

## **PREPARATION OF THE REACTOR VESSEL AT THE BIG ROCK POINT RESTORATION PROJECT FOR SHIPMENT AND FINAL DISPOSAL.**

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### **ABSTRACT**

The Big Rock Point boiling water reactor at Charlevoix, MI was shut down for the last time in 1997. In 1999, BNFL Inc.'s Decommissioning Operations Group was awarded the contract by Consumers Energy for the Big Rock Point major component removal project. BNFL Inc. teamed with MOTA, Sargent & Lundy, to plan and execute the decommissioning project.

Details are provided for the methodology of addressing the engineering, regulatory, logistic and technical challenges associated with developing a removal method for the reactor vessel and subsequent placement of a low density cellular concrete (LDCC) within the reactor vessel and the annulus between the vessel and its shipping container. LDCC has been demonstrated to possess excellent structural properties and flow characteristics for placement in remote situations. It is to be noted that this reactor vessel transportation is the first and only fully compliant 10 CFR Part 71 shipment in US history.

The reactor vessel was required to be placed within a licensed shipping container. Once in the container any voids in the reactor vessel and the container were filled with LDCC. The container lid was then welded shut onto the container, sealing the package prior to shipment. The sealed container was then removed from the containment sphere and loaded onto a transporter for truck and rail shipment to Barnwell for ultimate disposal.

### **INTRODUCTION**

The Big Rock Point boiling water reactor at Charlevoix, MI was shut down for the last time in 1997. Early in 1999, BNFL Inc.'s Decommissioning Operations Group was awarded the contract by Consumers Energy for the Big Rock Point major component removal project. BNFL Inc. teamed with MOTA and Sargent & Lundy (S&L), to plan and execute the major component removal project.

The key component for removal under the contract was the reactor vessel (RV). BNFL, Inc's responsibility included the design, fabrication, licensing and delivery of a shipping container and the provision of ancillary equipment to transport the container. This was collectively called the reactor vessel transportation system (RVTS). In addition to the RVTS, BNFL were responsible for:

- Preparation for removal
- Removal
- Loading of the RV into the shipping container
- Preparing the loaded container for shipment
- Transportation of the RVTS on road and rail from the plant in northern Michigan to the Duratek low level waste facility in Barnwell, South Carolina.

### **CONCEPTUAL DESIGN**

The conceptual design was conceived in late 1999 once the RV radiological characterization had been completed by WMG on behalf of the utility owner Consumers Energy (CECo) in June of that year. Prior

to this the Major Component Removal contract was let on the basis that the shipping container would be an IP2 type but with the option to vary the contract to provide a Type B container should the characterization identify that IP2 radiological limits were exceeded. The characterization, based on internal RV measurements, was used as the source data from which the resulting RV external dose rates were calculated. The characterization identified that the RV would have approximately 13,000 curies of activity once the remaining Greater Than Class 'C' (GTCC) material was removed (i.e. neutron windows and grid bars). Using a shipping date of September 1, 2002, this residual radionuclide source term was well below the Barnwell disposal limit of 40,000 Curies. More significantly though, the results indicated that the unshielded dose rate at 3m would be greater than the IP2 limit of 1R/hr precluding the licensing of the container as an IP2. Consequently it was determined that the package would need to satisfy the NRC 10 CFR Part 71 Type 'B', exclusive use, radioactive material transportation package criteria.

The key aspect of this newly identified requirement was the need to provide analyses to support the shipping containers ability to meet all the requirements of the 10 CFR 71.71 normal condition of transport (NCT) and 10 CFR 71.73 hypothetical accident conditions (HAC), not required for an IP2, and the provision of a Safety Analysis Report (SAR) for review and approval by the NRC prior to RVTS use. The project identified that all facets of NCT and HAC could be successfully analyzed with the exception of the 71.73 (c) (1) HAC '30' Free Drop' requirement. This had never been successfully demonstrated on any previous RV Type B shipping container so the decision was taken to apply for an exemption, as had been successfully done in the past. From a project perspective this would have potentially significant schedule and cost implications because of the need to analyze all of the transportation equipment and routing details and include the analyses in the submission to the NRC for review and approval. Additionally BNFL Inc were required to develop, implement and gain NRC approval for a 10 CFR 71 Subpart H Quality Assurance Program to enable BNFL, as the package licensee, to ensure appropriate quality assurance and oversight was imparted during the fabrication and use of the RVTS.

