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L-AREA STS MTR/NRU/NRX GRAPPLE ASSEMBLY CLOSURE MECHANICS REVIEW

Introduction

Reference 1 was issued to have Structural Mechanics (SM) perform a review of the closure mechanics associated with the Shielded Transfer System (STS) MTR/NRU/NRX grapple assembly utilized at the Savannah River Site (SRS). This review was prompted by an operational event which occurred at the Canadian Nuclear Laboratories (CNL) utilizing a DTS-XL grapple assembly which is essentially identical to the STS MTR/NRU/NRX grapple assembly used at the SRS. The CNL operational event occurred when a NRU/NRX fuel basket containing spent nuclear fuel assemblies was inadvertently released by the DTS-XL grapple assembly during a transfer.

The SM review of the STS MTR/NRU/NRX grapple assembly will examine the operational aspects of the STS and the engineered features of the STS which prevent such an event at the SRS. The design requirements for the STS NRU/NRX modifications were provided in Reference 2 and the overall layout of the STS is provided by Reference 3.

Discussion

The SRS receives the NRU/NRX fuel baskets in a Legal Weight Truck (LWT) cask. The LWT cask is lifted and placed onto the LWT Adapter (Reference 4) inside of the STS Dry Well and the Cask Alignment Installation (Reference 4) is utilized to ensure the LWT cask is properly aligned for acceptance of the STS MTR/NRU/NRX grapple assembly (Reference 5). The lid for the LWT cask is removed which exposes the lid of the NRU/NRX fuel basket to allow acceptance of the STS MTR/NRU/NRX grapple assembly. The STS moves the Transfer Cask Assembly (Reference 6) into position directly over the LWT cask with the NRU/NRX fuel basket. The STS MTR/NRU/NRX grapple assembly is lowered into the LWT cask to capture the lid of the NRU/NRX fuel basket utilizing the air operated fingers associated with the STS MTR/NRU/NRX grapple assembly. Once captured, the NRU/NRX fuel basket is lifted into the Transfer Cask Assembly and the STS moves the transfer cask assembly into position over the Shielded Transfer Tube (Reference 7). The NRU/NRX fuel basket is lowered from the transfer cask assembly through the shielded transfer tube into the Fuel Basket Carriage Assembly (Reference 8). The lid of the NRU/NRX fuel basket is released by the STS MTR/NRU/NRX

grapple assembly and the NRU/NRX fuel basket remains in the fuel basket carriage assembly for further processing and movement utilizing hand tools.

The alignment of the LWT cask with the STS is assured to be within the specified tolerances utilizing the LWT adapter and the cask alignment installation. The alignment is critical because the STS MTR/NRU/NRX grapple assembly and the NRU/NRX fuel basket are required to travel along the guide keys provided in the LWT cask, the Transfer Cask Assembly, and the Shielded Transfer Tube. In addition to the visual cues previously identified, Forward Stop and Reverse Stop Limit Switches are utilized on the drive system of the STS as shown on Reference 9. The Forward Stop and Reverse Stop Limit Switches control the positional alignment of the STS transfer cask assembly over the LWT cask or the Shielded Transfer Tube.

The alignment of the STS MTR/NRU/NRX grapple assembly directly over the NRU/NRX fuel basket is accomplished by the previously mentioned guide keys, the upper and lower guides on the STS MTR/NRU/NRX grapple assembly (Reference 10) and the guide on the NRU/NRX fuel basket along with the guide on the NRU/NRX fuel basket lid (Reference 18), the two (2) guide arms of the STS MTR/NRU/NRX grapple assembly (Reference 10) and the two (2) guide arm receivers on the NRU/NRX fuel basket lid, and the square base of the guide plate (References 5 and 11) of the STS MTR/NRU/NRX grapple assembly and the square receiver opening of the NRU/NRX fuel basket lid (Reference 18). The alignment of the STS MTR/NRU/NRX grapple assembly on top of the NRU/NRX fuel basket lid can be visually verified by the camera located at the top of the Transfer Cask Assembly (Reference 12) in the Cap Assembly (Reference 13).

