Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2019
August 4-9, 2019, New Orleans, Louisiana, USA

Paper No. 19-A-1404-PATRAM

Logistics preparation for the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test using the ENUN 32P cask

A. Palacio
Ensa

I. Fernández Ensa | **R.G. Garmendia** Ensa | **G. Calleja** Ensa

ABSTRACT

Equipos Nucleares SA, SME (Ensa) together with the support of the U.S. national labs Sandia National Laboratories (SNL), Pacific Northwest National Laboratory (PNNL) and the transport engineering company COORDINADORA, was in charge of preparing the logistics for the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test, using an ENUN 32P dual-purpose cask. To accommodate all the instrumentation for measuring the accelerations and the strains in the rods of the surrogate fuel assemblies, Ensa designed, manufactured and assembled several auxiliary equipment in its factory in the surroundings of Santander, in the North coast of Spain.

The basket of the cask was loaded with three surrogate fuel assemblies instrumented for the data acquisition. The rest of the basket positions were occupied by twenty-nine simulated assemblies, constituted by blocks of steel filled with concrete that represented the dimensions and the weight of 17x17 spent fuel assemblies. A specific test cover substituted the original two lid closure system and was specifically manufactured for the test. The new lid included an open penetration to extract all the instrumentation cables of the accelerometers and the strain gages from the inner cavity of the cask. In addition, the original impact limiters designed to protect the cask during transportation events were replaced by two simulated ones. Finally, an extension was welded to the transport cradle, to place the batteries and the data acquisition system necessary to collect all data during the entire test.

After providing support to SNL and PNNL for the instrumentation of the cask and the surrogate fuel assemblies, several handling tests were performed at Ensa with different crane operators, to tune and adjust the sensors and the data acquisition system.

Together with COORDINADORA, Ensa’s team provided support during the first phase of the test, the heavy-haul truck road across the North of Spain. And later the transference to a barge from the port of Santander (Spain) to the port of Zeebrugge (Belgium), and from there across the Atlantic Ocean to Baltimore (Maryland, USA) by ship.

After performing the rail tests across the USA, from Baltimore to Pueblo (Colorado) and at the Transportation Technology Center, Inc. (TTCI) testing facilities, all the test equipment was returned to Spain. Ensa’s staff disassembled all the equipment and prepared the cask to be used for its original purpose: store and transport PWR spent nuclear fuel from Almaraz Nuclear Power Plant (NPP) in Spain.

INTRODUCTION

In 2017 Sandia National Laboratories (SNL) led an international team in a research project where a transportation spent fuel cask was instrumented to measure the accelerations and the deformations suffered by spent fuel rods during normal conditions of transport and analyze the potential damage and risk to failure. The test has been a big success with huge repercussion within the international spent fuel management community and was awarded in 2018 an Achievement Award from the U.S. Department of Energy Secretary's Honour Award.

The role of Ensa was to provide a real unit of a dual-purpose cask and develop some modifications for the test, to instrument and acquire data from the content during the different transportation modes by road, sea and rail.

The type of cask used for the test was the ENUN 32P, a dual-purpose (Storage and Transportation) cask designed, licensed and fabricated by Ensa for PWR spent nuclear fuel. The first units of that cask have been loaded by Ensa in Almaraz and Trillo NPPs (Spain) in 2018. The ENUN 32P is a bare-fuel type B(M) cask, fabricated in a monolithic carbon steel forging with two carbon steel lids, including several basket configurations that allow storage and transport of German KWU 16x16-20 and U.S. W17x17 high burnup spent fuel from all Spanish PWR reactors.

The main design modifications implemented by Ensa's Engineering department for the purpose of the research project affected the closure system, the impact limiters, the transport cradle and the simulated fuel assemblies. The main goal was to extract the cables form the surrogate fuel assemblies instrumented in the basket of the cask and connect them with an instrumentation and battery box fixed to the transportation cradle.

The design and manufacturing of all the equipment was performed by Ensa's staff at the main facilities located in the surroundings of Santander, in the North coast of Spain. The Project Manager from SNL and other staff from SNL and PNNL travelled to Ensa in May 2017 to verify the state of the cask and the modifications implemented for the purpose of the test. Then, instrumented the surrogate fuel assemblies and leaded Ensa's staff in the logistics of the first part of the test: the handling test at Ensa, the heavy-haul truck road test across the North of Spain and the transference by barge to the port of Zeebrugge (Belgium), before being shipped by boat to the port of Baltimore in the East coast of the U.S.A.