To facilitate this development a Peer Review Group (PRG) was established early in 2000 with members who were experts in the industry experienced with the shipment of NRC licensed waste, and analysis of large fabrications or experience in the rail industry. Additional representatives were members from the utility CECo, the design authority S&L and BNFL Inc. The PRG meet seven times between May 2000 and August 2002 and proved to be fundamental in driving the project to success.

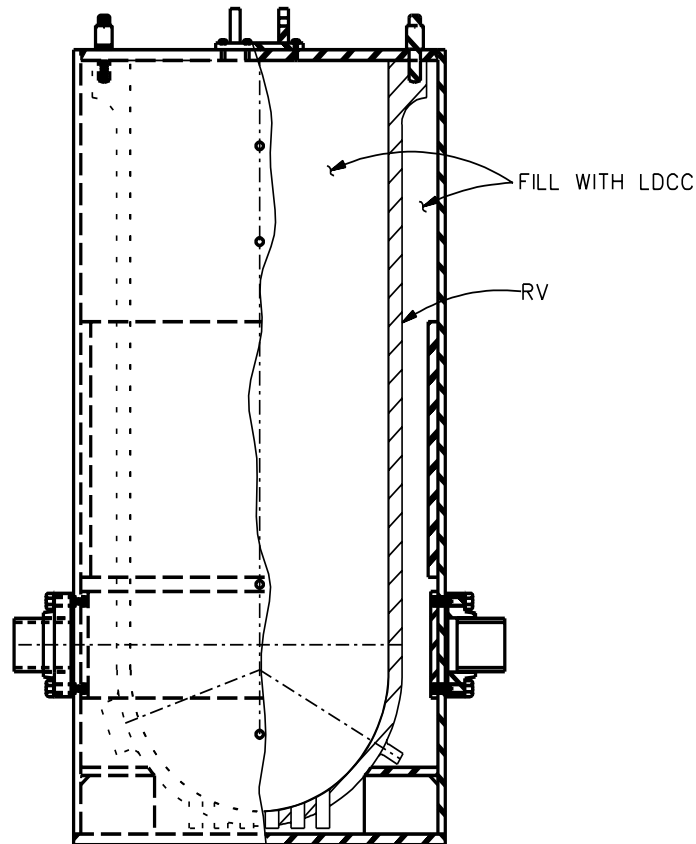
## **DESIGN**

The design excluded the shipment of the RV head, because characterization identified the head was Class 'A' waste and therefore separate shipping and disposal of the head provided cost savings. The cost savings benefited both BNFL Inc, in terms of reduced fabrication and transportation costs associated with the RVTS, and to CECo, associated with reduced disposal costs at Barnwell, due to reduced container volume.

The 'headless' RV allowed for the design of a shipping container top cover plate (TCP) that performed two duties, one during the RV removal phase and the other during shipment and disposal phases. During the removal phase the TCP was designed to fit onto the RV flange itself utilizing 14 modified RV head studs.

The RV head was bolted onto the RV using 42 studs during its operation. Early RVTS design calculations identified that 14 of the 42 original studs would be required to provide the structural support necessary to lift the RV out of its cavity for placement into the container and support the shipping needs. Due to the thickness of the TCP, which was 4", the thickness needed to provide the radiological shielding necessary to meet shipping criterion, the required 14 studs would need to be shortened, reduced in diameter and rethreaded. This ensured that the use of the existing studs would be 'clean' for reuse in

radiological terms. The TCP itself would be secured to the RV via new cap studs that would be snug tightened onto the TCP and welded in place to ensure a secure leak seal. The unused 28 studs were cut back flush with the RV flange. The stud cutting and re-threading work was completed by PCI. Services a Westinghouse / BNFL subsidiary based in Chicago.



