SAND2018-0468R

Rail-Cask Tests: Normal-Conditions-of-Transport Tests of Surrogate PWR Fuel Assemblies in an ENSA ENUN 32P Cask

Spent Fuel and Waste Disposition

Paul McConnell (SNL) and Steven Ross (PNNL)

Carissa Grey, William Uncapher, Mike Arviso (SNL)

Rafael Glez. Garmendia, Ismael Fernández Pérez, Alejandro Palacio, Guillermo Calleja (ENSA)

and David Garrido,

Ana Rodríguez Casas, Luis González García (COORDINADORA)

Wes Chilton, Doug Ammerman, Jacob Walz, Sabina Gershon, Sylvia Saltzstein, Ken Sorenson (SNL)

Nicholas Klymyshyn, Brady Hanson (PNNL)

Ruben Peña, Russell Walker (TTCI)

January 16, 2018

SFWD-SFWST-2017-000004

SAND2018-0468R

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SUMMARY

This report describes tests conducted using a full-size rail cask, the ENSA ENUN 32P, involving handling of the cask and transport of the cask via truck, ships, and rail.

The purpose of the tests was to measure strains and accelerations on surrogate pressurized water reactor fuel rods when the fuel assemblies were subjected to Normal Conditions of Transport within the rail cask. In addition, accelerations were measured on the transport platform, the cask cradle, the cask, and the basket within the cask holding the assemblies.

These tests were an international collaboration that included Equipos Nucleares S.A., Sandia National Laboratories, Pacific Northwest National Laboratory, Coordinadora Internacional de Cargas S.A., the Transportation Technology Center, Inc., the Korea Radioactive Waste Agency, and the Korea Atomic Energy Research Institute.

All test results in this report are PRELIMINARY – complete analyses of test data will be completed and reported in FY18. However, preliminarily:

The strains were exceedingly low on the surrogate fuel rods during the rail-cask tests for all the transport and handling modes.

The test results provide a compelling technical basis for the safe transport of spent fuel.

This page is intentionally left blank.

ACKNOWLEDGEMENTS

These tests would not have been possible without the courageous foresight and sagacity of David Garrido Quevedo, previously of ENSA, who arranged for the rail cask to be used in this international test program. The results of these tests benefit all who must eventually transport spent fuel and the regulators worldwide who must ensure that spent fuel is transported safely.

The authors thank Ned Larson and John Orchard of DOE/LV for their sustained support and sage advice for the rail-cask fuel assembly tests.

Technical support for the assembly tests was invaluable. The authors thank Sandians William Chavez, Garrett Kleist, Jeff Harkins, Lori Harkins, Amanda Pavlakos, Vince Gasparich, Mark Means, and Jeri Sue Crenshaw.

At ENSA, the authors extend thanks to Marcos Fernández and Roberto Naval for expertly handling the cask and all the test equipment, and to Lucia Bilbao for loaning "her" cask to the project! And thanks to the excellent Spanish videographers for their work in Spain and Belgium, Jose Manuel Guerra and Rafael Guerra.

Formal technical review of the report was provided by Elena Kalinina.

Technical editing of the report was performed by Laura A. Connolly.

This page is intentionally left blank.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

REVISION HISTORY

Document Number/Revision	Date	Description
FCRD-SFWST-2016-000067 Sandia Tracking # 529772	September 15, 2016	Not yet approved for Unlimited Release Satisfies SFWST Milestone Number M2FT-16SN08020422 (WBS SF-17SN1.02.08.02.04)
FCRD-SFWST-2016-000067, Revision 1 Sandia Tracking #577399	January 19, 2017	Not yet approved for Unlimited Release 1. Removed OUO markings per ENSA. 2. Revised first sentence of first paragraph on page 17: Changed “SNL” to “PNNL.” 3. Added sentence to bottom of page 41: “SNL will be the Importer of Record (IOR) at the Port of Baltimore Mid-Atlantic Terminal.” 4. Added to page 41 Figure 23: “Port of Baltimore/US Customs.”
SFWD-SFWST-2017-000004 Sandia Tracking #703204	September 30, 2017	Not yet approved for Unlimited Release Update of FCRD-SFWST-2016-000067, Revision 1 to incorporate rail-cask tests.

SFWD-SFWST-2017-000004, January 16, 2018, Approved for Unlimited Release.

ACRONYMS

AAR	Association of American Railroads
ANL	Argonne National Laboratory
BNSF	Burlington Northern Santa Fe Railway
CoCIM	Chain of Custody Item Monitor
DAC	Data Acquisition and Control
DOE	US Department of Energy
ENRESA	Empresa Nacional de Residuos Radiactivos Sociedad Anónima
ENSA	Equipos Nucleares Sociedad Anónima
ENUSA	ENUSA Industrias Avanzandas, Sociedad Anónima (formerly Empresa Nacional del Uranio S.A.)
ENUN	ENSA Universal [cask]
GPS	Global Positioning System
KAERI	Korea Atomic Energy Research Institute
KNFC	Korea Nuclear Fuel Company Ltd
KORAD	Korea Radioactive Waste Agency
MAT	Mid-Atlantic Terminal
NDA	Non-Disclosure Agreement
NRC	US Nuclear Regulatory Commission
OTLR	AAR Open Top Loading Rules
PNNL	Pacific Northwest National Laboratory
PWR	pressurized water reactor
RF	radio frequency
RO/RO	Roll-On/Roll-Off [ship]
SFWD	Spent Fuel & Waste Disposition
SNF	spent nuclear fuel
SNL	Sandia National Laboratories
TBD	To Be Determined
TBV	To Be Verified
TTCI	Transportation Technology Center, Inc.
USA/US	United States of America

SPENT FUEL AND WASTE DISPOSITION

RAIL-CASK TESTS: NORMAL-CONDITIONS-OF-TRANSPORT TESTS OF SURROGATE PWR FUEL ASSEMBLIES IN AN ENSA ENUN 32P CASK

1. INTRODUCTION

This report describes a series of tests of surrogate pressurized water reactor (PWR) fuel assemblies in a rail cask during various modes of transportation and cask handling conducted between June and October 2017. The primary purpose of the tests is to measure strains and accelerations on surrogate fuel rods when the assemblies are subjected to normal conditions of transport within the Equipos Nucleares Sociedad Anónima (ENSA) (Figure 1-1) UNiversal (ENUN) 32P cask. Accelerations on the cask basket, the cask, the cask cradle, and the transport platforms were also measured.

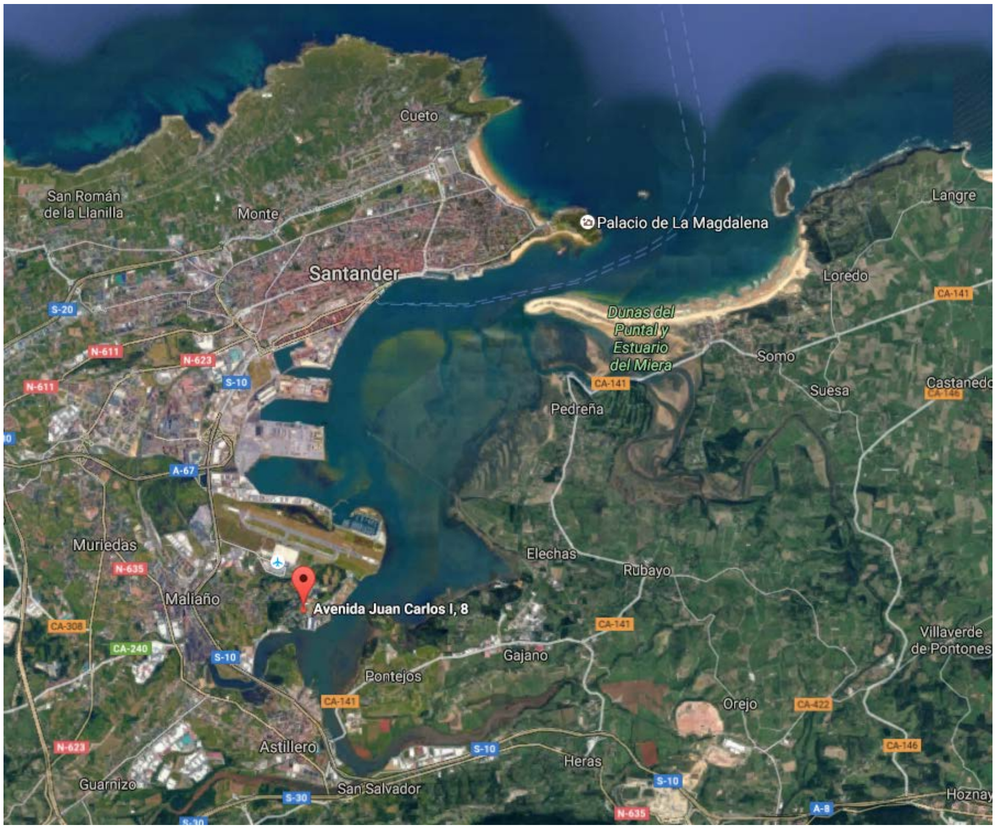
The report describes details of the tests, the logistics and operations for performing the tests, and the dates of the tests. Huge amounts of data were collected during the tests – 77 channels of instrumentation recorded for many days of testing – so the results reported herein must be considered PRELIMINARY. Detailed analyses of the data will be performed and reported in FY18.

An ENSA ENUN 32P cask and associated hardware was provided by ENSA for performing the tests.

The impetus for these tests was twofold: 1) spent nuclear fuel (SNF) will be dry stored for significant periods of time before disposal; aging of the fuel cladding may occur during storage which may embrittle the cladding. 2) Fuel will be subjected to higher burnups prior to storage which can cause embrittlement of the cladding. These two factors call into question the integrity of SNF cladding during normal conditions of transport should the stresses and strains applied to the fuel rods during transport exceed the yield strength of the Zircaloy-4 cladding. These tests measured strains on the cladding during transport which can be compared with mechanical property data for aged, high burnup cladding. Should the strains be sufficiently low compared with the properties of the cladding, a technical basis will have been demonstrated for the safe transport of high burnup SNF after extended storage.

This is the report for Milestone M2SF-17SN010202021-Initial Report for Full-scale Rail Cask Normal Condition of Transport Tests for the Transportation – SNL Work Package (Parent WBS # 1.08.01.02.02; Work Package # SF-17SN01020202 Rev. 4)

(a)



(b)

Figure 1-1. Aerial view of ENSA (a) and its location near Santander, Spain (b).

Three PWR assemblies were placed within the thirty-two cell ENSA ENUN 32P cask basket along with twenty-nine dummy assemblies. Selected rods within the PWR assemblies were instrumented with strain gauges and accelerometers.

The ENSA ENUN 32P cask/cradle was placed, sequentially, on a heavy-haul truck, ships (coastal and trans-oceanic), and a railcar[a]. The ENSA ENUN 32P cask, cask cradle, and transportation platforms (truck trailer, ship trailers, and railcar) were instrumented with accelerometers. Data were collected from the instrumentation for all these transportation modes.

The ENSA ENUN 32P cask tests follow a series of tests simulating normal conditions of transport performed using a surrogate 17 X 17 PWR assembly on shaker tables and on a truck. These tests are described in References 1 – 3.

These tests present a unique opportunity to collect shock and vibration data for surrogate spent fuel assemblies in a full-scale transportation cask since data was collected for three different modes of transportation (heavy-haul truck, ship, and rail) and for intermodal transfer. Data was also collected during operations simulating the vertical placement of the ENSA ENUN 32P cask onto a surrogate storage pad. The combination of these modes of transportation and handling offers an understanding of the cumulative effects of transportation and handling of high burnup SNF and allow the collection of data necessary for closing the Stress Profiles technical data gap as identified in Reference 4.

Gap closure with respect to stresses associated with cask movement and normal conditions of transport will be accomplished by measuring and quantifying the mechanical loads (e.g., strains and accelerations) on various components, but especially on the fuel assembly. This information will guide materials research and establish a technical basis for review organizations such as the United States (US) Nuclear Regulatory Commission (NRC). While limited experimental and numerical modeling data of loads and failure limits applicable to normal conditions of rail transport exist, the data are either outdated relative to present-day railroad operations and equipment, or are based on assumptions that can only be verified through experimental testing. Structural performance models using the material properties of the ENSA ENUN 32P cask and assembly components used in this testing program will be validated by comparing against the stress profile data.

Data from rail shock and vibration tests is important to the US nuclear power industry, the NRC, the US Department of Energy (DOE), as well as for the worldwide nuclear regulators and industry. These types of tests provide information to regulators regarding shock and vibration loads during normal condition of transportation including movements associated with dry storage operations. The results will validate that spent fuel can be handled safely—considering aging of SNF placed in dry storage and the ability to safely transport large amounts of SNF to an off-site destination. The data will also assist the Spent Fuel & Waste Storage & Transportation (SFWST) Campaign in confirming and validating models to provide confidence in assurances of the robustness of SNF properties for extended storage periods and for potentially multiple transport and handling activities.

The performance of different systems and actual spent fuel assemblies can then be modeled with confidence by substituting the material properties obtained in other testing performed by the SFWST Campaign and using the stress profile loads in these structural performance models.

The data from these transport shock and vibration tests can be used to support predictive modeling and simulation of high burnup spent fuel performance under conditions of normal transportation. The simulation results will then be supported by observations of the condition of high-burnup SNF at the end of the Electric Power Research Institute/DOE High Burnup Confirmatory Demonstration Project when the demonstration cask is opened, the fuel recovered, and the aged (and transported) fuel rods are characterized. All of these data can be used by industry in

[a] Virtually all SNF in the US will be shipped by rail. There may be some fuel that will be shipped initially from storage facilities via barge or heavy-haul truck to a rail line.

support of their extended dry storage licensing strategies and to support certification of transportation casks for shipping high-burnup and long-cooled SNF.

The objective of the transport shock and vibration testing program is to obtain data necessary for closing the Stress Profiles Technical [4]. Gap closure with respect to stresses associated with cask movement and normal conditions of transport will be accomplished by measuring and quantifying the mechanical loads (e.g., strains and accelerations) on various components, but especially on the fuel assembly. This information will guide materials research and establish a technical basis for review organizations such as the NRC. While limited experimental and numerical modeling data of loads and failure limits applicable to normal conditions of rail transport exist, the data are either outdated relative to present-day railroad operations and equipment, or are based on assumptions that can only be verified through experimental testing. Structural performance models using the material properties of the cask and assembly components used in this testing program will be validated by comparing against the stress profile data. The performance of different systems and actual spent fuel assemblies can then be modeled with confidence by substituting the material properties obtained in other testing performed by the SFWSTC and using the stress profile loads in these structural performance models.

This plan represents a collaboration among many stakeholders to define the path for acquiring the new data needed to determine the validity of the assumptions of previous work, validate modeling methods that will be needed to evaluate the mechanical responses of irradiated fuel that will be transported in the future in large transport casks, and inform material test campaigns on the anticipated range of stresses that will be imposed on nuclear fuel cladding. This work included full-scale multimodal transport testing of a spent nuclear fuel cask, cradle, heavy-haul truck, commercial ocean going vessels, railcar, and surrogate fuel assemblies. The ultimate goal of this testing is to close some of the existing knowledge gaps related to the mechanical loads that would be imposed on spent fuel under normal conditions of transportation and inform the experiments and analysis.

This work is sponsored by the DOE, Office of Nuclear Energy, Spent Fuel and Waste Disposition (SFWD). The mission of the SFWD is to identify alternatives and conduct scientific research and technology development to enable storage, transportation, and disposal of spent nuclear fuel and wastes generated by existing and future nuclear fuel cycles. The Storage and Transportation staff members within the SFWSTC are responsible for addressing issues regarding the extended or long-term storage of spent nuclear fuel and its subsequent transportation.

This test also presents a unique opportunity to collaborate with three National Laboratories and ENSA, an international company that supplies equipment and services for the nuclear industry. This work

- Provided data for all transport modes
  - Heavy-haul truck
  - Coastal shipment
  - Open ocean transport
  - Normal rail
  - Inter-modal transfers.
  - And storage facility handling operations
- Added to the library of normal conditions of transportation for rail and truck loadings. These data will be used to benchmark models, thus making it possible to analytically extend our assessments to many types of railcars and any other transport platforms.
- Reduces uncertainty in the existing data by testing under more real-life conditions.
- Supports future licensing and transport of high burnup spent nuclear fuel.
- Removes many of the compromises inherent to the previous tests.

These tests were conducted by Sandia National Laboratories (SNL), Pacific Northwest National Laboratory (PNNL), ENSA, and Transportation Technology Center, Inc., (TTCI) under the auspices of the DOE, Office of Nuclear Energy, SFWD. Argonne National Laboratory also had a role discussed in Section 6.

2. ENSA/DOE TRANSPORT CASK TESTING KEY PROJECT AGREEMENTS

The ENSA ENUN 32P transport cask testing involves the coordination of, primarily, two national laboratories (SNL and PNNL), ENSA (nuclear equipment global supplier), an international shipping company (COORDINADORA), Korea Radioactive Waste Agency (KORAD) and Korea Atomic Energy Research Institute (KAERI), the Association of American Railroads (AAR), TTCI, and other entities. This Rail Cask Shock and Vibration Test Project (the Project) using the ENSA ENUN 32P cask involved international movement and operation of high-value advanced technology equipment, and involved use of commercial technologies that are proprietary. Because of the project scope, international and commercial agreements that are required by the laws of the involved countries (the US/Spain/Korea) and the commercial interests of private corporations (e.g., ENSA, Empresa Nacional de Residuos Radiactivos Sociedad Anónima (ENRESA), and Westinghouse) were established.

Establishing these key agreements (Non-Disclosure Agreements (NDAs) and Borrowed Property Agreements) among the parties involved or having legal, commercial, or contractual interests involved in implementing and executing the Project was a major task. This Key Project Agreements task was the first step before conducting the remaining tasks of the Project.

ENSA entered an agreement with a private corporation, COORDINADORA, specializing in international transportation logistics and freight forwarding to accomplish the following:

- Transload the ENSA ENUN 32P cask test unit onto a heavy-haul truck arranged by the freight forwarding company.
- Round-trip heavy-haul road transport of the ENSA ENUN 32P cask test unit[b] from its facility in Maliaño, Spain, to a selected destination in northern Spain.
- Transload the ENSA ENUN 32P cask test unit onto a Roll-On/Roll-Off (RO/RO) ship at the Port of Santander, Spain, for European coastal shipment to the Port of Zeebrugge, Belgium then from Zeebrugge by ocean cargo ship to the Port of Baltimore, Maryland.
- Transload the ENSA ENUN 32P cask test unit from the ocean cargo ship at the Port of Baltimore to a 12-axle heavy-duty rail flatcar for cross-country shipment by railroad to TTCI located near Pueblo, Colorado. The railcar was also used for testing at TTCI in Pueblo, Colorado.
- Return shipment of the ENSA ENUN 32P cask test unit by railroad from Pueblo, Colorado, to the Port of Baltimore, and then by cargo ship ultimately to the ENSA facility near Santander, Spain.

3. TEST CONFIGURATION AND TRANSPORT ROUTES

The ENSA ENUN 32P cask tests of the assemblies were conducted by placing instrumented PWR assemblies within the rail-cask basket. The rail-cask was transported by heavy-haul truck within northern Spain, ship (two segments/two ships: Port of Santander to Port of Zeebrugge and Port of Zeebrugge to Port of Baltimore), and rail (round-trip from Baltimore to the TTCI near Pueblo, Colorado) (Figure 3-1). Testing was also done at TTCI using the same railcar that transported the cask there.

---

[b] ENSA ENUN 32P cask test unit comprises: 1) the ENSA ENUN 32P cask body and internal basket with test lid, 2) 29 dummy fuel assemblies inserted into the cask's basket, 3) three instrumented surrogate PWR fuel assemblies inserted into the cask's basket (one supplied by SNL and considered proprietary via a NDA between SNL and Westinghouse, one supplied by ENRESA (fabricated by ENUSA) covered under the SNL/ENSA NDA, and a third supplied by KORAD and KAERI (fabricated by Korea Nuclear Fuel Company Ltd (KNFC)), 4) a transport cradle, 5) an instrumentation lid, 6) two surrogate impact limiters, 7) a system of instrumentation leads and connectors, 8) a data acquisition system, 9) a satellite positioning module (via ANL), and 10) a battery power supply unit.

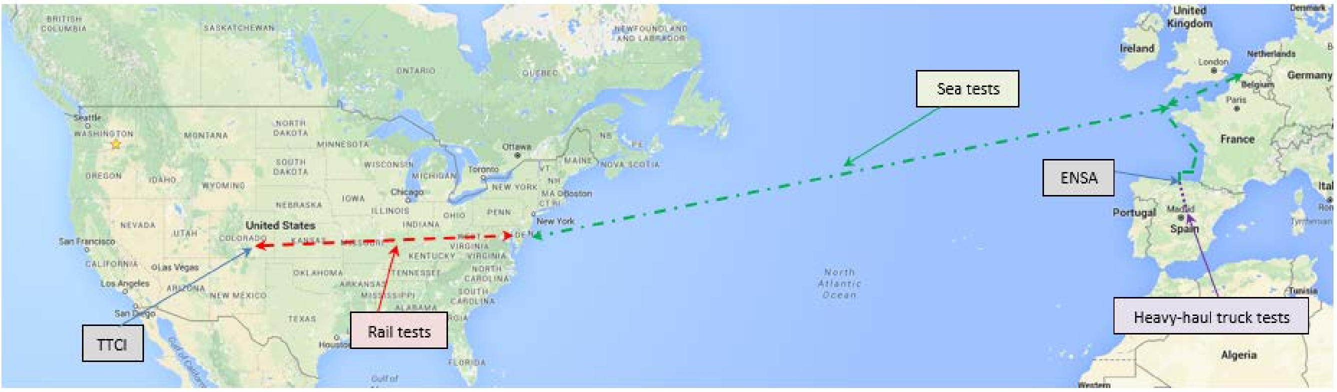


Figure 3-1. Route for ENSA ENUN 32P cask transportation tests.

3.1 ENSA ENUN 32P Cask

The rail cask was the ENSA ENUN 32P cask with its 32-assembly basket. The basket was populated with the three surrogate PWR assemblies (SNL, ENRESA, Korean) and twenty-nine "dummy" assemblies which simulated the weight of actual fuel assemblies.

The ENSA ENUN P32 cask is illustrated in Figure 3-2. The cask basket is shown in Figure 3-3. The cask cradle is shown in Figure 3-4. The ENSA ENUN 32P cask is a Storage/Transport package. It has a 32-cell PWR assembly basket. The cask's loaded weight is 120 tonnes without impact limiters and 137 tonnes with the limiters. The overall length of the cask without the limiters—the configuration to be used for the tests—is 5 meters. The diameter of the cask body is 2.65 meters. The cask body is constructed with carbon steel. The basket is constructed with stainless steel, aluminum, and MMC (Al + B_4C). Cask and cradle drawings are in Appendix A.

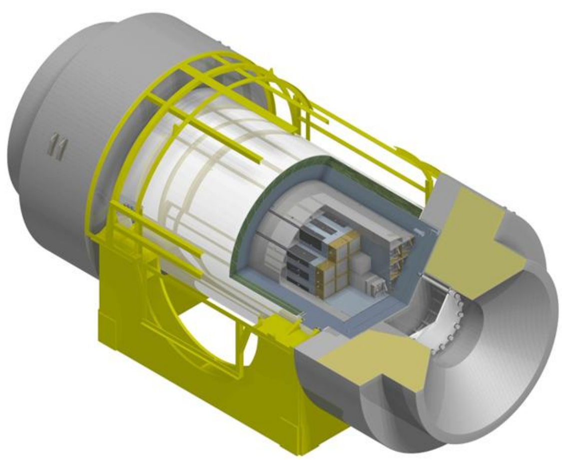


Figure 3-2. Cross-section schematic of ENSA ENUN 32P cask.

(a) 

(b) 

Figure 3-3. ENUN 32P cask basket (a) and its insertion into cask (b).

(a) 

(b)

(c)

Figure 3-4. ENSA ENUN 32P cask cradle used for rail-cask test. Note the extension on the front of the cradle (bottom of photograph (c)) on which the Data Acquisition/Battery Box was mounted.

3.2 Test Lid and Impact Limiters

Each lid for the cask is bolted to the cask body and includes metallic seals inside the bolt circle at its periphery Figure 3-5. The two lids have a combined weight of about 27,500 lb. Impact limiters are also components of an ENSA ENUN 32P cask and together add approximately 25,000 lb. to overall weight. The actual cask lid cannot be used for the tests because holes would need to be drilled to allow egress of the instrumentation cables attached to the assemblies. Therefore, an Instrumentation Test Lid was constructed to replace the actual ENUN 32 P lids. This Instrumentation Lid was designed by ENSA. The Instrumentation Lid simulated the weight of the actual lid. Surrogate impact limiters simulating the weight of actual limiters were attached to the Instrumentation Lid and to the bottom of the cask for purposes of the transport tests.

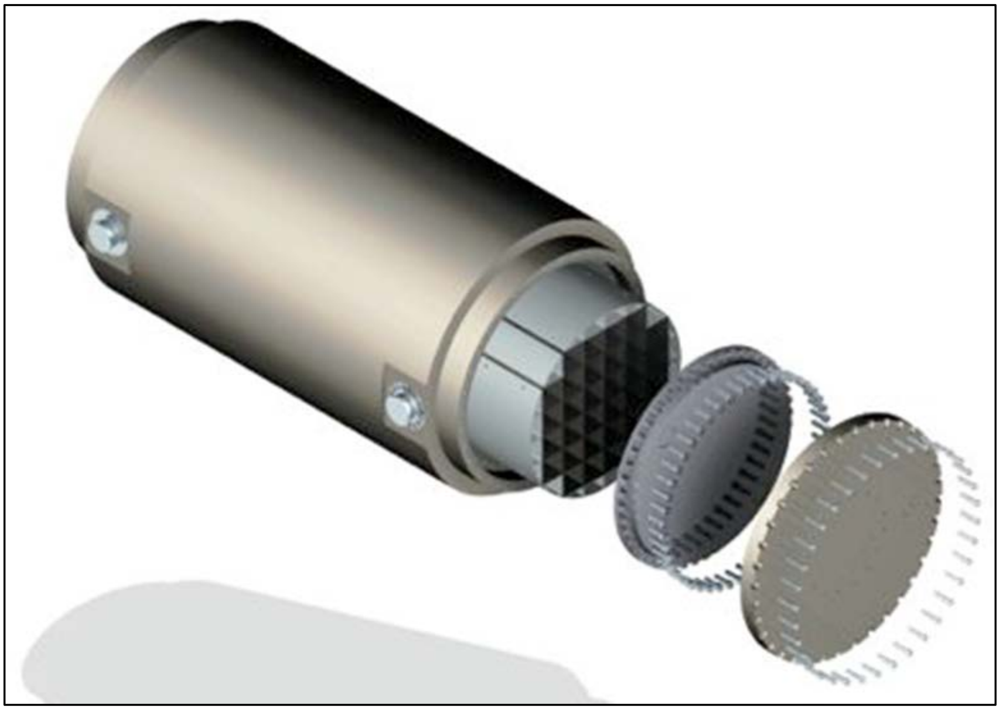


Figure 3-5. Illustration of the two lids of the ENSA ENUN 32P cask, which were replaced with an instrumentation test lid for the tests.

Since the dynamic effects can be simulated using bolt-on surrogate impact limiters, actual impact limiters were not needed in the rail shock and vibration tests. Instead, ENSA simulated the mass of the impact limiters with alternative means including additional mass in the instrumentation lid, additional mass associated with the instrumentation enclosure, and/or additional bolted on mass to reasonably simulate weight of the ENSA ENUN 32P cask’s bottom impact limiter. The test lid is an item that ENSA designed, constructed, and installed on the ENSA ENUN 32P cask.

The Test Lid that was installed on the ENSA ENUN 32P cask at the ENSA facility replaced the actual inner and outer lids (Figure 3-6) of the ENSA ENUN 32P cask and provided additional weight to simulate the weight of the ENSA ENUN 32P cask’s top impact limiter. Photographs showing the instrumentation lid being placed on the cask are shown in Figure 3-7. Figure 3-8 shows the surrogate impact limiter being placed on the instrumentation lid (Figure 3-9). Figure 3-10 shows the exterior surface of the instrumentation lid.

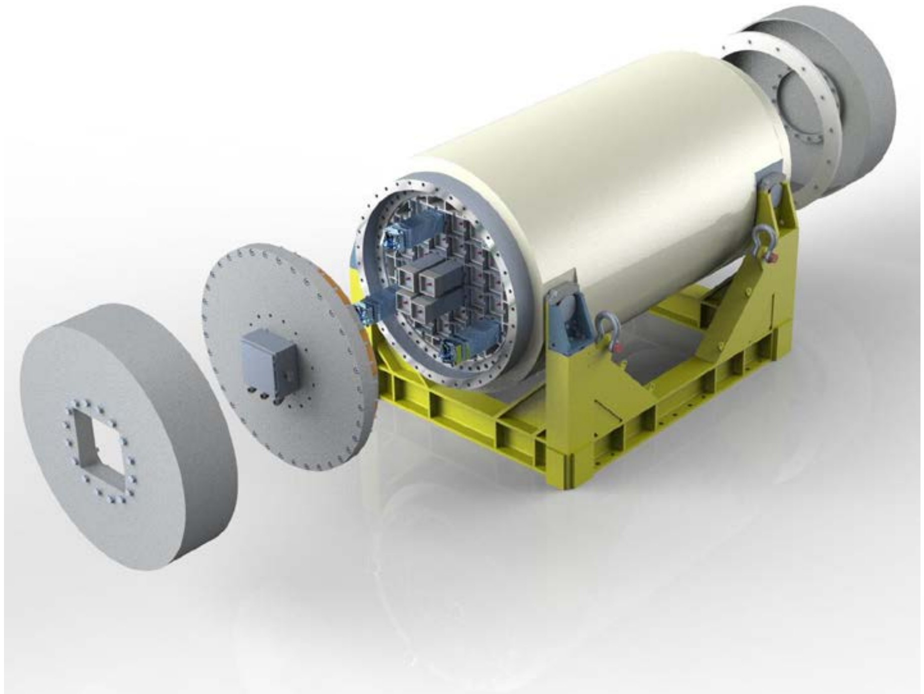
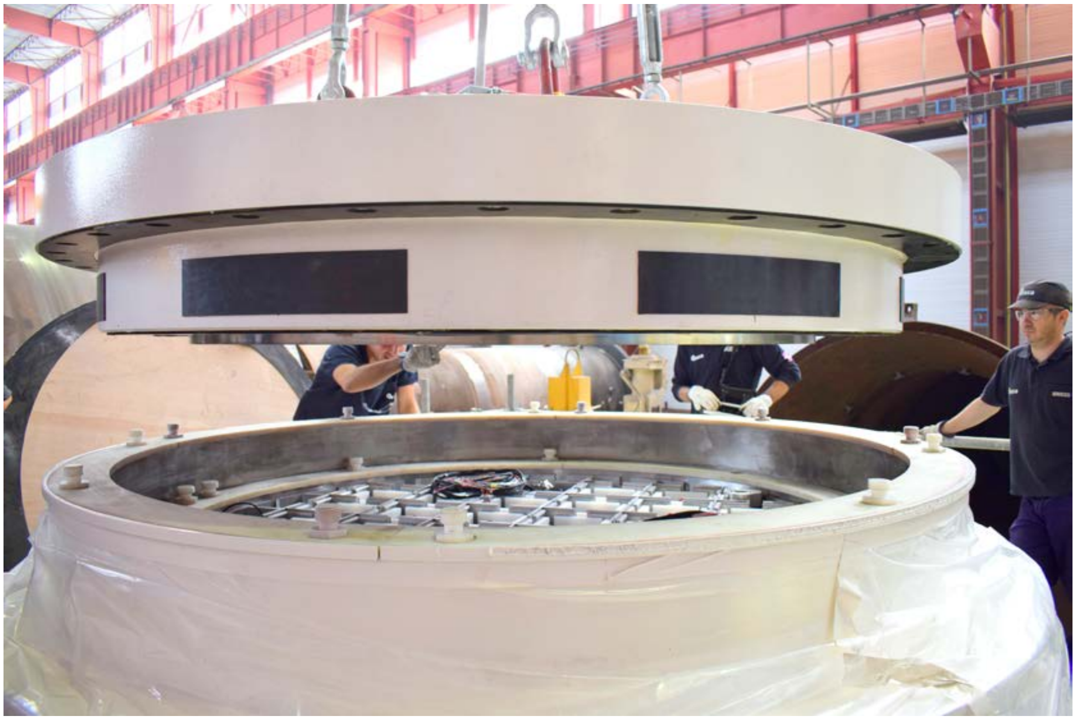


Figure 3-6. Schematic of the interior of the ENUN 32P basket with surrogate (blue) and dummy (gray) assemblies, the instrumentation lid with the cable junction box and the surrogate impact limiters (at top and bottom of cask).

(a) 



(b)

(c)

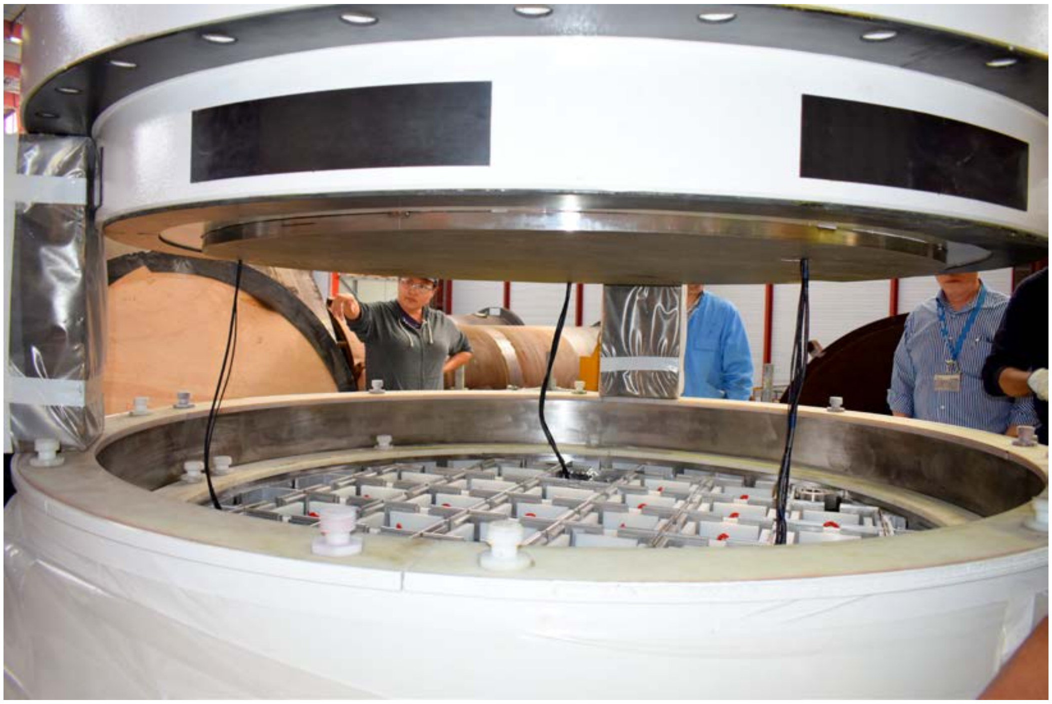
(d) 

Figure 3-7. Placing the instrumentation lid on the cask.

(a) 

(b)

Figure 3-8. Placing instrumentation cables through lid.

(a)

Figure 3-9. Surrogate impact limiter (top) being installed on the test lid (bottom). The gray box is the Junction Box for the instrumentation cables exiting the interior of the cask.

Figure 3-10. Cask test lid. Note the three holes at the end of the recesses machined into the lid. The holes provided the exit path for the instrumentation cables, which were laid into the recesses to the circular region in the middle of the lid from which the cables entered the Junction Box.

The design of the test lid was developed by ENSA. The test lid had channels and openings for instrument cables. The bottom-side channels and through-openings were sufficient to accommodate leads from instrument sensors installed on components in the ENSA ENUN 32P cask interior including three surrogate fuel assemblies and two locations on the ENSA ENUN 32P cask's basket.

The number of instrument leads that were routed through and under the bottom of the test lid are identified in the ENSA/DOE RAIL CASK TRANSPORTATION TEST PROCEDURE in Appendix B. Attachments of instrument sensors to internal components of the ENSA ENUN 32P cask were determined by agreement between ENSA and the Sandia. Sandia instrumentation technicians were at the ENSA facility to place instrumentation on the ENSA ENUN 32P cask and other test components.

In addition, the test lid accommodated installation of an instrument-lead connection panel – the Junction Box. Sandia National Laboratories provided the specification for the instrument-lead connection panel's design. Sandia also provided the panel.

3.3 Assemblies

The three assemblies used for the tests were surrogate 17 x 17 PWR assemblies. One assembly is owned by SNL. This same assembly was used for previous tests [1 - 3]. The Sandia assembly is populated mostly with copper tubes filled with a continuous rod of lead (lead "rope"). Three of the rods are Zircaloy-4, one populated with a lead rod, one with lead pellets, and the third with molybdenum pellets. The SNL assembly was instrumented at Sandia and shipped to ENSA.

The second assembly is owned by ENRESA (fabricated by ENUSA) and loaned to ENSA for the rail-cask tests. It is a surrogate 17 x 17 PWR assembly populated with Zirlo™ rods, which contain lead pellets. It was instrumented by SNL staff at the ENSA facilities.

The third assembly was provided by KORAD and KAERI (fabricated by KPFC). It is a surrogate 17 x 17 PWR assembly populated with Zirlo™ rods, which contain lead pellets. This assembly was shipped to ENSA. It was instrumented by SNL staff at the ENSA facilities.

Each assembly was instrumented with strain gauges and accelerometers. Figure 3-11, Figure 3-12, and Figure 3-13 show the instrumentation locations on the SNL, ENRESA, and Korean assemblies. In the figures, the top of the assembly is to the right. "SG" refers to strain gauge; "A" for accelerometer. The Sandia assembly had strain gauges around the circumference of the Zircaloy-4 rods, at 0° (top of rod), 90°, and 225°. Both the ENRESA and Korean assemblies had strain gauges only at 0°. All accelerometers were at 0°, denoted as the "Z" direction which is vertical when the assembly/cask were in the horizontal position. An exception was the biaxial accelerometer A12 within the top nozzle of the Korean assembly which measured vertical (Z) and lateral (Y) accelerations.

Note that strain gauges SG4-0, SG17, and SG28 were in the same relative position on the three assemblies which allowed direct comparison of a measured strain on the three assemblies; similarly, for accelerometers A2, A7, and A11.

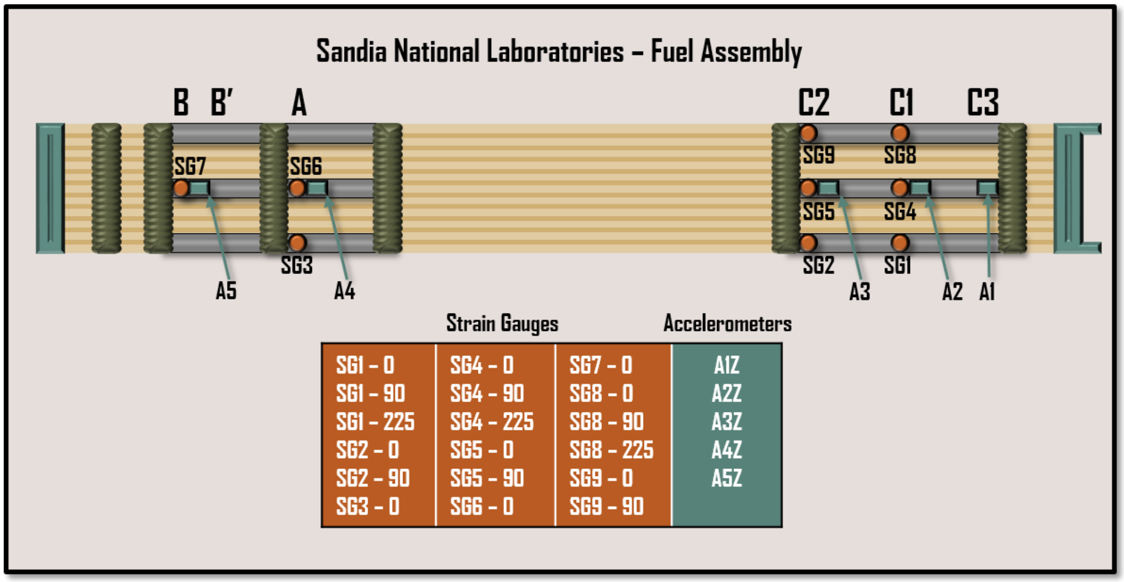


Figure 3-11. Location and nomenclature of instruments on the SNL fuel assembly. The SNL assembly weighed 710 kg.

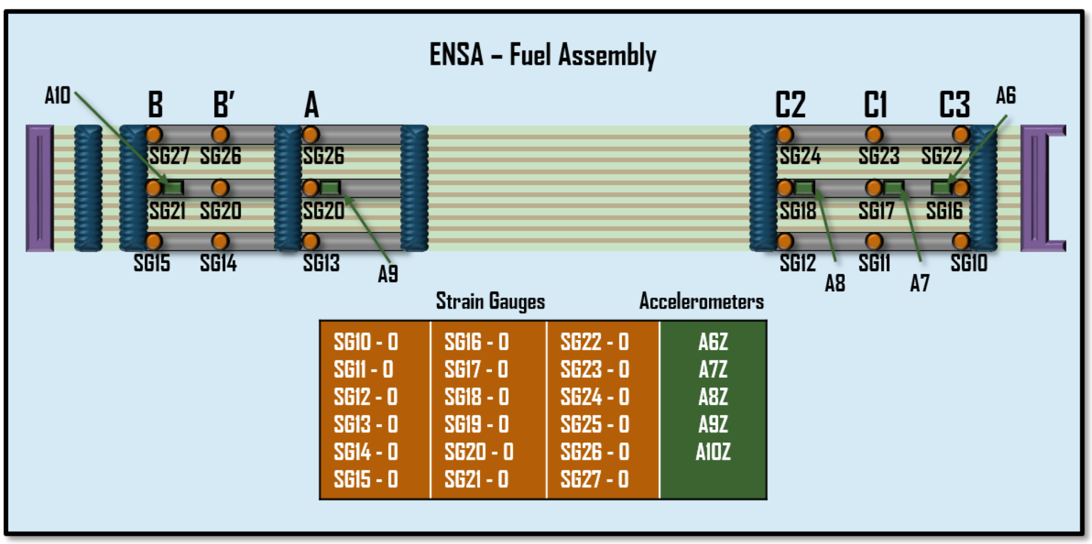


Figure 3-12. Location and nomenclature of instruments on the ENRESA fuel assembly. The ENRESA assembly weighed 680 kg.

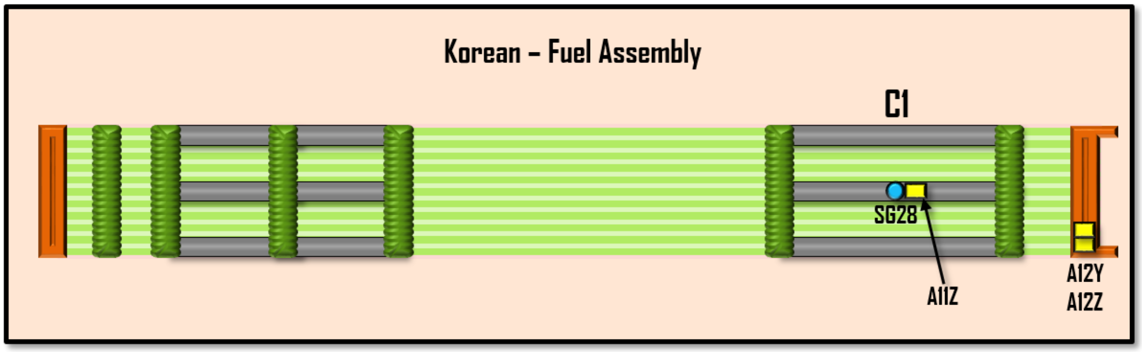


Figure 3-13. Location and nomenclature of instruments on the Korean fuel assembly. The Korean assembly weighed 650 kg.

The surrogate PWR fuel assemblies simulate the mechanical and structural dynamics characteristics of irradiated commercial SNF assemblies, and were subjected to normal truck, ship, and railroad shock and vibration when transported in the state-of-the-art large rail cask.

The data of greatest interest is the dynamic responses of individual fuel rods within the fuel assemblies and the resulting strains that occur in the fuel-rod cladding. To determine these metrics for fuel rods it was necessary to affix accelerometers and strain gauges to selected rods at selected locations. The rods and locations to which instrumentation was affixed was determined by insights from prior tests conducted by SNL [2] and analyses conducted at PNNL (Appendix C) and by practical limitations of accessibility for instrument installers.

Conductor leads, which provide power to and transmit electronic signals from instrument sensors, were installed on the three surrogate PWR fuel assemblies and secured in and on the assemblies. The installation and securement of the leads in and on the assemblies were such that, with reasonable care, the assemblies could be handled and loaded into the ENSA ENUN 32P cask without risk of damage to the leads or the sensors (Figure 3-14).

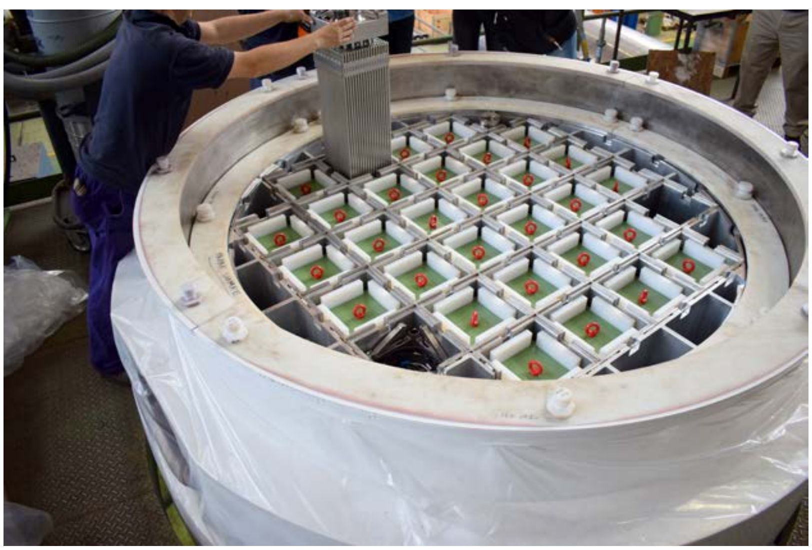


Figure 3-14. Insertion of the ENRESA assembly into the cask basket. Note the green dummy assemblies.

3.4 Instrumentation

For the SNL assembly, the Zircaloy rods (green arrows in Figure 3-15) were removed for reconfiguration for the rail-cask tests. (The configuration shown in the figure is that for the previous multi-axis shaker tests.) The adjacent copper rods (red arrows) in the top row, and the copper rods in the second row directly below those top-row copper rods, were also removed. The Zircaloy rods were then placed in the second row below the vacant top-row position (blue arrows). The previous positons of the relocated Zircaloy rods were filled with a copper rod. So, the position of the of the Zircaloy rods for the rail-cask tests (blue arrows) were in the second row; there was no rod above the Zircaloy rods. There was not enough clearance within the cask basket to instrument the Zircaloy rods when they were on the top row.

As shown in Figure 3-11, at some of the stain-gauge location there were three strain gauges around the circumference of the rod (SG1, SG4, SG8 locations: 0^{0}, 90^{0}, 225^{0}), at other locations two strain gauges (SG2, SG5, SG9 locations: 0^{0} and 90^{0}), and the remaining locations one strain gauge (SG3, SG6, SG7 locations: 0^{0}, 90^{0}).

Figure 3-16shows the instrumentation specialist gathering cables from an assembly which will then be passed through the instrumentation lid.

The Zirlo™ rods in the ENRESA assembly were similarly instrumented with strain gauges and accelerometers. All the strain gauges in the ENRESA assembly were in the 0° orientation, however.

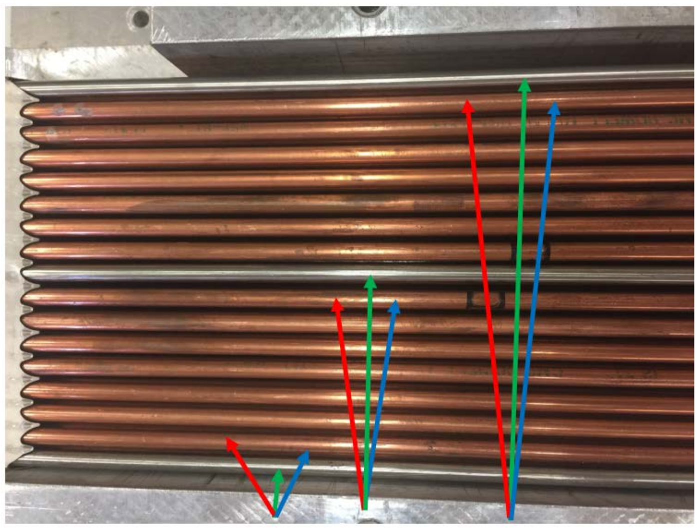


Figure 3-15. The Zircaloy rods (green arrows) were removed from the SNL assembly for reconfiguration for the tests. (The configuration shown in the figure is that for the previous multi-axis shaker tests.) The adjacent copper rods (red arrows) in the top row, and the copper rods in the second row directly below those top-row copper rods, were also removed. The Zircaloy rods were then placed in the second row below the vacant top-row position (blue arrows). The previous positions of the relocated Zircaloy rods were populated with a copper rod. So, the position of the of the Zircaloy rods for the rail-cask tests (blue arrows) was in the second row; there was no rod above the Zircaloy rods.

The Korean assembly was instrumented with one strain gauge and three accelerometers. The Korean strain gauge, SG28, was in the 0° orientation, the same as the SNL SG4-0 and the ENRESA SG17-0 strain gauges, thus provided a means of comparing strain at corresponding locations in all three assemblies. In addition, the Korean accelerometer A11Z matched the location of the SNL accelerometer A2Z and the ENRESA accelerometer A7Z.

A unique aspect of the instrumentation on the Korean assembly is that a biaxial accelerometer A12 (Figure 3-18) consisting of uniaxial accelerometers oriented in the Y and Z directions was placed on the top nozzle (Figure 3-19). These were the only accelerometers on any of the three assembly top nozzles. The accelerometers on the basket, external surface of the cask, cradle, and transport platforms were triaxial accelerometers (Figure 3-17).

The instrumentation cables exited the cask through holes in the cask test lid. Each hole was directly adjacent to the basket cells that the SNL and ENRESA assemblies were placed. The cables were approximately 100 feet long. The cables passed through a box attached to the external side of the test lid. This box houses the strain gauge bridge completion modules. The strain gauge bridge completion modules cannot be attached directly to the assemblies as in previous tests because of the lack of sufficient clearance between the assemblies and the basket-cell walls.

Triaxial accelerometers were attached to the exterior of the cask, the cradle, and the transport platforms (Figure 3-20). The nomenclature for these accelerometers when the cask was in a horizontal position is X = axial, Y = lateral, Z = vertical relative to the transport platform on which the cask/cradle were placed (Figure 3-21).

Figure 3-16. Sandia instrumentation specialist gathering assembly instrumentation cables to be passed through instrumentation lid.

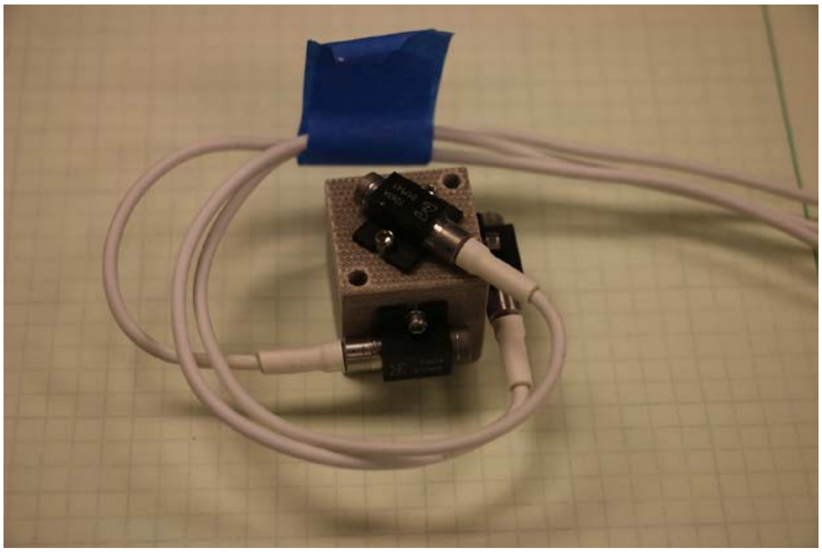


Figure 3-17. Triaxial accelerometer used for basket, and external locations on cask, cradle, and transport platforms, composed of three Endevco 7265A uniaxial accelerometers mounted on a glass-reinforced phenolic block (17x17x17 mm^3).

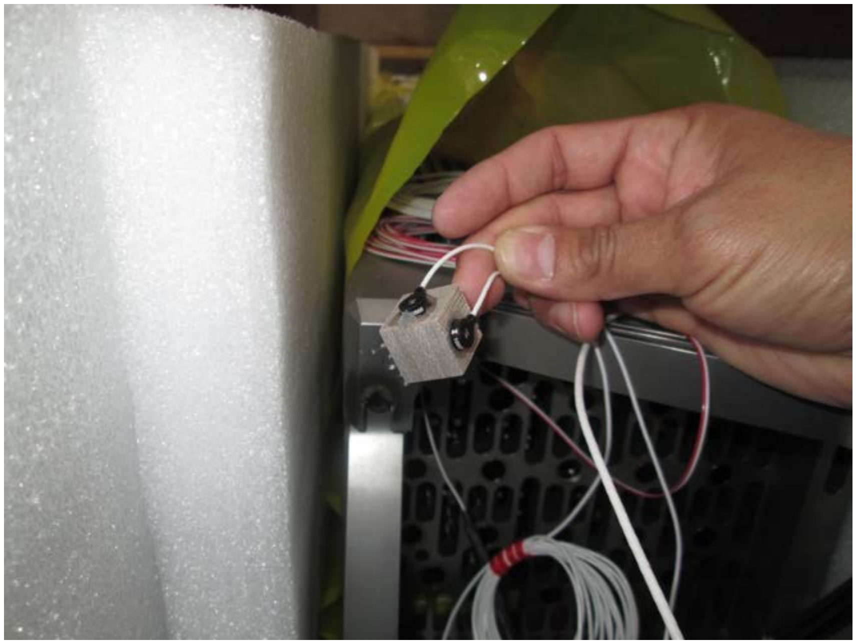


Figure 3-18. The biaxial accelerometer mounted on the top nozzle of the Korean assembly.

(a) 

(b)

Figure 3-19. The biaxial accelerometer mounted inside the top nozzle of the Korean assembly (a) and the cable leads from the biaxial accelerometer (b).

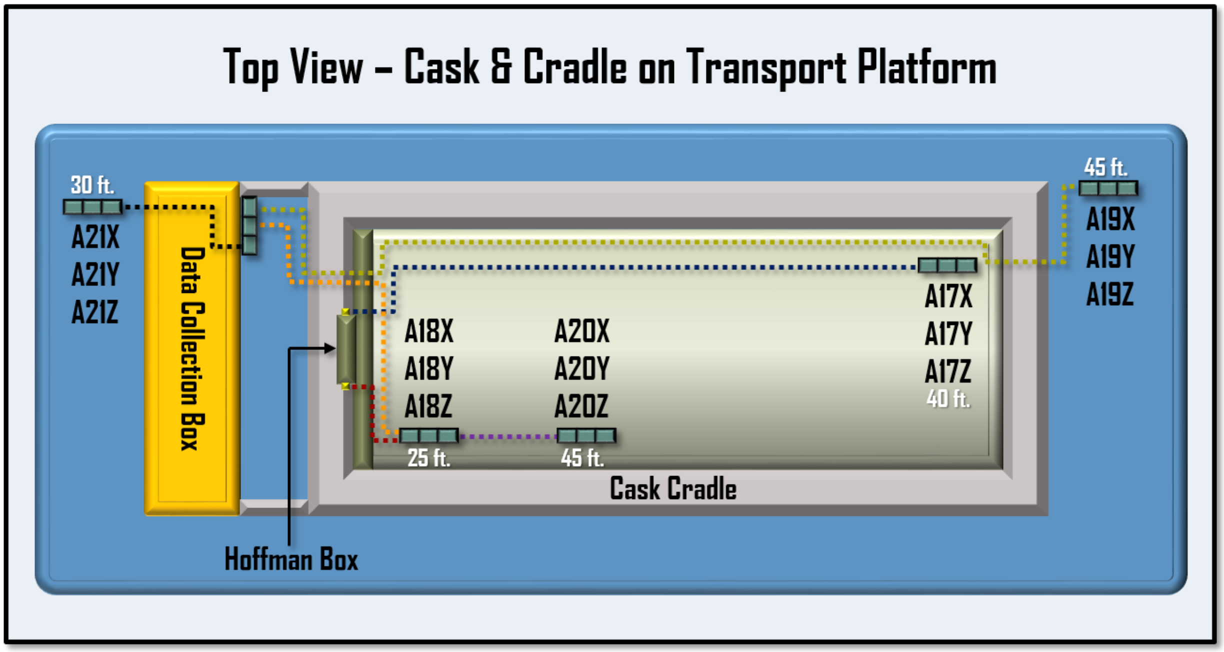


Figure 3-20. Schematic of location of cradle accelerometers (A17 and A18) and accelerometers on transport platform (A19, A20, A21).

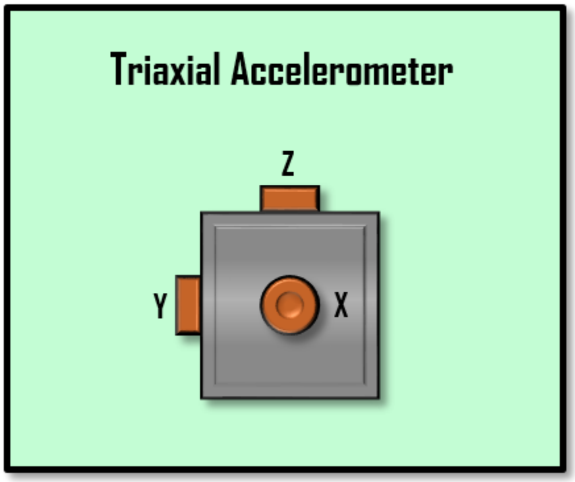


Figure 3-21. Schematic of triaxial accelerometer. When cask was in horizontal positon, X = axial direction, Y = lateral, and Z = vertical.

With reasonable care, the installation and securing of the leads in and on the assemblies enabled assembly handling and loading into the ENSA ENUN 32P cask without damage to the leads or the sensors.

Instrumentation Channel List

Barge, Handling Tests

SNL Assembly 23 Channels
- 18 – Strain Gages
- 5 – Accelerometers

ENSA Assembly 23 Channels
- 18 – Strain Gages
- 5 – Accelerometers

Korean Assembly 4 Channels
- 1 - Strain Gage
- 3 – Accelerometers (1 – Triaxial Block)

Cask Basket 6 Channels
- 6 – Accelerometers (2 – Triaxial Blocks)

Cask Body 6 Channels
- 6 – Accelerometers (2 – Triaxial Blocks)

Cask Cradle 6 Channels
- 6 – Accelerometers (2 – Triaxial Blocks)

Trigger 1 Channel

Total 69 Channels

Instrumentation Channel List

Ocean, Rail No. 1 (Baltimore to Pueblo)

SNL Assembly 13 Channels
9 – Strain Gages
4 – Accelerometers

ENSA Assembly 13 Channels
9 – Strain Gages
4 – Accelerometers

Korean Assembly 4 Channels
1 - Strain Gage
3 – Accelerometers (1 – Triaxial Block)

Cask Basket 3 Channels
3 – Accelerometers (1 – Triaxial Blocks)

Cask Body 3 Channels
3 – Accelerometers (2 – Triaxial Blocks)

Cask Cradle 3 Channels
3 – Accelerometers (2 – Triaxial Blocks)

Trigger 1 Channel

Total 40 Channels

Instrumentation Channel List

Heavy Haul Truck, TTCI Configuration, and Rail No. 2 (Pueblo to Baltimore)

SNL Assembly 23 Channels
18 – Strain Gages
5 – Accelerometers

ENSA Assembly 23 Channels
18 – Strain Gages
5 – Accelerometers

Korean Assembly 4 Channels
1 - Strain Gage
3 – Accelerometers (1 – Triaxial Block)

Cask Basket 6 Channels
6 – Accelerometers (2 – Triaxial Blocks)

Cask Body 6 Channels
6 – Accelerometers (2 – Triaxial Blocks)

Cask Cradle 6 Channels
6 – Accelerometers (2 – Triaxial Blocks)

Trigger 1 Channel

Transporter 9 Channels
9 – Accelerometers (3 – Triaxial Blocks)

Total 78 Channels

A list of the instrumentation to be used for the tests is in Appendix.

3.5 Location of Assemblies in Cask Basket

The locations of the three assemblies within the cask basket (Figure 3-22) were determined by analyses at PNNL that suggested the potentially most severe vibrations and shocks on assemblies would occur in the cells shown in Figure 3-23.

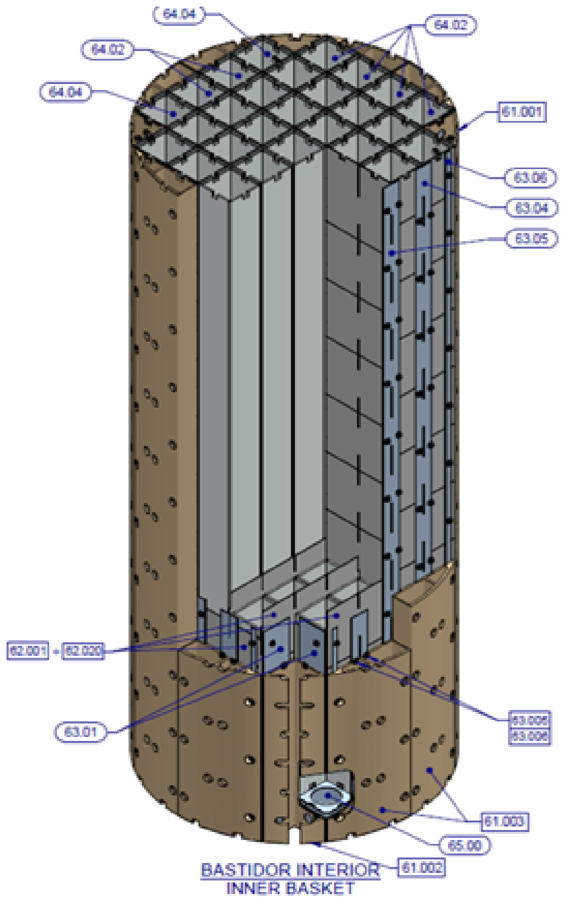


Figure 3-22. Diagram of ENUN 32P cask basket.

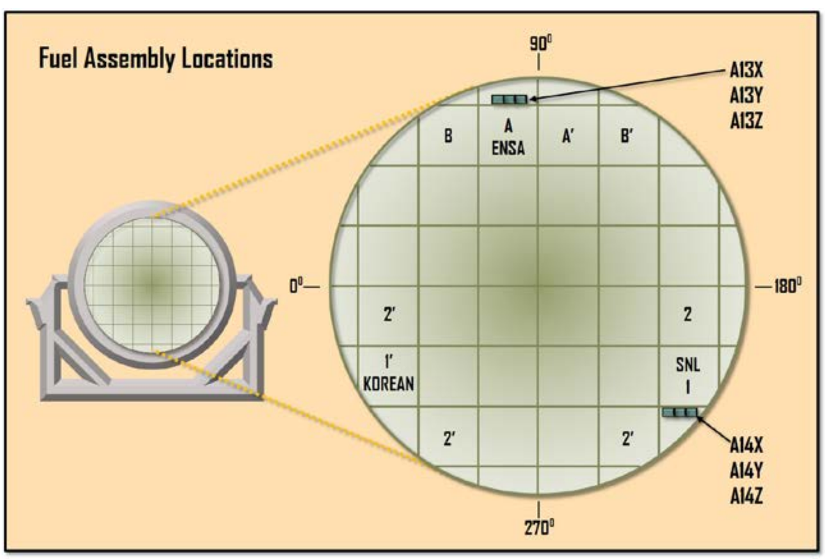
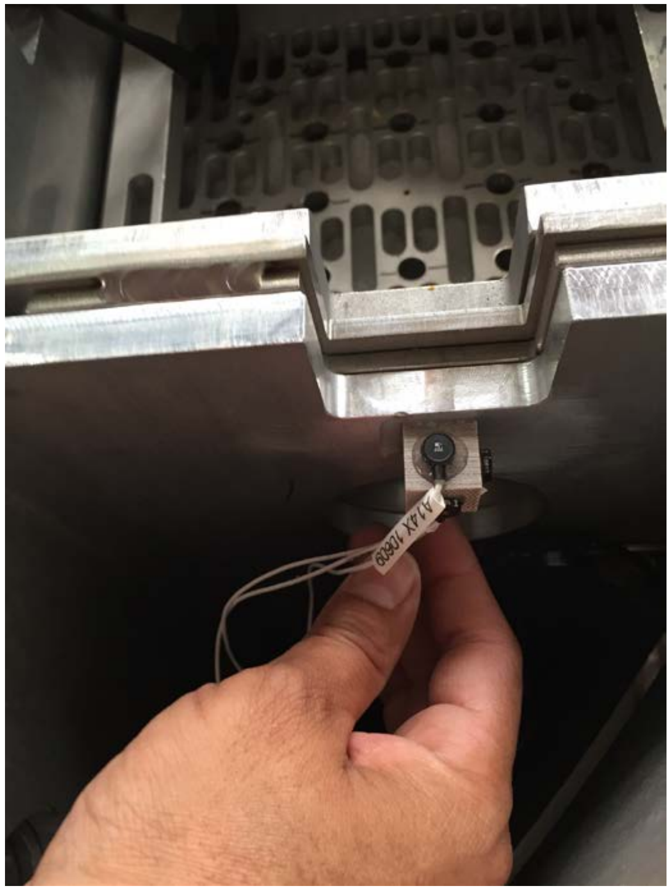


Figure 3-23. Fuel assembly locations within ENUN 32P basket. Location of two triaxial accelerometers mounted on wall of basket also shown.

Most severe locations were predicted to be 1 and 1' and A or A'. The figure shows the locations at which the three assemblies were placed in the basket.

The figure also shows the location where two triaxial accelerometers, A13 and A14, were placed on the basket (photographs in Figure 3-24).

(a) 

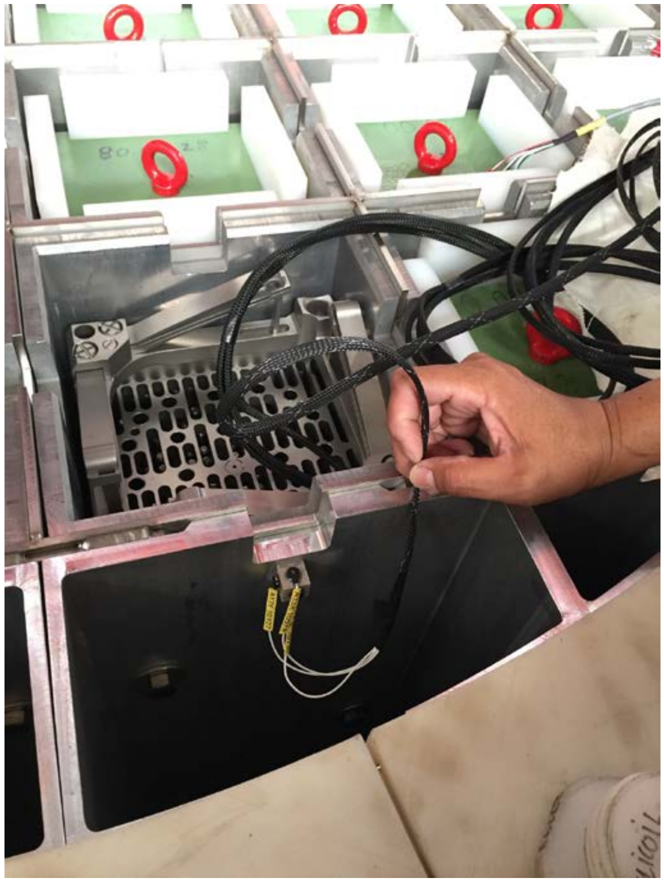
(b) 

Figure 3-24. Triaxial accelerometer on basket wall adjacent to instrumented surrogate fuel assembly.

3.6 Data Acquisition System

The cables from all the instrumentation within and external to the cask were passed into a Data Acquisition and Control (DAC) Box to one of the ten Siemens LMS SCADAC Mobile 8-channel universal durability input modules. Five of each 8-channel input modules were coupled to one of two Siemens LMS SCADAC 5-slot Recorders (Figure 3-25). Each slot of the Recorder accommodates one 8-channel input module. Up to 40 cables from 40 instruments were attached to each Recorder via five 8-channel input modules. The total number of channels available with this data acquisition system is 80. Cabling for the instrumentation channels is shown in Figure 3-26.

A specially-designed box was constructed to house the Siemens data acquisition system.

The DAC was powered by a 20-battery system that was designed to power the two 40-channel DACs for up to three weeks. Charging of the batteries was required upon arrival at ENSA, prior to the heavy-haul truck test, before its departure of the ships, prior to the cross-country rail trip, upon arrival at TTCI, and when the system departed TTCI to return to ENSA. Two battery chargers traveled with the cask system DAC. The DAC was equipped with Wi-Fi and Global Positioning System (GPS). In addition, the DAC had removable hard drives that were replaced after each data collection activity to ensure availability of the collected data. Hard drives were replaced after the following activities:

1. Simulated transloading activities at the ENSA facility
2. Completion of the round-trip heavy-haul route prior to shipment from the Port of Santander
3. At the completion of the shipment to the Port of Zeebrugge

4. Upon entry into the US at the Port of Baltimore
5. Upon arrive at the TTCI facilities in Pueblo, Colorado
6. Upon completion of testing at the TTCI facilities and periodically during the tests

Before beginning any data collection at each location power to the DAC system was turned on and the system's functions initialized to test the system. The DAC was programmed to power and sample the test unit's instrument sensors during travel while the unit was in motion and during all operations that could be incidental to and include stopping and starting.

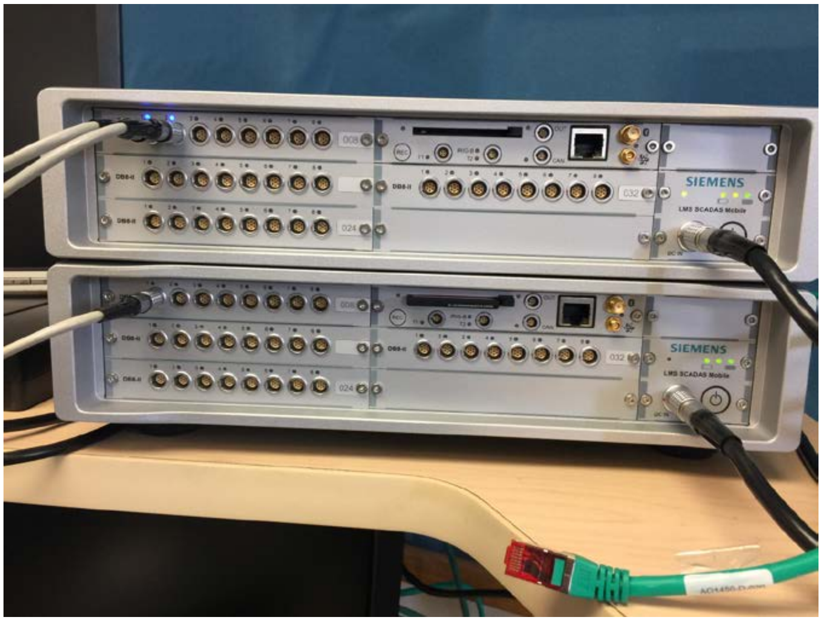


Figure 3-25 Siemens LMS SCADAC 5-slot Recorders with LMS SCADAC Mobile 8-channel universal durability input modules.

Figure 3-26. Siemens LMS SCADAC 5-slot Recorders with LMS SCADAC Mobile 8-channel universal durability input modules, instrumentation cables, junction panels, and batteries used to power the data acquisition system.

3.7 Data Acquisition System Box

The Data Acquisition System Box was 34 inches high by 64 inches wide by 96 inches in length Figure 3-27, Figure 3-28, and Figure 3-29). The interior is constructed with steel and the sides of the box was aluminum. The sides of the box were bolted to the steel interior with security bolts. Access to the interior of the box was possible via three hinged (and bolted) doors. Access to the batteries for charging was via two outlets on one side of the box. There were small holes on the top of the box for egress of GPS antennas.

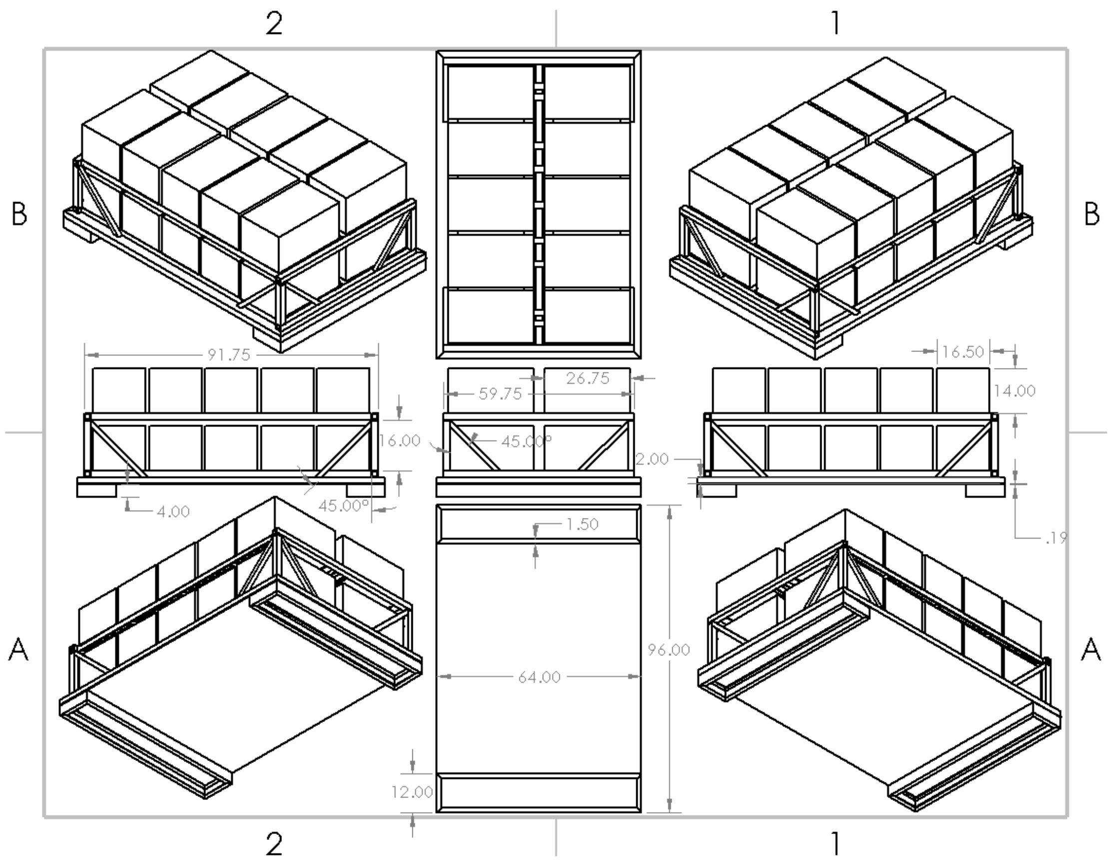
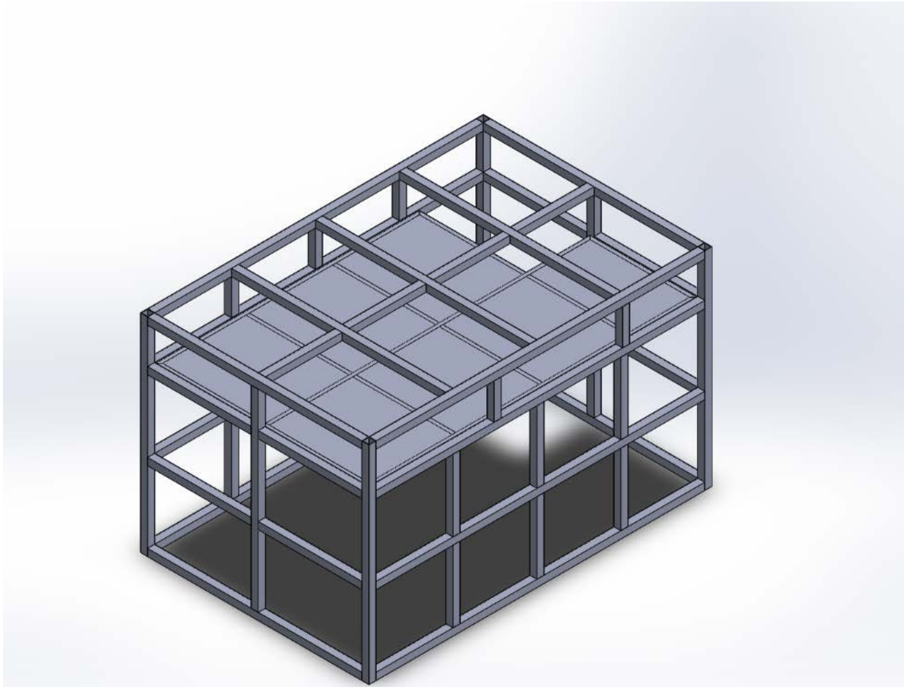
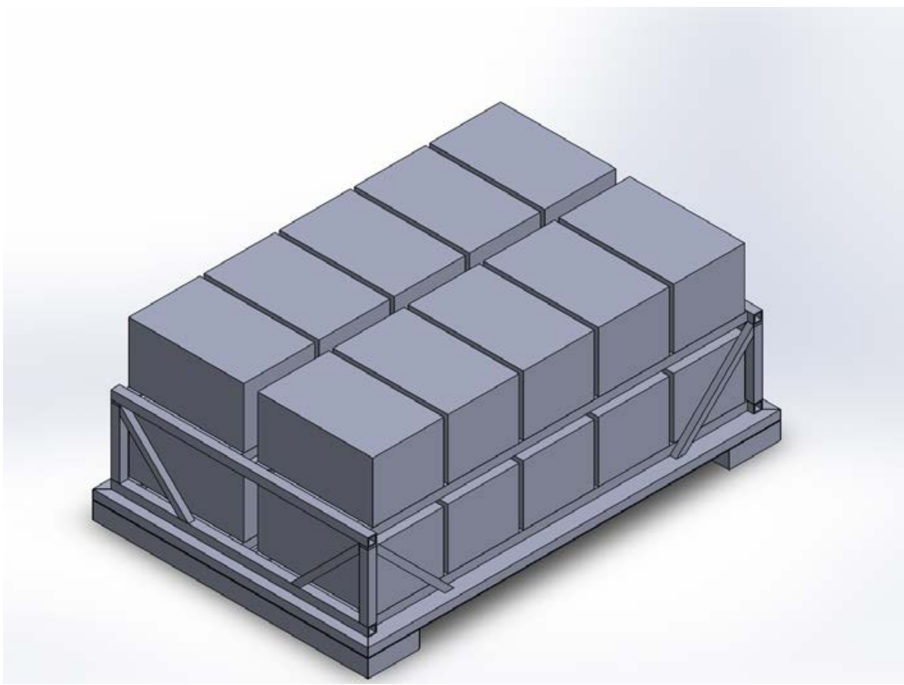


Figure 3-27. Dimensions of Data Acquisition System/Battery Box.

The box contained twenty LifeLine Model GPL-8DL 12-volt batteries. Each battery was housed within a battery strongbox designed for these batteries. The batteries powered the data acquisition system and the instrumentation. Twenty batteries were sufficient to power the entire system for approximately three weeks. The actual life of the batteries when powering the entire system was evaluated prior to shipping the assemblies and associated hardware to Spain.



(a)



(b)

Figure 3-28. Interior view of DAC Box. There were two shelves (top shelf is shown) on which twenty batteries, the DAC, and related hardware were placed (a). Schematic of interior of DAC Box showing boxes housing the batteries and data acquisition system (b).

Figure 3-29. Data Acquisition/Battery Box. Siemens LMS SCADAC 5-slot Recorders with LMS SCADAC Mobile 8-channel universal durability input modules and battery chargers shown

The batteries were charged via two Associated Equipment Company ESS6011 battery chargers (one charger per ten batteries). Access to the batteries was from the outside of the data acquisition box via DC Master Disconnect Switches for batteries mounted to the inner wall of the box. It took approximately thirty hours to fully recharge the batteries after a three-week period of powering the entire system. Access to the batteries for recharging is essential prior to unique modes of transport. The batteries were charged at ENSA facilities after loading the assemblies into the cask.

The batteries were also charged after the heavy-haul truck tests just prior to loading the cask/cradle onto the ship in Santander for shipment to Zeebrugge. The batteries were charged again at the Port of Zeebrugge prior to loading the system onto the ship for the trans-oceanic voyage. The batteries were charged at the Port of Baltimore upon arrival from Europe and prior to loading the cask/cradle onto the railcar. Finally, the batteries were charged upon arrival at the TTCI in Pueblo (and as required during the testing at TTCI).

On the occasions when the LifeLine batteries are charged, the 256 GB high speed flash cards in each of the Siemens LMS SCADAC Recorders were removed and replaced in order to physically retrieve data throughout the transport of the cask from Spain to the US.

There were two Sanyo Denki 24-volt fans in the box to cool the data acquisition system. One fan continuously ran for air circulation. (There were two vent panels on the side of the box.) The second fan was started, if necessary, by a signal from a Senasys DC 2570 Series Thermostat if the temperature in the box reached 100°F. This fan then continued to run until the temperature dropped below 85°F.

There was a TandD® MCR-4TC Multichannel Temperature Recorder in the box. Two thermocouples on this recorder recorded the temperature within the box. The battery life on the temperature recorder is approximately one month.

The Data Acquisition System Box was mounted to the cask cradle. ENSA staff established the exact configuration of the mounting of the box. However, during the tests at the ENSA facilities which simulated the vertical placement of the cask onto a simulated fuel storage pad, the data acquisition box was placed adjacent to the pad. Instrumentation cables exceeding 100-feet in length lead from the instrumentation to the box. After these tests the cables were shortened to the length required to lead from the cask to the box when the cask/cradle were placed horizontally on a transport platform.

3.8 Dummy Assemblies

For the test project, ENSA manufactured twenty-nine dummy PWR fuel assemblies (Figure 3-30 and Figure 3-31). The function of the dummy assemblies in the tests was to reasonably replicate the structural dynamic characteristics of PWR fuel assemblies if such assemblies were placed in the twenty-nine cells of the ENSA ENUN 32P cask's basket that are not occupied by the surrogate PWR fuel assemblies. The dummy assemblies weighed approximately the same as actual fuel assemblies.

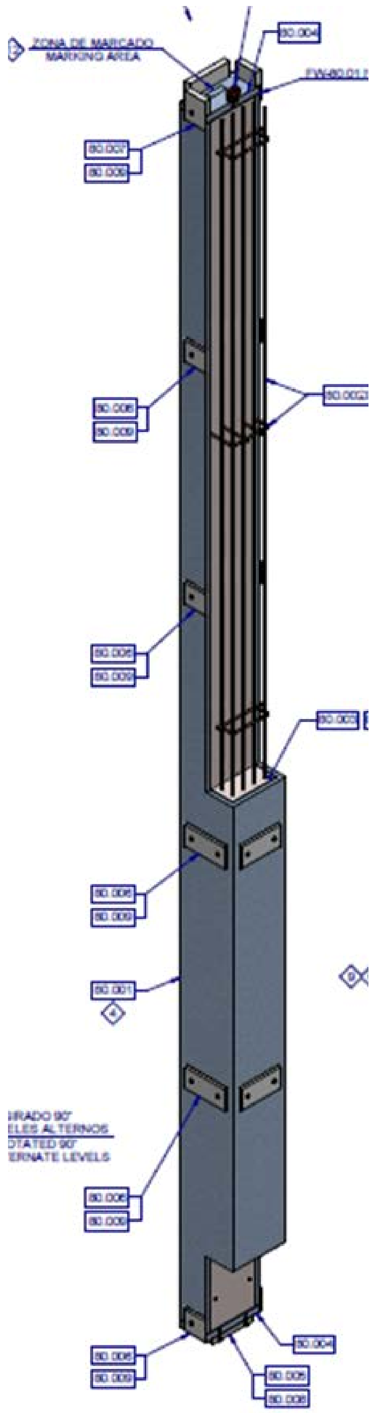


Figure 3-30. Diagram of dummy assembly used for rail-cask tests.

The response of the Dummy Fuel Assemblies to shock and vibration forces imparted by the ENSA ENUN 32P cask's basket influenced the dynamic response of the ENSA ENUN 32P cask's basket to forces imparted by the ENSA ENUN 32P cask body. Thus, it was desirable for the dummy fuel assemblies, in combination with the ENSA ENUN 32P cask's basket structure, to have a similar response to forces transmitted from the ENSA ENUN 32P cask body to that of the basket loaded with SNF. Achieving such similarity will ensure that the forces imparted by the basket to the surrogate fuel assemblies instrumented for the shock and vibration tests are representative of those that would be experienced during normal transportation of the ENSA ENUN 32P cask with all basket cells loaded with SNF.

Figure 3-31. Twenty-nine dummy steel and concrete assemblies used to simulate the weight of actual fuel assemblies.

This was achieved by collaborating with ENSA on the construction of the dummy fuel assemblies with the objective of fabricating dummy fuel assemblies whose structural dynamic response to shock and vibration forces imparted by the ENSA ENUN 32P cask basket was reasonably similar to the structural dynamic response of SNF assemblies that would be loaded into a basket.

ENSA fabricated the dummy fuel assemblies at its facility. The dummy assemblies were loaded into the cask basket before the surrogate PWR assemblies (Figure 3-32). The weights and locations of each of the dummy assemblies are shown in Appendix A.

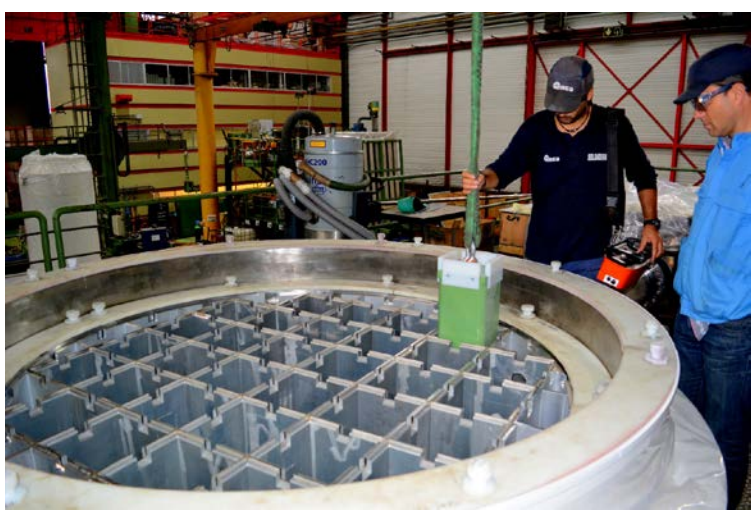


Figure 3-32. Example of a dummy fuel assembly. Dummy assemblies similar to the one shown were placed in 29 of the ENSA ENUN 32P cask basket cells for the tests to simulate the weight of actual PWR assemblies. The other three cells held the surrogate PWR assemblies.

3.9 Pre-test Cask Handling Operations

This section is a photo documentary of the many pre-test handling operations performed at ENSA (Figure 3-33 through Figure 3-40).

Figure 3-33. Placing the instrumentation lid on the cask.