Prior to contact of the STS MTR/NRU/NRX grapple assembly with the NRU/NRX fuel basket lid, the fingers (Reference 14) utilized for lifting are placed into the open position utilizing an air operated cylinder by applying air pressure into the lower port of the air cylinder and compressing the springs located between the actuator plate weldment and the guide plate weldment. The open position of the fingers can be visually verified utilizing the camera located on the STS MTR/NRU/NRX grapple assembly along with the adjustable arrows, indicator base on the guide plate, and the markings on the actuator plate weldment (Reference 5).

Contact of the STS MTR/NRU/NRX grapple assembly with the NRU/NRX fuel basket lid can be verified with the load cell located at the top of the Transfer Cask Assembly (Reference 12). In addition to the load cell, visual verification of contact of the MTR/NRU/NRX grapple assembly with the NRU/NRX fuel basket lid can be achieved utilizing the camera located on the STS MTR/NRU/NRX grapple assembly (Reference 5). The STS MTR/NRU/NRX grapple assembly camera can see a bottom portion of the grapple guide assembly, a bottom portion of grapple guide arm, and the bottom of the camera side fingers utilized for lifting the NRU/NRX fuel basket (References 5 and 10).

After contact of the STS MTR/NRU/NRX grapple assembly with the NRU/NRX fuel basket lid, the fingers (Reference 14) utilized for lifting are placed into the closed position utilizing an air cylinder by releasing the air pressure from the lower port of the air cylinder and uncompressing the springs located between the actuator plate weldment and the guide plate weldment. The springs located between the actuator plate weldment and the guide plate weldment force the actuator plate weldment and the guide plate weldment to separate and place the fingers utilized for lifting the NRU/NRX fuel basket into the

closed position. The closed position of the fingers can be visually verified utilizing the camera located on the STS MTR/NRU/NRX grapple assembly along with the adjustable arrows, indicator base on the guide plate, the markings on the actuator plate weldment, and the engagement of the camera side fingers utilized for lifting the NRU/NRX fuel basket with the NRU/NRX fuel basket lid.

The NRU/NRX fuel basket is lifted into the Transfer Cask Assembly with weight verification performed by the load cell located at the top of the Transfer Cask Assembly. The height of the lifted NRU/NRX fuel basket is controlled by the Hoist Full Up Limit Switch as shown on Reference 9. The location of the NRU/NRX fuel basket inside the transfer cask assembly can be visually verified by the camera located at the top of the Transfer Cask Assembly in the Cap Assembly.

After lifting the NRU/NRX fuel basket into the Transfer Cask Assembly, the STS moves from the position directly over the LWT cask to a position directly over the Shielded Transfer Tube. The Transfer Cask Assembly position over the Shielded Transfer Tube is aligned using the previously mentioned end of travel limit switches on the STS drive system. The STS MTR/NRU/NRX grapple assembly with the NRU/NRX fuel basket is lowered through the Shielded Transfer Tube with alignment maintained by the previously mentioned guide keys. The NRU/NRX fuel basket is lowered into the Fuel Basket Carriage Assembly (Reference 15). Contact of the NRU/NRX fuel basket with the Fuel Basket Carriage Assembly can be verified with the load cell located at the top of the of the Transfer Cask Assembly. Additionally, contact can be visually verified by the one (1) of the STS operators through the L Basin water. Once contact is verified, the fingers utilized for lifting the NRU/NRX fuel basket are placed into the open position utilizing an air operated cylinder by applying air pressure into the lower port of the air cylinder and compressing the springs located between the actuator plate weldment and the guide plate weldment. The open position of the fingers can be visually verified utilizing the camera located on the STS MTR/NRU/NRX grapple assembly along with the adjustable arrows, indicator base on the guide plate, and the markings on the actuator plate weldment. The STS MTR/NRU/NRX grapple assembly is lifted up into the transfer cask assembly and the STS is moved back to a position over the LWT cask to allow further processing of the NRU/NRX fuel basket.