## PACKAGE GENERAL CONFIGURATION

The TCP had a detachable lifting lug installed in the center that served as a crane connection to lift the RV out of its cavity, to allow the once located container to be down ended. It was also removable to allow for the locating bolt holes to be utilized as grout injection ports to enable the RV internal volume to be fully grouted. Once the RV was grouted the lifting lug holes/grout injection ports were plugged and seal welded closed by PCI to ensure no leak paths were present.

Grouting was necessary to ensure that any potential loose contamination present both in the RV and in the volume between the RV and the container would be fixed during transportation and also to provide additional radiological shielding to maintain shipping dose levels beneath the prescribed limits. The grout utilized was a low density cellular concrete (LDCC) provided by AEC Engineering from Haverhill, Massachusetts.

During the shipment phase the TCP provided the obvious closure to the container. The closure was completed by a very unique 4" deep 'J' weld, also completed by PCI, which actually required 1220lb of filler material, 3 robotic machines and round the clock working for 6 days to complete. The welding was completed and inspected to the requirements of the appropriate subsections NB of the ASME Boiler & Pressure Vessel Code.

The TCP itself was a very precisely fabricated and machined component which located within the top 4 1/2" of the container with a maximum peripheral gap of 1/16". This precision fabrication was completed by Precision Components Corporation (PCC) from York, Pennsylvania, who fabricated the complete RVTS to very exacting specifications.

The container was a cylindrical steel shell with welded steel top (TCP) and bottom cover plates. The overall dimensions of the shipping container were approximately 13 feet in diameter and 25 feet long. The container shell was 3" thick with an additional 4" thick shield plate welded to the interior surface of the 3" thick cylinder shell. This interior shield plate was approximately 8 feet long covering the former RV core region. The TCP and bottom cover plates were 4" thick with the container construction material being ASME SA-516 Grade 70. In the bottom of the container, to enable location of the RV once placed within and to locate the TCP adjacent to the top lip area of the container, a support ring, donut, was installed to support the RV bottom head. The total weight of the container when it was loaded with the RV and the LDCC was 565,000 lbs.

During the design phase a number of confirmatory check work activities took place to ensure that the empirical data used was substantiated by actual data. Two noteworthy areas included the obtaining of RV external surface metal samples from the active core region which were analyzed off site to confirm the characterization data previously calculated from the internal measurements taken in 1999. This sample data confirmed that the characterization and associated extrapolations were bounded by the design without excessive margin. The benefit of having this data instilled additional confidence with the regulators in the technical approach, engineering and quality assurance aspect of the project. The second was the use of laser scanning techniques to provide extremely accurate RV bottom head dimensions to allow the fabricator to manufacture and locate the donut support ring in the bottom of the container. This was required to ensure that the RV/TCP location enabled the critical 4" full penetration weld to be performed without the need for either excessive high radiation dose, manual welding once loaded or even worse, the protrusion of the TCP above the top rim of the container.

One of the key requirements for a Type B container under 10 CFR 71 was that it is designed for ambient temperatures as low as -20°F. At this temperature several types of ferritic steels are brittle and subject to fracture. The chosen material, SA-516 Grade 70, has a lowest achievable nil ductility temperature (NDT) in manufacture of -20°F. To ensure the container was not challenged in meeting the 10 CFR 71 requirements BNFL chose to limit the lowest shipping temperature to 0°F to provide a highly defensible margin.

To enable the empty container to be placed into the reactor building containment sphere ahead of RV loading, and its removal once loaded, the container had to be placed into the sphere in the horizontal position then up ended to allow loading of the RV due to access limitations. The container was designed with two detachable trunnions at the lower end to facilitate up and subsequent down ending.

The balance of the RVTS included the road transporter cradle weighing 60,000lb which was bolted onto the back of a Barnhart Crane and Rigging (BCR) provided 18 line Goldhofer trailer. There was also a rail car box beam, weighing 30,000lb, which allowed the shipping container and road transporter cradle to be transferred from the Goldhofer to the rail car (reduced pivot ETMX 1001), provided by Etarco Mammoet, to support the rail journey to Barnwell.