CASK MODIFICATIONS FOR THE PURPOSE OF THE TEST

Once the fabrication of the first set of ENUN 32P casks had been started, Ensa requested its customer ENRESA, the Spanish public company in charge of the safe management of the radioactive waste, to borrow the first unit that was going to be sent to Almaraz NPP, in order to use it during several months in the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test. ENRESA accepted, and also offered one W17x17 surrogate fuel assembly fabricated by ENUSA, to be instrumented and used during the test.

Ensa, together with the support of SNL and PNNL, launched a new research & development project to introduce some temporary modifications in one unit of the

ENUN 32P cask for the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test. Those modifications are described below.

<u>Modifications introduced in the closure system.</u> The ENUN 32P cask includes two lids. The inner lid is part of the containment barrier while the outer lid is an auxiliary protection barrier. Both are bolted to the cask body and envelope the inter-lid space that has a higher pressure during the Storage configuration and is monitored through a pressure transducer installed in the outer lid. This configuration was not necessary for the test, so the double lid closure system was substituted by a single test cover bolted to the cask body. This test cover had a mass and a centre of gravity very similar to the combination of the inner and outer lid of the ENUN 32P cask. The test cover was fabricated from two carbon steel thick plates and was epoxy painted. It included a 3-wings machined groove to facilitate the extraction of the instrumentation cables of the surrogate assemblies from the inner cavity. Rubber protections where glued to the outer rim, for avoiding any damage in the cask body during the installation and the vibrations suffered by the cask during the transportation test.

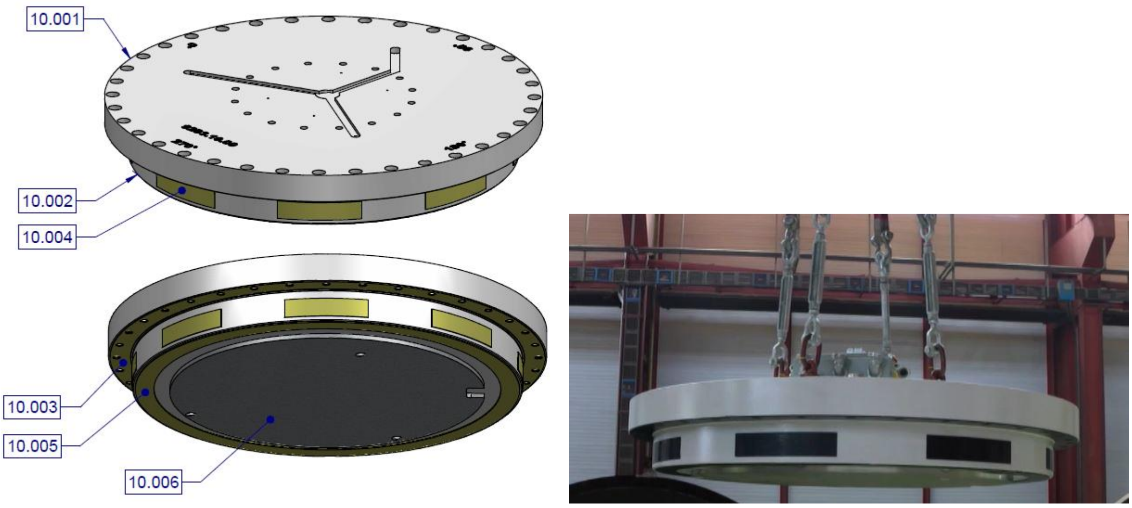

Figure 1. Test Cover

<u>Modifications introduced in the impact limiters.</u> The upper and lower impact limiters of the ENUN 32P were designed to withstand all postulated accidents during hypothetical accident conditions (including 9 m drops and 1 m puncture drops, as requested by IAEA SSR-6 regulation [1]). However, they were too big (3.8 m diameter) to be used during the entire test project. Furthermore, its configuration did not allow the extraction of the instrumentation cables of the surrogate fuel assemblies. Therefore, it was necessary to design and fabricate a couple of simulated impact limiters specifically for the test. They had a reduced diameter (2.4 m) and instead of using advanced energy absorption materials, they were made of carbon steel plates and lead just to reproduce the same weight and centre of gravity of the real impact limiters of the ENUN 32P cask. Three lifting lugs where equally spaced around the outer rim for its handling. In the upper one, a big squared penetration was opened to place an electric box where all instrumentation cables that left the inner cavity through the test cover, where joined together.