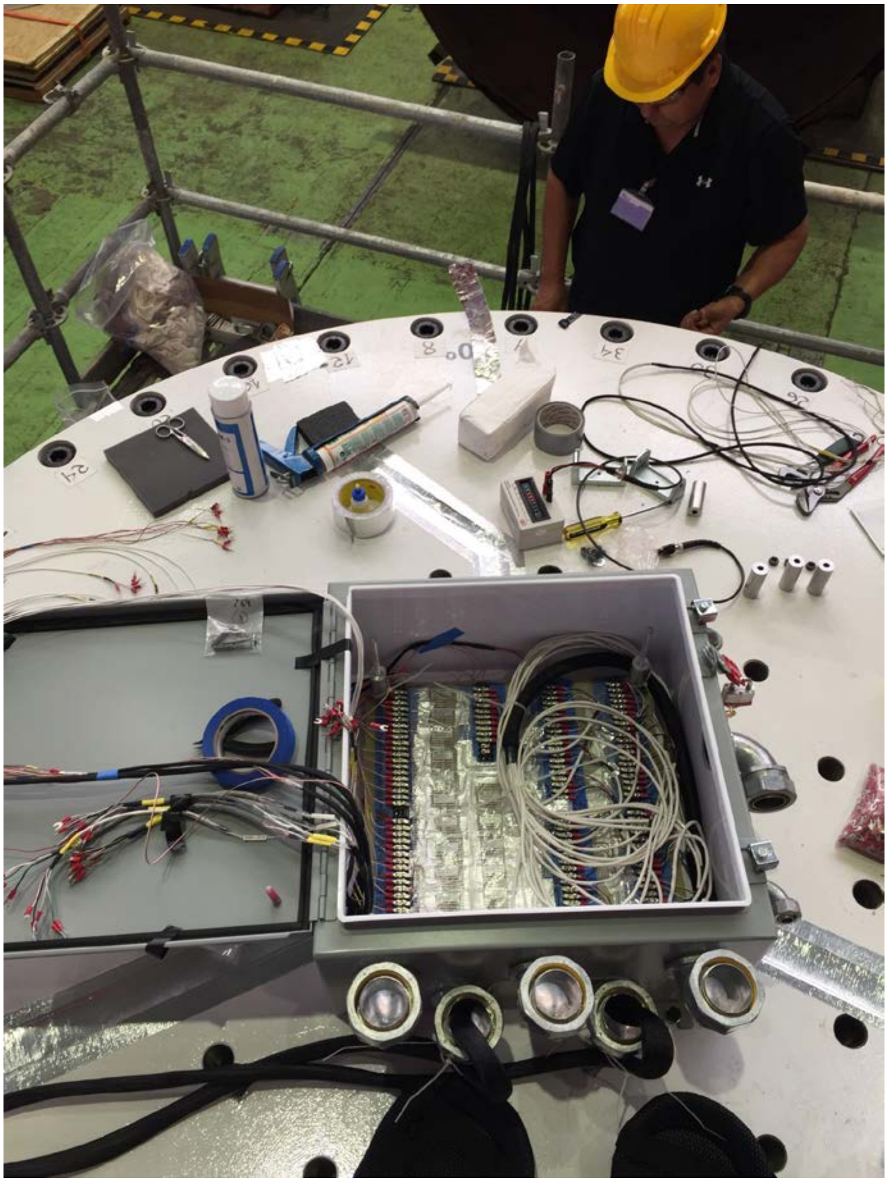


Figure 3-34. Connecting instrumentation cable to connectors in the Junction Box. The Junction Box was mounted on the instrumentation lid.

Figure 3-35. SNL instrumentation specialists threading cables into recesses on the instrumentation lid (top) and attaching accelerometers cable along length of cask (bottom).

Figure 3-36. Data Acquisition/Battery Box being placed onto cradle.

(a)

(b)

(c) 

Figure 3-37. Cask being set on cradle.

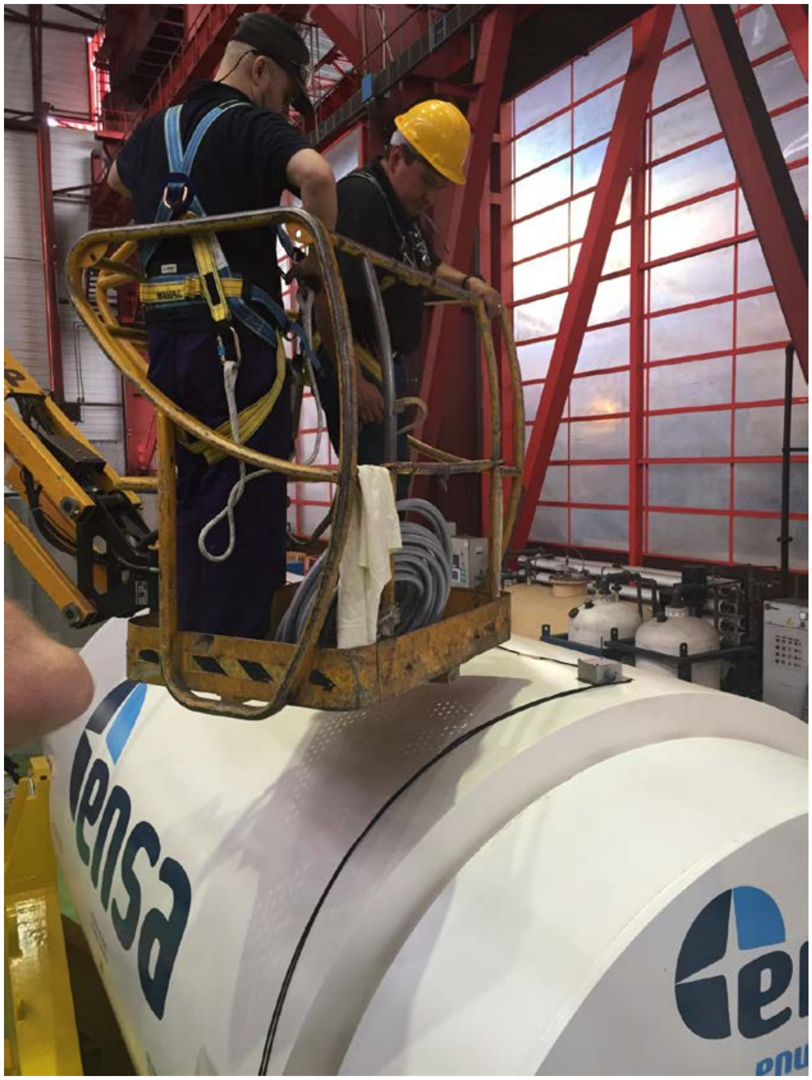
Figure 3-38. Cask being rotated to horizontal position on cradle.

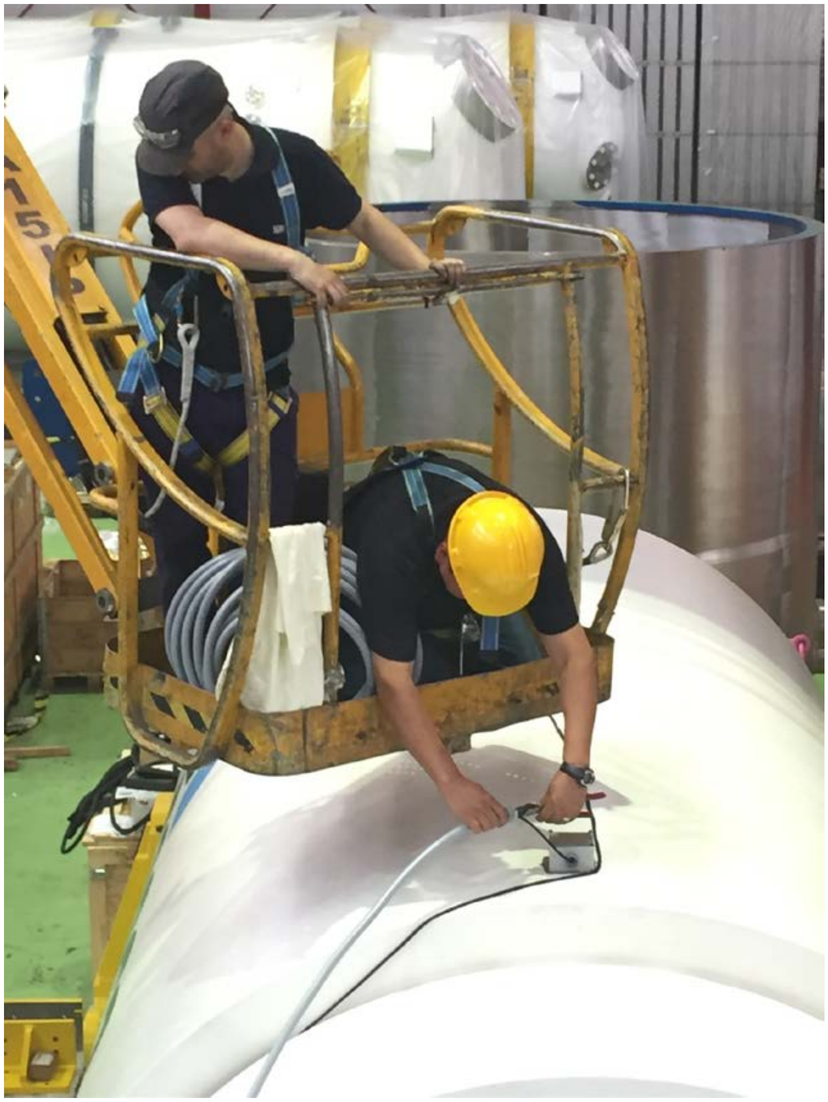
(a) 

(b) 

(c)

Figure 3-39. Top impact limiter g placed on instrumentation lid. An opening had been machined into the limiter to accommodate the Junction Box.

(a) 


(b)

(c)


Figure 3-40. ENSA and SNL staff attaching triaxial accelerometers to exterior surface of the cask.

3.10 Install Surrogate and Dummy Fuel Assemblies and Instrumentation in and on the ENSA ENUN 32P Cask

After instrumented surrogate and dummy fuel assemblies were placed into the ENSA ENUN 32 cask basket, two triaxial accelerometers were placed on a surface of the basket inside the cask body at the ENSA. The location(s) of the accelerometer was informed based on computer simulation analyses at PNNL as shown in Figure 3-32.

SNL's technical staff installed and tested the instrumentation on the three surrogate assemblies at SNL prior to shipping the assemblies to ENSA for placement in the cask. Additional instrumentation in and on the cask was installed at ENSA's facility prior to any testing. Conductor leads from the sensors were routed and secured such that, with reasonable care, the cask could be handled, loaded with surrogate and dummy fuel assemblies, and assembled without damaging the leads or the sensors. A procedure for handling a surrogate PWR fuel assembly that has installed instrument sensors and instrumentation leads was developed in consultation with ENSA to ensure the integrity of the assembly and its instrumentation was protected. Particular attention was given to protecting the sensors and leads when the assembly was being transferred or transported, up righted and lowered into the cask basket. The "top" of the instrumented assemblies was benchmarked to the "top" of the cask when the cask was placed horizontally onto its cradle so that there was clearance between the cables attached to the assembly instruments and the cell-wall of the basket.

Two sets of instrumentation cables were used. The first was long enough (about 100 feet) to facilitate the simulation of vertical placement of the cask on a storage pad. The second set was for all other data collection during the different modes of transportation when the cask is in a horizontal position on its cradle.

The surrogate and dummy fuel assemblies were loaded into the basket of the ENSA ENUN 32P cask by ENSA technical staff at the ENSA facility in Maliaño (Cantabria), Spain. When placing the fuel assemblies into the cask the ENSA technicians exercised caution to ensure that instrument leads from fuel assembly sensors and from instrument sensors placed on the ENSA ENUN 32P cask's basket and inside wall were protected from damage. The location of the surrogate assemblies within the basket has been informed by computer modeling Figure 4-1.

On the exit, or top side of the protective interface plate, instrument leads from the surrogate fuel assemblies were organized into bundles. Instrument leads from dummy fuel assemblies, basket, and the cask's basket were identified separately.

Next, ENSA installed the test lid on the ENSA ENUN 32P cask. Instrument leads exiting the protective interface plate under the test lid passed through openings in the test lid that were larger than, and circumscribed, the top openings in the interface plate.

After installing the test lid on the cask, ENSA technicians installed an instrument panel[c][d] on the outside surface of the surrogate upper impact limiter. The instrument panel may be installed after the cask is placed on its transport cradle. The instrument leads from inside the cask were connected into the instrument panel and the instrument panel thus provided the interface for the external DAC system to communicate with the sensors inside the cask. The instrument panel also provided the connection interface for leads from all other sensors installed on the ENSA ENUN 32P cask test unit including those on the outside of the ENSA ENUN 32P cask's body, the cask's cradle, and ultimately the railcar or any other transport platform.

After installing the test upper end components, the ENSA technicians moved the ENSA ENUN 32P cask from its vertical loading station to rest horizontally on its transport cradle and installed the surrogate lower impact limiter. On the transport cradle at the ENSA facility in Maliaño (Cantabria), Spain, ENSA and SNL technicians installed

---

[c] The instrument panel and its securement to the test lid was designed to sustain shock and vibration forces and frequencies expected to occur during normal rail transportation in the US.

[d] When installed, the instrument panel and its securement to the test lid was designed to provide a clear travel path for the lifting yoke for the ENSA ENUN 32P cask when the cask was being rotated from the vertical to horizontal orientation.

accelerometers at locations on the external surfaces of the cask body and transport cradle. These locations were informed by computer simulations conducted at PNNL.

The specifications for the accelerometers and strain gauges that were installed on the external surface of the ENSA ENUN 32P cask and on its transport cradle are described in the ENSA/DOE Transport Cask Testing Instrumentation Plan.

3.11 Assemble and Test ENSA ENUN 32P Cask Test Unit with Installed Data Acquisition System

After placing surrogate and dummy fuel assemblies into the ENSA ENUN 32P cask, installing the test lid and surrogate upper impact limiter, moving the assembled cask onto the transport cradle, and installing the surrogate lower impact limiter and external instrument sensors, SNL and ENSA staff members attached the power supply and DAC Instrumentation Box to the transport cradle. The Instrumentation Box may attach to the transport cradle's cask top end or be distributed across the cask cradle to better distribute the load. For perspective, the outer lid of another ENSA cask design (ENSA-DPT) is on the visible end of the cask shown on a transport cradle in Figure 4-1. This figure is only for information and is not representative of the ENSA ENUN 32P design.

The power supply and DAC Instrumentation Box was fabricated by SNL, shipped to ENSA with the instrumented surrogate assemblies, and was attached to the ENSA ENUN 32P cask's transport cradle at ENSA's facility.

The power supply and DAC Instrumentation Box supported, secured, and contained 20 heavy-duty industrial batteries. Dimensions of the batteries are 53 cm by 28 cm by 25 cm and their weight is 70 kg each. In addition, the Instrumentation Box contained (and provided protection from weather) the DAC, the instrument panel on the cask's top-end, and instrument leads.

The power supply and DAC Instrumentation Box must be very durable because the ENSA ENUN 32P cask test was loaded on and off heavy-haul trucks, ocean-going vessels, and railcars during transport tests. The structure of the housing and its attachments to the ENSA ENUN 32P cask's cradle could support and secure the contents while sustaining forces imposed by AAR Open Top Loading Rules Standards [5] for transport on US railroads.

After the Instrumentation Box was securely attached to the ENSA ENUN 32P cask's transport cradle, ENSA and SNL technical staff installed the battery power system, DAC, battery charger, and conducted a full-system functional test. The installation of all components[e] required 2-5 days, because each major installation step was subjected to independent test and verification that the installation(s) or connection(s) were correct, secure, and functional.

4. TRANSPORTATION NODES

This section provides the details on the operations at each of the transportation nodes including the transloading operations. Included in this section are discussions of the heavy-haul truck, the two ships, and the rail transportation of the ENSA ENUN 32P cask. Figure 4-1 is a map of the planned routing as of this writing. Specific routes and destinations are still being evaluated by ENSA's Spanish shipping agent, COORINADORA.

At every opportunity at each transportation node, batteries were charged and the 256 GB compact flash cards (one for each Recorder) which collected data were removed and replaced. Two battery chargers (one for each set of ten batteries) were sent from SNL to ENSA.

[e] Procedures/checklists for component installation were developed for battery installation and securement; DAC installation, securement, and test; securement, and test; battery charger installation, securement, and test; and instrument lead installation, securement, and test.

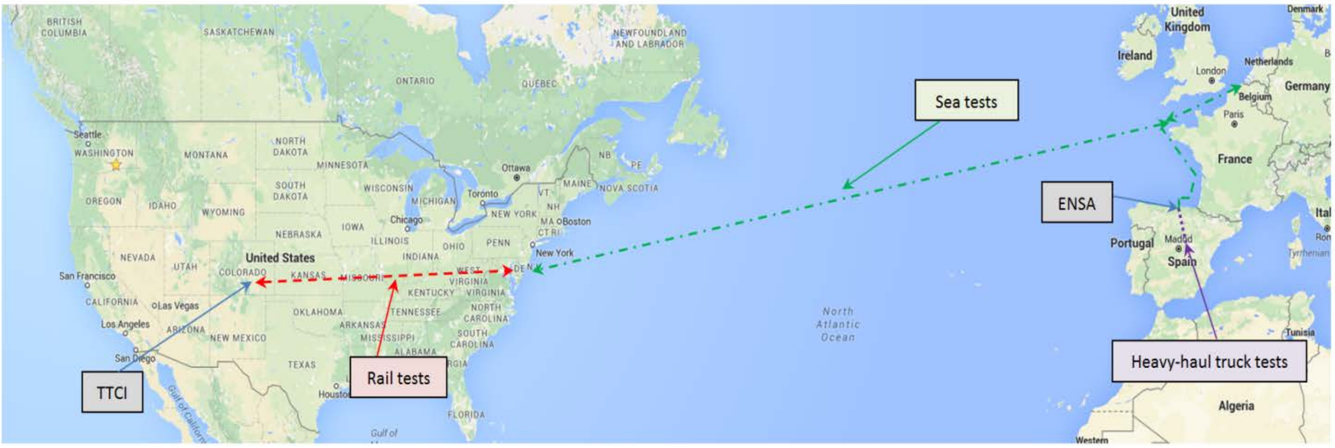


Figure 4-1. The route of the ENSA ENUN 32P cask from Spain to Colorado. Data were continuously collected on the entire route.

4.1 Cask Handling Tests for Simulating Dry Storage Operations

A very important phase of the test project, prior to loading the cask onto any transport platform, was collecting data from the assembly, basket, and cask as the cask was lifted vertically and lowered a number of times onto a concrete pad to simulate dry cask storage handling. This testing was the first to be performed and occurred immediately after the assemblies were loaded into the cask basket with the cask in a vertical position.

This testing was the first actual check of the data acquisition system, instrumentation, and related equipment. This was conducted at ENSA's facilities under controlled conditions. Sixty-eight channels of instrumentation were used for these tests. The sampling rate for each channel for all the handling tests was 10240 Hz. These tests were invaluable for ensuring the reliability of the instrumentation and data acquisition system which was required to operate for up to three weeks without being accessed by technicians.

Three different ENSA crane operators each raised and lowered the cask onto a concrete pad three times each with varying degrees of aggressiveness in the setting of the cask onto the pad. This provided a range of impacts onto the pad. This data will be useful to operators of spent fuel storage facilities and cask designers (Figures 4-2 through 4-6).

Following the handling tests the cask was lowered onto its cradle for all the remaining transport testing. Data was collected during the operation of vertically raising the cask and rotating it to a horizontal position on the cradle.

Immediately after the cask test unit was secured onto the cradle, shock and vibration data recorded during the dry cask storage handling operations was secured by removing the 256 GB compact flash cards (two) from each recorder and replacing them with new compact flash cards for the heavy-haul truck portion of the test.

Figure 4-2. Positioning of the cask for Handling Test simulating vertical positioning of cask onto a storage pad.

Figure 4-3. Positioning cask for Cask Handling Test.

Figure 4-4. Cask Handling Test.

Figure 4-5. Cask Handling Test.

Figure 4-6. Cask Handling Test

4.2 Heavy-Haul Truck Road Transport

During the execution of the project work scope there are specific elements of the testing that are common to all transportation nodes (heavy-haul truck, ship, and rail). Those elements are described in this section and are not repeated in the following sections.

Transload operations at ENSA's facility and heavy haul truck transport provided data about the effects of shock and vibration during handling and transportation for the heavy-haul truck mode of transportation. The transload and heavy-haul truck operations were similar to transload and intermodal transportation operations involving shipments of SNF expected to occur in the future in the US. In addition to understanding of the effects of shock and vibration from normal conditions of transportation, it was important to understand the shock and vibration effects of loading and unloading a cask and its transport cradle to and from transport vehicles including heavy-haul trucks, barges and ships, and railcars.

Photographs of the preparation for the Heavy-haul Truck Tests are in Figures 4-7 to 4-12.

Figure 4-7. Moving cask system to Heavy-Haul Truck Trailer.

Figure 4-8. Lowering cask system on to Heavy-Haul Truck Trailer.

Figure 4-9. Lowering cask system on to Heavy-Haul Truck Trailer.

Figure 4-10. Triaxial accelerometer enclosure on Heavy-Haul Truck Trailer.

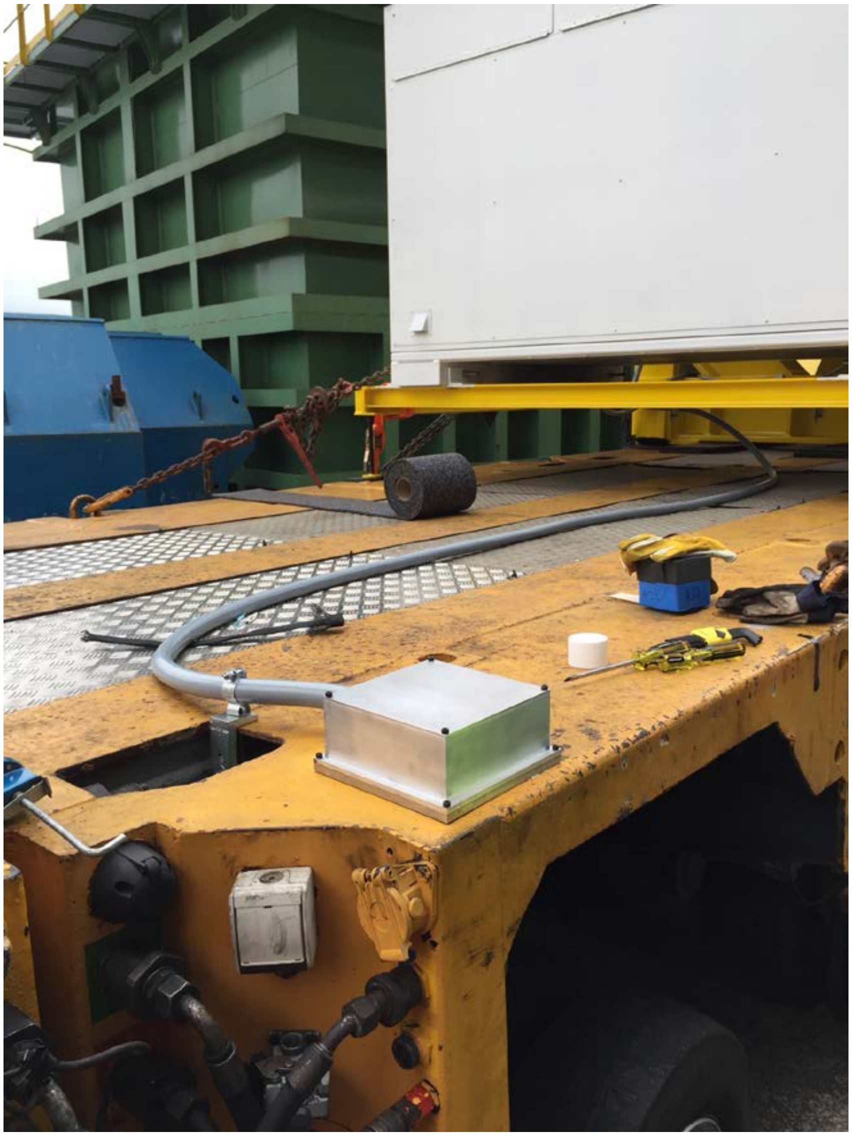


Figure 4-11. Triaxial accelerometer enclosure on Heavy-Haul Truck Trailer.

Figure 4-12. Cask system departing ENSA for Heavy-Haul Truck Test.

Heavy-haul truck shock and vibration data was recorded from the ENSA facility in Maliaño, Spain via the 395 km, two-day route shown in Figure 4-14. Seventy-seven channels of instrumentation were recorded at 512 Hz per channel. External triaxial accelerometer locations and nomenclature are shown in Figure 4-13.

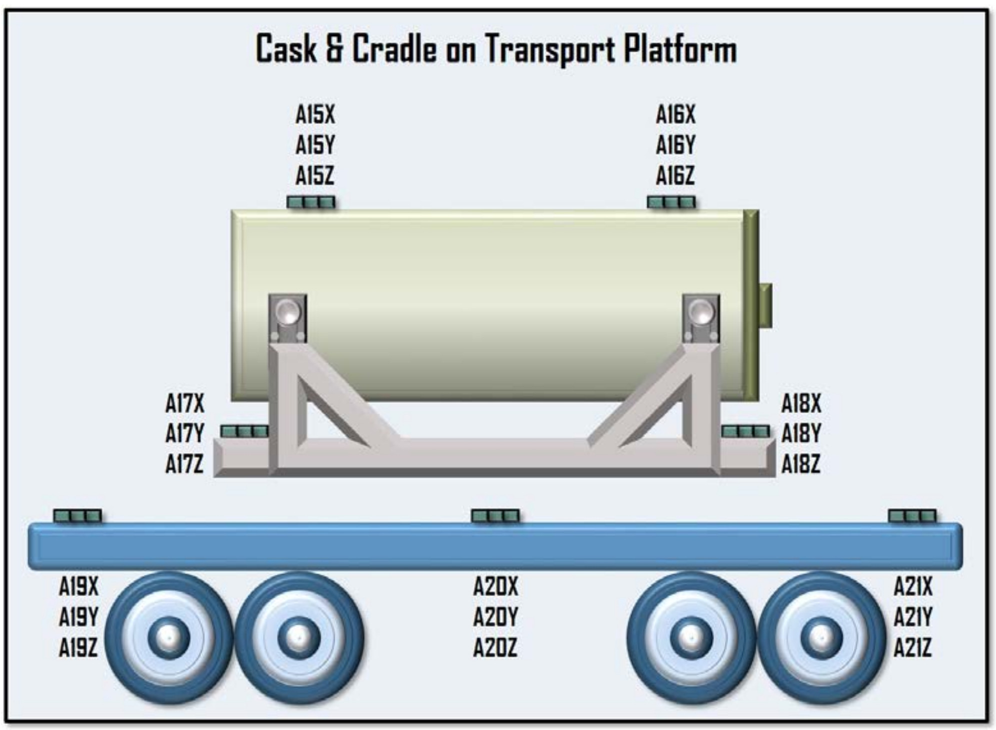


Figure 4-13. Schematic of cask, cradle, and transport platform accelerometer locations and nomenclature.

ENSA and Project team staff accompanied the heavy-haul truck from ENSA's facilities to the ultimate destination and back to Maliaño. During overnight stop of the heavy-haul truck, the instrumentation and data acquisition system was checked.

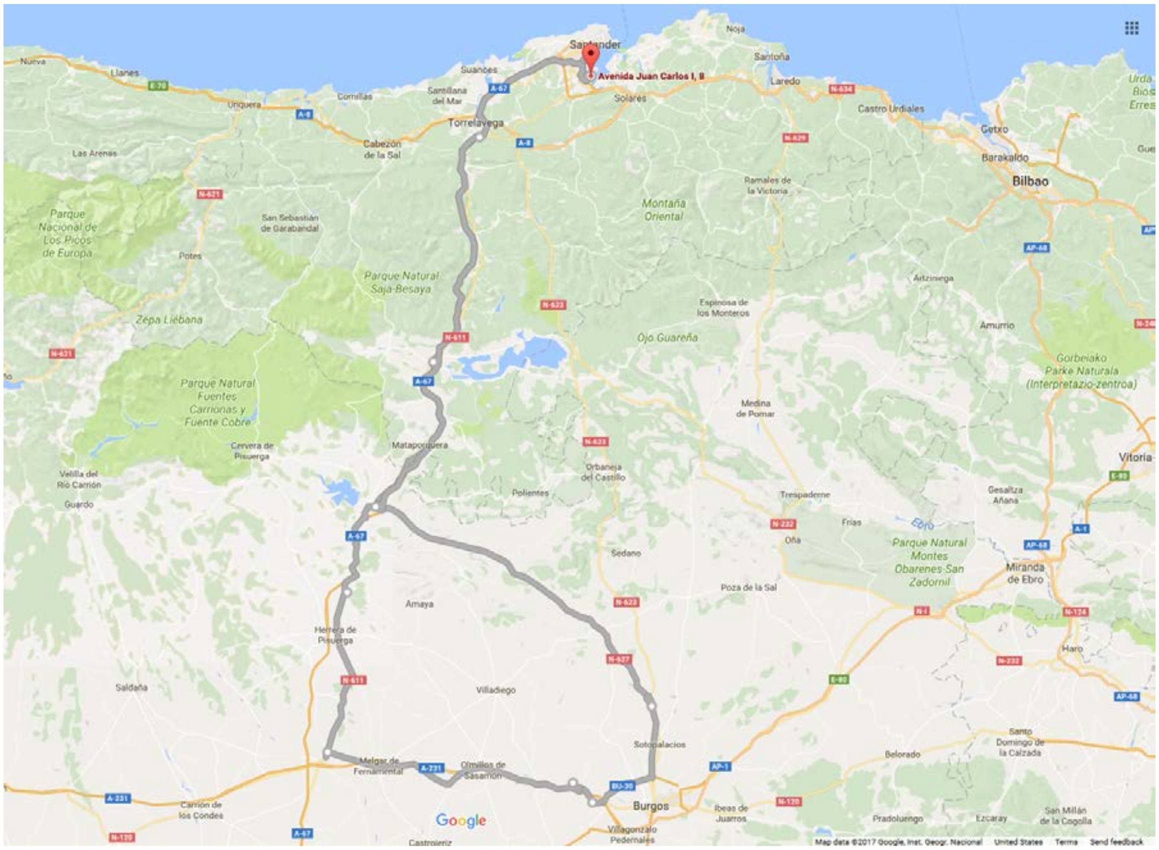


Figure 4-14. Route for heavy-haul truck transport of the cask unit. The truck left from the ENSA facility in Maliaño. The truck turned east from A-67 onto N-627 and stopped for the night near Ubierna north of Burgos.

Following the road travel by heavy-haul truck, shock and vibration data was collected by removing the compact flash cards from the DAC before the ENSA ENUN 32P cask test unit is loaded onto a roll-on/roll-off ship using the same heavy-haul trailer as used for the truck transport (i.e., the same heavy-haul trailer was used as the RO/RO vehicle for loading and transport of the ENSA ENUN 32P cask test unit onto the RO/RO ship).

Before the unit was loaded onto the RO/RO ship at the Port of Santander, ENSA and SNL technical staff thoroughly inspected the ENSA ENUN 32P cask test unit's housing, power supply, DAC, and the general functional integrity of instrument leads and external sensors. Any necessary reinforcements or repairs were made at that time. The compact flash cards were replaced with new compact flash cards for the trip from the Port of Santander to the Port of Zeebrugge, Belgium.

Figures 4-15 through 4-20 show the cask being transported by the heavy-haul truck.

Figure 4-15. Heavy-haul truck transport.

Figure 4-16. Heavy-haul truck negotiating one of the ubiquitous roundabouts. Note length of the 17-axle trailer mandated for this transport by the Spanish Ministry of Public Works and Transport.

Figure 4-17. Heavy-haul truck transport.

Figure 4-18. Heavy-haul truck transport.

Figure 4-19. Cask system passing through tiny village of Quitano del Pino.

Figure 4-20. Overnight location of cask system near Ubierna. Truck to left in photograph was used to assist in pushing the cask system up hills.

Table 4-1 provides a summary of major land transportation activities that occurred as the ENSA ENUN 32P cask test unit is

1. Transloaded and shipped by heavy-haul truck from the ENSA facility at Maliaño, Spain to a destination Ubierna and back to ENSA.
2. Shipped from the ENSA by heavy-haul truck to the Port of Santander.
3. Loaded onto a RO/RO ship for transport to the Port of Zeebrugge, Belgium (TBV).

Table 4-1. Major activities for over-the-road transportation in Spain of the ENSA ENUN 32P cask

Activity	Description
1. Charge power supply batteries	Batteries used to provide power to the ENSA ENUN 32P cask test unit's DAC and instrument sensors were fully charged.
2. Readiness Review	ENSA/DOE Project team conducted a review of the readiness of the ENSA ENUN 32P cask test unit, the heavy-haul truck transporter, and the accompanying technical and operations personnel for the transload and heavy-haul transport of the ENSA ENUN 32P cask test unit to a TBD destination and subsequent return travel to the Port of Santander, Spain.
3. Initialize DAC	Proper functioning of the DAC and instrumentation was verified prior to the readiness review. This was the first operational startup of the DAC, and the ENSA ENUN 32P cask test unit's instrumentation.
4. Transload to Heavy-Haul Truck	The ENSA ENUN 32P cask test unit was lifted using an overhead or mobile crane, placed onto, then secured to the payload deck of the heavy-haul truck's trailer. This step may have to be repeated to obtain additional data on the simulation of transloading or dry cask storage movements.
5. Obtain DAC data	Immediately after the ENSA ENUN 32P cask test unit was transloaded onto the heavy-haul trailer the compact flash cards containing the data was removed and replaced with new compact flash cards. At this time the DAC was reinitialized.
6. Heavy-Haul Truck Transport to TBD	The ENSA ENUN 32P cask test unit was transported by heavy-haul truck from the ENSA facility at Maliaño, Spain to its destination. The DAC recorded shock and vibration incident to heavy-haul truck transport during the shipment.
7. Obtain DAC data	After the ENSA ENUN 32P cask test unit completed travel from the ENSA facility to its destination on the heavy-haul truck, the DAC compact flash cards were removed and replaced to secure the heavy-haul routing data and the DAC were reinitialized.
8. Inspect the Test Unit	The DAC and instrumentation components of the test unit were inspected to ensure their readiness and integrity for continued operation.
9. Readiness Review	ENSA/DOE project team conducted a review of the readiness of the ENSA ENUN 32P cask test unit, the heavy-haul truck transporter for the heavy-haul transport of the ENSA ENUN 32P cask test unit from the TBD location for travel to the Port of Santander, Spain.
10. Initialize DAC	The DAC was initialized prior to beginning the return transportation to Santander.
11. Heavy-Haul Truck Transport (back to ENSA or directly to Port of Santander	The ENSA ENUN 32P cask test unit was transported by heavy-haul truck from the location in Spain back to ENSA and then to the Port of Santander, Spain. The DAC recorded shock and vibration incident to heavy-haul truck transport during the shipment.
12. Obtain DAC data	Immediately after the ENSA ENUN 32P cask test unit has completed travel from the location in Spain to the Port of Santander on the heavy-haul truck and before direct movement onto a RO/RO ship, the DAC hard drives were removed and replaced to secure the heavy-haul truck data and the DAC was reinitialized. A checklist was used to ensure that important inspections, preparation steps, or maintenance were not overlooked.
13. Charge power supply batteries	At ENSA following the heavy-haul truck shipment, the batteries used to provide power to the test unit's DAC and instrument sensors were fully charged.

Heavy Haul Truck

0 – 2000 seconds Heavy Haul Truck stopped (2,000 seconds) = 0.5 hours

2,000 – 12,900 seconds Heavy Haul Truck moving (10,900 seconds) = 3 hours

12,900 – 24,000 seconds Heavy Haul Truck stopped (11,100 seconds) = 3.1 hours

24,000 – 28,700 seconds Heavy Haul Truck moving (4,700 seconds) = 1.3 hours

28,700 – 30,800 seconds Heavy Haul Truck stopped (2,100 seconds) = 0.6 hours

30,800 – 36,000 seconds Heavy Haul Truck moving (5,200 seconds) = 1.4 hours

36,000 – 81,650 seconds Heavy Haul Truck stopped (45,650 seconds) = 12.7 hours

81,650 – 94,000 seconds Heavy Haul Truck moving (12,350 seconds) = 3.4 hours

94,000 – 104,660 seconds Heavy Haul Truck stopped (10,660 seconds) = 3.0 hours

Total moving time = 9.1 hours moving
Total stopped time = 20 hours stationary

4.3 Ocean Transport ENSA ENUN 32P Cask Test Unit from Spain to the Port of Baltimore

Shock and vibration was recorded during coastal shipment of the ENSA ENUN 32P cask test unit from the Port of Santander, Spain to the Port of Zeebrugge, Belgium then by larger ocean vessel from Zeebrugge to the Port of Baltimore, Maryland. As with all the transport tests, 77 channels of data were recorded at 512 Hz.

After being secured aboard a coastal freight carrier (Figure 4-21) at the Port of Santander (Figure 4-22), the ENSA ENUN 32P cask test unit operated autonomously without external power and unattended until arrival at the Port of Zeebrugge, Belgium. Figures 4-23 through 4-27 show some of the operations at the Port of Santander. Operations at the Port of Zeebrugge are shown in Figures 4-28 through 4-35.

Figure 4-21. The “Autosky,” a UECC Roll On / Roll Off ship that transported the cask system to the Port of Zeebrugge, arriving at the Port of Santander.

Figure 4-22. Location of Port of Santander relative to ENSA and downtown Santander.

The ENSA ENUN 32P cask test unit arrived at the Port of Zeebrugge and was taken off of the “Autosky.” The test unit was moved by Zeebrugge port workers for loading onto a Samson heavy-lift trailer with a suitable crane. In the interim, between its arrival at the Port of Zeebrugge and departure from this port, personnel representing the ENSA/DOE team and ENSA’s freight forwarding contractor, replaced the compact flash drives on the test unit’s DAC and recharged the power supply batteries.

(a)

(b)

Figure 4-23. "Autosky" docked at Port of Santander.

Figure 4-24. 10-axle truck trailer used for Roll-on/Roll-off ship transport from Santander to Zeebrugge.

(a) 

(b) 

Figure 4-25. Cask approaching the "Autosky" at the Port of Santander.

Figure 4-26. Cask entering the Ro/Ro ship "Autosky" at the Port of Santander.

Figure 4-27. Cask system in the "Autosky."

Figure 4-28. Port of Zeebrugge, Belgium. The "Autosky" took the cask system from the Port of Santander to the UECC terminal. The cask unit was transferred to the Wallenius terminal to be loaded onto Roll On / Roll Off ship "Tarago" for the transport to the Port of Baltimore.

Figure 4-29. "Tarago," the Ro/Ro ship that transported the cask from the Port of Zeebrugge to the Port of Baltimore.

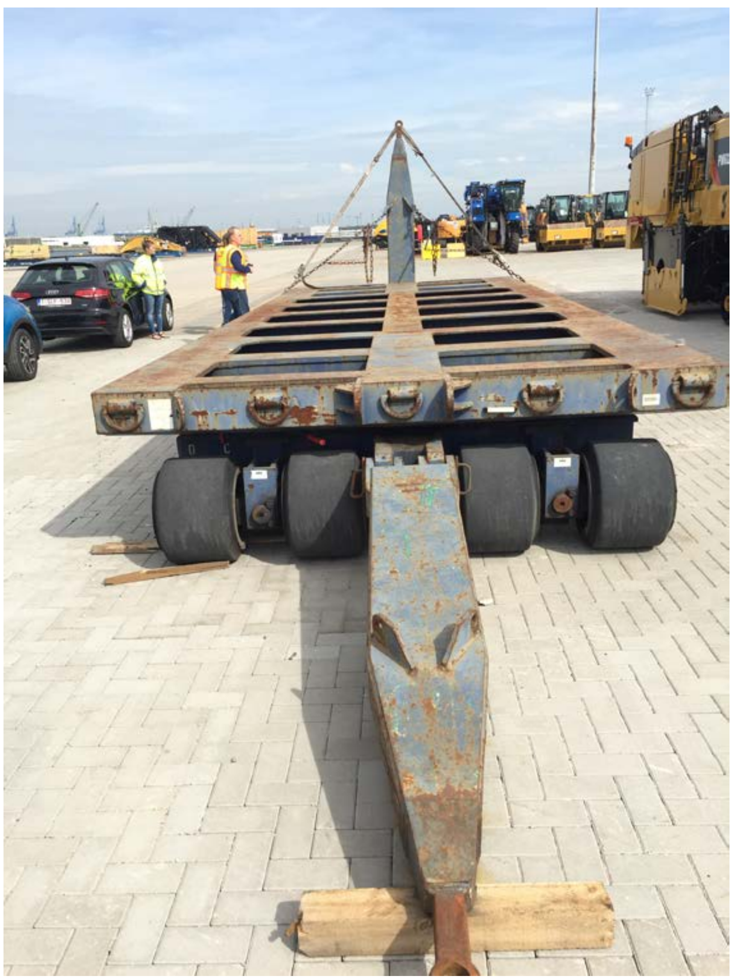


Figure 4-30. Wallenius Wilhelmsen Logistics Samson heavy-lift trailer used on the "Tarago."

Figure 4-31. Cask system being placed onto Samson at Port of Zeebrugge for transport to Port of Baltimore.

Figure 4-32. Cask system being moved on Samson to dock.

Figure 4-33. "Tarago" at the Port of Zeebrugge

Figure 4-34. Cask within the "Tarago."

Figure 4-35. Cask lashed to the interior deck of the "Tarago."

Also, before the test unit is loaded onto the merchant vessel for the Atlantic Ocean crossing, power to the DAC system was turned on and the system's functions were initialized to prepare to collect ocean-crossing test data between the Port of Zeebrugge, Belgium and the Port of Baltimore, Maryland. In addition, at the Port of Zeebrugge, before the test unit was shipped to the US, ENSA/DOE team's technical staff thoroughly inspected the test unit's housing, power supply, and DAC systems as well as the general functional integrity of instrument leads and external sensors.

Advanced arrangements were made with authorities at the Port of Zeebrugge to permit designated personnel access to the test unit. Spare parts, replacement components (e.g., batteries, instrument leads, connectors, etc.) and a portable generator to charge the batteries was brought to the port by the ENSA/DOE team.

Table 4-2 provides a summary of the major activities that occurred during or for the European coastal and Atlantic Ocean transport of the ENSA ENUN 32P cask test unit from Spain to Baltimore, Maryland.

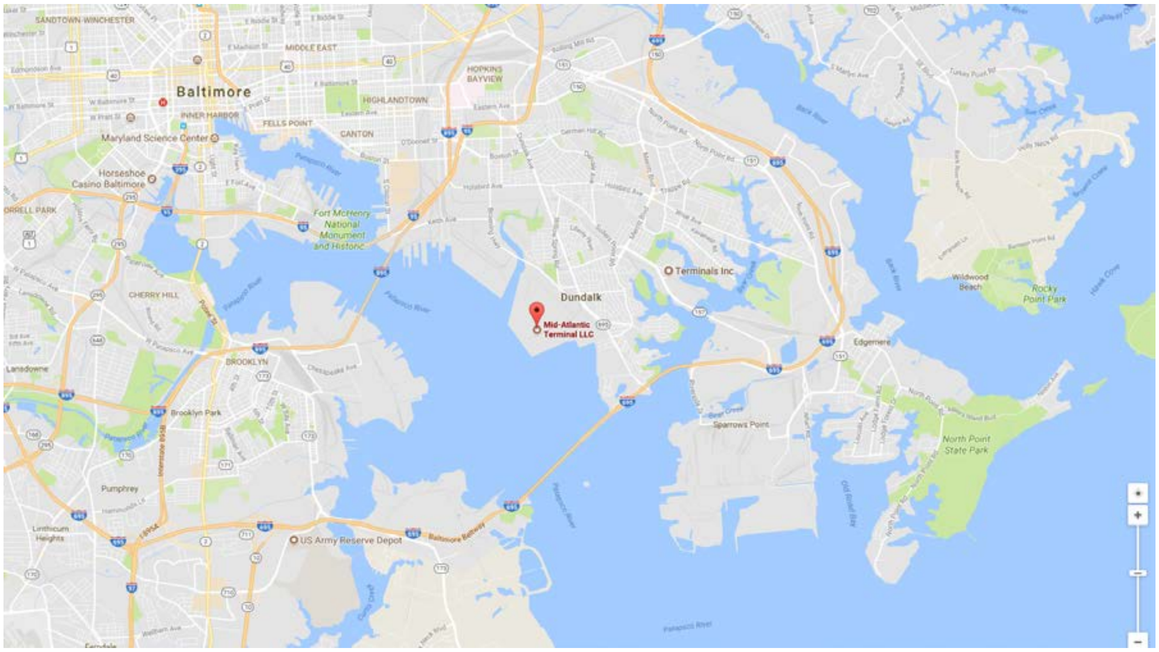
Table 4-2. Major activities during European Coastal and Atlantic Ocean Transport of the ENSA ENUN 32P cask test unit

Activity	Description
1. Spain to Zeebrugge coastal transit	
2. Arrange for use of staging area at the Port of Zeebrugge	ENSA's freight forwarding contractor arranged for the use of a staging area that is accessible by Port of Zeebrugge' s MAFI Services to allow movement of the ENSA ENUN 32P cask test unit to a location where batteries were recharged, components replaced, compact flash cards containing the coastal ocean transport data removed and replaced and the DAC reinitialized. The shipper made all necessary arrangements to allow designated ENSA/DOE team's technical staff and associated tools and equipment to have access to the Test Unit to perform work to prepare the unit for Atlantic Ocean shipment to Baltimore, Maryland.
3. Transload from coastal RO/RO merchant ship and at-dock operations at Port of Zeebrugge	At the Port of Zeebrugge, ENSA and the shipper arranged for ENSA/DOE team personnel to have access to the ENSA ENUN 32P cask test unit following its off-load from the coastal ship and before it is loaded onto the merchant vessel that transported it across the Atlantic Ocean. At a pre-arranged area of the Port, ENSA/DOE team's technical personnel inspected the Test Unit, recharged batteries, replaced components. Lastly, the compact flash cards from the DAC containing the coastal sea crossing data was removed and replaced with new compact flash cards and the DAC will be reinitialized. Checklists were used to help avoid overlooking important inspection, maintenance, or preparation steps.
4. Load onto Atlantic Ocean merchant vessel at Port of Zeebrugge	The ENSA ENUN 32P cask test unit was placed onto a Samson Trailer which was rolled directly onto an Atlantic Ocean crossing RO/RO ship at the Port of Zeebrugge, Belgium. Data was collected during this operation. The Test Unit remained on its transporter and secured at an inside deck location on board the ship.
5. Atlantic Ocean crossing from Zeebrugge, Belgium to Baltimore, Maryland	Ship-board shock and vibration data was recorded by sensors in the ENSA ENUN 32P cask test unit that are monitored by the DAC.

4.4 Configure ENSA ENUN 32P Cask Test Unit at Port of Baltimore for Rail Shipment to the TTCI

During this phase of the test, the ENSA ENUN 32P cask and railcar was prepared for cross country rail shipment to the TTCI near Pueblo, Colorado. The ENSA freight forwarding contractor[f] arranged for a suitable staging area at the Mid-Atlantic Terminal at the Port of Baltimore (Figure 4-36) to which the port's services moved the ENSA ENUN 32P cask test unit following completion of import clearance requirements and off-loading of the test unit from its ocean freight carrier ship. At the staging area, Mid-Atlantic Terminal (MAT) staff loaded the ENSA ENUN 32P cask test unit onto a railcar. After transfer of the test unit to the railcar, triaxial accelerometers were attached to the railcar and the cables from the accelerometers attached to the DAC.

[f] All necessary import clearances for the ENSA ENUN 32P cask test unit were coordinated by ENSA and their contractor.

(a) 
SANDTOWN-WINCHESTER
MIDDLE EAST
Baltimore
INNER HARBOR
FELLS POINT
CANTON
HIGHLANDTOWN
HOPKINS BAYVIEW
Maryland Science Center
Horseshoe Casino Baltimore
Fort McHenry National Monument and Historic
CHERRY HILL
BROOKLYN
Brooklyn Park
Lansdowne
Pumphrey
Linthicum Heights
US Army Reserve Depot
Dundalk
Mid-Atlantic Terminal LLC
Terminals Inc
Edgemere
Sparrows Point
North Point State Park
Wildwood Beach
Rocky Point Park

(b) 
Steamship Trade Association
MTC Logistics
Rukert Terminals Corporation
Amazon BWI2
Mediterranean Shipping Co
Ports America
CNX Marine Terminals Inc
POINT BREEZE
SAINT HELENA
Seagirt Marine Terminal Port of Baltimore
Balterm
Stansbury Park
Terminals Inc
Sparrows Point Country Club
Patapsco River
Dundalk
Amports
Mid-Atlantic Terminal LLC
Dundalk Marine Terminal GWTF
SHORELINE
Ceres Marine Terminals Inc
FAIRFIELD
WAGNERS POINT
CURTIS BAY

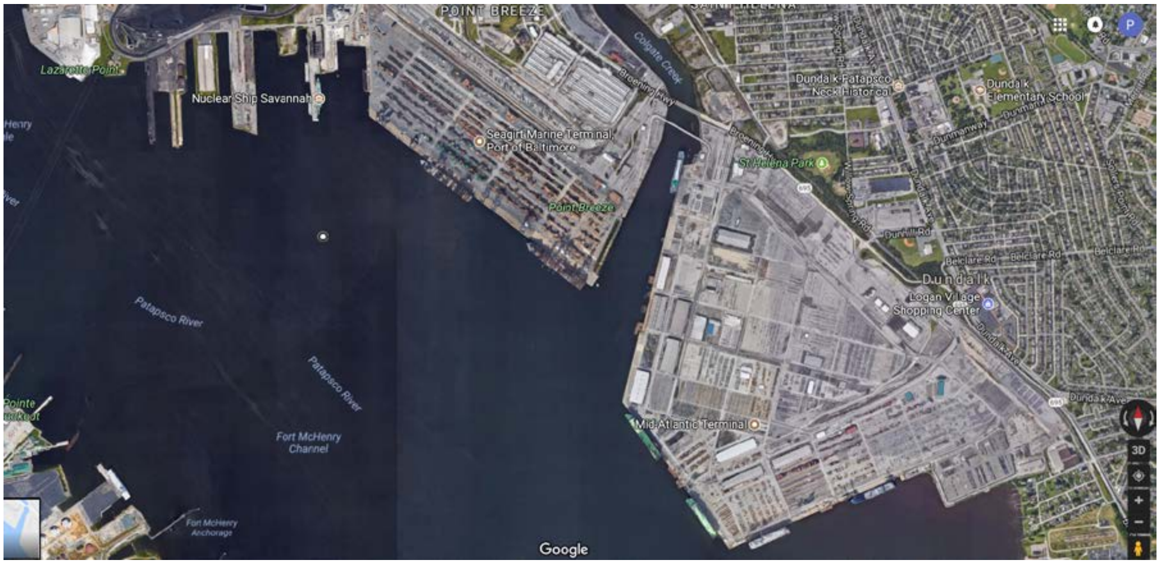
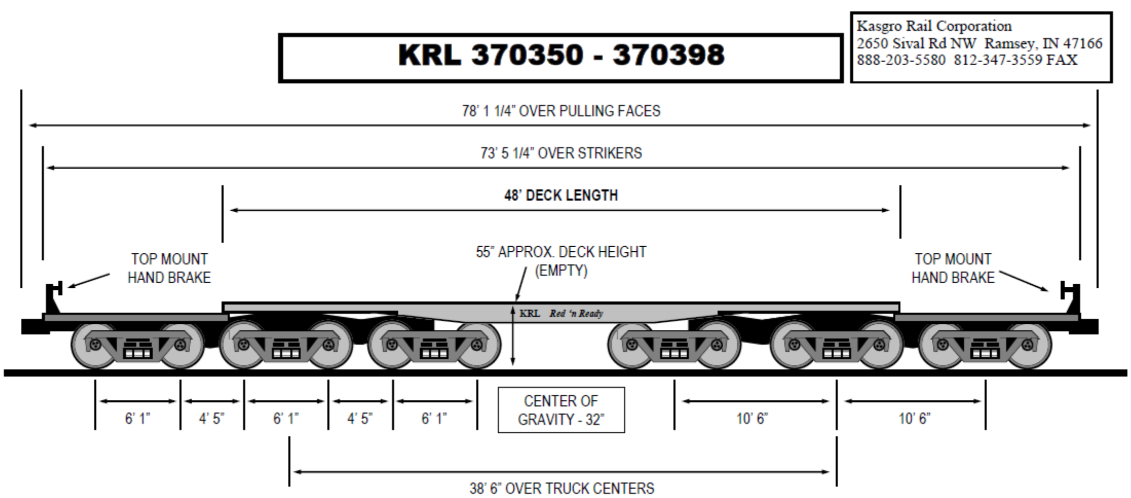
(c) 

Figure 4-36. Mid-Atlantic Terminal at the Port of Baltimore.

Prior to the arrival of the test unit at the Port of Baltimore, agents for the shipper arranged for the lease of a suitable 12-axle heavy-duty rail flatcar that was used to ship the ENSA ENUN 32P cask test unit from Baltimore, Maryland to the TTCI facility (Figure 4-37 through 4-39). The railcar's arrival was scheduled so that it was at the staging area and accessible by MAFI service before the arrival of the test unit.



LENGTH OF LADING (ft)	LOAD LIMITS (lbs)	CAR NUMBERS	LOAD LIMITS (lbs)	LIGHT WEIGHTS (lbs)	MAXIMUM GROSS (lbs)	SPRING TRAVEL (in)	DECK LENGTH (ft-in)	DECK HEIGHT (ft-in)	JOURNAL SIZE BEARING TYPE
4' & OVER	744,000 MAX LOAD	**370350-370398**	744,000	201,000	945,000	4 1/4"	48' 0"	4' 7" EMPTY	7 X 12 ROLLER
						WHEEL DIAMETER (in)	DECK WIDTH (ft-in)	DRAFT GEAR	
						38"	10- 8"	15" EOC	

KRL 370350 - 370398
370 Ton - 48' Straight Deck Flat Car
Drawing No. A19626 Rev. C

Figure 4-37. Kasgro KRL 370 railcar. The car used for the rail tests was the 370355.

Figure 4-38. Kasgro KRL 370355 flat deck railcar used for the rail tests.

Figure 4-39. Kasgro 12-axle railcar used for transport of cask unit from Port of Baltimore to the TTCI near Pueblo, Colorado. Note the ANL Traveler GPS unit in the white-topped gray box and the Data Acquisition/Battery Box to the right of the cask.

ENSA/DOE and the shipper also arranged for and obtained the services of craft workers from the Baltimore region who made modifications to the leased railcar's tie-down features to secure the ENSA ENUN 32P cask test unit in accordance with AAR Open Top Loading Rules [5]. Modifications to the railcar's cargo securement features were directed by the ENSA/DOE team and the shipper with the permission of the railcar owner.

After being moved by Port of Baltimore MAFI services to the staging area, loaded, and secured onto the railcar, batteries in the ENSA ENUN 32P cask test unit's power supply was charged. Two battery chargers and the generator to provide power were shipped to the Port from Zeebrugge for this purpose. Also at this time, the ENSA/DOE team's staff[g] removed the DAC compact flash cards that contain ocean-crossing shock and vibration data and data from the handling of the cask at the Port from the DAC. New compact flash cards were installed for the cross-country shipment, the DAC was reinitialized, and a detailed functionality check was performed to ensure the system is operating as expected[h].

Table 4-3 provides a summary of major activities that occurred at or near the Port of Baltimore, Maryland beginning before the merchant ship carrying the ENSA ENUN 32P cask test unit arrives from Europe and continuing until the Test Unit is released to a US railroad company for shipment to TTCI near Pueblo, Colorado.

Table 4-3. Major activities at the Port of Baltimore to prepare the ENSA ENUN 32P cask test unit for rail shipment to TTCI

Activity	Description
1. Arrange for use of staging area at or near the Port of Baltimore	ENSA's freight forwarding contractor arranged for the use of a staging area that has a rail siding or spur that accesses commercial railroads in the Baltimore area. The staging area was accessible by the Port of Baltimore's services to allow delivery of the ENSA ENUN 32P cask test unit and loading of the unit onto a 12-axle heavy-duty railcar. The shipper and the ENSA/DOE team made all necessary arrangements to allow designated ENSA, PNNL, SNL, and crafts workers and associated tools and equipment access to the test unit to perform work to prepare it for rail shipment to Pueblo, Colorado.
2. Lease 8-axle heavy-duty railcar	ENSA's freight forwarding contractor leased a 12-axle heavy-duty railcar that was available at the staging area at the Port of Baltimore one week before the ENSA ENUN 32P cask test unit is delivered to the Port by an Atlantic Ocean crossing merchant ship.
3. Modify railcar load securement features	The ENSA/DOE team and the shipper arranged to have modifications made to the leased railcar. The modifications installed features on the railcar for securing the test unit to the railcar in a manner that meets the requirements of the AAR Open Top Loading Rules (OTLR). The OTLR also required that the load placed on a railcar (e.g., the ENSA ENUN 32P cask test unit) was capable of meeting requirements for load integrity when being transported.)
4. Transload at Port of Baltimore, Maryland	Port of Baltimore Services moved the ENSA ENUN 32P cask test unit directly off the RO/RO trans-Atlantic merchant ship onto the ship-side dock on its RO/RO transporter. From shipside, by prior arrangement with the ENSA/DOE team and the ENSA freight forwarding contractor, the Port's Services will moved the test unit to a prearranged staging area.
5. Load ENSA ENUN 32P cask test unit onto railcar	At the staging area on or near the Port of Baltimore the port's Services loaded the test unit onto a waiting 12-axle heavy-duty railcar.
6. Secure ENSA ENUN 32P cask test unit to railcar for shipment to TTCI	The test unit was secured to the 12-axle, heavy-duty railcar and a railroad inspector determined that the securement of the test unit and the test unit's transportation integrity satisfied the AAR OTLR requirements. These actions were accomplished through prior arrangements made by the ENSA/DOE team and the shipper

[g] The shipper and the ENSA/DOE team made advanced arrangements to permit designated personnel access to, and perform work on, the Test Unit, which was freight in transit to the US destination of Pueblo, Colorado.

[h] Spare parts and replacement components (e.g., fasteners, sections of housing cover, instrument leads, connectors, batteries, battery charger, tri-axial accelerometers for installation on the railcar, etc. Check List to be developed.) was brought to the staging area by the ENSA/DOE team's staff.

7. Prepare ENSA ENUN 32P cask test unit to collect rail shock and vibration data	After the ENSA ENUN 32P cask test unit was secured to its railcar, ENSA, Sandia, and PNNL technical personnel inspected the test unit, recharged batteries, replaced components. Lastly, DAC compact flash cards were removed and replaced to secure the data collected during Port of Baltimore handling operations and ocean transport data.
8. Rail Shipment Readiness Review	Following completion of all individual preparations and inspections identified by a prearranged checklist and independent verifications, the ENSA/DOE team's project leaders conducted a rail shipment readiness review with the project team members. The purpose of the review was to verify that all necessary actions to ensure the ENSA ENUN 32P cask test unit was properly prepared and ready for rail shipment to the TTCI.
9. Release ENSA ENUN 32P cask test unit to railroad for shipment to TTCI	Following completion of the readiness review and notification by the ENSA/DOE team that the ENSA ENUN 32P cask test unit was ready to ship, the shipper notified its contracted US railroad carrier that the ENSA ENUN 32P cask test unit was available for rail company pickup at the staging area rail siding or rail spur.

4.5 Rail Shipment of ENSA ENUN 32P Cask Test Unit from Port of Baltimore to TTCI

During this phase of the testing shock and vibration data from the transportation mode that will normally occur during the future transport of SNF in the US -- rail -- was recorded during the approximately 1650-mile rail shipment of the ENSA ENUN 32P cask test unit from the Port of Baltimore to the TTCI near Pueblo, Colorado on Class I railroads (Figure 4-40). This rail shipment was on a dedicated train to ensure that all the data for the trip would be recorded. The DAC is designed to collect data during the entire shipment whether in motion or stationary but the hard drives have approximately an 18-day capacity when recording 83 channels at 512 samples/second.

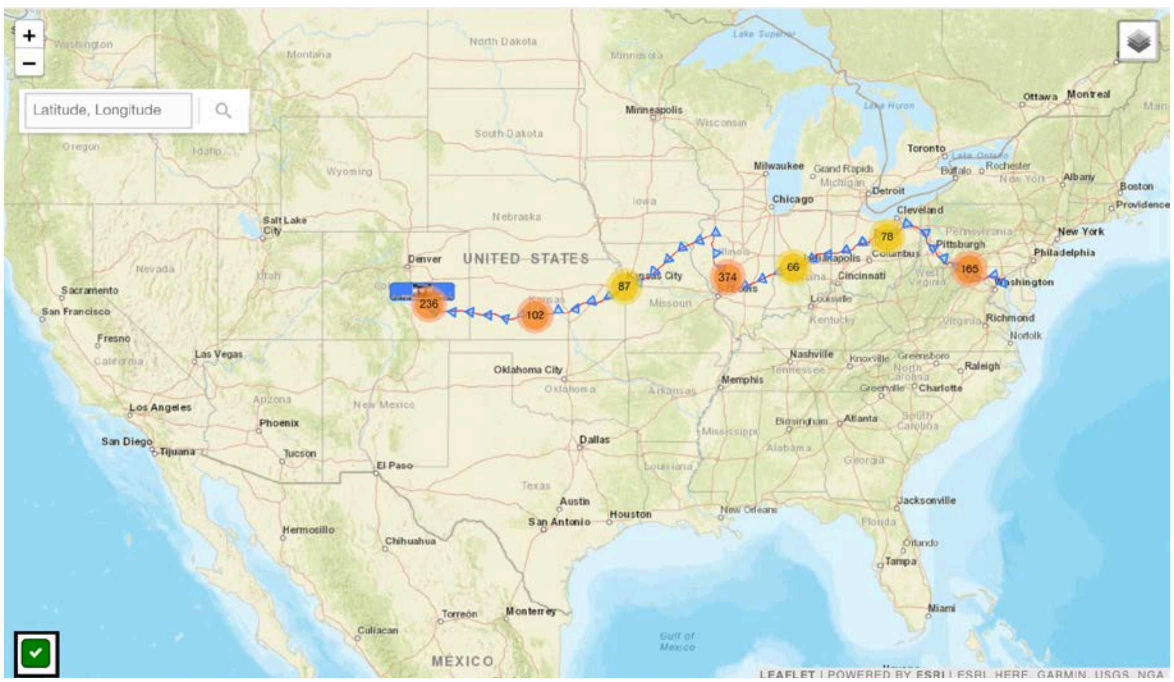


Figure 4-40. Rail route from Baltimore to Avondale, Colorado per data retrieved from the ANL Traveler GPS. The railcar/cask moved for approximately 44 hours of the 6 days of travel to Avondale.

The total recording time for this trip, "Rail 1", was 518,400 seconds, so approximately the trip to Avondale was 6 days. However, during the recording time the railcar was stopped between 0 – 8150 seconds, 157,500 – 276,400 seconds, and 438,500 – 518,400 seconds, and several shorter stops of approximately 3600 to 7200 seconds. The railcar was, therefore, stopped for significant periods of totaling approximately more 56.5 hours of the 144-hour journey. However, of the 87.5 hours of "movement", the railcar appeared to be stopped for "short" periods of 3600 – 7200 seconds. It is estimated that the railcar was actually moving about 43.75 hours of the 144 trip/data recording time at an average velocity of 38 miles/hour.

After the railroad company delivered the ENSA ENUN 32P cask test unit on its railcar to the Burlington Northern Santa Fe the DAC system was shut off and the data retrieved to secure the western rail shipment shock and vibration data. Transport to the TTCI test tracks (Figure 4-41) was on a rail network that runs from the Avondale through the US Army Pueblo Chemical Depot. The DAC power supply was recharged (requires up to 30 hours) at TTCI before initiating any tests. The Project Team and ENSA staff thoroughly inspected the cask and cradle, the test unit's housing, power supply, and DAC systems, and the general functional integrity of instrument leads and external sensors.

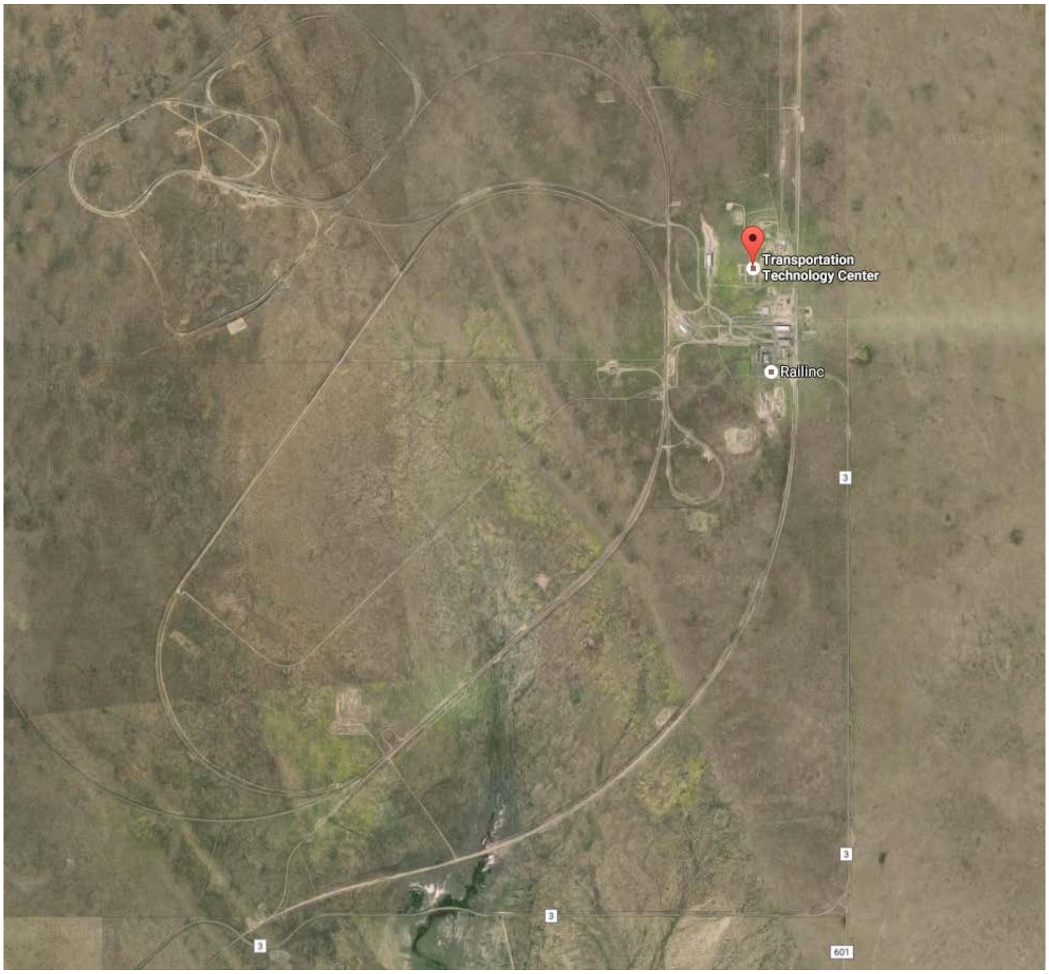


Figure 4-41. Aerial view of the TTCI facility.

Table 4-4 provides a summary of major activities that occurred during the US cross-country rail transport of the ENSA ENUN 32P cask test unit from the time it was picked up by the railroad at the staging area at the Port of Baltimore until it was delivered for pickup by a TTCI locomotive and rail crew at the BNSF Avondale yard near Pueblo, Colorado.

Table 4-4. Major activities during the US cross-country rail transport of the ENSA ENUN 32P cask test unit

1. Railroad company picks up ENSA ENUN 32P cask test unit shipment	After notification by the shipper, a local Baltimore area rail freight service train and crew will arrive to pick up the test unit. The local freight service train will move the test unit on its railcar from the staging area at the Port of Baltimore to a Baltimore rail yard where, about two days later, the shipment will be placed in a west-bound train of a Class 1 Railroad. The DAC hard drives will be removed and replaced after the test unit arrival and movement to the railcar.
2. ENSA ENUN 32P cask test unit transit from Baltimore to Midwest railroad interchange yard	While in transit, the DAC will record and store eastern rail transit shock and vibration signal data from the test unit's instrument sensors.
3. Set out ENSA ENUN 32P cask test unit shipment on a side track at Midwest interchange yard	The opportunity and need to access the railcar/cask during its transit to TTCI in Pueblo, Colorado will be evaluated and decided as the test planning proceeds. At that stop, if it occurs, it is expected that the team would use the system's WIFI connectivity with assistance from the railroad and the freight forwarder to interrogate the system and download a selected amount of data.
4. Arrival of ENSA ENUN 32P cask test unit at the BNSF Avondale yard.	Delivery of the test unit to the BNSF Avondale yard by the western national railroad(s) will be the end of the commercial rail shipment of the unit from Baltimore to TTCI. At the Avondale yard ENSA/DOE and the shipper will accept the unit's delivery from the railroad. The ENSA/DOE team and the shipper will inspect the delivered test unit and its railcar as may be prudent for accepting the shipment from the railroad.
5. Delivery of the test unit to TTCI	Following acceptance of delivery by DOE/ENSA and the shipper from the railroad at the Avondale yard, the unit will be moved by a TTCI locomotive and crew to the TTCI facility on a rail network that runs from Avondale through the US Army Pueblo Chemical Depot.
6. ENSA ENUN 32P cask test unit readied for captive track testing	After its arrival at the TTCI facility, the railcar carrying the test unit will be set out on an accessible side track and designated by TTCI personnel so work can be done on and around it. The ENSA/DOE team's technical staff will inspect the test unit's housing, power supply, and DAC systems and the general functional integrity of instrument leads and external sensors and make repairs as needed. Following completion of inspections, the DAC hard drives will be removed and replaced to secure the cross-country rail data and the power supply batteries will be charged. The test unit on its railcar will then be available at TTCI for preparations for use in captive track testing.

4.6 Testing at the TTCI

A series of eight tests were performed at the TTCI on track with design parameters somewhat beyond the type of track expected on the commercial railroads. In addition, some of the tests were conducted at speeds beyond those expected during commercial railroad travel. Appendix G contains the Test Plan prepared by TTCI for this series of tests. Also in Appendix G is an overview of the TTCI facilities.

In brief, there were eight types of rail tests performed with the cask system railcar at TTCI which are described in the TTCI Test Plan:

1. Twist and Roll
2. Pitch and Bounce
3. Dynamic Curving
4. Tests at the Pueblo Chemical Deport
5. Single Bump Test
6. Crossing Diamond Tests
7. Hunting
8. Coupling Impact Tests

One-hundred twenty-five files were generated during the testing at TTCI during eight-test series. In addition to the accelerometers used by the DOE team on the railcar, TTCI added some accelerometers. The data from the

TTCI accelerometers was supplied to PNNL to assist in their modeling activities and is not reported herein. The test matrices for the tests at TTCI are in the following sections (Figures 4-42 through 4-47).

4.6.1 Test Matrix for Twist & Roll and Pitch & Bounce Tests at TTCI

8/15/2017	TUESDAY		TWIST AND ROLL PERFORMED ON PRECISION TEST TRACK (PTT) 10-26 MPH IN 2 MPH INCREMENTS	
SPEED(MPH)	START	STOP	DESCRIPTION	FILE NAME
0	9:21	9:23	BASELINE CHECKS	TTCI000
	12:44:00	12:46:30	ENGINE COUPLING	TTCI001
10	1:24	1:26	FORWARD	TTCI002
14	1:27	1:29	REVERSE	TTCI003
12	1:32	1:34	FORWARD	TTCI004
8	1:35	1:37	REVERSE	TTCI004
14	1:39	1:40:40	FORWARD	TTCI005
8	1:41	1:44	REVERSE	TTCI005
16	2:36	2:38	FORWARD	TTCI006
9	2:38	2:41	REVERSE	TTCI006
18	2:43	2:44:50	FORWARD	TTCI007
9	2:45	2:48	REVERSE	TTCI007
20	2:48	2:49:35	FORWARD	TTCI007
9	2:49:50	2:52:26	REVERSE	TTCI007
22	2:52:40	2:54:16	FORWARD	TTCI007
9	2:54:30	2:57:20	REVERSE	TTCI007
24	2:57:30	2:59:03	FORWARD	TTCI007
9	2:59:20	3:02:22	REVERSE	TTCI007
26	3:02:30	3:04:05	FORWARD	TTCI007
9	3:04:25	3:07:36	REVERSE	TTCI007
8/15/2017	TUESDAY		TWIST AND ROLL WITH PITCH AND BOUNCE PERFORMED ON PTT 30-70 MPH IN 5 MPH INCREMENTS	
SPEED(MPH)	START	STOP	DESCRIPTION	FILE NAME
30	3:08:57	3:13:16	FORWARD	TTCI008
35	3:20:40	3:24:35	FORWARD	TTCI009
40	3:30:47	3:34:30	FORWARD	TTCI010
45	3:47:44	3:51:44	FORWARD	TTCI011
50	3:59:00	4:03:00	FORWARD	TTCI012
55	4:10:20	4:14:40	FORWARD	TTCI013
60	4:24:30	4:29:05	FORWARD	TTCI014
65	4:38:27	4:45:55	FORWARD (RESTART TEST AT 4:41??)	TTCI015
70	4:54:47	4:59:20	FORWARD	TTCI016

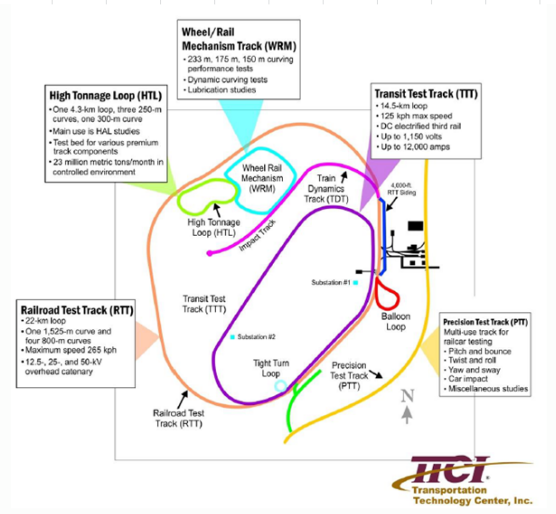


Figure 4-42. Test Matrix for Twist & Roll and Pitch & Bounce Tests at TTCI

4.6.2 Test Matrix for Dynamic Curve Tests at TTCI

8/16/2017	WEDNESDAY		DYNAMIC CURVING PERFORMED ON DYNAMIC CURVE TEST ZONE IN BODY OF 10 DEGREE ARC ON WHEEL RAIL MECHANISM (WRM)		
			10-32 MPH IN 2 MPH INCREMENTS IN CW AND CCW DIRECTIONS		
SPEED(MPH)	START	STOP	DESCRIPTION		FILE NAME
10	10:02:22	10:05:02	CW		TTCI017
12	10:10:05	10:05:02	CW		TTCI018
14	10:15:55	10:18:20	CW		TTCI019
18	10:28:30	10:30:44	CW		TTCI020
17	10:37:00	10:40:10	CW		TTCI021
20	10:45:43	10:47:50	CW		TTCI022
22	10:51:25	10:53:25	CW		TTCI023
24	10:57:10	10:59:16	CW		TTCI024
26	11:03:29	11:05:26	CW		TTCI025
28	11:09:50	11:11:37	CW		TTCI026
30	11:15:48	11:18:06	CW		TTCI027
32	11:22:25	11:24:45	CW		TTCI028
10	12:52:47	12:55:05	CCW		TTCI029
16	12:57:55	1:00:55	CCW		TTCI030
14	1:05:05	1:07:24	CCW		TTCI031
15	1:12:50	1:15:16	CCW		TTCI032
18	1:19:04	1:21:23	CCW		TTCI033
20	1:25:32	1:27:28	CCW		TTCI034
22	1:31:17	1:33:17	CCW		TTCI035
24	1:37:30	1:39:52	CCW		TTCI036
26	1:44:15	1:46:15	CCW		TTCI037
28	1:50:44	1:52:55	CCW		TTCI038
30	1:57:55	ERROR	CCW	RECORD NOT STARTED??	TTCI039
30	2:04:30	2:06:28	CCW		TTCI040
32	2:11:05	2:13:14	CCW		TTCI041

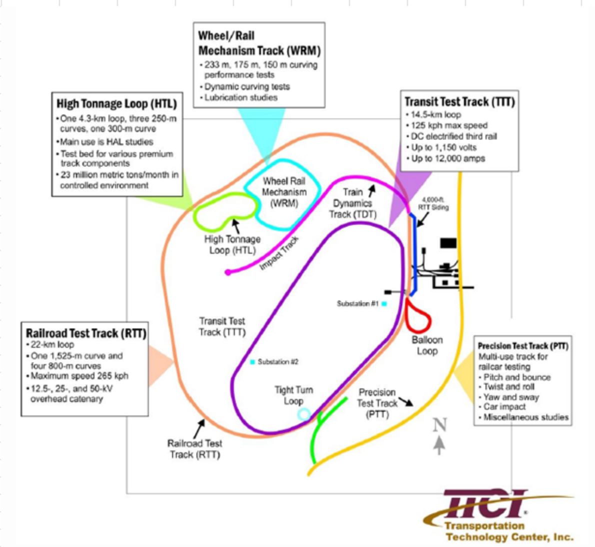


Figure 4-43. Test Matrix for Dynamic Curve Tests at TTCI

4.6.3 Test Matrix for Tests at the US Army Pueblo Chemical Depot

8/17/2017 THURSDAY TTCI WILL TEST ON THE TRACKS AT PUEBLO CHEMICAL DEPOT (PCD)

SPEED(MPH)	START	STOP	DESCRIPTION	FILE NAME
20	8:44	9:05:44	NORTH GATE TO WYE AT 8:50	TTCI042
15	9:06:50	9:10:57	WYE TO SOUTH GATE WITH TURN AT 9:09	TTCI043
20	10:17:43	10:21:50	WEST TO EAST CLASS YARD TRACK 1 WITH TURNOUT	TTCI044
20	10:30:20	10:33:53	WEST TO EAST CLASS YARD TRACK 2 WITH TURNOUT	TTCI045
5	10:40:35	10:48:00	CROSSOVER, W TO E, CLASS YARD TRACK 2 TO 1	TTCI046
10	10:54:10	11:01:25	CROSSOVER, W TO E, CLASS YARD TRACK 2 TO 1 (EXTRA REVERSE DATA)	TTCI047
15	11:04:12	11:08:00	CROSSOVER, W TO E, CLASS YARD TRACK 2 TO 1	TTCI048
19	11:12:50	11:16:05	CROSSOVER, W TO E, CLASSYARD TRACK 2 TO 1	TTCI049
20	11:31:33	11:34:20	EAST TO WEST CLASS YARD 2 WITH TURNOUT	TTCI050
18	11:42:35	11:45:42	E TO W, CLASS YARD1, WITH TURNOUT	TTCI051
20	11:50:45	11:53:35	REPEAT LAST AT 18 MPH	TTCI052
5	12:00:22	12:08:25	CROSSOVER, E TO W, CLASS YARD TRACK 1 TO 2	TTCI053
10	12:14:15	12:19:12	CROSSOVER, E TO W, CLASS YARD TRACK 1 TO 2	TTCI054
15	12:25:12	12:28:45	CROSSOVER, E TO W, CLASS YARD TRACK 1 TO 2	TTCI055
15	12:49:26	12:53:00	CROSSOVER, E TO W, CLASS YARD TRACK 1 TO 2 (REPEAT)	TTCI056
19	12:58:45	1:02:05	CROSSOVER, E TO W, CLASS YARD TRACK 1 TO 2	TTCI057
20	1:10:42	1:28:15	SOUTH GATE TO NORTH GATE	TTCI058

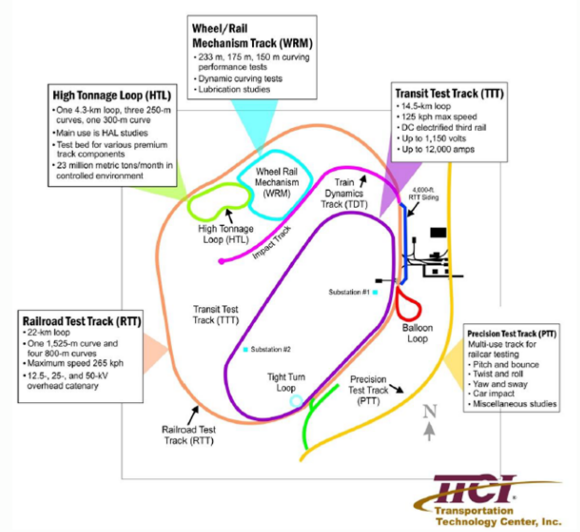


Figure 4-44. Test Matrix for Tests at the US Army Pueblo Chemical Depot.

4.6.4 Test Matrix for Single Bump Tests at TTCI

8/18/2017 FRIDAY SINGLE BUMP TEST (SBT) AT TRANSIT TEST TRACK (TTT) 40- 75 MPH IN 5 MPH INCREMENTS

SPEED(MPH)	START	STOP	DESCRIPTION	FILE NAME
40	9:14:43	9:19:25	SBT	TTCI059
45	9:22:26	9:26	INSTRUMENTATION TRAILER LOST POWER	TTCI060
40	10:01:25	10:03:44	SBT REPEAT 40 MPH	TTCI061
45	10:07:05	10:03:44	SBT	TTCI062
50	10:14:13	10:16:57	SBT	TTCI063
55	10:20:57	10:23:50	SBT	TTCI064
60	10:28:00	10:31:02	SBT	TTCI065
60	10:35:15	10:38:35	SBT REPEAT FOR TTCI DAQ	TTCI066
65	10:43:25	10:46:55	SBT	TTCI067
70	10:52:43	10:56:16	SBT	TTCI068
75	11:02:44	11:06:50	SBT DID NOT REACH 75 MPH	TTCI069
75	11:14:02	11:18:20	SBT REPEAT 75 MPH	TTCI070
			CROSSING DIAMOND TEST (CDT) AT 10, 20, 25 - 40 IN 5 MPH INCREMENTS	
10	11:46:05	11:47:16	CDT	TTCI071
20	11:48:45	11:49:59	CDT	TTCI072
25	11:52:00	11:53:10	CDT	TTCI073
30	11:55:13	11:57:02	CDT	TTCI074
35	11:59:21	12:01:34	CDT	TTCI075
40	12:04:35	12:06:30	CDT	TTCI076

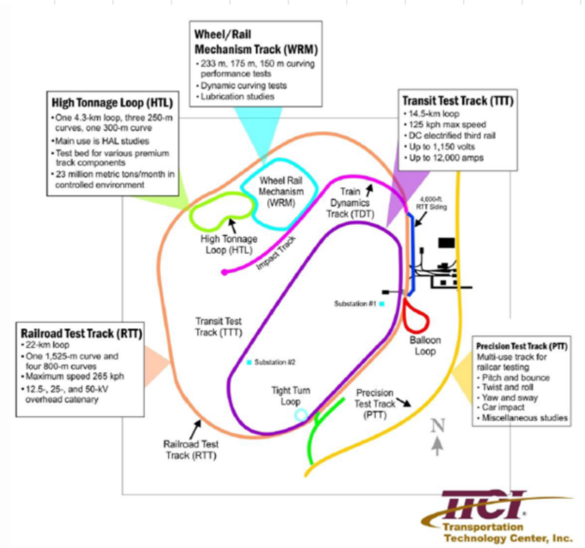


Figure 4-45. Test Matrix for Single Bump Tests at TTCI.

4.6.5 Test Matrix for Hunting Tests at TTCI

8/22/2017 TUESDAY HUNTING TESTS ON RAILROAD TEST TRACK (RTT) AND TRANSIT TEST TRACK (TTT) LOOPS IN 30, 40, 50-75 MPH IN 5 MPH INCREMENTS

RTT IS 14 MILE LOOP & TTT IS 9 MILE LOOP

SPEED(MPH)	START	STOP	DESCRIPTION	FILE NAME
30	9:30:30	9:40	RTT LOOP (R42 - R31)	TTCI100
40	9:56:20	9:59:50	RTT LOOP (R42 - R31)	TTCI101
50	10:14:50	10:17:45	RTT LOOP (R42 - R31)	TTCI102
55	10:30:30	10:33:05	RTT LOOP (R42 - R31)	TTCI103
60	10:44:50	10:47:07	RTT LOOP (R42 - R31)	TTCI104
65	10:57:58	11:00:09	RTT LOOP (R42 - R31)	TTCI105
70	11:09:58	11:12:03	RTT LOOP (R42 - R31)	TTCI106
75	11:21:22	11:23:15	RTT LOOP (R42 - R31)	TTCI107
			TTT LOOP IN TWO SEGMENTS FROM T45 - T27 & T21 - T51	
30	1:01:46	1:10:20	TTT LOOP T45 - T27 (TRAIN SLOWED DOWN SO REPEAT)	TTCI108
30	1:12:35	1:18:40	TTT LOOP T21 - T51	TTCI109
30	1:21:07	1:28:23	TTT LOOP T45 - T27	TTCI110
30	1:30:20	1:36:35	TTL LOOP T21 - T51	TTCI111
40	1:38:32	1:44:05	TTL LOOP T45 - T27	TTCI112
40	1:45:47	1:50:01	TTL LOOP T21 - T51	TTCI113
50	1:51:40	1:56:13	TTL LOOP T45 - T27	TTCI114
50	1:57:33	2:01:24	TTL LOOP T21 - T51	TTCI115
55	2:02:33	2:06:33	TTL LOOP T45 - T27	TTCI116
55	2:07:47	2:11:30	TTL LOOP T21 - T51	TTCI117
60	2:12:23	2:16:00	TTL LOOP T45 - T27	TTCI118
60	2:17:13	2:20:43	TTL LOOP T21 - T51	TTCI119
65	2:21:37	2:24:58	TTL LOOP T45 - T27	TTCI120
65	2:25:58	2:29:10	TTL LOOP T21 - T51	TTCI121
70	2:30:00		TTL LOOP T45	TTCI122
70			TTL LOOP T27 AT 2:33:00	TTCI122
70			TTL LOOP T21 AT 2:33:57	TTCI122
70			TTL LOOP T51 AT 2:37:00	TTCI122
70			TTL LOOP T45 AT 2:37:50	TTCI122
70			TTL LOOP T27 AT 2:40:30	TTCI122
70			TTL LOOP T21 AT 2:41:27	TTCI122
70			TTL LOOP T51 AT 2:43:15	TTCI122

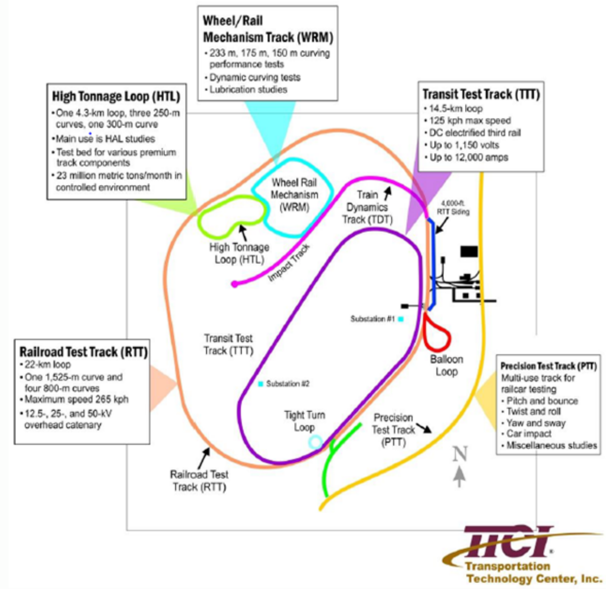


Figure 4-46. Test Matrix for Hunting Tests at TTCI.

4.6.6 Test Matrix for Coupling Tests at TTCI

8/24/2017 THURSDAY COUPLING IMPACT TESTS PERFORMED ON PRECISION TEST TRACK (PTT)

B END AND A END FROM 2 - 8 MPH IN 2 MPH INCREMENTS

USING ON-BOARD MEMORY CARDS FOR 36 MIN RECORD LENGTHS

SPEED(MPH)	START	STOP	DESCRIPTION	FILE NAME
4.1	9:42:55			TTCI000
2.1			IMPACT AT 9:51:37	TTCI000
5.8			IMPACT AT 9:57:38	TTCI000
5.8			IMPACT AT 10:04:50	TTCI000
7		10:19:55	IMPACT AT 10:10:27	TTCI000
8.5	10:23:15	11:02:46	IMPACT AT 10:26:46	TTCI001
			TRAIN CAR TURNED AROUND FOR SECOND SERIES OF TESTS	
4	11:04:35		IMPACT AT 11:07:47	TTCI002
5			IMPACT AT 11:11:30	TTCI002
6			IMPACT AT 11:14:23	TTCI002
8.2		11:24:00	IMPACT AT 11:18:00	TTCI002

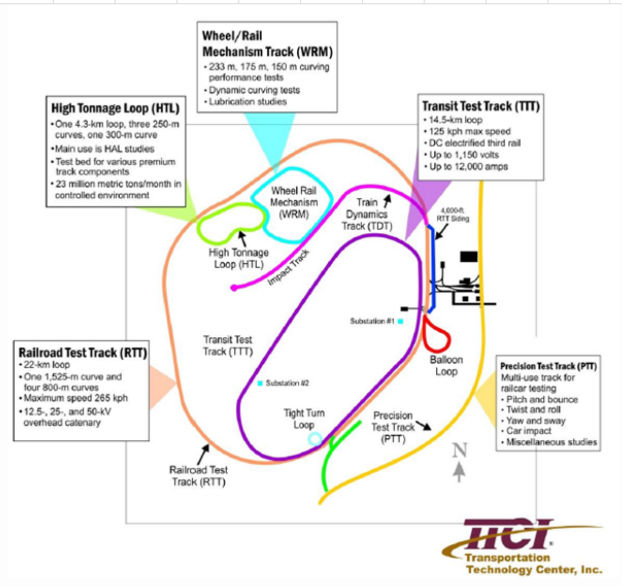


Figure 4-47. Test Matrix for Coupling Tests at TTCI.