## **FABRICATION**

The fabrication of the RVTS, as stated previously, was completed by PCC. The container and removable trunnions were fabricated and inspected in accordance with ASME Boiler and Pressure Vessel (BPV) Code Section III, Division 1, Subsection NB with the lifting lug in accordance with AISC Manual of Steel Construction and welded per ANSI/AWS D1.1. The road transporter cradle and rail box beam were fabricated and inspected in accordance with ANSI/AWS D1.1. The RVTS was then painted to the requirements of SSPC. The cradle and box beam were fabricated from ASTM A572 Grade 50 carbon steel.

All container fabrication was classified as 'Important to Safety A' (ITS 'A') with the transportation cradles to ITS 'C'. All ITS 'A' fabrication was subjected to the requirement of Quality Assurance as described in 10 CFR 71 Subpart H with CECO providing additional oversight throughout the fabrication evolution.

Despite an extremely tight contract schedule PCC completed their efforts 2 weeks ahead of schedule with the RVTS arriving on site on September 6, 2002.

## **LICENSING**

During the completion of the design phase of the RVTS the PRG had decided to conclude their discussions on the potential to apply for a fully compliant Type B shipping container, i.e. it was felt that there existed an opportunity to license the container without seeking the 30' free fall exemption, a first of a kind. The PRG discussed the approaches available from the analysis perspective and identified and quantified the risks associated with the approach in terms of cost, schedule and probability of success. Key drivers in moving the PRG and the project down this path was the then recently identified costs associated with completely assessing the shipment route, some 1200 miles, and generating the required Probability Risk Assessment (PRA) to support the exemption.

At the September 2000 meeting of the PRG the decision was taken to apply for a fully compliant Type B shipping container. The impact, a complete rework of the structural analysis and calculations based upon using plastic elastic analysis as opposed to the traditionally used inelastic plastic analysis, both approaches being allowed in the NUREG. The basis of the acceptability to use the former was the understanding that if the analysis could demonstrate that the inevitable damage would occur for all the free drop scenarios but that the radiological consequences of such an occurrence were negligible, the case could be made.

Discussions with NRC's regarding then revised strategy were conducted in late November 2000. Eight months later the SAR 'BRP RVP SAR-5339' was issued to the NRC for review and approval. In December a request for additional information (RAI) was received, the response was drafted and issued in January 2002. The NRC issued Certificate of Compliance (CoC) Number 9300, Docket No. 71-9300 with package identification number USA/9300/B(U)-85 on April 8, 2002

## **RV PREPARATION REMOVAL LOADING AND SHIPMENT**

The work completed to enable the RV to be removed, loaded and prepared for shipping included:

- Removal of the RV internals top grid bars and loading them into GTCC containers.
- Removal of the neutron windows and placement into GTCC containers.

- Evaluation of the existing structure for floor load and crane reactions associated with Major Component Removal
- Providing an Opening in the Containment Sphere (the CCA)
- Upgrading the Containment Crane to single failure proof and 125T from 75T
- Removing a Section of the Concrete Pedestal to Facilitate RV Removal
- Removing the Concrete Block Surrounding the RV
- Preparing the Nozzles
- NRC Approval of the BNFL Inc. 10CFR71 Subpart H QA Program
- NRC Approval of the RVTS Shipping Package – Certificate of Compliance issued April 8, 2002, with amendments in July and August 2003.
- Installation of cribbing beneath the RV to provide a contingency for crane failure
- Removing the Stabilizer Arms and Support Brackets
- Removing potential obstructions around the RV/Cavity interface
- Producing and rehearsing RV removal with a full size mock-up
- Producing custom lifting and rigging equipment to support removal, loading and loaded container handling
- During the mock up using lasers to precisely identify the placement location for the container
- Receiving and Placing the RV Shipping Package
- Closure welding of the Shipping Package following RV loading
- Acceptance testing of the Shipping Package prior to shipment
- Liaison with authorities, local, state and federal, to obtain the necessary clearances
- RVTS road and rail shipment to Barnwell, SC
- Disposal and final burial of the RV.

RV removal evaluations were made of the existing structures within the containment sphere to determine that an adequate travel path for a load approaching 600,00lbs existed. The original design loads on the structures did not consider movement of a component, such as the RV and the loaded container and, as a result, BNFL had to install additional shoring to ensure safe load movement once defined load paths had been identified. This work was completed by BNFL early in 2001.