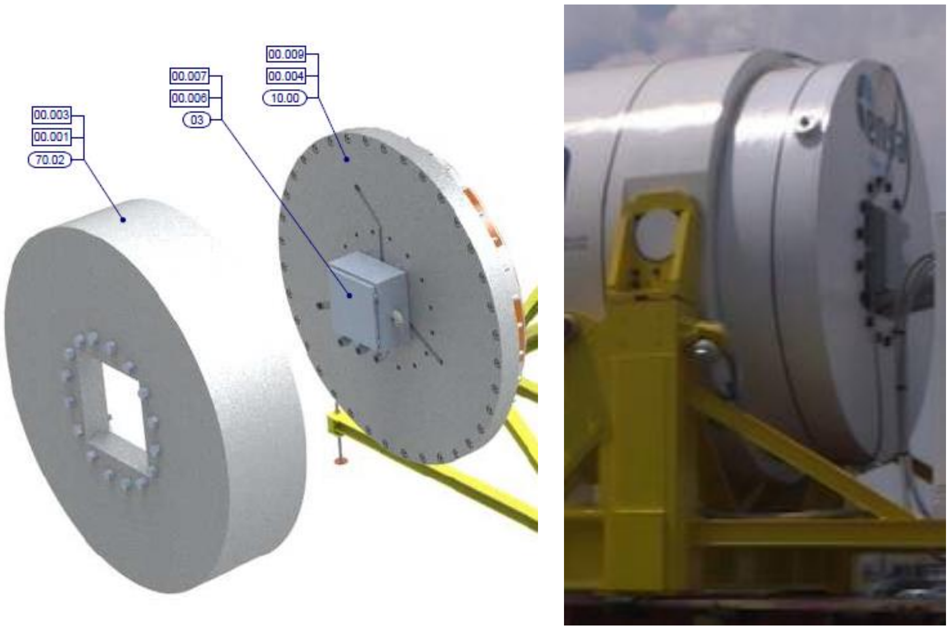

Figure 2. Upper surrogate impact limiter + test cover with electric box

Modifications introduced in the transport cradle. For the collect the measured data from the accelerometers and strain gages installed in the three surrogate fuel assemblies, it was necessary to include a data acquisition system and batteries together with the test equipment. Both components were introduced in a heavy instrumentation battery box that was fixed to the transport cradle. Several steel profiles were welded to the front pillars of the transportation cradle and created a base support where the battery box was screwed. Four steel shackles where attached to the four pillars of the transport cradle for handling the overall test assembly and facilitate the transference between the different transportation modes (truck, barge, ship, rail and vice versa) used during the test.