Photographs of some of the rail tests at TTCI are shown in Figures 4-48 through 4-50.

Figure 4-48. Cask system on the Kasgro 12-axle railcar. The gray car between the locomotive and cask railcar is the TTCI Instrumentation Car where TTCI and SNL technicians were located during the rail tests.

Figure 4-49. Rail test in progress at TTCI.

Figure 4-50. Rail test in progress at TTCI.

4.7 Rail Shipment of ENSA ENUN 32P Cask Test Unit back to Port of Baltimore from TTCI

The cask system departed TTCI on 29 August 2017. The railcar was moved to a BNSF rail line spur south of TTCI near Avondale and Boone, Colorado (Figures 4-51 and 4-52). The DAC was turned on so data was collected starting the afternoon of 29 August. As of this writing the cask system is traveling is sitting on its railcar near Venice, Illinois. It will be switched from the BNSF to the CSX Transport rail road and then travel to the Port of Baltimore.

After delivery of the ENSA ENUN 32P cask test unit on its railcar to the Port of Baltimore and acceptance from the railroad by ENSA/DOE team and the shipper, the ENSA ENUN 32P cask test unit will be moved to the staging area at the Mid-Atlantic Terminal to prepare it for shipment to ENSA.

At the staging area, the ENSA/DOE team will remove the compact flash cards containing the shock and vibration data collected during the travel from TTCI to Baltimore. At this time, the DAC, the batteries, exposed instrument leads, and accessible instruments from the test unit will be removed. The DAC Instrumentation Box will also be removed from the cradle and all the equipment removed will be shipped back to Albuquerque.

ENSA/DOE and the shipper will arrange for and obtain any necessary services of craft workers to assist removal the ENSA ENUN 32P cask test unit from the railcar, and transport it to dockside for movement onto an ocean cargo vessel for return shipment to Spain. ENSA and the shipper will be responsible for returning the railcar to its owner.

Figure 4-51. Red arrow denotes staging area for cask system railcar upon arrival near Avondale, Colorado (approximately two miles south of TTCI) and departure from TTCI prior to trip back to Baltimore.

Figure 4-52. Cask being transferred to BNSF rail line from TTCI.

Figure 4-53. Cask awaiting pickup by the BNSF Railway.

Route of 18-day data collection (bottom) as recorded by Lat-Lon GPS unit mounted on cask.

Figure 4-54. Route of 18-day data collection (bottom) as recorded by Lat-Lon GPS unit mounted on cask.

Figure 4-54 represents the route the cask traveled on its railcar from TTCI to near East St. Louis, Illinois on the BNSF Railway in the 18 days that data was being collected. (The railcar will be switched to CSX Transportation [Rail Road] for the trip to Baltimore.) The map represents 199 miles within Colorado; 462 miles within Kansas; 197 miles in Missouri; 17 miles in Iowa, and 251 miles in Illinois. That is a total of 1125 miles of data collected in 18 days of travel - an average speed of 2.6 miles/hour! – a testament to the efficiency of America's rail road companies.

From the East St. Louis area, the cask will travel east via CSX Transport on a route expected to pass through Toad Hop, Indiana; Terre Haute, Indiana; Avon, Indiana; Sidney, Ohio; Marion, Ohio; Fostoria, Ohio; Willard, Ohio; New Castle, Pennsylvania; Cumberland, Maryland; Brunswick, Maryland; and Bayview (Baltimore), Maryland arriving in early October, 2017 (Figure 4-55).

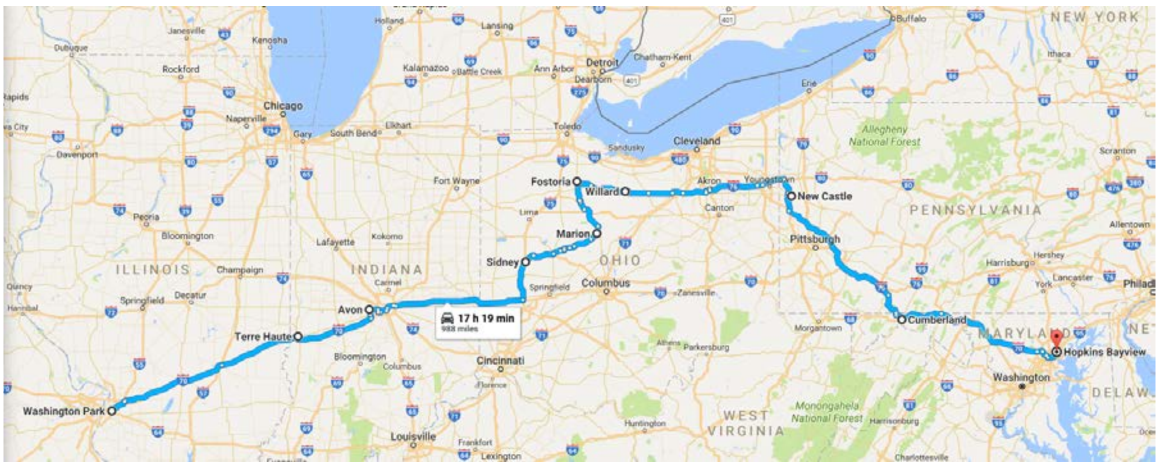


Figure 4-55. Approximate CSX Transport rail route for completion of trip from East St. Louis to Port of Baltimore.

Table 4-5 provides a summary of the major activities that will occur during the US cross-country rail return trip of the ENSA ENUN 32P cask test unit from the time it is moved from the TTCI facility to the BNSF Avondale yard east of Pueblo, Colorado until it is delivered to the staging area at the Port of Baltimore for return shipment to Spain.

Table 4-5. Major activities during return trip US cross-country rail transport of the ENSA ENUN 32P cask test unit

Activity	Description
1. Verify securement of ENSA ENUN 32P cask test unit to railcar for shipment to Port of Baltimore	Securement of the test unit to the 8-axle, heavy-duty railcar will be verified and a railroad inspector will determine that the securement of the test unit and the unit’s transportation integrity satisfy the AAR requirements. These actions will be accomplished through prior arrangements made by the ENSA/DOE team and the shipper. Potential inspection by TTCI personnel may provide the necessary assurance that the test unit is ready for transport on commercial track.
2. Prepare ENSA ENUN 32P cask test unit to collect rail shock and vibration data	After securement of the ENSA ENUN 32P cask test unit to its railcar has been verified, the ENSA/DOE team’s technical personnel will inspect the test unit recharge batteries, replace components (including replace hard drives), and make repairs (if needed). The DAC will be reinitialized. Also, the cellular (TBV) network download will be tested.
3. Rail Shipment Readiness Review	Following completion of all individual preparations and inspections identified by a prearranged checklist and independent verifications as may be prudent, the ENSA/DOE team’s project leaders will conduct a rail shipment readiness review with the project team members. The review will verify that all necessary actions to ensure the ENSA ENUN 32P cask test unit is properly prepared and ready for data collection and return rail shipment to the Port of Baltimore have been satisfactorily completed.
4. Release ENSA ENUN 32P cask test unit to railroad for shipment to TTCI	Following completion of the readiness review and notification by the ENSA/DOE team that the ENSA ENUN 32P cask test unit is ready to ship, a TTCI locomotive and crew will move the test unit to the BNSF Avondale yard where it will be placed for pick up by a Class 1 western US railroad for shipment east-bound to the Port of Baltimore.
5. Railroad company picks up ENSA ENUN 32P cask test unit shipment	A Class 1 US railroad company will transport the ENSA ENUN 32P cask test unit in one of its east-bound trains from the BNSF Avondale yard east of Pueblo, Colorado. The shipment will be picked up at the Avondale yard after being delivered from TTCI by a TTCI rail crew and locomotive. The shipper will coordinate with the western railroad company to schedule pick up of the shipment.
6. ENSA ENUN 32P cask test unit transit from BNSF Avondale yard to Port of Baltimore	While in transit, the DAC will record and store eastern rail transit shock and vibration signal data from the test unit’s instrument sensors.
7. Delivery of the test unit to staging area side track or rail spur	Delivery of the test unit to the staging area at the Port of Baltimore by an eastern railroad will be the end of the commercial rail shipment of the unit to Baltimore from TTCI. Following delivery by the railroad company to the staging area, ENSA/DOE team and the shipper will inspect the shipment and accept it from the railroad.
8. ENSA ENUN 32P cask test unit readied for ocean transport to Spain	After its arrival at the staging area’s side track or rail spur at the Port of Baltimore, the railcar carrying the test unit will be secured so work can be done on and around it. The ENSA/DOE team’s technical staff (who will have arrived before to prepare for arrival of the railcar) will remove the hard drives that contain the data collected during the trip from TTCI to the Port of Baltimore. The DAC will be removed at that time along with the batteries, and removable instrument leads and external instrument sensors from the test unit and prepared for shipment to SNL. The DAC/Battery Box will also be removed. In addition, the overall test unit will be inspected to ensure its integrity for the return trip to Spain.

9. ENSA ancillary equipment prepared for return shipment to Spain	The ancillary equipment that is shipped to the US with the ENSA ENUN 32P cask test unit, will be returned with the test unit when the unit is returned to Spain. If ancillary equipment is not needed at the Port of Baltimore that equipment may be shipped directly to ENSA from TTCI. It is anticipated that ancillary equipment would be transported in an ISO container that would be handled and shipped separately from the test unit.
10. Return of DAC, batteries, battery charger, removable instrument leads, and external instrument sensors	The DAC, power supply batteries, battery charger, removable instrument leads, and external instrument sensors that can be removed from the test unit at the Port of Baltimore will be removed and shipped separate from the test unit and/or as directed by their respective owners in the ENSA/DOE team.

5. PRELIMINARY TEST RESULTS

As of this writing, the rail-cask transportation tests are ongoing: the cask system is on its railcar traveling from TTCI to the Port of Baltimore.

Nevertheless, large amount of raw data has been collected from the several 256 GB Scan Disk drives used for the various phases of the tests – only the data from the rail transport from Colorado to Baltimore remains to be collected. The data from the data acquisition system for the other phases of the testing have been collected. This is a huge amount of data to review in order to identify significant events that may have resulted in significant, or, at least, greater than baseline strains or accelerations.

The data (voltage versus time) for each instrument is recorded in the DAC via a proprietary Siemens binary file format denoted as TMD. That file format is converted to another Siemens proprietary binary format LDSF. Sandia has developed software, K2, to use the LDSF files in order to analyze the data and convert the data into strain versus time or acceleration versus time plots and to convert that data via fast Fourier transformations and SRS.

Other organizations that will analyze the data will need ASCII files which are eight times larger than the TMD or LDSF files. Sandia will convert all the files for PNNL, ENSA, and KORAD/KAERI.

Examining the data for analysis for a given transportation mode is time consuming – millions of seconds of data were recorded at 512 or 10240 samples/second/instrument. Therefore, at this writing, there is not many results to report and those must be considered PRELIMINARY. In depth analyses of the data and correlations of data between assemblies and various accelerometers will be thoroughly performed in FY18 by SNL and PNNL. ENSA and KORAD/KAERI will also perform analyses.

Some of the data that has been analyzed at Sandia to date is shown below. PRELIMINARY conclusions:

Strains on the surrogate fuel rods in all three assemblies were extremely low.

No strain greater than 100 με was detected in the data.

This is a very encouraging and important result. The primarily impetus for preforming tests on surrogate fuel assemblies and rods since FY13 was the need to establish what the strains on the rods are during Normal Conditions of Transport. The measured strains can be compared to the mechanical properties of Zircaloy and Zirlo in order to identify the safety margin against failure by an excessive applied load or by fatigue. In other words, the:

Data from the assembly tests establishes a technical basis for the safe transport of spent fuel under Normal Conditions of Transport.

5.1 Summary of All Tests

An enormous amount of data was collected for the transportation tests. The following is a summary of the amount of data collected sans the tests at TTCI and the Rail 2 tests of the transport from Colorado.

5.1.1 Multimode Test Data Summary

Handling Tests (Raising and lowering of cask in a vertical position)

Handling Run No. 1: ASCII = 9.7 GB

Handling Run No. 3: ASCII = 11.6 GB

Handling Run No. 5: ASCII = 6.7 GB

Heavy-Haul Handling (Cask onto cradle)

ASCII = 34.0 GB

Heavy Haul Truck

ASCII = 164 GB

Ship 1 (Port of Santander to Port of Zeebrugge)

ASCII = 556 GB

Ship 2 (Port of Zeebrugge to Port of Baltimore)

ASCII = 1.64 TB

Rail No. 1 (Baltimore to Avondale, Colorado)

ASCII = 723 GB

TOTAL DATA

ASCII = 3.15 TB

Siemens LMS (18-day Trial Run)

Configuration 77 channels + 6 GPS channels
Sample Rate = 512 Hz
Segments = 36
Blocks = 12
Run Time = 432 hours
TRD File Size = 238 GB
LDSF File Size = 238 GB

796,262,400 samples/channel (structural Data)
ASCII = 35,597 files
ASCII Block File Size = 67 MB

Total file size = 2.12 TB
K2 Conversion time = 60 hours

Total Sample Size
796,262,400 samples/channel x 77 channels = 61,312,204,800 samples
311,040,000 samples/channel x 6 GPS channels = 1,866,240,000 samples
Total Samples = 63,178,444,800 samples

K2 LDSF Preview Generator Processing time (18Day Run) = 26 hours

Siemens LMS Estimated (14-day Trial Run)

Configuration 77 channels + 6 GPS channels
Sample Rate = 512 Hz
Segments = 28
Blocks = 12
Run Time = 336 hours
TRD File Size = 185 GB
LDSF File Size = 185 GB

619,315,200 samples/channel (structural Data)
ASCII = 27,690 files
ASCII Block File Size = 67 MB

Total file size = 1.65 TB
K2 Conversion time = 47 hours

Total Sample Size
619,315,200 samples/channel x 77 channels = 47,687,270,800 samples
311,040,000 samples/channel x 6 GPS channels = 1,866,240,000 samples
Total Samples = 49,553,510,400 samples

Siemens binary TRD files loaded onto 256 GB SD cards

TRD files transferred to 2 TB Seagate hard drives

TRD files converted to binary Siemens LDSF files via Siemens software.

LDSF files transferred from computer to 2 TB Seagate hard drives

LDSF files analyzed by Sandia K2 software

LDSF files converted to ASCII files via the K2, Revision 11 convertor

ASCII files loaded onto 4 TB Seagate hard drives

ASCII data distributed to others via 4 TB hard drives.

Data File: Test Type / Instrumentation Channel / Segment (12 hours) / Block 0 – 11 (1 hour)

= 67 MB ASCII

77 instrumentation channels + 8 GPS channels = 3.33 hours/data-day to convert LDSF files (binary) to ASCII via K2.

Handling tests

Truck tests = 3 days

Ship Spain to Belgium = 4 days

Ship Belgium to USA = 14 days

Train across USA = 6 days

Handling &TTCI (higher sampling rate, 10240 Hz v. 512 Hz) = equivalent 10 days

= 130 hours to convert data to ASCII

Total Days ≈ 37 days of data to process = 123 hours to convert to ASCII

5.2 PRELIMINARY Tabulated Data

In the following sections are some PRELIMINARY tabulated results from some of the tests. Locations and nomenclature of instruments is shown in Figure 5-1.

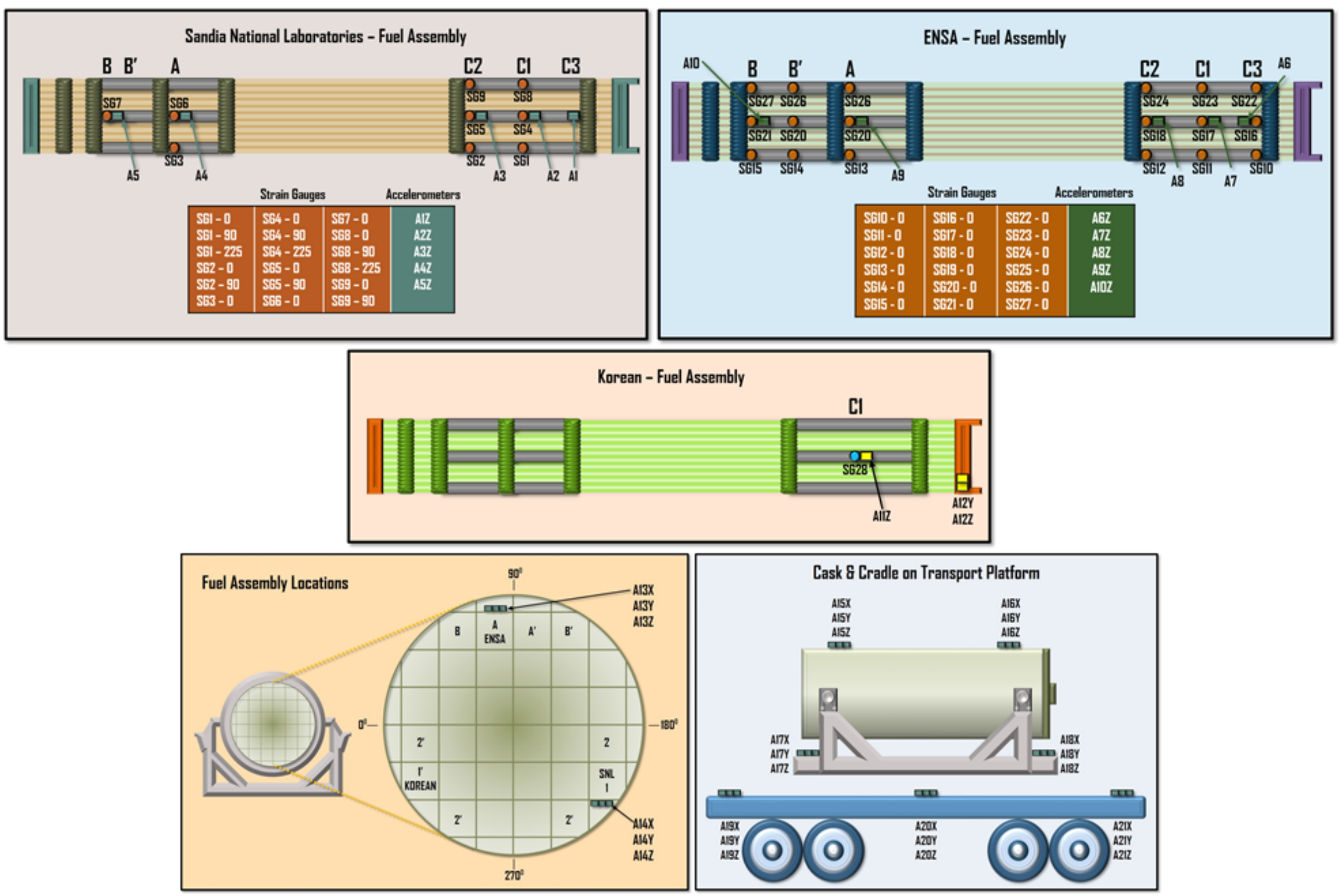


Figure 5-1. Instrumentation nomenclature and locations on the assemblies and cask system. The instrumentation designations are listed in the tables in the following sections. The top nozzles of the assemblies and lid of the cask are to the right.

All the data has yet to be analyzed – that is to be completed in FY18. However, a few preliminary results – windows of time for various phases of the testing – are in the following sections. From the data in those sections maximum strains are reported in Table 5-1, which gives a comparison of the maximum strains recorded in the three previous assembly tests and some maximum values noted in the rail-cask tests. Strain gauges and accelerometers highlighted in yellow are gauges on the three assemblies in identical locations, SG4 (SNL), SG17 (ENRESA), and SG28 (Korean assembly) and A2Z (SNL), A7Z (ENRESA), and A11Z (Korean assembly). Strains and accelerations highlighted in green are the maximums observed for the particular test.

Table 5-1. Comparison of maximum strains in the rail-cask tests and previous SNL assembly tests ENSA cask data is PRELIMINARY.

	SNL Assembly Vertical Shaker FY13	SNL Assembly Truck Test FY14	SNL Assembly Multi-axis Shaker FY15	ENSA Cask Heavy-Haul Truck Test FY17
Maximum truck shock micro-strain (μm/m)	**119**	**143**	**160 - 301**	**97**

5.2.1 Cask Handling Tests

Table 5-2. Handling Test 1 Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Max/Min Value (g)
A1Z	SNL Assembly	0°	C3	2.08/-2.17
A2Z	SNL Assembly	0°	C1	2.38/-1.34
A3Z	SNL Assembly	0°	C2	1.69/-1.69
A4Z	SNL Assembly	0°	A	0.59/-1.34
A5Z	SNL Assembly	0°	B	0.25/-0.26
~~A6Z~~	~~ENSA Assembly~~	~~0°~~	~~C3~~	~~Open~~
A7Z	ENSA Assembly	0°	C1	1.26/-1.04
A8Z	ENSA Assembly	0°	C2	1.04/-1.09
A9Z	ENSA Assembly	0°	A	0.75.-0.88
A10Z	ENSA Assembly	0°	B	1.22/-1.35
A11Z	Korean Assembly	0°	C1	2.33/-1.26
A12Y	Korean Assembly	0°	Top Nozzle	3.41/-4.01
A12Z	Korean Assembly	0°	Top Nozzle	2.59/-7.9
A13X	Cask Basket	0°	A	0.30/-0.18
A13Y	Cask Basket	0°	A	0.21/-0.14
A13Z	Cask Basket	0°	A	1.49/-1.76
~~A14X~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Suspect*~~
A14Y	Cask Basket	135°	1	0.13/-0.11
~~A14Z~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0°	Top Base	0.66/-0.04
A15Y	Cask Body	0°	Top Base	0.02/-0.02
A15Z	Cask Body	0°	Top Base	0.03/-0.02
A16X	Cask Body	0°	Top Closure	0.06/-0.04

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Max/Min Value (g)
A16Y	Cask Body	0˚	Top Closure	0.08/-0.05
A16Z	Cask Body	0˚	Top Closure	0.04/-0.05

Table 5-3. Handling Test 1 Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Max/Min Value (με)
SG1-0	SNL Assembly	C1-LR	0°	9/-7
SG1-90	SNL Assembly	C1-LR	90°	6/-8
SG1-225	SNL Assembly	C1-LR	225°	8/-8
SG2-0	SNL Assembly	C2-LR	0°	11/-2
SG2-90	SNL Assembly	C2-LR	90°	7/-8
SG3-0	SNL Assembly	A-LR	0°	6/-10
SG4-0	SNL Assembly	C1-MO	0°	8/-4
SG4-90	SNL Assembly	C1-MO	90°	8/-6
SG4-225	SNL Assembly	C1-MO	225°	8/-7
SG5-0	SNL Assembly	C2-MO	0°	10/-2
SG5-90	SNL Assembly	C2-MO	90°	8/-7
SG6-0	SNL Assembly	A-MO	0°	6/-5
SG7-0	SNL Assembly	B-MO	0°	4/-4
SG8-0	SNL Assembly	C1-LP	0°	9/-4
SG8-90	SNL Assembly	C1-LP	90°	6/-4
SG8-225	SNL Assembly	C1-LP	225°	4/-8
SG9-0	SNL Assembly	C2-LP	0°	10/-2
SG9-90	SNL Assembly	C2-LP	90°	11/-7
SG10-0	ENSA Assembly	C3-Left	0°	8/-26
SG11-0	ENSA Assembly	C1-Left	0°	7/-5
SG12-0	ENSA Assembly	C2-Left	0°	24/-11
SG13-0	ENSA Assembly	A-Left	0°	22/-40
SG14-0	ENSA Assembly	B´-Left	0°	8/-11
SG15-0	ENSA Assembly	B-Left	0°	10/-51
SG16-0	ENSA Assembly	C3-Center	0°	9/-26
SG17-0	ENSA Assembly	C1-Center	0°	8/-8
SG18-0	ENSA Assembly	C2-Center	0°	25/-9
SG19-0	ENSA Assembly	A-Center	0°	19/-27
SG20-0	ENSA Assembly	B´-Center	0°	12/-11
SG21-0	ENSA Assembly	B-Center	0°	5/-38
SG22-0	ENSA Assembly	C3-Center	0°	9/-21
SG23-0	ENSA Assembly	C1-Center	0°	12/-8
SG24-0	ENSA Assembly	C2-Center	0°	26/-9
SG25-0	ENSA Assembly	A-Center	0°	18/-31
SG26-0	ENSA Assembly	B´-Center	0°	11/-12
SG27-0	ENSA Assembly	B-Center	0°	12/-37
SG28-0	Korean Assembly	C1-Center	0°	14/-19

Table 5-4. Handling Test 3 Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Max/Min Value (g)
A1Z	SNL Assembly	0°	C3	0.82/-0.55
A2Z	SNL Assembly	0°	C1	1.05/-1.6
A3Z	SNL Assembly	0°	C2	0.66/-1.17
A4Z	SNL Assembly	0°	A	0.29/-0.25
A5Z	SNL Assembly	0°	B	0.12/-0.12
~~A6Z~~	~~ENSA Assembly~~	~~0°~~	~~C3~~	~~Open~~
A7Z	ENSA Assembly	0°	C1	0.7/-0.52
A8Z	ENSA Assembly	0°	C2	0.91/-1.24
A9Z	ENSA Assembly	0°	A	0.64/-0.73
A10Z	ENSA Assembly	0°	B	0.86/-0.95
A11Z	Korean Assembly	0°	C1	0.48/-0.49
A12Y	Korean Assembly	0°	Top Nozzle	1.02/-2.73
A12Z	Korean Assembly	0°	Top Nozzle	1.68/-2.83
A13X	Cask Basket	0°	A	0.27/-0.18
A13Y	Cask Basket	0°	A	0.12/-0.11
A13Z	Cask Basket	0°	A	1.29/-1.65
~~A14X~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Suspect*~~
A14Y	Cask Basket	135°	1	0.06/-0.06
~~A14Z~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0°	Top Base	0.03/-0.14
A15Y	Cask Body	0°	Top Base	0.02/-0.02
A15Z	Cask Body	0°	Top Base	0.01/-0.02
A16X	Cask Body	0°	Top Closure	0.03/-0.02
A16Y	Cask Body	0°	Top Closure	0.03/-0.02
A16Z	Cask Body	0°	Top Closure	0.01/-0.03

* Data contains high noise floor

Table 5-5. Handling Test 3 Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Max/Min Value (με)
SG1-0	SNL Assembly	C1-LR	0°	5/-5
SG1-90	SNL Assembly	C1-LR	90°	3/-3
SG1-225	SNL Assembly	C1-LR	225°	5/-5
SG2-0	SNL Assembly	C2-LR	0°	7/-6
SG2-90	SNL Assembly	C2-LR	90°	5/-4
SG3-0	SNL Assembly	A-LR	0°	4/-9
SG4-0	SNL Assembly	C1-MO	0°	7/-7
SG4-90	SNL Assembly	C1-MO	90°	3/-3
SG4-225	SNL Assembly	C1-MO	225°	3/-8
SG5-0	SNL Assembly	C2-MO	0°	10/-7
SG5-90	SNL Assembly	C2-MO	90°	3/-3
SG6-0	SNL Assembly	A-MO	0°	5/-5
SG7-0	SNL Assembly	B-MO	0°	2/-3
SG8-0	SNL Assembly	C1-LP	0°	6/-4
SG8-90	SNL Assembly	C1-LP	90°	2/-2
SG8-225	SNL Assembly	C1-LP	225°	4/-5
SG9-0	SNL Assembly	C2-LP	0°	9/-5
SG9-90	SNL Assembly	C2-LP	90°	4/-3
SG10-0	ENSA Assembly	C3-Left	0°	4/-11
SG11-0	ENSA Assembly	C1-Left	0°	4/-3
SG12-0	ENSA Assembly	C2-Left	0°	11/-7
SG13-0	ENSA Assembly	A-Left	0°	20/-28
SG14-0	ENSA Assembly	B´-Left	0°	7/-9
SG15-0	ENSA Assembly	B-Left	0°	9/-39
SG16-0	ENSA Assembly	C3-Center	0°	5/-17
SG17-0	ENSA Assembly	C1-Center	0°	7/-5
SG18-0	ENSA Assembly	C2-Center	0°	18/-6
SG19-0	ENSA Assembly	A-Center	0°	20/-21
SG20-0	ENSA Assembly	B´-Center	0°	10/-10
SG21-0	ENSA Assembly	B-Center	0°	5/-31
SG22-0	ENSA Assembly	C3-Center	0°	5/-16
SG23-0	ENSA Assembly	C1-Center	0°	10/-5
SG24-0	ENSA Assembly	C2-Center	0°	18/-5
SG25-0	ENSA Assembly	A-Center	0°	18/-22
SG26-0	ENSA Assembly	B´-Center	0°	11/-6
SG27-0	ENSA Assembly	B-Center	0°	7/-29
SG28-0	Korean Assembly	C1-Center	0°	4/-5

Table 5-6. Handling Test 5 Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Max/Min Value (g)
A1Z	SNL Assembly	0°	C3	8.5/-3.5
A2Z	SNL Assembly	0°	C1	3/35/-2.94
A3Z	SNL Assembly	0°	C2	4,13/-4.44
A4Z	SNL Assembly	0°	A	6.36/-6.33
A5Z	SNL Assembly	0°	B	2.15/-3.50
~~A6Z~~	~~ENSA Assembly~~	~~0°~~	~~C3~~	~~Open~~
A7Z	ENSA Assembly	0°	C1	3.98/-2.20
A8Z	ENSA Assembly	0°	C2	4.40/-4.53
A9Z	ENSA Assembly	0°	A	3.67/-3.41
A10Z	ENSA Assembly	0°	B	6.17/-9.68
A11Z	Korean Assembly	0°	C1	5.66/-3.98
A12Y	Korean Assembly	0°	Top Nozzle	8.55/-13.42
A12Z	Korean Assembly	0°	Top Nozzle	6.53/-23.3
A13X	Cask Basket	0°	A	1.62/-1.06
A13Y	Cask Basket	0°	A	0.84/-0.72
A13Z	Cask Basket	0°	A	8.5/-10.3
~~A14X~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Suspect*~~
A14Y	Cask Basket	135°	1	0.65/-0.48
~~A14Z~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0°	Top Base	0.15/-0.1
A15Y	Cask Body	0°	Top Base	0.04/-0.06
A15Z	Cask Body	0°	Top Base	0.07/-0.07
A16X	Cask Body	0°	Top Closure	0.15/-0.1
A16Y	Cask Body	0°	Top Closure	0.15/-0.1
A16Z	Cask Body	0°	Top Closure	0.13/-0.14

* Data contains high noise floor

Table 5-7. Handling Test 5 Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Max/Min Value (με)
SG1-0	SNL Assembly	C1-LR	0°	24/-21
SG1-90	SNL Assembly	C1-LR	90°	15/-20
SG1-225	SNL Assembly	C1-LR	225°	27/-25
SG2-0	SNL Assembly	C2-LR	0°	26/-30
SG2-90	SNL Assembly	C2-LR	90°	14/-29
SG3-0	SNL Assembly	A-LR	0°	15/-19
SG4-0	SNL Assembly	C1-MO	0°	35/-12
SG4-90	SNL Assembly	C1-MO	90°	14/-17
SG4-225	SNL Assembly	C1-MO	225°	16/-32
SG5-0	SNL Assembly	C2-MO	0°	30/-31
SG5-90	SNL Assembly	C2-MO	90°	15/-15
SG6-0	SNL Assembly	A-MO	0°	13/-11
SG7-0	SNL Assembly	B-MO	0°	10/-16
SG8-0	SNL Assembly	C1-LP	0°	38/-31
SG8-90	SNL Assembly	C1-LP	90°	8/-18
SG8-225	SNL Assembly	C1-LP	225°	27/-31
SG9-0	SNL Assembly	C2-LP	0°	31/-46
SG9-90	SNL Assembly	C2-LP	90°	11/-13
SG10-0	ENSA Assembly	C3-Left	0°	34/-49
SG11-0	ENSA Assembly	C1-Left	0°	26/-24
SG12-0	ENSA Assembly	C2-Left	0°	59/-28
SG13-0	ENSA Assembly	A-Left	0°	28/-73
SG14-0	ENSA Assembly	B´-Left	0°	22/-31
SG15-0	ENSA Assembly	B-Left	0°	23/-87
SG16-0	ENSA Assembly	C3-Center	0°	34/-54
SG17-0	ENSA Assembly	C1-Center	0°	26/-39
SG18-0	ENSA Assembly	C2-Center	0°	66/-40
SG19-0	ENSA Assembly	A-Center	0°	33/-59
SG20-0	ENSA Assembly	B´-Center	0°	24/-40
SG21-0	ENSA Assembly	B-Center	0°	16/-60
SG22-0	ENSA Assembly	C3-Center	0°	31/-53
SG23-0	ENSA Assembly	C1-Center	0°	41/-71
SG24-0	ENSA Assembly	C2-Center	0°	62/-41
SG25-0	ENSA Assembly	A-Center	0°	33/-72
SG26-0	ENSA Assembly	B´-Center	0°	20/-41
SG27-0	ENSA Assembly	B-Center	0°	24/-66
SG28-0	Korean Assembly	C1-Center	0°	30/-54

Table 5-8. Handling (Cask to Cradle) Test Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Max/Min Value (g)*
A1Z	SNL Assembly	0˚	C3	1.34/-1.12
A2Z	SNL Assembly	0˚	C1	1.73/-1.25
A3Z	SNL Assembly	0˚	C2	1.60/-1.58
A4Z	SNL Assembly	0˚	A	1.6/-0.92
A5Z	SNL Assembly	0˚	B	1.07/-0.55
~~A6Z~~	~~ENSA Assembly~~	~~0˚~~	~~C3~~	~~Open~~
A7Z	ENSA Assembly	0˚	C1	1.77.-1.28
A8Z	ENSA Assembly	0˚	C2	1.53/-1.35
A9Z	ENSA Assembly	0˚	A	1.15/-0.63
A10Z	ENSA Assembly	0˚	B	1.36/-0.9
A11Z	Korean Assembly	0˚	C1	1.6/-1.36
A12Y	Korean Assembly	0˚	Top Nozzle	1.3/-4.08
A12Z	Korean Assembly	0˚	Top Nozzle	1.6/-2.44
A13X	Cask Basket	0˚	A	0.8/-0.4
A13Y	Cask Basket	0˚	A	0.8/-0.8
A13Z	Cask Basket	0˚	A	1.9/-1.34
~~A14X~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Suspect**~~
A14Y	Cask Basket	135˚	1	1.8/-1.64
~~A14Z~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0˚	Top Base	0.11/-1.01
A15Y	Cask Body	0˚	Top Base	1.3/-0.14
A15Z	Cask Body	0˚	Top Base	1.12/-0.05
A16X	Cask Body	0˚	Top Closure	0.11/-1.05
A16Y	Cask Body	0˚	Top Closure	0.13/-0.15
A16Z	Cask Body	0˚	Top Closure	1.06/-0.04

*****Data Max/Min includes gravity contribution (1g) during rotation on X and Z measuring accelerometers

** Data contains high noise floor

These data are represented in Figure 5-2.

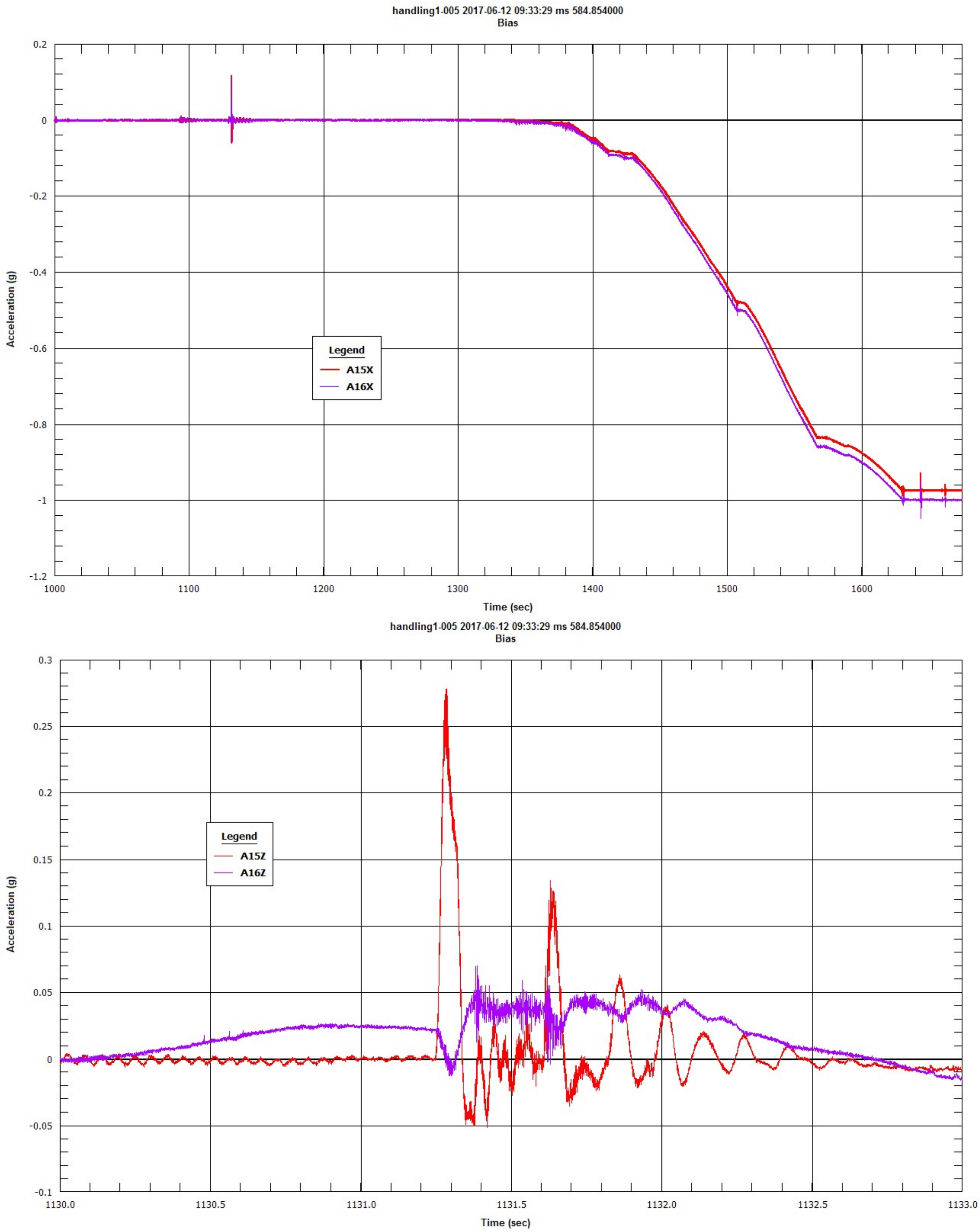


Figure 5-2. Cask-body accelerometer data as cask was rotated from vertical position to horizontal position on cradle.

Table 5-9. Handling (Cask to Cradle) Test Strain Gauge Data

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Max or Min Value (με)
SG1-0	SNL Assembly	C1-LR	0°	-32
SG1-90	SNL Assembly	C1-LR	90°	-25
SG1-225	SNL Assembly	C1-LR	225°	33
SG2-0	SNL Assembly	C2-LR	0°	41
SG2-90	SNL Assembly	C2-LR	90°	20
SG3-0	SNL Assembly	A-LR	0°	44
SG4-0	SNL Assembly	C1-MO	0°	-32
SG4-90	SNL Assembly	C1-MO	90°	9
SG4-225	SNL Assembly	C1-MO	225°	26
SG5-0	SNL Assembly	C2-MO	0°	66
SG5-90	SNL Assembly	C2-MO	90°	6
SG6-0	SNL Assembly	A-MO	0°	22
SG7-0	SNL Assembly	B-MO	0°	39
SG8-0	SNL Assembly	C1-LP	0°	-27
SG8-90	SNL Assembly	C1-LP	90°	-13
SG8-225	SNL Assembly	C1-LP	225°	25
SG9-0	SNL Assembly	C2-LP	0°	47
SG9-90	SNL Assembly	C2-LP	90°	17
SG10-0	ENSA Assembly	C3-Left	0°	-27
SG11-0	ENSA Assembly	C1-Left	0°	-17
SG12-0	ENSA Assembly	C2-Left	0°	39
SG13-0	ENSA Assembly	A-Left	0°	11
SG14-0	ENSA Assembly	B´-Left	0°	12
SG15-0	ENSA Assembly	B-Left	0°	9
SG16-0	ENSA Assembly	C3-Center	0°	-24
SG17-0	ENSA Assembly	C1-Center	0°	-21
SG18-0	ENSA Assembly	C2-Center	0°	35
SG19-0	ENSA Assembly	A-Center	0°	16
SG20-0	ENSA Assembly	B´-Center	0°	-11
SG21-0	ENSA Assembly	B-Center	0°	24
SG22-0	ENSA Assembly	C3-Center	0°	-20
SG23-0	ENSA Assembly	C1-Center	0°	-25
SG24-0	ENSA Assembly	C2-Center	0°	27
SG25-0	ENSA Assembly	A-Center	0°	-13
SG26-0	ENSA Assembly	B´-Center	0°	-12
SG27-0	ENSA Assembly	B-Center	0°	15
SG28-0	Korean Assembly	C1-Center	0°	-15

5.2.2 Heavy Haul Truck Tests

Table 5-10. Heavy Haul Truck Test Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Maximum Value (g)
A1Z	SNL Assembly	0˚	C3	≤0.2
A2Z	SNL Assembly	0˚	C1	0.18/-0.30
A3Z	SNL Assembly	0˚	C2	≤0.2
A4Z	SNL Assembly	0˚	A	0.3/-.35
A5Z	SNL Assembly	0˚	B	0.46/-0.52
A6Z	ENSA Assembly	0˚	C3	Open
A7Z	ENSA Assembly	0˚	C1	0.58/-0.43
A8Z	ENSA Assembly	0˚	C2	0.92/-0.85
A9Z	ENSA Assembly	0˚	A	0.64/-0.74
A10Z	ENSA Assembly	0˚	B	0.31/-.22
A11Z	Korean Assembly	0˚	C1	0.40/-0.35
A12Y	Korean Assembly	0˚	Top Nozzle	0.46/-0.24
A12Z	Korean Assembly	0˚	Top Nozzle	0.39/-0.22
A13X	Cask Basket	0˚	A	≤0.2
~~A13Y~~	~~Cask Basket~~	~~0˚~~	~~A~~	~~Suspect***~~
A13Z	Cask Basket	0˚	A	≤0.2
~~A14X~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Suspect**~~
A14Y	Cask Basket	135˚	1	≤0.2
~~A14Z~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0˚	Top Base	≤0.2
A15Y	Cask Body	0˚	Top Base	≤0.2
A15Z	Cask Body	0˚	Top Base	≤0.2
A16X	Cask Body	0˚	Top Closure	≤0.2
A16Y	Cask Body	0˚	Top Closure	≤0.2
A16Z	Cask Body	0˚	Top Closure	≤0.2
A17X	Cask Cradle	0˚	Cradle Rear	≤0.2
A17Y	Cask Cradle	0˚	Cradle Rear	≤0.2
A17Z	Cask Cradle	0˚	Cradle Rear	≤0.2
A18X	Cask Cradle	0˚	Cradle Front	≤0.2
A18Y	Cask Cradle	0˚	Cradle Front	≤0.2
A18Z	Cask Cradle	0˚	Cradle Front	≤0.2
A19X	Transporter	0˚	Transport Rear	0.56/-0.53
A19Y	Transporter	0˚	Transport Rear	0.7/-0.6
A19Z	Transporter	0˚	Transport Rear	4.2/-3.2
A20X	Transporter	0˚	Transport Center	0.45/-0.35
A20Y	Transporter	0˚	Transport Center	0.5/-0.5
A20Z	Transporter	0˚	Transport Center	2.2/-2.1
A21X	Transporter	0˚	Transport Front	2.2/-2.3
A21Y	Transporter	0˚	Transport Front	0.8/-0.8
A21Z	Transporter	0˚	Transport Front	2.3/-2.4

* Data contains large measurement drift
** Data contains high noise floor
** Channel is intermittent and suspect until approximately 38,000 seconds

Table 5-11. Heavy Haul Truck Test Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Maximum Value (με)
SG1-0	SNL Assembly	C1-LR	0°	≤20
SG1-90	SNL Assembly	C1-LR	90°	≤20
SG1-225	SNL Assembly	C1-LR	225°	≤20
SG2-0	SNL Assembly	C2-LR	0°	≤20
SG2-90	SNL Assembly	C2-LR	90°	≤20
SG3-0	SNL Assembly	A-LR	0°	≤20
SG4-0	SNL Assembly	C1-MO	0°	≤20
SG4-90	SNL Assembly	C1-MO	90°	≤20
SG4-225	SNL Assembly	C1-MO	225°	≤20
SG5-0	SNL Assembly	C2-MO	0°	≤20
SG5-90	SNL Assembly	C2-MO	90°	≤20
SG6-0	SNL Assembly	A-MO	0°	≤20
SG7-0	SNL Assembly	B-MO	0°	≤20
SG8-0	SNL Assembly	C1-LP	0°	≤20
SG8-90	SNL Assembly	C1-LP	90°	≤20
SG8-225	SNL Assembly	C1-LP	225°	≤20
SG9-0	SNL Assembly	C2-LP	0°	≤20
SG9-90	SNL Assembly	C2-LP	90°	≤20
SG10-0	ENSA Assembly	C3-Left	0°	≤20
SG11-0	ENSA Assembly	C1-Left	0°	≤20
SG12-0	ENSA Assembly	C2-Left	0°	25
SG13-0	ENSA Assembly	A-Left	0°	83
SG14-0	ENSA Assembly	B´-Left	0°	85
SG15-0	ENSA Assembly	B-Left	0°	86
SG16-0	ENSA Assembly	C3-Center	0°	≤20
SG17-0	ENSA Assembly	C1-Center	0°	≤20
SG18-0	ENSA Assembly	C2-Center	0°	≤20
SG19-0	ENSA Assembly	A-Center	0°	65
SG20-0	ENSA Assembly	B´-Center	0°	65
SG21-0	ENSA Assembly	B-Center	0°	70
SG22-0	ENSA Assembly	C3-Center	0°	≤20
SG23-0	ENSA Assembly	C1-Center	0°	≤20
SG24-0	ENSA Assembly	C2-Center	0°	≤20
SG25-0	ENSA Assembly	A-Center	0°	65
SG26-0	ENSA Assembly	B´-Center	0°	70
SG27-0	ENSA Assembly	B-Center	0°	85
SG28-0	Korean Assembly	C1-Center	0°	≤20

5.2.3 Ship 1 from Santander to Zeebrugge

Table 5-12. Ship 1 Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Maximum Value (g)
A1Z	SNL Assembly	0˚	C3	≤0.3
A2Z	SNL Assembly	0˚	C1	≤0.3
A3Z	SNL Assembly	0˚	C2	≤0.3
A4Z	SNL Assembly	0˚	A	≤0.3
A5Z	SNL Assembly	0˚	B	≤0.3
A6Z	ENSA Assembly	0˚	C3	-735*
A7Z	ENSA Assembly	0˚	C1	≤0.3
A8Z	ENSA Assembly	0˚	C2	≤0.3
A9Z	ENSA Assembly	0˚	A	≤0.3
A10Z	ENSA Assembly	0˚	B	≤0.3
A11Z	Korean Assembly	0˚	C1	≤0.3
A12Y	Korean Assembly	0˚	Top Nozzle	≤0.3
A12Z	Korean Assembly	0˚	Top Nozzle	≤0.3
A13X	Cask Basket	0˚	A	≤0.3***
A13Y	Cask Basket	0˚	A	≤0.3
A13Z	Cask Basket	0˚	A	≤0.3
~~A14X~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Suspect****~~
A14Y	Cask Basket	135˚	1	≤0.3
~~A14Z~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0˚	Top Base	≤0.3
A15Y	Cask Body	0˚	Top Base	≤0.3
A15Z	Cask Body	0˚	Top Base	≤0.3
A16X	Cask Body	0˚	Top Closure	≤0.3
A16Y	Cask Body	0˚	Top Closure	≤0.3
A16Z	Cask Body	0˚	Top Closure	≤0.3
A17X	Cask Cradle	0˚	Cradle Rear	≤0.3
A17Y	Cask Cradle	0˚	Cradle Rear	≤0.3
A17Z	Cask Cradle	0˚	Cradle Rear	≤0.3
A18X	Cask Cradle	0˚	Cradle Front	≤0.3
A18Y	Cask Cradle	0˚	Cradle Front	≤0.3
A18Z	Cask Cradle	0˚	Cradle Front	≤0.3
A19X	Transporter	0˚	Transport Rear	0.42**
A19Y	Transporter	0˚	Transport Rear	0.38**
A19Z	Transporter	0˚	Transport Rear	0.6**
A20X	Transporter	0˚	Transport Center	0.3**
A20Y	Transporter	0˚	Transport Center	≤0.3
A20Z	Transporter	0˚	Transport Center	0.41**
A21X	Transporter	0˚	Transport Front	0.47**
A21Y	Transporter	0˚	Transport Front	≤0.g
A21Z	Transporter	0˚	Transport Front	0.86**

- * Intermittent data response, wiring problem, data not valid at that measurement time
- ** Acceleration peak at 15,000 to 25,000 seconds
- *** Data contains large measurement drift

  **** Data contains high noise floor

Table 5-13. Ship 1 Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Maximum Value (με)
SG1-0	SNL Assembly	C1-LR	0°	≤20
SG1-90	SNL Assembly	C1-LR	90°	≤20
SG1-225	SNL Assembly	C1-LR	225°	≤20
SG2-0	SNL Assembly	C2-LR	0°	≤20
SG2-90	SNL Assembly	C2-LR	90°	≤20
SG3-0	SNL Assembly	A-LR	0°	≤20
SG4-0	SNL Assembly	C1-MO	0°	≤20
SG4-90	SNL Assembly	C1-MO	90°	≤20
SG4-225	SNL Assembly	C1-MO	225°	≤20
SG5-0	SNL Assembly	C2-MO	0°	≤20
SG5-90	SNL Assembly	C2-MO	90°	≤20
SG6-0	SNL Assembly	A-MO	0°	≤20
SG7-0	SNL Assembly	B-MO	0°	≤20
SG8-0	SNL Assembly	C1-LP	0°	≤20
SG8-90	SNL Assembly	C1-LP	90°	≤20
SG8-225	SNL Assembly	C1-LP	225°	≤20
SG9-0	SNL Assembly	C2-LP	0°	≤20
SG9-90	SNL Assembly	C2-LP	90°	≤20
SG10-0	ENSA Assembly	C3-Left	0°	≤20
SG11-0	ENSA Assembly	C1-Left	0°	≤20
SG12-0	ENSA Assembly	C2-Left	0°	≤20
SG13-0	ENSA Assembly	A-Left	0°	≤20
SG14-0	ENSA Assembly	B´-Left	0°	≤20
SG15-0	ENSA Assembly	B-Left	0°	≤20
SG16-0	ENSA Assembly	C3-Center	0°	≤20
SG17-0	ENSA Assembly	C1-Center	0°	≤20
SG18-0	ENSA Assembly	C2-Center	0°	≤20
SG19-0	ENSA Assembly	A-Center	0°	≤20
SG20-0	ENSA Assembly	B´-Center	0°	≤20
SG21-0	ENSA Assembly	B-Center	0°	≤20
SG22-0	ENSA Assembly	C3-Center	0°	≤20
SG23-0	ENSA Assembly	C1-Center	0°	≤20
SG24-0	ENSA Assembly	C2-Center	0°	≤20
SG25-0	ENSA Assembly	A-Center	0°	≤20
SG26-0	ENSA Assembly	B´-Center	0°	≤20
SG27-0	ENSA Assembly	B-Center	0°	≤20
SG28-0	Korean Assembly	C1-Center	0°	≤20

5.2.4 Ship 2 Zeebrugge to Baltimore

Table 5-14. Ship 2 Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Maximum Value (g)
A1Z	SNL Assembly	0°	C3	≤0.2
A2Z	SNL Assembly	0°	C1	≤0.2
A3Z	SNL Assembly	0°	C2	≤0.2
A4Z	SNL Assembly	0°	A	≤0.2
A5Z	SNL Assembly	0°	B	≤0.2
A6Z	ENSA Assembly	0°	C3	≤0.2
A7Z	ENSA Assembly	0°	C1	≤0.2
A8Z	ENSA Assembly	0°	C2	≤0.2
~~A9Z~~	~~ENSA Assembly~~	~~0°~~	~~A~~	~~Shorted~~
A10Z	ENSA Assembly	0°	B	0.22
A11Z	Korean Assembly	0°	C1	≤0.2
A12Y	Korean Assembly	0°	Top Nozzle	≤0.2
A12Z	Korean Assembly	0°	Top Nozzle	≤0.2
A13X	Cask Basket	0°	A	≤0.2
A13Y	Cask Basket	0°	A	≤0.2
A13Z	Cask Basket	0°	A	≤0.2
~~A14X~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Suspect**~~
A14Y	Cask Basket	135°	1	≤0.2
~~A14Z~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0°	Top Base	≤0.2
A15Y	Cask Body	0°	Top Base	≤0.2
A15Z	Cask Body	0°	Top Base	≤0.2
A16X	Cask Body	0°	Top Closure	≤0.2
A16Y	Cask Body	0°	Top Closure	≤0.2
A16Z	Cask Body	0°	Top Closure	≤0.2
A17X	Cask Cradle	0°	Cradle Rear	≤0.2
A17Y	Cask Cradle	0°	Cradle Rear	≤0.2
A17Z	Cask Cradle	0°	Cradle Rear	≤0.2
A18X	Cask Cradle	0°	Cradle Front	≤0.2
A18Y	Cask Cradle	0°	Cradle Front	≤0.2
A18Z	Cask Cradle	0°	Cradle Front	≤0.2
A19X	Transporter	0°	Transport Rear	≤0.2
A19Y	Transporter	0°	Transport Rear	≤0.2
A19Z	Transporter	0°	Transport Rear	0.38
A20X	Transporter	0°	Transport Center	≤0.2
A20Y	Transporter	0°	Transport Center	≤0.2
A20Z	Transporter	0°	Transport Center	≤0.2
A21X	Transporter	0°	Transport Front	≤0.2
A21Y	Transporter	0°	Transport Front	≤0.2
A21Z	Transporter	0°	Transport Front	0.28

* Data contains large measurement drift to 300,000 seconds

** Data contains high noise floor

Table 5-15. Ship 2 Test Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Maximum Value (με)
SG1-0	SNL Assembly	C1-LR	0°	≤20
SG1-90	SNL Assembly	C1-LR	90°	≤20
SG1-225	SNL Assembly	C1-LR	225°	≤20
SG2-0	SNL Assembly	C2-LR	0°	≤20
SG2-90	SNL Assembly	C2-LR	90°	≤20
SG3-0	SNL Assembly	A-LR	0°	≤20
SG4-0	SNL Assembly	C1-MO	0°	≤20
SG4-90	SNL Assembly	C1-MO	90°	≤20
SG4-225	SNL Assembly	C1-MO	225°	≤20
SG5-0	SNL Assembly	C2-MO	0°	≤20
SG5-90	SNL Assembly	C2-MO	90°	≤20
SG6-0	SNL Assembly	A-MO	0°	≤20
SG7-0	SNL Assembly	B-MO	0°	≤20
SG8-0	SNL Assembly	C1-LP	0°	≤20
SG8-90	SNL Assembly	C1-LP	90°	≤20
SG8-225	SNL Assembly	C1-LP	225°	≤20
SG9-0	SNL Assembly	C2-LP	0°	≤20
SG9-90	SNL Assembly	C2-LP	90°	≤20
SG10-0	ENSA Assembly	C3-Left	0°	≤20
SG11-0	ENSA Assembly	C1-Left	0°	≤20
SG12-0	ENSA Assembly	C2-Left	0°	≤20
SG13-0	ENSA Assembly	A-Left	0°	≤20
SG14-0	ENSA Assembly	B´-Left	0°	≤20
SG15-0	ENSA Assembly	B-Left	0°	≤20
SG16-0	ENSA Assembly	C3-Center	0°	≤20
SG17-0	ENSA Assembly	C1-Center	0°	≤20
SG18-0	ENSA Assembly	C2-Center	0°	≤20
SG19-0	ENSA Assembly	A-Center	0°	≤20
SG20-0	ENSA Assembly	B´-Center	0°	≤20
SG21-0	ENSA Assembly	B-Center	0°	≤20
SG22-0	ENSA Assembly	C3-Center	0°	≤20
SG23-0	ENSA Assembly	C1-Center	0°	≤20
SG24-0	ENSA Assembly	C2-Center	0°	≤20
SG25-0	ENSA Assembly	A-Center	0°	≤20
SG26-0	ENSA Assembly	B´-Center	0°	≤20
SG27-0	ENSA Assembly	B-Center	0°	≤20
SG28-0	Korean Assembly	C1-Center	0°	≤20

5.2.5 Rail No. 1 Baltimore to Avondale, Colorado

Table 5-16. Rail 1 Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Maximum Value (g)
A1Z	SNL Assembly	0˚	C3	0.45
A2Z	SNL Assembly	0˚	C1	0.80
A3Z	SNL Assembly	0˚	C2	0.65
A4Z	SNL Assembly	0˚	A	0.90
A5Z	SNL Assembly	0˚	B	1.20
A6Z	ENSA Assembly	0˚	C3	0.80
A7Z	ENSA Assembly	0˚	C1	1.30
A8Z	ENSA Assembly	0˚	C2	0.88
A9Z	ENSA Assembly	0˚	A	Shorted
A10Z	ENSA Assembly	0˚	B	0.55
A11Z	Korean Assembly	0˚	C1	0.80
A12Y	Korean Assembly	0˚	Top Nozzle	0.52
A12Z	Korean Assembly	0˚	Top Nozzle	0.60
A13X	Cask Basket	0˚	A	0.40*
A13Y	Cask Basket	0˚	A	0.30
A13Z	Cask Basket	0˚	A	0.30
~~A14X~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Suspect**~~
A14Y	Cask Basket	135˚	1	0.30
~~A14Z~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0˚	Top Base	0.38
A15Y	Cask Body	0˚	Top Base	0.22
A15Z	Cask Body	0˚	Top Base	0.28
A16X	Cask Body	0˚	Top Closure	0.35
A16Y	Cask Body	0˚	Top Closure	0.37
A16Z	Cask Body	0˚	Top Closure	0.42
A17X	Cask Cradle	0˚	Cradle Rear	0.65
A17Y	Cask Cradle	0˚	Cradle Rear	0.48
A17Z	Cask Cradle	0˚	Cradle Rear	0.68
A18X	Cask Cradle	0˚	Cradle Front	0.61
A18Y	Cask Cradle	0˚	Cradle Front	0.55
A18Z	Cask Cradle	0˚	Cradle Front	0.70
A19X	Transporter	0˚	Transport Rear	0.82
A19Y	Transporter	0˚	Transport Rear	1.60
A19Z	Transporter	0˚	Transport Rear	6.80
A20X	Transporter	0˚	Transport Center	0.40
A20Y	Transporter	0˚	Transport Center	1.80
A20Z	Transporter	0˚	Transport Center	3.30
A21X	Transporter	0˚	Transport Front	0.89
A21Y	Transporter	0˚	Transport Front	1.20
A21Z	Transporter	0˚	Transport Front	8.40

* Data contains large measurement drift

** Data contains high noise floor

Table 5-17. Rail No. 1 Test Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Maximum Value (με)
SG1-0	SNL Assembly	C1-LR	0°	32
SG1-90	SNL Assembly	C1-LR	90°	≤30
SG1-225	SNL Assembly	C1-LR	225°	≤30
SG2-0	SNL Assembly	C2-LR	0°	≤30
SG2-90	SNL Assembly	C2-LR	90°	≤30
SG3-0	SNL Assembly	A-LR	0°	≤30
SG4-0	SNL Assembly	C1-MO	0°	≤30
SG4-90	SNL Assembly	C1-MO	90°	≤30
SG4-225	SNL Assembly	C1-MO	225°	≤30
SG5-0	SNL Assembly	C2-MO	0°	≤30
SG5-90	SNL Assembly	C2-MO	90°	≤30
SG6-0	SNL Assembly	A-MO	0°	≤30
SG7-0	SNL Assembly	B-MO	0°	32μ
SG8-0	SNL Assembly	C1-LP	0°	32
SG8-90	SNL Assembly	C1-LP	90°	≤30
SG8-225	SNL Assembly	C1-LP	225°	32
SG9-0	SNL Assembly	C2-LP	0°	≤30
SG9-90	SNL Assembly	C2-LP	90°	≤30
SG10-0	ENSA Assembly	C3-Left	0°	≤30
SG11-0	ENSA Assembly	C1-Left	0°	≤30
SG12-0	ENSA Assembly	C2-Left	0°	≤30
SG13-0	ENSA Assembly	A-Left	0°	≤30
SG14-0	ENSA Assembly	B´-Left	0°	38
SG15-0	ENSA Assembly	B-Left	0°	36
SG16-0	ENSA Assembly	C3-Center	0°	≤30
SG17-0	ENSA Assembly	C1-Center	0°	≤30
SG18-0	ENSA Assembly	C2-Center	0°	≤30
SG19-0	ENSA Assembly	A-Center	0°	≤30
SG20-0	ENSA Assembly	B´-Center	0°	≤30
SG21-0	ENSA Assembly	B-Center	0°	≤30
SG22-0	ENSA Assembly	C3-Center	0°	≤30
SG23-0	ENSA Assembly	C1-Center	0°	≤30
SG24-0	ENSA Assembly	C2-Center	0°	≤30
SG25-0	ENSA Assembly	A-Center	0°	35
SG26-0	ENSA Assembly	B´-Center	0°	38
SG27-0	ENSA Assembly	B-Center	0°	38
SG28-0	Korean Assembly	C1-Center	0°	47.

5.2.6 Heavy Haul Truck Test between 33,880 to 33,940 Seconds

Table 5-18. Heavy Haul Truck 33,880-33,940 seconds Accelerometer Data Summary

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Position	Maximum Value (g)
A1Z	SNL Assembly	0°	C3	≤0.1
A2Z	SNL Assembly	0°	C1	0.1/-0.1
A3Z	SNL Assembly	0°	C2	≤0.1
A4Z	SNL Assembly	0°	A	0.13/-0.14
A5Z	SNL Assembly	0°	B	0.18/-0.16
~~A6Z~~	~~ENSA Assembly~~	~~0°~~	~~C3~~	~~Open~~
A7Z	ENSA Assembly	0°	C1	0.19/-0.16
A8Z	ENSA Assembly	0°	C2	0.9/-.86
A9Z	ENSA Assembly	0°	A	0.6/-0.8
A10Z	ENSA Assembly	0°	B	0.09/-0.13
A11Z	Korean Assembly	0°	C1	0.15/-0.18
A12Y	Korean Assembly	0°	Top Nozzle	0.16/-0.12
A12Z	Korean Assembly	0°	Top Nozzle	0.1/-0.09
A13X	Cask Basket	0°	A	≤0.1*
A13Y	Cask Basket	0°	A	0.14/-0.11
A13Z	Cask Basket	0°	A	≤0.1
~~A14X~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Suspect**~~
A14Y	Cask Basket	135°	1	≤0.1
~~A14Z~~	~~Cask Basket~~	~~135°~~	~~1~~	~~Disconnected~~
A15X	Cask Body	0°	Top Base	≤0.1
A15Y	Cask Body	0°	Top Base	≤0.1
A15Z	Cask Body	0°	Top Base	≤0.1
A16X	Cask Body	0°	Top Closure	≤0.1
A16Y	Cask Body	0°	Top Closure	≤0.1
A16Z	Cask Body	0°	Top Closure	≤0.1
A17X	Cask Cradle	0°	Cradle Rear	≤0.1
A17Y	Cask Cradle	0°	Cradle Rear	≤0.1
A17Z	Cask Cradle	0°	Cradle Rear	≤0.1
A18X	Cask Cradle	0°	Cradle Front	≤0.1
A18Y	Cask Cradle	0°	Cradle Front	≤0.1
A18Z	Cask Cradle	0°	Cradle Front	≤0.1
A19X	Transporter	0°	Transport Rear	0.08/-0.11
A19Y	Transporter	0°	Transport Rear	0.16/-0.21
A19Z	Transporter	0°	Transport Rear	0.75/-0.8
A20X	Transporter	0°	Transport Center	≤0.1
A20Y	Transporter	0°	Transport Center	0.12/-0.15
A20Z	Transporter	0°	Transport Center	0.52/-0.62
A21X	Transporter	0°	Transport Front	≤0.1
A21Y	Transporter	0°	Transport Front	0.15/-0.27
A21Z	Transporter	0°	Transport Front	0.83/-0.72

* Data contains large measurement drift

** Data contains high noise floor

Table 5-19. Heavy Haul Truck Test 33,880-33,940 Seconds Strain Gauge Data Summary

Strain Gauge Designation	Location	Assembly Location	Circumferential Location on Rod	Maximum Value (με)
SG1-0	SNL Assembly	C1-LR	0°	≤10
SG1-90	SNL Assembly	C1-LR	90°	≤10
SG1-225	SNL Assembly	C1-LR	225°	≤10
SG2-0	SNL Assembly	C2-LR	0°	≤10
SG2-90	SNL Assembly	C2-LR	90°	≤10
SG3-0	SNL Assembly	A-LR	0°	17/-17
SG4-0	SNL Assembly	C1-MO	0°	≤10
SG4-90	SNL Assembly	C1-MO	90°	≤10
SG4-225	SNL Assembly	C1-MO	225°	≤10
SG5-0	SNL Assembly	C2-MO	0°	≤10
SG5-90	SNL Assembly	C2-MO	90°	≤10
SG6-0	SNL Assembly	A-MO	0°	10/-11
SG7-0	SNL Assembly	B-MO	0°	15/-17
SG8-0	SNL Assembly	C1-LP	0°	≤10
SG8-90	SNL Assembly	C1-LP	90°	≤10
SG8-225	SNL Assembly	C1-LP	225°	≤10
SG9-0	SNL Assembly	C2-LP	0°	≤10
SG9-90	SNL Assembly	C2-LP	90°	8/-12
SG10-0	ENSA Assembly	C3-Left	0°	≤10
SG11-0	ENSA Assembly	C1-Left	0°	14/-16
SG12-0	ENSA Assembly	C2-Left	0°	23/-25
SG13-0	ENSA Assembly	A-Left	0°	72/-80
SG14-0	ENSA Assembly	B´-Left	0°	73/-83
SG15-0	ENSA Assembly	B-Left	0°	86/-97
SG16-0	ENSA Assembly	C3-Center	0°	≤10
SG17-0	ENSA Assembly	C1-Center	0°	9/-11
SG18-0	ENSA Assembly	C2-Center	0°	12/-14
SG19-0	ENSA Assembly	A-Center	0°	65/-73
SG20-0	ENSA Assembly	B´-Center	0°	65/-73
SG21-0	ENSA Assembly	B-Center	0°	65/-70
SG22-0	ENSA Assembly	C3-Center	0°	≤10
SG23-0	ENSA Assembly	C1-Center	0°	12/-14
SG24-0	ENSA Assembly	C2-Center	0°	17/-20
SG25-0	ENSA Assembly	A-Center	0°	61/-69
SG26-0	ENSA Assembly	B´-Center	0°	68/-78
SG27-0	ENSA Assembly	B-Center	0°	83/-95
SG28-0	Korean Assembly	C1-Center	0°	16/-18

5.2.7 Rail No. 1 Test - Typical Shock Event - Accelerometer Data in Vertical Path from Railcar to Rods

Table 5-20. Accelerometer Data in Vertical Path from Railcar to Rods

Accelerometer Designation	Location	Circumferential Location on Rod or in Cask	Rod Axial Position	Maximum Value (g)
A2Z	SNL Assembly	0˚	C1	0.80
A7Z	ENSA Assembly	0˚	C1	1.30
A11Z	Korean Assembly	0˚	C1	0.80
A12Z	Korean Assembly	0˚	Top Nozzle	0.60
A13Z	Cask Basket	0˚	A	0.30
~~A14Z~~	~~Cask Basket~~	~~135˚~~	~~1~~	~~Disconnected~~
A15Z	Cask Body	0˚	Top Base	0.28
A16Z	Cask Body	0˚	Top Closure	0.42
A17Z	Cask Cradle	0˚	Cradle Rear	0.68
A18Z	Cask Cradle	0˚	Cradle Front	0.70
A19Z	Transporter	0˚	Railcar Rear	6.80
A20Z	Transporter	0˚	Railcar Center	3.30
A21Z	Transporter	0˚	Railcar Front	8.40

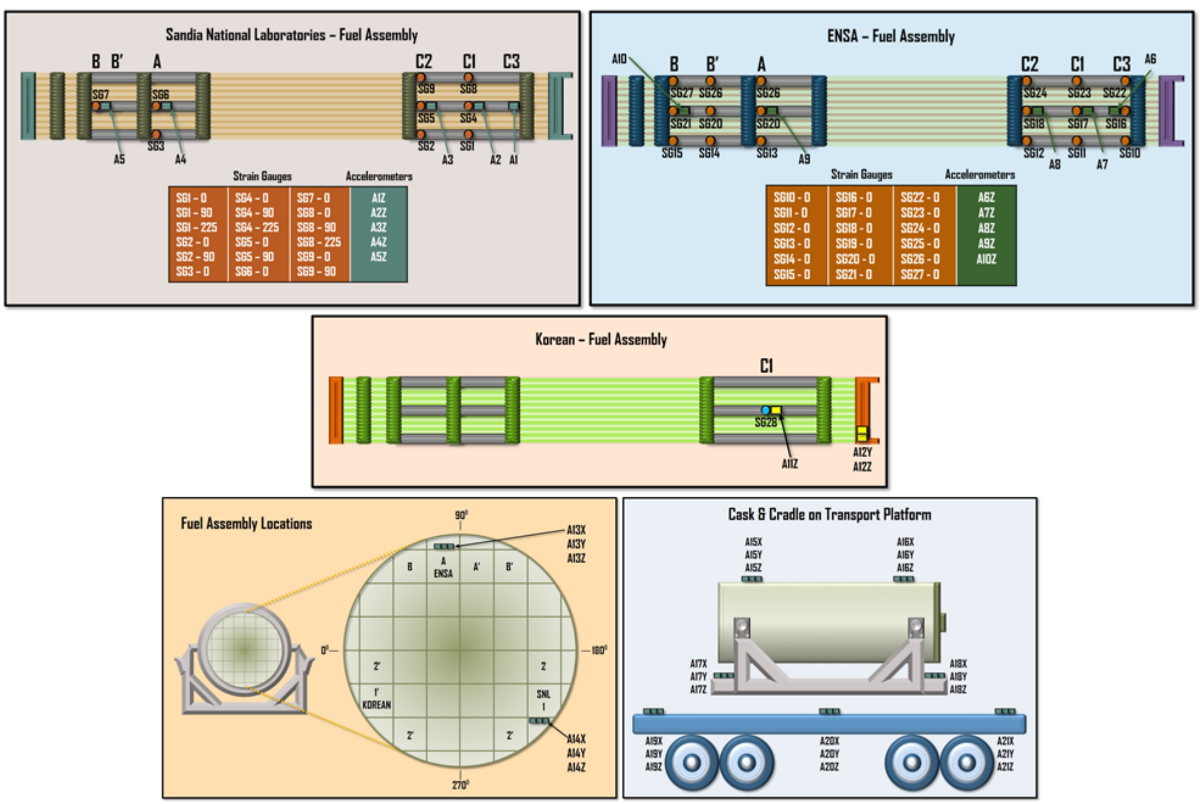


Figure 5-3. Location of accelerometers for reference for Table 5-20. The acceleration data in the table suggests that the accelerations recorded on the railcar were attenuated at the cradle, cask basket, and rods.

6. ARGONNE NATIONAL LABORATORY TRAVELER SYSTEM

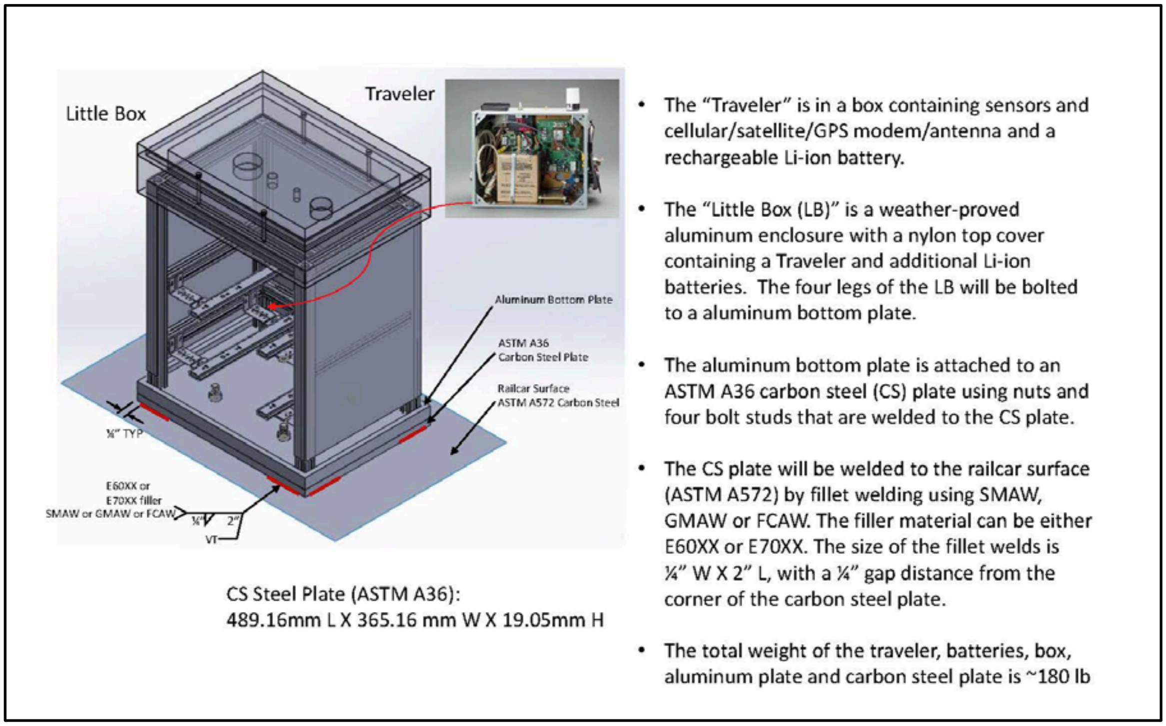


Figure 6-1. Details of ANL Traveler Box and sensors.

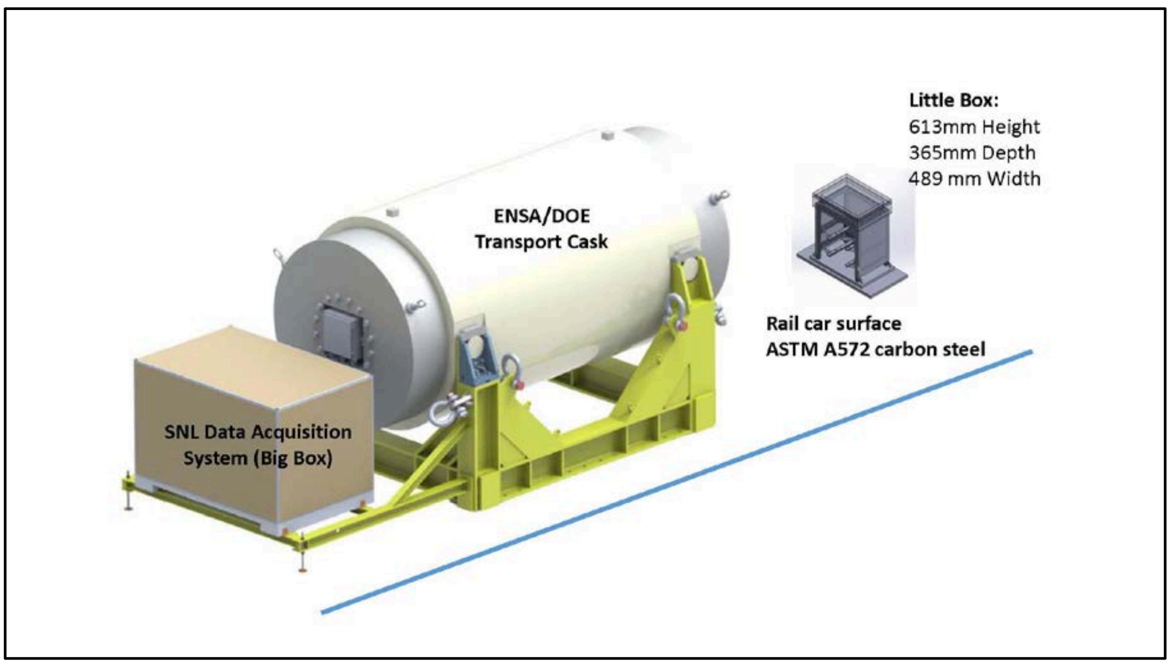


Figure 6-2. Relative position of Traveler with respect to cask on railcar.

(a)

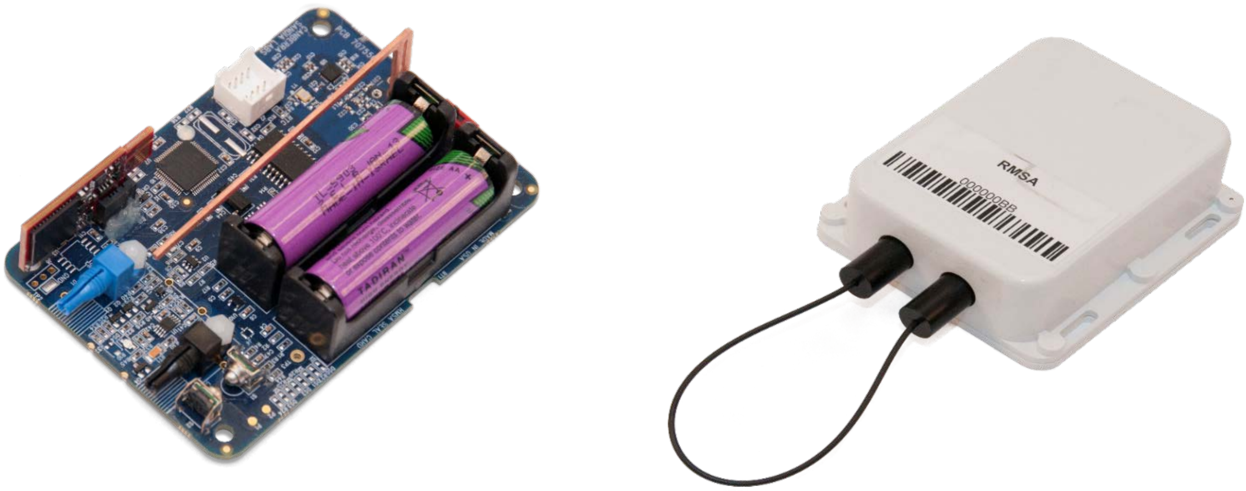
(b)

(c) 

Figure 6-3. Views of ANL Traveler box on railcar (white-topped gray box).

7. CHAIN OF CUSTODY ITEM MONITOR (CoCIM)

The Chain of Custody Item Monitor (CoCIM) is a Sandia-developed containment technology designed to securely monitor items for security, nuclear safeguards, and treaty applications in a low-cost and minimally-intrusive manner. The CoCIM maintains continuity of knowledge on nuclear materials, treaty accountable items, cabinets, doors, and other items of interest. It works by attaching a fiber optic loop to the item and actively monitors the loop and immediately creates a timestamped message of any change in loop status (which may constitute unauthorized access to the item). The CoCIM incorporates tamper-indicating features and uses public key cryptography for digitally signing and verifying message authenticity. There are three options for the CoCIM to communicate its data: 1) encrypted radio frequency (RF) communication, 2) short-range infrared communication, and 3) directly-connected wired communication (using a flush-mounted interface on the enclosure).

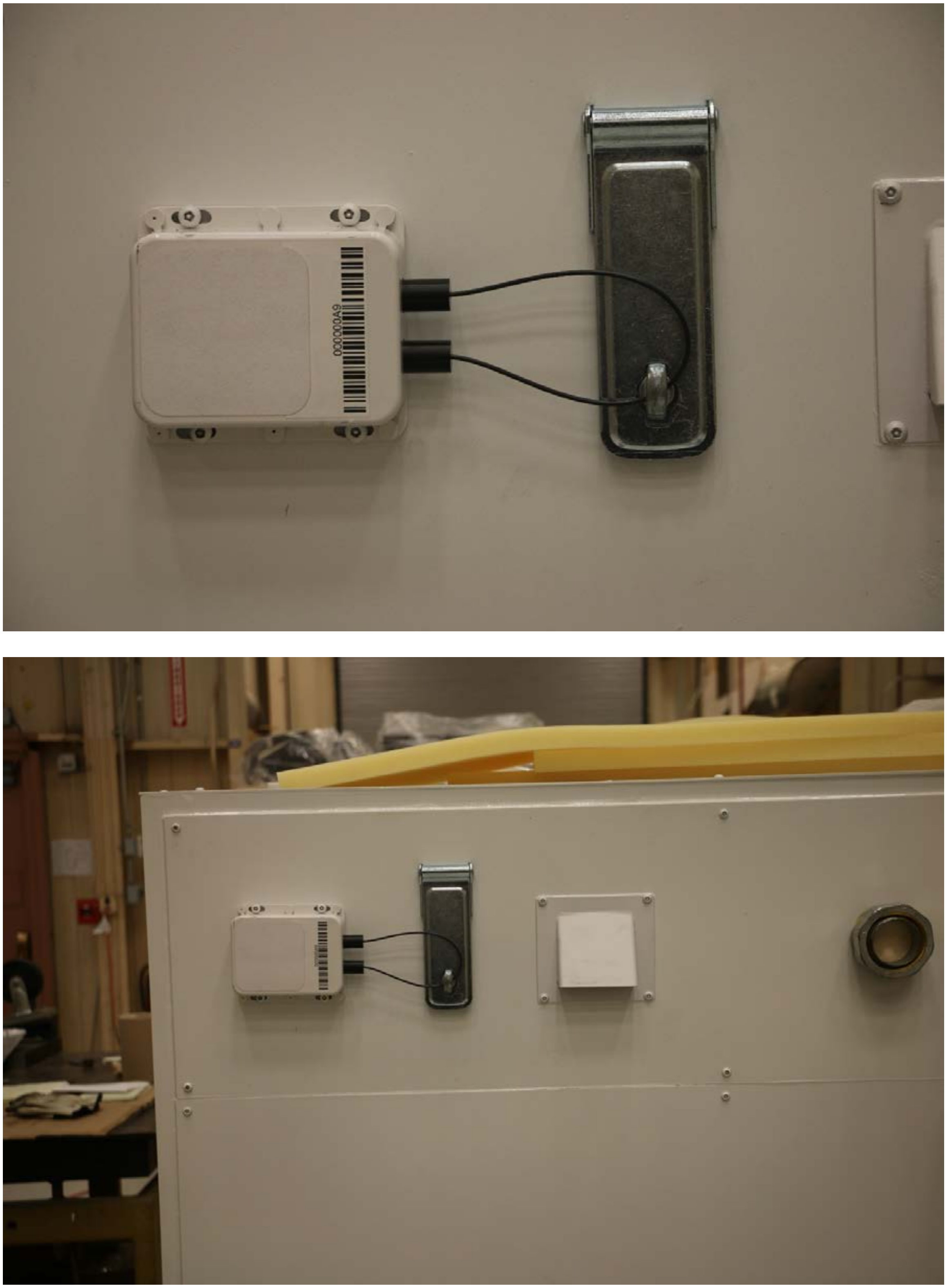


(a) (b)

Figure 7-1: (a) Electronics for RF CoCIM. (b) CoCIM Fiber Optic Loop Seal.

The CoCIM seal was used for the ENSA Cask Transport project to demonstrate maintenance of continuity of knowledge on the cask of SNF during transport. The fiber optic loop was applied to the back of the Instrumentation Box and attached to a surrogate lock hasp. If the CoCIM was opened during the transport, it will have securely record the event. The CoCIM was powered by 2 AA batteries, and did not require an external power source.

The RF version of the CoCIM was used, even though there were no RF base stations to receive messages; the CoCIM simply stored all its data internally until it can be downloaded at a later time after the Instrumentation Box is returned to Sandia National Laboratories from the Port of Baltimore. Upon return, the CoCIM data will be downloaded and analyzed. The ENSA transport exercise could lend evidence for the CoCIM as a valuable tool as a low-cost and minimally intrusive method to maintain continuity of knowledge for the transport of SNF.



(a)

(b)

Figure 7-2. CoCIM attached to dummy hasp.

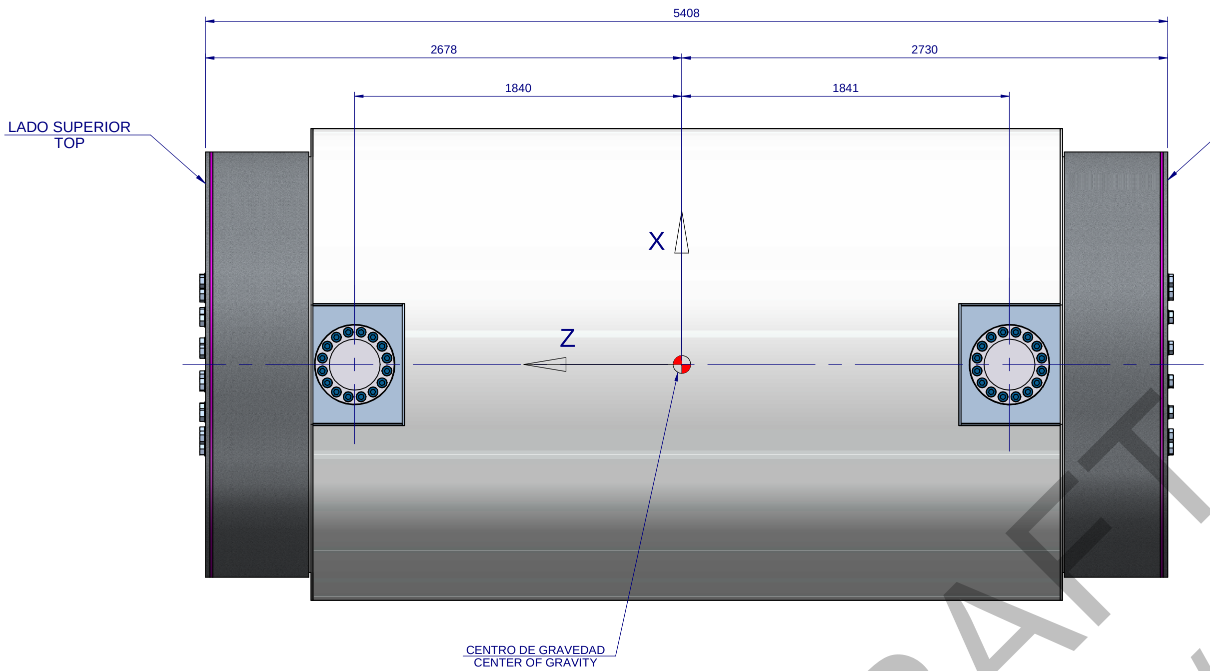
7.1 CoCIM: Disconnect Times

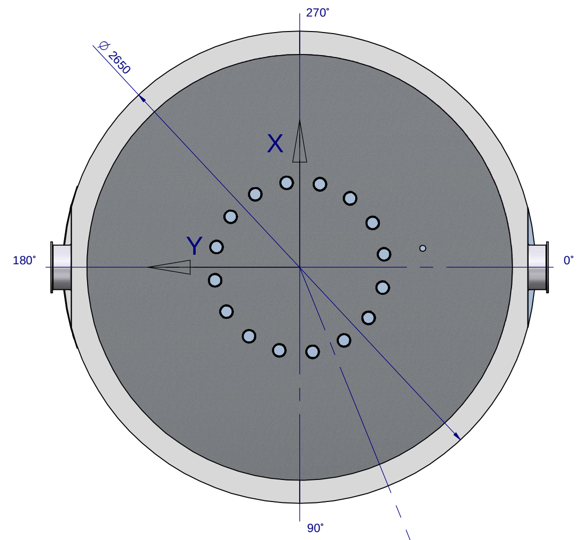
07:30 CET 8 June 2017
12:53 CET 12 June 2017
11:00 CET 19 June 2017
11:20 CET 29 June 2017
12:46 CET 3 July 2017

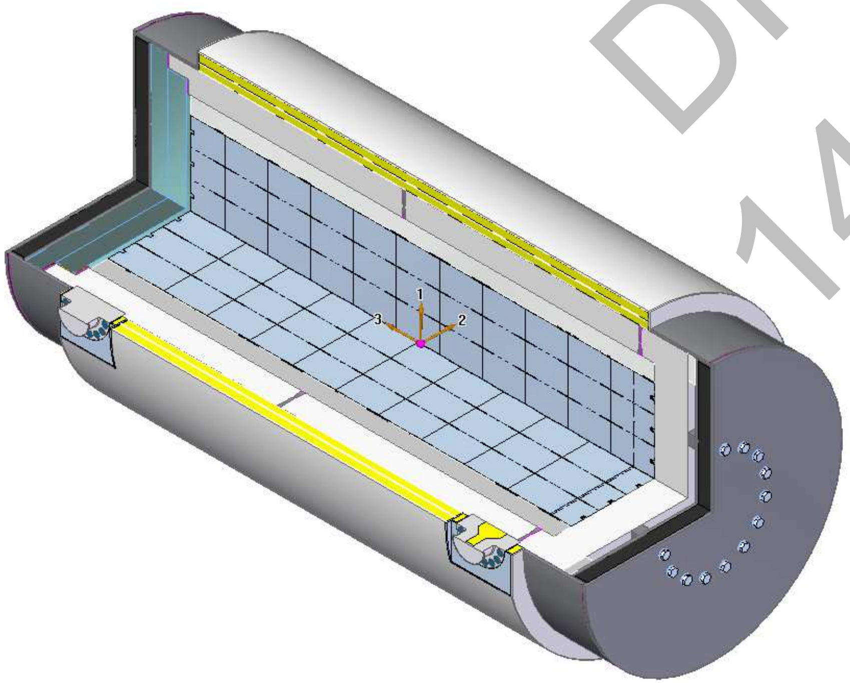
8. REFERENCES

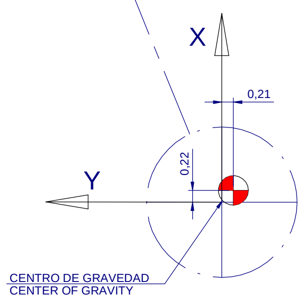
1. McConnell, et al., “Fuel Assembly Shaker Test for Determining Loads on a PWR Assembly under Surrogate Normal Conditions of Truck Transport,” FCRD-SFWST-2013-000190, Rev. 0.1, SAND2013-5210P, December 1, 2013.
2. McConnell, et al., “Normal Conditions of Transport Truck Test of a Surrogate Fuel Assembly,” FCRD-SFWST-2014-000066, Revision 0.1, SAND2014-20495, December 15, 2014.
3. McConnell, et al., “Surrogate Fuel Assembly Multi-Axis Shaker Tests to Simulate Normal Conditions of Rail and Truck Transport,” FCRD-UFRD-2015-00128, Rev. 1, SAND2016-4576, May 12, 2016.
4. McConnell, et al., “Test Plan for Rail-Cask Tests: Equipos Nucleares S.A. an US Department of Energy: Normal-Conditions of Transport Tests of Surrogate PWR Assemblies in an ENSA ENUN 32P Cask”, FCRD-UFD-2016-000067, September 15, 2016.
5. Hanson, et al., “Used Nuclear Fuel Storage and Transportation Data Gap Prioritization,” DRAFT FCRD-SFWST-2012-000109 (Draft), PNNL-21360.
6. American Association of Railroads, AAR Open Top Loading Rules Manual, 2010.