As stated earlier the containers access into and out of the sphere had to be conducted with it in the horizontal position. Notwithstanding this the existing equipment needed enlarging to allow horizontal access. The access was enlarged during 2000 and was designed to withstand seismic and tornado loads by the introduction of substantial additional steel reinforcing around the enlarged access.

In order to lift the RV from its cavity the existing electric overhead traveling crane had to be upgraded to 125 tons. The required upgrade was provided by CECO and incorporates a temporary column/bridge/single failure proof trolley configuration that will be reused at another location during 2004.

When the RV was installed during plant construction it was transported into the sphere on a sled and upended before the cavity was completed. To allow the RV to clear the cavity for removal, in 2001, BNFL created a 4' deep trench in the cavity structure using diamond wire cutting technology. The removed concrete sections were placed into containers and removed from the plant. Additional concrete was also removed around RV pipes to provide access to cut the RV pipes and cap the resulting nozzles and to ensure clearance for removal existed.

The RV had sixty one penetrations of differing diameters ranging from 1 ½" to 20". Each one was capped once the pipes were cut back close to the RV wall using diamond wire, power split ring cutters,

thermal and EDM techniques dependant on location and access restrictions. PCI, WSI and Cutting Edge supported this work which was completed in July 2003.

To ensure clearance for placement of the RV into the container all the pipes were cut back to ensure they were within the 11' 8" diameter envelope of the container. The control rod drive (CRD) tube studs on the RV bottom head were trimmed to within 1 3/4" of the bottom of the RV lower head lowest most point to ensure no interference occurred in that location.

Twelve brackets that are attached to the exterior of the RV shell were connected to the fixed cavity supports by 24 2 1/2" diameter hanger rods, 6 of these were classified as the primary supports and the remaining 18 as secondary. To provide an opportunity to test cutting techniques, etc. without the potential schedule pressure, BNFL performed analyses of these supports with S&L during 2000 to justify the removal of 3 secondaries without jeopardizing the integrity of the RV and its structure. The result was successful and during 2001 BNFL removed the 3 secondaries and proved techniques for removal that were ultimately used for the final removal evolution once the TCP and crane were attached in preparation for the lift during July and August 2003.

Barnhart Crane and Rigging (BCR) managed the removal process. This commenced with the placement of the empty container within the sphere in the horizontal position. To achieve this BCR placed the container onto their hydraulic slide rail system supported by an 'A' frame arrangement at the trunnions and a stool underneath the open end region. The container was then slid into the sphere and upended using a novel rigging arrangement that required no actual fixings onto the container. When the container was in the vertical orientation it was supported by the two trunnions on the 'A' frame and by the installation of support stools and shims beneath the bottom plate. A multi platform scaffold was then built around the container to provide access for welding of the TCP, grouting of the RV internal and radiological surveying. Once the scaffold was built the RV was connected to the crane via the TCP lifting lug and a BCR custom built pin directly onto the crane hook and the RV was removed from its cavity and placed within the container. The removal took a number of days due to the need to remove some unforeseen obstructions and a crane failure that required the RV to be disconnected from the crane.

The removal of the RV from the crane required the design and installation of a support system because of the fact that the RV had had all of its supports removed prior to the lift. BCR, S&L and BNFL designed, fabricated and installed the support system within 3 days of the crane failure allowing CECO to conduct the necessary fault finding and maintenance and returned the crane to service a week later.

Once the RV was placed into the container and confirmed as correctly located, radiological surveys were conducted and PCI commenced the setting up of their equipment to perform the TCP 4" full penetration weld. The equipment consisted of mounting a radial track above the weld area to enable the mounting of 3 remote operated welding machines with onboard cameras that basically crawled backwards and forwards, each over their 120° arc for 6 days with almost no stops, to deposit the 1200 lbs of filler wire, to successfully complete the weld. Additionally the 14 cap nuts were welded to remove potential leak paths through the stud/TCP interface. The required post weld heat treatment and NDE was completed and the PCI equipment and scaffolding was removed in preparation for the next phase, the injection of the LDCC.