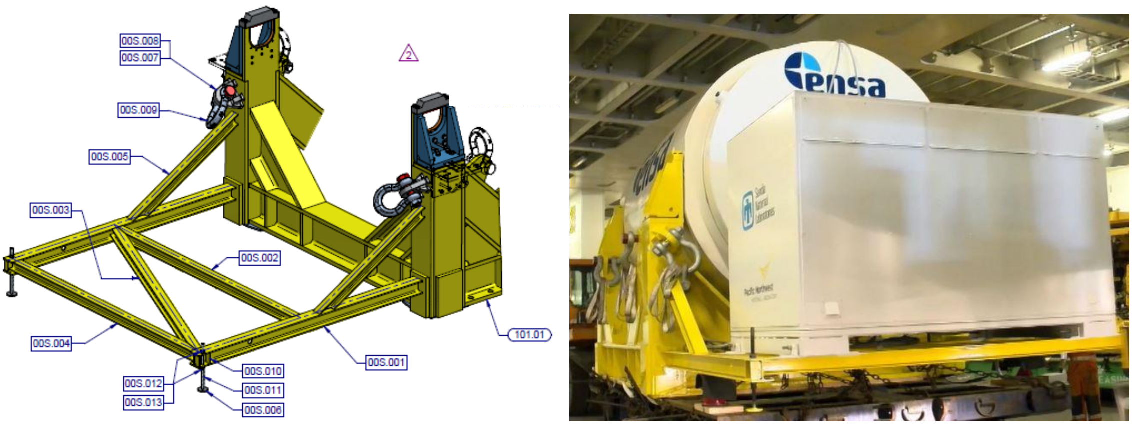

Figure 3. Modifications introduced in the transport cradle

Simulated fuel assemblies. The content for the test was constituted by 3 surrogate fuel assemblies and 29 simulated fuel assemblies. The 3 surrogate fuel assemblies were exact replicas from 17x17 fuel assemblies, with the uranium pellets replaced by lead pellets. They were provided for its use in the test by SNL (USA), ENUSA (Spain) and the group of South Korean nuclear companies constituted by Korea Radioactive Waste Agency

(KORAD), Korea Atomic Energy Research Institute (KAERI) and Korea Nuclear Fuel (KNF). The simulated fuel rods of the three of them were instrumented by several three axial accelerometers and strain gages.

The other 29 basket positions were occupied by 29 simulated fuel assemblies developed by Ensa. They were constituted by squared carbon steel tubes, filled with non-structural concrete and corrugated steel rebars to increase its toughness. Nylon layers were placed in the periphery to avoid damaging the basket plates during the introduction and removal of the assemblies from the basket, and the vibrations suffered during transportation. They had the same dimensions as the 17x17 fuel assemblies and the same weight to maintain the centre of gravity of the ENUN 32P cask in its transport configuration.