APPENDIX A: ENSA ENUN 32P CASK AND CRADLE DRAWINGS









Physical Properties Report

Mass (loaded with 32 FA and Impact Limiters)= 134205 kg

With respect to the Global Coordinate System

Mass Moments Of Inertia:

Ixx= 435397,909 kg-m^2
Iyy= 434577,050 kg-m^2
Izz= 116421,649 kg-m^2

Ixy= -18,872 kg-m^2
Ixz= 2,371 kg-m^2
Iyz= -0,873 kg-m^2

Principal Axes Orietation:

1= 1,00 0,02 0,00
2= -0,02 1,00 0,00
3= 0,00 0,00 1,00

With respect to the Principal Axes

Principle Moments Of Inertia:

I1= 435398,343 kg-m^2
I2= 434576,616 kg-m^2
I3= 116421,649 kg-m^2

Radii Of Gyration:

Rx= 1801,19 mm
Ry= 1799,49 mm
Rz= 931,39 mm

REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
04	-	-	-
03	-	-	-
02	-	-	-
01	-	-	-
00	PRIMERA EMISION / FIRST ISSUE	09/09/16	P. CEBALLOS

CLIENTE/CUSTOMER ***
PROYECTO/PROJECT **ENSAYO VIBRACIONES ENUN 32P**
ORDEN DEL CLIENTE/CUSTOMER ORDER ***
VALIDO PARA COMPONENTES/APPL. FOR THE COMPONENTS ***

DIBUJADO POR / DFTM:		REVISADO POR / CHECKED BY:		APROBADO POR / APPROVED BY:	
	FECHA/DATE		FECHA/DATE		FECHA/DATE
P. Design	25/05/16	P. Design	25/05/16	Stress Analysis	30/05/16

TITULO
TITLE
CENTRO DE GRAVEDAD Y MOMENTOS DE INERCIA
CONJUNTO TRANSPORTE (17x17)
CENTER OF GRAVITY AND MASS MOMENTS OF INERTIA
TRANSPORT ASSEMBLY (17x17)

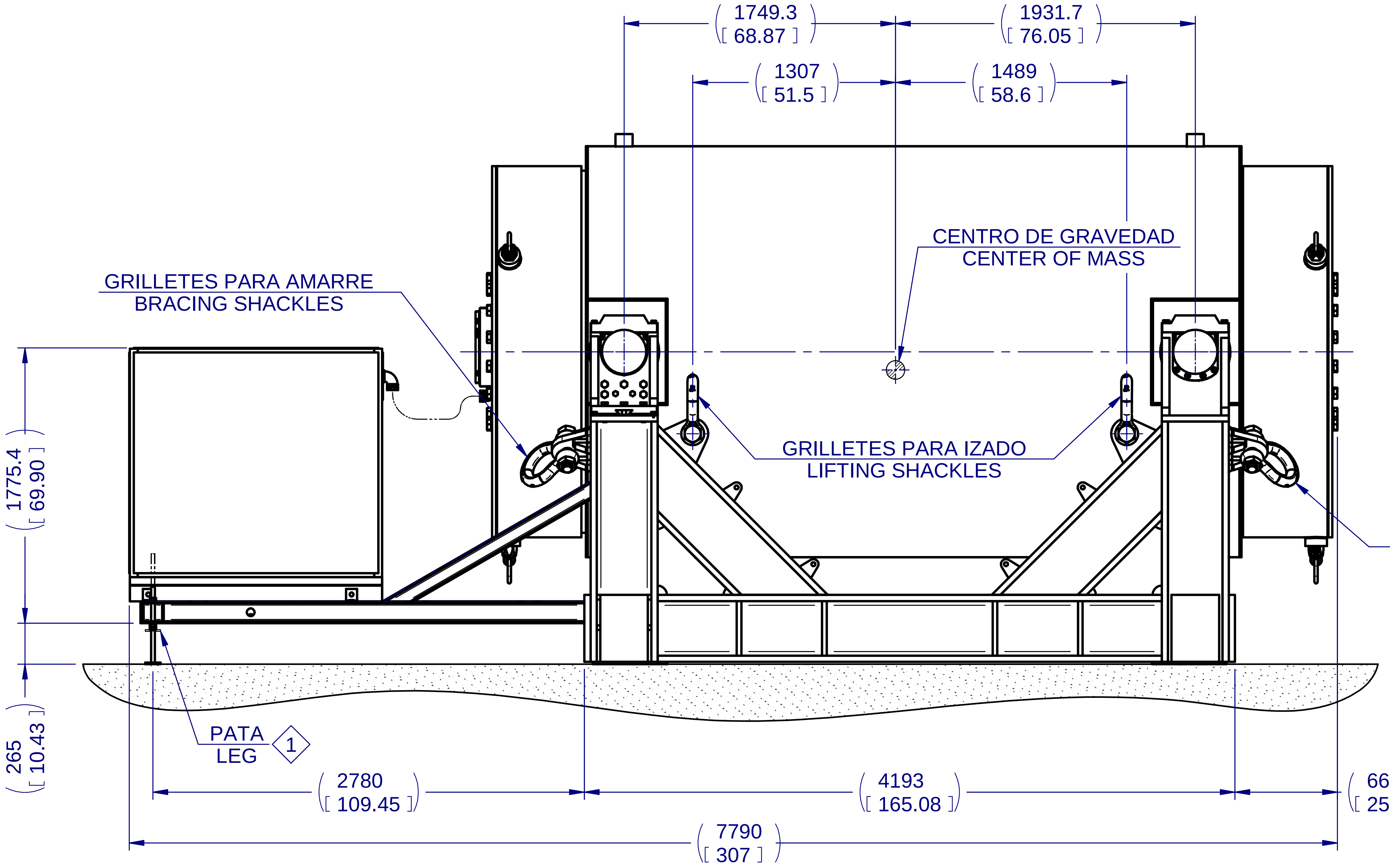
NUMERO DE PLANO / DRAWING NUMBER: 9293.SKT001
REV.: 00
HOJA / SHEET 1 DE / OF 1
ESCALA / SCALE
FORMATO / FORMAT A1
DOCUMENTO REFERENCIA-REF. DOCUMENT: CONTRATO 9231

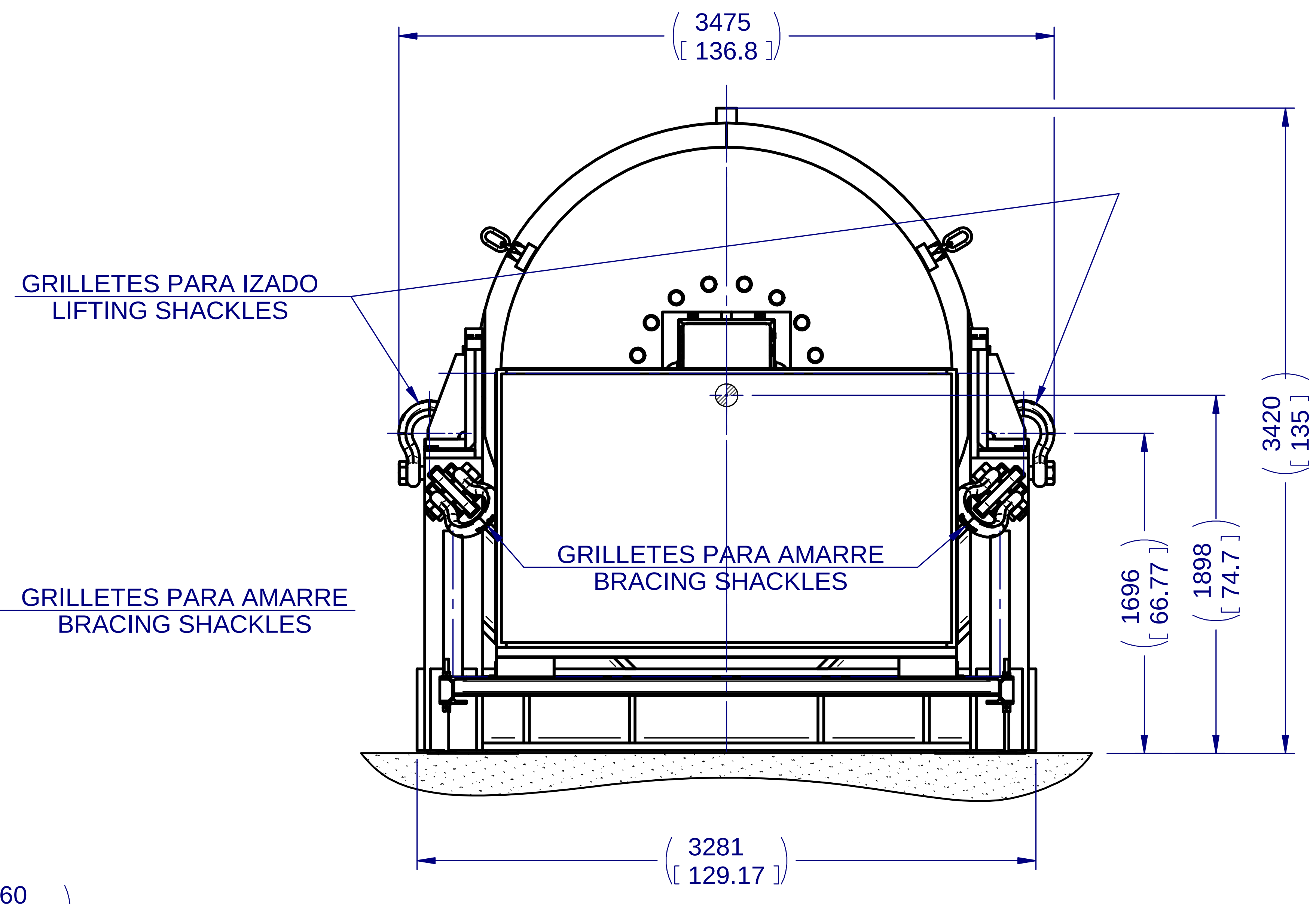
Ensa

INGENIERIA.
DISEÑO PRODUCTO.
ENGINEERING. PRODUCT DESIGN.

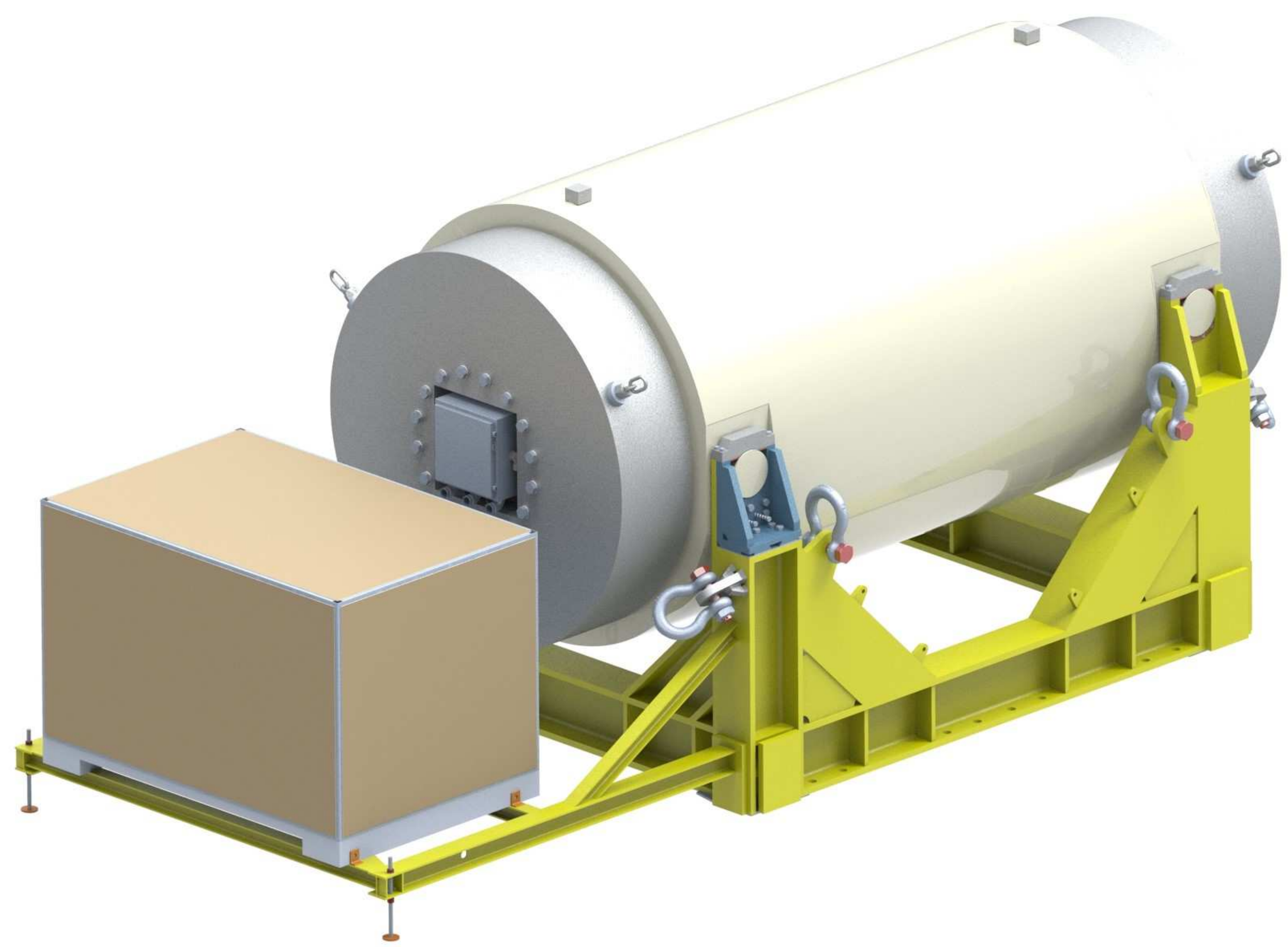
NOTAS/NOTES

1	ANTES DE EFECTUAR LA MANIOBRA DE ELEVACION DEL CONJUNTO, TENER LA PRECAUCION DE SUBIR LAS PATAS COMPLETAMENTE. PRIOR TO PERFORM THE ASSEBLY LIFT OPERATION, BE CAREFUL TO UP THE LEGS COMPLETELY.
2	EN LAS MANIOBRAS DE MOVIMIENTOS DEL CONJUNTO PRESTAR ATENCION PARA NO DAÑAR EL CUERPO EXTERIOR DEL CONTENEDOR. IN THE MOVEMENT OPERATIONS, BE CAREFUL TO AVOID DAMAGE ON THE OUTER BODY OF THE CASK.





PESO TOTAL APROXIMADO: 149.000 kg.
TOTAL APPROXIMATE WEIGHT: 328,500 lb.



REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
04	-	-	-
03	-	-	-
02	-	-	-
01	-	-	-
00	-	29/03/2017	P. CEBALLOS

CLIENTE/CUSTOMER N/A

PROYECTO/PROJECT DETERMINACION VIBRACIONES EN BARRA DE COMBUSTIBLE DURANTE EL TRANSPORTE EN CONTENEDOR ENUN 32P

ORDEN DEL CLIENTE/CUSTOMER ORDER ***

VALIDO PARA COMPONENTES/APPL. FOR THE COMPONENTS

DIBUJADO POR / DFTM:		REVISADO POR / CHECKED BY:		APROBADO POR / APPROVED BY:	
P. Ceballos	FECHA/DATE	L. Demetrio	FECHA/DATE	R. G. Garmendia	FECHA/DATE
P. Design	31/03/17	P. Design	31/03/17	P. Engineer	31/03/17

TITULO
TITLE

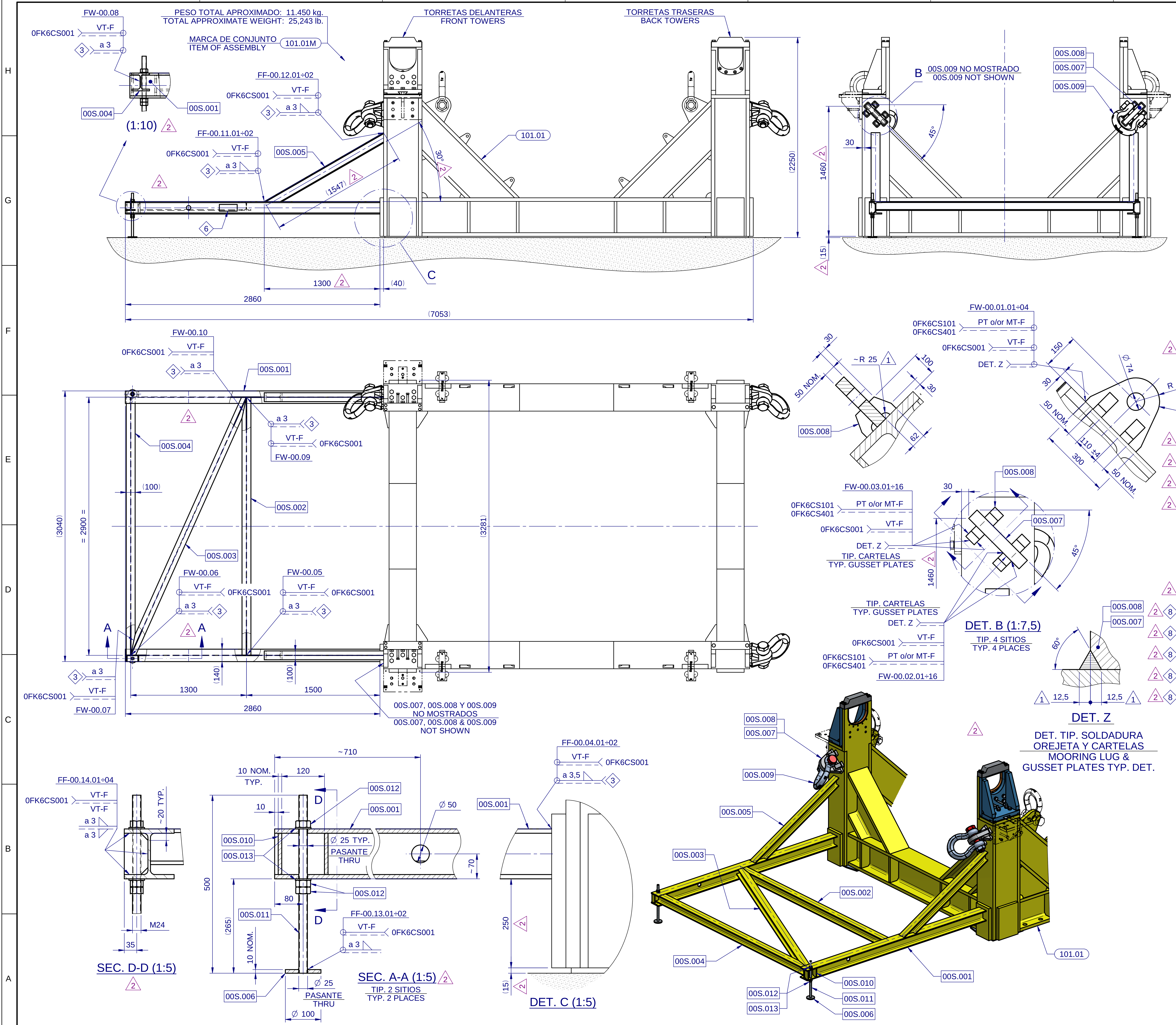
DIMENSIONES GENERALES PARA TRANSPORTE
GENERAL DIMENSIONS FOR TRANSPORT

NUMERO DE PLANO / DRAWING NUMBER	REV.	HOJA SHEET	DE OF	ESCALA SCALE	FORMATO FORMAT
9293.00S1	00	1	1	1:30	A2

DOCUMENTO REFERENCIA-REF. DOCUMENT

ensa

INGENIERIA.
DISEÑO PRODUCTO.
ENGINEERING. PRODUCT DESIGN.



NOTAS / NOTES

1. MATAR ARISTAS VIVAS Y ELIMINAR REBABAS.
BREAK ALL SHARP EDGES AND REMOVE ALL BURRS.
2. SERAN TOLERANCIAS ACEPTABLES, CUANDO NO SE INDIQUEN OTRAS, AQUELLAS QUE ASEGUREN EL MONTAJE CORRECTO DE LAS PIEZAS Y EL CUMPLIMIENTO DE LAS COTAS TOLERADAS.
PERMISSIBLE DEVIATIONS UNLESS OTHERWISE IS SPECIFIED, SHALL GUARANTEE THE PERFECT ASSEMBLY OF ALL THE PIECES AND ENSURE COMPLIANCE WITH THE DIMENSIONS INDICATED.
3. SOLDAR TODOS LOS PERFILES ENTRE SI, CON CORDON CONTINUO DE GARGANTA O PENETRACION, SEGUN SEA EL CASO, SALVO QUE SE INDIQUE OTRA COSA.
WELD PROFILES ALL AROUND WITH A NECK OR A PARTIAL PENETRATION, UNLESS OTHERWISE.
4. ESTE PLANO REPRESENTA AL CONJUNTO EN CONDICION FINAL. EL SUBCONTRATISTA SERA RESPONSABLE DE TOMAR LAS MEDIDAS NECESARIAS PARA SU CUMPLIMIENTO.
DRAWING SHOWS ASSEMBLY IN FINAL CONDITION.
SUBCONTRACTOR SHALL ADOPT THE NECESSARY MEASURES FOR COMPLIANCE.
5. PINTAR SEGUN ESPECIFICACION ENSA 0FE6FS702.
PAINT AS PER ENSA SPECIFICATION 0FE6FS702.
6. GRABAR O ESTAMPAR EN UNA CHAPA INOX. EL NUMERO DE ESTE PLANO Y PUNTEARLA DONDE SE INDICA.
ENGRAVE OR STAMP ON AN INOX PLATE THE NUMBER OF THIS DRAWING AND FIX WITH TACK WELD IN THE INDICATED POSITION.
7. TODA LA FABRICACION CUMPLIRA CON LOS REQUISITOS DEL CODIGO ASME B&PV, SECCION III NF.
ALL FABRICATION SHALL MEET THE ASME B&PV CODE SECTION III NF REQUIREMENTS.
8. MINIMA CALIDAD REQUERIDA.
MINIMUM QUALITY REQUIRED.

MARCA / ITEM	DENOMINACION / DESCRIPTION	CANT / QTY	MATERIAL / MATERIAL	PESO UN.(Kg) / WEIGHT (Lbs)	PLANO Nº / DWG Nr
00S.013	ARANDELA A25 / WASHER A25	4	Acero	--- / ---	DIN 125
00S.012	TUERCA M24 / NUT M24	6	8	--- / ---	DIN 934
00S.011	VARILLA ROSCADA M24 / THREADED ROD M24	2	8.8	1,8 / 4	DIN 976
00S.010	REFUERZO / REINFORCEMENT	4	Acero	0,6 / 1,3	---
00S.009	GRILLLETES (55 Tm) / SHACKLES (55 Tm)	4	Acero	44,6 / 98,25	CROSBY G-2130 2-1/2"
00S.008	CARTELAS / GUSSET PLATES	16	Acero	1,7 / 3,75	---
00S.007	OREJETAS AMARRE / MOORING LUGS	4	Acero	19,5 / 57,32	---
00S.006	APOYO / SUPPORT PLATE	2	Acero	0,6 / 1,3	---
00S.005	PERFIL HEB 100 x 1547 / HEB 100 x 1547 PROFILE	2	S 235 JR	29,5 / 65	---
00S.004	PERFIL HEB 100 x 2893 / HEB 100 x 2893 PROFILE	1	S 235 JR	57 / 125,66	---
00S.003	PERFIL HEB 100 x 3171 / HEB 100 x 3171 PROFILE	1	S 235 JR	62 / 136,69	---
00S.002	PERFIL HEB 100 x 2893 / HEB 140 x 2893 PROFILE	1	S 235 JR	57 / 125,66	---
00S.001	PERFIL HEB 140 x 2860 / HEB 140 x 2860 PROFILE	2	S 235 JR	96 / 211,64	---
101.01	BASTIDOR DE TRANSPORTE / TRANSPORT SADDLE	1	---	11039 / 24337	4DU8.101.00

REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
04	-	-	-
03	-	-	-
02	26 CAMBIOS / CHANGES	23/03/17	P. CEBALLOS
01	3 CAMBIOS / CHANGES	10/03/17	P. CEBALLOS
00	-	10/02/17	P. CEBALLOS

CLIENTE/CUSTOMER N/A
PROYECTO/PROJECT **DETERMINACION VIBRACIONES EN BARRA DE COMBUSTIBLE DURANTE EL TRANSPORTE EN CONTENEDOR ENUN 32P**
ORDEN DEL CLIENTE/CUSTOMER ORDER ***
VALIDO PARA COMPONENTES/APPL. FOR THE COMPONENTS ***

DIBUJADO POR / DFTM:		REVISADO POR / CHECKED BY:		APROBADO POR / APPROVED BY:	
P. Ceballos	FECHA/DATE	E. Gomez Mnez.	FECHA/DATE	Ismael Fernández	FECHA/DATE
P. Design	28/03/17	P. Design	28/03/17	Tech. Coord. Projects	28/03/17

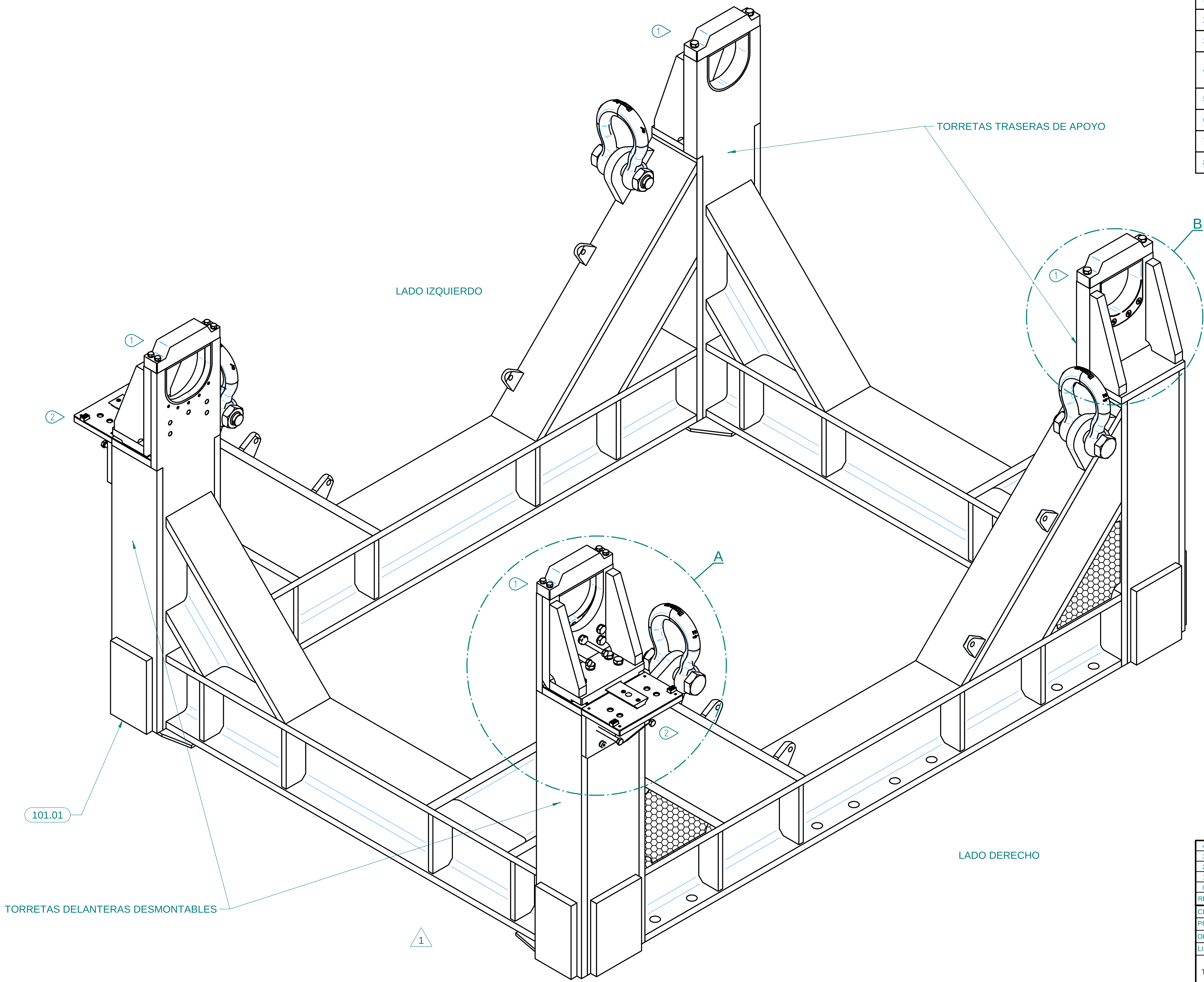
TITULO / TITLE

MODIFICACION DE BASTIDOR DE TRANSPORTE PARA ENSAYO
SADDLE MODIFICATION FOR TRANSPORT TEST

NUMERO DE PLANO / DRAWING NUMBER: 9293.00S0
REV.: 02
HOJA / SHEET 1 DE / OF 1
ESCALA / SCALE 1:20
FORMATO / FORMAT A1
DOCUMENTO REFERENCIA-REF. DOCUMENT

INGENIERIA.
DISEÑO PRODUCTO.
ENGINEERING. PRODUCT DESIGN.

	NOTAS/NOTES
1	MONTAR ITEMS 101.08 Y 101.17 EN SUS TORRETAS CORRESPONDIENTES PARA GARANTIZAR EL CORRECTO CONTACTO DE LOS CIERRES DE LA CUNA Y LOS BULONES.
2	ITEM 101.24 SÓLO SERÁN MONTADOS EN LA CUNA PARA LA OPERACIÓN DE RETIRADO DE LOS ITEM 101.02.
3	UNA VEZ COLOCADO EL CONTENEDOR EN POSICIÓN SOBRE LA CUNA, LOS BULONES SERÁN FIJADOS CON CUÑAS DE MADERA.
4	DEFINIR DIMENSIONES Y ADAPTAR SUPLEMENTOS AL MONTAJE (ITEMS 101.08 Y 101.17) PARA GARANTIZAR EL CORRECTO CONTACTO ENTRE CIERRES DE TORRETAS (ITEMS 101.07 Y 101.14) Y BULONES DEL CONTENEDOR. UNA VEZ COMPROBADO EL CORRECTO ENSAMBLAJE, FIJAR CON ADHESIVO A DICHOS CIERRES.
5	REBAJAR LA LONGITUD DEL TORNILLO CENTRAL EN 5 MM. PARA EVITAR INTERFERENCIA.
6	NO ATORNILLAR TORNILLO CENTRAL EN POSICIÓN SUPLEMENTO RETRAIDO.
7	UNA VEZ DEFINIDA LA POSICIÓN DEL CONTENEDOR, FIJAR MUÑONES CON CUÑAS DE MADERA.
8	PROTEGER AGUJEROS ROSCADOS CUANDO NO ESTÉN SIENDO USADOS.



CONJUNTO CUNA DE TRANSPORTE

PESO TOTAL APROX. CONJUNTO = 145566 KG.

PESO CUNA DE TRANSPORTE = 11039 KG.
PESO MÁX. CONTENEDOR CARGADO (COMBUSTIBLE 16x16-20) = 118219 KG.
PESO LIMITADOR IMPACTO INFERIOR = 8258 KG.
PESO LIMITADOR IMPACTO SUPERIOR = 8050 KG.

REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
4	-	-	-
3	-	-	-
2	-	-	-
1	DÓNDE SE INDICA 1 (x 10)	25/01/2017	J.DE LA GALA
0	PRIMERA EMISIÓN	26/10/2016	J.DE LA GALA

CLIENTE/CUSTOMER: ENRESA
PROYECTO/PROJECT: EQUIPOS AUXILIARES CONTENEDOR ENUN 32P
ORDEN DEL CLIENTE/CUSTOMER ORDER: 0044001136
LISTA DE MATERIALES/MATERIALS LIST: 4DU8LM101

DIBUJADO / DFTM	FECHA/DATE	REVISADO / CHECKED	FECHA/DATE	APROBADO / APPROVED	FECHA/DATE
Technical Office		Technical Office		P. Engineer	
J. de la Gala	25/01/17	J. Santoveña	25/01/17	L. López	26/01/17

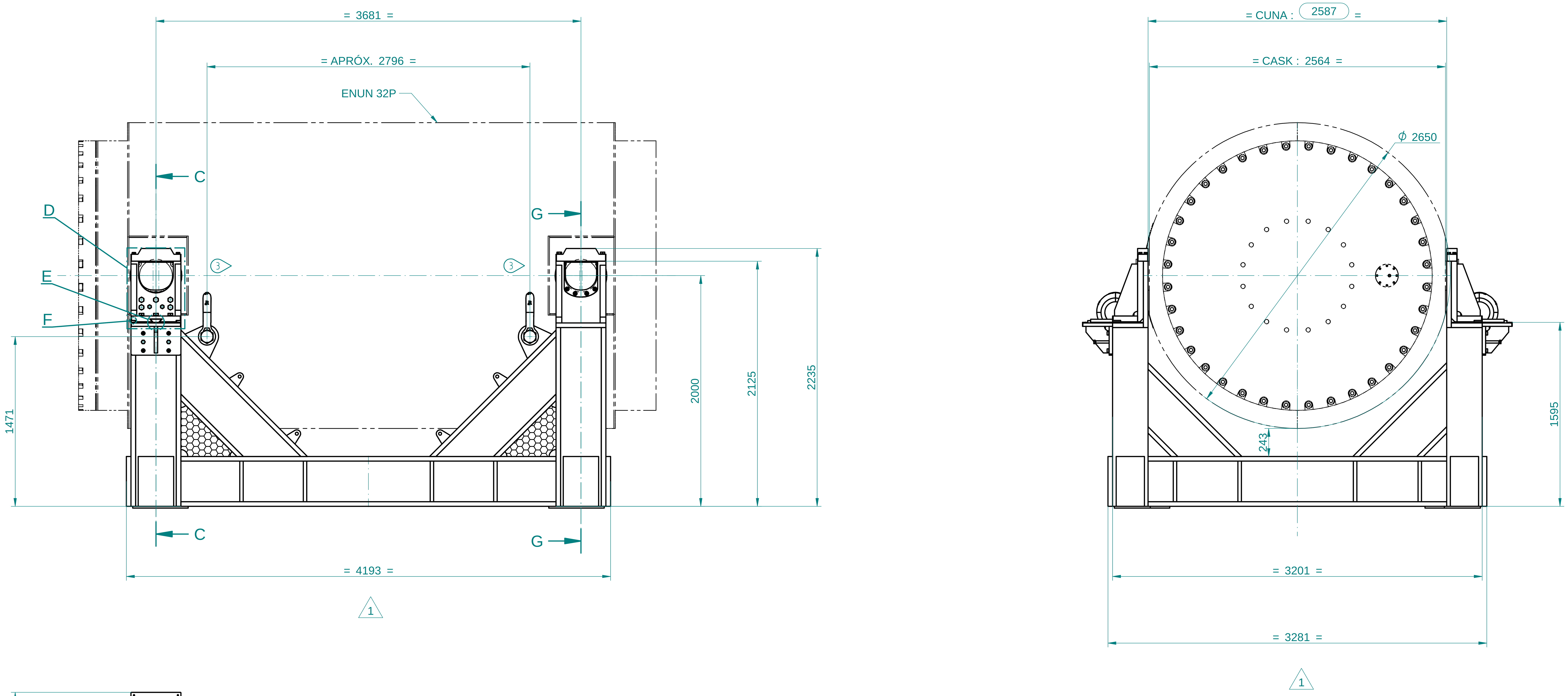
TITULO TITLE: CUNA DE TRANSPORTE
Conjunto General
***
***

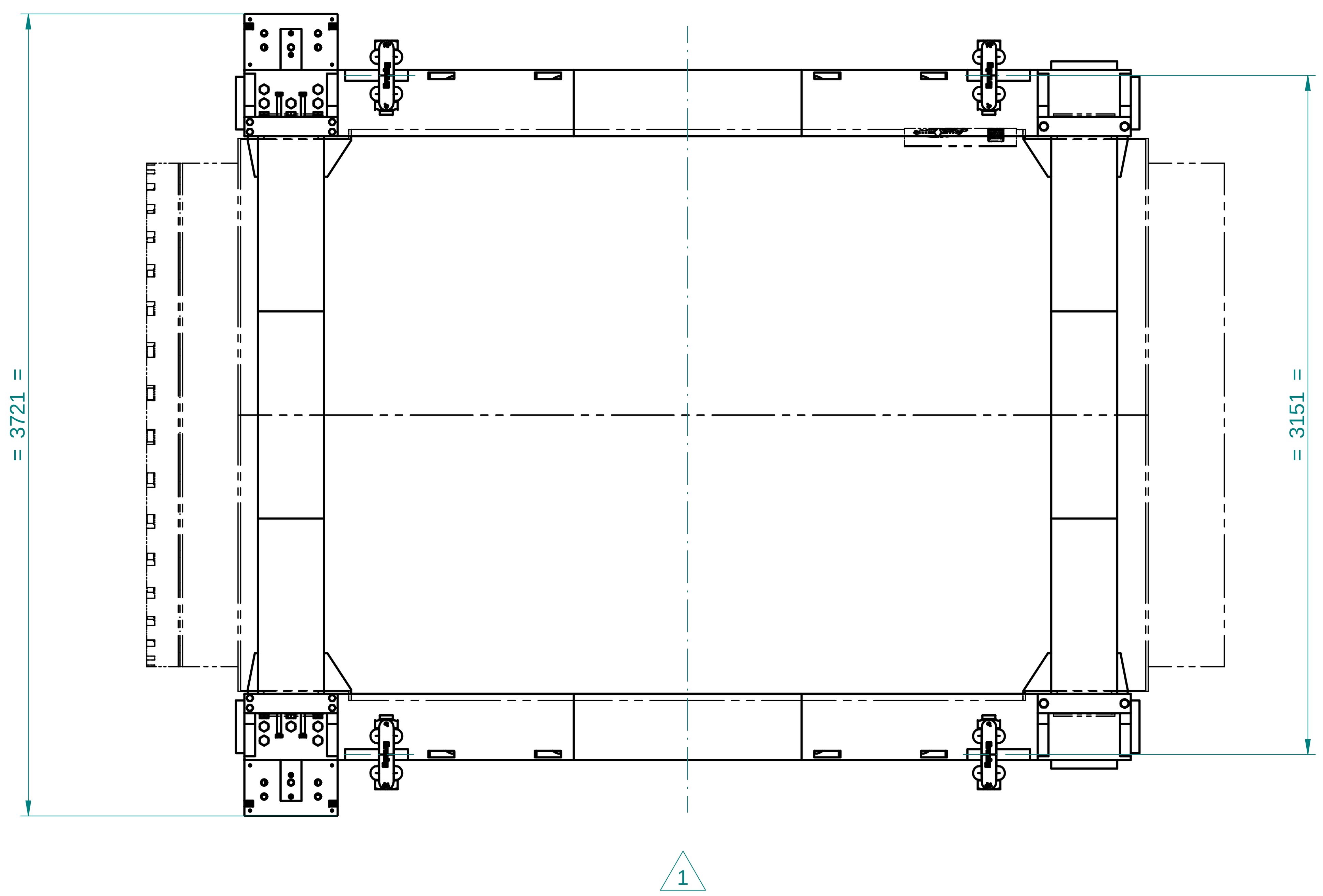
NUMERO DE PLANO / DRAWING NUMBER	REV.	HOJA SHEET	DE OF	ESCALA SCALE	FORMATO FORMAT
4DU8.101.00	01	1	5	/	A1

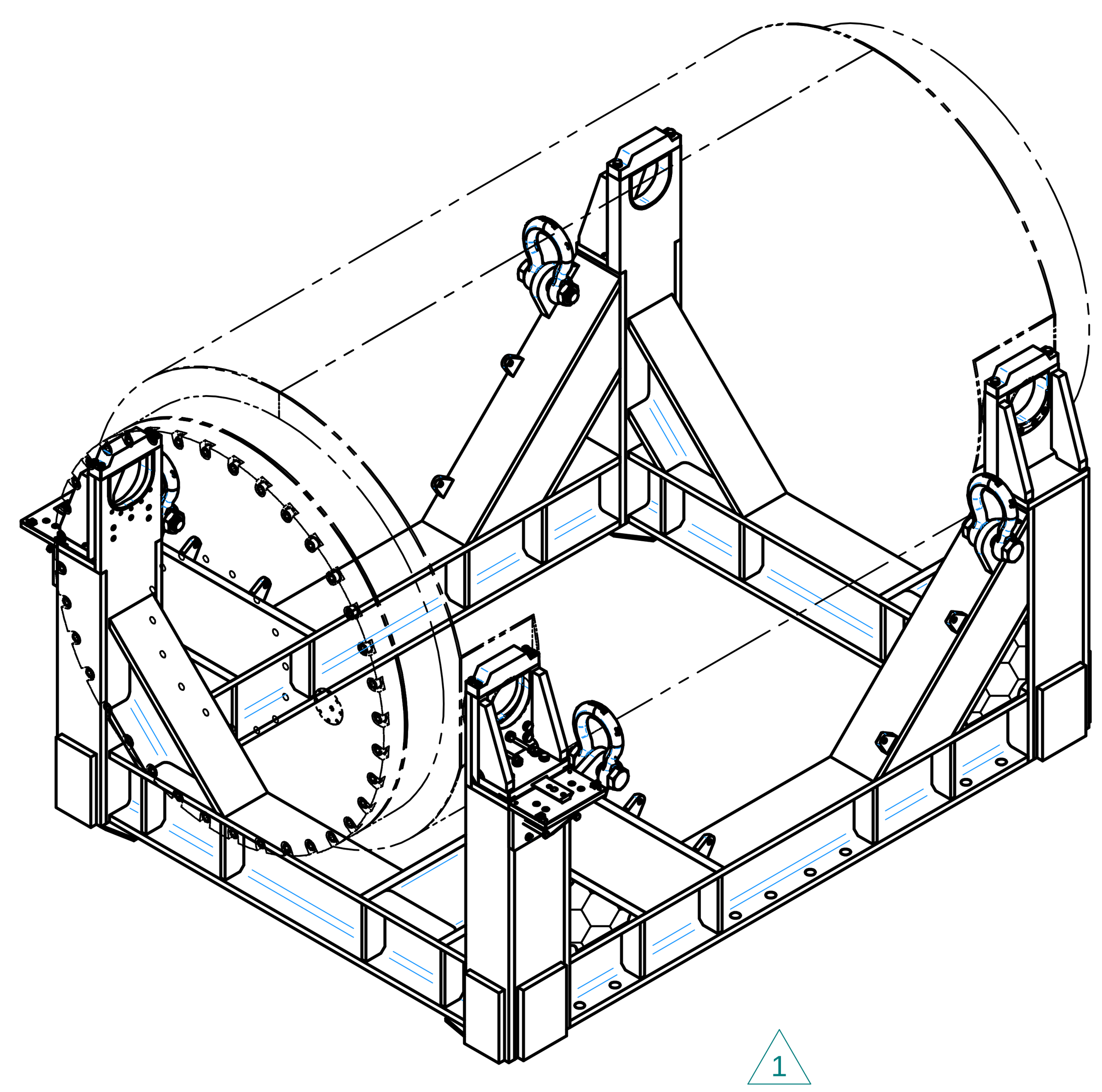
DOCUMENTO REFERENCIA-REF. DOCUMENT
4DU8.D101.00 ***
4DU8RDT02 ***

DESARROLLO DE NEGOCIOS
BUSINESS DEVELOPMENT

NOTAS/NOTES	
-	VER NOTAS EN HOJA 1.







REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
4	-	-	-
3	-	-	-
2	-	-	-
1	DÓNDE SE INDICA 1 (x 10)	25/01/2017	J.DE LA GALA
0	PRIMERA EMISIÓN	26/10/2016	J.DE LA GALA

CLIENTE/CUSTOMER: ENRESA

PROYECTO/PROJECT: EQUIPOS AUXILIARES CONTENEDOR ENUN 32P

ORDEN DEL CLIENTE/CUSTOMER ORDER: 0044001136

LISTA DE MATERIALES/MATERIALS LIST: 4DU8LM101

DIBUJADO / DFTM	FECHA/DATE	REVISADO / CHECKED	FECHA/DATE	APROBADO / APPROVED	FECHA/DATE
Technical Office		Technical Office		P. Engineer	
J. de la Gala	25/01/17	J. Santoveña	25/01/17	L. López	26/01/17

TITULO / TITLE:

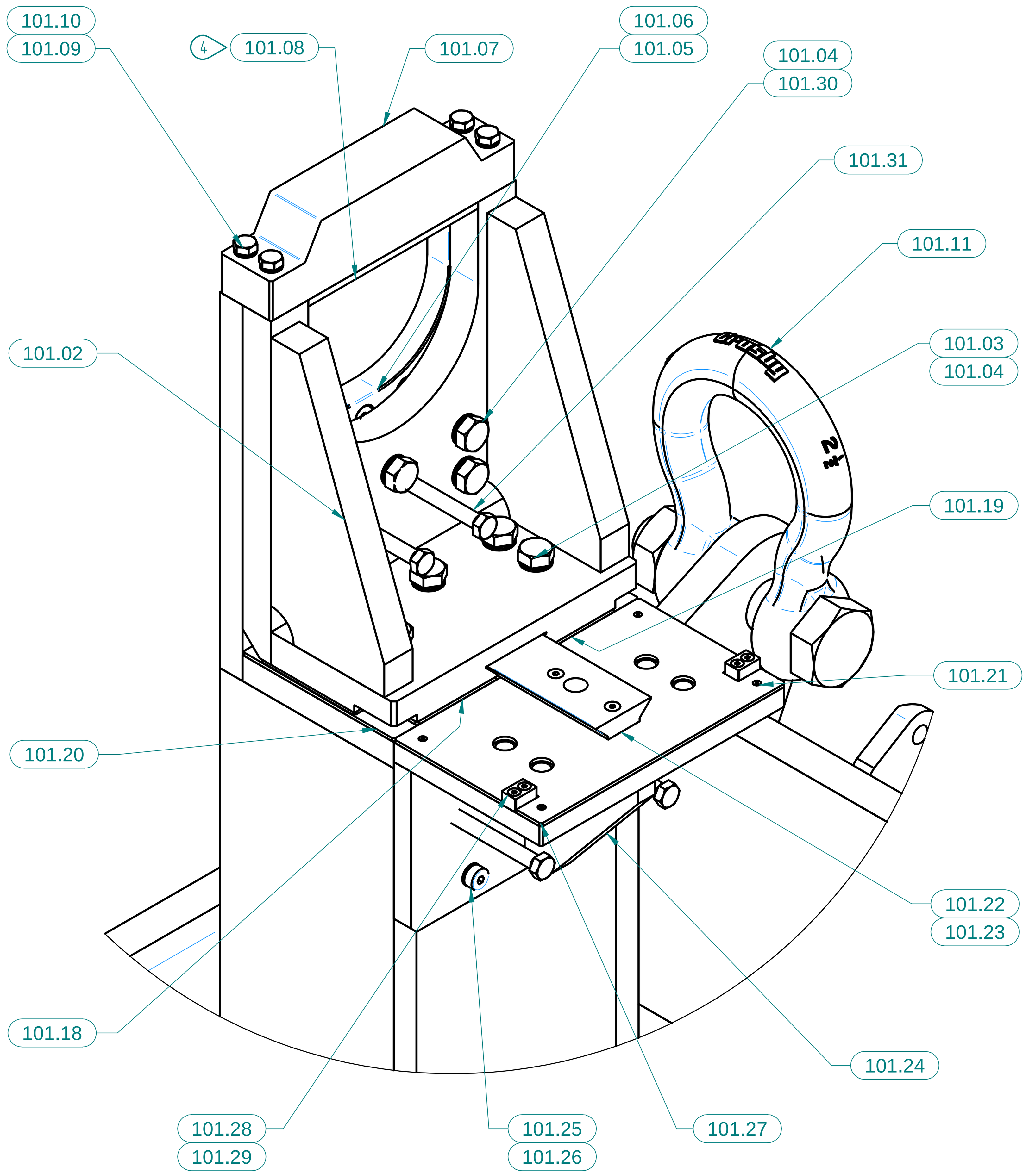
CUNA DE TRANSPORTE
Conjunto General
***
***

NUMERO DE PLANO / DRAWING NUMBER	REV.	HOJA / SHEET	DE / OF	ESCALA / SCALE	FORMATO / FORMAT
4DU8.101.00	01	2	5	/	A1

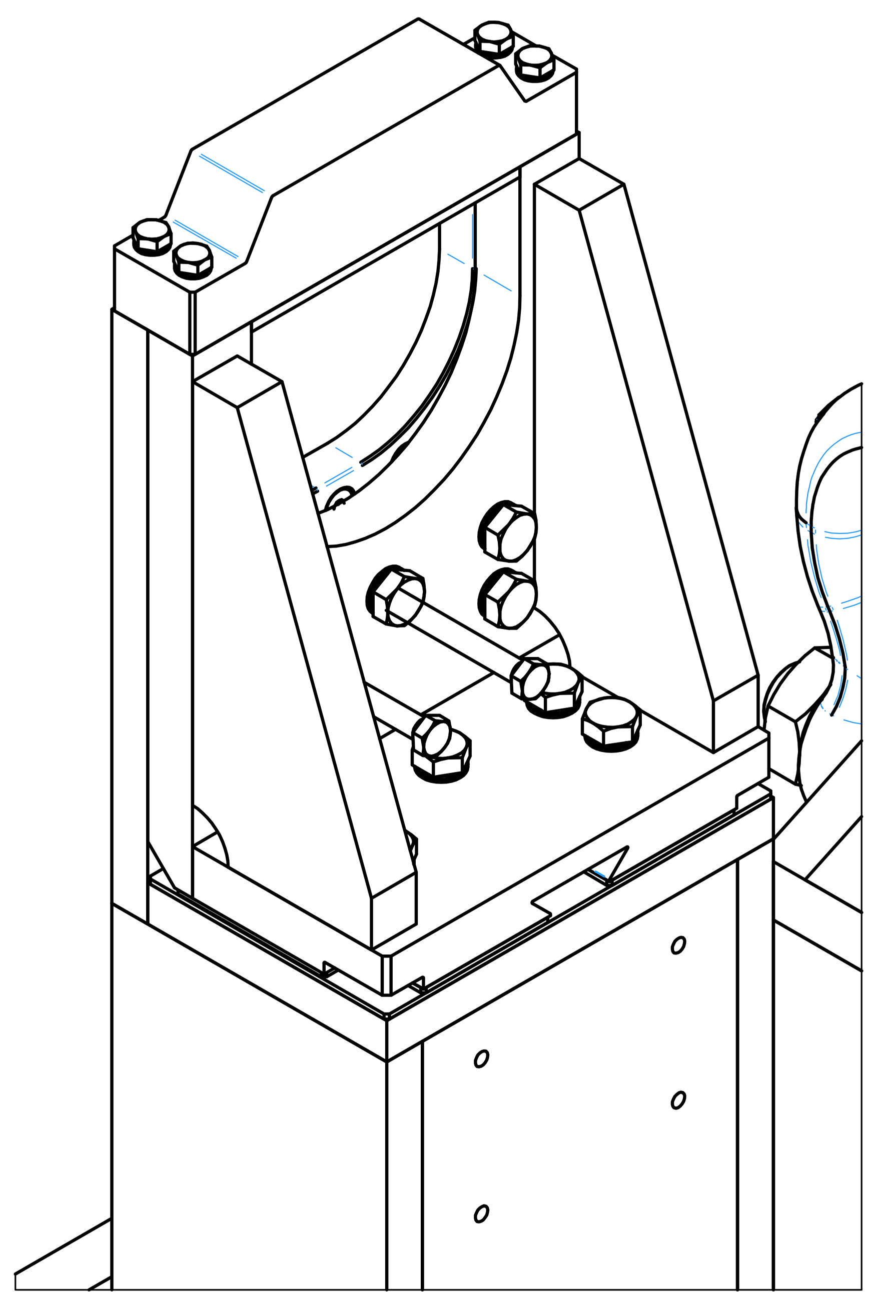
DOCUMENTO REFERENCIA-REF. DOCUMENT
4DU8.D101.00 ***
4DU8RDT02 ***

DESARROLLO DE NEGOCIOS
BUSINESS DEVELOPMENT

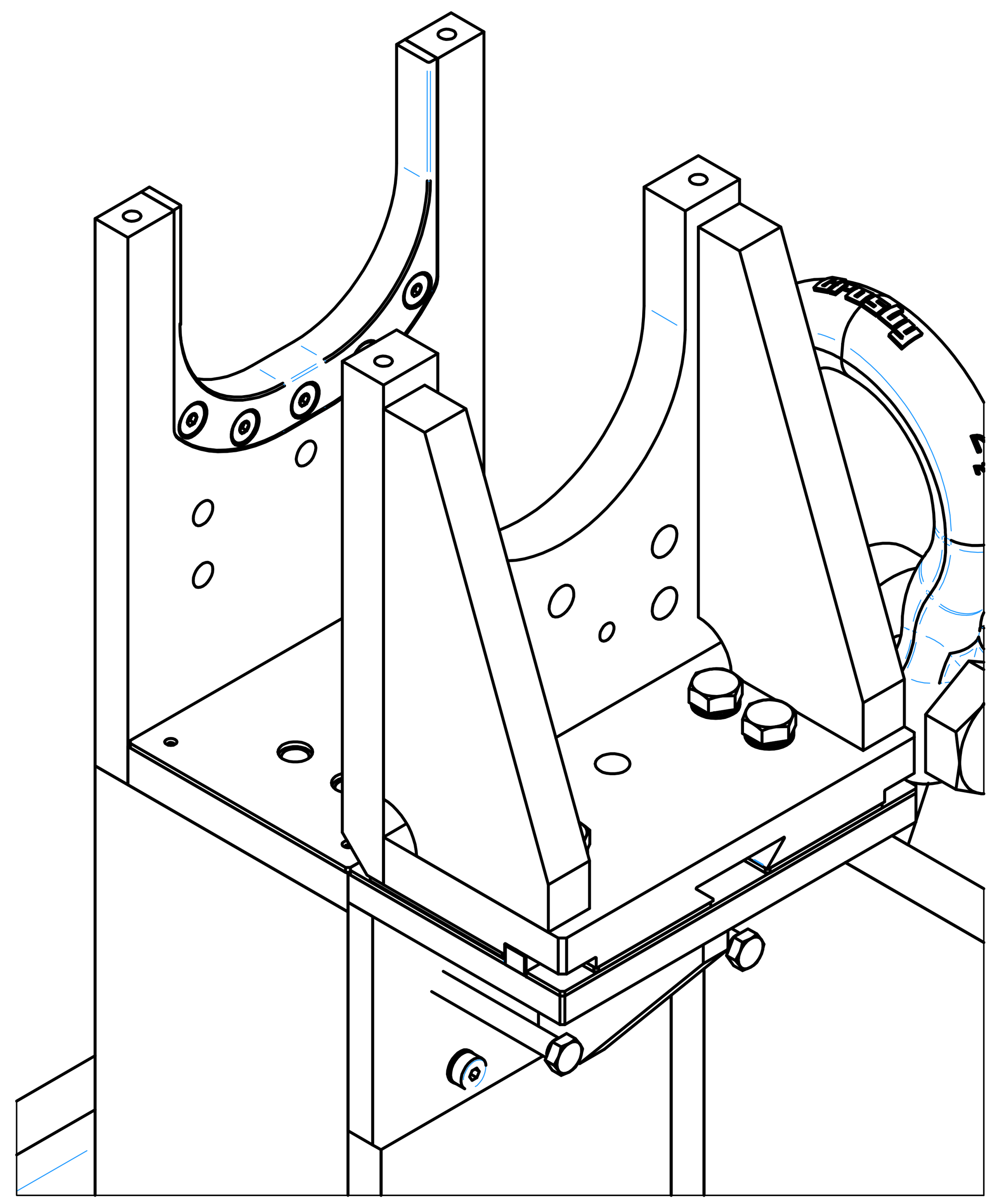
NOTAS/NOTES	
-	VER NOTAS EN HOJA 1.



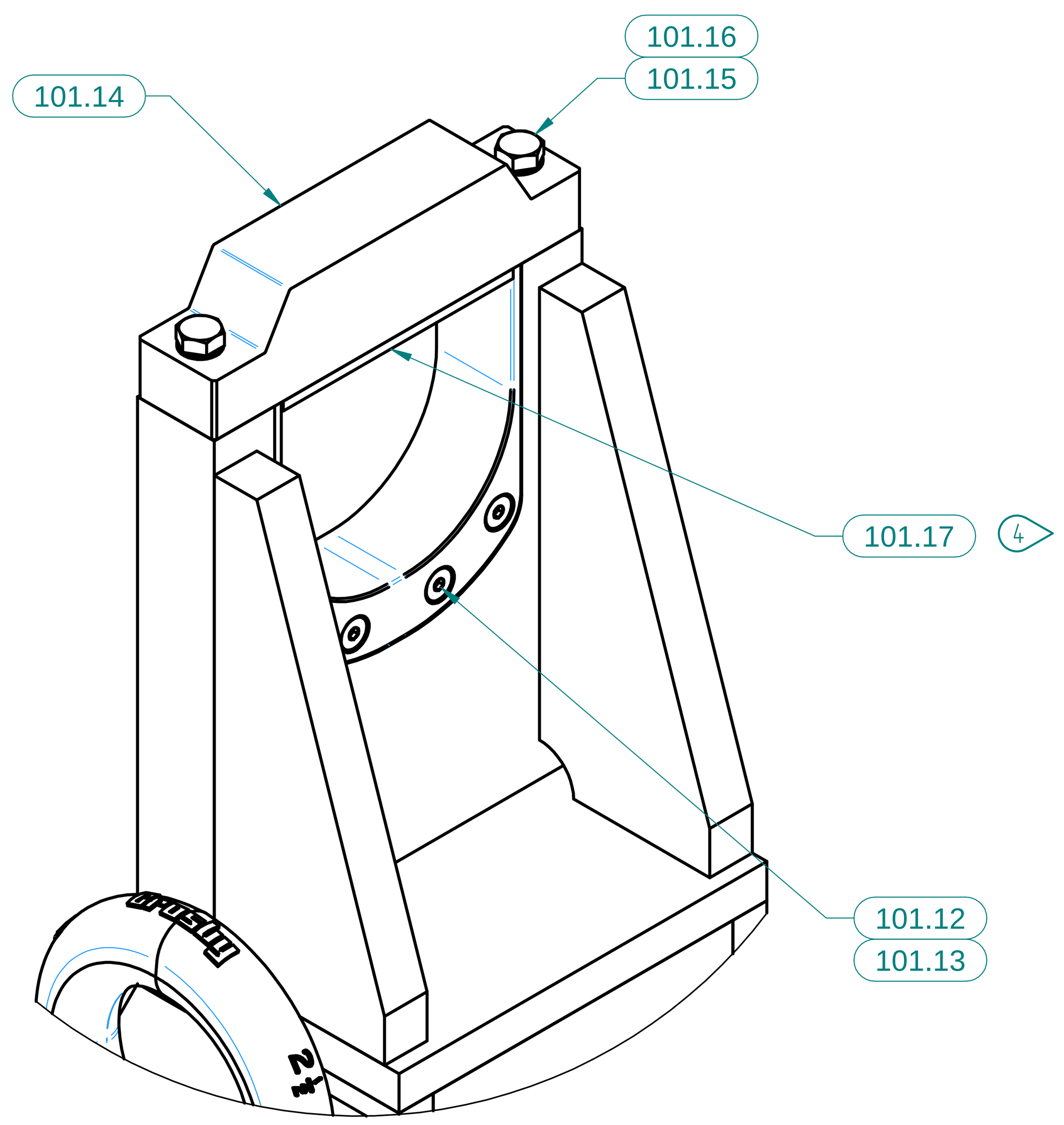
DETALLE TORRETA DELANTERA DESMONTABLE
(POSICIÓN TRANSPORTE)



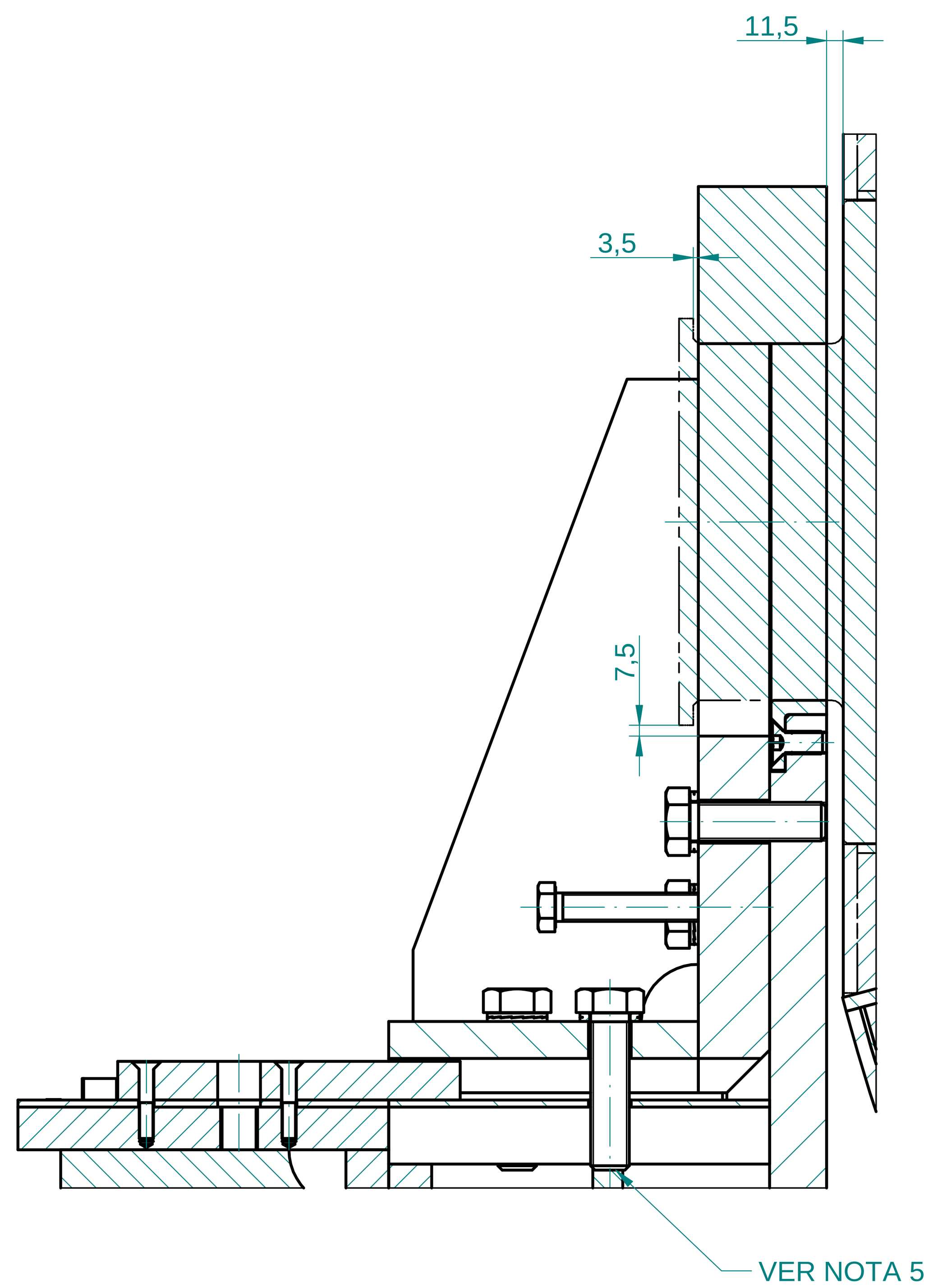
DETALLE TORRETA DELANTERA DESMONTABLE
(SOPORTE LATERAL RETIRADO)



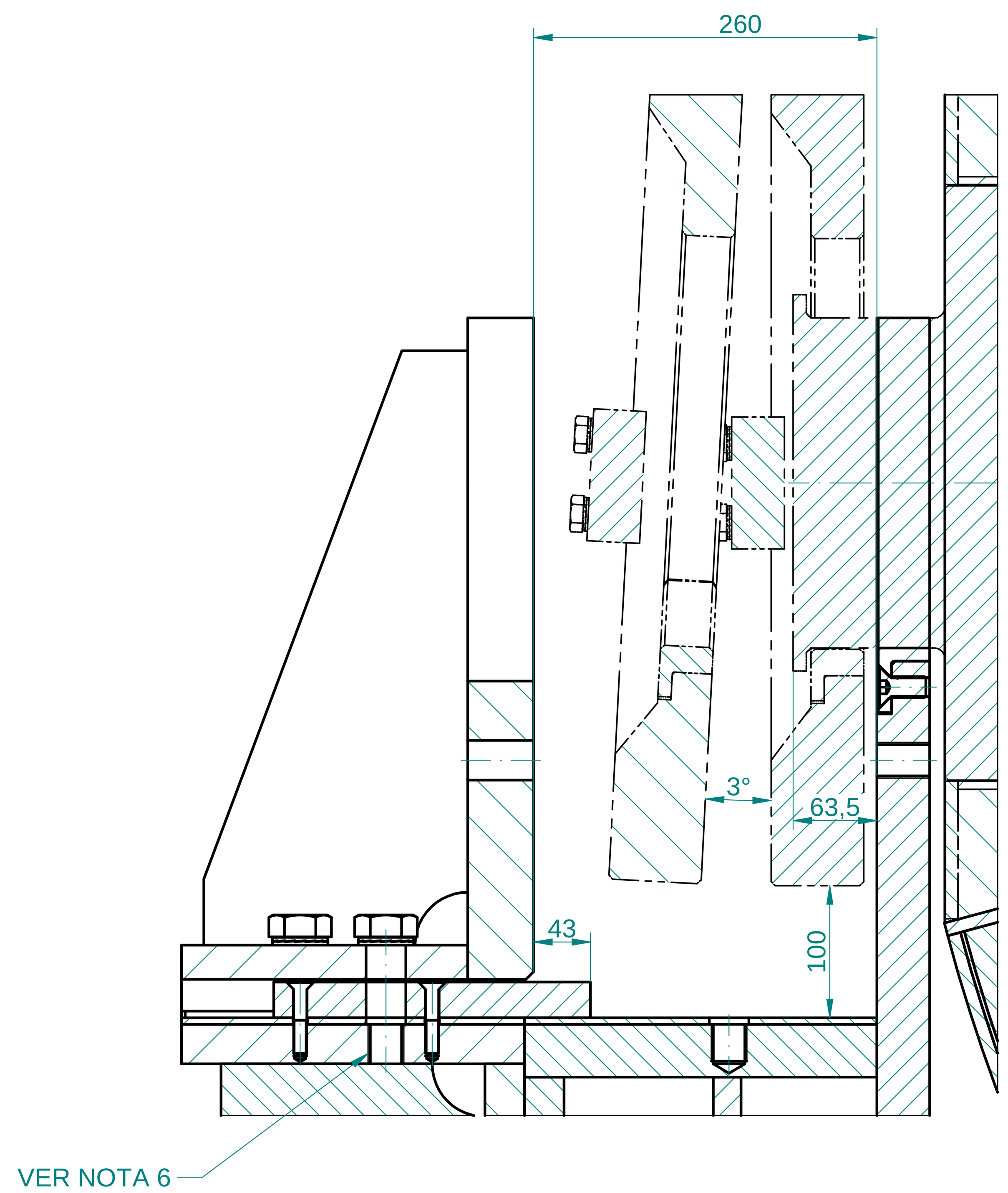
DETALLE TORRETA DELANTERA DESMONTABLE
(POSICIÓN SUPLEMENTO RETRAIDO)



DETALLE TORRETA TRASERA DE APOYO



CORTE C-C
TORRETA DELANTERA DESMONTABLE
(POSICIÓN EN CARGA)



CORTE C-C
TORRETA DELANTERA DESMONTABLE
(POSICIÓN SUPLEMENTO RETRAIDO)

1 SIN CAMBIOS EN ESTA HOJA

REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
4	-	-	-
3	-	-	-
2	-	-	-
1	DÓNDE SE INDICA 1 (x 10)	25/01/2017	J.DE LA GALA
0	PRIMERA EMISIÓN	26/10/2016	J.DE LA GALA

CLIENTE/CUSTOMER: ENRESA
PROYECTO/PROJECT: EQUIPOS AUXILIARES CONTENEDOR ENUN 32P
ORDEN DEL CLIENTE/CUSTOMER ORDER: 0044001136
LISTA DE MATERIALES/MATERIALS LIST: 4DU8LM101

DIBUJADO / DFTM	FECHA/DATE	REVISADO / CHECKED	FECHA/DATE	APROBADO / APPROVED	FECHA/DATE
Technical Office		Technical Office		P. Engineer	
J. de la Gala	25/01/17	J. Santoveña	25/01/17	L. López	26/01/17

TITULO / TITLE: CUNA DE TRANSPORTE
Conjunto General
***
***

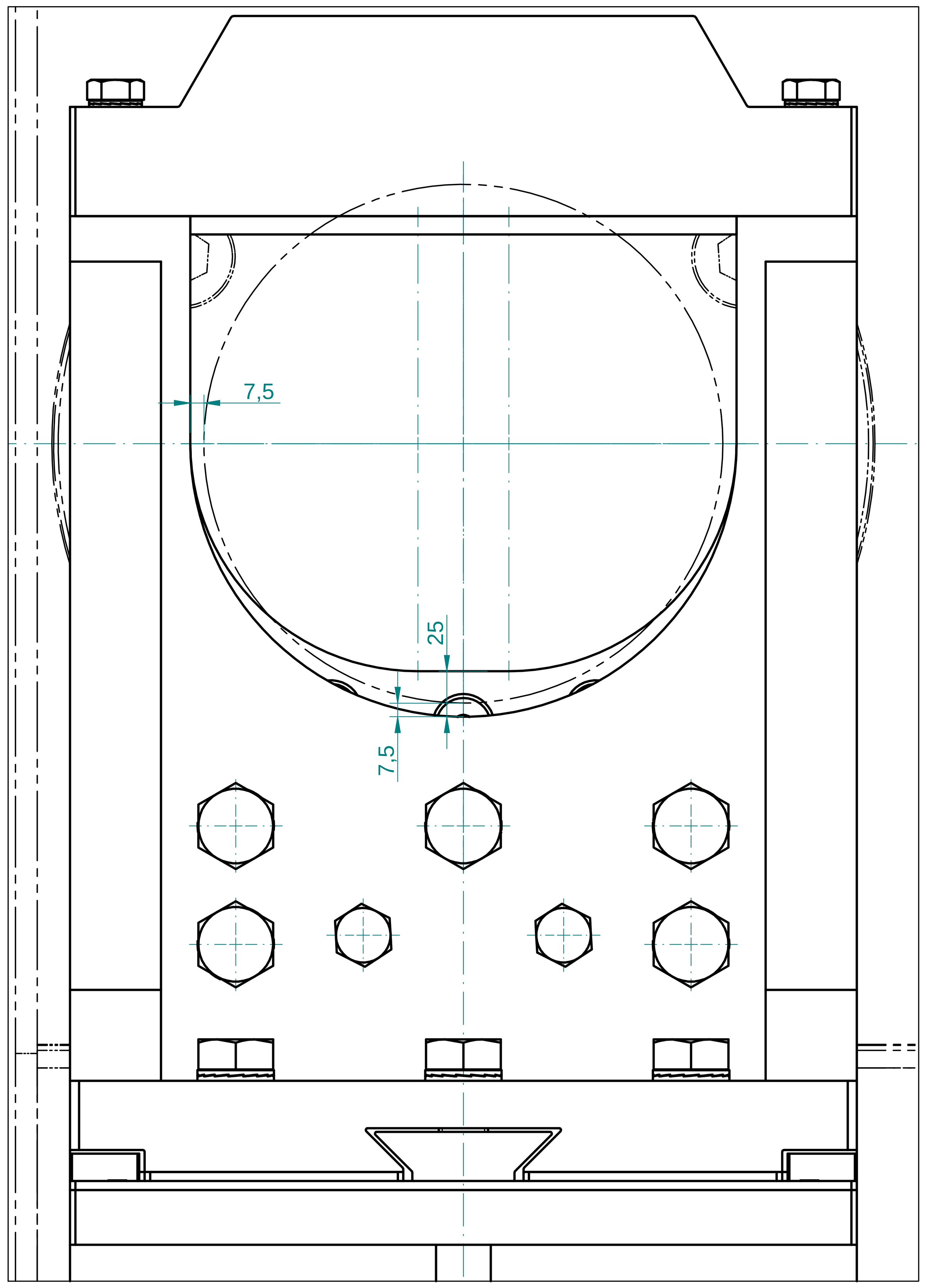
NUMERO DE PLANO / DRAWING NUMBER	REV.	HOJA / SHEET	DE / OF	ESCALA / SCALE	FORMATO / FORMAT
4DU8.101.00	01	3	5	/	A1

DOCUMENTO REFERENCIA-REF. DOCUMENT
4DU8.D101.00 ***
4DU8RDT02 ***

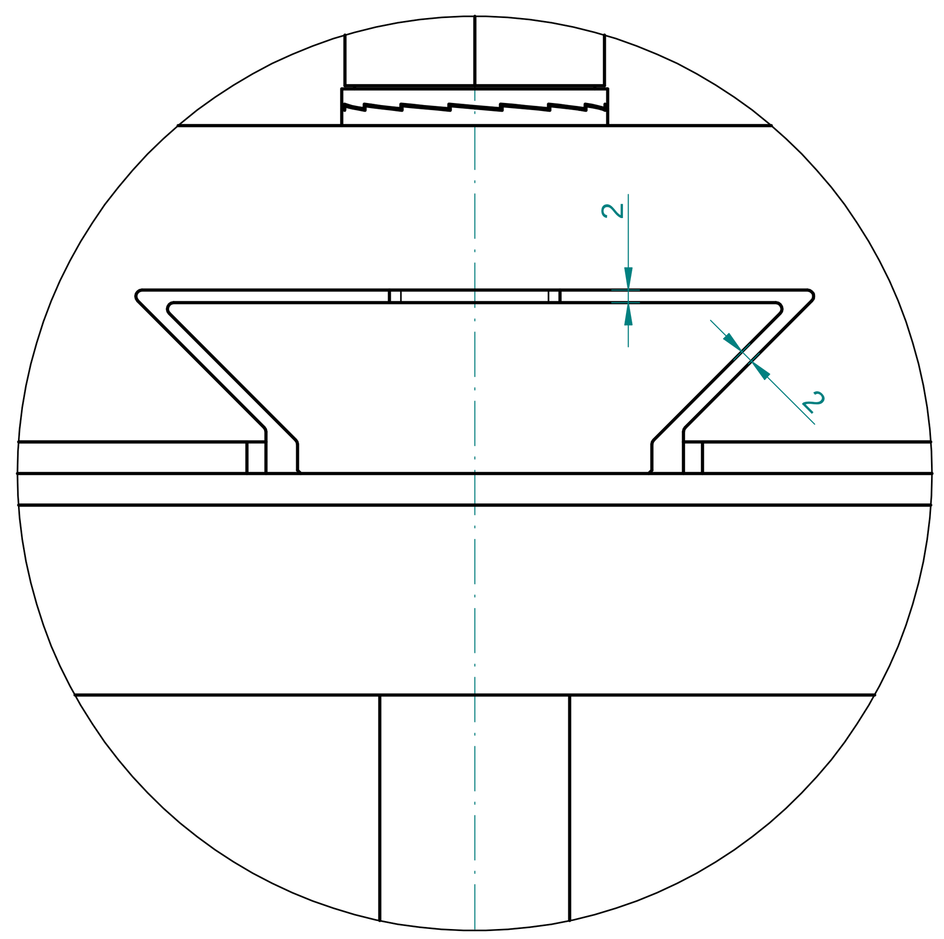
ensa

DESARROLLO DE NEGOCIOS
BUSINESS DEVELOPMENT

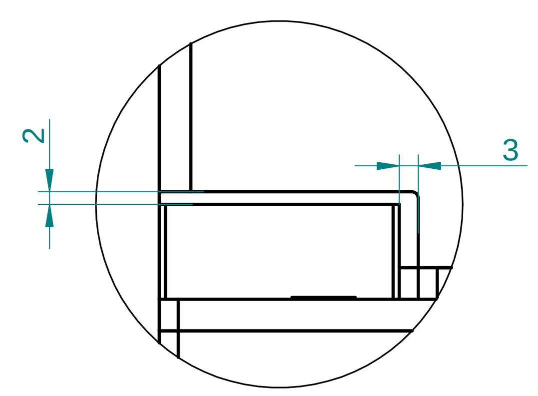
NOTAS/NOTES	
-	VER NOTAS EN HOJA 1.