Now that the operational aspects and engineered features have been reviewed, the analysis and design of the STS MTR/NRU/NRX grapple assembly can be reviewed.

Reference 2 considered the STS MTR/NRU/NRX grapple assembly to be below-the-hook rigging, Category A, Service Class 0 per ASME BTH-1 while the remaining components of the STS Hoisting System were required to be Single Failure Proof with previously accepted dual load paths or two (2) times normal factors of safety accepted. Reference 17 utilized a rounded design weight of 1,100 lbs for a loaded NRU/NRX fuel basket which is less than the rated capacity of 2,500 lbs for the STS grapple assembly. The new STS grapple Assembly for MTR/NRU/NRX, as analyzed and designed in Reference 17, maintains the rated capacity of the STS grapple assembly as 2,500 lbs and is marked to be used for MTR/NRU/NRX fuel baskets. The fingers utilized for lifting the NRU/NRX fuel basket are analyzed and designed in Reference 16. Reference 16 checks the fingers for adequacy in accordance with ANSI N14.6 using only two (2) of the four (4) fingers utilized for lifting of the rated capacity which is 2,500 lbs. The fingers utilized for lifting of the rated capacity have a calculated Von Mises Stress of 24,300 psi versus an Allowable Stress of 27,000 psi ($S_u/5$) with a margin of safety equal to 0.11 in terms of allowable. The fingers utilized for lifting a NRU/NRX fuel basket, using the same methodology, would

be stressed to a Von Mises Stress of 10,692 psi versus an Allowable Stress of 27,000 psi with a margin of safety equal to 1.52 in terms of allowable.

The operational event which occurred at the CNL caused the generation of a white paper by NAC International (Reference 19), a CNL Memo (Reference 20), and a CNL Assessment (Reference 21). These References were reviewed by SM for applicability to the STS MTR/NRU/NRX grapple assembly. Reference 19 and Reference 20 conclude that DTS-XL grapple meets the requirements of ASME B30.20 and/or ASME BTH-1. Reference 19 and Reference 21 conclude that the DTS-XL grapple is designed such that the lifted load on the fingers results in a moment that wants to open the grapple and that the grapple requires the use of friction to prevent the DTS-XL grapple from opening. Additionally, Reference 21 concludes that the springs are stressed beyond the requirements of ASME BTH-1, the springs are compressed beyond the manufacturer's recommendation, the springs are required to ensure an acceptable margin against the opening of the DTS-XL grapple, and a relatively small side load may allow the DTS-XL grapple to open.

SM has performed an analysis of the operational requirements similar to those performed in Reference 19 and Reference 21 for the STS MTR/NRU/NRX grapple assembly. This analysis utilized the design requirements for the STS MTR/NRU/NRX grapple assembly and the rated capacity of 2,500 lbs. The analysis does not utilize the associated springs as a component of the lifting device such that the spring forces are not utilized to maintain closure of the lifting fingers of the STS MTR/NRU/NRX grapple assembly. The springs are only utilized to perform the closure operation of the lifting fingers of the STS MTR/NRU/NRX grapple assembly on the NRU/NRX fuel basket lifting lugs until the NRU/NRX fuel basket is lifted. For the closure operation, the springs are not required to meet the requirements of ASME BTH-1. Once the NRU/NRX fuel basket is lifted, a static coefficient of friction of 0.12 is capable of holding the lifting fingers of the STS MTR/NRU/NRX grapple assembly in position to maintain closure on the NRU/NRX fuel basket which is less than the static coefficient of friction for lubricated metal on metal of 0.15 (Reference 19). The friction force does not affect the analysis of the lifting finger of the STS MTR/NRU/NRX grapple assembly performed in Reference 16 since the lifting finger does not provide resistance to the opening of the STS MTR/NRU/NRX grapple assembly. The resistance to opening of the STS MTR/NRU/NRX grapple assembly utilizing the friction force is provided by the lifting lugs of the NRU/NRX fuel basket. Each lifting lug of the NRU/NRX fuel basket resists equal and opposite friction forces which are side loads on the lifting lugs of the NRU/NRX fuel basket. The analysis of the NRU/NRX fuel basket is outside the scope of this document since the NRU/NRX fuel basket is owned by NAC International but the side loads caused by the friction forces are small (approximately 147 lbs for the rated load of 2,500 lbs). Although a positive closure mechanism is preferred, it is not required and the use of the friction forces to maintain closure of the lifting fingers of the STS MTR/NRU/NRX grapple assembly on the NRU/NRX fuel basket is acceptable.