To allow the injection of the LDCC into the RV internal void the TCP lifting lug was removed revealing the 12 bolt holes through the TCP. Of these two holes would be used, one for the injection and one for the insertion of a camera to monitor the injection.

## GROUTING OF THE RV AND RVTS ANNULUS

The decision to utilize LDCC for filling of the void space in the RV and the annulus between the RV and the RVTS was based upon current best practice. LDCC is favored because it is lightweight, durable, relatively simple to produce and deliver to the work site, can absorb impact shock and is free flowing, thus can fill voids completely. With these characteristics LDCC offered the potential to produce a stable package with the properties of a homogenous monolith.

The contractor selected for this work was Accurate Engineered Concrete (AEC) of Haverhill, MA, because of their previous experience supporting grouting operations at nuclear facilities and the company's considerable non-nuclear experience of specialist application of LDCC in the construction industry. Additional support was provided by a technical representative from the manufacturer of the foam used, the Mearlcrete division of Cellular Concrete LLC, Roselle Park, NJ.

Technical challenges faced in the production of LDCC are concerned with developing the correct ratio of Portland cement to water and foaming agent, in order to produce a cellular concrete with the appropriate number of air cells per unit area, to meet the density specification and the compressive strength requirements. This requires on the job development of formulations based upon a theoretical model and the vast body of experience represented by AEC and Mearlcrete.

Before proceeding with the grouting project a Commercial Dedication process was performed by BNFL Inc and a Commercial Dedication Plan produced with respect to a nuclear facility or activity licensed pursuant to 10 CFR 71, the Commercial Grade Product became a basic component and classified "Important To Safety, Category – "B". This classification is applied to Structures, Systems and Components and associated activities whose failure or malfunction could result in a condition adversely affecting public safety.

The regulatory guidance for the production and placement of the LDCC into the RV void and RVTS annulus was provided by ASTM C - 495 and a supporting work instruction with clarifications.

The predominant regulatory driver required to be satisfied by the LDCC was a density range of 30 - 36 pounds per cubic foot (pcf) for the RV void space and 50 – 60 pcf for the RV to RVTS annulus, both were required to exhibit a compressive strength of greater than 100 psi after a 28 day cure period. Meeting this requirement ensured the spread of contamination would be minimized in an accident scenario where package integrity was compromised. It also provided a degree of additional radiation shielding. Additional regulatory requirements that were satisfied during the development of the grouting process were:

- Confirmation of placement of the grout and filling of all void spaces, this was achieved by use of remote cameras and lighting, video data logging was employed to record the filling process.
- The water cement ratio (W/C) utilized for both mixtures of LDCC (30-36 pcf and 50 -60 pcf) were such that after curing, the free water remaining was be less than 10%.
- Additionally, the LDCC had nominal thermal conductivity values as follows:  
For the 30 pcf (dry) LDCC:  $K=0.09 \pm 10\%$  BTU/HR-FT-°F  
For the 50 pcf (dry) LDCC:  $K=0.15 \pm 10\%$  BTU/HR-FT-°F

**Note:** Through extrapolation of the of the specific heat capacity of the materials used in the LDCC and the associated densities, the thermal conductivity values are inferred (not measured).

- An ambient temperature range of  $60^{\circ} \leq T \leq 85^{\circ}\text{F}$  was maintained during the placement of LDCC.



The purpose of the Qualification Batching, Placement and Testing was:

- To demonstrate the methodology used to manufacture the LDCC.
- To test the LDCC to ensure the Critical Characteristics for Design (CCD) of the two LDCC mixtures, namely wet cast density and uniformity of placement, would be achieved when performing the actual LDCC injection process at BRP.
- To qualify processes, procedures, materials, equipment and personnel to be used on-site prior to mobilization within the radiological controlled area of the site.

The work performed during grouting of the RV and RVTS annulus included qualification of LDCC in the non-radiological controlled area of the Big Rock Point site and installation of LDCC into the RV and RVTS cask inside the former containment sphere. This consisted of the following:

- Demonstrating qualification of LDCC mix formulations by measurement of the wet cast density using quality assured, calibrated laboratory apparatus.
- Providing test samples in quadruplicate, for testing of the compressive strength at an accredited laboratory.
- Establishing LDCC batch / installation facility.
- Demonstrating qualification of LDCC installation system.
- Installing LDCC into RV.
- Installing LDCC into RVTS annulus outside RV.
- Providing test samples and wet cast density results.
- Demobilizing the LDCC batch/installation facility.