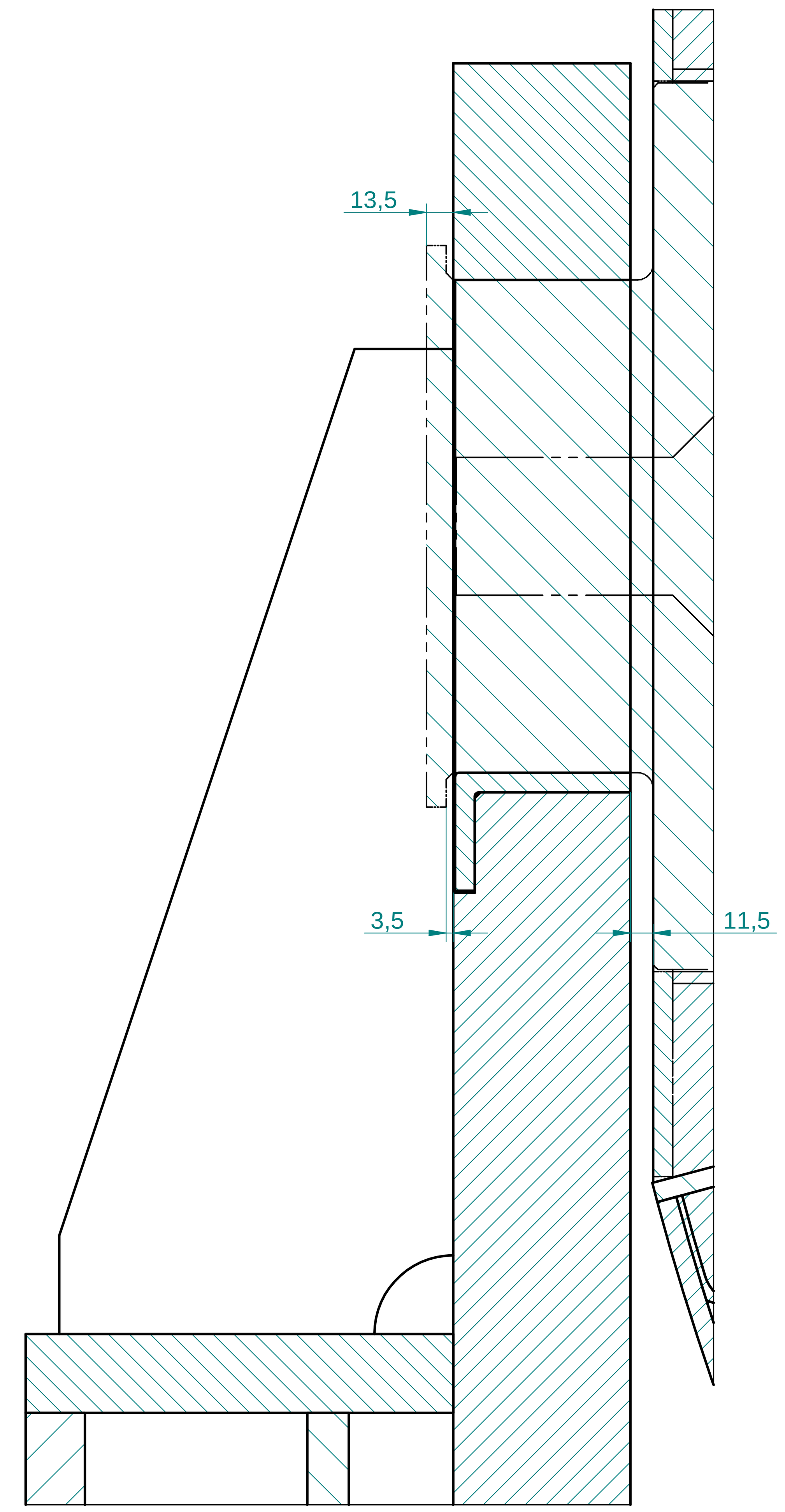
DETALLE D
TORRETA DELANTERA DESMONTABLE
(HOLGURAS)



DETALLE E
(HOLGURA COLA DE MILANO)



DETALLE F
(HOLGURA TOPE LATERAL)



CORTE G-G
TORRETA TRASERA DE APOYO
(CONTENEDOR APOYADO)

1 SIN CAMBIOS EN ESTA HOJA

REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
4	-	-	-
3	-	-	-
2	-	-	-
1	DONDE SE INDICA 1 (x 10)	25/01/2017	J.DE LA GALA
0	PRIMERA EMISIÓN	26/10/2016	J.DE LA GALA

CLIENTE/CUSTOMER: ENRESA
PROYECTO/PROJECT: EQUIPOS AUXILIARES CONTENEDOR ENUN 32P
ORDEN DEL CLIENTE/CUSTOMER ORDER: 0044001136
LISTA DE MATERIALES/MATERIALS LIST: 4DU8LM101

DIBUJADO / DFTM	FECHA/DATE	REVISADO / CHECKED	FECHA/DATE	APROBADO / APPROVED	FECHA/DATE
Technical Office		Technical Office		P. Engineer	
J. de la Gala	25/01/17	J. Santoveña	25/01/17	L. López	26/01/17

TITULO / TITLE: CUNA DE TRANSPORTE
Conjunto General
***
***

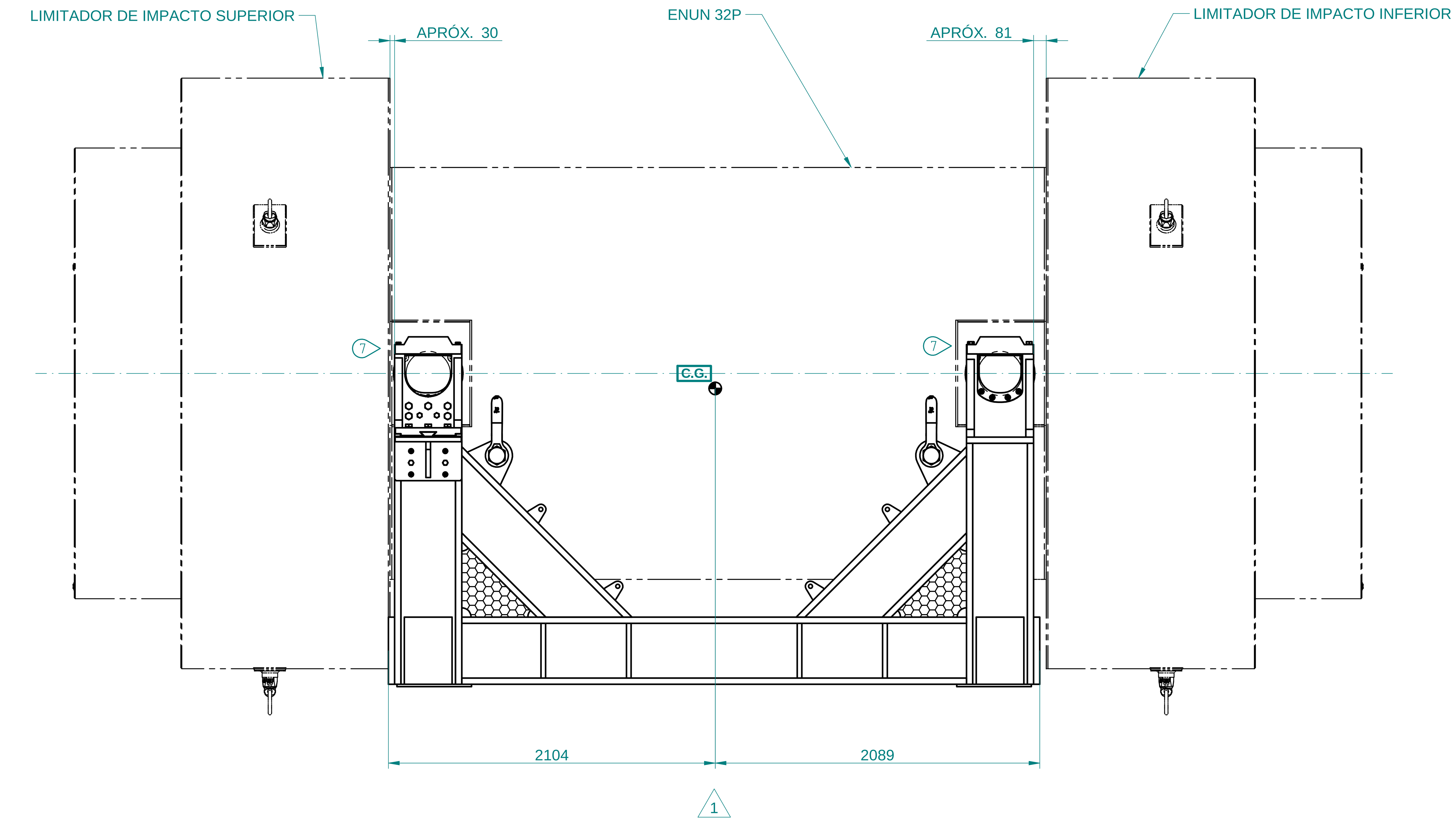
NUMERO DE PLANO / DRAWING NUMBER: 4DU8.101.00
REV.: 01
HOJA / SHEET: 4 DE / OF: 5
ESCALA / SCALE: /
FORMATO / FORMAT: A1

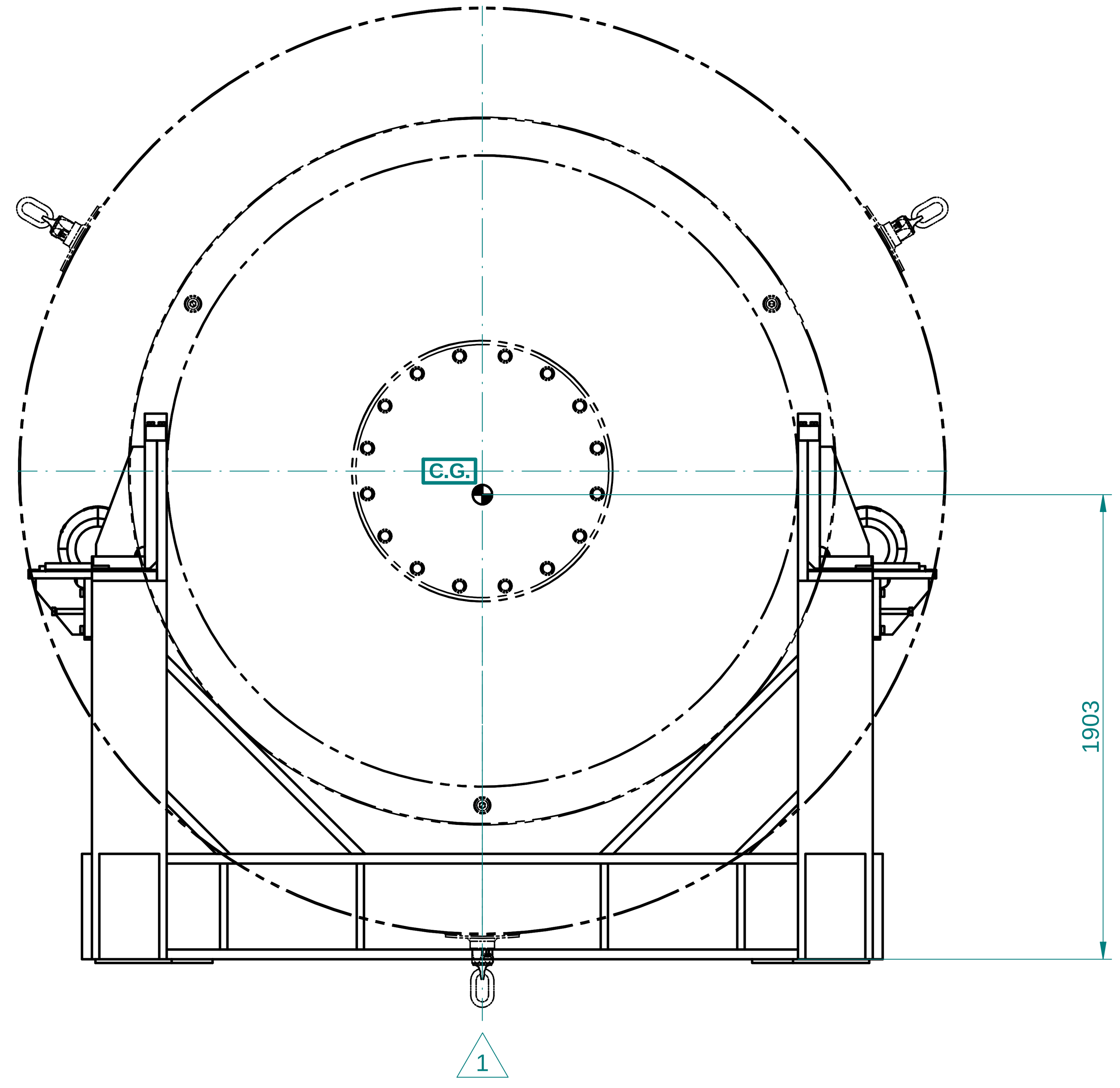
DOCUMENTO REFERENCIA-REF. DOCUMENT
4DU8.D101.00 ***
4DU8RDT02 ***

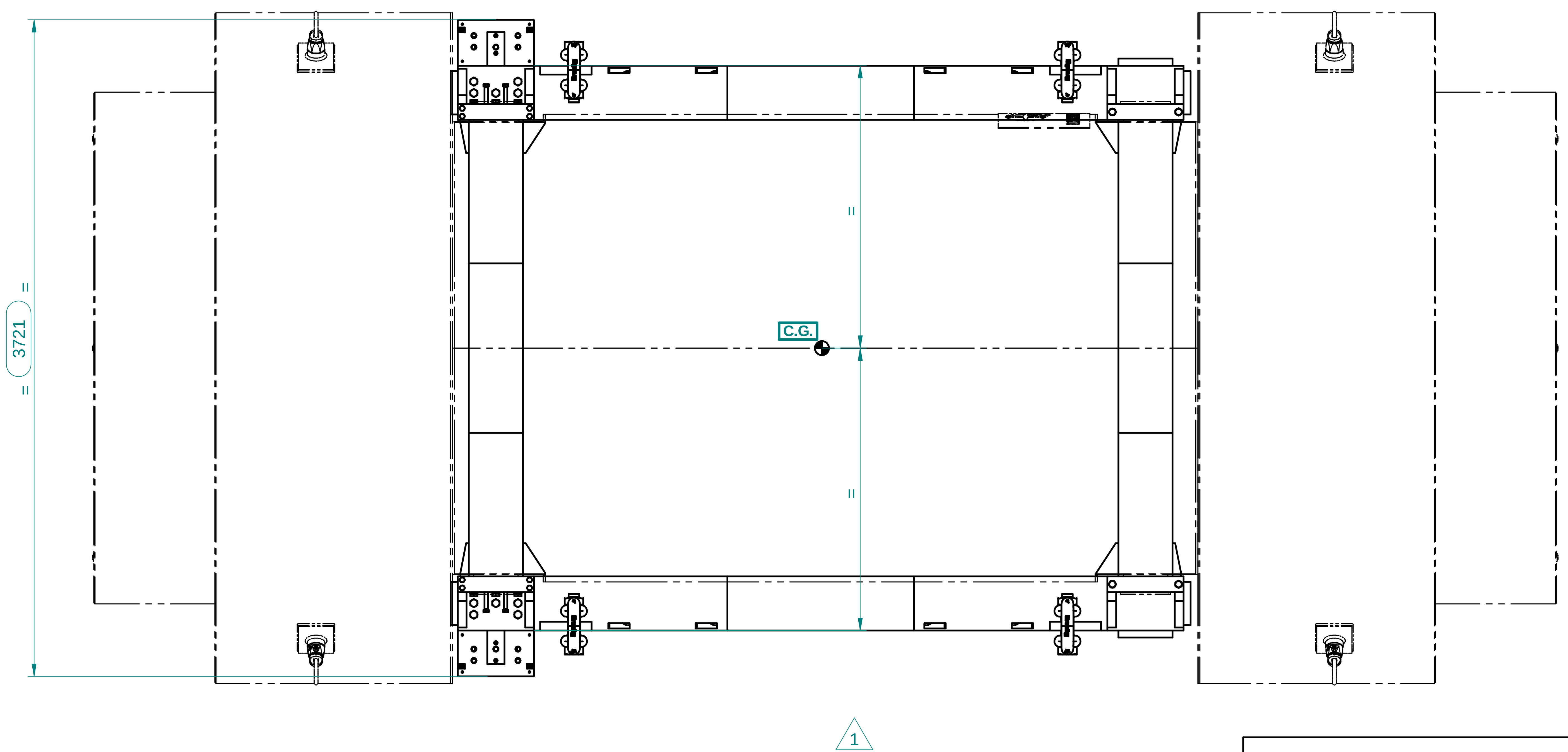
ensa
DESARROLLO DE NEGOCIOS
BUSINESS DEVELOPMENT

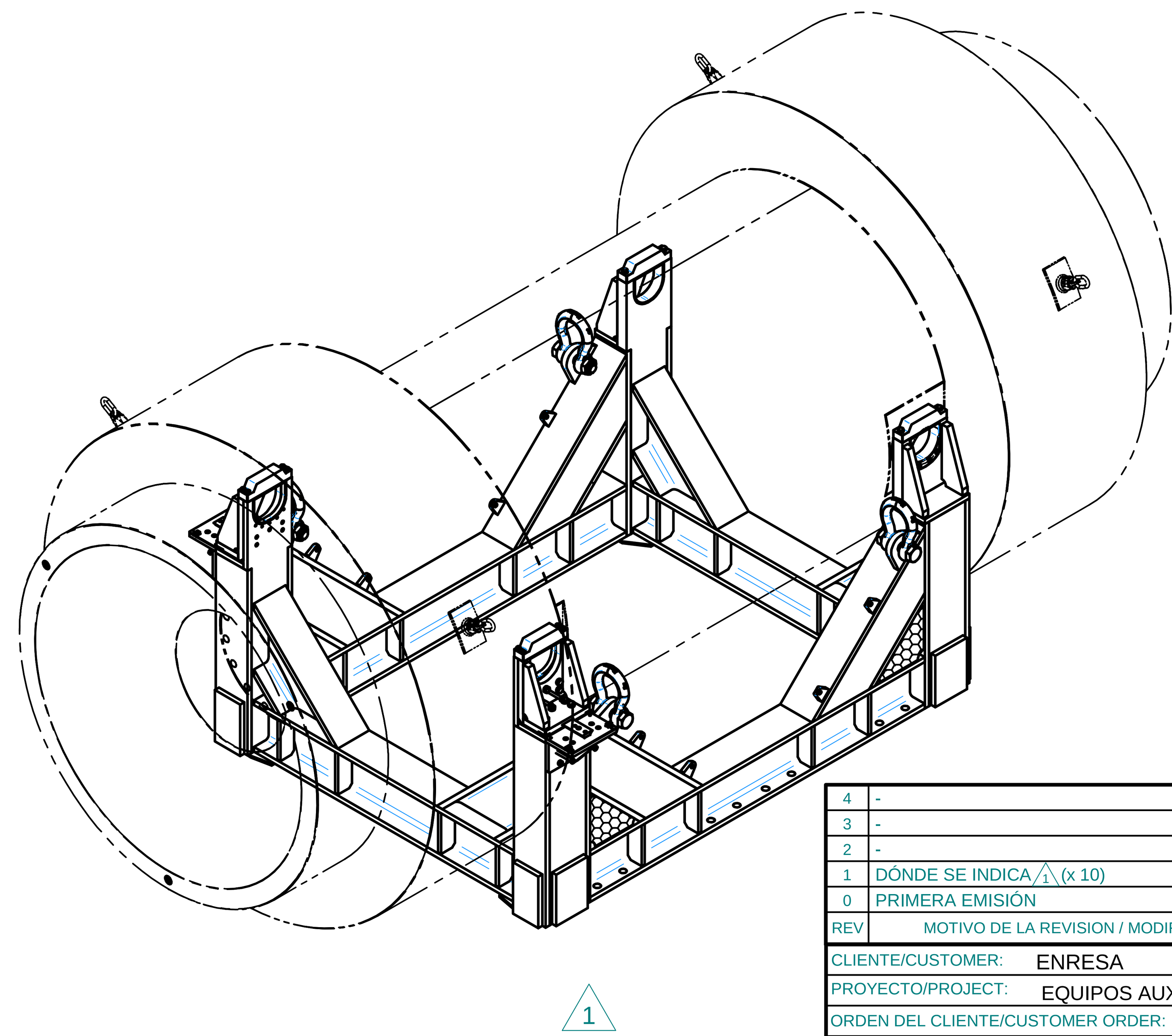
NOTAS/NOTES

- VER NOTAS EN HOJA 1.









POSICIÓN C.G CUNA + CONTENEDOR (KWU 16x16) + LIMITADORES DE IMPACTO

REV	MOTIVO DE LA REVISION / MODIFICATION REASON	FECHA/DATE	DIBUJADO/DFTM
4	-	-	-
3	-	-	-
2	-	-	-
1	DÓNDE SE INDICA 1 (x 10)	25/01/2017	J.DE LA GALA
0	PRIMERA EMISIÓN	26/10/2016	J.DE LA GALA

CLIENTE/CUSTOMER: ENRESA

PROYECTO/PROJECT: EQUIPOS AUXILIARES CONTENEDOR ENUN 32P

ORDEN DEL CLIENTE/CUSTOMER ORDER: 0044001136

LISTA DE MATERIALES/MATERIALS LIST: 4DU8LM101

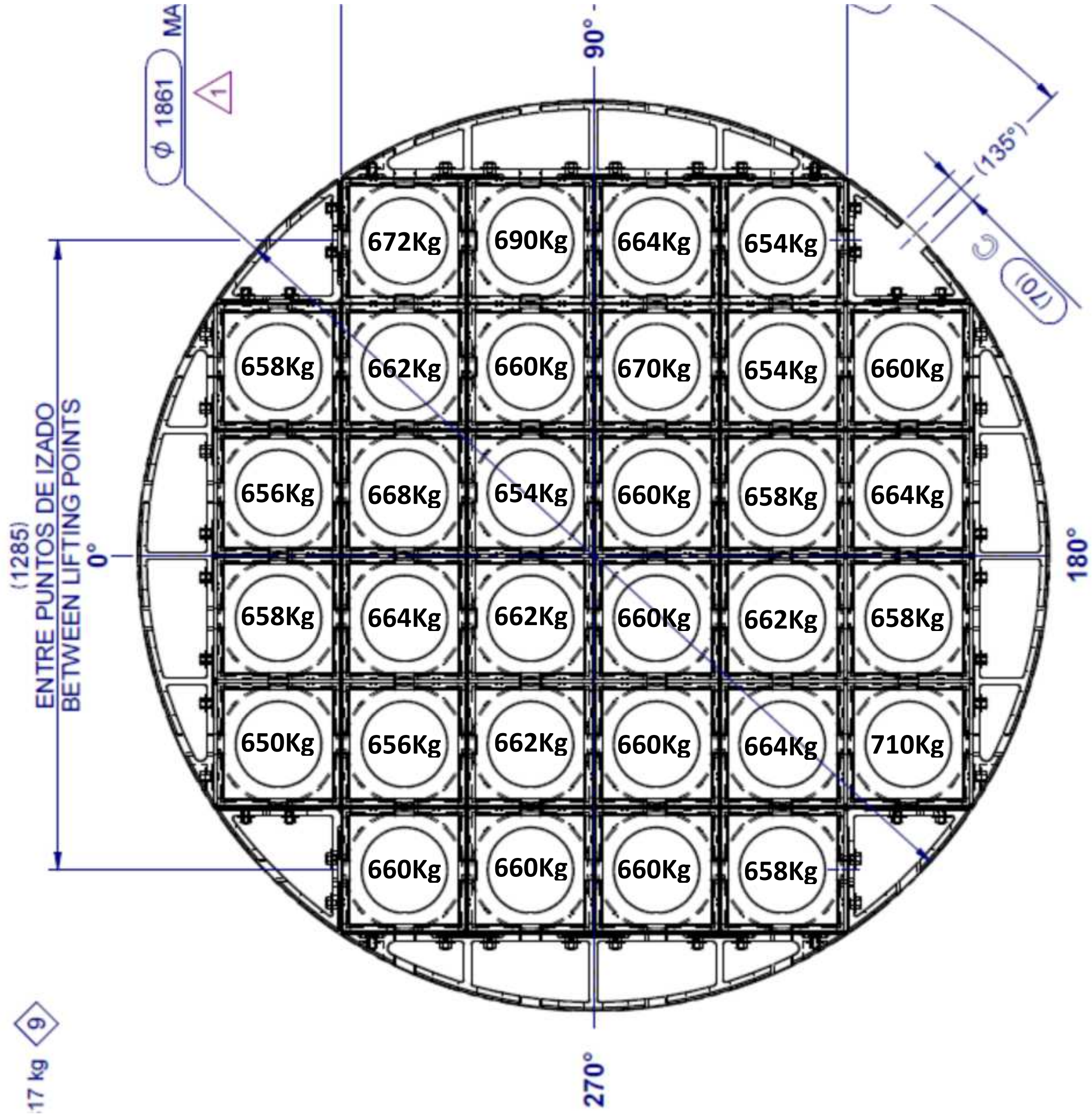
DIBUJADO / DFTM	FECHA/DATE	REVISADO / CHECKED	FECHA/DATE	APROBADO / APPROVED	FECHA/DATE
Technical Office		Technical Office		P. Engineer	
J. de la Gala	25/01/17	J. Santoveña	25/01/17	L. López	26/01/17

TITULO / TITLE: CUNA DE TRANSPORTE
Conjunto General
***
***

NUMERO DE PLANO / DRAWING NUMBER: 4DU8.101.00 | REV.: 01 | HOJA / SHEET 5 DE / OF 5 | ESCALA / SCALE: / | FORMATO / FORMAT: A1

DOCUMENTO REFERENCIA-REF. DOCUMENT
4DU8.D101.00 ***
4DU8RDT02 ***

DESARROLLO DE NEGOCIOS
BUSINESS DEVELOPMENT


90°
180°
270°
0°
Φ 1861
(135°)
(70)
(1285)
ENTRE PUNTOS DE IZADO
BETWEEN LIFTING POINTS
672Kg
690Kg
664Kg
654Kg
658Kg
662Kg
660Kg
670Kg
654Kg
660Kg
656Kg
668Kg
654Kg
660Kg
658Kg
664Kg
658Kg
664Kg
662Kg
660Kg
662Kg
658Kg
650Kg
656Kg
662Kg
660Kg
664Kg
710Kg
660Kg
660Kg
660Kg
658Kg
9

APPENDIX B: SANDIA RAIL-CASK TEST PLANS

ENSA/DOE RAIL CASK TRANSPORTATION TEST PROCEDURE
RAIL SHOCK AND VIBRATION TEST PROGRAM

Prepared By
Sandia National Laboratories
Albuquerque, New Mexico

May 10, 2017

Approved by:

Sylvia J. Saltzstein | 5/10/17
S. J. Saltzstein, 8845 | Date
Department Manager

5/10/17
P. E. McConnell, 8845 | Date
Project Manager

5/10/2017
C. A. Grey, 1522 | Date
Instrumentation Coordinator

CONTENTS

CONTENTS (Continued)

TABLES

FIGURES

ATTACHMENTS

1.0 INTRODUCTION

The objective of this testing program is to measure and quantify the mechanical response of a spent fuel rail cask assembly during normal conditions of transportation (NCT). This testing program will evaluate a rail transportation system during four different modes of transportation as well as during normal handling environments. The data will be used to guide materials research and establish a technical basis for review organizations such as the U.S. Nuclear Regulatory Commission (NRC). NCT rail data has been collected in the past, however, a significant amount of this data may not relate to current day transportation operations. This program will include instrumenting a full scale spent fuel rail transportation system with accelerometers and strain gages to measure the response of the system during each of the four transportation modes and handling operations. The transportation modes include heavy haul truck, barge, ship and rail. In addition, normal handling operations of the rail cask system will be evaluated. The transportation system will include a spent fuel cask, cradle, basket assembly, closure, impact limiters and surrogate fuel assembly provided by ENSA. In addition, Sandia National Laboratories will provide a second surrogate fuel assembly and KAERI, Korea will provide a third surrogate fuel assembly. The ultimate goal of this testing will be to provide hundreds of hours of data representing the response of a large rail spent fuel transportation system under NCT conditions in each of four transportation modes. This work is sponsored by U.S. Department of Energy Office of Nuclear Energy, Used Fuel Disposition Campaign (UFDC). The mission of the UFDC is to identify alternatives and conduct scientific research and technology development to enable storage, transportation, and disposal of used nuclear fuel (UNF) and wastes generated by existing and future nuclear fuel cycles.

2.0 PURPOSE

The purpose of this document is to define the data collection portion of the ENSA/DOE Transportation Test Program. This procedure will identify the individuals involved and define their responsibilities and define the steps required to instrument and perform the NCT rail cask testing. This procedure applies to the instrumentation, test setup, performance, and documentation of the ENSA/DOE transportation testing. Instrumentation data for this test program will be collected using an 80 channel portable Siemens LMS data collection system. The data will be processed and converted using the Sandia developed K2 analysis package.

3.0 SCOPE

This document:

- Describes the steps required to perform the data collection portion of the ENSA/DOE Transportation Test Program and defines the parameters for the test.

- Identifies the individuals involved in the program and defines their responsibilities.

- Defines applicable support documents that relate to the test program.

4.0 RESPONSIBILITIES

4.1 Department Manager S. J. Saltzstein, 8845

The Department Manager is responsible for and authorized to perform functions to attain technical and quality objectives, including implementing this procedure. These responsibilities and authorities may be delegated to other organizations and individuals but the primary responsibility for attaining the data collection test objectives rests with the Department Manager, and ultimately with the Project Manager.

4.2 Project Manager P. E. McConnell, 8845

The Project Manager has overall responsibility for all aspects of the test program and will oversee the work of all individuals involved. He is responsible for approving and implementing this procedure and must approve any changes to the program, including changes to this procedure, or related documents. The Project Manager has the authority to delegate specific tasks or responsibilities to other members of the project team.

4.3 Instrumentation Coordinator C. A. Grey, 1522

The Instrumentation Coordinators will install and connect the instrumentation measurement devices specified in the test procedures to the recording equipment. He/she will assure that this procedure is followed and recording equipment is configured and approved instrumentation tables are completed and the data collection system check lists are followed and documented. Copies of the raw, processed and archived data will be delivered to the Project Manager, as required, for additional processing.

5.0 REFERENCES

AAR - Association of American Railroads. 2008. *Performance Specification for Trains Used to Carry High-Level Radioactive Material*. Standard S-2043. Association of American Railroads, Washington, D.C.

AAR - Association of American Railroads. 2013. *AAR Open Top Loading Rules Manual*, American Association of Railroad, Washington, D.C.

DOE – U.S. Department of Energy. 2014. *Normal Conditions of Transport Truck Test of a Surrogate Fuel Assembly*. FCRD-UFD-2014-000066. Revision 0.1, U.S. Department of Energy, Washington, D.C.

Hanson, BD, SC Marschman, MC Billone, J Scaglione, KB Sorenson, SJ Saltzstein. 2016. *High Burnup Spent Fuel Data Project: Sister Rod Test Plan Overview*. FCRD-UFD-2016-000063, PNNL-25374. Prepared for the U.S. Department of Energy, Washington, D.C.

Hanson, BD, AA Alsaed, and CT Stockman. 2012. *Used Nuclear Fuel Storage and Transportation Data Gap Prioritization*. DRAFT FCRD-USED-2012-000109, PNNL-21360. Prepared for the U.S. Department of Energy, Washington, D.C.

Klymyshyn 2016 - "Finite Element & Modeling in Support of S&V Test Plan, FCRD-UFD-2016-000425

Livermore Software Technology Corporation. 2013. *LS-DYNA® Keyword User's Manual*, Volume I, Version R7.0. Livermore Software Technology Corporation, Livermore, California.

McConnell PE, R Wauneka, G Koenig, W Uncapher, C Grey, C Engelhardt, S Saltzstein, and K Sorenson. 2015. *Surrogate Fuel Assembly Multi-Axis Shaker Tests to Simulate Normal Conditions of Rail and Truck Transport*, Sandia National Laboratory, Albuquerque, NM. FCRD-UFD-2015-000128.

TTCI – Transportation Technology Center, Inc. 2015. *NUCARS© User Manual*, Version 2015.2, Transportation Technology Center, Inc., Pueblo, Colorado

6.0 INSTRUMENTATION REQUIREMENTS

The ENSA/DOE transportation cask test hardware will be instrumented with a combination of accelerometers and strain gages. The following sections detail the instrumentation and installation requirements for the measurement devices.

6.1 Transducer Requirements

The general requirements (designation, type, and location) of the measurement devices for the ENSA/DOE Transportation cask test hardware are listed in Table 1 for accelerometers and Table 2 for strain gages.

6.2 Transducer Procurement

The following transducers shall be installed on the ENSA/DOE transportation test hardware in accordance with manufacturer's requirements.

Accelerometers - Endevco Corporation

Model No. 727-2K-10-120, ±2,000g (19 each)
Model No. 7265A, (21 each)

Strain Gages – Micro-Measurements Group

CEA-03-062UW-350, 350 ohm uni-axial (37 each)

6.3 Channel Identification

Each installed transducer will be assigned an identifying designation corresponding to the type and location on the test hardware. The identification of each transducer is defined in Tables 1 and Table 2 of this procedure. The location of each transducer is shown on Figure 1-5, ENSA/DOE Transportation Test Instrumentation Locations. Channel identification shall be consistently maintained for transducer lead wires, terminal strip connections, field wiring, and data acquisition.

7.0 ACCELEROMETER INSTALLATION

7.1 Equipment and Supplies

Accelerometers listed in Table 1
Isolated Model 727 uni-axial mounting block
Isolated Model 727 tri-axial mounting blocks
Isolated Model 7265A tri-axial mounting blocks
Torque wrench, 0 - 30 in-lb.
Digital multimeter,
Thread tap, 2-56 UNC
Aluminum foil tape
Acrylic adhesive, Hardman 04001 two-part epoxy
Screws and washers supplied by the manufacturer, #2-56 UNC
Alcohol, denatured
Sandpaper, 600 grit
Wire heat strippers/cutters

7.2 Accelerometer Block Attachment Procedure

Locate the accelerometer mounting blocks per Figure 1-5 and Table 1. Remove any excess paint, burrs or other foreign material from the attachment area using sandpaper. Visually inspect the accelerometer mounting block for damage. Using a 2-56 UNC tap assure the threaded accelerometer mounting holes for the 7265A accelerometers are clear of dirt or debris. The accelerometer mounting blocks will be secured to the transportation cask components using two-part epoxy or screwed to a threaded adapter that is glued to the transporter. Care will be taken to minimize the amount of adhesive that is allowed to flow outside the mounting block. Excess adhesive should be removed from the mounting block. The model 727 accelerometers will be glued directly to either a uni-axial or tri-axial accelerometer mounting blocks.

7.3 Accelerometer Installation

A total of 40 accelerometers will be installed on the ENSA/DOE Transportation Test hardware during the course of the test program. The location of each of the accelerometers can be found in Table 1 and Figure 1-5. The calibration sheet(s) will be included in this procedure as Attachment 1.

Table 1
ENSA/DOE Transportation Test Instrumentation Requirements
Accelerometers

Accelerometer Designation	Type/Catalog Number	Location	Angular Location	Cask Position	Measurement Direction
A1Z	727-2K-10-120	SNL Assembly	0˚	C3	+Z
A2Z	727-2K-10-120	SNL Assembly	0˚	C1	+Z
A3Z	727-2K-10-120	SNL Assembly	0˚	C2	+Z
A4Z	727-2K-10-120	SNL Assembly	0˚	A	+Z
A5Z	727-2K-10-120	SNL Assembly	0˚	B	+Z
A6Z	727-2K-10-120	ENSA Assembly	0˚	C3	+Z
A7Z	727-2K-10-120	ENSA Assembly	0˚	C1	+Z
A8Z	727-2K-10-120	ENSA Assembly	0˚	C2	+Z
A9Z	727-2K-10-120	ENSA Assembly	0˚	A	+Z
A10Z	727-2K-10-120	ENSA Assembly	0˚	B	+Z
A11Z	727-2K-10-120	Korean Assembly	0˚	C1	+Z
A12Y	727-2K-10-120	Korean Assembly	0˚	Top Nozzle	+Y
A12Z	727-2K-10-120	Korean Assembly	0˚	Top Nozzle	-Z
A13X	727-2K-10-120	Cask Basket	0˚	A	+X
A13Y	727-2K-10-120	Cask Basket	0˚	A	-Y
A13Z	727-2K-10-120	Cask Basket	0˚	A	+Z
A14X	727-2K-10-120	Cask Basket	135˚	1	+X
A14Y	727-2K-10-120	Cask Basket	135˚	1	-Y
A14Z	727-2K-10-120	Cask Basket	135˚	1	+Z
A15X	7265A	Cask Body	0˚	Top Base	+X
A15Y	7265A	Cask Body	0˚	Top Base	-Y
A15Z	7265A	Cask Body	0˚	Top Base	+Z
A16X	7265A	Cask Body	0˚	Top Closure	+X
A16Y	7265A	Cask Body	0˚	Top Closure	-Y
A16Z	7265A	Cask Body	0˚	Top Closure	+Z
A17X	7265A	Cask Cradle	0˚	Cradle Rear	+X
A17Y	7265A	Cask Cradle	0˚	Cradle Rear	-Y
A17Z	7265A	Cask Cradle	0˚	Cradle Rear	+Z
A18X	7265A	Cask Cradle	0˚	Cradle Front	+X
A18Y	7265A	Cask Cradle	0˚	Cradle Front	-Y
A18Z	7265A	Cask Cradle	0˚	Cradle Front	+Z
A19X	7265A	Transporter	0˚	Transport Rear	+X
A19Y	7265A	Transporter	0˚	Transport Rear	-Y
A19Z	7265A	Transporter	0˚	Transport Rear	+Z
A20X	7265A	Transporter	0˚	Transport Center	+X
A20Y	7265A	Transporter	0˚	Transport Center	-Y
A20Z	7265A	Transporter	0˚	Transport Center	+Z
A21X	7265A	Transporter	0˚	Transport Front	+X
A21Y	7265A	Transporter	0˚	Transport Front	-Y
A21Z	7265A	Transporter	0˚	Transport Front	+Z

Note. The sign convention for the accelerometer measurements will be a right-hand rule with the longitudinal (x) along the track in direction of travel, lateral (y) positive to the left when facing the direction of travel, and the vertical (z) positive upwards.

Table 2
ENSA/DOE Transportation Test Instrumentation Requirements
Strain Gages

Strain Gage Designation	Micro-Measurements Part Number	Assembly Location	Angular Location	Cask Assembly
SG1-0	CEA03—062UW-350	C1-LR	0°	SNL
SG1-90	CEA03—062UW-350	C1-LR	90°	SNL
SG1-225	CEA03—062UW-350	C1-LR	225°	SNL
SG2-0	CEA03—062UW-350	C2-LR	0°	SNL
SG2-90	CEA03—062UW-350	C2-LR	90°	SNL
SG3-0	CEA03—062UW-350	A-LR	0°	SNL
SG4-0	CEA03—062UW-350	C1-MO	0°	SNL
SG4-90	CEA03—062UW-350	C1-MO	90°	SNL
SG4-225	CEA03—062UW-350	C1-MO	225°	SNL
SG5-0	CEA03—062UW-350	C2-MO	0°	SNL
SG5-90	CEA03—062UW-350	C2-MO	90°	SNL
SG6-0	CEA03—062UW-350	A-MO	0°	SNL
SG7-0	CEA03—062UW-350	B-MO	0°	SNL
SG8-0	CEA03—062UW-350	C1-LP	0°	SNL
SG8-90	CEA03—062UW-350	C1-LP	90°	SNL
SG8-225	CEA03—062UW-350	C1-LP	225°	SNL
SG9-0	CEA03—062UW-350	C2-LP	0°	SNL
SG9-90	CEA03—062UW-350	C2-LP	90°	SNL
SG10-0	CEA03—062UW-350	C3-Left	0°	ENSA
SG11-0	CEA03—062UW-350	C1-Left	0°	ENSA
SG12-0	CEA03—062UW-350	C2-Left	0°	ENSA
SG13-0	CEA03—062UW-350	A-Left	0°	ENSA
SG14-0	CEA03—062UW-350	B´-Left	0°	ENSA
SG15-0	CEA03—062UW-350	B-Left	0°	ENSA
SG16-0	CEA03—062UW-350	C3-Center	0°	ENSA
SG17-0	CEA03—062UW-350	C1-Center	0°	ENSA
SG18-0	CEA03—062UW-350	C2-Center	0°	ENSA
SG19-0	CEA03—062UW-350	A-Center	0°	ENSA
SG20-0	CEA03—062UW-350	B´-Center	0°	ENSA
SG21-0	CEA03—062UW-350	B-Center	0°	ENSA
SG22-0	CEA03—062UW-350	C3-Center	0°	ENSA
SG23-0	CEA03—062UW-350	C1-Center	0°	ENSA
SG24-0	CEA03—062UW-350	C2-Center	0°	ENSA
SG25-0	CEA03—062UW-350	A-Center	0°	ENSA
SG26-0	CEA03—062UW-350	B´-Center	0°	ENSA
SG27-0	CEA03—062UW-350	B-Center	0°	ENSA
SG28-0	CEA03—062UW-350	C1-Center	0°	Korean

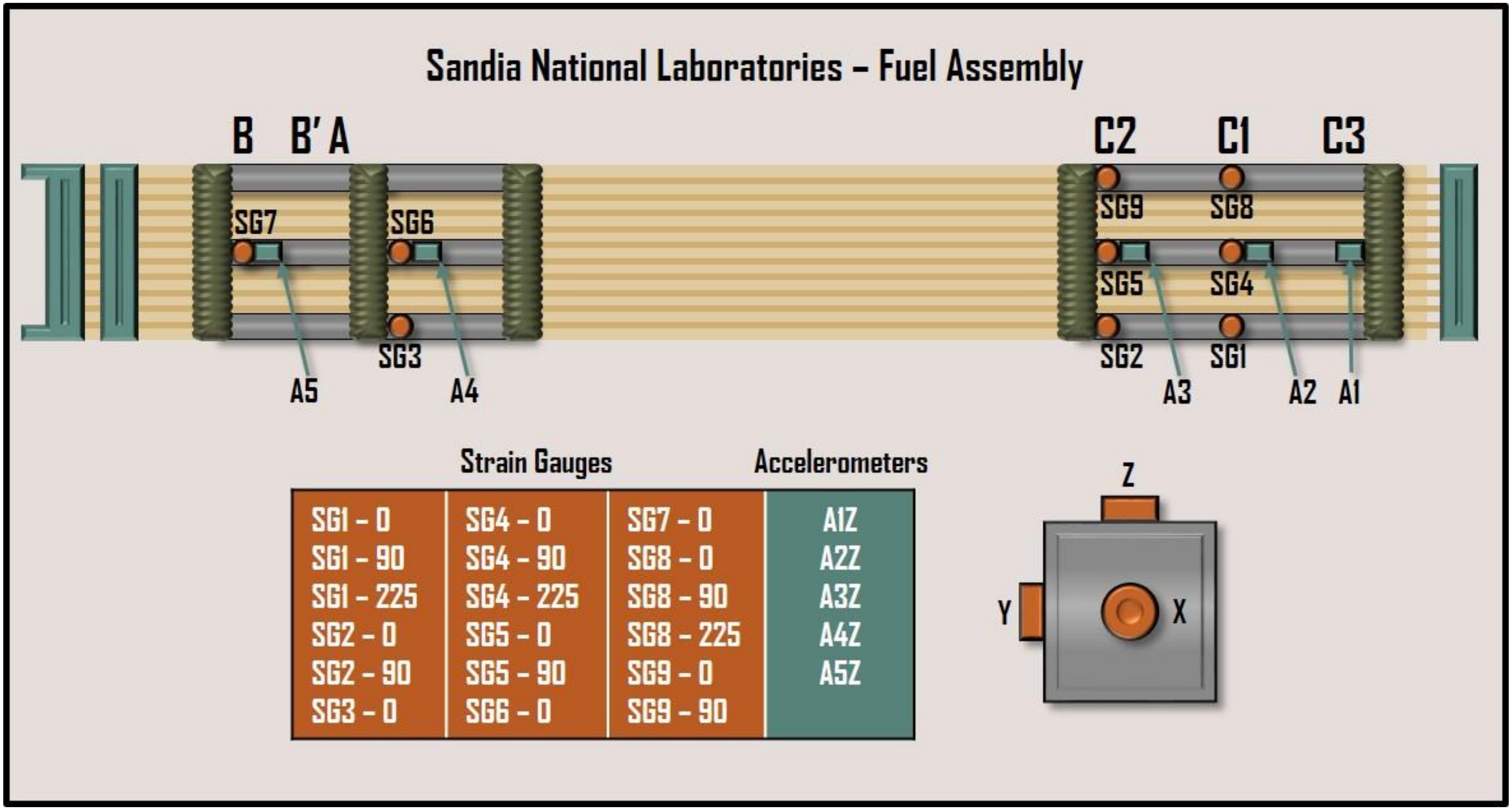


Figure 1. ENSA/DOE Test Instrumentation Locations (Sandia Fuel Assembly)

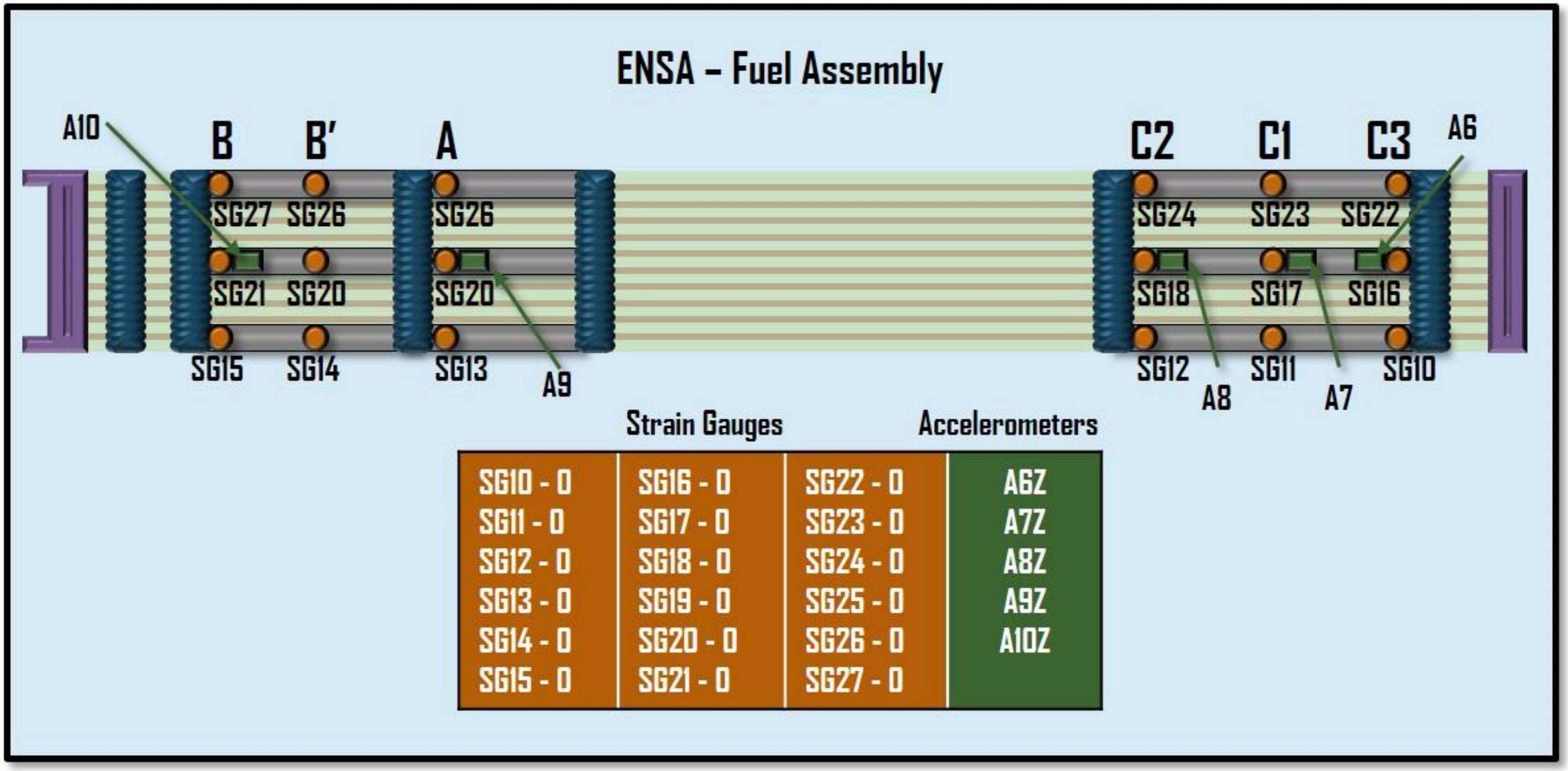


Figure 2. ENSA/DOE Test Instrumentation Locations (ENSA Fuel Assembly)

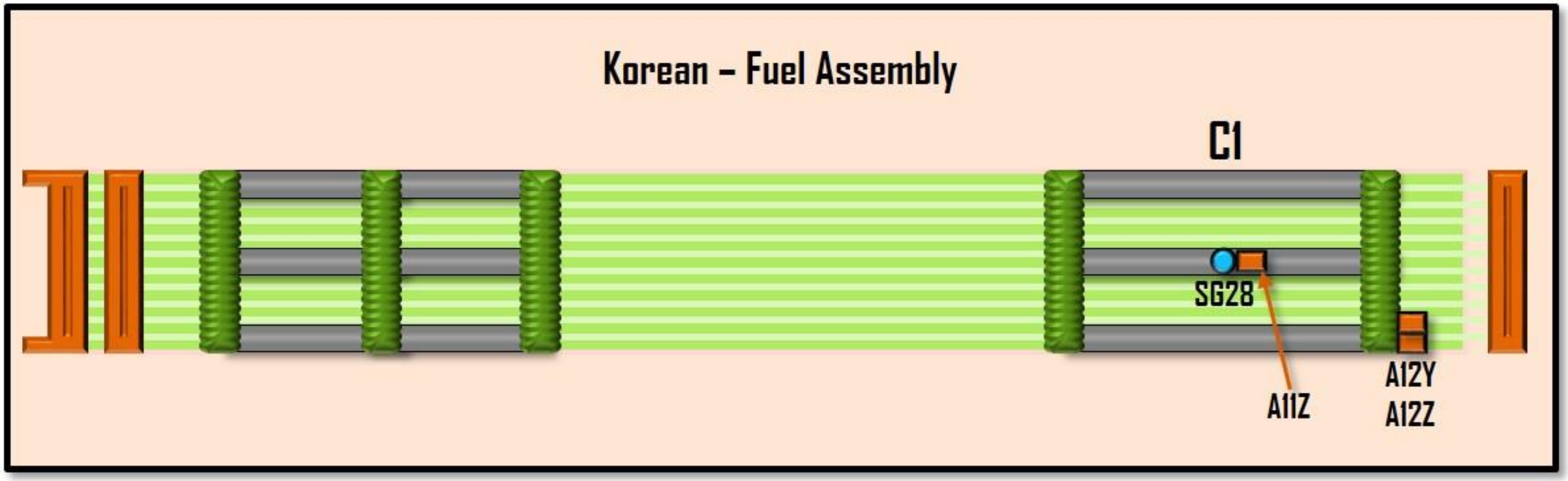


Figure 3. ENSA/DOE Test Instrumentation Locations (Korean Fuel Assembly)

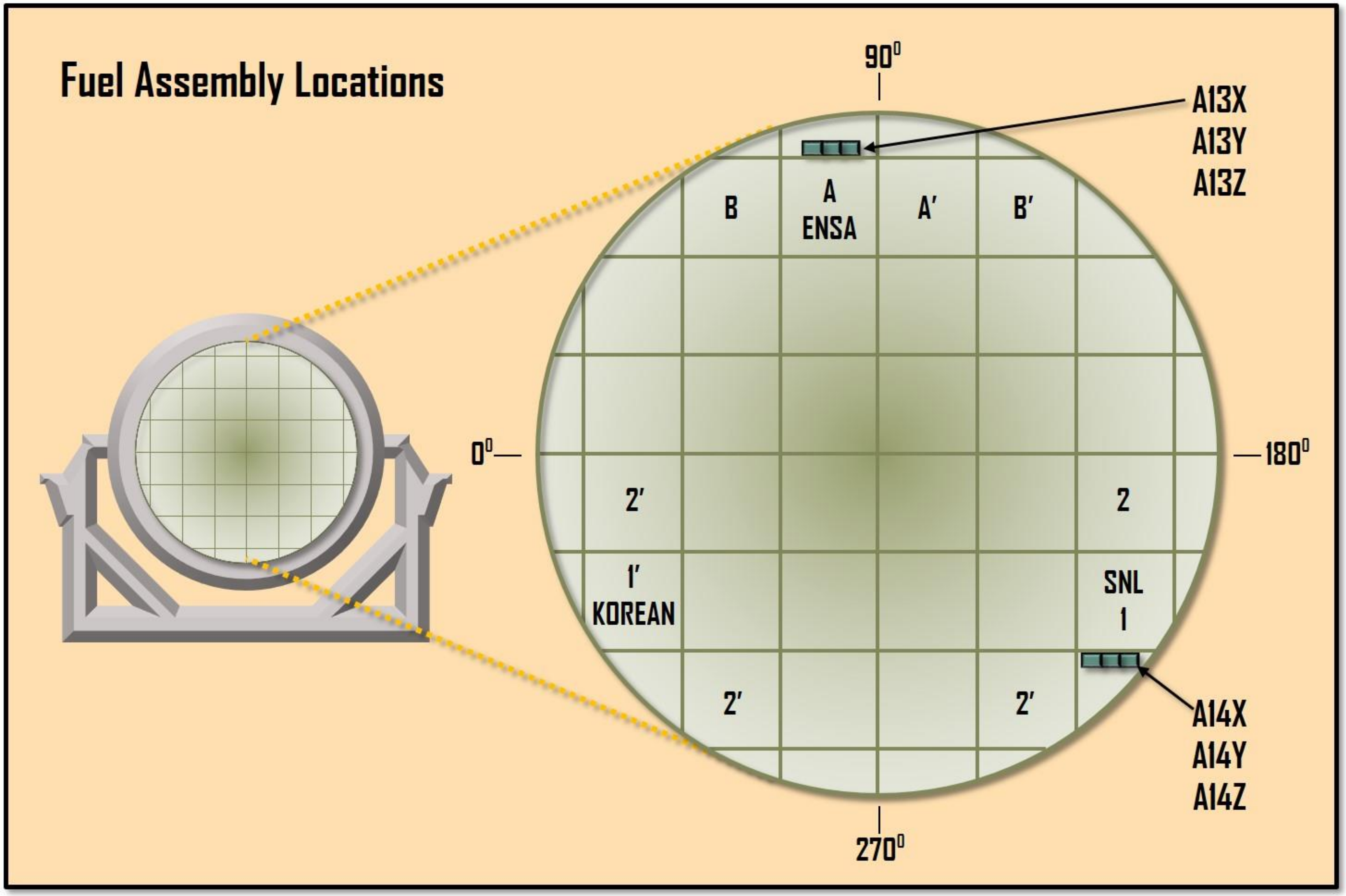


Figure 4. ENSA/DOE Test Instrumentation Locations (Basket Assembly)

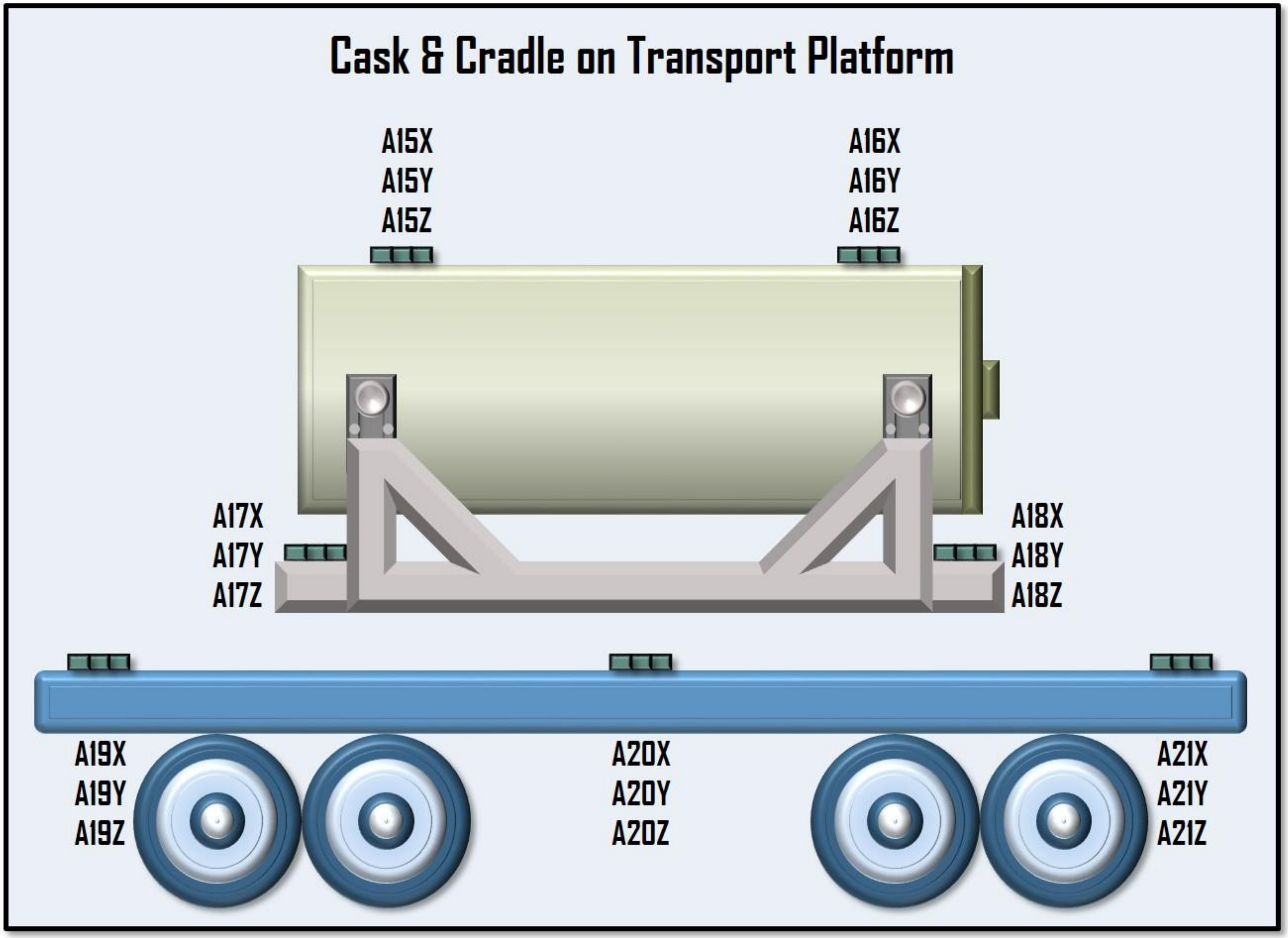


Figure 5. ENSA/DOE Test Instrumentation Locations (Cask and Transporter)

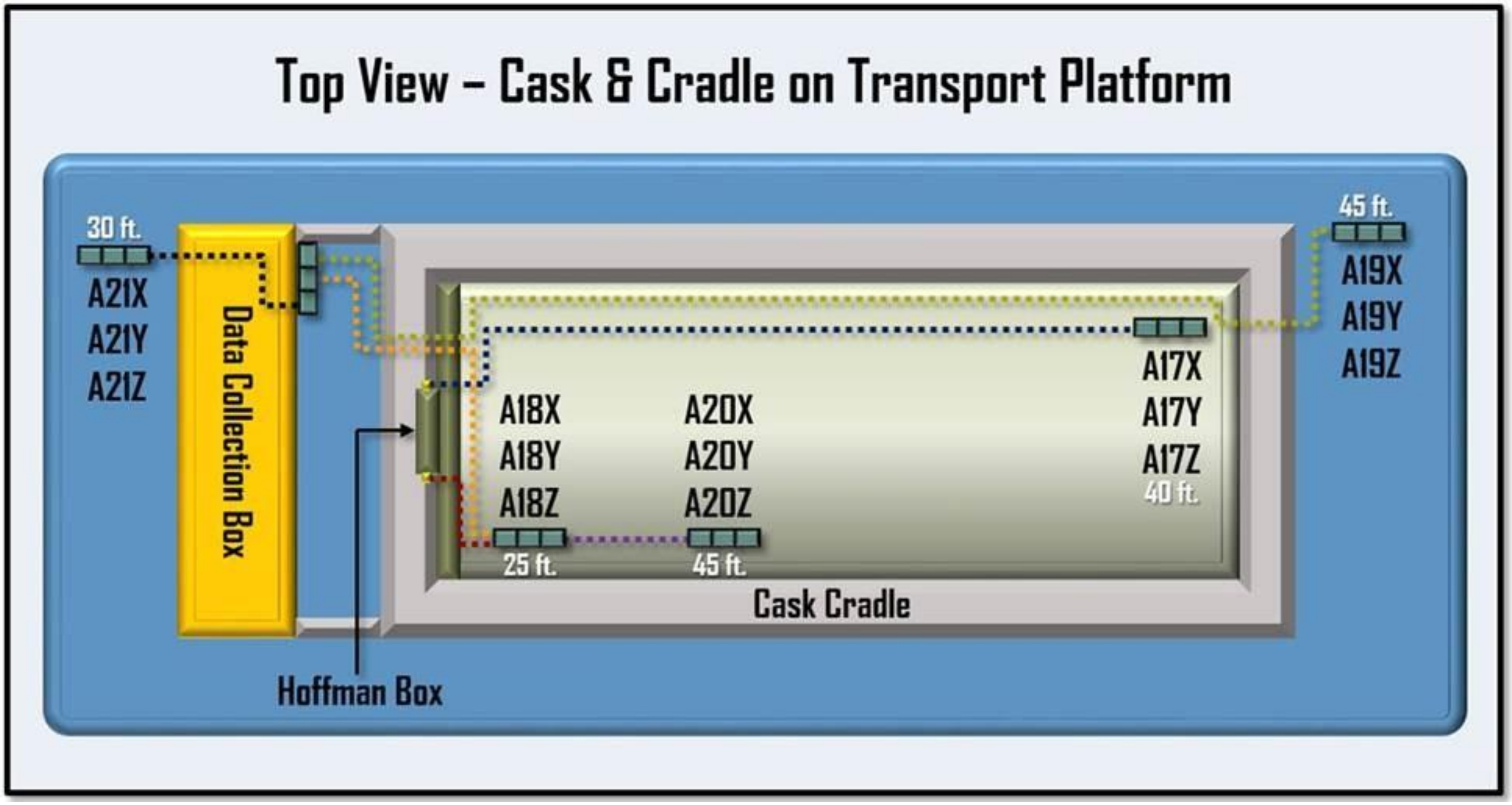


Figure 5. ENSA/DOE Test Instrumentation Locations (Cask and Transporter)

Accelerometers will be mounted on isolated uni-axial and tri-axial mounting blocks that are glued to the test hardware using Hardman 04001 two-part epoxy. The accelerometer mounting block surfaces will be cleaned with 600 grit sandpaper and denatured alcohol. The 727 accelerometers will be glued directly to the mounting blocks using the Hardman 04001 two-part epoxy. The 7265A accelerometers will be attached to the tri-axial mounting blocks using the manufacture supplied mounting hardware. The 7265A accelerometers will be installed by alternately torquing the two manufacturer supplied 2-56 UNC mounting screws in 2 in-lb increments to a final torque of 5 in-lb ± 1 in-lb.

The ends of each accelerometer lead wire will be modified with extension cables. These extension cables will transition from the manufacturer's supplied four conductor 36 AWG shielded copper wire for the 727 accelerometers to a four conductor 26 AWG shielded copper wire. This larger diameter extension cable will allow for a more reliable termination of the accelerometer cabling to the terminal strips located in the closure mounted junction box. The 727 extension cable will be installed using a flat wire splice using the shield wire as the conductor transferring any mechanical loads. The 727 extension cable is manufactured by Micro-Tek Inc., part number 30/7385PC/026. The 7265A accelerometers will also be modified with extension cables using the same type and gage of cable used on the accelerometer. As with the 727 accelerometers the 7265A extension wire will be installed using a flat wire splice using the shield wire as the conductor transferring any mechanical loads. The 7265A extension cable is manufactured by Endevco, Meggitt, part number 24328-3.

After installing the extension cables, the ends of each accelerometer lead wire will be marked with the appropriate accelerometer designation defined in Table 1. The measurement direction of each accelerometer has been included as part of the designation. The sign convention for the accelerometer measurements will be a right-hand rule with the longitudinal (x) along the track in direction of travel, lateral (y) positive to the left when facing the direction of travel, and the vertical (z) positive upwards.

8.0 STRAIN GAGE INSTALLATION

8.1 Equipment and Supplies

Strain gages listed in Table 2
Soldering station, temperature controlled
Gage adhesive, Micro-Measurements (M-M) M-Bond 200
Wire, M-M #330-FFE or Gore #A01B120/2
M-Prep conditioner A and neutralizer 5, M-M
Rosin and rosin solvent, M-M
Solder, 63/37 tin-lead
RTV, Dow Corning 3145
Strain gage installation weights
Aluminum foil tape

8.2 Strain Gage Installation Reference Documents

M-M B-129-4, Surface Preparation for Strain Gage Bonding
M-M B-127-9, Strain Gage Application with M-Bond 200
M-M TT-607, Strain Gage Installation
M-M TT-609, Soldering Techniques

8.3 Strain Gage Installation

A total of 37 uni-axial strain gages will be installed on the three surrogate spent fuel assemblies. 18 strain gages will be mounted on the ENSA and Sandia assemblies and one strain gage will be mounted on the KAERI, Korean assembly. The location of each strain gage can be found in Table 2 and Figure 1-5. A copy of the gage manufacturer's product specification sheet is located in Attachment 2.

The mounting area surfaces for each strain gage installation will be prepared using sandpaper and the M-M Conditioner A and Neutralizer 5 using the applicable installation procedure per Micro Measurements Document B-129-4. The strain gages will be installed per Micro-Measurements reference documents B-127-9 using M-Bond 200 adhesive and weights.

After installation of the strain gages, attach lead wires (long enough to connect to the terminal strips mounted in the closure junction box) to each gage following Micro-Measurements reference document TT-609. After the lead wires have been installed, coat each strain gage with a thin layer of clear coat polyurethane for protection. The strain gage leads will be twisted, as required, and carefully routed and secured along the surrogate fuel rods using glass tape. The appropriate strain gage designations will be marked on the individual strain gage lead wires. After installation of the three instrumented surrogate spent fuel assemblies in the cask basket the lead wires will be routed through holes in the cask closure during installation of the closure assembly. Care must be taken not to pinch the wiring during installation of the closure. After installation of the closure assembly the instrumentation cabling will be routed in grooves cut in the exterior of the closure assembly toward the junction box located at the center of the closure. Again, care must be taken so the instrumentation cabling is not damaged during installation of the closure and the closure junction box.

9.0 INSTRUMENTATION WIRE ROUTING

9.1 Equipment and Supplies

Soldering station, temperature controlled
Heat gun
Terminal strips
Acrylic adhesive, Hardman 04001 two-part epoxy
Rosin and rosin solvent, M-M
Solder, 63/37 tin-lead
Crimp/Solder lugs
Heat shrink tubing to fit lugs
Wire strippers/cutters
Aluminum foil tape

9.2 Connection

The wires from each measurement transducer will be routed to three phenolic panels located in the closure mounted junction box. Terminal strips will be mounted on each 17 x 17 inch phenolic panels located inside the junction box using Hardman 04001 two-part epoxy. The phenolic panels will be sanded and a thin layer of adhesive will be used to secure each terminal strip to the terminal panel. The individual wire leads will either be attached using insulated crimp type terminals or soldered to terminal lugs and covered with heat shrink tubing to protect the wire connection. The terminal lugs will be secured to the terminal strips using the manufacturers supplied terminal strip screws.

The measurement transducer identification will be marked on the terminal panel adjacent to the terminal strip where the cabling is terminated. The measurement transducer wiring will be secured inside the junction box using cable ties. The cabling will be secured to the junction box to minimize movement of the cabling during the test program.

10.0 INSTALLATION ELECTRICAL TESTING PRE-TEST

After installation of the measurement transducers, resistance measurements will be made at the terminal strips before installation of the Siemens LMS field cabling. These pre-test resistance measurements will be recorded in Tables 3 and 4.

10.1 Accelerometers

Using a digital multimeter, measure the input, output, and insulation resistances of the accelerometer at the terminal strips or at the end of the field wire for accelerometers A19X through A21Z. Record the resistance data on the Accelerometer Installation Data Sheet, Table 3. If the accelerometer field cables are installed when making these resistance measurements, make sure the extension cable between the junction box and the LMS data collection system are not connected.

10.2 Strain Gages

Using a digital multimeter, measure the gage resistance and insulation resistance at the terminal strips. Record the resistance data on the Strain Gage Data Sheet, Table 4. If the strain gage field cables are installed when making these resistance measurements, make sure the extension cable between the junction box and the LMS data collection system are not connected.

10.3 Measurement Comparisons

Compare all resistance measurements to the calibration or manufacturer’s information for deviations which might indicate a problem with the measurement device. Any channel with a resistance measurement that is significantly different than expected will be inspected for wiring or transducer damage. Any such damage will be corrected by repair or replacement, if possible, prior to starting the test program.

Table 3
Accelerometer Installation Data Sheet

Accelerometer Identification	Endevco Accelerometer Type	Serial Number	Closure Junction Box		
			Input Resistance (ohms)	Output Resistance (ohms)	Insulation Resistance (ohms)
A1Z	727-2K-10-120	10157	600.1	599.3	≥20M
A2Z	727-2K-10-120	10143	633.0	637.0	≥20M
A3Z	727-2K-10-120	10199	613.0	609.0	≥20M
A4Z	727-2K-10-120	10124	614.0	617.0	≥20M
A5Z	727-2K-10-120	10693	593.7	591.9	≥20M
A6Z	727-2K-10-120	10664	591.0	586.0	≥20M
A7Z	727-2K-10-120	10668	594.0	591.0	≥20M
A8Z	727-2K-10-120	10671	583.0	591.0	≥20M
A9Z	727-2K-10-120	10674	599.0	606.0	≥20M
A10Z	727-2K-10-120	10675	609.0	605.0	≥20M
A11Z	727-2K-10-120	10684	619.0	624.0	≥20M
A12Y	727-2K-10-120	10555	598.0	604.0	≥20M
A12Z	727-2K-10-120	10685	608.0	614.0	≥20M
A13X	727-2K-10-120	10574	608.0	613.0	≥20M
A13Y	727-2K-10-120	10127	647.0	642.0	≥20M
A13Z	727-2K-10-120	10130	624.0	628.0	≥20M
A14X	727-2K-10-120	10609	605.0	600.0	≥20M
A14Y	727-2K-10-120	10613	618.0	623.0	≥20M
A14Z	727-2K-10-120	10653	629.0	624.0	≥20M
A15X	7265A	D17460	745.0	946.0	≥20M
A15Y	7265A	D17456	753.0	974.0	≥20M
A15Z	7265A	D17467	749.0	963.0	≥20M
A16X	7265A	D17475	712.0	854.0	≥20M
A16Y	7265A	D17477	745.0	953.0	≥20M
A16Z	7265A	D17480	737.0	926.0	≥20M
A17X	7265A	D17481	745.0	947.0	≥20M
A17Y	7265A	D17503	754.0	975.0	≥20M
A17Z	7265A	D17526	734.0	902.0	≥20M
A18X	7265A	D17528	720.0	871.0	≥20M
A18Y	7265A	D17533	734.0	913.0	≥20M
A18Z	7265A	D17545	751.0	979.0	≥20M
A19X	7265A	D17546	744.0	972.0	≥20M
A19Y	7265A	D17551	733.0	933.0	≥20M
A19Z	7265A	D17557	704.0	842.0	≥20M
A20X	7265A	D17571	726.0	906.0	≥20M
A20Y	7265A	D17573	729.0	916.0	≥20M
A20Z	7265A	D17583	704.0	838.0	≥20M
A21X	7265A	D17589	743.0	967.0	≥20M
A21Y	7265A	D17590	694.0	812.0	≥20M
A21Z	7265A	D17603	705.0	840.0	≥20M

Table 4
Strain Gage Installation Data Sheet

Strain Gage Designation	Strain Gage Resistance (ohms)	Closure Junction Box	
		Input Resistance (ohms)	Output Resistance (ohms)
SG1-0	354.1		
SG1-90	353.4		
SG1-225	354.1		
SG2-0	353.7		
SG2-90	353.5		
SG3-0	354.1		
SG4-0	353.5		
SG4-90	352.9		
SG4-225	353.2		
SG5-0	353.1		
SG5-90	353.5		
SG6-0	354.0		
SG7-0	354.9		
SG8-0	353.3		
SG8-90	354.3		
SG8-225	354.0		
SG9-0	353.2		
SG9-90	353.7		
SG10-0	352.9		
SG11-0	353.9		
SG12-0	353.4		
SG13-0	356.2		
SG14-0	356.2		
SG15-0	356.4		
SG16-0	354.6		
SG17-0	354.3		
SG18-0	354.3		
SG19-0	356.2		
SG20-0	356.3		
SG21-0	355.1		
SG22-0	354.8		
SG23-0	354.7		
SG24-0	354.9		
SG25-0	356.4		
SG26-0	357.2		
SG27-0	357.4		
SG28-0	351.2		

11.0 PRE-TEST FIELD CABLE INSTALLATION

11.1 Installation

Field cabling will be installed between the closure junction box and the Siemens LMS data collection system. This field cabling will connect the individual measurement devices to the data collection system located in the instrumentation enclosure. The data collection enclosure is a large metal box that contains 20- 12 volt batteries and the power distribution systems to power and control the Siemens data collection system.

Each field cable will be identified with a cable designation that is referenced to the measurement transducer designation. The cable designation and measurement transducer identification information can be found in Appendix 3, ENSA/DOE Transportation Cask Instrumentation Cabling Definition. The Appendix includes instrumentation cable definition tables for the handling, heavy haul truck, barge, ocean, rail no. 1, TTCI and rail no. 2 testing. These tables provide all of the information required to define the measurement device, gage designation, cable interconnection to the LMS data collection hardware and the parameters needed to prepare a data collection database for the individual test. These tables are key elements in controlling the configuration of the data collection hardware and the appropriate sample rates and filter requirements.

12.0 ENSA/DOE DATA COLLECTION TRANSPORTATION TEST PROCEDURE

After installation and verification of the measurement devices on the spent fuel transportation system the Siemens LMS data collection system will be configured for one of the test modes. The preparation of the data collection system including the portable battery power source will be controlled and verified by the use of hold point check lists. The check lists will assist personnel responsible for the data collection operations to assure all of the steps required to collect the data have been performed, verified and documented. Since many of the transportation mode tests can’t be repeated the data collection effort for these events is considered a single shot event. In order to increase to chance of collecting data from these events a checklist has been developed to document the critical steps required prior to starting the test. These required activities will be verified and initialed by the project manager. The goal is to provide the highest probability of collecting data during the test.

12.1 ENSA/DOE Data Collection Transportation Test Program Hold Point Checklist

Prior to starting the ENSA/DOE Transportation testing, the Project Manager shall verify that the activities defined the hold point check list for each transportation mode have been completed. The hold point check lists are found in Appendix 4. The following section contains a sample hold point check list.

SAMPLE
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST
(APPENDIX 4 CONTAINS PROGRAM HOLD POINT CHECK LISTS)

Transportation Test Mode ____________________
LMS Sample Rate ____________________
Number of Segments __________________
Segment Duration ____________________

Initials **Required Activity**

________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

________ 3. The LMS database has been created and verified using information from Appendix 3.

________ 4. The LMS database has been downloaded to the test SD card and verified.

________ 5. The LMS data collection system has been connected to the laptop and the hardware is operating and the baselines have been reviewed.

________ 6. The 24 Volt batteries have been charged.

________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

________ 8. The master 24 Volt power switch has been turned on.

________ 9. The 24 Volt timer power switch has been turned on.

________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) __________
Battery Voltage (Under Load) ___________

________ 11. The test SD card has been installed in the LMS master recorder.

________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

SAMPLE
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST
(APPENDIX 4 CONTAINS PROGRAM HOLD POINT CHECK LISTS)
(continued)

Initials	Required Activity
_________	14. Verify the LMS system communications with the Tablet in scope mode.
_________	15. Verify LMS GPS is locked and providing data to the Tablet.
_________	16. Verify LMS system control and balance function using the Tablet.
_________	17. Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights
_________	18. Determine the Project Manager and support personnel are ready to start the test.
_________	19. Verify battery voltage and all four fans are running.
_________	20. Project Manager authorizes to start the test.
_________	21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.
_________	22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
_________	23. Record the start time of the test. ________________________________
_________	24. Turn the timer trigger to the on position for 5 seconds and turn the trigger off. Verify the timer position is at 360 hours.
_________	25. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

Completed:

____________________ _________
Project Manager Date

____________________ _________
Instrumentation Coordinator Date

13.0 ENSA/DOE TEST PROGRAM POST-TEST ACTIVITIES

13.1 Post-Test Program Accelerometer and Strain Gage Electrical Testing

Prior to removing the accelerometers from the ENSA/DOE transportation cask an electrical check of the instrumentation will be performed at the closure mounted junction box for cask instrumentation or at the end of the cable for the transporter accelerometers. The resistance measurements will be recorded on the Post-Test Accelerometer Data Sheet, Table 5 and Post-Test Strain Gage Data Sheet, Table 6. If the accelerometer field cables are installed when making these resistance measurements, make sure the extension cable between the junction box and the LMS data collection system are not connected. The resistance data will be compared to pre-test resistance measurement data. Any significant deviations between pre- and post-test data will be noted in the applicable measurement table.

14.0 DOCUMENTATION

Documentation for the ENSA/DOE transportation test program will include: (1) a completed ENSA/DOE Transportation Test Procedure (2) electronic external hard drive(s) media containing all of the Siemens LMS raw .TRD and formatted .LDSF data collected during the test program. Multiple external hard drives will be required to store the large volume of data. The data from each of the four transportation modes and handling tests will each be stored on a separate external hard drive. In addition to the external hard drives the Siemens LMS SD cards will be saved and stored with the program documentation. Post processing of the collected transportation data will be part of a separate follow-on activity.

After completion of these activities the documentation package with the SD cards and external hard drives will be turned over to the Sandia ENSA/DOE Transportation Test Program Project Manager.

Table 5
Post-Test Accelerometer Data Sheet

Accelerometer Identification	Endevco Accelerometer Type	Serial Number	Closure Junction Box		
			Input Resistance (ohms)	Output Resistance (ohms)	Insulation Resistance (ohms)
A1Z	727-2K-10-120	10157			
A2Z	727-2K-10-120	10143			
A3Z	727-2K-10-120	10199			
A4Z	727-2K-10-120	10124			
A5Z	727-2K-10-120	10693			
A6Z	727-2K-10-120	10664			
A7Z	727-2K-10-120	10668			
A8Z	727-2K-10-120	10671			
A9Z	727-2K-10-120	10674			
A10Z	727-2K-10-120	10675			
A11Z	727-2K-10-120	10684			
A12Y	727-2K-10-120	10555			
A12Z	727-2K-10-120	10685			
A13X	727-2K-10-120	10574			
A13Y	727-2K-10-120	10127			
A13Z	727-2K-10-120	10130			
A14X	727-2K-10-120	10609			
A14Y	727-2K-10-120	10613			
A14Z	727-2K-10-120	10653			
A15X	7265A	D17460			
A15Y	7265A	D17456			
A15Z	7265A	D17467			
A16X	7265A	D17475			
A16Y	7265A	D17477			
A16Z	7265A	D17480			
A17X	7265A	D17481			
A17Y	7265A	D17503			
A17Z	7265A	D17526			
A18X	7265A	D17528			
A18Y	7265A	D17533			
A18Z	7265A	D17545			
A19X	7265A	D17546			
A19Y	7265A	D17551			
A19Z	7265A	D17557			
A20X	7265A	D17571			
A20Y	7265A	D17573			
A20Z	7265A	D17583			
A21X	7265A	D17589			
A21Y	7265A	D17590			
A21Z	7265A	D17603			

Table 6
Post-Test Strain Gage Data Sheet

Strain Gage Designation	Strain Gage Resistance (ohms)	Closure Junction Box	
		Input Resistance (ohms)	Output Resistance (ohms)
SG1-0			
SG1-90			
SG1-225			
SG2-0			
SG2-90			
SG3-0			
SG4-0			
SG4-90			
SG4-225			
SG5-0			
SG5-90			
SG6-0			
SG7-0			
SG8-0			
SG8-90			
SG8-225			
SG9-0			
SG9-90			
SG10-0			
SG11-0			
SG12-0			
SG13-0			
SG14-0			
SG15-0			
SG16-0			
SG17-0			
SG18-0			
SG19-0			
SG20-0			
SG21-0			
SG22-0			
SG23-0			
SG24-0			
SG25-0			
SG26-0			
SG27-0			
SG28-0			

Attachment 1

ENSA/DOE Transportation Test
Accelerometer Data

Attachment 2

ENSA/DOE Transportation Test
Strain Gage Data

Attachment 3

ENSA/DOE Transportation Test Instrumentation Cabling Definition

ENSA/DOE Transportation Cask Instrumentation Cabling Definition
Cask Handling Test

ENSA Transportation Cask Instrumentation Cabling Definition
Cask Handling Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-0	MM-330-FFE	1	BX13-68314	1	10,240	Full	5.0V	1,000Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-90	MM-330-FFE	2	BX13-68314	2	10,240	Full	5.0V	1,000Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-225	MM-330-FFE	3	BX13-68314	3	10,240	Full	5.0V	1,000Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-0	MM-330-FFE	4	BX13-68314	4	10,240	Full	5.0V	1,000Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-90	MM-330-FFE	5	BX13-68314	5	10,240	Full	5.0V	1,000Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG3-0	MM-330-FFE	6	BX13-68314	6	10,240	Full	5.0V	1,000Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-0	MM-330-FFE	7	BX13-68314	7	10,240	Full	5.0V	1,000Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-90	MM-330-FFE	8	BX13-68314	8	10,240	Full	5.0V	1,000Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-225	MM-330-FFE	9	BX13-68314	9	10,240	Full	5.0V	1,000Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-0	MM-330-FFE	10	BX13-68314	10	10,240	Full	5.0V	1,000Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-90	MM-330-FFE	11	BX13-68314	11	10,240	Full	5.0V	1,000Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG6-0	MM-330-FFE	12	BX13-68314	12	10,240	Full	5.0V	1,000Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG7-0	MM-330-FFE	13	BX13-68314	13	10,240	Full	5.0V	1,000Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-0	MM-330-FFE	14	BX13-68314	14	10,240	Full	5.0V	1,000Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-90	MM-330-FFE	15	BX13-68314	15	10,240	Full	5.0V	1,000Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-225	MM-330-FFE	16	BX13-68314	16	10,240	Full	5.0V	1,000Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-0	MM-330-FFE	17	BX13-68314	17	10,240	Full	5.0V	1,000Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-90	MM-330-FFE	18	BX13-68314	18	10,240	Full	5.0V	1,000Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG10-0	MM-330-FFE	19	BX13-68314	19	10,240	Full	5.0V	1,000Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG11-0	MM-330-FFE	20	BX13-68314	20	10,240	Full	5.0V	1,000Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG12-0	MM-330-FFE	21	BX13-68314	21	10,240	Full	5.0V	1,000Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG13-0	MM-330-FFE	22	BX13-68314	22	10,240	Full	5.0V	1,000Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG14-0	MM-330-FFE	23	BX13-68314	23	10,240	Full	5.0V	1,000Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG15-0	MM-330-FFE	24	BX13-68314	24	10,240	Full	5.0V	1,000Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG16-0	MM-330-FFE	25	BX13-68314	25	10,240	Full	5.0V	1,000Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG17-0	MM-330-FFE	26	BX13-68314	26	10,240	Full	5.0V	1,000Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG18-0	MM-330-FFE	27	BX13-68314	27	10,240	Full	5.0V	1,000Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG19-0	MM-330-FFE	28	BX13-68314	28	10,240	Full	5.0V	1,000Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG20-0	MM-330-FFE	29	BX13-68314	29	10,240	Full	5.0V	1,000Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG21-0	MM-330-FFE	30	BX13-68314	30	10,240	Full	5.0V	1,000Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG22-0	MM-330-FFE	31	BX13-68314	31	10,240	Full	5.0V	1,000Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG23-0	MM-330-FFE	32	BX13-68314	32	10,240	Full	5.0V	1,000Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG24-0	MM-330-FFE	33	BX13-68314	33	10,240	Full	5.0V	1,000Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG25-0	MM-330-FFE	34	BX13-68314	34	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Cask Handling Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG26-0	MM-330-FFE	35	BX13-68314	35	10,240	Full	5.0V	1,000Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG27-0	MM-330-FFE	36	BX13-68314	36	10,240	Full	5.0V	1,000Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG28-0	MM-330-FFE	37	BX13-68314	37	10,240	Full	5.0V	1,000Hz
A1Z	727-2K-10-120	10157	8.953 µV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	10,240	Full	5.0V	1,000Hz
A2Z	727-2K-10-120	10143	5.709 µV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	10,240	Full	5.0V	1,000Hz
A3Z	727-2K-10-120	10199	5.893 µV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	10,240	Full	5.0V	1,000Hz
A4Z	727-2K-10-120	10124	5.873 µV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	10,240	Full	5.0V	1,000Hz
A5Z	727-2K-10-120	10693	8.299 µV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	10,240	Full	5.0V	1,000Hz
A6Z	727-2K-10-120	10664	8.438 µV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	10,240	Full	5.0V	1,000Hz
A7Z	727-2K-10-120	10668	8.014 µV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	10,240	Full	5.0V	1,000Hz
A8Z	727-2K-10-120	10671	8.057 µV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	10,240	Full	5.0V	1,000Hz
A9Z	727-2K-10-120	10674	8.160 µV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	10,240	Full	5.0V	1,000Hz
A10Z	727-2K-10-120	10675	8.408 µV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	10,240	Full	5.0V	1,000Hz
A11Z	727-2K-10-120	10684	7.951 µV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	10,240	Full	5.0V	1,000Hz
A12Y	727-2K-10-120	10555	8.712 µV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	10,240	Full	5.0V	1,000Hz
A12Z	727-2K-10-120	10685	8.394 µV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	10,240	Full	5.0V	1,000Hz
A13X	727-2K-10-120	10574	8.301 µV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	10,240	Full	5.0V	1,000Hz
A13Y	727-2K-10-120	10127	5.925 µV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	10,240	Full	5.0V	1,000Hz
A13Z	727-2K-10-120	10130	5.448 µV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	10,240	Full	5.0V	1,000Hz
A14X	727-2K-10-120	10609	8.668 µV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	10,240	Full	5.0V	1,000Hz
A14Y	727-2K-10-120	10613	8.240 µV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	10,240	Full	5.0V	1,000Hz
A14Z	727-2K-10-120	10653	8.724 µV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	10,240	Full	5.0V	1,000Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	10,240	Full	5.0V	1,000Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	10,240	Full	5.0V	1,000Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	10,240	Full	5.0V	1,000Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	10,240	Full	5.0V	1,000Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	10,240	Full	5.0V	1,000Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	10,240	Full	5.0V	1,000Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Handling Test

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Handling Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-0	MM-330-FFE	1	BX13-68314	1	10,240	Full	5.0V	1,000Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-90	MM-330-FFE	2	BX13-68314	2	10,240	Full	5.0V	1,000Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-225	MM-330-FFE	3	BX13-68314	3	10,240	Full	5.0V	1,000Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-0	MM-330-FFE	4	BX13-68314	4	10,240	Full	5.0V	1,000Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-90	MM-330-FFE	5	BX13-68314	5	10,240	Full	5.0V	1,000Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG3-0	MM-330-FFE	6	BX13-68314	6	10,240	Full	5.0V	1,000Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-0	MM-330-FFE	7	BX13-68314	7	10,240	Full	5.0V	1,000Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-90	MM-330-FFE	8	BX13-68314	8	10,240	Full	5.0V	1,000Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-225	MM-330-FFE	9	BX13-68314	9	10,240	Full	5.0V	1,000Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-0	MM-330-FFE	10	BX13-68314	10	10,240	Full	5.0V	1,000Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-90	MM-330-FFE	11	BX13-68314	11	10,240	Full	5.0V	1,000Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG6-0	MM-330-FFE	12	BX13-68314	12	10,240	Full	5.0V	1,000Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG7-0	MM-330-FFE	13	BX13-68314	13	10,240	Full	5.0V	1,000Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-0	MM-330-FFE	14	BX13-68314	14	10,240	Full	5.0V	1,000Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-90	MM-330-FFE	15	BX13-68314	15	10,240	Full	5.0V	1,000Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-225	MM-330-FFE	16	BX13-68314	16	10,240	Full	5.0V	1,000Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-0	MM-330-FFE	17	BX13-68314	17	10,240	Full	5.0V	1,000Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-90	MM-330-FFE	18	BX13-68314	18	10,240	Full	5.0V	1,000Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG10-0	MM-330-FFE	19	BX13-68314	19	10,240	Full	5.0V	1,000Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG11-0	MM-330-FFE	20	BX13-68314	20	10,240	Full	5.0V	1,000Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG12-0	MM-330-FFE	21	BX13-68314	21	10,240	Full	5.0V	1,000Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG13-0	MM-330-FFE	22	BX13-68314	22	10,240	Full	5.0V	1,000Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG14-0	MM-330-FFE	23	BX13-68314	23	10,240	Full	5.0V	1,000Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG15-0	MM-330-FFE	24	BX13-68314	24	10,240	Full	5.0V	1,000Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG16-0	MM-330-FFE	25	BX13-68314	25	10,240	Full	5.0V	1,000Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG17-0	MM-330-FFE	26	BX13-68314	26	10,240	Full	5.0V	1,000Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG18-0	MM-330-FFE	27	BX13-68314	27	10,240	Full	5.0V	1,000Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG19-0	MM-330-FFE	28	BX13-68314	28	10,240	Full	5.0V	1,000Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG20-0	MM-330-FFE	29	BX13-68314	29	10,240	Full	5.0V	1,000Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG21-0	MM-330-FFE	30	BX13-68314	30	10,240	Full	5.0V	1,000Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG22-0	MM-330-FFE	31	BX13-68314	31	10,240	Full	5.0V	1,000Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG23-0	MM-330-FFE	32	BX13-68314	32	10,240	Full	5.0V	1,000Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG24-0	MM-330-FFE	33	BX13-68314	33	10,240	Full	5.0V	1,000Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG25-0	MM-330-FFE	34	BX13-68314	34	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Handling Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG26-0	MM-330-FFE	35	BX13-68314	35	10,240	Full	5.0V	1,000Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG27-0	MM-330-FFE	36	BX13-68314	36	10,240	Full	5.0V	1,000Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG28-0	MM-330-FFE	37	BX13-68314	37	10,240	Full	5.0V	1,000Hz
A1Z	727-2K-10-120	10157	8.953 µV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	10,240	Full	5.0V	1,000Hz
A2Z	727-2K-10-120	10143	5.709 µV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	10,240	Full	5.0V	1,000Hz
A3Z	727-2K-10-120	10199	5.893 µV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	10,240	Full	5.0V	1,000Hz
A4Z	727-2K-10-120	10124	5.873 µV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	10,240	Full	5.0V	1,000Hz
A5Z	727-2K-10-120	10693	8.299 µV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	10,240	Full	5.0V	1,000Hz
A6Z	727-2K-10-120	10664	8.438 µV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	10,240	Full	5.0V	1,000Hz
A7Z	727-2K-10-120	10668	8.014 µV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	10,240	Full	5.0V	1,000Hz
A8Z	727-2K-10-120	10671	8.057 µV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	10,240	Full	5.0V	1,000Hz
A9Z	727-2K-10-120	10674	8.160 µV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	10,240	Full	5.0V	1,000Hz
A10Z	727-2K-10-120	10675	8.408 µV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	10,240	Full	5.0V	1,000Hz
A11Z	727-2K-10-120	10684	7.951 µV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	10,240	Full	5.0V	1,000Hz
A12Y	727-2K-10-120	10555	8.712 µV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	10,240	Full	5.0V	1,000Hz
A12Z	727-2K-10-120	10685	8.394 µV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	10,240	Full	5.0V	1,000Hz
A13X	727-2K-10-120	10574	8.301 µV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	10,240	Full	5.0V	1,000Hz
A13Y	727-2K-10-120	10127	5.925 µV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	10,240	Full	5.0V	1,000Hz
A13Z	727-2K-10-120	10130	5.448 µV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	10,240	Full	5.0V	1,000Hz
A14X	727-2K-10-120	10609	8.668 µV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	10,240	Full	5.0V	1,000Hz
A14Y	727-2K-10-120	10613	8.240 µV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	10,240	Full	5.0V	1,000Hz
A14Z	727-2K-10-120	10653	8.724 µV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	10,240	Full	5.0V	1,000Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	10,240	Full	5.0V	1,000Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	10,240	Full	5.0V	1,000Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	10,240	Full	5.0V	1,000Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	10,240	Full	5.0V	1,000Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	10,240	Full	5.0V	1,000Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	10,240	Full	5.0V	1,000Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	10,240	Full	5.0V	1,000Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	10,240	Full	5.0V	1,000Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	10,240	Full	5.0V	1,000Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	10,240	Full	5.0V	1,000Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	10,240	Full	5.0V	1,000Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Truck Test

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Truck Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-0	MM-330-FFE	1	BX13-68314	1	512	Full	5.0V	200Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-90	MM-330-FFE	2	BX13-68314	2	512	Full	5.0V	200Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-225	MM-330-FFE	3	BX13-68314	3	512	Full	5.0V	200Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-0	MM-330-FFE	4	BX13-68314	4	512	Full	5.0V	200Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-90	MM-330-FFE	5	BX13-68314	5	512	Full	5.0V	200Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG3-0	MM-330-FFE	6	BX13-68314	6	512	Full	5.0V	200Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-0	MM-330-FFE	7	BX13-68314	7	512	Full	5.0V	200Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-90	MM-330-FFE	8	BX13-68314	8	512	Full	5.0V	200Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-225	MM-330-FFE	9	BX13-68314	9	512	Full	5.0V	200Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-0	MM-330-FFE	10	BX13-68314	10	512	Full	5.0V	200Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-90	MM-330-FFE	11	BX13-68314	11	512	Full	5.0V	200Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG6-0	MM-330-FFE	12	BX13-68314	12	512	Full	5.0V	200Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG7-0	MM-330-FFE	13	BX13-68314	13	512	Full	5.0V	200Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-0	MM-330-FFE	14	BX13-68314	14	512	Full	5.0V	200Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-90	MM-330-FFE	15	BX13-68314	15	512	Full	5.0V	200Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-225	MM-330-FFE	16	BX13-68314	16	512	Full	5.0V	200Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-0	MM-330-FFE	17	BX13-68314	17	512	Full	5.0V	200Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-90	MM-330-FFE	18	BX13-68314	18	512	Full	5.0V	200Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG10-0	MM-330-FFE	19	BX13-68314	19	512	Full	5.0V	200Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG11-0	MM-330-FFE	20	BX13-68314	20	512	Full	5.0V	200Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG12-0	MM-330-FFE	21	BX13-68314	21	512	Full	5.0V	200Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG13-0	MM-330-FFE	22	BX13-68314	22	512	Full	5.0V	200Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG14-0	MM-330-FFE	23	BX13-68314	23	512	Full	5.0V	200Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG15-0	MM-330-FFE	24	BX13-68314	24	512	Full	5.0V	200Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG16-0	MM-330-FFE	25	BX13-68314	25	512	Full	5.0V	200Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG17-0	MM-330-FFE	26	BX13-68314	26	512	Full	5.0V	200Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG18-0	MM-330-FFE	27	BX13-68314	27	512	Full	5.0V	200Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG19-0	MM-330-FFE	28	BX13-68314	28	512	Full	5.0V	200Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG20-0	MM-330-FFE	29	BX13-68314	29	512	Full	5.0V	200Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG21-0	MM-330-FFE	30	BX13-68314	30	512	Full	5.0V	200Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG22-0	MM-330-FFE	31	BX13-68314	31	512	Full	5.0V	200Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG23-0	MM-330-FFE	32	BX13-68314	32	512	Full	5.0V	200Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG24-0	MM-330-FFE	33	BX13-68314	33	512	Full	5.0V	200Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG25-0	MM-330-FFE	34	BX13-68314	34	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Truck Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG26-0	MM-330-FFE	35	BX13-68314	35	512	Full	5.0V	200Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG27-0	MM-330-FFE	36	BX13-68314	36	512	Full	5.0V	200Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG28-0	MM-330-FFE	37	BX13-68314	37	512	Full	5.0V	200Hz
A1Z	727-2K-10-120	10157	8.953 µV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	512	Full	5.0V	200Hz
A2Z	727-2K-10-120	10143	5.709 µV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	512	Full	5.0V	200Hz
A3Z	727-2K-10-120	10199	5.893 µV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	512	Full	5.0V	200Hz
A4Z	727-2K-10-120	10124	5.873 µV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	512	Full	5.0V	200Hz
A5Z	727-2K-10-120	10693	8.299 µV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	512	Full	5.0V	200Hz
A6Z	727-2K-10-120	10664	8.438 µV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	512	Full	5.0V	200Hz
A7Z	727-2K-10-120	10668	8.014 µV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	512	Full	5.0V	200Hz
A8Z	727-2K-10-120	10671	8.057 µV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	512	Full	5.0V	200Hz
A9Z	727-2K-10-120	10674	8.160 µV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	512	Full	5.0V	200Hz
A10Z	727-2K-10-120	10675	8.408 µV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	512	Full	5.0V	200Hz
A11Z	727-2K-10-120	10684	7.951 µV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	512	Full	5.0V	200Hz
A12Y	727-2K-10-120	10555	8.712 µV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	512	Full	5.0V	200Hz
A12Z	727-2K-10-120	10685	8.394 µV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	512	Full	5.0V	200Hz
A13X	727-2K-10-120	10574	8.301 µV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	512	Full	5.0V	200Hz
A13Y	727-2K-10-120	10127	5.925 µV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	512	Full	5.0V	200Hz
A13Z	727-2K-10-120	10130	5.448 µV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	512	Full	5.0V	200Hz
A14X	727-2K-10-120	10609	8.668 µV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	512	Full	5.0V	200Hz
A14Y	727-2K-10-120	10613	8.240 µV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	512	Full	5.0V	200Hz
A14Z	727-2K-10-120	10653	8.724 µV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	512	Full	5.0V	200Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	512	Full	5.0V	200Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	512	Full	5.0V	200Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	512	Full	5.0V	200Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	512	Full	5.0V	200Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	512	Full	5.0V	200Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	512	Full	5.0V	200Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	512	Full	5.0V	200Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	512	Full	5.0V	200Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	512	Full	5.0V	200Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	512	Full	5.0V	200Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	512	Full	5.0V	200Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Heavy Haul Truck Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
A19X	7265A	D17546	0.6198 mV/V/g	300 g	A19X	24328-3	69	BX13-68314	69	512	Full	5.0V	200Hz
A19Y	7265A	D17551	0.6957 mV/V/g	300 g	A19Y	24328-3	70	BX13-68314	70	512	Full	5.0V	200Hz
A19Z	7265A	D17557	0.5323 mV/V/g	300 g	A19Z	24328-3	71	BX13-68314	71	512	Full	5.0V	200Hz
A20X	7265A	D17571	0.5930 mV/V/g	300 g	A20X	24328-3	72	BX13-68314	72	512	Full	5.0V	200Hz
A20Y	7265A	D17573	0.5651 mV/V/g	300 g	A20Y	24328-3	73	BX13-68314	73	512	Full	5.0V	200Hz
A20Z	7265A	D17583	0.4734 mV/V/g	300 g	A20Z	24328-3	74	BX13-68314	74	512	Full	5.0V	200Hz
A21X	7265A	D17589	0.7275 mV/V/g	300 g	A21X	24328-3	75	BX13-68314	75	512	Full	5.0V	200Hz
A21Y	7265A	D17590	0.4363 mV/V/g	300 g	A21Y	24328-3	76	BX13-68314	76	512	Full	5.0V	200Hz
A21Z	7265A	D17603	0.4668 mV/V/g	300 g	A21Z	24328-3	77	BX13-68314	77	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Barge Test

