 | 2.7365 | 0 |
| Upper Impact Limiter | TIL | 2458 | 2.8119 | 0 |
| **Total Assembly, empty** | TOTAL | 33864 | 1.6494 | 0 |
| **Total Assembly, with payload** | N/A | 40924 | (1.6123, 1.6800)[1] | (+/-)0.0298[2] |

1) Determined using payload center of gravity at 10% of cask interior height below or above the cask interior geometric centerline, respectively; see Section 7.0 for calculation
2) Determined using payload center of gravity at (+/-)10% of cask interior width away from the cask interior geometric centerline in horizontal directions; see Section 7.0 for calculation

## 3.0 References

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

3.2 Drawings
   A. ROBATEL Industries Drawing RT100 PE 1001-1 Rev. D, "ROBATEL TRANSPORT PACKAGE RT100 GENERAL ASSY SHEET 1/2"
   B. ROBATEL Industries Drawing RT100 PE 1001-2 Rev. D, "ROBATEL TRANSPORT PACKAGE RT100 GENERAL ASSY SHEET 2/2"
   C. ROBATEL Industries Drawing 102885 PD 1012 Rev. B, "ROBATEL TRANSPORT PACKAGE RT100 S/E EMBALLAGE DETAILS COUVERCLE PRIMAIRE"
   D. ROBATEL Industries Drawing 102885 PD 1013 Rev. B, "ROBATEL TRANSPORT PACKAGE RT100 S/E EMBALLAGE DETAILS COUVERCLE SECONDAIRE"
   E. ROBATEL Industries Drawing 102885 PD 1031 Rev. B, "ROBATEL TRANSPORT PACKAGE RT100 S/E EMBALLAGE DETAILS CAPOT INFERIEUR"
   F. ROBATEL Industries Drawing 102885 PD 1032 Rev. B, "ROBATEL TRANSPORT PACKAGE RT100 S/E EMBALLAGE DETAILS CAPOT SUPERIEUR"

3.3 ANSYS – Mechanical, Version 14, ANSYS, Inc., Canonsbury, PA 15137 (See note)

3.4 NRC Memorandum "Summary of June 26-27, 2012, Meeting with ROBATEL Technologies, LLC," (Non-Proprietary Version), ADAMS Ascension No. ML12200A018

3.5 Fundamentals of Heat and Mass Transfer, Frank P. Incorpera, David P. DeWitt, 2002, 5th ed., John Wiley & Sons, Inc.

3.6 Design Guide, "LAST-A-FOAM FR-3700 Crash & Fire Protection of Radioactive Material Shipping Containers," dated 02/23/2012, General Plastic Manufacturing Company

Note: ANSYS is a commercially available computer software that is procured and maintained under the Enercon Services QA program.

## 4.0 Assumptions

There are no 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 maximum payload weight is 15,000 lbs, or 6,803.9 kg (see Appendix A). Conservatively, a value of 7,060 kg will be used for this evaluation.

Proprietary Information Content Withheld Under 10 CFR 2.390

## 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 wall, ductile stainless steel and foam upper and lower impact limiters, a pair of concentric, removable stainless steel cask lids, a pair of removable stainless steel lifting pockets on opposite sides of the cask body and a pair of stainless steel tie-down arms on opposite sides of the cask body (Ref. 3.2).

Components of the RT-100 cask will be created in the ANSYS computer program (Ref. 3.3). Geometric features and material types of all components will be confirmed against the drawings (Ref. 3.2). However, for simplification of the model, intricate cask details such as chamfered edges were not modeled. This leads to a maximum of 5% difference in weight between the model and the drawings. This has an insignificant effect on the center of gravity locations for the fully assembled unloaded and loaded cask and is therefore acceptable.

The ANSYS command VSUM will be used to obtain the weight and center of gravity locations of the components and assemblies. However, weights calculated in the ANSYS computer program are doubled as only half of the cask is modeled (see Appendix B for cask image).

The center of gravity locations are based on a coordinate system located at the bottom, center of the lower impact limiter, with (+y) as vertical up and (x) and (z) in perpendicular horizontal directions. In order to determine the center of gravity locations for components and assemblies based on the bottom, center of the lower impact limiter, the ANSYS coordinate system must be adjusted in the vertical direction (see Section 7.0 for example calculation).

A maximum payload of 7,060 kg will be applied to the fully assembled cask in order to determine the weight and center of gravity locations for the loaded, fully assembled cask (see Section 7.0). Per Reference 3.4, the cask "*contents shall be placed such that the CG of the package is at approximately the same location as the geometric center of the package – approximately the same location being defined as having a ±10% difference in distance of the cavity inside dimensions from the geometric center of the package in any direction*." All other horizontal center of gravity locations are assumed to be located at the geometric center of components and assemblies.

## 7.0 Calculations

Adjusting ANSYS Coordinate System

$y_{cg}$ = distance from base of lower impact limiter to ANSYS coordinate system (+) component/assembly center of gravity based on ANSYS coordinate system

Example (center of gravity location of component BIL_FR3705):

$y_{cg} = 0.497 + (-)0.318 = 0.179m$

Center of Gravity Locations of Payload

The payload center of gravity located at 10% of the cask interior height below the cask interior geometric centerline was determined as follows:

$y_{cg}$ = distance from base of lower impact limiter to base of cask interior (+) distance to center of cask interior (–)10% of the cask interior height

$$y_{cg} = 0.652 + \frac{1.956}{2} - (1.956 \times 0.1) = 1.4344m$$

The payload center of gravity located at 10% of the cask interior height above the cask interior geometric centerline was determined as follows:

$y_{cg}$ = distance from base of lower impact limiter to base of cask interior (+) distance to center of cask interior (+)10% of the cask interior height

$$y_{cg} = 0.652 + \frac{1.956}{2} + (1.956 \times 0.1) = 1.8256m$$

The payload center of gravity located at (+/-)10% of the cask interior width away from the cask interior geometric centerline was determined as follows:

$x_{cg} = z_{cg}$ = (+/-)10% of the cask interior width

$x_{cg} = z_{cg} = \pm (1.730 \times 0.1) = \pm 0.1730m$

Center of Gravity Locations of Total Assembly with Payload

The center of gravity for the loaded total assembly, using a payload center of gravity 10% of cask interior height below the cask interior geometric centerline, was determined using the following equation:

$$y_{cg} = \frac{\sum_{i=1}^{N} m_i y_i}{M} = \frac{(33864 \times 1.6494) + (7060 \times 1.4344)}{40924} = 1.6123m$$

Where: $y_{cg}$ = distance to center of gravity in y-direction (m)
$m_i$ = weight of each assembly (kg)
$y_i$ = center of gravity of each assembly in the y-direction (m)
$M$ = total mass (kg)

The center of gravity for the loaded total assembly, using a payload center of gravity 10% of cask interior height above the cask interior geometric centerline, was determined using the following equation:

$$y_{cg} = \frac{\sum_{i=1}^{N} m_i y_i}{M} = \frac{(33864 \times 1.6494) + (7060 \times 1.8256)}{40924} = 1.6800m$$

Where: $y_{cg}$ = distance to center of gravity in y-direction (m)
$m_i$ = weight of each assembly (kg)
$y_i$ = center of gravity of each assembly in the y-direction (m)
$M$ = total mass (kg)

The center of gravity for the loaded total assembly, using a payload center of gravity (+/-)10% of cask interior width away from the cask interior geometric centerline in the horizontal directions, was determined using the following equation:

$$x_{cg} = z_{cg} = \frac{\sum_{i=1}^{N} m_i x_i}{M} = \frac{\sum_{i=1}^{N} m_i z_i}{M} = \frac{(33864 \times 0) + (7060 \times 0.1730)}{40924} = 0.0298m$$

Where: $x_{cg}$, $z_{cg}$ = distance to center of gravity in perpendicular, horizontal directions (m)
$m_i$ = weight of each assembly (kg)
$x_i$, $z_i$ = center of gravity of each assembly in perpendicular, horizontal directions (m)
$M$ = total mass (kg)

**Table 7.1 - Weights and Center of Gravity Locations**

| Assembly | ANSYS Component Name | Weight (kg) | Center of Gravity, y-dir (m) | Center of Gravity, x, z-dir (m) |
|---|---|---|---|---|
| Payload | N/A | 7060[1] | (1.4334, 1.8256)[2] | (+/-)0.1730[3] |
| Total Assembly, empty | TOTAL | 33863 | 1.6494 | 0 |
| **Total Assembly, with payload** | N/A | 40634 | 1.6123, 1.6800 | (+/-)0.0298 |

1) See Section 5.0 for payload weight determination
2) Payload center of gravity is 10% of cask interior height below or above the cask interior geometric centerline, respectively
3) Payload center of gravity is (+/-)10% of cask interior width away from the cask interior geometric centerline in horizontal directions

# Appendix A

Emails

**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 | FEDERAL SERVICES, INC.
clindner@enercon.com
office: 770-497-8818 x237
cell: 678-362-7110

# Appendix B

ANSYS Output

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

# Appendix C

ANSYS Input

The following ANSYS files are used in this calculation:

```
Volume in drive M has no label.
 Volume Serial Number is 164B-772E

 Directory of M:\Projects\ROBATEL\ROBATEL002 - RT-100 Calculations\3.0 Calculations\Civil\ST0101
Wgt n CG RT100\ANSYSFILES

08/28/2012  01:26 PM    <DIR>          .
08/28/2012  01:26 PM    <DIR>          ..
08/28/2012  01:21 PM    <DIR>          Archives
08/28/2012  01:24 PM    <DIR>          Backup
08/28/2012  08:18 AM               988 BIL.txt
08/28/2012  08:18 AM               988 BIL_FR3705.txt
08/28/2012  08:18 AM               988 BIL_FR3720.txt
08/28/2012  08:18 AM               988 BIL_FR3740.txt
08/28/2012  08:18 AM               988 CASK.txt
08/28/2012  08:18 AM               988 CASK_PB.txt
08/28/2012  01:26 PM                 0 filelist.txt
08/28/2012  08:18 AM               988 PLID.txt
08/28/2012  08:18 AM               988 SLID.txt
08/28/2012  08:18 AM               988 SLID_PB.txt
08/28/2012  08:18 AM               988 TIL.txt
08/28/2012  08:18 AM               988 TIL_FR3705.txt
08/28/2012  08:18 AM               988 TIL_FR3720.txt
08/28/2012  08:18 AM               988 TIL_FR3740.txt
08/28/2012  08:18 AM               988 TOTAL.OUT
08/28/2012  09:03 AM       117,637,120 WGTCG.db
08/28/2012  08:18 AM       117,571,584 WGTCG.dbb
08/28/2012  09:03 AM               956 WGTCG.err
08/26/2012  02:16 PM             2,214 WGTCG.inp
08/28/2012  09:03 AM             2,682 WGTCG.log
08/28/2012  08:13 AM            51,519 WGTCG000.png
08/28/2012  08:14 AM            51,515 WGTCG001.png
              22 File(s)    235,331,422 bytes
               4 Dir(s)  1,622,861,828,096 bytes free
```

These files are archived in the ENERCON project files and provided to the client in electronic format.