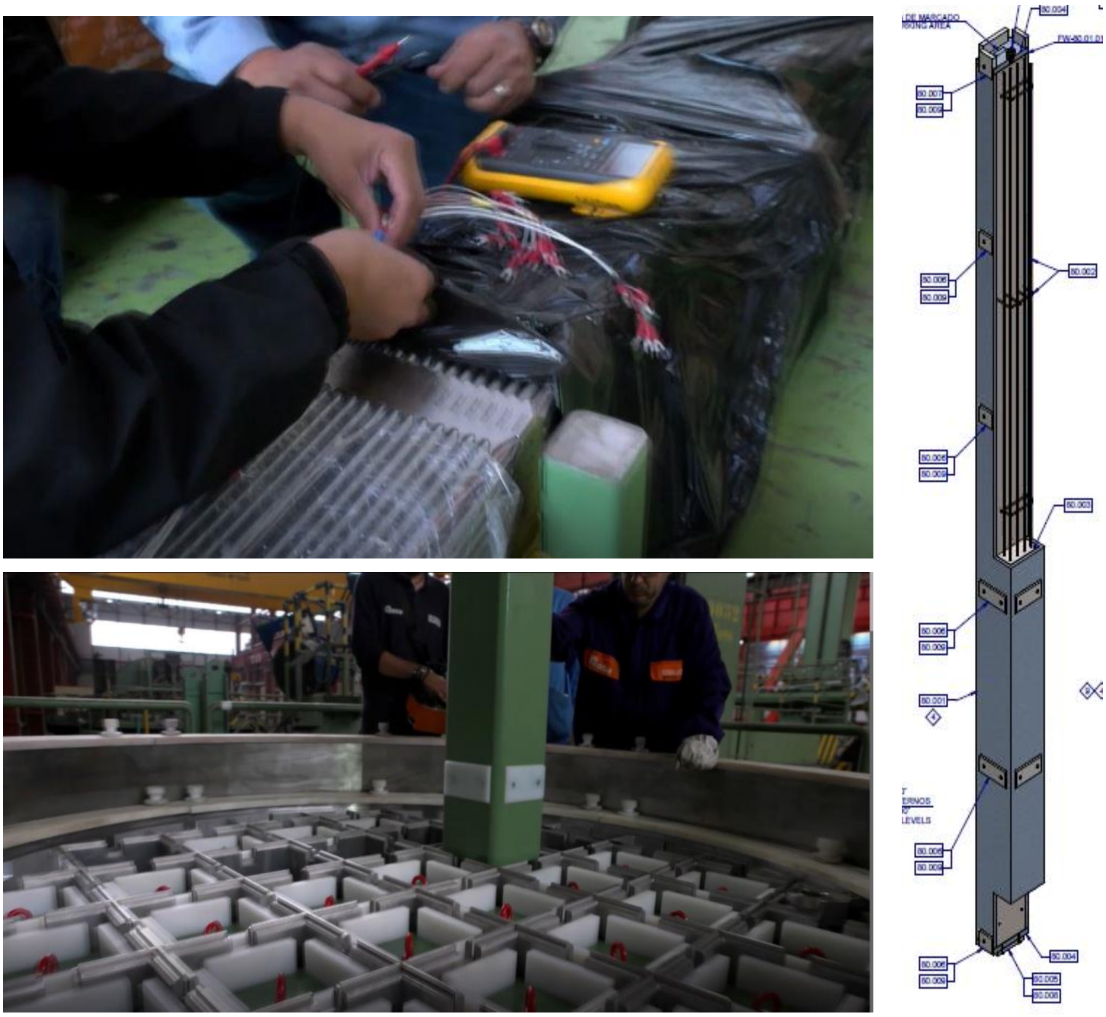

Figure 4. SNL staff instrumenting the rods of the three surrogate fuel assemblies (up), sketch of a simulated fuel assembly (right) and loading process of the simulated fuel assembly in the basket of the cask (bottom)

All these modifications were designed by Ensa with the approval of SNL and PNNL. The were manufactured by Ensa. The test configuration with all the modified components assembled in the ENUN 32P cask is shown in Figure 4. The total weight, including the 3 surrogate fuel assemblies and the 29 dummy assemblies was 140 metric tons.

Figure 4. Test configuration for the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test

SUPPORT FROM ENSA STAFF TO FIRST SET OF TESTS

Ensa's staff collaborated with the testing team providing support during the assembly of all the equipment at Ensa facilities, during the first part of the test (the heavy-haul truck road test), during the boarding of the equipment in the barge in the port of Santander (North coast of Spain), reception in the port of Zeebrugge (Belgium), boarding again on a ship to cross the Atlantic Ocean, reception in Baltimore (Maryland, East coast of the USA) and transference to the dedicated rail that crossed several states up to Pueblo (Colorado, USA).

The activities developed at Ensa facilities during May and June 2017 prior to the beginning of the test included the instrumentation of the three surrogate fuel assemblies, the cask and the cradle. The accelerometers and the strain gages where carefully installed and tested by SNL staff. After that, both types of fuel assemblies where introduced in their designated positions in the basket of the ENUN 32P cask. The cables where extracted through the penetration drilled in the test cover and joined together in the 3-wings machined groove. They were stored in the electric box installed in the test cover. Later, the lower and upper impact limiters where bolted to the bottom of the cask and the test cover plate, respectively. Then the cask was lifted and tilted to the horizontal position and placed in the modified transportation cradle. The battery box was installed in the extension profiles welded in the upper side of the cradle, and the instrumentation cables were connected.

Once all the equipment was assembled, SNL staff performed several electric tests to check that all sensors where electrically powered, and the signals measured were appropriately collected by the data acquisition system stored in the battery box. These tests were combined with the series of handling tests. During the handling tests the cask was lifted from the ground several times by different crane operator from Ensa and then and placed in the transportation cradle. The objective was to identify the sensibility of the sensors in different handling manoeuvres. These handling tests where supervised, apart from Ensa, SNL and PNNL staff, by a delegation of people from the South Korean nuclear companies constituted by KORAD, KAERI and KNF. Also, by personnel from the Spanish Nuclear Safety Council, the nuclear regulator who wanted to be informed about the development of the test.

Figure 5. Cask Handling Test at Ensa's facilities[1]

All the logistic activities of the various phases of the test through the different transportation means where contracted and managed by COORDINADORA, an engineering company subcontracted by Ensa and PNNL with experience in the transportation of large equipment.

Once the pre-test activities where concluded the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test officially began with the heavy-haul truck road test, at the end of June 2017 [2]. All the equipment was escorted through a transportation route of 395 km across the North of Spain (through the provinces of Cantabria, Palencia and Burgos) and back to Ensa facilities.