ENSA Transportation Cask Instrumentation Cabling Definition
Barge Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-0	MM-330-FFE	1	BX13-68314	1	512	Full	5.0V	200Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-90	MM-330-FFE	2	BX13-68314	2	512	Full	5.0V	200Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-225	MM-330-FFE	3	BX13-68314	3	512	Full	5.0V	200Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG2-0	MM-330-FFE	4	BX13-68314	4	512	Full	5.0V	200Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG2-90	MM-330-FFE	5	BX13-68314	5	512	Full	5.0V	200Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG3-0	MM-330-FFE	6	BX13-68314	6	512	Full	5.0V	200Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-0	MM-330-FFE	7	BX13-68314	7	512	Full	5.0V	200Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-90	MM-330-FFE	8	BX13-68314	8	512	Full	5.0V	200Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-225	MM-330-FFE	9	BX13-68314	9	512	Full	5.0V	200Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG5-0	MM-330-FFE	10	BX13-68314	10	512	Full	5.0V	200Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG5-90	MM-330-FFE	11	BX13-68314	11	512	Full	5.0V	200Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG6-0	MM-330-FFE	12	BX13-68314	12	512	Full	5.0V	200Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG7-0	MM-330-FFE	13	BX13-68314	13	512	Full	5.0V	200Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-0	MM-330-FFE	14	BX13-68314	14	512	Full	5.0V	200Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-90	MM-330-FFE	15	BX13-68314	15	512	Full	5.0V	200Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-225	MM-330-FFE	16	BX13-68314	16	512	Full	5.0V	200Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG9-0	MM-330-FFE	17	BX13-68314	17	512	Full	5.0V	200Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG9-90	MM-330-FFE	18	BX13-68314	18	512	Full	5.0V	200Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG10-0	MM-330-FFE	19	BX13-68314	19	512	Full	5.0V	200Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG11-0	MM-330-FFE	20	BX13-68314	20	512	Full	5.0V	200Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG12-0	MM-330-FFE	21	BX13-68314	21	512	Full	5.0V	200Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG13-0	MM-330-FFE	22	BX13-68314	22	512	Full	5.0V	200Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG14-0	MM-330-FFE	23	BX13-68314	23	512	Full	5.0V	200Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG15-0	MM-330-FFE	24	BX13-68314	24	512	Full	5.0V	200Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG16-0	MM-330-FFE	25	BX13-68314	25	512	Full	5.0V	200Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG17-0	MM-330-FFE	26	BX13-68314	26	512	Full	5.0V	200Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG18-0	MM-330-FFE	27	BX13-68314	27	512	Full	5.0V	200Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG19-0	MM-330-FFE	28	BX13-68314	28	512	Full	5.0V	200Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG20-0	MM-330-FFE	29	BX13-68314	29	512	Full	5.0V	200Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG21-0	MM-330-FFE	30	BX13-68314	30	512	Full	5.0V	200Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG22-0	MM-330-FFE	31	BX13-68314	31	512	Full	5.0V	200Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG23-0	MM-330-FFE	32	BX13-68314	32	512	Full	5.0V	200Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG24-0	MM-330-FFE	33	BX13-68314	33	512	Full	5.0V	200Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG25-0	MM-330-FFE	34	BX13-68314	34	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Barge Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG26-0	MM-330-FFE	35	BX13-68314	35	512	Full	5.0V	200Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG27-0	MM-330-FFE	36	BX13-68314	36	512	Full	5.0V	200Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG28-0	MM-330-FFE	37	BX13-68314	37	512	Full	5.0V	200Hz
A1Z	727-2K-10-120	10157	8.953 μV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	512	Full	5.0V	200Hz
A2Z	727-2K-10-120	10143	5.709 μV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	512	Full	5.0V	200Hz
A3Z	727-2K-10-120	10199	5.893 μV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	512	Full	5.0V	200Hz
A4Z	727-2K-10-120	10124	5.873 μV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	512	Full	5.0V	200Hz
A5Z	727-2K-10-120	10693	8.299 μV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	512	Full	5.0V	200Hz
A6Z	727-2K-10-120	10664	8.438 μV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	512	Full	5.0V	200Hz
A7Z	727-2K-10-120	10668	8.014 μV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	512	Full	5.0V	200Hz
A8Z	727-2K-10-120	10671	8.057 μV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	512	Full	5.0V	200Hz
A9Z	727-2K-10-120	10674	8.160 μV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	512	Full	5.0V	200Hz
A10Z	727-2K-10-120	10675	8.408 μV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	512	Full	5.0V	200Hz
A11Z	727-2K-10-120	10684	7.951 μV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	512	Full	5.0V	200Hz
A12Y	727-2K-10-120	10555	8.712 μV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	512	Full	5.0V	200Hz
A12Z	727-2K-10-120	10685	8.394 μV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	512	Full	5.0V	200Hz
A13X	727-2K-10-120	10574	8.301 μV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	512	Full	5.0V	200Hz
A13Y	727-2K-10-120	10127	5.925 μV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	512	Full	5.0V	200Hz
A13Z	727-2K-10-120	10130	5.448 μV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	512	Full	5.0V	200Hz
A14X	727-2K-10-120	10609	8.668 μV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	512	Full	5.0V	200Hz
A14Y	727-2K-10-120	10613	8.240 μV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	512	Full	5.0V	200Hz
A14Z	727-2K-10-120	10653	8.724 μV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	512	Full	5.0V	200Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	512	Full	5.0V	200Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	512	Full	5.0V	200Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	512	Full	5.0V	200Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	512	Full	5.0V	200Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	512	Full	5.0V	200Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	512	Full	5.0V	200Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	512	Full	5.0V	200Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	512	Full	5.0V	200Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	512	Full	5.0V	200Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	512	Full	5.0V	200Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	512	Full	5.0V	200Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Barge Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
A19X	7265A	D17546	0.6198 mV/V/g	300 g	A19X	24328-3	69	BX13-68314	69	512	Full	5.0V	200Hz
A19Y	7265A	D17551	0.6957 mV/V/g	300 g	A19Y	24328-3	70	BX13-68314	70	512	Full	5.0V	200Hz
A19Z	7265A	D17557	0.5323 mV/V/g	300 g	A19Z	24328-3	71	BX13-68314	71	512	Full	5.0V	200Hz
A20X	7265A	D17571	0.5930 mV/V/g	300 g	A20X	24328-3	72	BX13-68314	72	512	Full	5.0V	200Hz
A20Y	7265A	D17573	0.5651 mV/V/g	300 g	A20Y	24328-3	73	BX13-68314	73	512	Full	5.0V	200Hz
A20Z	7265A	D17583	0.4734 mV/V/g	300 g	A20Z	24328-3	74	BX13-68314	74	512	Full	5.0V	200Hz
A21X	7265A	D17589	0.7275 mV/V/g	300 g	A21X	24328-3	75	BX13-68314	75	512	Full	5.0V	200Hz
A21Y	7265A	D17590	0.4363 mV/V/g	300 g	A21Y	24328-3	76	BX13-68314	76	512	Full	5.0V	200Hz
A21Z	7265A	D17603	0.4668 mV/V/g	300 g	A21Z	24328-3	77	BX13-68314	77	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Ship Test

ENSA Transportation Cask Instrumentation Cabling Definition
Ship Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-0	MM-330-FFE	1	BX13-68314	1	512	Full	5.0V	200Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-90	MM-330-FFE	2	BX13-68314	2	512	Full	5.0V	200Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-225	MM-330-FFE	3	BX13-68314	3	512	Full	5.0V	200Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG2-0	MM-330-FFE	4	BX13-68314	4	512	Full	5.0V	200Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG2-90	MM-330-FFE	5	BX13-68314	5	512	Full	5.0V	200Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG3-0	MM-330-FFE	6	BX13-68314	6	512	Full	5.0V	200Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-0	MM-330-FFE	7	BX13-68314	7	512	Full	5.0V	200Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-90	MM-330-FFE	8	BX13-68314	8	512	Full	5.0V	200Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-225	MM-330-FFE	9	BX13-68314	9	512	Full	5.0V	200Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG5-0	MM-330-FFE	10	BX13-68314	10	512	Full	5.0V	200Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG5-90	MM-330-FFE	11	BX13-68314	11	512	Full	5.0V	200Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG6-0	MM-330-FFE	12	BX13-68314	12	512	Full	5.0V	200Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG7-0	MM-330-FFE	13	BX13-68314	13	512	Full	5.0V	200Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-0	MM-330-FFE	14	BX13-68314	14	512	Full	5.0V	200Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-90	MM-330-FFE	15	BX13-68314	15	512	Full	5.0V	200Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-225	MM-330-FFE	16	BX13-68314	16	512	Full	5.0V	200Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG9-0	MM-330-FFE	17	BX13-68314	17	512	Full	5.0V	200Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG9-90	MM-330-FFE	18	BX13-68314	18	512	Full	5.0V	200Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG10-0	MM-330-FFE	19	BX13-68314	19	512	Full	5.0V	200Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG11-0	MM-330-FFE	20	BX13-68314	20	512	Full	5.0V	200Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG12-0	MM-330-FFE	21	BX13-68314	21	512	Full	5.0V	200Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG13-0	MM-330-FFE	22	BX13-68314	22	512	Full	5.0V	200Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG14-0	MM-330-FFE	23	BX13-68314	23	512	Full	5.0V	200Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG15-0	MM-330-FFE	24	BX13-68314	24	512	Full	5.0V	200Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG16-0	MM-330-FFE	25	BX13-68314	25	512	Full	5.0V	200Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG17-0	MM-330-FFE	26	BX13-68314	26	512	Full	5.0V	200Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG18-0	MM-330-FFE	27	BX13-68314	27	512	Full	5.0V	200Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG19-0	MM-330-FFE	28	BX13-68314	28	512	Full	5.0V	200Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG20-0	MM-330-FFE	29	BX13-68314	29	512	Full	5.0V	200Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG21-0	MM-330-FFE	30	BX13-68314	30	512	Full	5.0V	200Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG22-0	MM-330-FFE	31	BX13-68314	31	512	Full	5.0V	200Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG23-0	MM-330-FFE	32	BX13-68314	32	512	Full	5.0V	200Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG24-0	MM-330-FFE	33	BX13-68314	33	512	Full	5.0V	200Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG25-0	MM-330-FFE	34	BX13-68314	34	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Ship Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG26-0	MM-330-FFE	35	BX13-68314	35	512	Full	5.0V	200Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG27-0	MM-330-FFE	36	BX13-68314	36	512	Full	5.0V	200Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG28-0	MM-330-FFE	37	BX13-68314	37	512	Full	5.0V	200Hz
A1Z	727-2K-10-120	10157	8.953 μV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	512	Full	5.0V	200Hz
A2Z	727-2K-10-120	10143	5.709 μV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	512	Full	5.0V	200Hz
A3Z	727-2K-10-120	10199	5.893 μV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	512	Full	5.0V	200Hz
A4Z	727-2K-10-120	10124	5.873 μV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	512	Full	5.0V	200Hz
A5Z	727-2K-10-120	10693	8.299 μV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	512	Full	5.0V	200Hz
A6Z	727-2K-10-120	10664	8.438 μV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	512	Full	5.0V	200Hz
A7Z	727-2K-10-120	10668	8.014 μV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	512	Full	5.0V	200Hz
A8Z	727-2K-10-120	10671	8.057 μV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	512	Full	5.0V	200Hz
A9Z	727-2K-10-120	10674	8.160 μV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	512	Full	5.0V	200Hz
A10Z	727-2K-10-120	10675	8.408 μV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	512	Full	5.0V	200Hz
A11Z	727-2K-10-120	10684	7.951 μV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	512	Full	5.0V	200Hz
A12Y	727-2K-10-120	10555	8.712 μV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	512	Full	5.0V	200Hz
A12Z	727-2K-10-120	10685	8.394 μV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	512	Full	5.0V	200Hz
A13X	727-2K-10-120	10574	8.301 μV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	512	Full	5.0V	200Hz
A13Y	727-2K-10-120	10127	5.925 μV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	512	Full	5.0V	200Hz
A13Z	727-2K-10-120	10130	5.448 μV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	512	Full	5.0V	200Hz
A14X	727-2K-10-120	10609	8.668 μV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	512	Full	5.0V	200Hz
A14Y	727-2K-10-120	10613	8.240 μV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	512	Full	5.0V	200Hz
A14Z	727-2K-10-120	10653	8.724 μV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	512	Full	5.0V	200Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	512	Full	5.0V	200Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	512	Full	5.0V	200Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	512	Full	5.0V	200Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	512	Full	5.0V	200Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	512	Full	5.0V	200Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	512	Full	5.0V	200Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	512	Full	5.0V	200Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	512	Full	5.0V	200Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	512	Full	5.0V	200Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	512	Full	5.0V	200Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	512	Full	5.0V	200Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Ship Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
A19X	7265A	D17546	0.6198 mV/V/g	300 g	A19X	24328-3	69	BX13-68314	69	512	Full	5.0V	200Hz
A19Y	7265A	D17551	0.6957 mV/V/g	300 g	A19Y	24328-3	70	BX13-68314	70	512	Full	5.0V	200Hz
A19Z	7265A	D17557	0.5323 mV/V/g	300 g	A19Z	24328-3	71	BX13-68314	71	512	Full	5.0V	200Hz
A20X	7265A	D17571	0.5930 mV/V/g	300 g	A20X	24328-3	72	BX13-68314	72	512	Full	5.0V	200Hz
A20Y	7265A	D17573	0.5651 mV/V/g	300 g	A20Y	24328-3	73	BX13-68314	73	512	Full	5.0V	200Hz
A20Z	7265A	D17583	0.4734 mV/V/g	300 g	A20Z	24328-3	74	BX13-68314	74	512	Full	5.0V	200Hz
A21X	7265A	D17589	0.7275 mV/V/g	300 g	A21X	24328-3	75	BX13-68314	75	512	Full	5.0V	200Hz
A21Y	7265A	D17590	0.4363 mV/V/g	300 g	A21Y	24328-3	76	BX13-68314	76	512	Full	5.0V	200Hz
A21Z	7265A	D17603	0.4668 mV/V/g	300 g	A21Z	24328-3	77	BX13-68314	77	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No. 1 Test

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No.1 Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG1-0	MM-330-FFE	1	BX13-68314	1	512	Full	5.0V	200Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG1-90	MM-330-FFE	2	BX13-68314	2	512	Full	5.0V	200Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG1-225	MM-330-FFE	3	BX13-68314	3	512	Full	5.0V	200Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG2-0	MM-330-FFE	4	BX13-68314	4	512	Full	5.0V	200Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG2-90	MM-330-FFE	5	BX13-68314	5	512	Full	5.0V	200Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG3-0	MM-330-FFE	6	BX13-68314	6	512	Full	5.0V	200Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG4-0	MM-330-FFE	7	BX13-68314	7	512	Full	5.0V	200Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG4-90	MM-330-FFE	8	BX13-68314	8	512	Full	5.0V	200Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG4-225	MM-330-FFE	9	BX13-68314	9	512	Full	5.0V	200Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG5-0	MM-330-FFE	10	BX13-68314	10	512	Full	5.0V	200Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG5-90	MM-330-FFE	11	BX13-68314	11	512	Full	5.0V	200Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG6-0	MM-330-FFE	12	BX13-68314	12	512	Full	5.0V	200Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG7-0	MM-330-FFE	13	BX13-68314	13	512	Full	5.0V	200Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG8-0	MM-330-FFE	14	BX13-68314	14	512	Full	5.0V	200Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG8-90	MM-330-FFE	15	BX13-68314	15	512	Full	5.0V	200Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG8-225	MM-330-FFE	16	BX13-68314	16	512	Full	5.0V	200Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG9-0	MM-330-FFE	17	BX13-68314	17	512	Full	5.0V	200Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG9-90	MM-330-FFE	18	BX13-68314	18	512	Full	5.0V	200Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG10-0	MM-330-FFE	19	BX13-68314	19	512	Full	5.0V	200Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG11-0	MM-330-FFE	20	BX13-68314	20	512	Full	5.0V	200Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG12-0	MM-330-FFE	21	BX13-68314	21	512	Full	5.0V	200Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG13-0	MM-330-FFE	22	BX13-68314	22	512	Full	5.0V	200Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG14-0	MM-330-FFE	23	BX13-68314	23	512	Full	5.0V	200Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG15-0	MM-330-FFE	24	BX13-68314	24	512	Full	5.0V	200Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG16-0	MM-330-FFE	25	BX13-68314	25	512	Full	5.0V	200Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG17-0	MM-330-FFE	26	BX13-68314	26	512	Full	5.0V	200Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG18-0	MM-330-FFE	27	BX13-68314	27	512	Full	5.0V	200Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG19-0	MM-330-FFE	28	BX13-68314	28	512	Full	5.0V	200Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG20-0	MM-330-FFE	29	BX13-68314	29	512	Full	5.0V	200Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG21-0	MM-330-FFE	30	BX13-68314	30	512	Full	5.0V	200Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG22-0	MM-330-FFE	31	BX13-68314	31	512	Full	5.0V	200Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG23-0	MM-330-FFE	32	BX13-68314	32	512	Full	5.0V	200Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG24-0	MM-330-FFE	33	BX13-68314	33	512	Full	5.0V	200Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/με	1,000 με	SG25-0	MM-330-FFE	34	BX13-68314	34	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No. 1 Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG26-0	MM-330-FFE	35	BX13-68314	35	512	Full	5.0V	200Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG27-0	MM-330-FFE	36	BX13-68314	36	512	Full	5.0V	200Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG28-0	MM-330-FFE	37	BX13-68314	37	512	Full	5.0V	200Hz
A1Z	727-2K-10-120	10157	8.953 µV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	512	Full	5.0V	200Hz
A2Z	727-2K-10-120	10143	5.709 µV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	512	Full	5.0V	200Hz
A3Z	727-2K-10-120	10199	5.893 µV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	512	Full	5.0V	200Hz
A4Z	727-2K-10-120	10124	5.873 µV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	512	Full	5.0V	200Hz
A5Z	727-2K-10-120	10693	8.299 µV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	512	Full	5.0V	200Hz
A6Z	727-2K-10-120	10664	8.438 µV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	512	Full	5.0V	200Hz
A7Z	727-2K-10-120	10668	8.014 µV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	512	Full	5.0V	200Hz
A8Z	727-2K-10-120	10671	8.057 µV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	512	Full	5.0V	200Hz
A9Z	727-2K-10-120	10674	8.160 µV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	512	Full	5.0V	200Hz
A10Z	727-2K-10-120	10675	8.408 µV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	512	Full	5.0V	200Hz
A11Z	727-2K-10-120	10684	7.951 µV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	512	Full	5.0V	200Hz
A12Y	727-2K-10-120	10555	8.712 µV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	512	Full	5.0V	200Hz
A12Z	727-2K-10-120	10685	8.394 µV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	512	Full	5.0V	200Hz
A13X	727-2K-10-120	10574	8.301 µV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	512	Full	5.0V	200Hz
A13Y	727-2K-10-120	10127	5.925 µV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	512	Full	5.0V	200Hz
A13Z	727-2K-10-120	10130	5.448 µV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	512	Full	5.0V	200Hz
A14X	727-2K-10-120	10609	8.668 µV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	512	Full	5.0V	200Hz
A14Y	727-2K-10-120	10613	8.240 µV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	512	Full	5.0V	200Hz
A14Z	727-2K-10-120	10653	8.724 µV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	512	Full	5.0V	200Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	512	Full	5.0V	200Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	512	Full	5.0V	200Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	512	Full	5.0V	200Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	512	Full	5.0V	200Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	512	Full	5.0V	200Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	512	Full	5.0V	200Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	512	Full	5.0V	200Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	512	Full	5.0V	200Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	512	Full	5.0V	200Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	512	Full	5.0V	200Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	512	Full	5.0V	200Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No. 1 Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
A19X	7265A	D17546	0.6198 mV/V/g	300 g	A19X	24328-3	69	BX13-68314	69	512	Full	5.0V	200Hz
A19Y	7265A	D17551	0.6957 mV/V/g	300 g	A19Y	24328-3	70	BX13-68314	70	512	Full	5.0V	200Hz
A19Z	7265A	D17557	0.5323 mV/V/g	300 g	A19Z	24328-3	71	BX13-68314	71	512	Full	5.0V	200Hz
A20X	7265A	D17571	0.5930 mV/V/g	300 g	A20X	24328-3	72	BX13-68314	72	512	Full	5.0V	200Hz
A20Y	7265A	D17573	0.5651 mV/V/g	300 g	A20Y	24328-3	73	BX13-68314	73	512	Full	5.0V	200Hz
A20Z	7265A	D17583	0.4734 mV/V/g	300 g	A20Z	24328-3	74	BX13-68314	74	512	Full	5.0V	200Hz
A21X	7265A	D17589	0.7275 mV/V/g	300 g	A21X	24328-3	75	BX13-68314	75	512	Full	5.0V	200Hz
A21Y	7265A	D17590	0.4363 mV/V/g	300 g	A21Y	24328-3	76	BX13-68314	76	512	Full	5.0V	200Hz
A21Z	7265A	D17603	0.4668 mV/V/g	300 g	A21Z	24328-3	77	BX13-68314	77	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
TTCI Rail Test

ENSA Transportation Cask Instrumentation Cabling Definition
TTCI Rail Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-0	MM-330-FFE	1	BX13-68314	1	10,240	Full	5.0V	1,000Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-90	MM-330-FFE	2	BX13-68314	2	10,240	Full	5.0V	1,000Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG1-225	MM-330-FFE	3	BX13-68314	3	10,240	Full	5.0V	1,000Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-0	MM-330-FFE	4	BX13-68314	4	10,240	Full	5.0V	1,000Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG2-90	MM-330-FFE	5	BX13-68314	5	10,240	Full	5.0V	1,000Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG3-0	MM-330-FFE	6	BX13-68314	6	10,240	Full	5.0V	1,000Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-0	MM-330-FFE	7	BX13-68314	7	10,240	Full	5.0V	1,000Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-90	MM-330-FFE	8	BX13-68314	8	10,240	Full	5.0V	1,000Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG4-225	MM-330-FFE	9	BX13-68314	9	10,240	Full	5.0V	1,000Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-0	MM-330-FFE	10	BX13-68314	10	10,240	Full	5.0V	1,000Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG5-90	MM-330-FFE	11	BX13-68314	11	10,240	Full	5.0V	1,000Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG6-0	MM-330-FFE	12	BX13-68314	12	10,240	Full	5.0V	1,000Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG7-0	MM-330-FFE	13	BX13-68314	13	10,240	Full	5.0V	1,000Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-0	MM-330-FFE	14	BX13-68314	14	10,240	Full	5.0V	1,000Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-90	MM-330-FFE	15	BX13-68314	15	10,240	Full	5.0V	1,000Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG8-225	MM-330-FFE	16	BX13-68314	16	10,240	Full	5.0V	1,000Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-0	MM-330-FFE	17	BX13-68314	17	10,240	Full	5.0V	1,000Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG9-90	MM-330-FFE	18	BX13-68314	18	10,240	Full	5.0V	1,000Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG10-0	MM-330-FFE	19	BX13-68314	19	10,240	Full	5.0V	1,000Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG11-0	MM-330-FFE	20	BX13-68314	20	10,240	Full	5.0V	1,000Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG12-0	MM-330-FFE	21	BX13-68314	21	10,240	Full	5.0V	1,000Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG13-0	MM-330-FFE	22	BX13-68314	22	10,240	Full	5.0V	1,000Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG14-0	MM-330-FFE	23	BX13-68314	23	10,240	Full	5.0V	1,000Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG15-0	MM-330-FFE	24	BX13-68314	24	10,240	Full	5.0V	1,000Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG16-0	MM-330-FFE	25	BX13-68314	25	10,240	Full	5.0V	1,000Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG17-0	MM-330-FFE	26	BX13-68314	26	10,240	Full	5.0V	1,000Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG18-0	MM-330-FFE	27	BX13-68314	27	10,240	Full	5.0V	1,000Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG19-0	MM-330-FFE	28	BX13-68314	28	10,240	Full	5.0V	1,000Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG20-0	MM-330-FFE	29	BX13-68314	29	10,240	Full	5.0V	1,000Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG21-0	MM-330-FFE	30	BX13-68314	30	10,240	Full	5.0V	1,000Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG22-0	MM-330-FFE	31	BX13-68314	31	10,240	Full	5.0V	1,000Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG23-0	MM-330-FFE	32	BX13-68314	32	10,240	Full	5.0V	1,000Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG24-0	MM-330-FFE	33	BX13-68314	33	10,240	Full	5.0V	1,000Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG25-0	MM-330-FFE	34	BX13-68314	34	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
TTCI Rail Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG26-0	MM-330-FFE	35	BX13-68314	35	10,240	Full	5.0V	1,000Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG27-0	MM-330-FFE	36	BX13-68314	36	10,240	Full	5.0V	1,000Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 µV/V/µE	1,000 µE	SG28-0	MM-330-FFE	37	BX13-68314	37	10,240	Full	5.0V	1,000Hz
A1Z	727-2K-10-120	10157	8.953 µV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	10,240	Full	5.0V	1,000Hz
A2Z	727-2K-10-120	10143	5.709 µV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	10,240	Full	5.0V	1,000Hz
A3Z	727-2K-10-120	10199	5.893 µV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	10,240	Full	5.0V	1,000Hz
A4Z	727-2K-10-120	10124	5.873 µV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	10,240	Full	5.0V	1,000Hz
A5Z	727-2K-10-120	10693	8.299 µV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	10,240	Full	5.0V	1,000Hz
A6Z	727-2K-10-120	10664	8.438 µV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	10,240	Full	5.0V	1,000Hz
A7Z	727-2K-10-120	10668	8.014 µV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	10,240	Full	5.0V	1,000Hz
A8Z	727-2K-10-120	10671	8.057 µV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	10,240	Full	5.0V	1,000Hz
A9Z	727-2K-10-120	10674	8.160 µV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	10,240	Full	5.0V	1,000Hz
A10Z	727-2K-10-120	10675	8.408 µV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	10,240	Full	5.0V	1,000Hz
A11Z	727-2K-10-120	10684	7.951 µV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	10,240	Full	5.0V	1,000Hz
A12Y	727-2K-10-120	10555	8.712 µV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	10,240	Full	5.0V	1,000Hz
A12Z	727-2K-10-120	10685	8.394 µV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	10,240	Full	5.0V	1,000Hz
A13X	727-2K-10-120	10574	8.301 µV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	10,240	Full	5.0V	1,000Hz
A13Y	727-2K-10-120	10127	5.925 µV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	10,240	Full	5.0V	1,000Hz
A13Z	727-2K-10-120	10130	5.448 µV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	10,240	Full	5.0V	1,000Hz
A14X	727-2K-10-120	10609	8.668 µV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	10,240	Full	5.0V	1,000Hz
A14Y	727-2K-10-120	10613	8.240 µV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	10,240	Full	5.0V	1,000Hz
A14Z	727-2K-10-120	10653	8.724 µV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	10,240	Full	5.0V	1,000Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	10,240	Full	5.0V	1,000Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	10,240	Full	5.0V	1,000Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	10,240	Full	5.0V	1,000Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	10,240	Full	5.0V	1,000Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	10,240	Full	5.0V	1,000Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	10,240	Full	5.0V	1,000Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	10,240	Full	5.0V	1,000Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	10,240	Full	5.0V	1,000Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	10,240	Full	5.0V	1,000Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	10,240	Full	5.0V	1,000Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	10,240	Full	5.0V	1,000Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
TTCI Rail Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
A19X	7265A	D17546	0.6198 mV/V/g	300 g	A19X	24328-3	69	BX13-68314	69	10,240	Full	5.0V	1,000Hz
A19Y	7265A	D17551	0.6957 mV/V/g	300 g	A19Y	24328-3	70	BX13-68314	70	10,240	Full	5.0V	1,000Hz
A19Z	7265A	D17557	0.5323 mV/V/g	300 g	A19Z	24328-3	71	BX13-68314	71	10,240	Full	5.0V	1,000Hz
A20X	7265A	D17571	0.5930 mV/V/g	300 g	A20X	24328-3	72	BX13-68314	72	10,240	Full	5.0V	1,000Hz
A20Y	7265A	D17573	0.5651 mV/V/g	300 g	A20Y	24328-3	73	BX13-68314	73	10,240	Full	5.0V	1,000Hz
A20Z	7265A	D17583	0.4734 mV/V/g	300 g	A20Z	24328-3	74	BX13-68314	74	10,240	Full	5.0V	1,000Hz
A21X	7265A	D17589	0.7275 mV/V/g	300 g	A21X	24328-3	75	BX13-68314	75	10,240	Full	5.0V	1,000Hz
A21Y	7265A	D17590	0.4363 mV/V/g	300 g	A21Y	24328-3	76	BX13-68314	76	10,240	Full	5.0V	1,000Hz
A21Z	7265A	D17603	0.4668 mV/V/g	300 g	A21Z	24328-3	77	BX13-68314	77	10,240	Full	5.0V	1,000Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No.2 Test

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No. 2 Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Bessel Filter
SG1-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-0	MM-330-FFE	1	BX13-68314	1	512	Full	5.0V	200Hz
SG1-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-90	MM-330-FFE	2	BX13-68314	2	512	Full	5.0V	200Hz
SG1-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG1-225	MM-330-FFE	3	BX13-68314	3	512	Full	5.0V	200Hz
SG2-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG2-0	MM-330-FFE	4	BX13-68314	4	512	Full	5.0V	200Hz
SG2-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG2-90	MM-330-FFE	5	BX13-68314	5	512	Full	5.0V	200Hz
SG3-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG3-0	MM-330-FFE	6	BX13-68314	6	512	Full	5.0V	200Hz
SG4-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-0	MM-330-FFE	7	BX13-68314	7	512	Full	5.0V	200Hz
SG4-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-90	MM-330-FFE	8	BX13-68314	8	512	Full	5.0V	200Hz
SG4-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG4-225	MM-330-FFE	9	BX13-68314	9	512	Full	5.0V	200Hz
SG5-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG5-0	MM-330-FFE	10	BX13-68314	10	512	Full	5.0V	200Hz
SG5-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG5-90	MM-330-FFE	11	BX13-68314	11	512	Full	5.0V	200Hz
SG6-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG6-0	MM-330-FFE	12	BX13-68314	12	512	Full	5.0V	200Hz
SG7-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG7-0	MM-330-FFE	13	BX13-68314	13	512	Full	5.0V	200Hz
SG8-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-0	MM-330-FFE	14	BX13-68314	14	512	Full	5.0V	200Hz
SG8-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-90	MM-330-FFE	15	BX13-68314	15	512	Full	5.0V	200Hz
SG8-225	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG8-225	MM-330-FFE	16	BX13-68314	16	512	Full	5.0V	200Hz
SG9-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG9-0	MM-330-FFE	17	BX13-68314	17	512	Full	5.0V	200Hz
SG9-90	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG9-90	MM-330-FFE	18	BX13-68314	18	512	Full	5.0V	200Hz
SG10-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG10-0	MM-330-FFE	19	BX13-68314	19	512	Full	5.0V	200Hz
SG11-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG11-0	MM-330-FFE	20	BX13-68314	20	512	Full	5.0V	200Hz
SG12-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG12-0	MM-330-FFE	21	BX13-68314	21	512	Full	5.0V	200Hz
SG13-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG13-0	MM-330-FFE	22	BX13-68314	22	512	Full	5.0V	200Hz
SG14-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG14-0	MM-330-FFE	23	BX13-68314	23	512	Full	5.0V	200Hz
SG15-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG15-0	MM-330-FFE	24	BX13-68314	24	512	Full	5.0V	200Hz
SG16-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG16-0	MM-330-FFE	25	BX13-68314	25	512	Full	5.0V	200Hz
SG17-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG17-0	MM-330-FFE	26	BX13-68314	26	512	Full	5.0V	200Hz
SG18-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG18-0	MM-330-FFE	27	BX13-68314	27	512	Full	5.0V	200Hz
SG19-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG19-0	MM-330-FFE	28	BX13-68314	28	512	Full	5.0V	200Hz
SG20-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG20-0	MM-330-FFE	29	BX13-68314	29	512	Full	5.0V	200Hz
SG21-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG21-0	MM-330-FFE	30	BX13-68314	30	512	Full	5.0V	200Hz
SG22-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG22-0	MM-330-FFE	31	BX13-68314	31	512	Full	5.0V	200Hz
SG23-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG23-0	MM-330-FFE	32	BX13-68314	32	512	Full	5.0V	200Hz
SG24-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG24-0	MM-330-FFE	33	BX13-68314	33	512	Full	5.0V	200Hz
SG25-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG25-0	MM-330-FFE	34	BX13-68314	34	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No. 2 Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
SG26-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG26-0	MM-330-FFE	35	BX13-68314	35	512	Full	5.0V	200Hz
SG27-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG27-0	MM-330-FFE	36	BX13-68314	36	512	Full	5.0V	200Hz
SG28-0	CEA03-062UW-350	A86AB811	0.27625 μV/V/μE	1,000 μE	SG28-0	MM-330-FFE	37	BX13-68314	37	512	Full	5.0V	200Hz
A1Z	727-2K-10-120	10157	8.953 μV/V/g	1,000 g	A1Z	30/738 SPC	38	BX13-68314	38	512	Full	5.0V	200Hz
A2Z	727-2K-10-120	10143	5.709 μV/V/g	1,000 g	A2Z	30/738 SPC	39	BX13-68314	39	512	Full	5.0V	200Hz
A3Z	727-2K-10-120	10199	5.893 μV/V/g	1,000 g	A3Z	30/738 SPC	40	BX13-68314	40	512	Full	5.0V	200Hz
A4Z	727-2K-10-120	10124	5.873 μV/V/g	1,000 g	A4Z	30/738 SPC	41	BX13-68314	41	512	Full	5.0V	200Hz
A5Z	727-2K-10-120	10693	8.299 μV/V/g	1,000 g	A5Z	30/738 SPC	42	BX13-68314	42	512	Full	5.0V	200Hz
A6Z	727-2K-10-120	10664	8.438 μV/V/g	1,000 g	A6Z	30/738 SPC	43	BX13-68314	43	512	Full	5.0V	200Hz
A7Z	727-2K-10-120	10668	8.014 μV/V/g	1,000 g	A7Z	30/738 SPC	44	BX13-68314	44	512	Full	5.0V	200Hz
A8Z	727-2K-10-120	10671	8.057 μV/V/g	1,000 g	A8Z	30/738 SPC	45	BX13-68314	45	512	Full	5.0V	200Hz
A9Z	727-2K-10-120	10674	8.160 μV/V/g	1,000 g	A9Z	30/738 SPC	46	BX13-68314	46	512	Full	5.0V	200Hz
A10Z	727-2K-10-120	10675	8.408 μV/V/g	1,000 g	A10Z	30/738 SPC	47	BX13-68314	47	512	Full	5.0V	200Hz
A11Z	727-2K-10-120	10684	7.951 μV/V/g	1,000 g	A11Z	30/738 SPC	48	BX13-68314	48	512	Full	5.0V	200Hz
A12Y	727-2K-10-120	10555	8.712 μV/V/g	1,000 g	A12Y	30/738 SPC	49	BX13-68314	49	512	Full	5.0V	200Hz
A12Z	727-2K-10-120	10685	8.394 μV/V/g	1,000 g	A12Z	30/738 SPC	50	BX13-68314	50	512	Full	5.0V	200Hz
A13X	727-2K-10-120	10574	8.301 μV/V/g	1,000 g	A13X	30/738 SPC	51	BX13-68314	51	512	Full	5.0V	200Hz
A13Y	727-2K-10-120	10127	5.925 μV/V/g	1,000 g	A13Y	30/738 SPC	52	BX13-68314	52	512	Full	5.0V	200Hz
A13Z	727-2K-10-120	10130	5.448 μV/V/g	1,000 g	A13Z	30/738 SPC	53	BX13-68314	53	512	Full	5.0V	200Hz
A14X	727-2K-10-120	10609	8.668 μV/V/g	1,000 g	A14X	30/738 SPC	54	BX13-68314	54	512	Full	5.0V	200Hz
A14Y	727-2K-10-120	10613	8.240 μV/V/g	1,000 g	A14Y	30/738 SPC	55	BX13-68314	55	512	Full	5.0V	200Hz
A14Z	727-2K-10-120	10653	8.724 μV/V/g	1,000 g	A14Z	30/738 SPC	56	BX13-68314	56	512	Full	5.0V	200Hz
A15X	7265A	D17460	0.5953 mV/V/g	300 g	A15X	24328-3	57	BX13-68314	57	512	Full	5.0V	200Hz
A15Y	7265A	D17456	0.6741 mV/V/g	300 g	A15Y	24328-3	58	BX13-68314	58	512	Full	5.0V	200Hz
A15Z	7265A	D17467	0.6590 mV/V/g	300 g	A15Z	24328-3	59	BX13-68314	59	512	Full	5.0V	200Hz
A16X	7265A	D17475	0.5770 mV/V/g	300 g	A16X	24328-3	60	BX13-68314	60	512	Full	5.0V	200Hz
A16Y	7265A	D17477	0.7017 mV/V/g	300 g	A16Y	24328-3	61	BX13-68314	61	512	Full	5.0V	200Hz
A16Z	7265A	D17480	0.5993 mV/V/g	300 g	A16Z	24328-3	62	BX13-68314	62	512	Full	5.0V	200Hz
A17X	7265A	D17481	0.6026 mV/V/g	300 g	A17X	24328-3	63	BX13-68314	63	512	Full	5.0V	200Hz
A17Y	7265A	D17503	0.6524 mV/V/g	300 g	A17Y	24328-3	64	BX13-68314	64	512	Full	5.0V	200Hz
A17Z	7265A	D17526	0.5580 mV/V/g	300 g	A17Z	24328-3	65	BX13-68314	65	512	Full	5.0V	200Hz
A18X	7265A	D17528	0.6014 mV/V/g	300 g	A18X	24328-3	66	BX13-68314	66	512	Full	5.0V	200Hz
A18Y	7265A	D17533	0.5529 mV/V/g	300 g	A18Y	24328-3	67	BX13-68314	67	512	Full	5.0V	200Hz
A18Z	7265A	D17545	0.6491 mV/V/g	300 g	A18Z	24328-3	68	BX13-68314	68	512	Full	5.0V	200Hz

ENSA Transportation Cask Instrumentation Cabling Definition
Rail No. 2 Test

Gauge Designation	Model Number	Serial Number	Gauge Sensitivity (V/V/EU)	Calibration Value (EU)	Cask Junction Box		Siemens Data Collection		Siemens Channel No.	Siemens Data Collection Setup			
					Cable No.	Cable Type	Cable No.	Cable Type		Sample Rate	Bridge Type	Amplifier Excitation	Amplifier Filter
A19X	7265A	D17546	0.6198 mV/V/g	300 g	A19X	24328-3	69	BX13-68314	69	512	Full	5.0V	200Hz
A19Y	7265A	D17551	0.6957 mV/V/g	300 g	A19Y	24328-3	70	BX13-68314	70	512	Full	5.0V	200Hz
A19Z	7265A	D17557	0.5323 mV/V/g	300 g	A19Z	24328-3	71	BX13-68314	71	512	Full	5.0V	200Hz
A20X	7265A	D17571	0.5930 mV/V/g	300 g	A20X	24328-3	72	BX13-68314	72	512	Full	5.0V	200Hz
A20Y	7265A	D17573	0.5651 mV/V/g	300 g	A20Y	24328-3	73	BX13-68314	73	512	Full	5.0V	200Hz
A20Z	7265A	D17583	0.4734 mV/V/g	300 g	A20Z	24328-3	74	BX13-68314	74	512	Full	5.0V	200Hz
A21X	7265A	D17589	0.7275 mV/V/g	300 g	A21X	24328-3	75	BX13-68314	75	512	Full	5.0V	200Hz
A21Y	7265A	D17590	0.4363 mV/V/g	300 g	A21Y	24328-3	76	BX13-68314	76	512	Full	5.0V	200Hz
A21Z	7265A	D17603	0.4668 mV/V/g	300 g	A21Z	24328-3	77	BX13-68314	77	512	Full	5.0V	200Hz

Attachment 4

ENSA/DOE Transportation Test Hold Point Check List

HANDLING TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Handling Test
LMS Sample Rate: 10,240 Hz, Bessel Filter @ 1,000Hz
Number of Segments: TBD
Segment Duration: 36 Minutes

Initials **Required Activity**

________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

________ 3. The LMS database has been created and verified using information from Appendix 3.

________ 4. The LMS database has been downloaded to the test SD card and verified.

________ 5. The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.

________ 6. The 24 Volt main batteries have been charged.

________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

________ 8. The master 24 Volt power switch has been turned on.

________ 9. The 24 Volt timer power switch has been turned on.

________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) ___________
Battery Voltage (Under Load) ____________

________ 11. The test SD card has been installed in the LMS master recorder.

________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

________ 14. Verify the LMS system can communicate with the Tablet in scope mode.

HANDLING TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials	Required Activity
________	15. Verify LMS GPS is locked and providing data to the Tablet.
________	16. Verify LMS system control and balance function using the Tablet.
________	17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights
________	18. Determine the Project Manager and support personnel are ready to start the first test.
________	19. Verify battery voltage and all four fans are running.
________	20. Project Manager authorizes to start the first test.
________	21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.
________	22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	23. Record the local start time of the test. ________________________________
________	24. After the first handling event stop the recorder using the Tablet.
________	25. Project Manager authorizes to start the second test.
________	26. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	27. After the second handling event stop the recorder using the Tablet.
________	28. Continue the process of starting and stopping the handling test events using the Tablet.
________	29. At the end of the testing stop the recorders, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.

HANDLING TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST (continued)

Initials **Required Activity**

________ 30. Verify the .TRD and .LDSF data is present on the external hard drive.

________ 31. Verify the SD card and external hard drive contain data and are labeled Handling Test. Place the SD card and external hard drive in a transportation case.

Completed:

____________________ ________
Project Manager Date

____________________ ________
Instrumentation Coordinator Date

HEAVY HAUL HANDLING TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: HH Handling Test
LMS Sample Rate: 10,240 Hz, Bessel Filter @ 1,000Hz
Number of Segments: TBD
Segment Duration: 36 Minutes

Initials **Required Activity**

________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

________ 3. The LMS database has been created and verified using information from Appendix 3.

________ 4. The LMS database has been downloaded to the test SD card and verified.

________ 5. The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.

________ 6. The 24 Volt main batteries have been charged.

________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

________ 8. The master 24 Volt power switch has been turned on.

________ 9. The 24 Volt timer power switch has been turned on.

________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) ___________
Battery Voltage (Under Load) ____________

________ 11. The test SD card has been installed in the LMS master recorder.

________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

________ 14. Verify the LMS system can communicate with the Tablet in scope mode.

HEAVY HAUL HANDLING TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

_________ 15. Verify LMS GPS is locked and providing data to the Tablet.

_________ 16. Verify LMS system control and balance function using the Tablet.

_________ 17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights

_________ 18. Determine the Project Manager and support personnel are ready to start the first test.

_________ 19. Verify battery voltage and all four fans are running.

_________ 20. Project Manager authorizes to start the first test.

_________ 21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.

_________ 22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

_________ 23. Record the local start time of the test. ___________________________________

_________ 24. After the first handling event stop the recorder using the Tablet.

_________ 25. Project Manager may authorize additional testing.

_________ 26. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

_________ 27. After the second handling event stop the recorder using the Tablet.

_________ 28. Continue the process of starting and stopping the handling test events using the Tablet.

_________ 29. At the end of the testing stop the recorders, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.

HEAVY HAUL HANDLING TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials		**Required Activity**
________	30.	Verify the .TRD and .LDSF data is present on the external hard drive.
________	31.	Verify the SD card and external hard drive contain data and are labeled Heavy Haul Handling Test. Place the SD card and external hard drive in a transportation case.

Completed:

____________________	________
Project Manager	Date
____________________	________
Instrumentation Coordinator	Date

HEAVY HAUL TRUCK
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Heavy Haul Truck Test
LMS Sample Rate: 512 Hz, Bessel Filter @ 200Hz
Number of Segments: 20 Segments (10 Days)
Segment Duration: 12 Hours

Initials **Required Activity**

________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

________ 3. The LMS database has been created and verified using information from Appendix 3.

________ 4. The LMS database has been downloaded to the test SD card and verified.

________ 5. The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.

________ 6. The 24 Volt main batteries have been charged.

________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

________ 8. The master 24 Volt power switch has been turned on.

________ 9. The 24 Volt timer power switch has been turned on.

________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) ___________
Battery Voltage (Under Load) ____________

________ 11. The test SD card has been installed in the LMS master recorder.

________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

________ 14. Verify the LMS system can communicate with the Tablet in scope mode.

HEAVY HAUL TRUCK
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 15. Verify LMS GPS is locked and providing data to the Tablet.

________ 16. Verify LMS system control and balance function using the Tablet.

________ 17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights

________ 18. Determine the Project Manager and support personnel are ready to start the first test.

________ 19. Verify battery voltage and all four fans are running.

________ 20. Project Manager authorizes to start the first heavy haul test day.

________ 21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.

________ 22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

________ 23. Record the local start time of the test. ___________________________________

________ 24. After the first 12 hour heavy haul test day stop the recorder using the Tablet if the recorders have not stopped.

________ 25. At the end of the first test day stop the recorders, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.

________ 26. Verify the .TRD and .LDSF data is present on the external hard drive in a test folder with the date and test mode.

________ 27. Verify the SD card and external hard drive are labeled Heavy Haul Test.

________ 28. At the beginning of subsequent heavy haul test days repeat steps 1 through 27 for each day.

________ 29. At the end of the heavy haul testing verify the SD card and external hard drive contain data and are labeled Heavy Haul Test. Place the SD card and external hard drive in a transportation case.

HEAVY HAUL TRUCK
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

Completed:

______________________ __________
Project Manager Date

______________________ __________
Instrumentation Coordinator Date

BARGE TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Barge Test
LMS Sample Rate: 512 Hz, Bessel Filter @ 200Hz
Number of Segments: 28 Segments (14 Days)
Segment Duration: 12 Hours

Initials **Required Activity**

________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

________ 3. The LMS database has been created and verified using information from Appendix 3.

________ 4. The LMS database has been downloaded to the test SD card and verified.

________ 5. The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.

________ 6. The 24 Volt main batteries have been charged.

________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

________ 8. The master 24 Volt power switch has been turned on.

________ 9. The 24 Volt timer power switch has been turned on.

________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) ___________
Battery Voltage (Under Load) ____________

________ 11. The test SD card has been installed in the LMS master recorder.

________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

________ 14. Verify the LMS system can communicate with the Tablet in scope mode.

BARGE TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

_________ 15. Verify LMS GPS is locked and providing data to the Tablet.

_________ 16. Verify LMS system control and balance function using the Tablet.

_________ 17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights

_________ 18. Determine the Project Manager and support personnel are ready to start the barge test.

_________ 19. Verify battery voltage and all four fans are running.

_________ 20. Project Manager authorizes the barge test to proceed.

_________ 21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.

_________ 22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

_________ 23. Record the local start time of the test. ________________________________

_________ 24. Turn the timer trigger to the on position for 5 seconds and turn the trigger off. Verify the timer position is at 360 hours.

_________ 25. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

_________ 26. At the end of the barge test stop the recorders if they are still running using the Tablet, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.

_________ 27. Verify the .TRD and .LDSF data is present on the external hard drive in a test folder with the date and test mode.

_________ 28. Verify the SD card and external hard drive are labeled Barge Test.

BARGE TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 29. At the end of the barge testing verify the SD card and external hard drive contain data and are labeled Barge Test. Place the SD card and external hard drive in a transportation case.

Completed:

______________________ _________
Project Manager Date

______________________ _________
Instrumentation Coordinator Date

SHIP TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Ship Test
LMS Sample Rate: 512 Hz, Bessel Filter @ 200Hz
Number of Segments: 28 Segments (14 Days)
Segment Duration: 12 Hours

Initials		Required Activity
________	1.	Instrumentation has been installed on the ENSA transportation cask assembly and verified.
________	2.	A copy of instrumentation calibration data has been included in Appendix 1 and 2.
________	3.	The LMS database has been created and verified using information from Appendix 3.
________	4.	The LMS database has been downloaded to the test SD card and verified.
________	5.	The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.
________	6.	The 24 Volt main batteries have been charged.
________	7.	The battery jumper has been installed and the two circuit breakers have been turned on.
________	8.	The master 24 Volt power switch has been turned on.
________	9.	The 24 Volt timer power switch has been turned on.
________	10.	The 24 Volt battery system voltage has been recorded. Battery Voltage (Open Circuit) ___________ Battery Voltage (Under Load) ____________
________	11.	The test SD card has been installed in the LMS master recorder.
________	12.	The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.
________	13.	The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.
________	14.	Verify the LMS system can communicate with the Tablet in scope mode.

SHIP TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

_________ 15. Verify LMS GPS is locked and providing data to the Tablet.

_________ 16. Verify LMS system control and balance function using the Tablet.

_________ 17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights

_________ 18. Determine the Project Manager and support personnel are ready to start the barge test.

_________ 19. Verify battery voltage and all four fans are running.

_________ 20. Project Manager authorizes the ocean test to proceed.

_________ 21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.

_________ 22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

_________ 23. Record the local start time of the test. ___________________________________

_________ 24. Turn the timer trigger to the on position for 5 seconds and turn the trigger off. Verify the timer position is at 360 hours.

_________ 25. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

_________ 26. At the end of the ocean test stop the recorders if they are still running using the Tablet, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.

_________ 27. Verify the .TRD and .LDSF data is present on the external hard drive in a test folder with the date and test mode.

_________ 28. Verify the SD card and external hard drive are labeled SHIP Test.

SHIP TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 29. At the end of the ocean testing verify the SD card and external hard drive contain data and are labeled Ship Test. Place the SD card and external hard drive in a transportation case.

Completed:

____________________ ________
Project Manager Date

____________________ ________
Instrumentation Coordinator Date

RAIL NO. 1 TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Rail No. 1 Test
LMS Sample Rate: 512 Hz, Bessel Filter @ 200Hz
Number of Segments: 28 Segments (14 Days)
Segment Duration: 12 Hours

Initials **Required Activity**

_________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

_________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

_________ 3. The LMS database has been created and verified using information from Appendix 3.

_________ 4. The LMS database has been downloaded to the test SD card and verified.

_________ 5. The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.

_________ 6. The 24 Volt main batteries have been charged.

_________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

_________ 8. The master 24 Volt power switch has been turned on.

_________ 9. The 24 Volt timer power switch has been turned on.

_________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) ___________
Battery Voltage (Under Load) ___________

_________ 11. The test SD card has been installed in the LMS master recorder.

_________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

_________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

_________ 14. Verify the LMS system can communicate with the Tablet in scope mode.

RAIL NO. 1 TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials	Required Activity
________	15. Verify LMS GPS is locked and providing data to the Tablet.
________	16. Verify LMS system control and balance function using the Tablet.
________	17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights
________	18. Determine the Project Manager and support personnel are ready to start the rail no. 1 test.
________	19. Verify battery voltage and all four fans are running.
________	20. Project Manager authorizes the ocean test to proceed.
________	21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.
________	22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	23. Record the local start time of the test. ________________________________
________	24. Turn the timer trigger to the on position for 5 seconds and turn the trigger off. Verify the timer position is at 360 hours.
________	25. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	26. At the end of the rail no. 1 test stop the recorders if they are still running using the Tablet, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.
________	27. Verify the .TRD and .LDSF data is present on the external hard drive in a test folder with the date and test mode.
________	28. Verify the SD card and external hard drive are labeled Rail No. 1 Test.

RAIL NO. 1 TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 29. At the end of the rail no. 1 testing verify the SD card and external hard drive contain data and are labeled Rail No. 1 Test. Place the SD card and external hard drive in a transportation case.

Completed:

____________________ ________
Project Manager Date

____________________ ________
Instrumentation Coordinator Date

TTCI TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: TTCI Test
LMS Sample Rate: 10,240 Hz, Bessel Filter @ 1,000Hz
Number of Segments: TBD
Segment Duration: 36 Minutes

Initials		Required Activity
________	1.	Instrumentation has been installed on the ENSA transportation cask assembly and verified.
________	2.	A copy of instrumentation calibration data has been included in Appendix 1 and 2.
________	3.	The LMS database has been created and verified using information from Appendix 3.
________	4.	The LMS database has been downloaded to the test SD card and verified.
________	5.	The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.
________	6.	The 24 Volt main batteries have been charged.
________	7.	The battery jumper has been installed and the two circuit breakers have been turned on.
________	8.	The master 24 Volt power switch has been turned on.
________	9.	The 24 Volt timer power switch has been turned on.
________	10.	The 24 Volt battery system voltage has been recorded. Battery Voltage (Open Circuit) ___________ Battery Voltage (Under Load) ____________
________	11.	The test SD card has been installed in the LMS master recorder.
________	12.	The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.
________	13.	The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.
________	14.	Verify the LMS system can communicate with the Tablet in scope mode. If the LMS system will not communicate install an Ethernet cable between the data collection box and a laptop on the train to communicate with the system.

TTCI TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 15. Verify LMS GPS is locked and providing data to the Tablet or laptop.

________ 16. Verify LMS system control and balance function using the Tablet or laptop.

________ 17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights

________ 18. Determine the Project Manager and support personnel are ready to start the test.

________ 19. Verify battery voltage and all four fans are running.

________ 20. Project Manager authorizes to start the first TTCI test.

________ 21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.

________ 22. Press record button on Tablet or laptop and verify the system is recording with the red light on the master recorder.

________ 23. Record the local start time of the test. ________________________________

________ 24. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.

________ 25. After the first handling event stop the recorder using the Tablet or laptop.

________ 26. Project Manager authorizes to start the second test.

________ 27. Press record button on Tablet or laptop and verify the system.

________ 28. After the second handling event stop the recorder using the Tablet or laptop.

________ 29. Continue the process of starting and stopping the handling test events using the Tablet or laptop.

________ 30. At the end of the test day stop the recorders, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto a external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.

TTCI TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 31. Verify the .TRD and .LDSF data is present on the external hard drive.

________ 32. Verify the SD card and external hard drive contain data and are labeled TTCI Test. Place the SD card and external hard drive in a transportation case.

________ 33. For subsequent TTCI test days repeat steps 1-32.

Completed:

____________________ ________
Project Manager Date

____________________ ________
Instrumentation Coordinator Date

RAIL NO. 2 TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Rail No. 2 Test
LMS Sample Rate: 512 Hz, Bessel Filter @ 200Hz
Number of Segments: 36 Segments (18 Days)
Segment Duration: 12 Hours

Initials		Required Activity
________	1.	Instrumentation has been installed on the ENSA transportation cask assembly and verified.
________	2.	A copy of instrumentation calibration data has been included in Appendix 1 and 2.
________	3.	The LMS database has been created and verified using information from Appendix 3.
________	4.	The LMS database has been downloaded to the test SD card and verified.
________	5.	The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.
________	6.	The 24 Volt main batteries have been charged.
________	7.	The battery jumper has been installed and the two circuit breakers have been turned on.
________	8.	The master 24 Volt power switch has been turned on.
________	9.	The 24 Volt battery system voltage has been recorded. Battery Voltage (Open Circuit) ___________ Battery Voltage (Under Load) ____________
________	10.	The test SD card has been installed in the LMS master recorder.
________	11.	The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.
________	12.	The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.
________	13.	Verify the LMS system can communicate with the Tablet in scope mode.

RAIL NO. 2 TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials	Required Activity
________	14. Verify LMS GPS is locked and providing data to the Tablet.
________	15. Verify LMS system control and balance function using the Tablet.
________	16. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights
________	17. Determine the Project Manager and support personnel are ready to start the rail no. 1 test.
________	18. Verify battery voltage and all four fans are running.
________	19. Project Manager authorizes the rail no. 2 test to proceed.
________	20. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.
________	21. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	22. Record the local start time of the test. ________________________________
________	23. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	24. At the end of the rail no. 2 test stop the recorders if they are still running using the Tablet, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.
________	25. Verify the .TRD and .LDSF data is present on the external hard drive in a test folder with the date and test mode.
________	26. Verify the SD card and external hard drive are labeled Rail No. 2 Test.

RAIL NO. 2 TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials **Required Activity**

________ 27. At the end of the rail no. 2 testing verify the SD card and external hard drive contain data and are labeled Rail No. 2 Test. Place the SD card and external hard drive in a transportation case.

Completed:

______________________ _________
Project Manager Date

______________________ _________
Instrumentation Coordinator Date

Attachment 5

ENSA/DOE Transportation Test Observations

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

ENSA/DOE Transportation Test Observations

photograph/sketch:

Comments

Attachment 6

ENSA/DOE Transportation Test Data Collection Hardware Definition

ENSA/DOE RAIL CASK TRANSPORTATION TEST PROCEDURE
RAIL SHOCK AND VIBRATION TEST PROGRAM
Data Collection Hardware Definition

Handling
Channels: 62
Sample Rate: 10,240Hz
Filter: 1,000Hz
Segment Length: 36 minutes
Timer: Off
Hardware Control: Tablet

Heavy Haul Handling
Channels: 68
Sample Rate: 10,240Hz
Filter: 1,000Hz
Segment Length: 36 minutes
Timer: Off
Hardware Control: Tablet

Heavy Haul
Channels: 77
Sample Rate: 512Hz
Filter: 200Hz
Segment Length: 12 Hours
Number of Segments: 20
Run Time: 10 Days
Timer: Off
Hardware Control: Tablet

Barge
Channels: 77
Sample Rate: 512Hz
Filter: 200Hz
Segment Length: 12 Hours
Number of Segments: 28
Run Time: 14 Days
Timer: On (360 Hours)
Hardware Control: Tablet

Ship
Channels: 77
Sample Rate: 512Hz
Filter: 200Hz
Segment Length: 12 Hours
Number of Segments: 28
Run Time: 14 Days
Timer: On (360 Hours)
Hardware Control: Tablet

Rail No. 1
Channels: 77
Sample Rate: 512Hz
Filter: 200Hz
Segment Length: 12 Hours
Number of Segments: 28
Run Time: 14 Days
Timer: On (360 Hours)
Hardware Control: Tablet

TTCI
Channels: 77
Sample Rate: 10,240Hz
Filter: 1,000Hz
Segment Length: 36 minutes
Timer: Off
Hardware Control: Tablet

Rail No. 2
Channels: 77
Sample Rate: 512Hz
Filter: 200Hz
Segment Length: 12 Hours
Number of Segments: 36
Run Time: 18 Days
Timer: Off
Hardware Control: Tablet

Attachment 7

ENSA/DOE Transportation Test Data Collection Hardware Additional Accelerometer and Strain Gage Data Sheets

Accelerometer Data Sheet

Accelerometer Identification	Endevco Accelerometer Type	Serial Number	Closure Junction Box		
			Input Resistance (ohms)	Output Resistance (ohms)	Insulation Resistance (ohms)
A1Z	727-2K-10-120	10157			
A2Z	727-2K-10-120	10143			
A3Z	727-2K-10-120	10199			
A4Z	727-2K-10-120	10124			
A5Z	727-2K-10-120	10693			
A6Z	727-2K-10-120	10664			
A7Z	727-2K-10-120	10668			
A8Z	727-2K-10-120	10671			
A9Z	727-2K-10-120	10674			
A10Z	727-2K-10-120	10675			
A11Z	727-2K-10-120	10684			
A12Y	727-2K-10-120	10555			
A12Z	727-2K-10-120	10685			
A13X	727-2K-10-120	10574			
A13Y	727-2K-10-120	10127			
A13Z	727-2K-10-120	10130			
A14X	727-2K-10-120	10609			
A14Y	727-2K-10-120	10613			
A14Z	727-2K-10-120	10653			
A15X	7265A	D17460			
A15Y	7265A	D17456			
A15Z	7265A	D17467			
A16X	7265A	D17475			
A16Y	7265A	D17477			
A16Z	7265A	D17480			
A17X	7265A	D17481			
A17Y	7265A	D17503			
A17Z	7265A	D17526			
A18X	7265A	D17528			
A18Y	7265A	D17533			
A18Z	7265A	D17545			
A19X	7265A	D17546			
A19Y	7265A	D17551			
A19Z	7265A	D17557			
A20X	7265A	D17571			
A20Y	7265A	D17573			
A20Z	7265A	D17583			
A21X	7265A	D17589			
A21Y	7265A	D17590			
A21Z	7265A	D17603			

Strain Gage Data Sheet

Strain Gage Designation	Strain Gage Resistance (ohms)	Closure Junction Box	
		Input Resistance (ohms)	Output Resistance (ohms)
SG1-0			
SG1-90			
SG1-225			
SG2-0			
SG2-90			
SG3-0			
SG4-0			
SG4-90			
SG4-225			
SG5-0			
SG5-90			
SG6-0			
SG7-0			
SG8-0			
SG8-90			
SG8-225			
SG9-0			
SG9-90			
SG10-0			
SG11-0			
SG12-0			
SG13-0			
SG14-0			
SG15-0			
SG16-0			
SG17-0			
SG18-0			
SG19-0			
SG20-0			
SG21-0			
SG22-0			
SG23-0			
SG24-0			
SG25-0			
SG26-0			
SG27-0			
SG28-0			

Accelerometer Data Sheet

Accelerometer Identification	Endevco Accelerometer Type	Serial Number	Closure Junction Box		
			Input Resistance (ohms)	Output Resistance (ohms)	Insulation Resistance (ohms)
A1Z	727-2K-10-120	10157			
A2Z	727-2K-10-120	10143			
A3Z	727-2K-10-120	10199			
A4Z	727-2K-10-120	10124			
A5Z	727-2K-10-120	10693			
A6Z	727-2K-10-120	10664			
A7Z	727-2K-10-120	10668			
A8Z	727-2K-10-120	10671			
A9Z	727-2K-10-120	10674			
A10Z	727-2K-10-120	10675			
A11Z	727-2K-10-120	10684			
A12Y	727-2K-10-120	10555			
A12Z	727-2K-10-120	10685			
A13X	727-2K-10-120	10574			
A13Y	727-2K-10-120	10127			
A13Z	727-2K-10-120	10130			
A14X	727-2K-10-120	10609			
A14Y	727-2K-10-120	10613			
A14Z	727-2K-10-120	10653			
A15X	7265A	D17460			
A15Y	7265A	D17456			
A15Z	7265A	D17467			
A16X	7265A	D17475			
A16Y	7265A	D17477			
A16Z	7265A	D17480			
A17X	7265A	D17481			
A17Y	7265A	D17503			
A17Z	7265A	D17526			
A18X	7265A	D17528			
A18Y	7265A	D17533			
A18Z	7265A	D17545			
A19X	7265A	D17546			
A19Y	7265A	D17551			
A19Z	7265A	D17557			
A20X	7265A	D17571			
A20Y	7265A	D17573			
A20Z	7265A	D17583			
A21X	7265A	D17589			
A21Y	7265A	D17590			
A21Z	7265A	D17603			

Strain Gage Data Sheet

Strain Gage Designation	Strain Gage Resistance (ohms)	Closure Junction Box	
		Input Resistance (ohms)	Output Resistance (ohms)
SG1-0			
SG1-90			
SG1-225			
SG2-0			
SG2-90			
SG3-0			
SG4-0			
SG4-90			
SG4-225			
SG5-0			
SG5-90			
SG6-0			
SG7-0			
SG8-0			
SG8-90			
SG8-225			
SG9-0			
SG9-90			
SG10-0			
SG11-0			
SG12-0			
SG13-0			
SG14-0			
SG15-0			
SG16-0			
SG17-0			
SG18-0			
SG19-0			
SG20-0			
SG21-0			
SG22-0			
SG23-0			
SG24-0			
SG25-0			
SG26-0			
SG27-0			
SG28-0			

Accelerometer Data Sheet

Accelerometer Identification	Endevco Accelerometer Type	Serial Number	Closure Junction Box		
			Input Resistance (ohms)	Output Resistance (ohms)	Insulation Resistance (ohms)
A1Z	727-2K-10-120	10157			
A2Z	727-2K-10-120	10143			
A3Z	727-2K-10-120	10199			
A4Z	727-2K-10-120	10124			
A5Z	727-2K-10-120	10693			
A6Z	727-2K-10-120	10664			
A7Z	727-2K-10-120	10668			
A8Z	727-2K-10-120	10671			
A9Z	727-2K-10-120	10674			
A10Z	727-2K-10-120	10675			
A11Z	727-2K-10-120	10684			
A12Y	727-2K-10-120	10555			
A12Z	727-2K-10-120	10685			
A13X	727-2K-10-120	10574			
A13Y	727-2K-10-120	10127			
A13Z	727-2K-10-120	10130			
A14X	727-2K-10-120	10609			
A14Y	727-2K-10-120	10613			
A14Z	727-2K-10-120	10653			
A15X	7265A	D17460			
A15Y	7265A	D17456			
A15Z	7265A	D17467			
A16X	7265A	D17475			
A16Y	7265A	D17477			
A16Z	7265A	D17480			
A17X	7265A	D17481			
A17Y	7265A	D17503			
A17Z	7265A	D17526			
A18X	7265A	D17528			
A18Y	7265A	D17533			
A18Z	7265A	D17545			
A19X	7265A	D17546			
A19Y	7265A	D17551			
A19Z	7265A	D17557			
A20X	7265A	D17571			
A20Y	7265A	D17573			
A20Z	7265A	D17583			
A21X	7265A	D17589			
A21Y	7265A	D17590			
A21Z	7265A	D17603			

Strain Gage Data Sheet

Strain Gage Designation	Strain Gage Resistance (ohms)	Closure Junction Box	
		Input Resistance (ohms)	Output Resistance (ohms)
SG1-0			
SG1-90			
SG1-225			
SG2-0			
SG2-90			
SG3-0			
SG4-0			
SG4-90			
SG4-225			
SG5-0			
SG5-90			
SG6-0			
SG7-0			
SG8-0			
SG8-90			
SG8-225			
SG9-0			
SG9-90			
SG10-0			
SG11-0			
SG12-0			
SG13-0			
SG14-0			
SG15-0			
SG16-0			
SG17-0			
SG18-0			
SG19-0			
SG20-0			
SG21-0			
SG22-0			
SG23-0			
SG24-0			
SG25-0			
SG26-0			
SG27-0			
SG28-0			

Accelerometer Data Sheet

Accelerometer Identification	Endevco Accelerometer Type	Serial Number	Closure Junction Box		
			Input Resistance (ohms)	Output Resistance (ohms)	Insulation Resistance (ohms)
A1Z	727-2K-10-120	10157			
A2Z	727-2K-10-120	10143			
A3Z	727-2K-10-120	10199			
A4Z	727-2K-10-120	10124			
A5Z	727-2K-10-120	10693			
A6Z	727-2K-10-120	10664			
A7Z	727-2K-10-120	10668			
A8Z	727-2K-10-120	10671			
A9Z	727-2K-10-120	10674			
A10Z	727-2K-10-120	10675			
A11Z	727-2K-10-120	10684			
A12Y	727-2K-10-120	10555			
A12Z	727-2K-10-120	10685			
A13X	727-2K-10-120	10574			
A13Y	727-2K-10-120	10127			
A13Z	727-2K-10-120	10130			
A14X	727-2K-10-120	10609			
A14Y	727-2K-10-120	10613			
A14Z	727-2K-10-120	10653			
A15X	7265A	D17460			
A15Y	7265A	D17456			
A15Z	7265A	D17467			
A16X	7265A	D17475			
A16Y	7265A	D17477			
A16Z	7265A	D17480			
A17X	7265A	D17481			
A17Y	7265A	D17503			
A17Z	7265A	D17526			
A18X	7265A	D17528			
A18Y	7265A	D17533			
A18Z	7265A	D17545			
A19X	7265A	D17546			
A19Y	7265A	D17551			
A19Z	7265A	D17557			
A20X	7265A	D17571			
A20Y	7265A	D17573			
A20Z	7265A	D17583			
A21X	7265A	D17589			
A21Y	7265A	D17590			
A21Z	7265A	D17603			

Strain Gage Data Sheet

Strain Gage Designation	Strain Gage Resistance (ohms)	Closure Junction Box	
		Input Resistance (ohms)	Output Resistance (ohms)
SG1-0			
SG1-90			
SG1-225			
SG2-0			
SG2-90			
SG3-0			
SG4-0			
SG4-90			
SG4-225			
SG5-0			
SG5-90			
SG6-0			
SG7-0			
SG8-0			
SG8-90			
SG8-225			
SG9-0			
SG9-90			
SG10-0			
SG11-0			
SG12-0			
SG13-0			
SG14-0			
SG15-0			
SG16-0			
SG17-0			
SG18-0			
SG19-0			
SG20-0			
SG21-0			
SG22-0			
SG23-0			
SG24-0			
SG25-0			
SG26-0			
SG27-0			
SG28-0			

SHIP TEST
ENSA/DOE TRANSPORTATION TEST HOLD POINT CHECKLIST

Transportation Test Mode: Ship Test
LMS Sample Rate: 512 Hz, Bessel Filter @ 200Hz
Number of Segments: 28 Segments (14 Days)
Segment Duration: 12 Hours

Initials **Required Activity**

_________ 1. Instrumentation has been installed on the ENSA transportation cask assembly and verified.

_________ 2. A copy of instrumentation calibration data has been included in Appendix 1 and 2.

_________ 3. The LMS database has been created and verified using information from Appendix 3.

_________ 4. The LMS database has been downloaded to the test SD card and verified.

_________ 5. The LMS data collection system has been connected to the laptop and the hardware is communicating. The baselines for all channels have been reviewed.

_________ 6. The 24 Volt main batteries have been charged.

_________ 7. The battery jumper has been installed and the two circuit breakers have been turned on.

_________ 8. The master 24 Volt power switch has been turned on.

_________ 9. The 24 Volt timer power switch has been turned on.

_________ 10. The 24 Volt battery system voltage has been recorded.

Battery Voltage (Open Circuit) ___________
Battery Voltage (Under Load) ____________

_________ 11. The test SD card has been installed in the LMS master recorder.

_________ 12. The Siemens LMS data collection systems are powered on by first powering the slave system followed by the master system.

_________ 13. The LMS system is allowed to warmup for approximately 10 minutes with excitation applied.

_________ 14. Verify the LMS system can communicate with the Tablet in scope mode.

SHIP TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

Initials	Required Activity
________	15. Verify LMS GPS is locked and providing data to the Tablet.
________	16. Verify LMS system control and balance function using the Tablet.
________	17. Balance the LMS data recorder and verify the baseline measurements are acceptable. Verify that all recorder channels have blue lights
________	18. Determine the Project Manager and support personnel are ready to start the barge test.
________	19. Verify battery voltage and all four fans are running.
________	20. Project Manager authorizes the ocean test to proceed.
________	21. Final Check - Balance the LMS data recorder and verify the baseline measurements are acceptable. All recorder channels have blue lights.
________	22. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	23. Record the local start time of the test. ________________________________
________	24. Turn the timer trigger to the on position for 5 seconds and turn the trigger off. Verify the timer position is at 360 hours.
________	25. Secure the three panels on the data collection box with security screws. Press record button on Tablet and verify the system is recording with the red light on the master recorder.
________	26. At the end of the ocean test stop the recorders if they are still running using the Tablet, power down the hardware and remove the SD card. Transfer the SD card to a card reader using the laptop and transfer the .TRD data onto an external hard drive. Convert the .TRD data to .LDSF and copy that data to the external hard drive.
________	27. Verify the .TRD and .LDSF data is present on the external hard drive in a test folder with the date and test mode.
________	28. Verify the SD card and external hard drive are labeled SHIP Test.

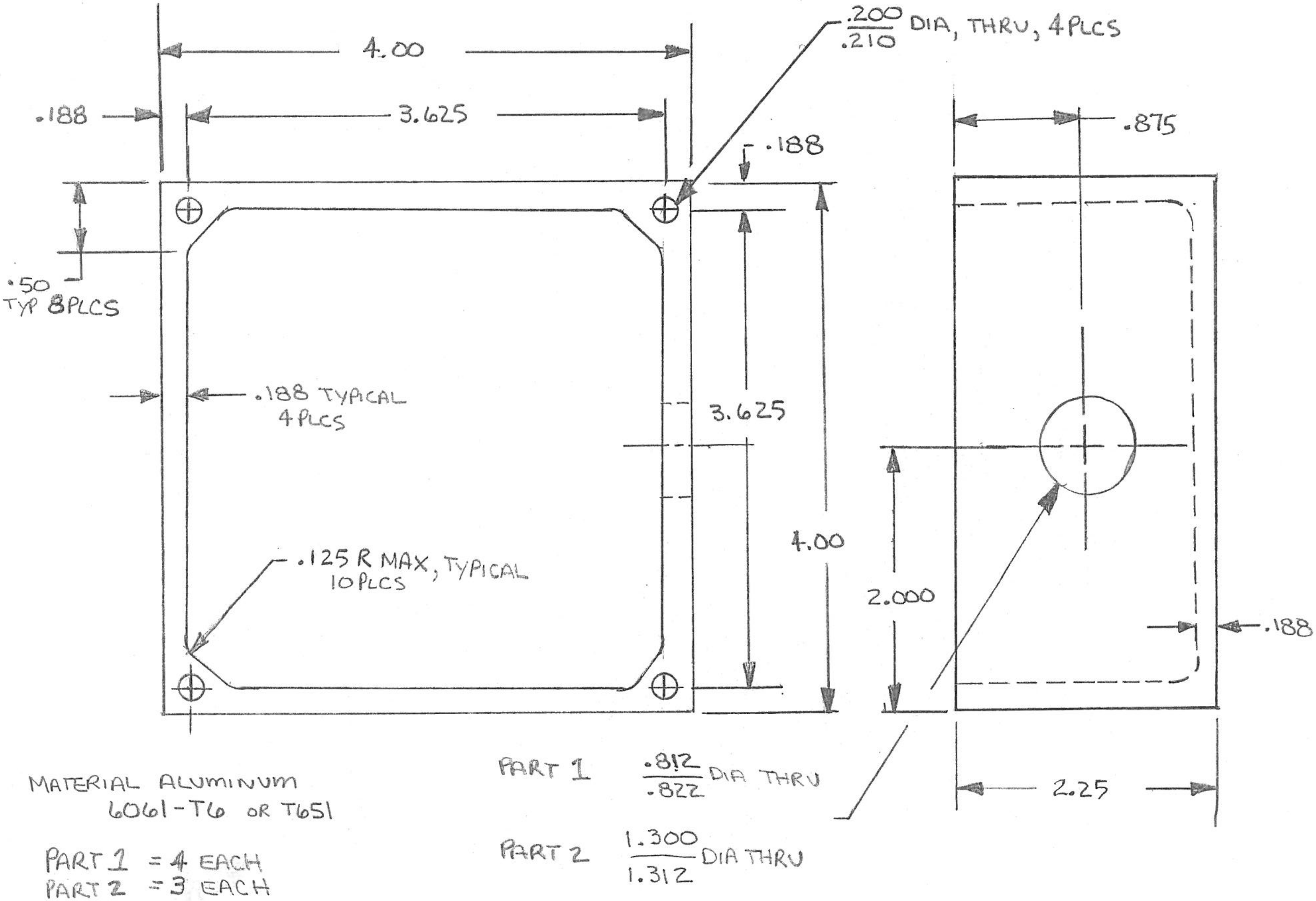
SHIP TEST
ENSA/DOE TRANSPORTATION TEST PROGRAM TEST HOLD POINT CHECKLIST
(continued)

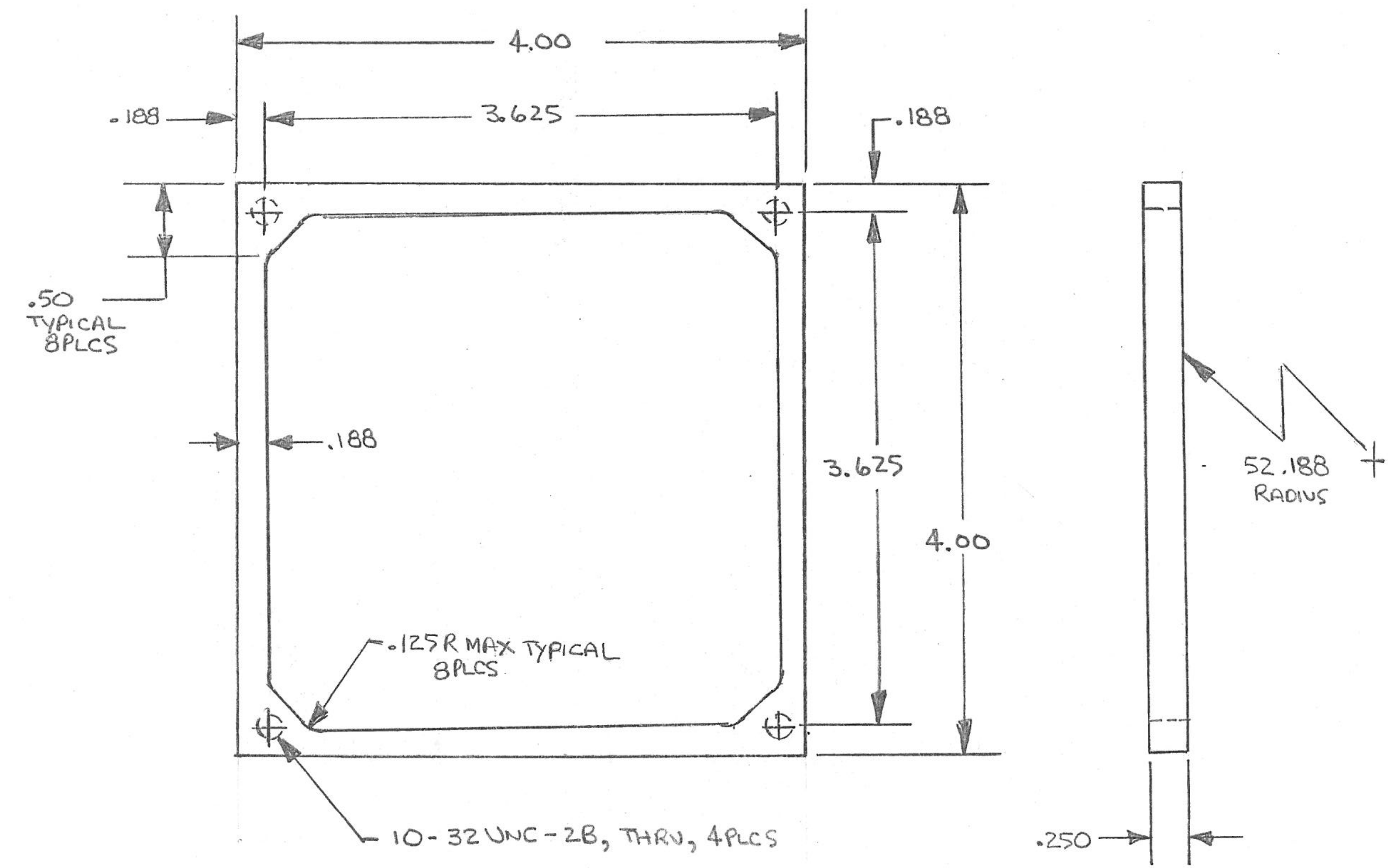
Initials	**Required Activity**
________	29. At the end of the ocean testing verify the SD card and external hard drive contain data and are labeled Ship Test. Place the SD card and external hard drive in a transportation case.

Completed:

____________________ ________
Project Manager Date

____________________ ________
Instrumentation Coordinator Date


.200 / .210 DIA, THRU, 4 PLCS
4.00
.188
3.625
.188
.875
.50
TYP 8 PLCS
.188 TYPICAL
4 PLCS
3.625
4.00
.125 R MAX, TYPICAL
10 PLCS
2.000
.188
2.25
MATERIAL ALUMINUM
6061-T6 OR T651
PART 1 = 4 EACH
PART 2 = 3 EACH
PART 1 .812 / .822 DIA THRU
PART 2 1.300 / 1.312 DIA THRU



MATERIAL STAINLESS STEEL
304

PART 1 = 6 EACH (STRAIGH FACE)
PART 2 = 2 EACH (RADIUS FACE)

APPENDIX C: PNNL INSTRUMENTATION PLACEMENT ANALYSIS

Strain Gage Placement Recommendations

Nick Klymyshyn

11/3/2016

Current Location Of Strain Gages

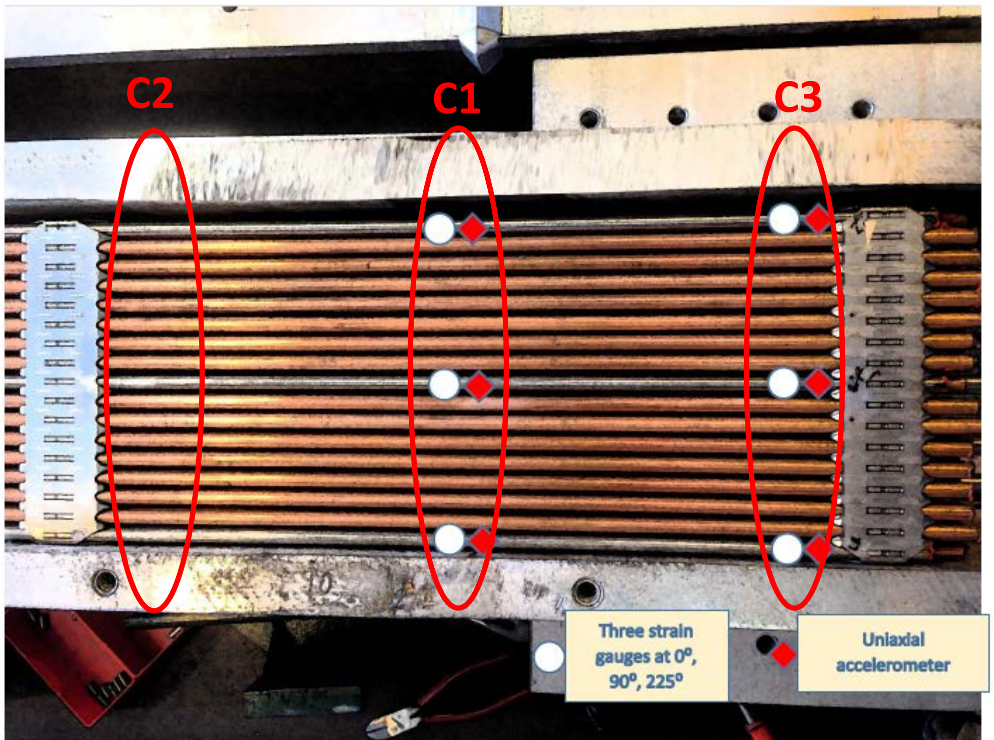
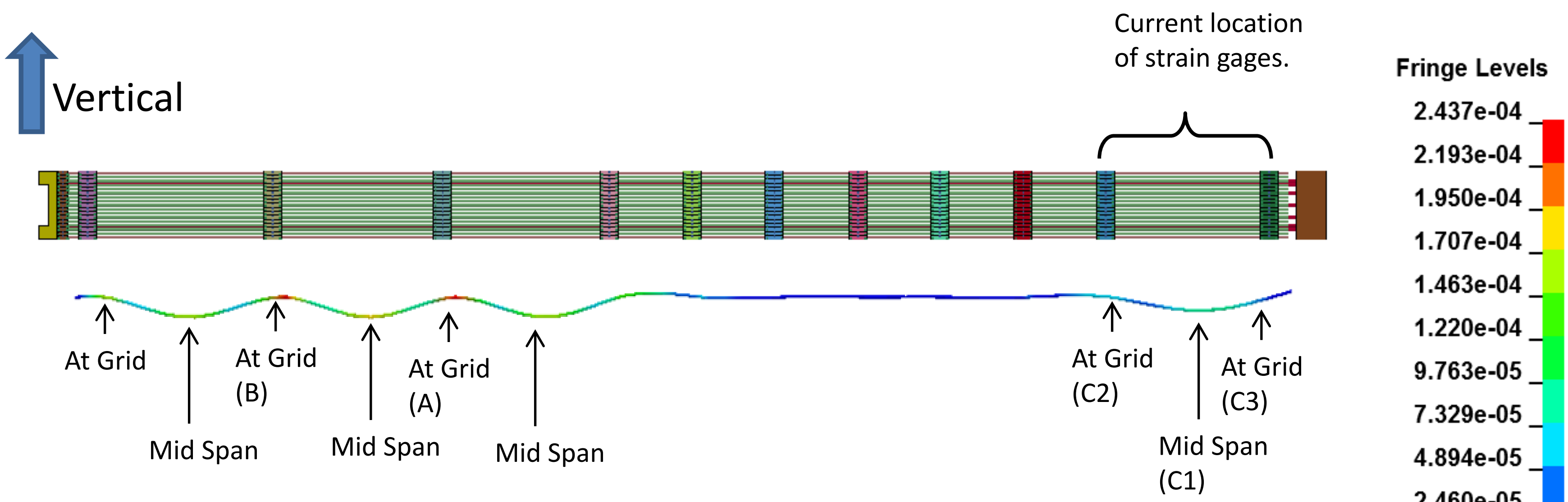


Figure 9. Axial locations of accelerometers and strain gages to be placed on the SNL PWR assembly rods. The rod position will be as described in Figure 6. The ENRESA assembly will have strain gages only on the top row rods. The is insufficient clearance to place accelerometers on the ENRESA assembly without removing rods from the top row as will be done with the SNL assembly.

