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NRIC DOME Crane Trade Study and Recommendation

May 2024

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Idaho National Laboratory

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M3RC-24IN0203016: Complete trade study and recommendation of crane option (gantry or polar)

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NRIC National Reactor Innovation Center

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REVISION LOG

Revision No.	Date	Affected Pages	Description
0	05/28/2024	All	New Report.

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ACRONYMS

DOE	U.S. Department of Energy
DOME	Demonstration of Microreactor Experiments
EBR II	Experimental Breeder Reactor II
INL	Idaho National Laboratory
MFC	Materials and Fuels Complex
NEICA	Nuclear Energy Innovation Capabilities Act
NRIC	National Reactor Innovation Center

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1. BACKGROUND

The National Reactor Innovation Center (NRIC) is a national program that was established as part of the Nuclear Energy Innovation Capabilities Act (NEICA). NRIC's mission is to accelerate the demonstration and deployment of advanced nuclear energy through its mission to inspire stakeholders and the public, empower innovators, and deliver successful outcomes through efficient coordination of partners and resources. NRIC is designed to bridge the gap between research, development, and the marketplace to help convert some of the nation's most promising advanced nuclear reactors into commercial applications.

The NRIC Demonstration of Microreactor Experiments (DOME) facility, formerly known as Experimental Breeder Reactor II (EBR II), located at the Materials and Fuels Complex (MFC) at the Idaho National Laboratory (INL) is intended to allow industrial and other partners the opportunity to test Advanced Microreactors up to 20MW thermal power.

The 75-ton capacity polar crane located in the EBR II facility was rendered inoperable to support planned facility demolition in 2015; small holes were flame cut in the girders; hoists and cables were removed; oil was drained from gear boxes; trolley drive, and then filled with absorbent; and the electrical and control umbilical's were disconnected, removed and disposed. Subsequently, the decision was made to convert the EBR II facility into the DOME test bed.

1.1 Purpose

The purpose of this report is to document the results of the DOME crane trade study performed by MPR and to provide a recommendation for the crane that will be used to support the testing of advanced microreactors in the DOME test bed.

2. DISCUSSION

In 2024, NRIC contracted with MPR to perform a crane trade study and to provide a recommendation for the crane to be used in DOME. MPR provided the report, Crane Recommendation for the DOME facility (Appendix A), which considered the various crane options: forklifts / reach stackers, mobile crane, free standing bridge crane and the repair of the existing DOME polar crane.

The recommendation is for the existing DOME polar crane to be refurbished instead of implementing other lifting options. The polar crane is recommended due to the numerous advantages it has over the other lifting options. For details of the crane trade study and functional parameters considered, see MPR's report in Appendix A Crane Recommendation for the DOME Facility

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Appendix A.

Crane Recommendation for the DOME Facility

Crane Recommendation for the DOME Facility

RECORD OF REVISIONS		
Revision Number	Pages/Sections Revised	Revision Description
0	All	Initial Issue.

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1.0 Purpose

The purpose of this document is to provide a recommendation for the crane that should be provided by the National Reactor Innovation Center (NRIC) for the Demonstration of Microreactor Experiments (DOME) facility.

2.0 Background

NRIC is refurbishing the Experimental Breeder Reactor II containment structure (now called DOME) for new reactor experiments. As part of the refurbishing process, the existing polar crane needs to be repaired or replaced by an alternate crane (e.g., gantry crane) because lifting capability is needed to support equipment installation and removal. This document evaluates different crane options and makes a recommendation on how to restore lifting capability to the DOME facility.

3.0 Recommendation

The existing polar crane in the DOME facility should be refurbished instead of implementing other lifting options such as bridge cranes, mobile cranes, or forklifts. The polar crane is recommended due to the numerous advantages it has over other lifting devices (see Section 5.0).

Furthermore, the existing polar crane should be refurbished to ASME NOG-1 standards to support critical lifts. Lifts are "critical" when they can directly or indirectly cause a release of radioactivity (Reference 2).

If critical lifts will not be performed in the DOME facility, the polar crane could be refurbished to CMAA Spec 70 standards to save roughly $1.5M to $2.5M in cost (see Table 5-2).

4.0 Considerations and Requirements for Lifting

4.1. Functional

The following functional considerations should be made when selecting a lifting device:

- 15 ton lifts are anticipated for fueling and defueling (Reference 1).
- 5 to 32 ton lifts are anticipated for reactor supplemental shielding assembly (Reference 1).
- To accommodate critical lifts, design loads need to be increased (e.g., 15%) when selecting parts subject to degradation due to wear and exposure (Reference 3).
- 37 feet and 10 inches of clearance between the floor and the lifting hook is expected to be needed (Reference 1).
- Precise lifting placement and slow lifting speeds will be needed.
- The lifting device will have long idle periods.
- Some lifts will likely approach the total capacity of the lifting device, while the majority of lifts are expected to be significantly less than the total lifting capacity.