Final placement of the grout involved injecting LDCC at 30-36 pcf wet cast density range into the void space in the RV through the existing penetration holes (12 each, with a 1 1/2" – 6 UNC thread in the top cover plate previously used for the lifting attachment.)

When the LDCC injection was completed and cured. The lifting lug was replaced on the TCP and the loaded container down ended by BCR using a custom designed link arrangement that enabled the combined lowering and sliding of the container to clear the biological shield. Once the container was in the horizontal orientation the crane was disconnected and the link and lifting lug were removed. The 12 lifting lug holes were plugged and seal welded. A scaffold was erected to allow access to grout the area between the RV and the container through 4 LDCC injection ports located on the no uppermost portion of the container.

The second grouting campaign to inject LDCC of 50-60 pcf wet cast density range into the RV and RVTS annulus was performed. The grout was injected into the annulus area through the existing penetration holes (4 each, with a 3" – 4 UNC thread) in the body of the RV container.

Once the LDCC had cured the 4 injection ports were plugged and seal welded shut. The container then became a fully enclosed containment for the RV and exhibited the properties of a homogenous structure.

Final clean up and painting of the container then took place, a further round of radiological surveys performed to confirm dose rates were below the required levels for shipment was performed and the scaffolding removed.

BCR then slid the loaded container out of the sphere and placed it onto the awaiting Goldhofer with the road cradle onboard. Once the loaded container was placed onto the Goldhofer, the support brackets were

adjusted to ensure full contact between the cradle and the container and they were welded into position. Tie ropes were then attached to hold the container down securely onto the cradle and a final set of radiological surveys completed. These surveys showed that the general contact dose rates were below 10% of the shipping limits and that the 2m dose rates were within 5% of said limits.



RVTS being prepared for road shipment

The RVTS was then removed out of the protected area and staged in the parking lot ready for a 03:00 am commencement of road transport from Big Rock Point to the rail siding at Gaylord, Michigan some 52 miles away. The decision to start the road transportation at 03:00 am was to ensure that the shipment went through the local town of Petoskey before rush hour to minimize disruption to the local community. During the RV removal BCR and BNFL worked at the rail siding preparing it for the RVTS road to rail transfer. This activity included the preparation of the siding to allow for the support of the 300T load and the setting up of the BCR overhead slide rail system. Additionally the rail box beam was attached onto the ETMX 1001 rail car in 'just in time' preparation to receive the load.

The road transportation phase took 2 days with full support from the county and state police and the local utilities to provide line lifting, etc. The predetermined and approved route required 3 bridges to be crossed that were not adequate to support the load so BCR installed mobile bridge jumpers just ahead of the arrival of the shipment to ensure no risk to the shipment or damage to the highway occurred. The journey was completed with no issues apart from a situation occurred when one of the half axles on the Goldhofer failed on one of the 18 lines. Because the load capacity of the Goldhofer was approaching twice the load of the RVTS the failed half axle was removed and the journey continued without any further incident.

Once the RVTS arrived at the rail-siding the Goldhofer was parked adjacent to the rail car and the transfer took place over a 2 day period. Once the RVTS was placed onto the rail car the road transporter cradle was welded to the box beam to secure it in place. Final checks were made, radiological surveys completed, bill of lading issued.

At approximately 10:00 am on Tuesday October 14, 2003 the rail journey commenced. Eight days later the RVTS arrived at Barnwell and within the week the RV was placed in the disposal site.

## **CONCLUSION**

The Big Rock Point Major Component Removal Project, currently being performed by BNFL Inc. and its team members, Sargent & Lundy and MOTA, completed the reactor vessel removal in fall of 2003. The challenging multidisciplinary project has benefited from an intensive pre-planning phase and an interactive dialogue with both the client and the regulator. These factors cannot be over emphasized in planning for success in future decommissioning projects.