Current Test Configuration

- All gages are in one span
  - Top long span
  - Labeling this span "C"
- 3 Zirc rods
  - Lead rope
  - Lead pellets
  - Moly pellets
- 2 Locations on each rod
  - End (C3)
  - Mid-span (C1)
  - No gages (C2)
- 3 Strain gages per location
  - 0° Vertical Bending
  - 90° Lateral Bending
  - 225° Combination

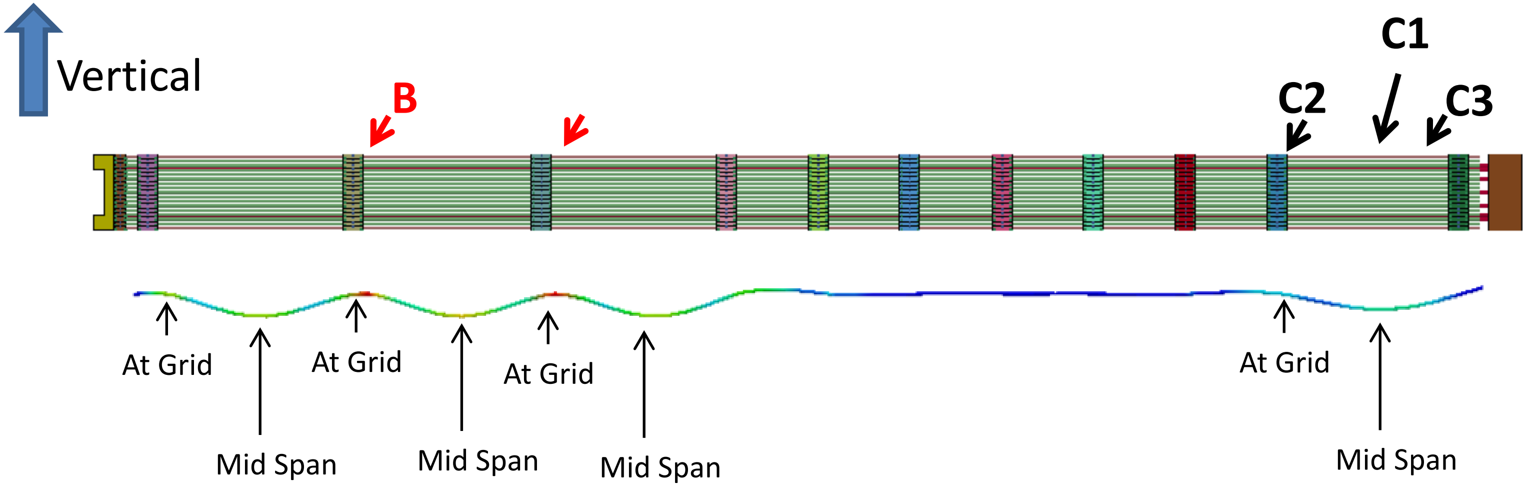
Peak Strain Locations Relative to Grids 56.4 Hz Forced Vertical Excitation

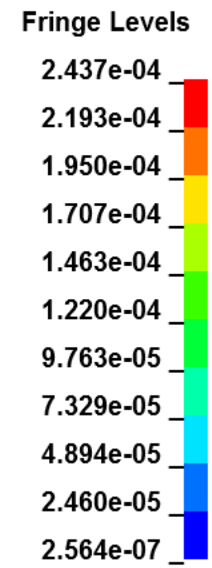


Evaluation of 56.4 Hz forced vibration response of single fuel rod:

- True peak is 244 με at A
- If the only strain gage is located at C1, peak recorded strain is 88 με
  - Correction factor to true peak is 2.8
- If the only strain gage is located at C2, peak recorded strain is 64 με
  - Correction factor to true peak is 3.8
- If the only strain gage is located at C3, peak recorded strain is <64 με
  - Correction factor to true peak is >3.8

Recommendations (Prioritized)



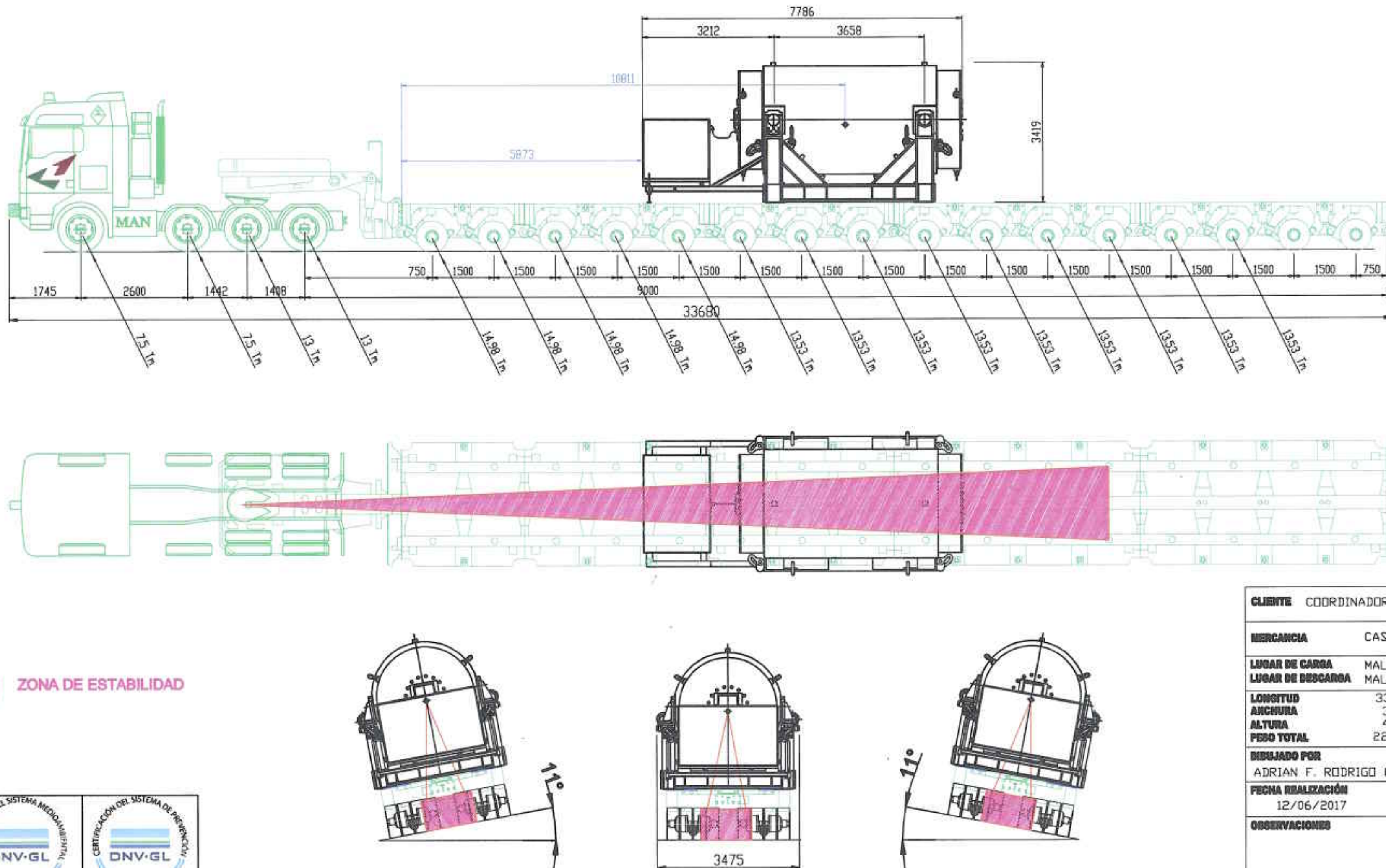


1. Add 3 channels of strain gages. Apply them at A 0° on the Moly pellet rod and Lead Rope rod, and B 0° on the Moly pellet rod. Moly rod offers cleanest frequency domain behavior from Sparks test, so it looks best for model validation.
2. If we can't add 3 channels, move the 3 225° strain gages from C3 to use at A and B at the same locations identified in 1.
3. If there is a problem reaching B, put the three strain gages at A 0° on all three Zirc rods.
4. If we can only move 1 strain gage, move the 225° strain gage from the C3 lead pellet rod to A 0° on the Moly pellet rod.
5. Optional: Consider moving all strain gages from location C3 to location C2. C3 is near a free end and model results suggests the strains at C2 will typically be higher than C3 in all forced vibration cases.
    1. This is optional because the mid-span location (C1) is the most limiting location in span C. C2 would record second-highest strains in the span. C3 is still useful data.

APPENDIX D: HEAVY-HAUL TRUCK DIAGRAM

LASARTE
TRANSPORTE · INGENIERÍA · LOGÍSTICA

CÁLCULO DE ESTABILIDAD
SUSPENSIÓN EN 3 PUNTOS



ZONA DE ESTABILIDAD

CLIENTE	COORDINADORA INTERNACIONAL DE CARGA		
MERCANCIA	CASK 149 T.		
LUGAR DE CARGA	MALIAÑO (CANTABRIA-ESPAÑA)		
LUGAR DE DESCARGA	MALIAÑO (CANTABRIA-ESPAÑA)		
LONGITUD	33.680 m	**TRACTOR**	**REMOLQ**
ANCHURA	3.475 m	4 EJES	GÓNDOL MODULA DE 16 E.
ALTURA	4.644 m		
PESO TOTAL	223,4 Tm		
DIBUJADO POR	ADRIAN F. RODRIGO GARCÍA	**CALIDAD**	VICTOR GUTIERRE
FECHA REALIZACIÓN	12/06/2017	**REVISIÓN**	1
OBSERVACIONES			

CERTIFICACIÓN DEL SISTEMA DE CALIDAD DNV·GL ISO 9001
CERTIFICACIÓN DEL SISTEMA MEDIOAMBIENTAL DNV·GL ISO 14001
CERTIFICACIÓN DEL SISTEMA DE PREVENCIÓN DNV·GL OHSAS 18001

APPENDIX E: COORDINADORA SEA ROUTES REPORTS FOR SANTANDER – ZEEBRUGGE – BALTIMORE AND ROUND-TRIP RAIL OPERATIONS REPORTS FOR BALTIMORE - TTCI

COORDINADORA
The transport engineering company

SEA ROUTES REPORT

OCEAN TRANSPORT OF ENUN 32P CASK FROM SANTANDER TO BALTIMORE

REV.	DATE	CONCEPT	PREPARED BY	REVISED BY	APPROVED
1	13th/July/2017	First edition	ARC	VM	LG

CUSTOMER: ENSA
CONTACT: Rafael González / Ismael Fernández
REF. CUSTOMER: TRANSPORT TESTS OF ENUN 32P CASK
REF. COORDINADORA: OF160057 / 17.0181.0009

TABLE OF CONTENTS

FIRST STAGE OF SEA TRANSPORT

COASTER VOYAGE: SANTANDER-ZEEBRUGGE

Actual Time of Sailing Santander: 23rd/June

Actual Time of Arrival Zeebrugge: 27th/June

Transit Time: 4 days

MV Autosky

Specifications

Vessel Capacity	2080	**Service Speed**	20 kn
Vessel Speed	20	**Length Overall**	140 m
Vessel Class	1A	**Breadth**	22.7 m
Built Year	2000	**Maximum Draft**	7.35 m
Shipyard	Tsuneishi Shipbuilder Co. Ltd. (Japan)	**Gross Tonnage**	21,010
		Net Tonnage	6304
Owner	UECC	**Car Decks**	7 + Tank Top
Flag	Madeira	**Deck Area**	16,870 m2
IMO Number	9206774	**Height Main Deck**	4.8 m
Call Sign	CQQA	**Stern Ramp Capacity**	82 t
Classification Society	LR	**Stern Ramp Width**	13.7 m
Ice Class	1A	**Stern Ramp Length**	15.5 m
Car Capacity (RT 43)	2080	**Lane Meters**	710 m

Image 1. Vessel description (MV Autosky)

SEA ROUTES REPORT
Santander-Zeebrugge-Baltimore

Reader will find below sea routes with distances between each port of call.

Note 1: Cask remained lashed and stowed until it arrived at Zeebrugge Port.

Note 2: Vessel speed is estimative.

FIRST CALL: PASAJES PORT

Santander Empt

89.65 mi (166.04 km)

Transit Time: a day (20 knots)

Pasajes

Image 2. First call: Pasajes. Route from Santander to Pasajes.

SECOND CALL: ROTTERDAM PORT

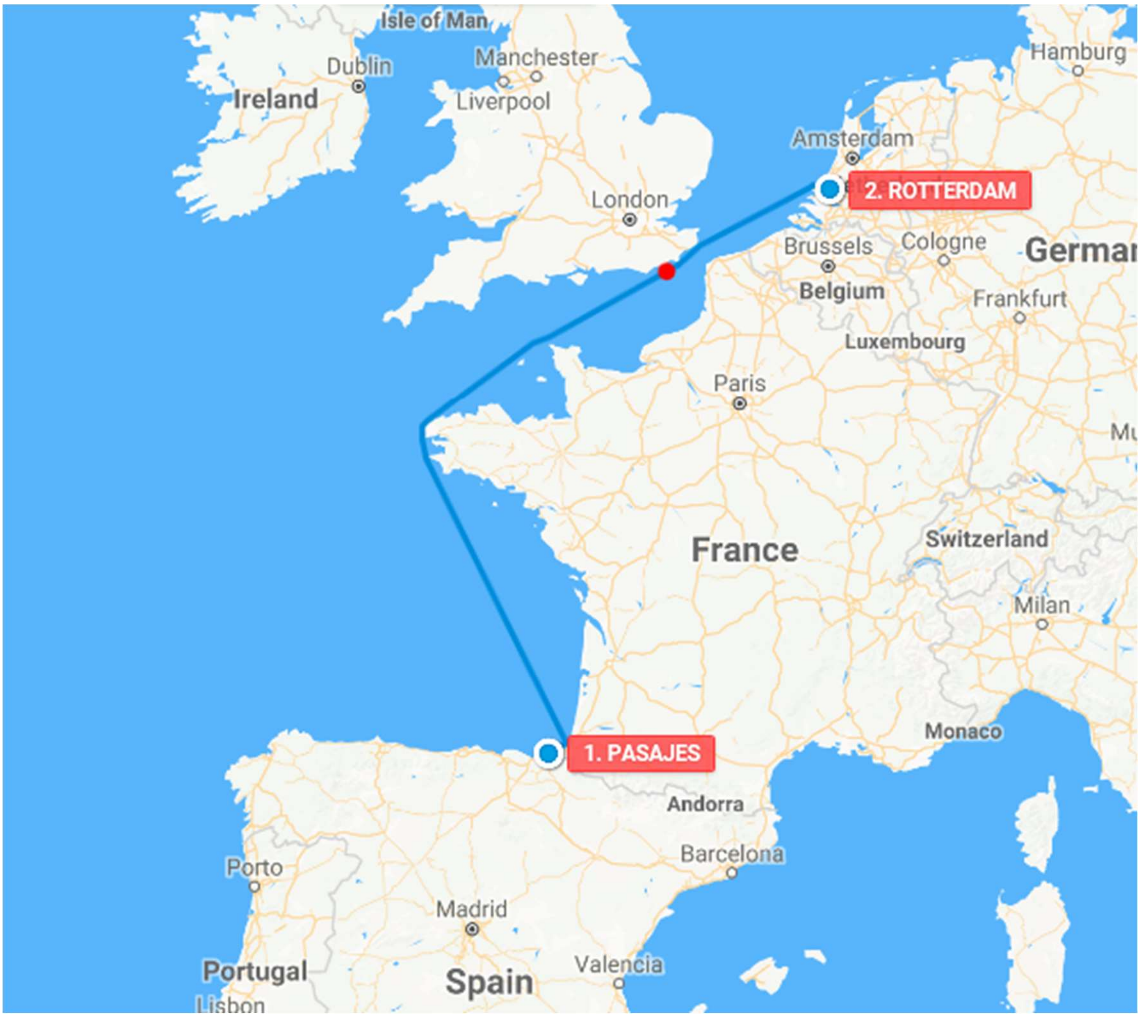


Image 3. Second call: Rotterdam. Route from Pasajes to Rotterdam.

THIRD AND LAST CALL OF THIS FIRST STAGE: ZEEBRUGGE PORT

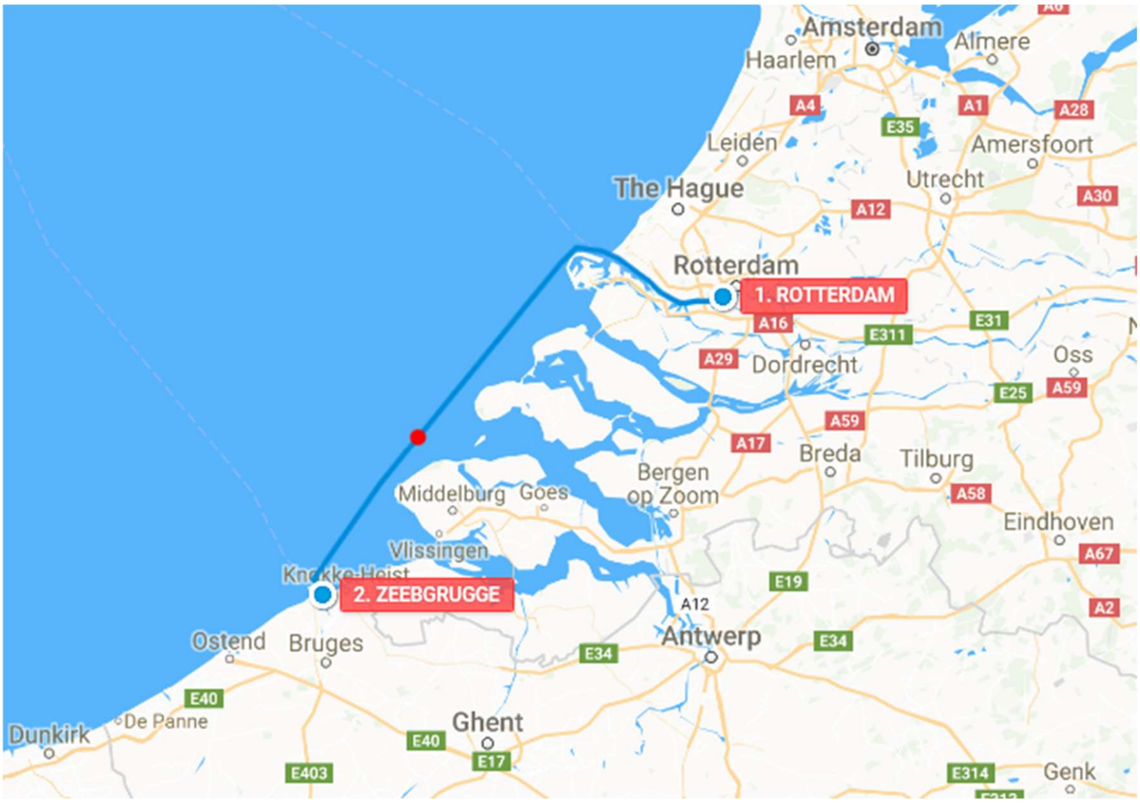


Image 4.Port of Destination: Zeebrugge. Route from Rotterdam to Zeebrugge.

Image 5. Photo of vessel MV Autosky accessing to Santander Port.

Image 6. Truck platform and cask on board MV Autosky, lashed and secured to vessel deck.

SECOND STAGE OF SEA TRANSPORT

OCEANIC VOYAGE: ZEEBRUGGE-BALTIMORE

Actual Time of Sailing Zeebrugge: 04th/July

Estimated Time of Arrival Zeebrugge: 18th/July

Transit Time: 14 days

MV Tarago

Vessel Name	Vessel Type	Year Built	Flag	IMO number	Dead Wt (MT)	Cap. Cars (RT43)	Hois-table Decks	Max RoRo Ht (m)	Max RoRo W (m)	Max RoRo Ramp Wt Cap. (t)
Tarago	RORO	2000	NO	9191321	39,404	5,496	4	6.40	12.00	380

Image 7. Vessel description (MV Tarago)

SEA ROUTES REPORT
Santander-Zeebrugge-Baltimore

Reader will find below sea routes with distances between each port of call.

Note 1: Cask remained lashed and stowed until it arrived at Baltimore Port.

Note 2: Vessel speed is estimative.

FIRST CALL: BREMERHAVEN PORT

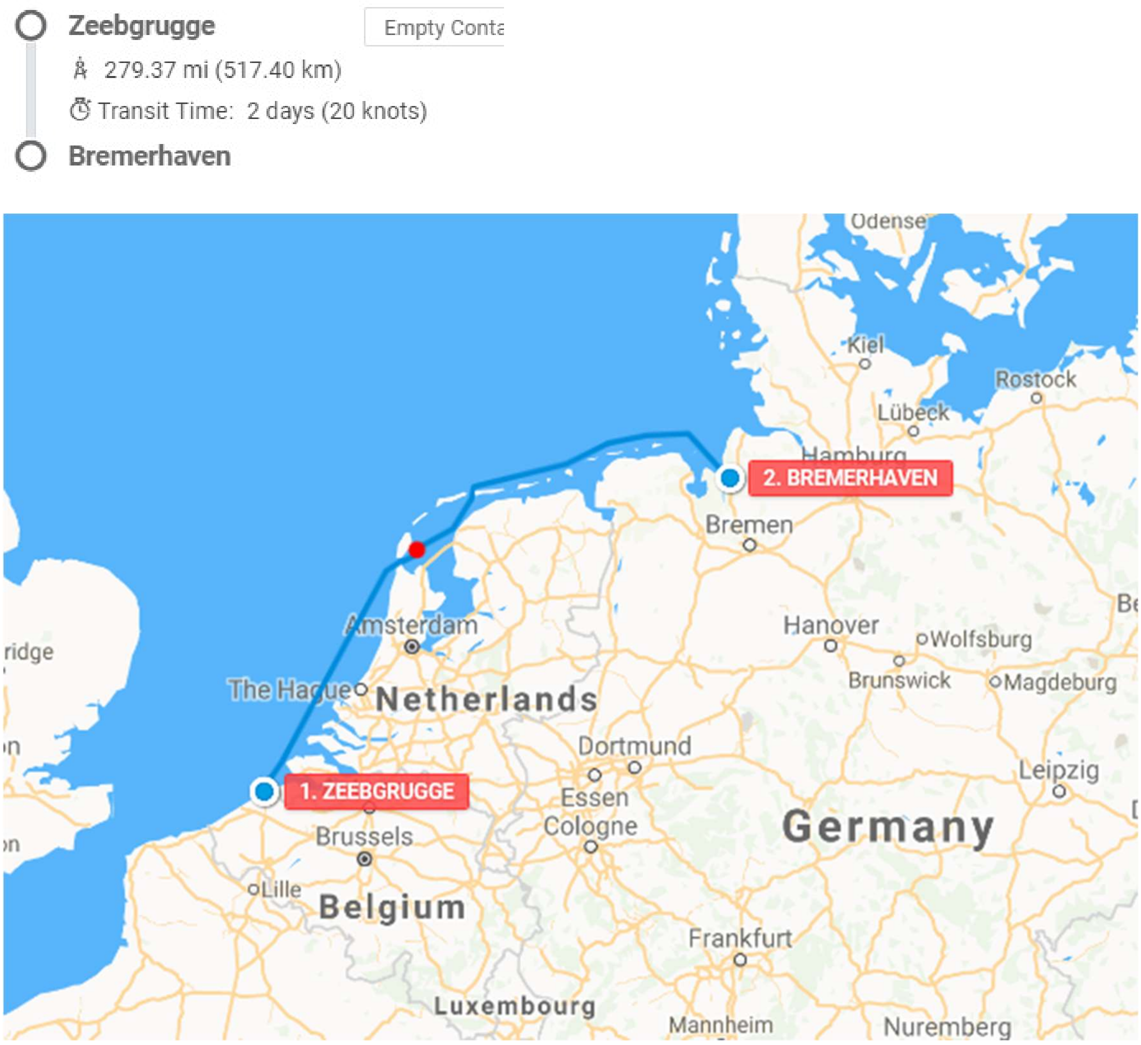


Image 8. First call: Bremerhaven. Route from Zeebrugge to Bremerhaven.

SECOND CALL: LE HAVRE PORT

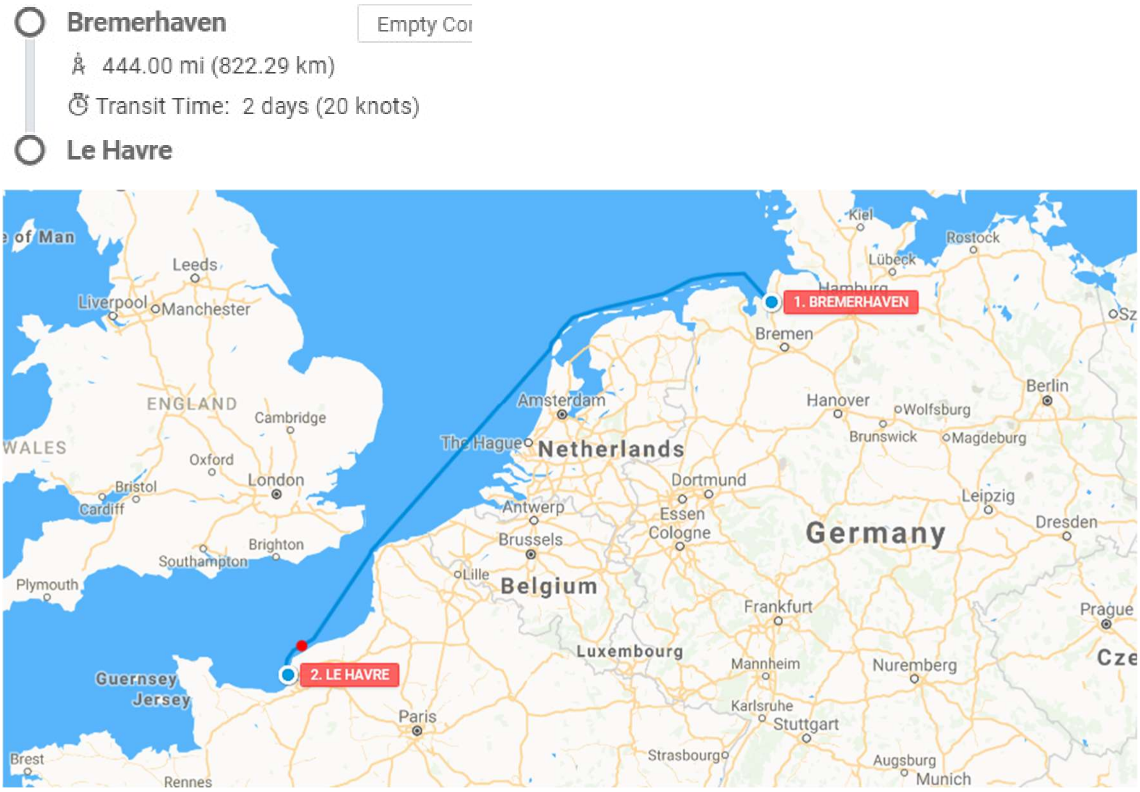


Image 9. Second call: Le Havre. Route from Bremerhaven to Le Havre.

THIRD CALL: SOUTHAMPTON PORT

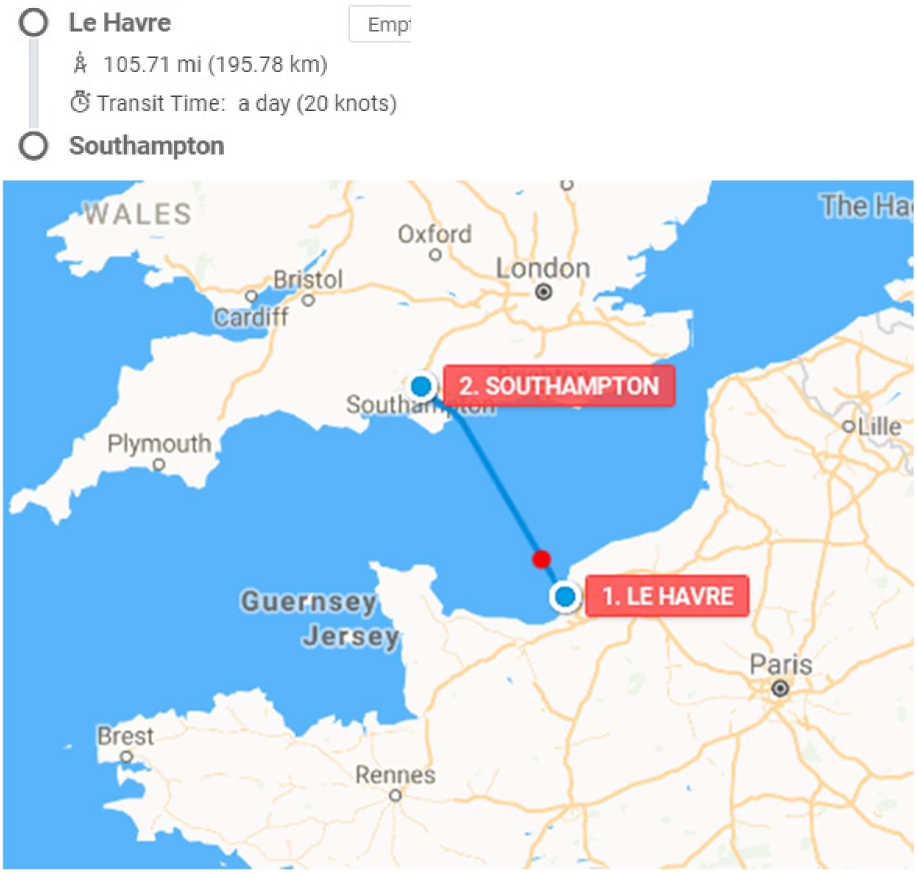


Image 10. Third call: Southampton. Route from Le Havre to Southampton.

FOURTH AND LAST CALL OF SECOND LEG OF SEA TRIP: BALTIMORE PORT

Southampton Empty Co

3392.99 mi (6283.81 km)

Transit Time: 12 days (20 knots)

Baltimore

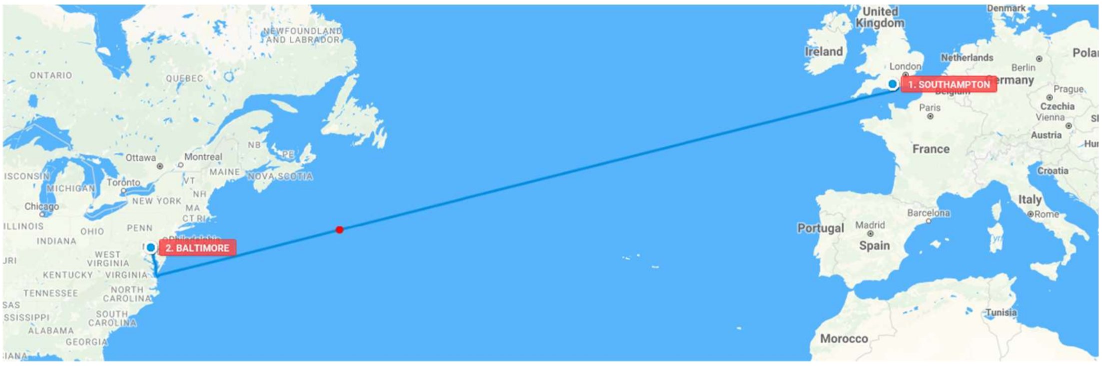


Image 11. Port of destination: Baltimore. Route from Southampton to Baltimore.

Image 12. Photo of CASK getting on board MV Tarago.

Image 13. SAMSON and CASK on board of MV Tarago, lashed and secured to vessel deck.

experience
COORDINADORA

P.º de la Castellana, 140, 8.ºA
28046 · Madrid · Spain
Tel. +34 91 590 33 60
Fax: +34 91 564 73 84
www.coordinadora.eu

COORDINADORA
The transport engineering company

STATEMENT OF FACTS

PORT OPERATIONS AT BALTIMORE PORT AND RAIL TRANSPORT OF ENUN 32P CASK FROM BALTIMORE TO AVONDALE

REV.	DATE	CONCEPT	PREPARED BY	REVISED BY	APPROVED
0	August/31st/2017	Draft edition	ARC	VA	LG
1	Sept/11st/2017	First edition	ARC	VA	LG

CUSTOMER: EQUIPOS NUCLEARES S.A. S.M.E.

CONTACT: Pablo Álvarez / Rafael González / Ismael Fernández

REF. CUSTOMER: TRANSPORT TESTS OF ENUN 32P CASK

REF. COORDINADORA: OF160057 / 17.0181.0009

TABLE OF CONTENTS

OPERATIONS AT BALTIMORE PORT

Vessel MV Tarago arrived Baltimore on July/18th at 0600h, being discharged from vessel during the evening of the same day.

The DAS[1] was turned off after the arrival of cask at the terminal and the next day (July/19th) the cask was transhipped from SAMSON to 12-axles KASGRO railcar.

Below table shows when the operations were performed at MAT:

ACTIVITY	DATE
Railcar waiting for cargo at Baltimore Port (MAT)	July/17th
Arrival of vessel MV Tarago at Baltimore Port (anchorage)	July/18th 0600h
Berthing of vessel MV Tarago at terminal (aprox. time)	July/18th 1900h
Access to switch on the DAS once discharged	July/18th evening
Removing accelerometers from SAMSON	July/19th
Unloading cask from SAMSON to loading onto railcar	July/19th 1300h
Recharging batteries during 36h	July/19th
Import Customs Clearance	July/20th
Lashing cask to RAILCAR	July/20th & July /21st
Installing accelerometers on RAILCAR	July /21st
Installing GPS little box on RAILCAR	July /21st
NS rail inspection at Baltimore Port	July /21st
CSX rail inspection at Baltimore Port	July /22nd
Railroads approve car for movement	July /21st & July /22nd
Pull car from dock to CSX Bayview Yard	July/26th
Access the CSX railyard to turn on the system prior to departure	July/28th
Departure of train from CSX Bayview Yard	July/28th 1949h

In next pages, reader will find pictures showing the course of port operations from July/19th to July/21st which corresponds to activities performed at Port.

[1] Data Acquisition System

Image 1. Cask on SAMSON with tug master about to be moved next to crane for transhipment from SAMSON to RAILCAR at Mid-Atlantic Terminal. July/19th

Image 2. Crane of 500Mt capacity.

Image 3. Tug master and cask on SAMSON being moved under crane's hook. July/19th

Image 4. Tug master and cask on SAMSON under crane's hook. July/19th

Image 5. Cask lifted. July/19th

Image 6. SAMSON removed under CASK and CASK lifted waiting for railcar to be moved under it. July/19th

Image 7. KASGRO RAILCAR moved under cask immediately after SAMSON was removed from under cask. July/19th

Image 8. Cask on KASGRO RAILCAR. July/19th

Image 9. Cask on RAILCAR being moved back the terminal to start lashing works. July/19th

Image 10. SANDIA/PNNL staff connecting chargers to the batteries. July/19th

Image 11. Hot works start (welding stoppers). July/20th

Image 12. Shackles were fixed by straps to the cradle or textile slings to the railcar to minimize any background noise caused during the railway transport that may affect the data.

.

Image 13. GPS system completely installed at "A end" of railcar. July /21st

Image 14. Picture showing "A end" of railcar.

Image 15. Picture showing "B end" of railcar.

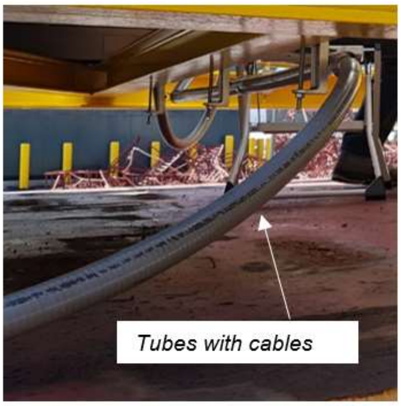
Image 16. Picture of final configuration of one complete stopper composed of several plates. [2]
(4 complete stoppers like image 16 were welded in total, 2 at both sides of CASK.).

[2] Lashing drawings are attached at the end of the present document in "Appendix 1"

Image 17. 2x stoppers in the back side of CASK.

Image 18. 2x stoppers in the front side of CASK

Image 19. Leg for supporting craddle for batteries was welded to avoid background vibrations.



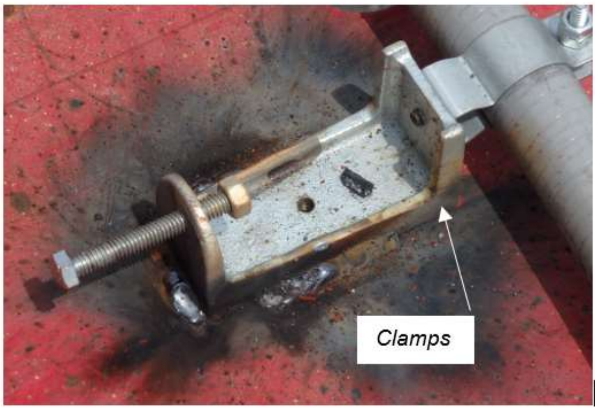


Image 20. Clamps used to fix the tubes with cables of accelerometers inside them were welded to railcar.

RAIL ROUTE

In this section it is described the rail transport from CSX Bayview yard to Avondale in a dedicated train[3].

The total transit time was of 7 days in total. Below table shows the schedule accomplished by dedicated train and the route followed by cask can be seen in next page.

ACTIVITY	DATE
Departure of train from CSX Bayview Yard	July/28th 1949h
Arrival at Smithboro	July/30th 1115h
Departure from Smithboro	July/31st 2043h
Arrival at Avondale and transfer to TTCI	August/02nd
Start of tests at TTCI	August/14th

Image 21. Shipment moving through Pennsylvania.

[3] Dedicated train consists of a locomotive only for this railcar, having high priority railroad over other conventional trains. This transport option minimises the transit time as much as possible. The estimation of transit time from Baltimore to Avondale was of 25-30 days in a conventional train while it took 7 days with a dedicated train.

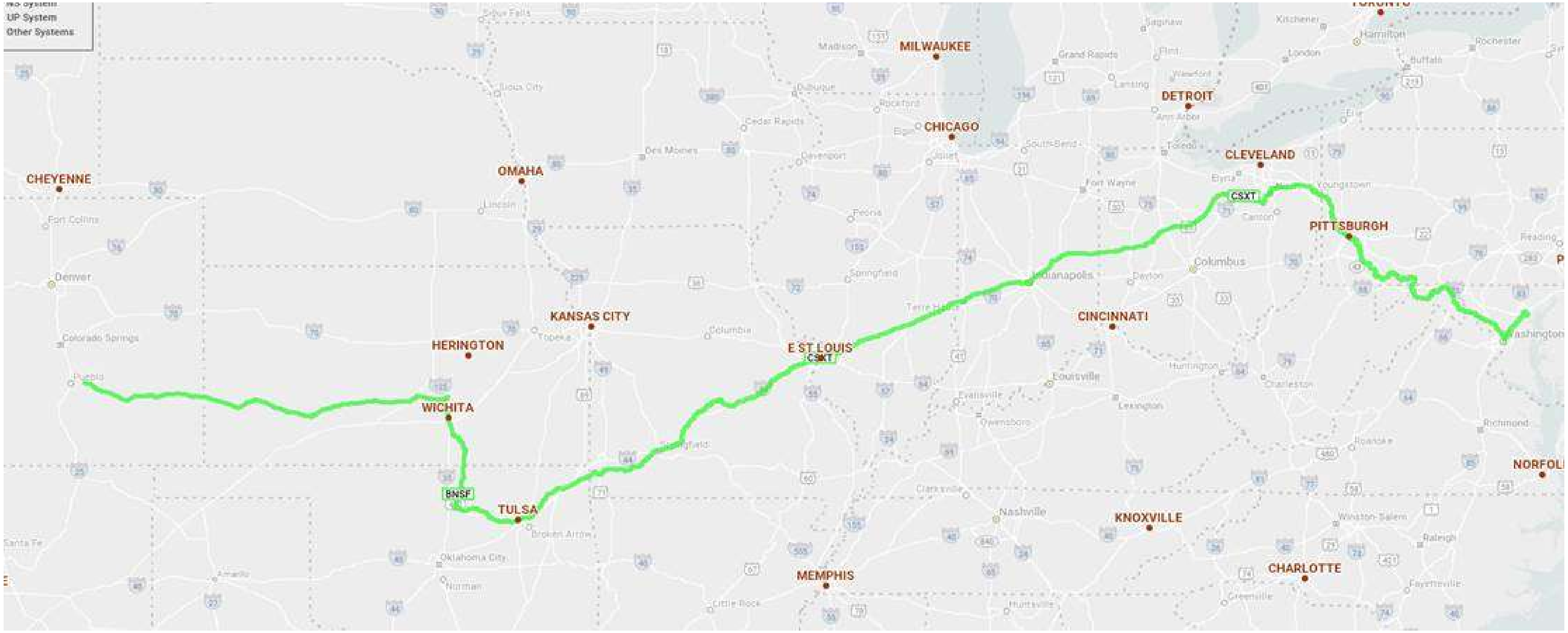
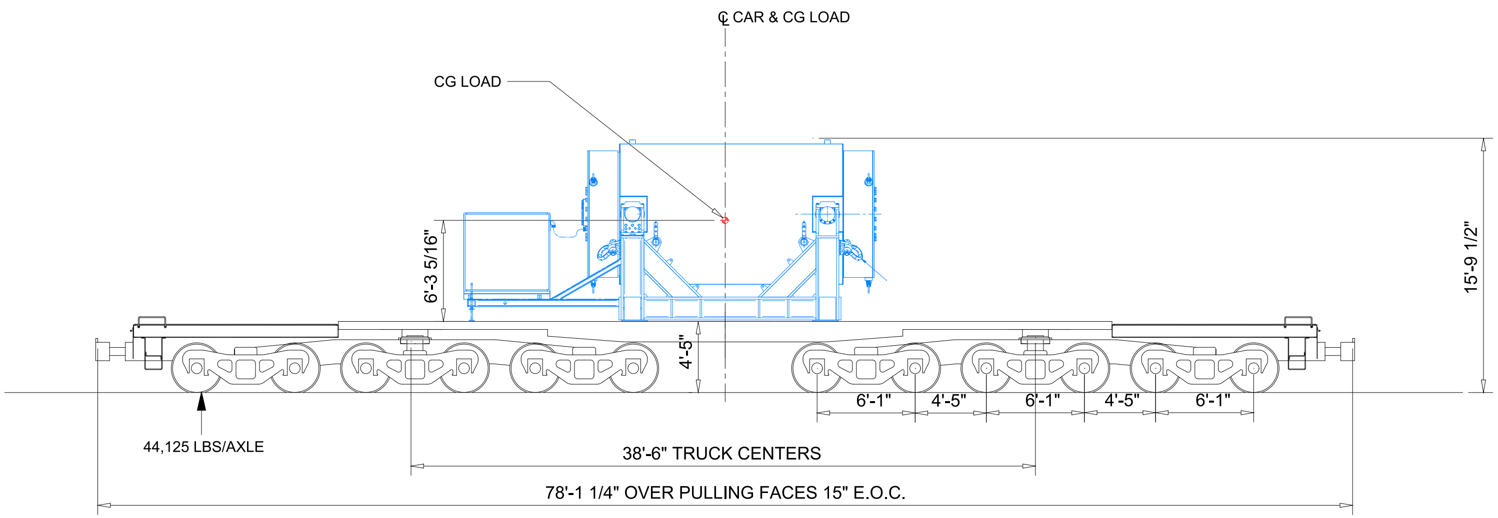


Image 22. Train route from CSX Bayview (Baltimore) to Avondale (Pueblo). ***Approximate*** *total distance: 1,900miles (3,057km)*

APPENDIX 1:

LASHING DRAWING FOR RAIL TRANSPORT



SECUREMENT REQUIREMENTS

(AAR OPEN TOP LOADING RULES - SECTION 1 GENERAL RULES)

LONGITUDINAL SECUREMENT REQUIRED - EACH END
328,500 LBS X 7.5G = 2,463,750 LBS

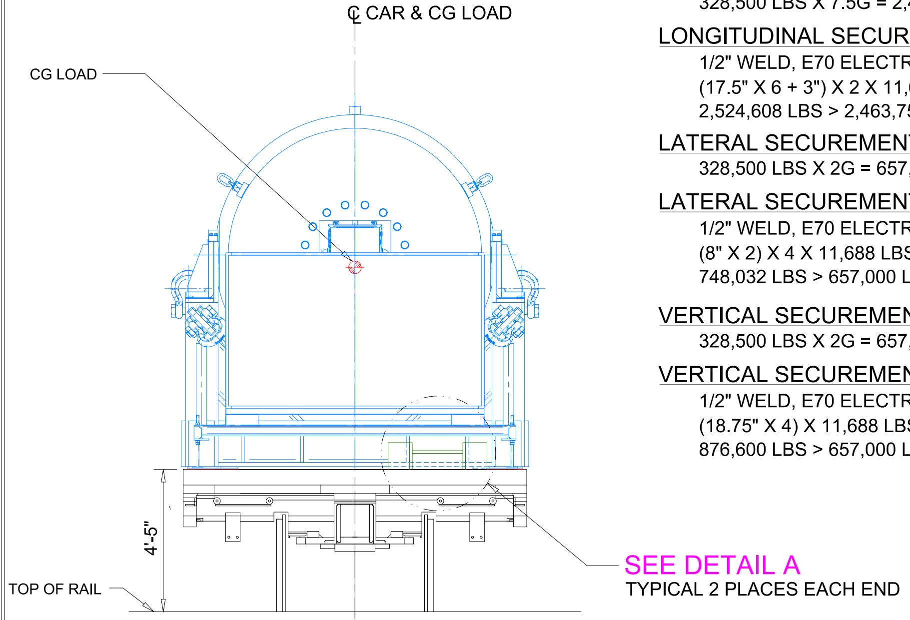
LONGITUDINAL SECUREMENT AVAILABLE - SEE DETAIL A
1/2" WELD, E70 ELECTRODE = 11,688 LBS/IN
(17.5" X 6 + 3") X 2 X 11,688 LBS/IN = 2,524,608 LBS
2,524,608 LBS > 2,463,750 LBS

LATERAL SECUREMENT REQUIRED - EACH SIDE
328,500 LBS X 2G = 657,000 LBS

LATERAL SECUREMENT AVAILABLE - SEE DETAIL A
1/2" WELD, E70 ELECTRODE = 11,688 LBS/IN
(8" X 2) X 4 X 11,688 LBS/IN = 748,032 LBS
748,032 LBS > 657,000 LBS

VERTICAL SECUREMENT REQUIRED
328,500 LBS X 2G = 657,000 LBS

VERTICAL SECUREMENT AVAILABLE - SEE DETAIL A
1/2" WELD, E70 ELECTRODE = 11,688 LBS/IN
(18.75" X 4) X 11,688 LBS/IN = 876,600 LBS
876,600 LBS > 657,000 LBS



SHIPPING DIMS: 307.0"L X 129.2"W X 135.0"H
LOAD WEIGHT: 328,500 LBS
RAIL CAR LT WT: 201,000 LBS
LOAD DWG: 9293.00S1
CCG CAR + LOAD = 92.6" ATR

CAR SERIES KRL 370350 - 370398

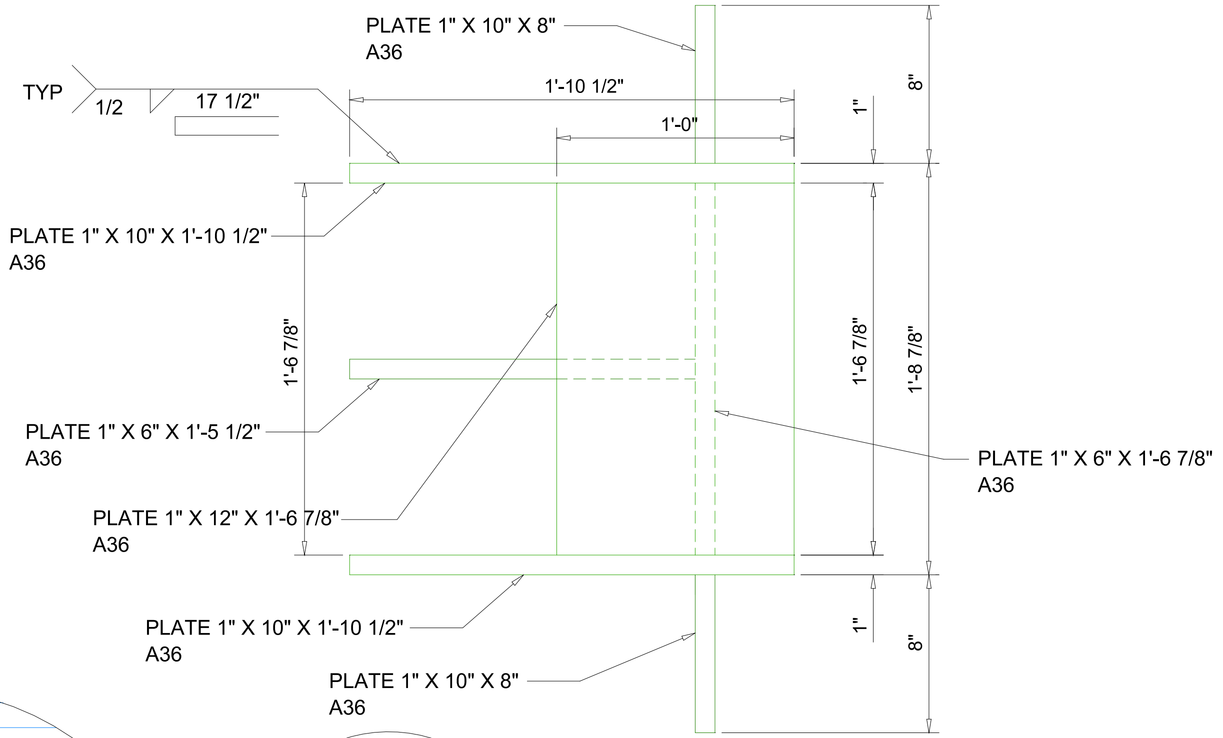
A	JS	6-28-17	REVISED FOR IRRADIATED CASK
REV	BY	DATE	REVISION

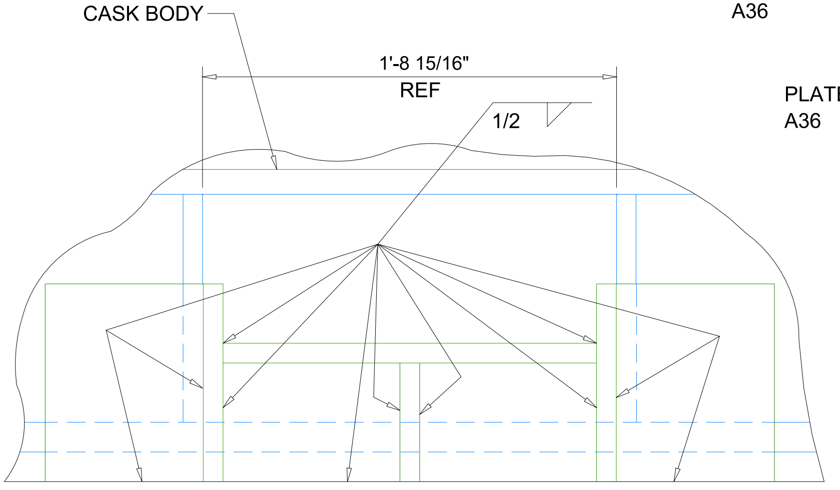
UNLESS OTHERWISE NOTED ON THIS DRAWING THE FOLLOWING TOLERANCES SHALL APPLY:
DIMENSIONS: ± 1/16"; ANGLES: ± 1°;

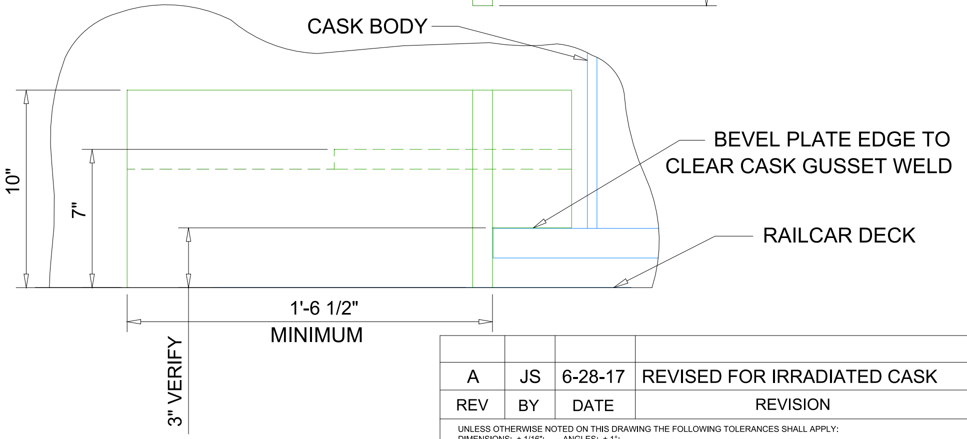
UTC Overseas, Inc.
2 Northpoint Drive, Suite 200 Houston, TX 77060

TIE-DOWN ARRANGEMENT COORDINADORA - PUEBLO

DRAWN	APPROVED	DATE	DRAWING NO.	SHT	REV
JS			D-17-0008-1	1/4	A







DETAIL A

TYPICAL 2 PLACES EACH END

REV	BY	DATE	REVISION
A	JS	6-28-17	REVISED FOR IRRADIATED CASK

UNLESS OTHERWISE NOTED ON THIS DRAWING THE FOLLOWING TOLERANCES SHALL APPLY:
DIMENSIONS: ± 1/16"; ANGLES: ± 1°;

UTC Overseas, Inc.
2 Northpoint Drive, Suite 200 Houston, TX 77060

TIE-DOWN ARRANGEMENT
COORDINADORA - PUEBLO

DRAWN	APPROVED	DATE	DRAWING NO.	SHT	REV
JS			D-17-0008-2	2/4	A

experience
COORDINADORA

P.º de la Castellana, 140, 8.ºA
28046 · Madrid · Spain
Tel. +34 91 590 33 60
Fax: +34 91 564 73 84
www.coordinadora.eu

REV.	DATE	CONCEPT	PREPARED BY	REVISED BY	APPROVED
0	Sept/ 11st /2017	Status of cask during rail transport so far.	ARC	VA	LG

CUSTOMER: EQUIPOS NUCLEARES S.A. S.M.E.

CONTACT: Pablo Álvarez / Rafael González / Ismael Fernández

REF. CUSTOMER: TRANSPORT TESTS OF ENUN 32P CASK

REF. COORDINADORA: OF160057 / 17.0181.0009

TABLE OF CONTENTS

SCOPE OF THIS DOCUMENT

The purpose of this document is to report about the situation of the cask during its rail trip back from Avondale to Baltimore port.

Note that this report will be updated frequently in order to have the last information about cask location during its rail transport until cask arrives Baltimore Port and the present report is finished.

DESCRIPTION OF STATUS DAY BY DAY.

DAY 0: August/31st

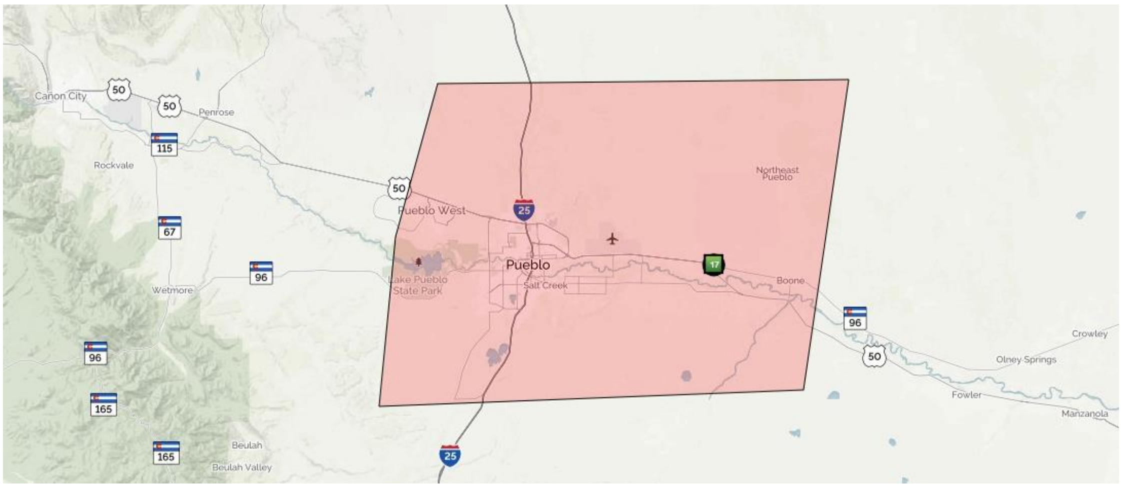


Image 1 5.99 miles W of Boone, Colorado.

DAY 1: Sept/01st

DEPARTURE FROM AVONDALE at 03:26pm (LT)

Journey from North Avondale to Pueblo.

Distance covered this day: 16mi (25.7km)

Total distance covered: 16mi (25.7km)

Image 2. Day 1. Origin of departure. North Avondale.

1.63 miles NW of Pueblo, Colorado.

DAY 2: Sept/02nd

Journey from Pueblo to South Dodge.

Distance covered this day: 276 mi (444km).

Total distance covered: 292mi (470km)

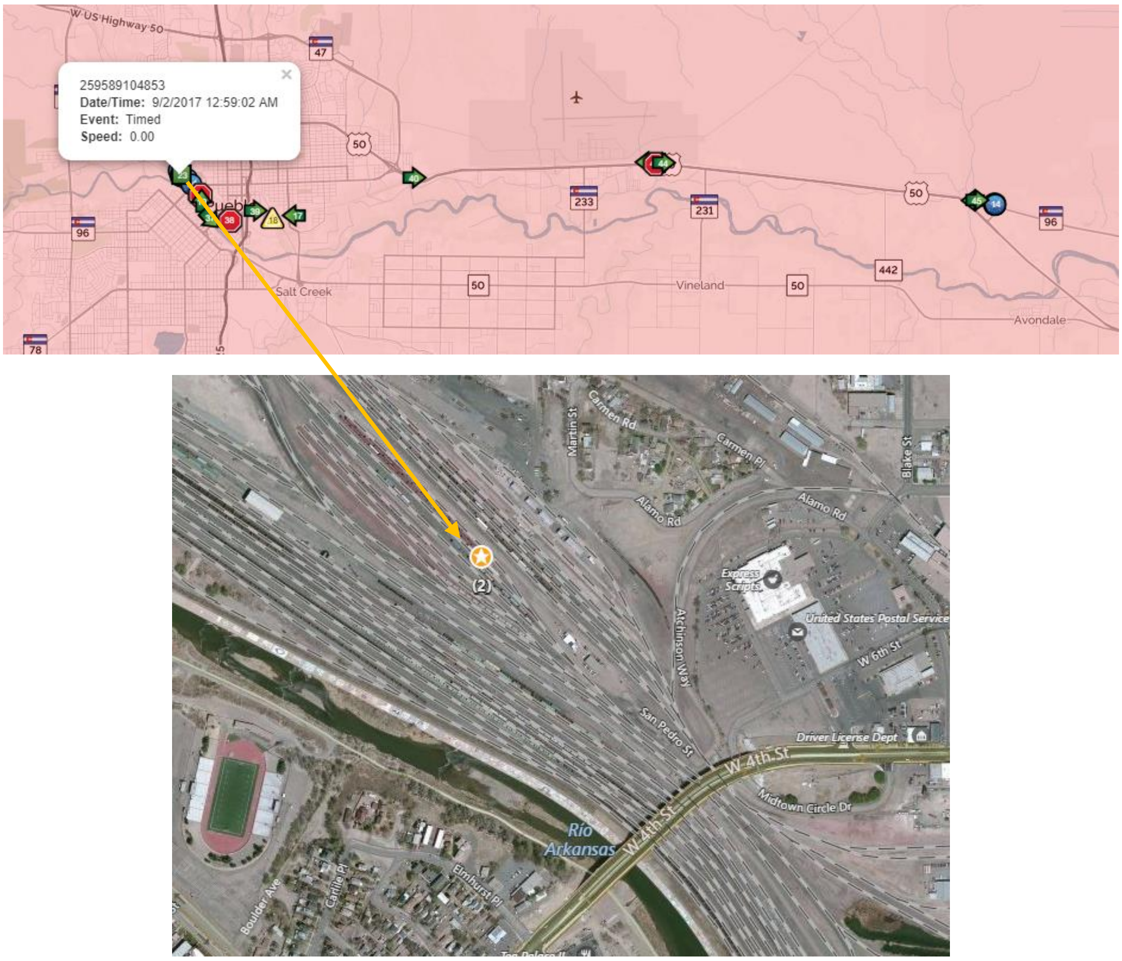


Image 3. Day 2. Starting point, Pueblo. 1.06 miles E of Dodge City, Colorado.

DAY 3: Sept/03rd

Cask stopped in South Dodge.

Distance covered this day: 0 mi (0km).

Total distance covered: 292mi (470km)

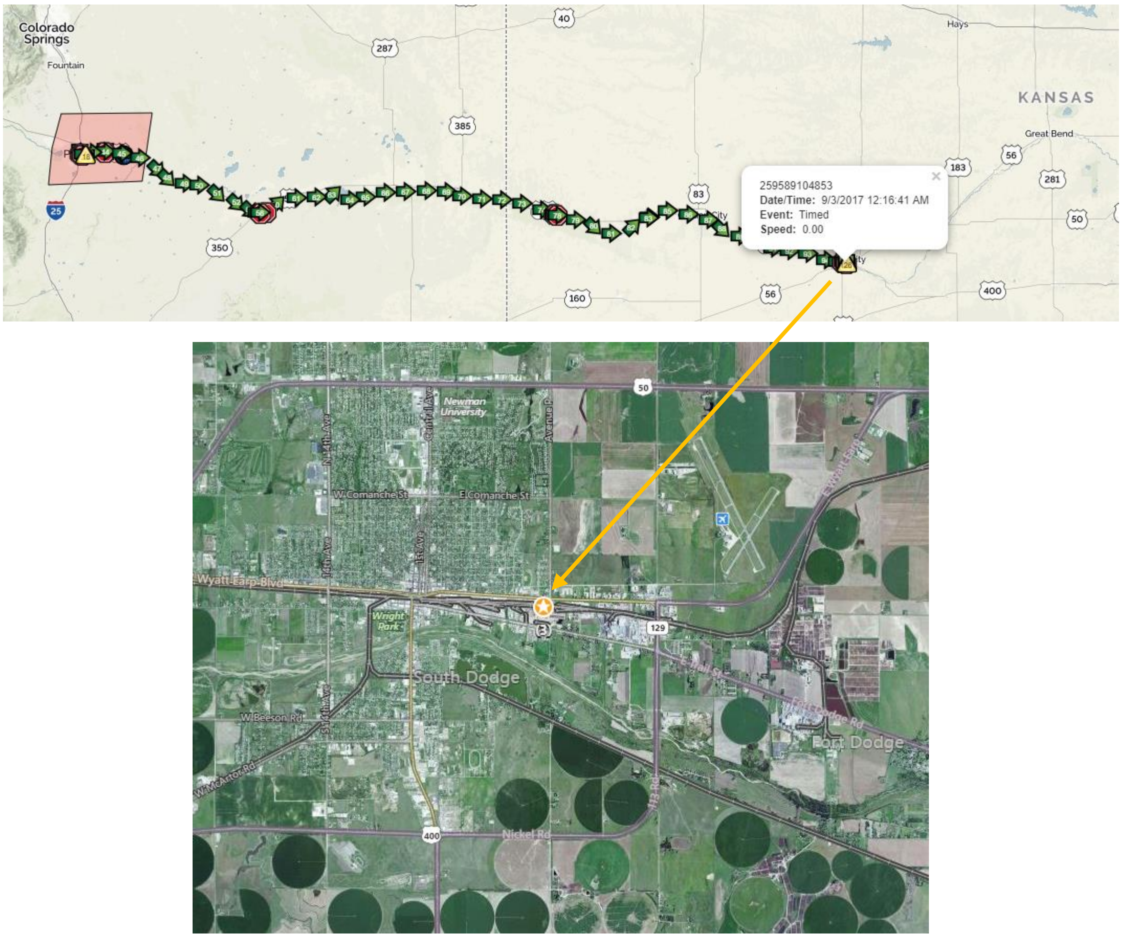


Image 4. 0.98 miles E of Dodge City (Kansas).

OVERVIEW OF RAIL TRANSPORT UNTIL SEPTEMBER/03rd

Below image shows the journey covered during the first three days of trip.

Total distance covered from Avondale to South Dodge during these 3 days: 291mi (468.3km).

DAY 4: Sept/ 04th

Journey from South Dodge to Elmdale.

Distance covered this day: 201mi (323km)

Total distance covered: 493mi (793km)

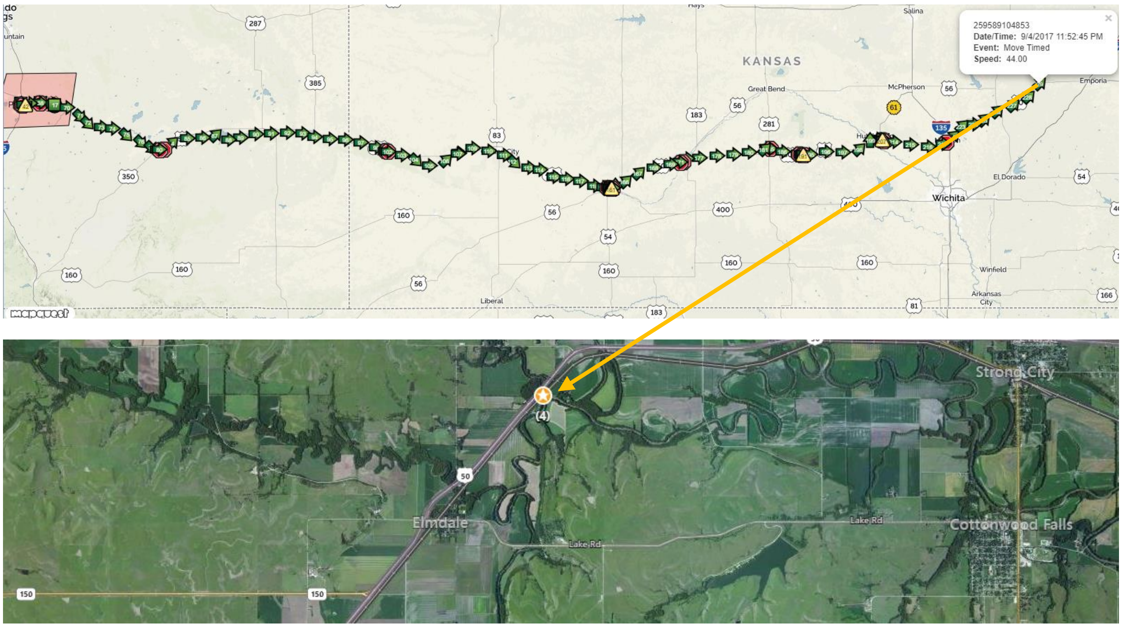


Image 5. 1.55 miles NE of Elmdale (Kansas)

DAY 5: Sept/05th

Journey from Elmdale to Shawnee.

Distance covered this day: 129mi (208km)

Total distance covered: 622mi (1,001km)

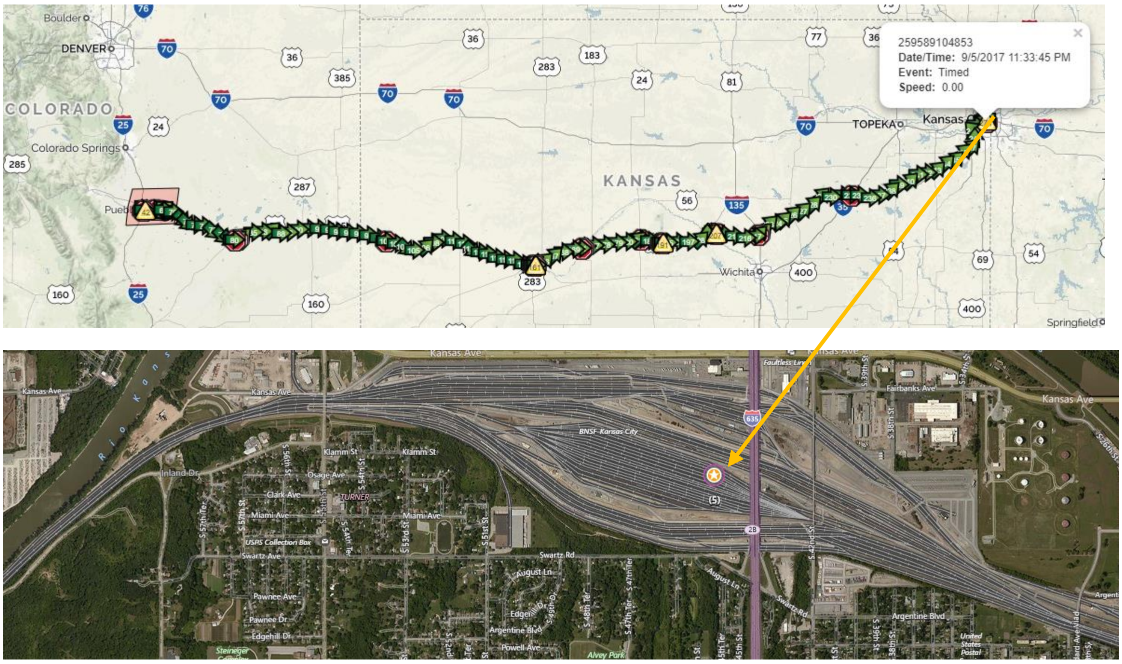


Image 6. 3.55 miles N of Shawnee (Kansas)

DAY 6: Sept/06th

Cask stopped in Shawnee. Short movements in BNSF Kansas City.

Distance covered this day: 0mi (0km)

Total distance covered: 622mi (1,001km)

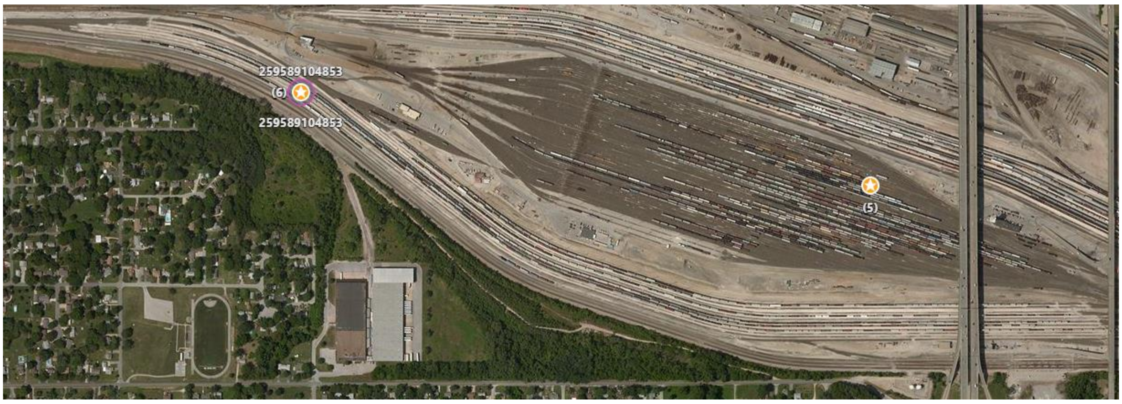


Image 7. 3.31 miles N of Shawnee (Kansas)

DAY 7: Sept/07th

Cask stopped in Shawnee. Short movements in BNSF Kansas City.

Distance covered this day: 0mi (0km)

Total distance covered: 622mi (1,001km)

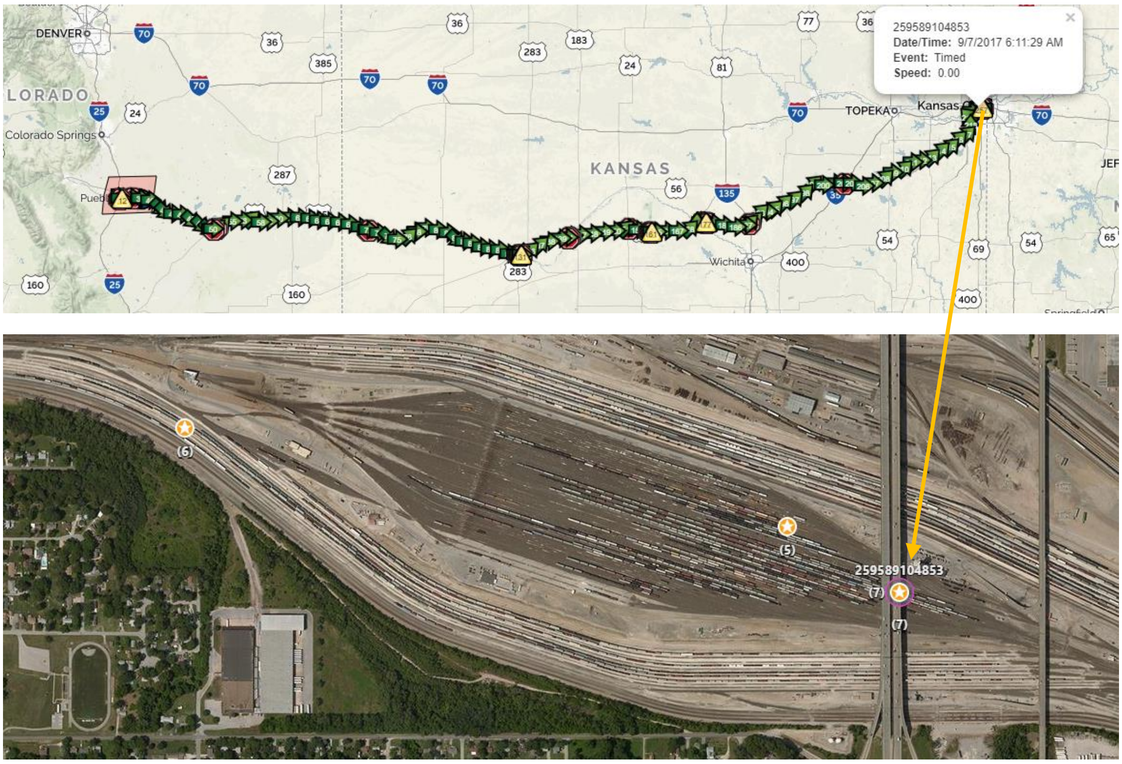


Image 8. 3.55 miles N of Shawnee (Kansas)

DAY 8: Sept/08th

Cask stopped in Shawnee. Short movements in BNSF Kansas City.

Distance covered this day: 0mi (0km)

Total distance covered: 622mi (1,001km)

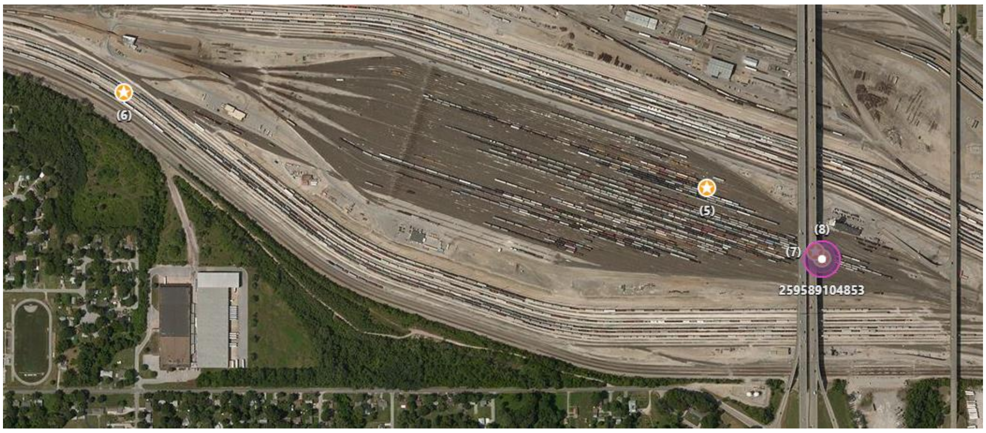


Image 9. 3.55 miles N of Shawnee (Kansas)

DAY 9: Sept/09th

Cask stopped in Shawnee. Short movements in BNSF Kansas City.

Distance covered this day: 0mi (0km)

Total distance covered: 622mi (1,001km)

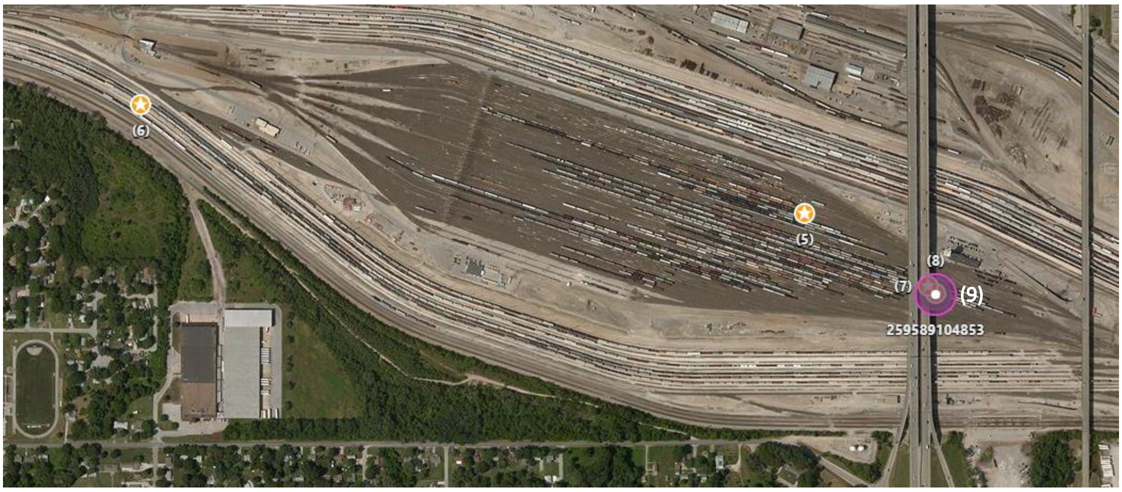


Image 10. 3.55 miles N of Shawnee (Kansas)

DAY 10: Sept/10th

Journey from Shawnee to Harding.

Distance covered this day: 56mi (90km)

Total distance covered: 678mi (1,091km)

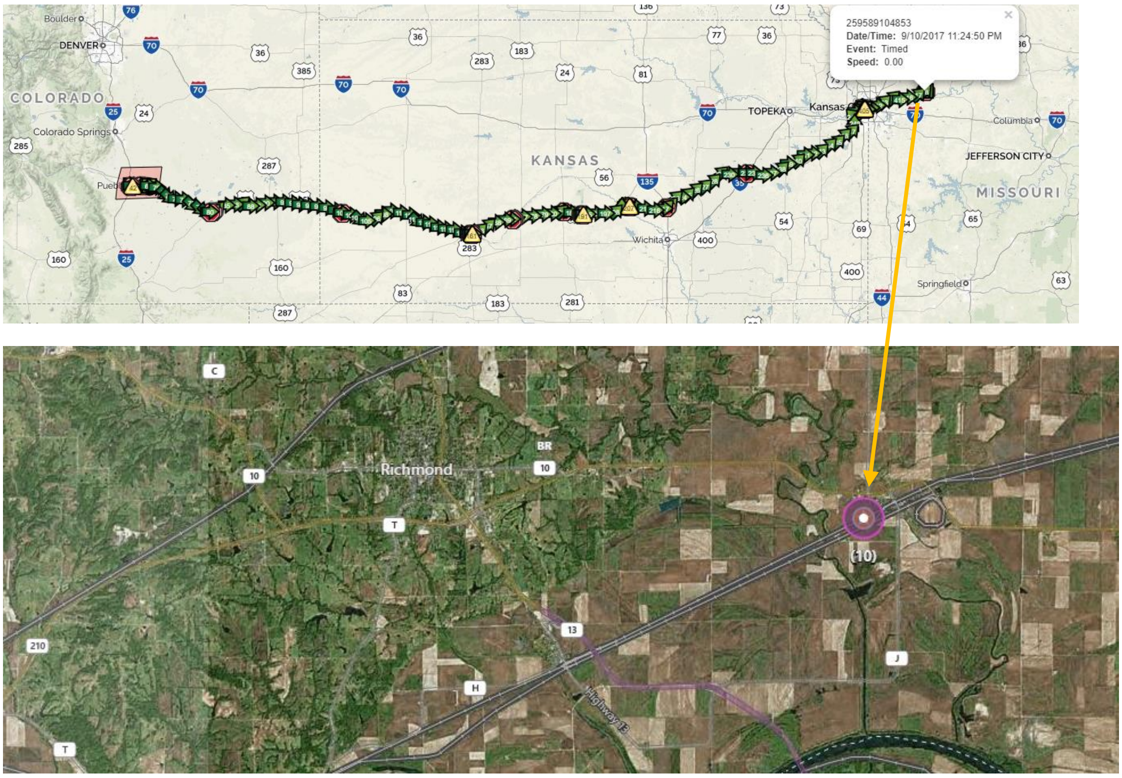


Image 11. 0.58miles SW of Hardin, Missouri.

DAY 11: Sept/11st

Cask stopped in Hardin.

Distance covered this day: 0mi (0km)

Total distance covered: 477mi (768km)

Image 12. 0.58miles SW of Hardin, Missouri.

OVERVIEW FOR RAIL TRANSPORT DAY BY DAY

Below table summarizes the distance[1] covered day by day, the total distance and the distance to be covered until Baltimore Port.

DAY NO.	DATE	DISTANCE/DAY		TOTAL DISTANCE		DISTANCE LEFT	
		mi	km	mi	km	mi	km
DAY 0	31-ago	0	0km	0.0 mi	0km	1,900 mi	3,058km
DAY 1	01-sep	16 mi	26km	16 mi	26km	1,884 mi	3,032km
DAY 2	02-sep	276	444km	292.0 mi	470km	1,608 mi	2,588km
DAY 3	03-sep	0 mi	0km	292 mi	470km	1,608 mi	2,588km
DAY 4	04-sep	201	323km	493.0 mi	793km	1,407 mi	2,264km
DAY 5	05-sep	129 mi	208km	622 mi	1,001km	1,278 mi	2,057km
DAY 6	06-sep	0	0km	622.0 mi	1,001km	1,278 mi	2,057km
DAY 7	07-sep	0 mi	0km	622 mi	1,001km	1,278 mi	2,057km
DAY 8	08-sep	0	0km	622.0 mi	1,001km	1,278 mi	2,057km
DAY 9	09-sep	0 mi	0km	622 mi	1,001km	1,278 mi	2,057km
DAY 10	10-sep	56	90km	678.0 mi	1,091km	1,222 mi	1,967km
DAY 11	11-sep	0 mi	0km	678 mi	1,091km	1,222 mi	1,967km

[1] Note that distances are approximated.

APPENDIX F: CASK LASHING DIAGRAMS FOR "AUTOSKY" (SANTANDER) AND "TARAGO" (ZEEBRUGGE)

SURVEY REPORT

M/V “AUTOSKY”

22th– JUNE – 2017

PORT OF SANTANDER (SPAIN)

SURVEY REPORT

ISSUE	**ACTING AS SURVEYOR**
VESSEL	**M/V “AUTOSKY”**
PORT	**SANTANDER (SPAIN)**
BERTH	**RAOS 8**
DATE	**22th - JUNE – 2017**
OPERATION	**Loading CASK and transport cradle on a truck platform**

According to the instructions received from:

"COORDINADORA INTERNACIONAL DE CARGAS”

We duly attended the above-mentioned vessel while berthed port side alongside RAOS 8 pier, in order to inspect the loading and lashing of a CASK in the M/**V “AUTOSKY”** at the port of Santander.

LASHING BETWEEN CRADLE AND TRUCK.

Lashing jobs between cask's cradle and the platform were carried out as follows:

→ Fore part. Six chains crossed.

→ Aft part. Four chains crossed and two chains along.

→ Aft part (box). Two slings were lashing between the cradle and the platform.

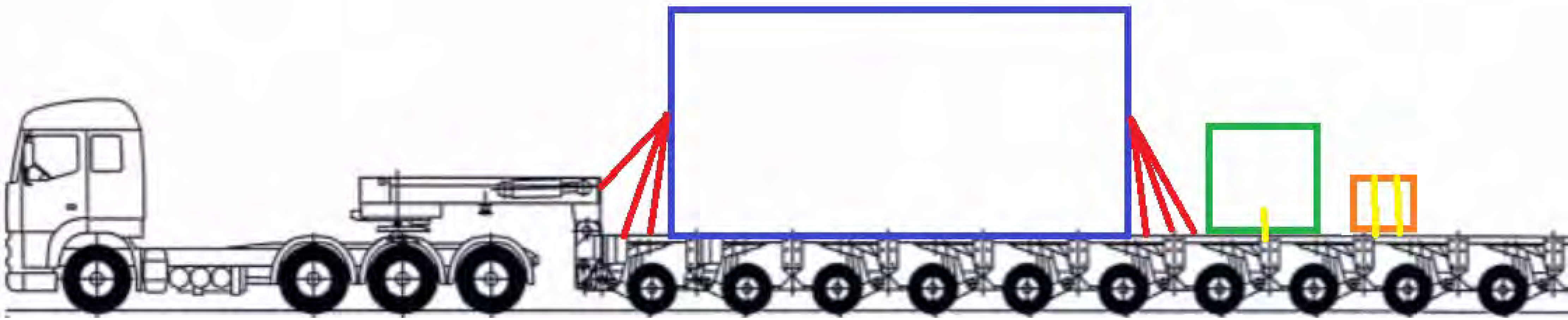
→ Aft part (wooden box). Two slings were used to lashed this item.

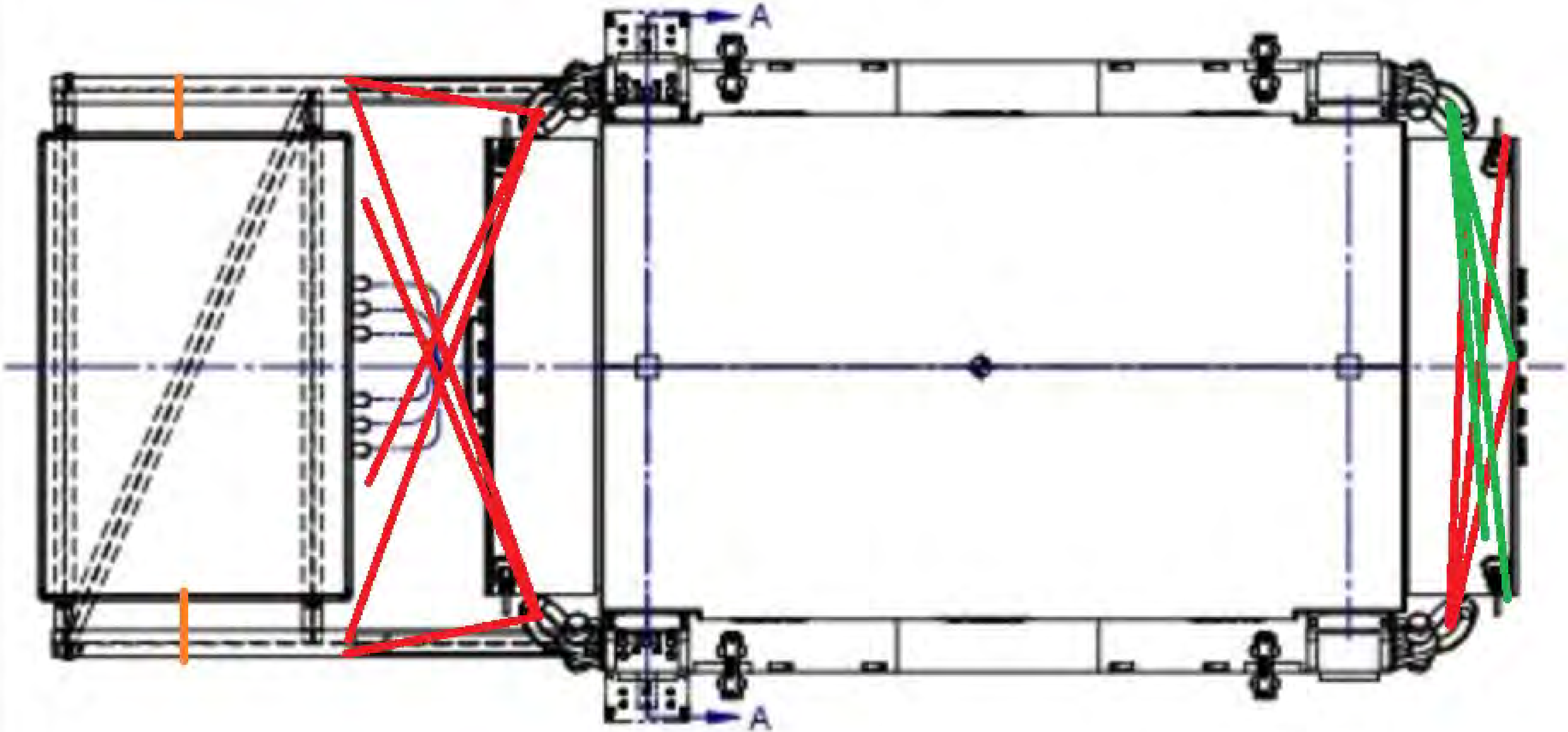
1. Lashing with chains in fore part

2. Lashing with chains in aft part

3. Lashing with slings wooden box

4. Lashing with slings cradle to platform




A
A

LASHING IN THE M/V "AUTOSKY"

Lashing jobs in the vessel were carried out as follows:

→ In fore part of the platform was put a steel support and lashing with four chains crossed (2+2)

*** **STARBOARD SIDE** ***

Seven chains were lashed in this side from platform to deck.

Seven chains were lashed in this side from shackles of the cradle to deck.

*** **PORTSIDE** ***

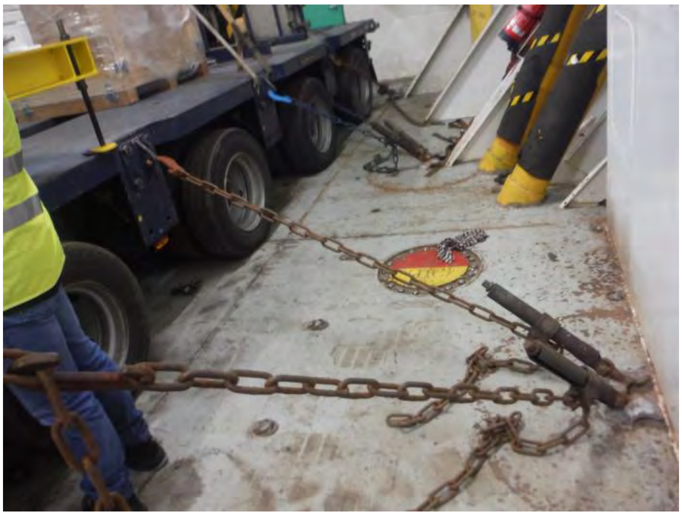
Six chains were lashed in this side from platform to deck.

Seven chains were lashed in this side from shackles of the cradle to deck.