Figure 6. Route followed by the heavy-haul truck road test, escorted across the North of Spain [1]

After the heavy-haul truck road test and before the sea transportation, all the electric connections were checked, and the batteries charged by SNL staff. One of the limiting aspects of the transport logistics of the test equipment was the life of the batteries, limited to approximately 16 days. That was the reason why between every transition to a different transportation mode the batteries had to be recharged.

At the port of Santander, very close from Ensa's facilities, Ensa's staff supported the testing team in the transference of the equipment to a coastal freight carrier (barge) that covered the route to the port of Zeebrugge in the west coast of Belgium. From there to the end of the official instrumented test in the facilities of TTCI in Pueblo (Colorado, USA) using a dedicated rail transport, different members of Ensa's Engineering department travelled to the port of Zeebrugge, to the port of Baltimore (Maryland, USA) and to TTCI for supporting the testing team and confirm any damaged had been produced in the ENUN 32P cask as a consequence of the different transportation modes and the transferences between each of them.

A final inspection was done at Ensa facilities in December 2017, once the test had concluded and all the equipment had returned to Spain. The conclusion was that the cask and the rest of the test equipment was in good conditions and only one single sensor failed during the entire project, obtaining a vast number of terabytes of measuring data. Thanks to it, the cask has been delivered to ENRESA for performing the loading campaigns of spent fuel at Almaraz NPP.

CONCLUSIONS

Ensa, together with the support of the U.S. national labs Sandia National Laboratories (SNL), Pacific Northwest National Laboratory (PNNL) and the transport engineering company COORDINADORA, was in charge of preparing the logistics for the Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test, using an ENUN 32P dual-purpose cask. The scope of this project was to measure the accelerations and the deformations suffered by spent fuel rods during normal conditions of transport and analyze the potential damage and risk to failure

Ensa designed, manufactured and assembled several auxiliary equipment to facilitate the data acquisition of the accelerations and deformation of the instrumented rods in three surrogate fuel assemblies, transported in the basket of the cask. The components developed by Ensa for the test were a specific single test cover, a couple of simulated impact limiters with reduced outer dimensions, twenty-nine simulated assemblies made of steel and concrete, and the addition of various profile extensions in the transportation cradle to place the battery box with the data acquisition system for the test.

Ensa's team provided support during the first phase of the test, the heavy-haul truck road across the North of Spain. Furthermore, personnel from the Engineering department accompanied the test equipment in the different stops until the arrival at TTCI facilities, for the rail transport tests at Pueblo (Colorado, USA)

Once all the tests had concluded and the equipment returned to Spain. Ensa's staff disassembled all the equipment and prepared the cask to be used for its original purpose: store and transport PWR spent nuclear fuel from Almaraz NPP in Spain.

ACKNOWLEDGEMENTS

Ensa would like to acknowledge all the members of the transportation test team, an international group of experts that thanks to its passion, commitment and excellent cooperation performed an excellent and high valuable work. The authors would like to thank very specially Paul McConnell, the leading Project Manager of the entire test project who recently retired from SNL. A special mention to Ken Sorenson, Sylvia Saltzstein, Carissa Grey, Mike Arviso (from SNL), Steve Ross, Nick Klymyshyn (from

PNNL) and David Garrido (from NAC Intl.) who promoted the importance of developing this project and provided its continuous support and experience during the different phases. This project has been possible thanks to all companies and research institutions who provided equipment and skilled staff for the different tests: SNL, PNNL, Ensa, ENRESA, ENUSA, COORDINADORA, KORAD, KAERI, KNF and TTCI. And the U.S. Department of Energy for providing funding to make possible the development of this project. Finally, the authors would like to acknowledge the excellent work performed by all Ensa personnel during the manufacturing and modification of all equipment, and the pre-tests performed before the launch of the official tests.

REFERENCES

[1] IAEA Safety Standards. Specific Safety Requirements No. SSR-6. Regulations for the Safe Transport of Radioactive Material. 2012 Edition.

[2] Data Analysis of ENSA/DOE Rail Cask Tests. Spent Fuel and Waste Disposition. E.A. Kalinina et. al. November 19, 2018. SFWD-SFWST-2018-000494. SAND2018-13258 R.