Differences between the DTS-XL grapple and the STS MTR/NRU/NRX grapple assembly have been identified by SM. One main difference between the DTS-XL grapple and the STS MTR/NRU/NRX grapple assembly is the installation of a plug in the upper port of the air operated cylinder of the DTS-XL grapple. The plug may generate a vacuum in the air operated cylinder depending upon when the plug was installed into the upper port of the air operated cylinder and this may increase the finger closure time as air bleeds around the piston of the air operated cylinder.

Another main difference between the DTS-XL grapple and the STS MTR/NRU/NRX grapple assembly is that the DTS-XL grapple operates free in the CNL basin water with closure of the fingers confirmed by a handheld underwater camera while the STS MTR/NRU/NRX grapple assembly is guided throughout the entire operation of the STS MTR/NRU/NRX grapple assembly and closure of the fingers is confirmed by a camera directly mounted to the STS MTR/NRU/NRX grapple assembly.

Conclusion

Based upon the review of the operational aspects associated with the STS MTR/NRU/NRX grapple assembly, the engineered features associated with the STS MTR/NRU/NRX grapple assembly, and the analysis and design of the STS MTR/NRU/NRX grapple assembly, SM concludes that STS System with the STS MTR/NRU/NRX grapple assembly is safe to operate in the current configuration since the engineered features and operation preclude an operational event similar to that which occurred at the CNL. Additionally, the use of the STS MTR/NRU/NRX grapple assembly for additional fuel baskets (MTR, SLOWPOKE, etc…) is deemed safe for operations even though various aspects of the grapple assembly/fuel basket interface are different. The NRU/NRX fuel basket was selected as the basis for the justification for continued operation based upon the fact that the NRU/NRX fuel basket bounds all other currently authorized fuel baskets in weight by a considerable margin.

References:

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3. Vendor Print File 0000141257-000045, Revision DE1, NAC International Drawing 610-100, STS Modifications, L-Basin
4. Vendor Print File 0000141257-000050, Revision DE1, NAC International Drawing 610-130, Cask Location and Alignment, L-Basin
5. Vendor Print File 0000141257-000047, Revision DE1, NAC International Drawing 610-120, Grapple Assembly, L-Basin
6. Vendor Print File 0000141257-000021, Revision DE1, NAC International Drawing, 610-003, Transfer Cask Assembly, L Basin
7. Vendor Print File 0000141257-000022, Revision DE1, NAC International Drawing, 610-004, Shielded Transfer Tube, L Basin
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9. Vendor Print File 0000141257-000069, Revision A, NAC International Drawing Provided by Control Logic, Shielded Transfer System, Control Device Layout and Notes
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13. Vendor Print File 0000141257-000046, Revision DE1, NAC International Drawing 610-110, Cap Assembly, Transfer Cask, L-Basin
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17. Vendor Print File 000014157-000091, Revision A, NAC International Calculation 65009200-2002, Revision 7, L-Basin STS NRU/NRX Fuel Basket Load Analysis
18. Vendor Print File 000014157-000095, Revision B, NAC International Calculation 65007700-2000, Revision 1, NRU/NRX Basket and Spacer Assemblies Structural Evaluation
19. NAC Document Number 50033-WP-04, Revision 2, DTS-XL Grapple Load Path Evaluation during Lift of NRU/NRX Basket
20. Canadian Nuclear Laboratories Document Number 361103-101710-021-000-0012, Revision 1, Review of NAC DTS_XL CNL F-088 Flask Grapple Design
21. Canadian Nuclear Laboratories Technical Document Number 361103-101710-450-000, Revision 0, DTS-XL Grapple Assessment

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