5. Metallic support and chains

6. Lashing with chains

7. Lashing from platform to deck



8. Lashing from platform to deck

9. Lashing from platform to deck

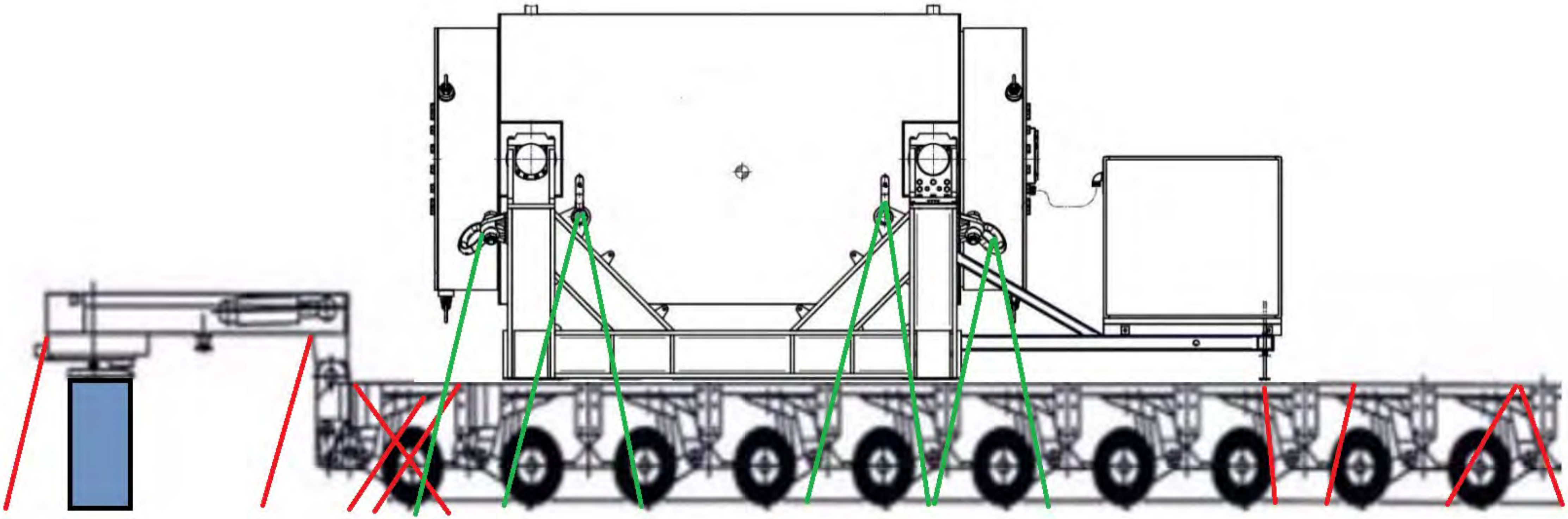
10. Lashing from platform to deck

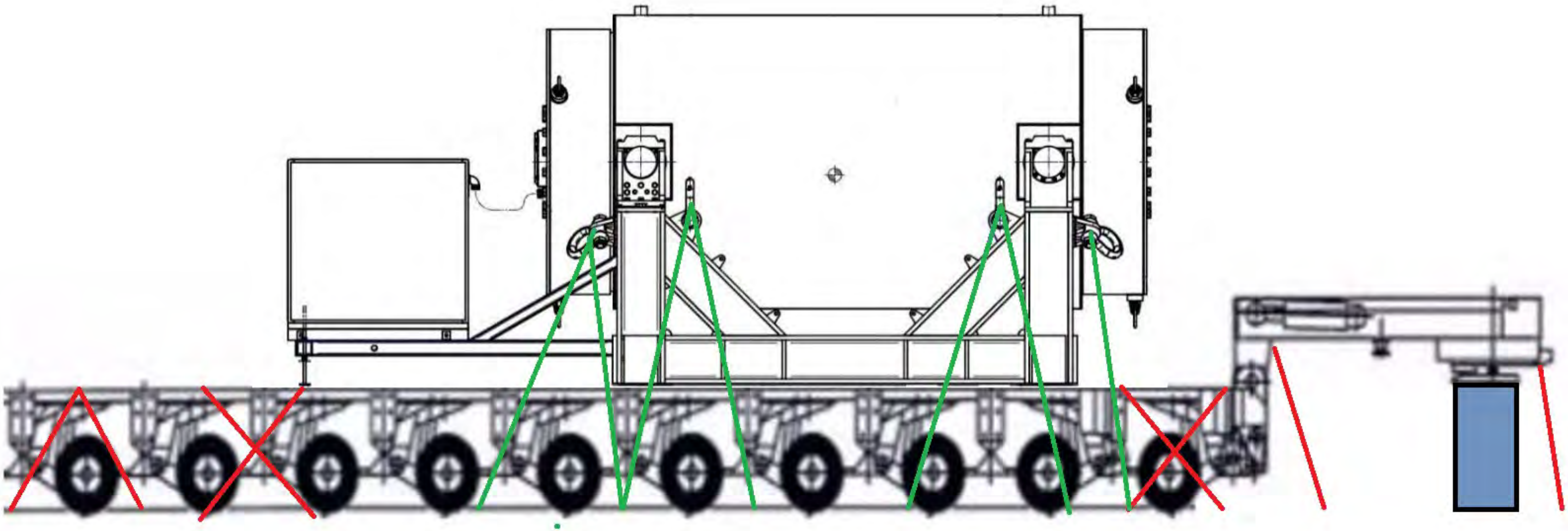
11. Lashing from cradle to deck

12. Lashing from cradle to deck

13. General view of lashing in portside

14. General view of lashing in starboard side

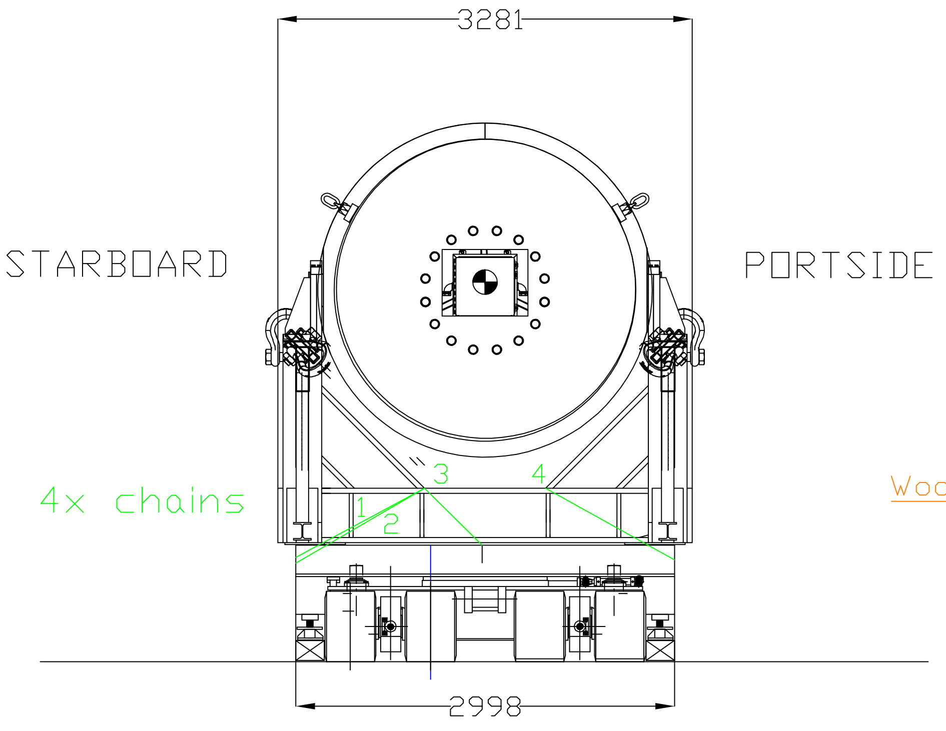




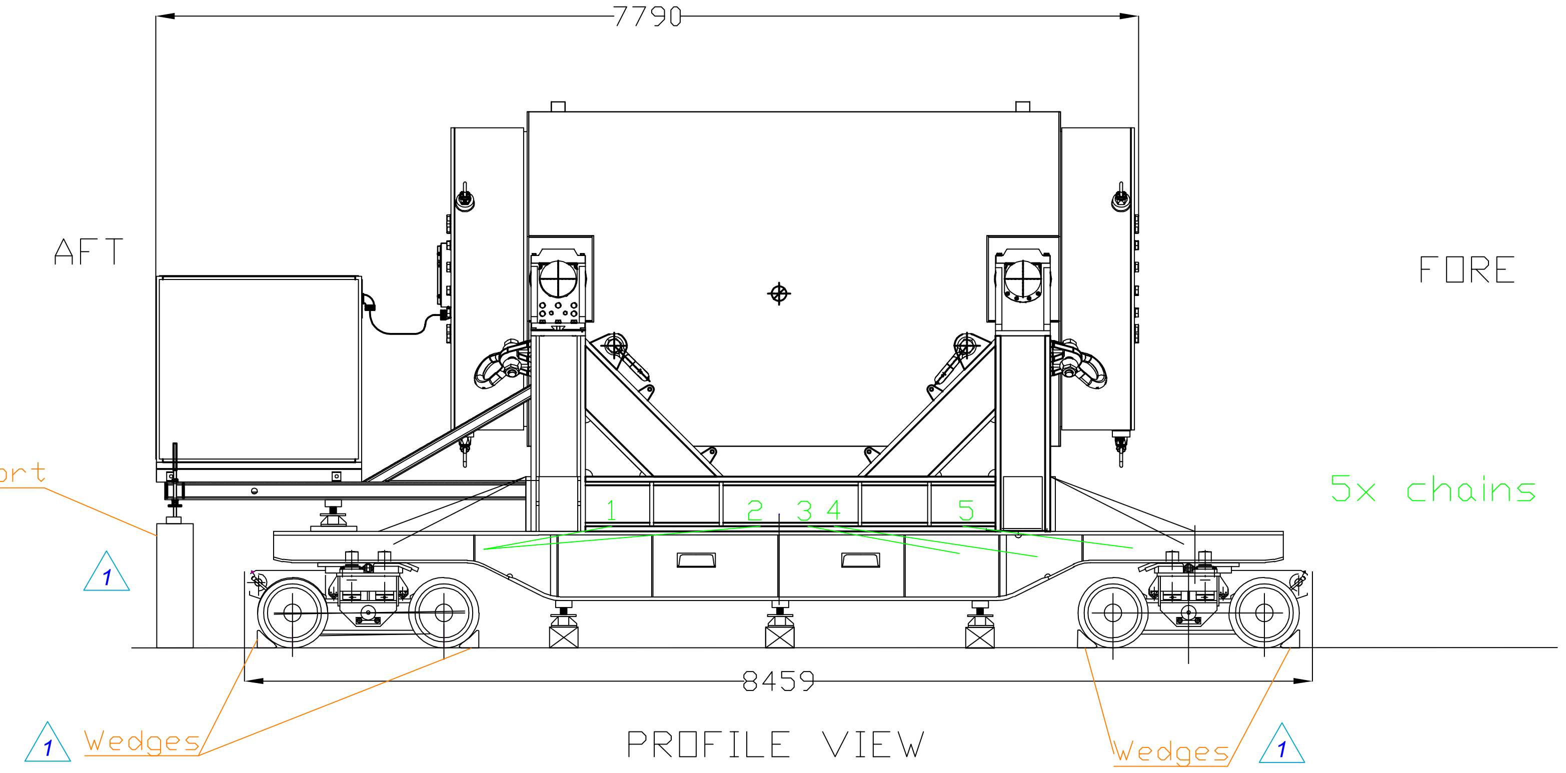
This document shows the results of the inspection carried out by us as per our principal instructions and as per the best diligence and technical capacity. This certificate does not exonerate neither seller nor buyer of any of their contractual obligations. No claim will be considered if it is not certified/confirmed of any negligence made by our Company. In any case, our liability will never exceed the total amount of our invoice.

Santander, 22th June of 2017

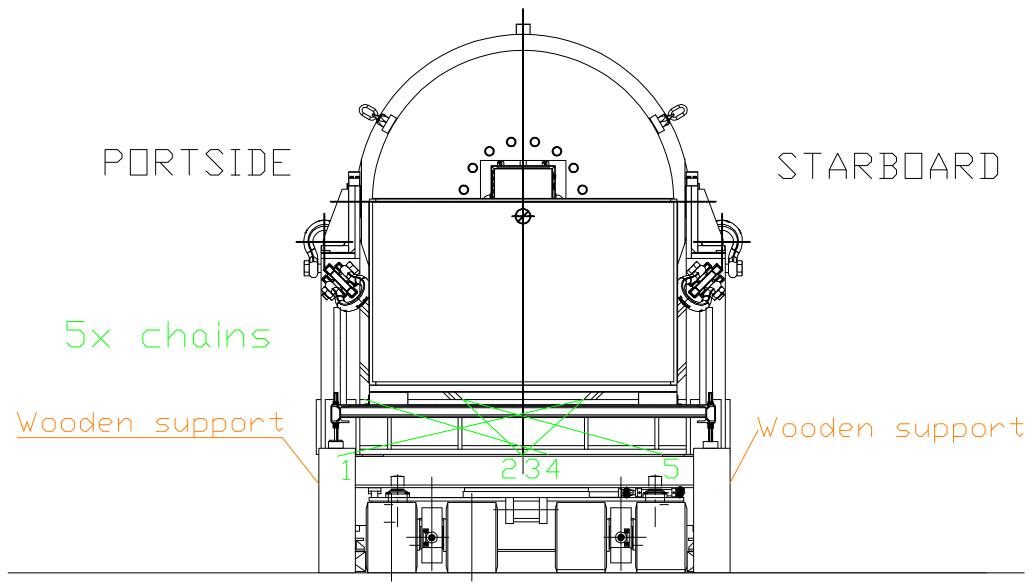
Marta Morante
-Grad. Ingeniería Náutica y Tte. Marítimo
Piloto de la Marina Mercante-



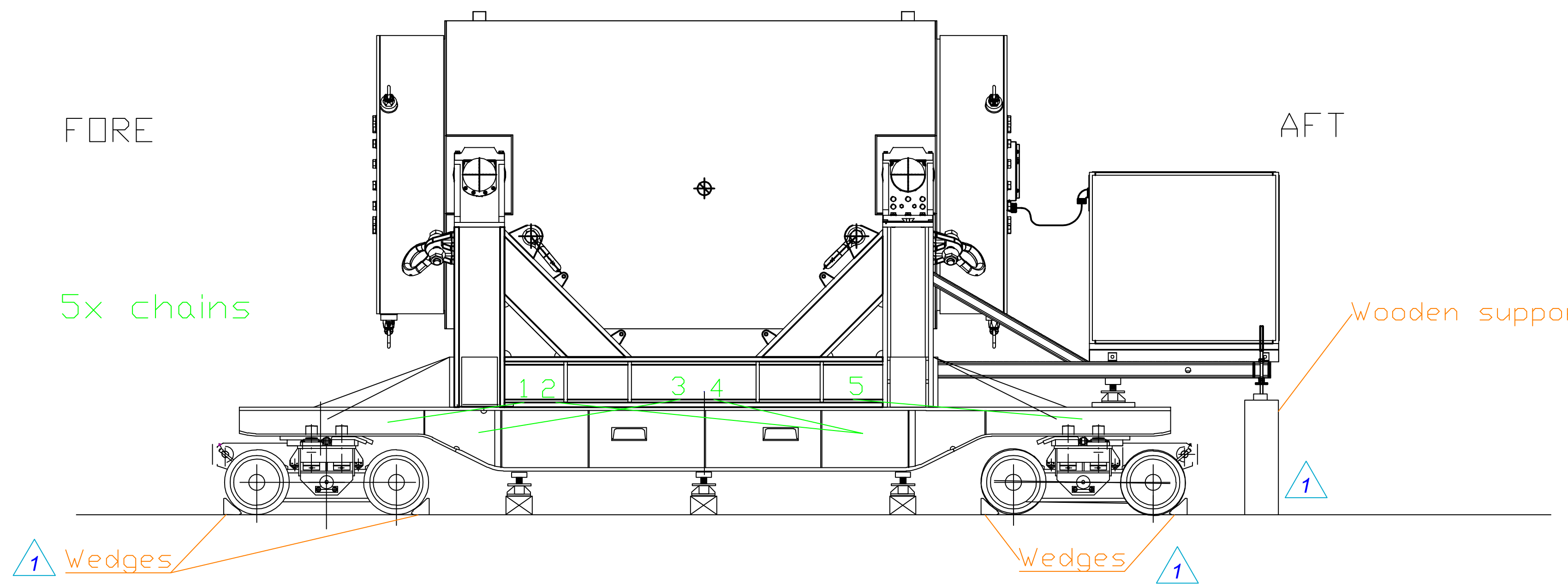
FRONT VIEW
cask looking to vessel's fore



PROFILE VIEW



Batteries looking to vessel's aft



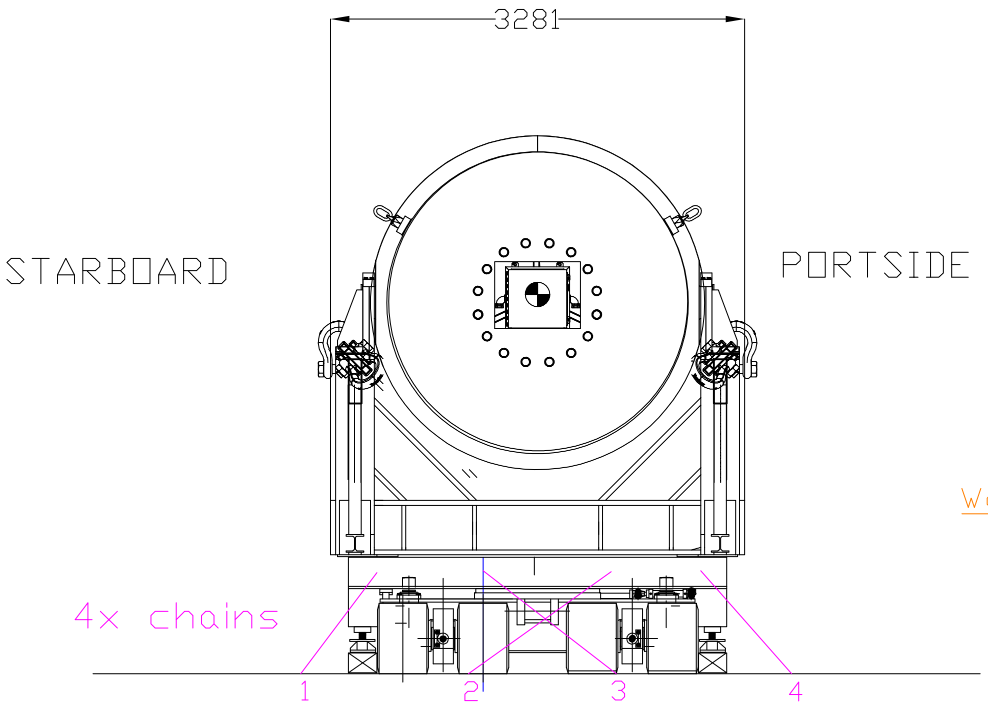
LASHING MATERIAL BETWEEN CASK AND SAMSON	
LOCATION	DESCRIPTION OF CHAINS
FORE	4x chains BL 15Mt
AFT	5x chains BL 15Mt
STARBOARD	5x chains BL 15Mt
PORT SIDE	5x chains BL 15Mt

Note: in the present drawing only lashing between cask and SAMSON is shown to make drawing clean.
Nevertheless, lashing between cask-deck and between SAMSON-deck were also performed.
Separately drawings have been issued for them.

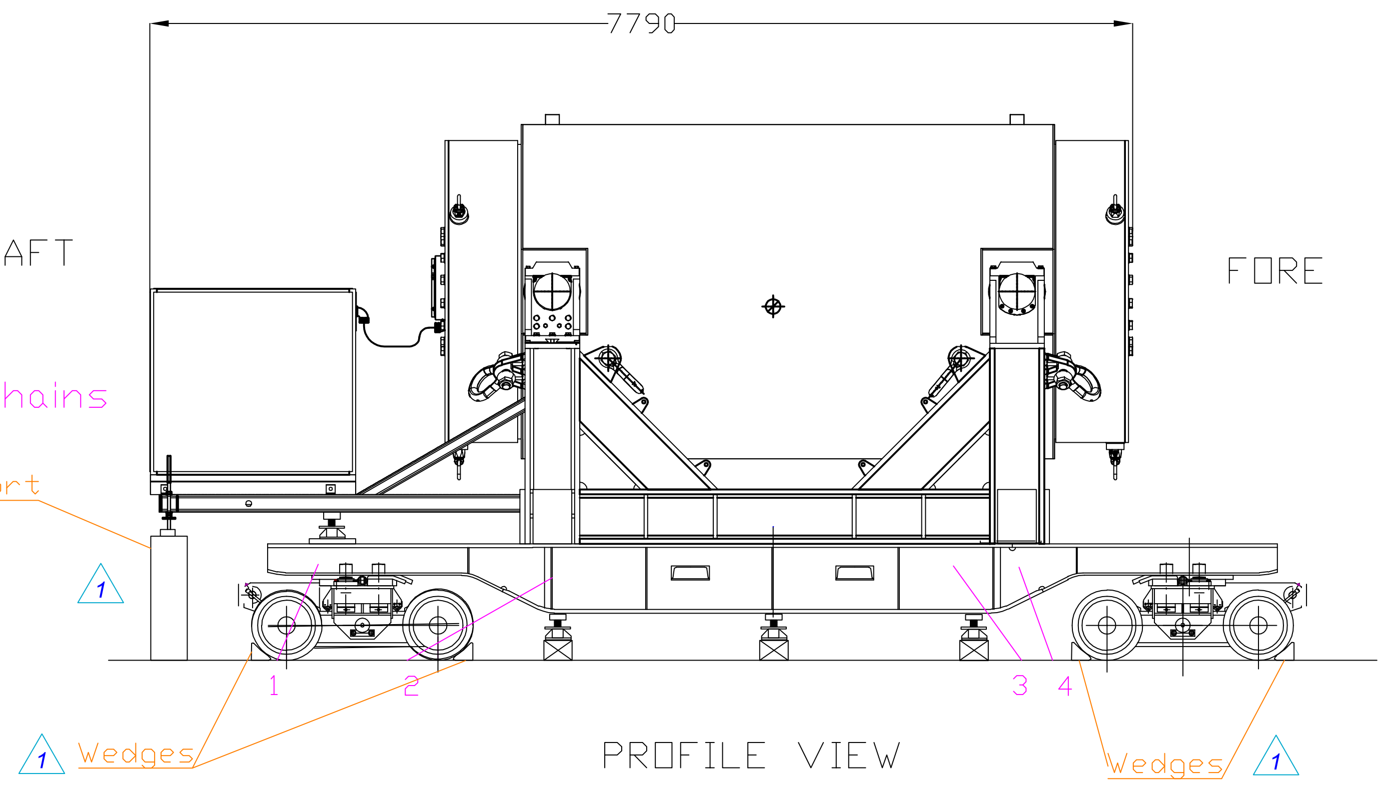
Elements added (wedges)	01	28-08-17	ARC	28-08-17	JMR	28-08-17	LGG
CLASS OF MODIFICATION:	MOD:	DATE:	DRAFTSMAN:	DATE:	REVISED:	DATE:	APPROVED:

COORDINADORA
THE TRANSPORT ENGINEERING COMPANY

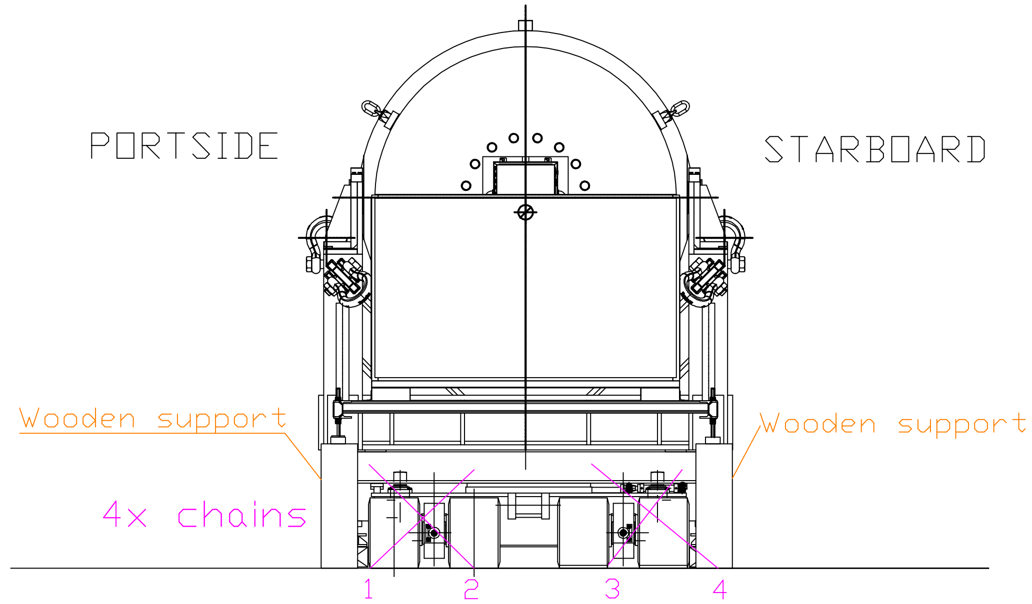
OFFER NUMBER: OF-160057
FILE: 17.0181.0009
CUSTOMER: EQUIPOS NUCLEARES
DRAWING Nº: 170716001
MOD.: 1
SHEET Nº: 01 OF: 04
SCALE: 1:1075 A2
DESCRIPTION: PARTIAL LASHING PLAN. LASHING BETWEEN CASK AND SAMSON
ORIGIN: ZEEBRUGGE
CARRIER: WALLENIUS
DESTIN: BALTIMORE



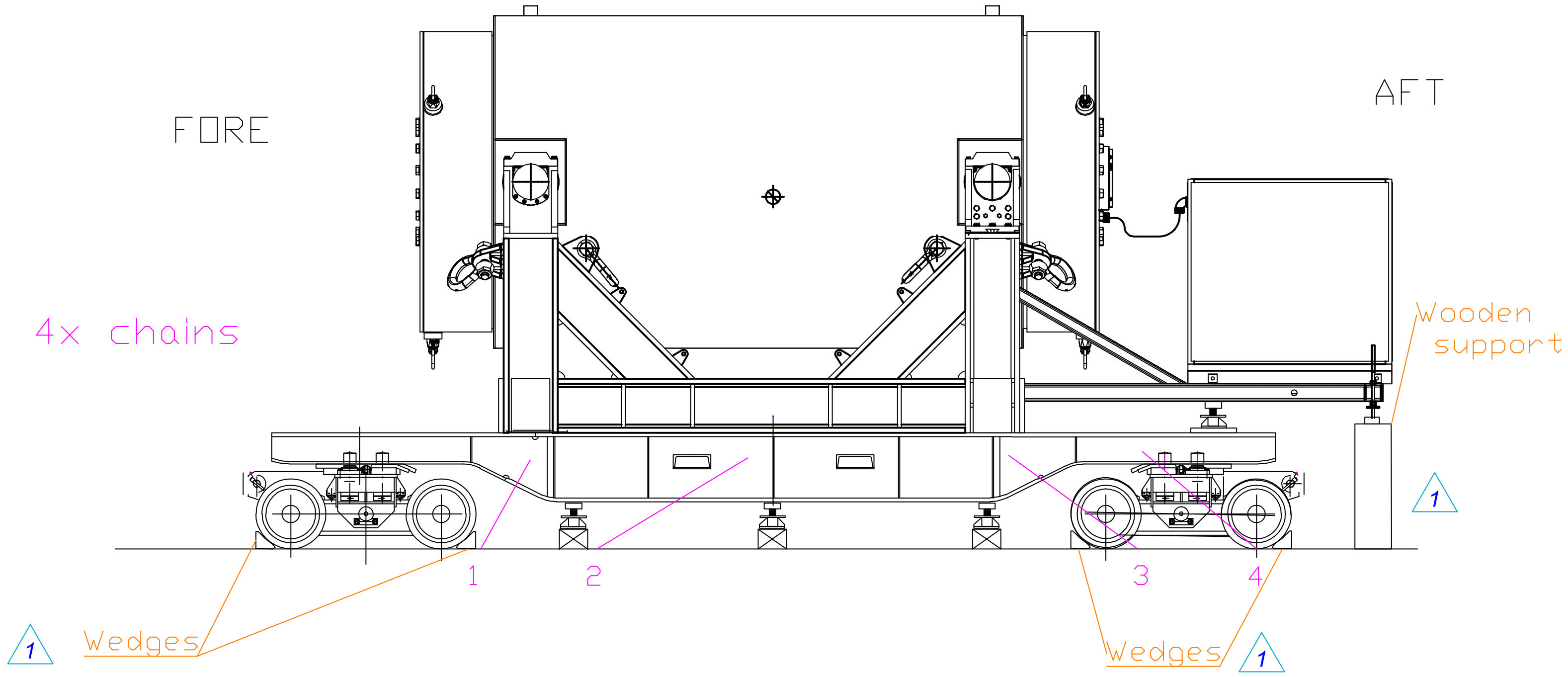
FRONT VIEW
cask looking to vessel's fore



PROFILE VIEW



Batteries looking to vessel's aft



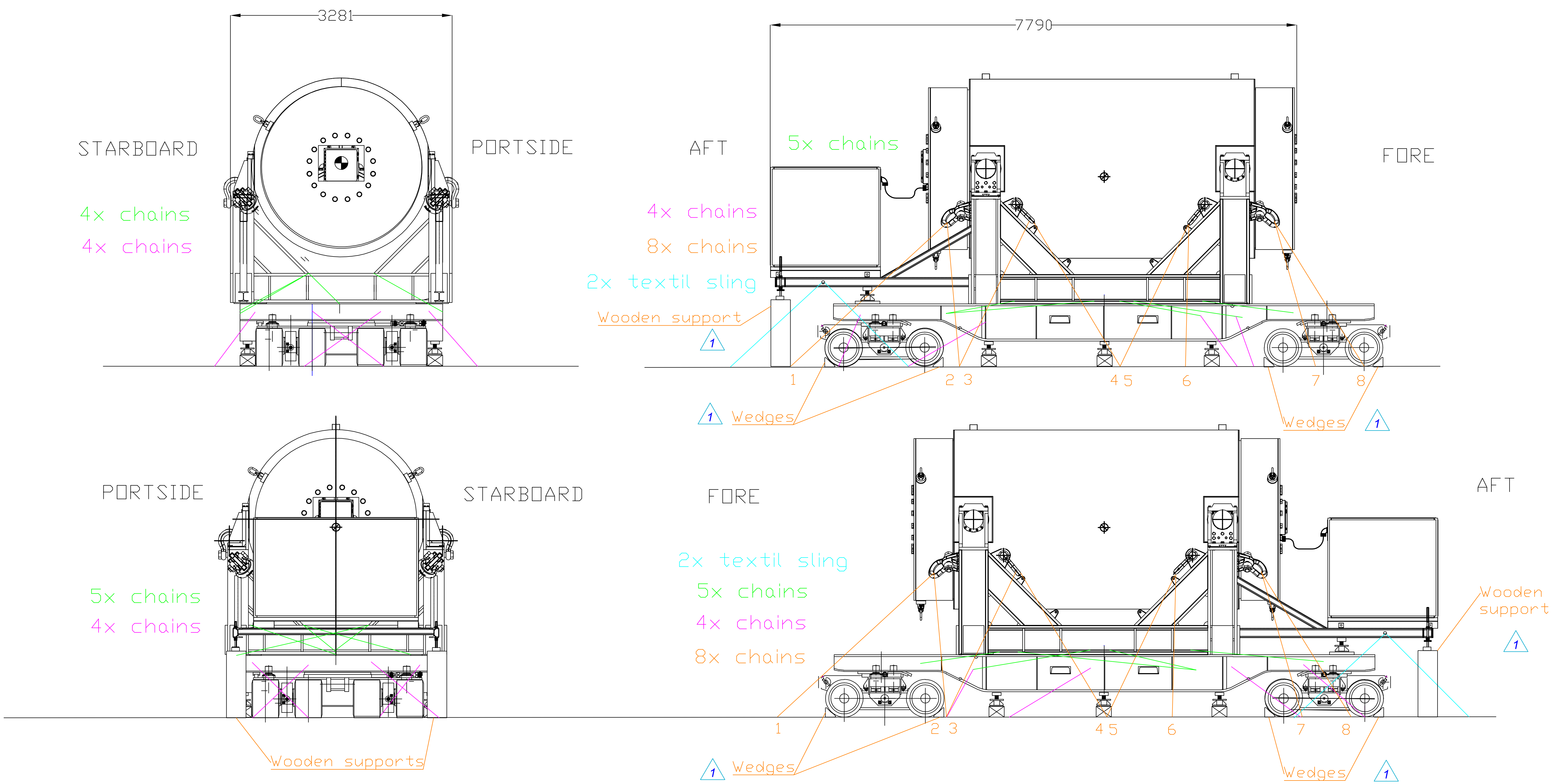
LASHING MATERIAL BETWEEN SAMSON AND DECK	
LOCATION	DESCRIPTION OF CHAINS
FORE	4x chains BL 15Mt
AFT	4x chains BL 15Mt
STARBOARD	4x chains BL 15Mt
PORT SIDE	4x chains BL 15Mt

Note: in the present drawing only lashing between SAMSON and deck is shown to make drawing clean.
Nevertheless, lashing between cask-deck and between SAMSON-cask were also performed. Separately drawings have been issued for them.

CLASS OF MODIFICATION:	MOD:	DATE:	DRAFTSMAN:	DATE:	REVISED:	DATE:	APPROVED:
Elements added (wedges	01	28-08-17	ARC	28-08-17	JMR	28-08-17	LGG

COORDINADORA
THE TRANSPORT ENGINEERING COMPANY

OFFER NUMBER: OF-160057 FILE: 17.0181.0009	CUSTOMER: EQUIPOS NUCLEARES	DRAWING N°: 1 SHEET N°: 02 OF: 04	MOD.: 1
SCALE: 1:1075 A2	DESCRIPTION: PARTIAL LASHING PLAN. LASHING BETWEEN SAMSON AND DECK	ORIGIN: ZEEBRUGGE CARRIER: WALLENIUS DESTIN: BALTIMORE	



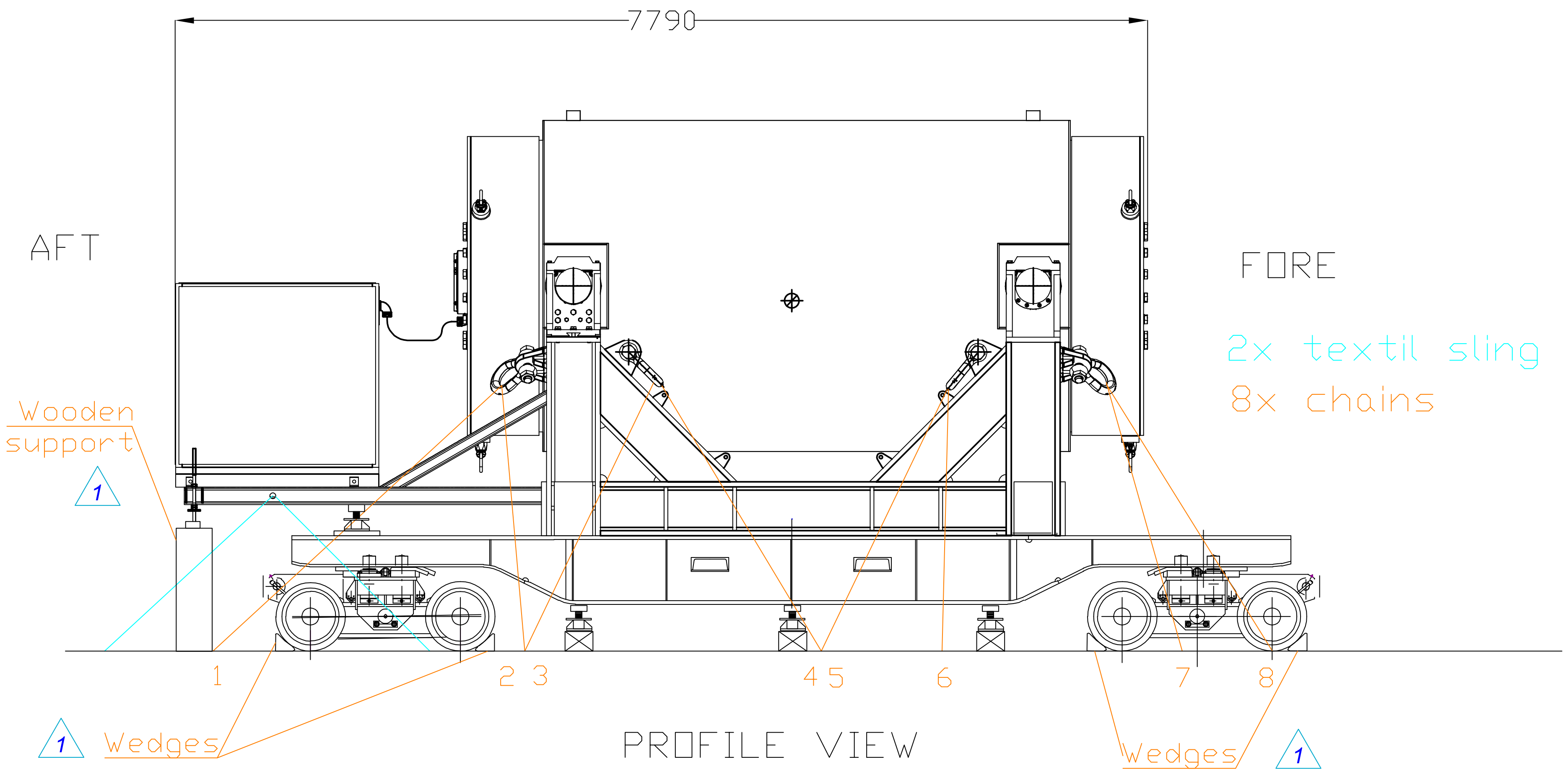
LASHING MATERIAL			
LOCATION	BETWEEN CASK AND SAMSON	BETWEEN SAMSON AND DECK	BETWEEN CASK AND DECK
FORE	4x chains BL 15Mt	4x chains BL 15Mt	-
AFT	5x chains BL 15Mt	4x chains BL 15Mt	-
STARBOARD	5x chains BL 15Mt	4x chains BL 15Mt	8x chains WLL 6.5Mt + 2x textil sling BL 5Mt
PORT SIDE	5x chains BL 15Mt	4x chains BL 15Mt	8x chains WLL 6.5Mt+ 2x textil sling BL 5Mt

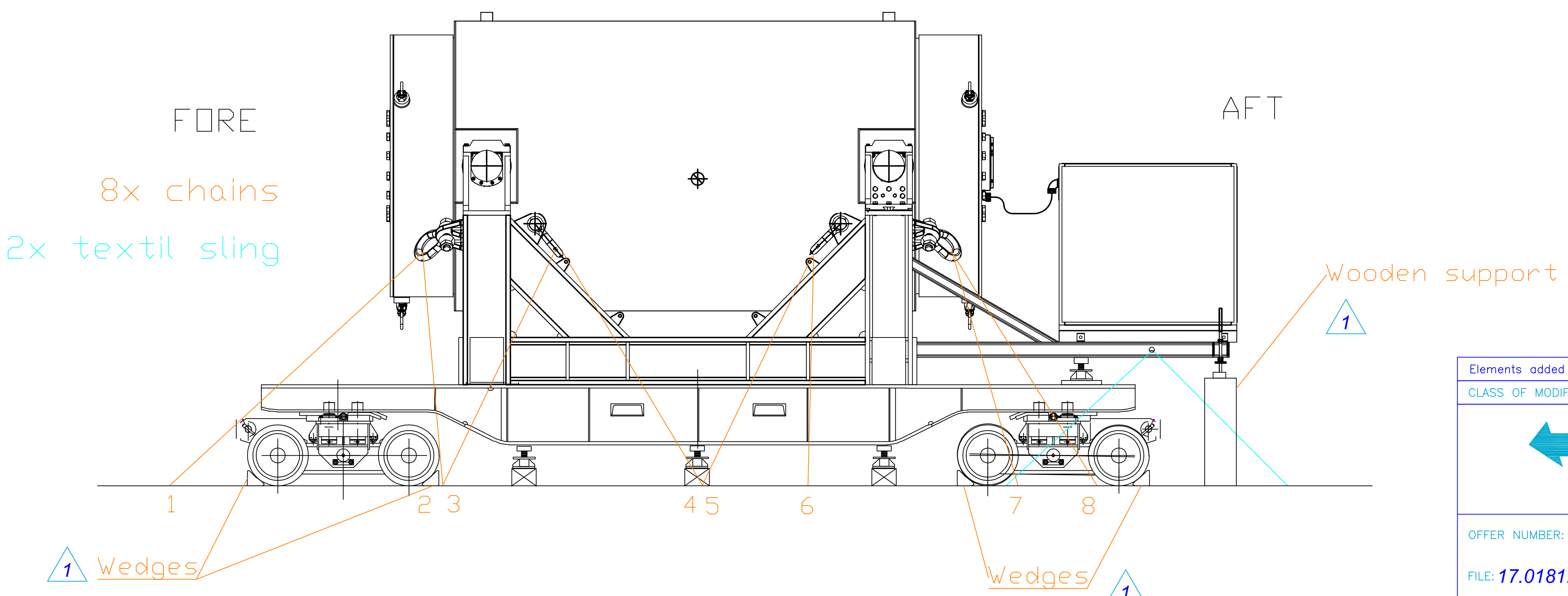
Elements added (wedges)	01	28-08-17	ARC	28-08-17	JMR	28-08-17	LGG
CLASS OF MODIFICATION:	MOD:	DATE:	DRAFTSMAN:	DATE:	REVISED:	DATE:	APPROVED:

COORDINADORA
THE TRANSPORT ENGINEERING COMPANY

OFFER NUMBER: OF-160057
FILE: 17.0181.0009
CUSTOMER: EQUIPOS NUCLEARES
DRAWING N°: 1
SHEET N°: 04 OF: 04
MOD.: 1

SCALE: 1:1075 A2
DESCRIPTION: COMPLETE LASHING PLAN: SAMSON-deck, CASK-deck, SAMSON-CASK
ORIGIN: ZEEBRUGGE
CARRIER: WALLENIUS
DESTIN: BALTIMORE





LASHING MATERIAL BETWEEN CASK AND DECK	
LOCATION	DESCRIPTION OF CHAINS
STARBOARD	8x chains WLL 6.5Mt + 2x textil sling BL 5Mt
PORT SIDE	8x chains WLL 6.5Mt + 2x textil sling BL 5Mt

Note: in the present drawing only lashing between CASK and deck is shown to make drawing clean.
Nevertheless, lashing between cask-SAMSON and between SAMSON-deck were also performed. Separately drawings have been issued for them.

Elements added (wedges)	01	28-08-17	ARC	28-08-17	JMR	28-08-17	LGG
CLASS OF MODIFICATION:	MOD:	DATE:	DRAFTSMAN:	DATE:	REVISED:	DATE:	APPROVED:

COORDINADORA
THE TRANSPORT ENGINEERING COMPANY

OFFER NUMBER: OF-160057
FILE: 17.0181.0009
CUSTOMER: EQUIPOS NUCLEARES
DRAWING Nº: 1
SHEET Nº: 03 OF: 04
MOD.: 1
SCALE: 1:1075 A2
DESCRIPTION: PARTIAL LASHING PLAN. LASHING BETWEEN CASK AND DECK
ORIGIN: ZEEBRUGGE
CARRIER: WALLENIUS
DESTIN: BALTIMORE

PORT OF ZEEBRUGGE

The following pictures were taken during the lashing operations in the port of Zeebrugge. These pictures complement the drawing 170716001 from COORDINADORA


Typical lashing between cradle and SAMSON


Typical lashing between SAMSON and deck

Typical lashing between cradle and deck

Several supports were placed under the the SAMSON, as well as under the platform for the DAC box. Wedges were placed to block the SAMSON wheels. See drawing drawing 170716001 from COORDINADORA for their location

Pieces of similar black rubber as the one used in the port of Baltimore were placed under the cradle.

Lugs in the cradle were tied with straps in order to reduce background noise to the data acquisition system

APPENDIX G: TTCI SITE INFORMATION AND RAIL-CASK TEST PLAN

Test Plan

DOE Cask Vibration and Impact Test

Prepared by Transportation Technology Center, Inc.

for

Pacific Northwest National Labs

September 2016

Contents

Illustrations

Tables

1. Introduction

Pacific Northwest National Laboratory (PNNL) contracted the Transportation Technology Center, Inc. (TTCI) to draft a test plan for testing services as part of a coordinated program intended to help characterize the shock and vibration environment likely to be experienced by a nuclear fuel cask when being transported by rail. The tests described in the plan are intended to be performed at the Federal Railroad Administration's (FRA) Transportation Technology Center (TTC) in Pueblo, Colorado. PNNL is performing this work on behalf of the Department of Energy (DOE).

The tests described in this test plan are not AAR certification tests. However TTCI has used AAR M-976[1] and AAR S-2043[2] as guidelines to prepare this test plan. M-976 is a specification that described truck performance requirements for railcars. S-2043 is a specification for trains used to carry high-level radioactive material.

1.1 Objectives

The objective of the test is to characterize and quantify the shock and vibration environment that the cask carrying railcars are likely to be subject to during normal railroad operations. The tests being proposed at TTC are those that are difficult to perform in revenue service operations.

1.2 Assumptions

TTCI understands that:

- PNNL has arranged to use a suitable cask for the tests, with a clean certificate required for entry onto the TTC site.
- PNNL will obtain a suitable railcar for the tests, with a clean certificate required for entry onto site. This will likely be either a 6-axle heavy duty flat car or an 8-axle or 12-axle span bolster flat car in good condition.
- PNNL will arrange loading of the cask onto the railcar and both the car and cask will arrive at TTC by rail in the condition to be tested.
- PNNL will make the relevant strain and acceleration measurements on and inside the cask that are not included in this test plan.

1.3 Transportation Technology Center (TTC)

TTC is located 21 miles northeast of Pueblo, Colorado and is operated by TTCI under a care, custody and control contract with the FRA. The secured facility occupies 52-square miles and offers a vast array of

[1] Association of American Railroads. Last Revised: 2009. *Manual of Standards and Recommended Practices*. Section D, Trucks and Truck Derails. Specification M-976 "Truck Performance for Rail Cars" Washington, DC.

[2] Association of American Railroads. Last Revised: 2009. *Manual of Standards and Recommended Practices*. Section C, Car Construction Fundamentals and Details. Standard S-2043 "Performance Specification for Trains Used to Carry High-level Radioactive Material." Washington, DC.

specialized laboratories and track. TTC offers unique isolated testing for all categories of freight and passenger rolling stock, vehicle and track components and safety devices.

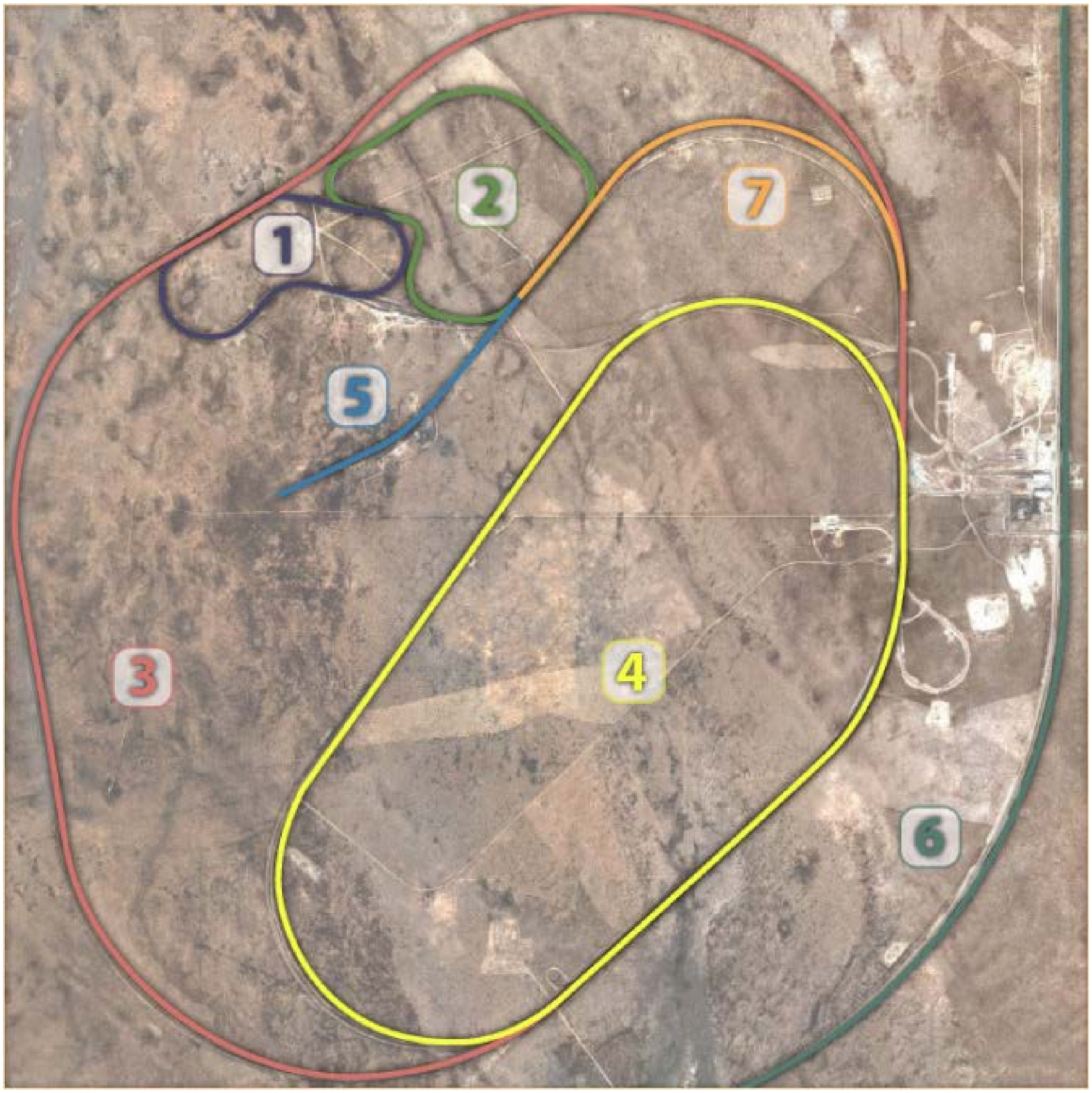


Figure 1. Test Tracks at TTC

Each of the various tracks at TTC offer unique capabilities for a vast array of rail vehicle testing. The list below offers a description of the various test tracks at TTC (refer to Figure 1):

- **Track #1 – High Tonnage Loop (HTL)**
  The HTL is used for track component reliability, wear, and fatigue research under heavy axle loads. Operations are restricted to a maximum 40 miles per hour. The HTL is

divided into test sections that generally correspond to tangents, spirals, curves (three 5-degree curves and one 6-degree curve), and turnouts.

- **Track #2 – Wheel Rail Mechanism Loop (WRM)**
  The WRM track is a 3.5-mile loop configured to determine vehicle performance on nominally smooth track and on track with perturbations designed to induce known poor performance modes. The WRM is used primarily for the evaluation of rail vehicle safety compliance in curving.

- **Track #3 – Railroad Test Track (RTT)**
  The RTT is a 13.5-mile loop with four 50-minute curves and a single 1-degree, 15-minute reverse curve. Maximum speed is 165 mph. All curves have 6-inches of superelevation. Track structure includes welded 136-pound per-yard rail, new concrete ties, and treated hardwood ties with elastic fasteners. The track loop is also equipped with a rail break detection and switch indication system. The RTT's catenary system can deliver a single-phase, 60 Hz alternating current at 12.5, 25, or 50 kV, in a single or dual voltage condition. The contact wire height is currently set at a 22 feet, 6 inches. It is also possible to energize the system with DC power.

  The RTT is the site of frequent high-speed stability and endurance tests for freight and passenger cars, electric powered cars and locomotives. Total performance evaluations of Northeast Corridor locomotives are carried out on the RTT. Connected to the RTT and used for turning trains, is a Balloon Loop, which has a 7-degree, 30-minute curve with 4.5 inches superelevation, and a 5-degree reverse curve with 3.5 inches of superelevation. This loop is the site of the rail defect gauntlet track used for rail defect detection research.
- **Track #4 – Transit Test Track (TTT)**
  The Transit Test Track (TTT) is a 9.1-mile oval track, equipped with a third rail power system, used for vehicle performance and specification compliance testing. Investigation of vehicle performance is possible at speeds up to 80 miles per hour over six segments of different track material construction; e.g., continuous welded rail versus jointed rail, wood versus concrete ties.

  The third rail DC electrified power system provides transit and commuter vehicles with a voltage variable from zero to 1,000 volts DC with a 3,700 amp continuous rating. The track includes a 10,000-foot-long overhead DC contact wire catenary, suitable for low-speed operation and evaluation of light rail urban vehicles.

  Located within the transit loop is the tight-turn or "screech loop." This 150-foot radius (38 degree, 12 minute) curve test track is used in the investigation of wheel noise, car curving performance, and suspension system stability.

- **Track #5 – Impact Track**
  The Impact Track is a 0.75-mile-tangent track and facilitates destructive impact test projects including full-scale train impacts, in support of crashworthiness modifications of locomotive cabs and passenger cars.

- **Track #6 – Precision Test Track (PTT)**
  The PTT is a 6.2-mile-long track used primarily for vehicle dynamic behavior, safety compliance, and impact tests. Construction consists of standard track materials maintained to include specified track perturbations used in conjunction with the performance of vehicle track worthiness testing. The PTT and other tracks at TTC have been configured to determine vehicle

performance on nominal smooth track and on track designed to induce known poor performance modes. These tracks are used in safety performance analysis and for vehicle certification. The AAR performs certification testing on freight rail vehicles of various designs at TTC according to Chapter 11 specifications as found in the AAR M-1001, Manual of Standards and Recommended Practices, to ascertain the interchange service worthiness of freight cars.

- **Track #7 – Train Dynamics Track (TDT)**
  The Train Dynamics Track has a 1°30' curve.

1.4 Pueblo Chemical Depot Track Layout

TTCI will test the cask and car on tracks at the Pueblo Chemical Depot (PCD). The PCD is located just south of TTC and contains several miles of railroad track maintained to FRA Class 2. It is about 7 miles from the border of TTC property to the west leg of the wye at Avondale. Figure 2 shows a sketch of the tracks at the PCD.

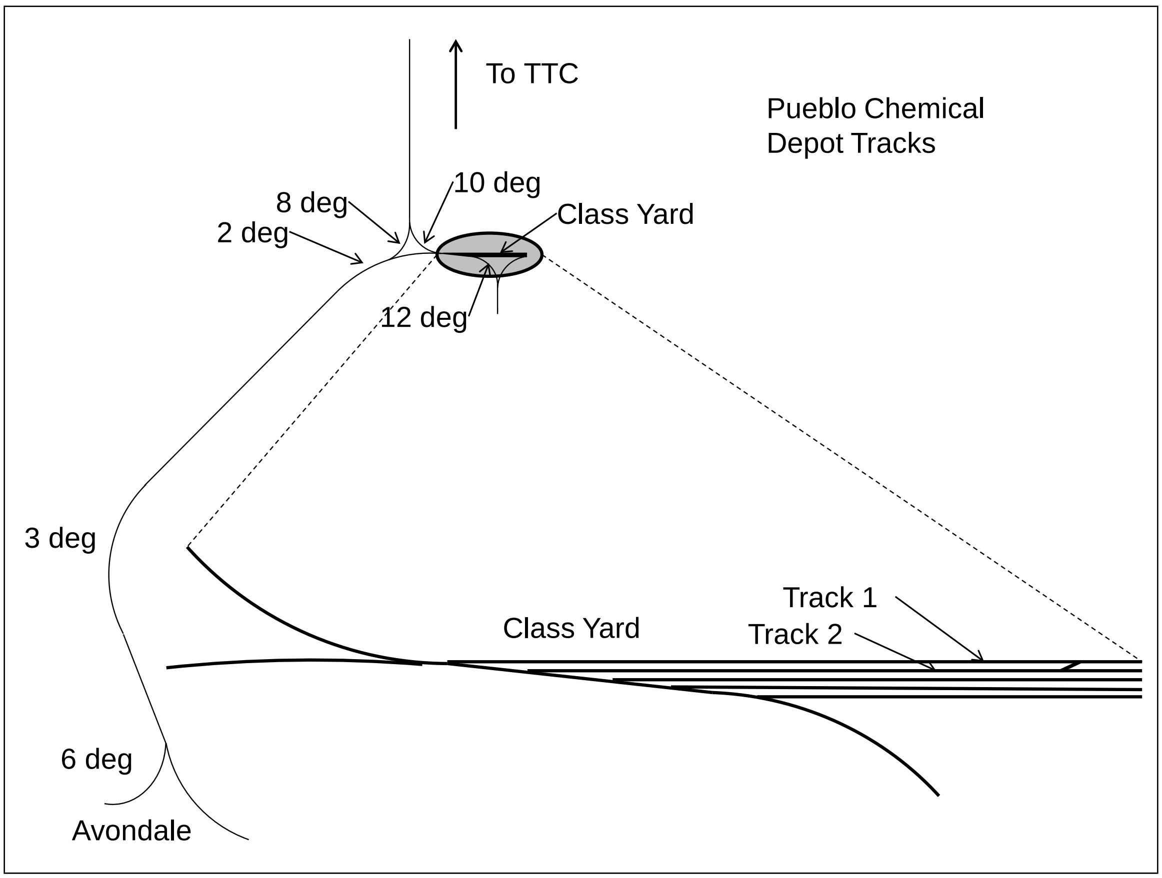


Figure 2. Sketch showing some of the tracks at the Pueblo Chemical Depot

1.5 Measurements

The measurements listed in the test plan address only the captive tests expected to be performed at TTC, and are the minimum required to verify safe test operations over perturbed track test zones. TTCI understands that PNNL will also have additional instrumentation and data collection system(s) on-board to measure the shock and vibration environment of the cask.

The AAR M-976 performance criteria will be used to assess vehicle safety performance during testing. These criteria are somewhat less conservative than the S-2043 criteria. This will help ensure that the maximum realistic and conservative levels of vibration for the cask are achieved during the testing without compromising test safety.

1.6 Test Car

This test plan is being written before the railcar to carry the cask is chosen. TTCI expects that an 8- or 12-axle span bolster flatcar will be used. It is unlikely the test car will have been designed or tested to the requirements of S-2043. Some details of the test plan can only be specified after car selection.

For most conditions the shock and vibration environment on a non S-2043 railcar will be similar to or more severe than that of an S-2043 railcar. The possible exception to this is the loaded hunting test regime. To meet the stringent curving requirements of S-2043 the trucks are often equipped with primary suspension pads. While these pads improve curving performance, they can sometimes adversely affect loaded hunting (lateral stability) performance. Special care will be taken to measure a reasonable range of loaded hunting performance during the test.

1.7 Scope

This section contain a brief description of the tests included in the test plan and why they are included. Some tests that are not included in the test plan are also briefly described together with the reasons they were omitted.

1.7.1 Tests Included in Plan

The following tests are described in the test plan:

- **Crossing Diamond Tests** – these tests are intended to subject the vehicle to typical vertical impacts resulting from the wheels traversing gaps in the rails where tracks intersect.

- **Twist and Roll Test** – this test is conducted to determine the car's ability to negotiate oscillatory cross level perturbations (Figure 3). These perturbations are designed to excite the natural twist and roll motions of the vehicle.

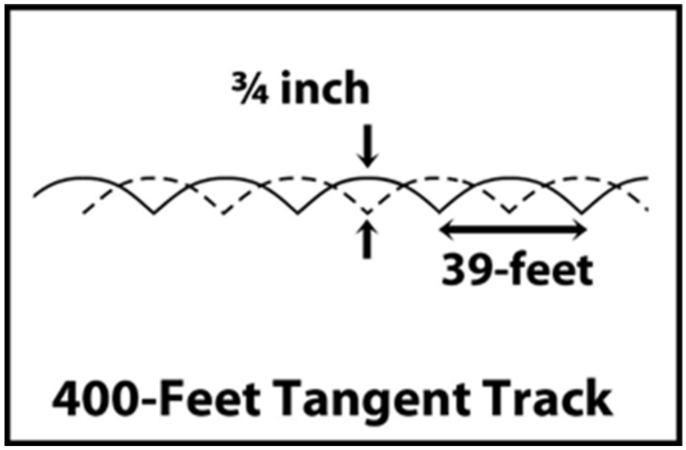


Figure 3. Twist and Roll test Zone

- **Pitch and Bounce Test** – these tests are conducted to determine the car's ability to negotiate parallel vertical rail perturbations (Figure 4). This test section is designed to excite the natural vertical pitch and bounce motions of the vehicle.

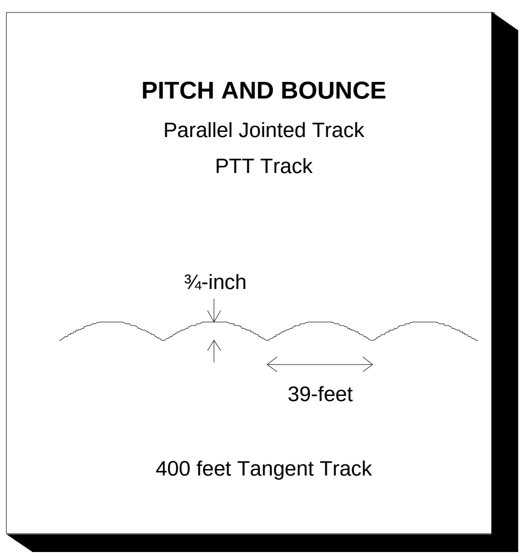


Figure 4. Pitch and Bounce Test Zone

- **Dynamic Curving Test** – these tests are conducted to determine the cars ability to negotiate curving over jointed track with a combination of lateral misalignment at the outer rail joints and cross-level due to low joints on the staggered rails (Figure 5).

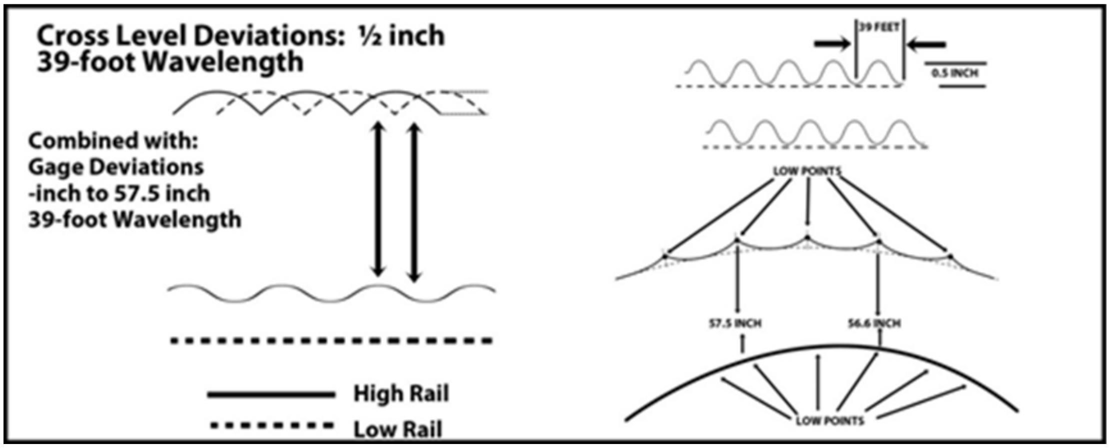


Figure 5. Dynamic Curve Test Zone

- **Tests at the Pueblo Chemical Depot** (see Figure 2) – These tests include runs over FRA class 2 railroad track and tests through No. 8 turnout and No. 8 crossovers.
- **Coupling Impact Test** – these tests are conducted to provide longitudinal inputs from coupling at higher than normal speeds. These inputs are similar to those that might also be caused by longitudinal train action.
- **Loaded Hunting Test** – these tests are conducted to determine the vehicle's lateral stability at higher speeds. This test is the one regime in which it is possible performance with a standard railcar may provide less conservative inputs than would be obtained with an S-2043 approved railcar. This, and possible mitigating actions will be described in section 4.2.
- **Single Bump Test** – This test is intended to represent a grade crossing. The test zone consists of a one-inch bump on tangent track. The bump is a flat topped ramp that rises up over 7 feet, has a steady elevation over 20 feet, and drops back down over 7 feet. Test speeds are 40 to 75 mph in 5 mph increments. Railroad industry experience is that vertical dynamic response at grade crossings is a significant source of large vertical accelerations and shock and vibration in freight cars.

1.7.2 Tests Not Included in the Plan

The tests listed here are ones required by S-2043 for single car testing, but were not included in the test plan for the reasons given. The number next to each test name is the section of S-2043 where the test is specified.

- 5.5.9 Yaw and Sway – The Yaw and Sway test zone (Figure 6) is lateral perturbation on a constant wide gage of 57.5 inches. The wavelength is 39 feet. The test is typically done from 30 to 70 mph in 5 mph increments.

  This test was not included in the test plan because, although the test zone remains in track, it is not often requested by the AAR for certification tests and is therefore not regularly maintained. If desired the test zone could be inspected and made ready for testing. Performing this test will also require moving the IWS from the positions used for M-976 tests.

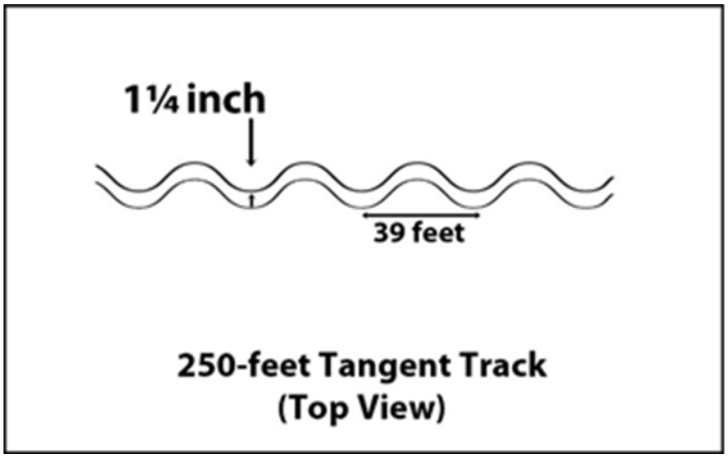


Figure 6. Yaw and Sway test zone.

- 5.5.12 Pitch and Bounce (Special) – This test zone is similar to the Pitch and Bounce test listed in section 0 except that the wavelength of the perturbations is adjusted to match the truck (or span bolster) center spacing of the test car. Testing at the truck center spacing increases the likely hood of resonant pitch and bounce response and consequent increased likelihood of large vertical accelerations.

  Performing this test requires that a test zone be built. This process is expensive and would likely impact other work being conducted at TTC, so it was not included in the test plan.

- 5.5.15 Curving with Single Rail Perturbation – This test is intended to represent a low or high joint in a yard. Two scenarios are run, one with a two-inch outside rail dip and another with a two-inch inside rail bump. The inside rail bump is a flat topped ramp with an intial elevation change over 6-feet, a steady elevation over 12-feet, then it ramps back down over 6-feet. The outside rail dip is the reverse. These tests zones are installed on a 12-degree curve with less that ½-inch superelevation. Tests are performed from 4 to 14 mph in two mph increments.

  Performing this test requires that a test zone be built. Building this test zone would be much simpler than the Special Pitch and Bounce zone, but it would still be relatively expensive and would impact other work at TTC. This is a severe test of a car's ability to negotiate poorly maintained track, but because of the low speeds, it is unlikely to expose the cask to significant shock or vibration. For these reasons it is not included in the test plan.

- 5.5.16 Standard Chapter 11 Constant Curving – These tests are performed to ensure the car is able to negotiate well maintained track curves. These tests are performed on the same test loop as the Dynamic Curving test on the WRM loop, only in different curves.

  Constant curving tests are not included in the test plan because the curves used for these tests are well maintained, yet the maximum speed on the track is 32 mph. This will limit the shock and vibration input in this test zone.

- Vibration Test Unit (VTU) – The VTU is a hydraulic shaker unit designed to accept an entire 4-axle railroad car. The VTU can move each axle of the car vertically, laterally, and in roll independently.

  Because the VTU is not capable of accepting cars with more than 4 axles its use was not included in the test plan.

- Simuloader (SMU) - The SMU is a hydraulic shaker unit designed to accept a railroad car body without the trucks or axles. The SMU can apply longitudinal loads to the car body and can move the body bolster locations vertically, laterally, and in roll independently. The SMU is used for fatigue testing of car bodies.

The SMU is designed to accept cars with 16-inch centerplates. A span bolster car is likely to be equipped with larger centerplates so the car or the SMU would require modifications for a test. Depending on the overall weight of the car and cask, the capacity of the SMU may be marginal depending on the desired excitation. Because of these limitations, tests with the SMU are not included in the test plan.

- Mini-Shaker Unit (MSU) – The MSU is a hydraulic shaker unit. The unit consists of two large reaction masses with hydraulic actuators attached. The hydraulic actuators are connected to a railroad car body to excite it vertically or laterally.

  The actuators are only capable of applying 77,000 pounds force each. Using the MSU requires that large steel connections for the actuators be welded to the carbody. The MSU is only attached to a car at one end. Because of these limitations, tests with the MSU are not included in the test plan.

2. Data Analysis/Criteria

TTCI will use the performance criteria in M-976[1] Table 4.1 as guidelines to safe test performance. These requirements are shown here in Table 1.

Table 1. Criteria for assessing testing requirements

Regime	Section	Criterion	Limiting Value
Hunting	4.1.2.4	maximum lateral acceleration (g)	1.5a
		standard deviation	0.13
Steady State Curving	4.1.2.1	95th percentile maximum wheel L/V	0.8
		95th percentile maximum axle sum L/V	1.5
Spiral	4.1.2.3	minimum vertical load (%)	10b
		maximum wheel L/V	1.0c
		maximum axle sum L/V	1.5c
Twist and Roll	4.1.2.5.1	maximum axle sum L/V	1.5c
		minimum vertical load (%)	10b
		dynamic augment acceleration (G)	1.0
		spring capacity maximum (%, loaded only)	95
Pitch and Bounce	4.1.2.5.2	minimum vertical load (%)	10b
		dynamic augment acceleration (G)	1.0
		spring capacity maximum (%, loaded only)	95
Yaw and Sway	4.1.2.5.3	maximum L/V truck side	0.7d
		maximum axle sum L/V	1.5c
Dynamic Curving	4.1.2.5.4	maximum wheel L/V	1.0c
		maximum axle sum L/V	1.5c
		minimum vertical load (%)	10b

a. Peak to peak
b. Not to fall below indicated value for a period greater than 50 milliseconds and a distance greater than 3 ft per instance as illustrated in Fig. 4.1.
c. Not to exceed indicated value for a period greater than 50 milliseconds and a distance greater than 3 ft per instance as illustrated in Fig. 4.1.
d. Not to exceed 0.6 for a duration equivalent to 6 feet of track.

3. Measurements

This section lists the measurements and instrumentation that will be used to measure the performance of the vehicle to verify safe test operation. TTCI understand that PNNL will measure strains, accelerations, and other parameters on and inside the cask to document the shock and vibration environment.

3.1 Instrumented Wheelsets

Instrumented wheelsets are railroad wheelsets designed to continuously measure the vertical, lateral, and longitudinal forces between the wheel and rail as a rail vehicle travels down the track. Depending on what type of test cask car is selected for this test, instrumented wheel sets (IWS) will be installed in either axle positions axles 1 and 5 of an 8-axle car, or axle positions 1 and 7 of a 12-axle car. Figure 7 shows an illustration of the likely train make-up scenarios, with the test car being either an 8-axle or 12-axle span-bolster flat car. The figure also shows the proposed IWS positions for either vehicle type.

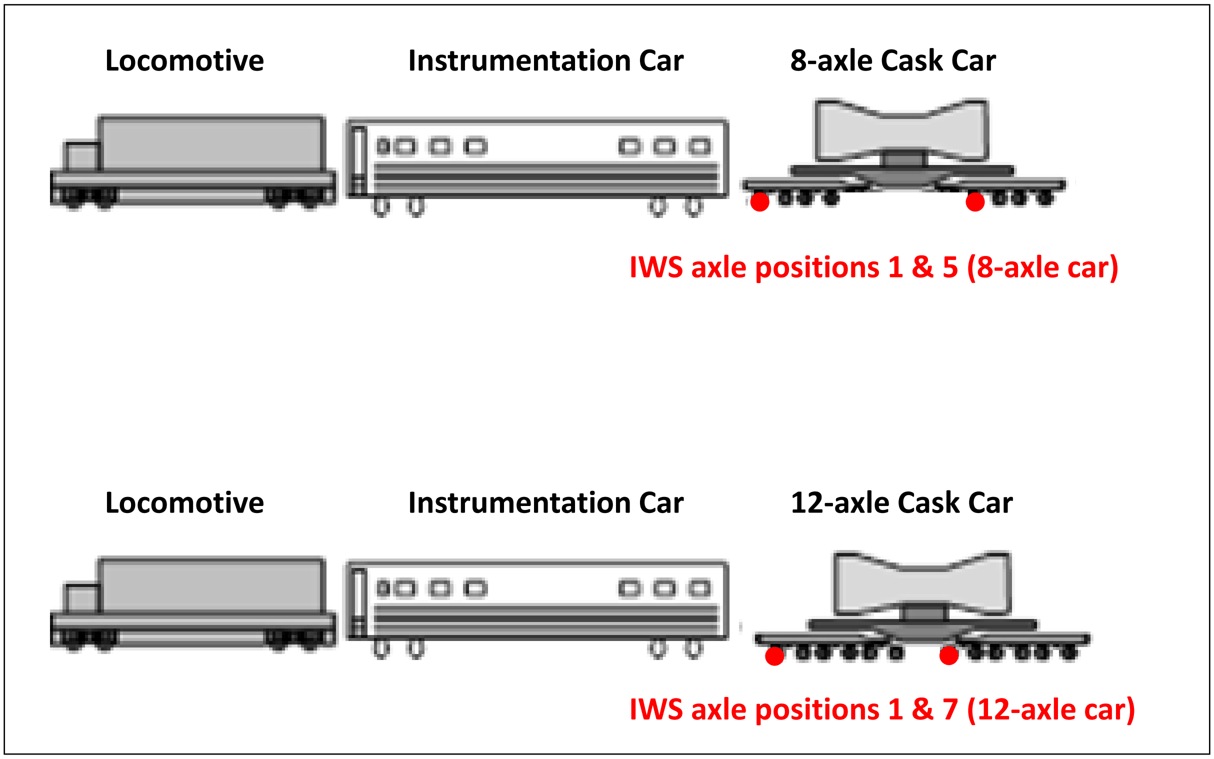


Figure 7. Test Train Make-Up

They type of IWS required will depend on the vehicle chosen to carry the cask. TTCI can supply:

- Two 38-inch IWS with 7x12 (Class G) bearings.
- Two 36-inch IWS with 6 ½x12 (Class F) bearings.
- Two 36-inch IWS with 6 ½x9 (Class K) bearings

Installation of the IWS requires the following steps

- Disconnecting train line, brake hoses, and brake rigging connected between the car body and span bolster.
- Jacking the car and rolling the span bolster from under the car
- Disconnecting brake hoses and brake rigging connected between the span bolster and trucks.
- Lifting of the span bolster and rolling out the truck
- Disassembly of the brake rigging
- Disconnecting brake hoses
- Removal of targeted wheelsets for IWS replacement
- Reassembly of the test car
- Installation of spinning amplifiers to the IWS
- Cabling of the IWS to the instrumentation coach

The brakes are disabled on the car while IWS are installed.

3.2 Acceleration and Displacement Measurements

This section lists the additional measurements and instrumentation that will be used to monitor the performance of the vehicle.

The sign convention for the following measurements should be a right-hand rule with the longitudinal (x) along the track in direction of travel, lateral (y) positive to the left when facing the direction of travel, and the vertical (z) positive upwards.

Tests will be conducted with the B-end leading.

Table 2 lists the channels required for the hunting tests.

Table 2. Measurement list for hunting tests

NO.	Channel Name	Measurement Description	Expected Range	Measurement Frequency Response	Digital Sample Rate	Estimated Accuracy	Special Comments/ Data Collection Presentation Requirements
1	Speed	Speed	0-80mph	0-1Hz	≥200Hz	better than 1%	
2	ALD	Automatic Location Device	0-5V	≥15Hz	≥200Hz	better than 2%	
3	YACBB	Lead carbody lateral acceleration	between ±2g and ±10g	≥15Hz	≥200Hz	better than 1%	
4	YACBA	Trail carbody lateral acceleration	between ±2g and ±10g	≥15Hz	≥200Hz	better than 1%	
5	GPS	GPS	TTC	≥1Hz	≥1Hz	better than 1%	

Table 3 shows the channel list for instrumented wheel set (IWS) testing.

Table 3. Measurement list for instrumented wheel set testing

NO.	Channel Name	Measurement Description	Expected Range	Measurement Frequency Response	Digital Sample Rate	Estimated Accuracy	Special Comments/ Data Collection Presentation Requirements
1	Speed	Speed	0-80mph	0-1Hz	≥600Hz	better than 1%	
2	ALD	Automatic Location Device	0-5V	≥15Hz	≥600Hz	better than 2%	
3		IWS in Axle 1		≥15Hz	≥600Hz	better than 5%	Display real time vert and L/V if using IWS capable of it
4		IWS in Axle 5 or 7		≥15Hz	≥600Hz	better than 5%	
5	ZACBB	Lead carbody vertical acceleration	between ±2g and ±10g	≥15Hz	≥200Hz	better than 1%	
6	ZACBA	Trail carbody vertical acceleration	between ±2g and ±10g	≥15Hz	≥200Hz	better than 1%	
7	ZDSNBL	Vertical Displacement B-end Left Side	>5 inch	≥15Hz	≥600Hz	better than 1%	
8	ZDSNBR	Vertical Displacement B-end Right Side	>5 inch	≥15Hz	≥600Hz	better than 1%	
9	ZDSNAL	Vertical Displacement A-end Left Side	>5 inch	≥15Hz	≥600Hz	better than 1%	
10	ZDSNAR	Vertical Displacement A-end Right Side	>5 inch	≥15Hz	≥600Hz	better than 1%	
11	GPS	GPS	TTC	≥1Hz	≥1Hz	better than 1%	

4. Test Matrix/Run List

The test matrix is grouped into sections according to the test. The order of the tests is not important. It will be determined by the project manager based on customer preference and test logistics.

The run lists are presented in tables. The filenames and worst case data value for each run can be entered in the table as a run log or checklist.

4.1 Test Configuration

Perform tests with the B-end leading. If possible, obtain a general arrangement drawing of the car and trucks from the customer or supplier. Document the following for the truck configuration. Table 4 is configured for a typical 4-axle car and may require expansion depending on the specific car selected to carry the cask.

Table 4. Test Configuration

Parameter	Description			
Secondary Suspension	Spring configuration including side coils			
Primary Suspension	Make and Model			
Sideframes	Serial Numbers, Pattern numbers			
Bolsters	Serial Numbers, Pattern numbers			
Side Bearings	Make and Model			
Friction Wedge	Make and Model			
Bearing Adapter	Make, Model, Size			
Center Bowl Liner (span bolster if applicable)	Make, Model, Type			
	A-End		**B-End**	
Cask car weight (pounds)				
	BL	**BR**	**AL**	**AR**
Spring Nest Height (inches)				
Side Bearing Height (inches)				
Free height of main coils (inches)				
Solid height (inches)				

Note: This table is presented as a template and may differ depending on the vehicle type.

4.2 Crossing Diamond Tests

There is currently a 78-degree crossing diamond installed in the HTL loop at TTC. The car may be tested at up to 40 mph over the diamond crossing.

TTCI may need to remove this diamond from the track depending on how it performs during FAST testing so it may not be available for the PNNL test. If the diamond is not available TTCI will simulate a diamond by grinding an appropriate gap pattern, including nominal rail batter, into a tangent segment of rail. This gap pattern could be installed on the TTT loop in a zone designed for installation of special perturbations.

Table 5 shows recommended runs for the crossing diamond test. To avoid damage to the instrumented wheelsets the unfiltered vertical wheel force will be monitored during the test. If the maximum vertical force exceeds 100 kips the test speed will not be increased further.

Table 5. Crossing diamond test runs.

Filename	Speed (mph)	Maximum carbody vertical acceleration (g)	Maximum vertical wheel force (kips)
	10		
	20		
	25		
	30		
	35		
	40		

4.3 Hunting

Hunting tests are typically performed on the RTT track between R39 and R33.5. However, for the purpose of this project, which is to expose the test cask to a dynamic environment, TTCI recommends the entire RTT loop be traversed as opposed to the designated test section only. This will allow running at higher speed over other typical track features such as turnouts.

The RTT track is the standard track used for hunting tests. As TTC's high speed test loop, the RTT is maintained to very tight track geometry requirements. The TTT track is also suitable for test speeds up to 75 mph. The track geometry of the TTT is not maintained to as tight a tolerance as the RTT. The different sections of the TTT have a variety to rail, tie, and fastener conditions. For these reasons, TTCI recommends that the hunting test be performed on the TTT in addition to the RTT so a wider variety of inputs may be measured.

The test requirements are:

- KR wheel profiles (there may only be four KR wheelsets available depending on the test car chosen)
- Dry rail, measure and document rail friction ≥0.4
- Leading stable buffer car (the instrumentation coach)
- No trailing buffer car

Table 6 shows recommended runs for the hunting test.

Table 6. Hunting test runs.

Filename	Speed (mph)	Track	Maximum peak-to-peak lateral acceleration (g)	Maximum standard deviation of lateral acceleration over 2000 feet (g)
	30	RTT		
	40	RTT		
	50	RTT		
	55	RTT		
	60	RTT		
	65	RTT		
	70	RTT		
	75	RTT		
	30	TTT		
	40	TTT		
	50	TTT		
	55	TTT		
	60	TTT		
	65	TTT		
	70	TTT		
	75	TTT		

Truck hunting is a common cause of sustained high lateral accelerations in railcars. If initial hunting tests do not produce maximum standard deviation of lateral acceleration over 2000-feet above about 0.09 TTCI suggests that modifications to the vehicle be made to promote a higher degree of instability. This will allow a wider range of possible performance to be measured.

The specifications already require using an alternative wheel profile (KR wheel profile) which is intended to help promote hunting. If the vehicle still does not show any lateral instability, then TTCI may install a primary adapter pads with a softer suspension characteristic in a further effort to promote hunting. It is anticipated that the car selected for this test program may not be an S-2043 car. Cars designed to meet S-2043 requirements are likely to be equipped with primary adapter pads.

If primary suspension pads are used for the test, great care will be taken while performing the test. Often loaded hunting performance will change from stable to very severe with an increase in speed of only a few mph. While S-2043 cars may be more prone to moderate instability when loaded than conventional cars, very severe hunting is unlikely. This is because S-2043 requires onboard safety monitoring systems on the railcars. As the railcar performance begins to degrade alerts from the monitoring system will trigger railcar maintenance to eliminate the problem.

4.4 Twist and Roll

Twist and roll tests will be performed on the PTT between St. 1644 + 10 and St 1651 + 70. The test requirements are:

- IWS with AAR1B wheel profiles in lead axle positions on both ends of the car.
- Dry rail

- Leading stable buffer car (the instrumentation coach)
- Trailing stable buffer car (TTX stable buffer car).

Table 7 shows suggested runs for the twist and roll test. Runs are performed starting at 10 mph and increasing in 2-mph increments until the lower center roll resonance is passed. Once lower center roll resonance is passed speeds are increased in 5 mph increments until 70 mph is reached. If performance is close to the limits smaller speed increments should be used to assure safety and closely identify the critical speed.

Table 7. Twist and roll test runs.

Filename	Speed	Maximum Axle Sum L/V Ratio	Minimum Vertical Wheel Load (percent of static)	Dynamic Augment Acceleration (g)
	10			
	12			
	14			
	16			
	18			
	20			
	22			
	24			
	26			
	30			
	35			
	40			
	45			
	50			
	55			
	60			
	65			
	70			

4.5 Pitch and Bounce

Pitch and bounce tests will be performed on the PTT between St. 1710 and St 1715. The test requirements are:

- IWS with AAR1B wheel profiles in lead axle positions on both ends of the car.
- Dry rail
- Leading stable buffer car (the instrumentation coach)
- Trailing stable buffer car (TTX stable buffer car).

Table 8 shows suggested runs for the pitch and bounce test. Runs are performed starting at 30 mph and increasing in 5 mph increments until 70 mph is reached. If performance is close to the limits smaller speed increments should be used to assure safety and closely identify the critical speed.

Table 8. Pitch and bounce test runs.

Filename	Speed	Minimum Vertical Wheel Load (percent of static)	Dynamic Augment Acceleration (g)
	30		
	35		
	40		
	45		
	50		
	55		
	60		
	65		
	70		

4.6 Single Bump Test

This test is intended to represent a grade crossing. Railroad industry experience is that vertical dynamic response at grade crossings is a significant source of large vertical accelerations and shock and vibration in freight cars. The test zone consists of a one-inch bump on tangent track. This test zone will likely be installed on the TTT loop in a section designed for special perturbations. The test requirements are:

- The bump is a flat topped ramp that rises up to one inch over 7 feet, has a steady elevation over 20 feet, and drops back down over 7 feet.
- IWS with AAR1B wheel profiles in lead axle positions on both ends of the car.
- Dry rail
- Leading stable buffer car (the instrumentation coach)
- No trailing buffer car

Table 8 shows suggested runs for the single bump test. Runs are performed starting at 40 mph and increasing in 5 mph increments until 75 mph is reached. If performance is close to the limits smaller speed increments should be used to assure safety and closely identify the critical speed.

Table 9. Single bump test runs.

Filename	Speed	Minimum Vertical Wheel Load (percent of static)	Dynamic Augment Acceleration (g)
	40		
	45		
	50		
	55		
	60		
	65		
	70		
	75		

4.7 Dynamic Curving

Dynamic curving tests will be performed on the dynamic curve test zone in the body of the 10-degree bypass on the WRM track. The test requirements are:

- IWS with AAR1B wheel profiles in lead axle positions on both ends of the car.
- Measure and document rail friction ≥0.4
- Leading stable buffer car (the instrumentation coach)
- Trailing stable buffer car (WRM Buffer)

Table 10 shows suggested runs for the dynamic curving test. Tests are done CW and CCW and will be performed from 10 mph to 32 mph in 2 mph increments.

Table 10. Loaded dynamic curving test runs.

Filename	Speed	Direction	Maximum Wheel L/V Ratio	Maximum Axle Sum L/V Ratio	Minimum Vertical Load (percent of static)
	10	CW			
	12	CW			
	14	CW			
	16	CW			
	18	CW			
	20	CW			
	22	CW			
	24	CW			
	26	CW			
	28	CW			
	30	CW			
	32	CW			
	10	CCW			
	12	CCW			
	14	CCW			
	16	CCW			
	18	CCW			
	20	CCW			
	22	CCW			
	24	CCW			
	26	CCW			
	28	CCW			
	30	CCW			
	32	CCW			

1.1.1.1

4.8 Pueblo Chemical Depot Matrix

TTCI will test on tracks at the Pueblo Chemical Depot (PCD). Note that these tests shall be performed on dry track. The PCD is located just south of TTC and contains several miles of railroad track maintained to FRA Class 2. It is about 7 miles from the border of TTC property to the west leg of the wye at Avondale.

Section 6.3.1.1 of S-2043 requires that the train be operated over number 10 or sharper turnouts and through a number 10 or sharper crossover on 15 feet or narrower track centers. The turnouts at the PCD class yard will be used to fulfill these requirements. All of the turnouts in the class yard are number 8. There is a crossover between class yard tracks 1 and 2 that uses number 8 turnouts on 14 feet 2 inch track centers.

TTCI operating rules allow speeds up to 20mph at the PCD. Speeds through the diverging route of number 8 turnouts and will be limited to 19 mph to maintain less than 3-inches unbalance in the closure curve. Speeds in the 12-degree curve will be limited to 19 mph to maintain less than 3-inches unbalance.

Table 11 shows a list of runs planned at the PCD. Note that S-2043 would require runs where the test vehicle was being both pulled and pushed through the test zone(s). However, because this program will only have IWS in lead axle positions, pushing runs will not be conducted. Reverse moves through the test zones will be made at no more than 10 mph.

Table 11. List of runs at PCD

Description	Speed	Maximum Wheel L/V Ratio	Maximum Axle Sum L/V Ratio	Minimum Vertical Load (percent of static)
North gate PCD to South Gate PCD*	20mph			
Slow speed runs on class yard track 1 and 2 including turnout and crossover to allow visual inspection for binding and interference	Walking Speed			
West-East Class Yard Track 1 Including turnout at beginning	20mph			
West-East Class Yard Track 2 Including turnout at beginning	20mph			
Crossover, West-East, Class Yard Track 2 to 1	5			
Crossover, West-East, Class Yard Track 2 to 1	10			
Crossover, West-East, Class Yard Track 2 to 1	15			
Crossover, West-East, Class Yard Track 2 to 1	19			
Turn on Wye				
South gate PCD to North Gate PCD	20mph			
Slow speed runs on class yard track 1 and 2 including turnout and crossover to allow visual inspection for binding and interference	Walking Speed			
East-West Class Yard Track 1 Including turnout at end	20mph			
East-West Class Yard Track 2 Including turnout at end	20mph			
Crossover, East-West, Class Yard Track 1 to 2	5			
Crossover, East-West, Class Yard Track 1 to 2	10			
Crossover, East-West, Class Yard Track 1 to 2	15			
Crossover, East-West, Class Yard Track 1 to 2	19			

4.9 Coupling Impact Test Matrix

Coupling impact tests will be performed on the PTT track north of the pitch and bounce test zone. The test car will be pulled up the 0.86% grade an appropriate distance and then released and allowed to roll freely into a standing sting of anvil cars.

The test will use three loaded cars as an anvil string. The last car of the anvil string will use a tightly set handbrake, but no other brakes will be set.

Impact speeds of 2, 4, 6, and 8-mph will be tested. TTCI will measure the coupler load and impact speed. If coupler loads reach the maximum design coupler force test speeds will not be increased. If coupler loads approach the maximum design coupler force the speed increments will be reduced from 2mph to 1mph or less.

The maximum coupler force will depend on the car selected as the cask car. The maximum design coupler force is defined in the Association of American Railroads (AAR) *Manual of Standards and Recommended Practices* (MSRP) Section C-Part II, Chapter 4, paragraph 4.1.10 *Impact Load*.

TTCI will provide an HD camcorder to record the impacts from wayside. The test car will be inspected between test runs to verify no damage has occurred to the car or the cask.

When tests of one end of the car are finished the car will be turned and the test repeated. Table 12 shows the coupling impact test matrix.

Table 12. Coupling Impact Test Matrix

Filename	Impacted End	Planned Speed (mph)	Actual Speed (mph)	Coupler Load (kips)
	B-End	2		
	B-End	4		
	B-End	6		
	B-End	8		
	A-End	2		
	A-End	4		
	A-End	6		
	A-End	8		