- The lifting device must fit through equipment hatch and operate efficiently within the confines of the DOME facility.
- The lifting device must enable efficient workflow to meet reactor experiment timelines (e.g., 12 months between setup and removal). Higher lifting capacities can reduce the total number of lifts needed. Wider lifting areas can reduce the number of times the lifting device needs to be repositioned.

4.2. Regulatory

Critical lifts occur when failure can directly or indirectly cause a release of radioactivity (Reference 5). No credible lift failure can result in the potential for releases of radioactive material exceeding 10 CFR 835 dose limits. Therefore, critical lifts can only be performed when a) failures are shown to not exceed 10 CFR 835 dose limits or when b) lift failure is not a credible scenario.

If the lifting device complies with the guidance given in Reference 3, including a single-fault-tolerant design, then failure is not a credible scenario.

The lifting device should enable adherence to NUREG-0612 guidelines (Reference 5) on lifting heavy loads at nuclear plants. For example, the guidance provided on planning safe load paths, developing lifting procedures, and proper training.

5.0 Comparison of Lifting Options

5.1. Overview

Table 5-1 compares the functional capabilities of different lifting options for the DOME facility. The main functional take-aways are:

- The only lifting option that fulfills all needs is the ASME NOG-1 polar crane.
- If critical lifts do not need to be performed in the DOME facility, then the only lifting options that could fulfill needs are the polar crane or the free-standing bridge crane. However, the polar crane is a much more attractive option.
- The mobile crane can be ruled out solely based on footprint.
- The forklift and reach stacker can be ruled out solely based on lift capacity and lift precision.

Table 5-2 compares the cost of refurbishing the polar or installing a free standing bridge crane for the DOME facility.

Table 5-1. Comparison of Crane Options for the DOME Facility

Function	Scoring (1)					
	Polar (2)		Free Standing Bridge		Mobile	Forklift
	NOG-1	CMAA Spec 70	NOG-1	CMAA Spec 70		
Lift Capacity	5 (75 to 140 ton)	5 (75 to 140 ton)	5	5	2 (6.3 to 19.7 tons)	2 (25 ton)
Lift Height	5 (38.5 ft)	5 (38.5 ft)	3 (34.8 ft)	3 (34.8 ft)	3 (36 ft)	1 (10.25 ft)
Lift Coverage	5 (Figure 5-7)	5 (Figure 5-7)	2 (Figure 5-6)	2 (Figure 5-6)	2 (Figure 5-4)	2 (Figure 5-2)
Lift Velocity (3)	5 (1.7 in/min)	5 (1.7 in/min)	5	5	3	1
Footprint	5 (Figure 5-7)	5 (Figure 5-7	3 (Figure 5-6)	3 (Figure 5-6)	1 (Figure 5-4)	1 (Figure 5-2)
Single Failure Proof	5	0	5	0	0	0
Efficiency (4)	5	5	2	2	2	2
Total Score	**35**	**30**	**25**	**20**	**13**	**9**

Note:

1. Score of 0 to 1: least desirable or does not fulfill needs.
   Score of 2 to 3: could fulfill needs if accommodations are made or additional design restrictions are made.
   Score of 4 to 5: most desirable. Meets or exceeds needs.
2. The polar crane values in this table are associated with main hoist. The auxiliary hoist of the polar crane can lift smaller loads (5 tons) to higher elevations (44 ft).
3. Slow and controlled lift velocity is important for the precise placement of heavy objects.
4. Quantity of operations needed to complete reactor experiment setup and teardown.

Table 5-2. Cost Estimates for Cranes in the DOME Facility

Vendor	Polar Crane (1)		Free-standing Bridge Crane (2)
	NOG-1	CMAA Spec 70	NOG-1
American CRANE	\$5.0M - \$5.5M	\$2.5M - \$3.0M	-
KONECRANES	\$4.5M	\$3.0M	\$5M
PAR Systems	-	\$9.5M	-

Notes:

1. Reference 12.
2. Reference 9.

5.2. Forklifts and Reach-Stackers

A forklift and reach-stacker are shown in Figure 5-1 for reference. The Hyster H550-700XD forklift is considered when assessing the feasibility of forklifts in DOME. The pertinent features of this forklift is listed below.

- Lifting Capacity: The capacity of a forklift truck that can fit into the DOME is 25 to 32 tons (Reference 9).
- Lifting Hook Height: The lifting height of a forklift truck is 10 feet 3 inch to the top of the fork (Reference 10).

- Lifting Coverage Area: The maneuverability of a forklift inside DOME will be very difficult when considering the relatively small space available (see Figure 5-2).
- Lifting Precision: Reach stackers are expected to be a better alternative to forklifts. However, forklifts and reach stackers have low precision when compared to the other lifting devices considered in this document.
- Footprint: The size of a forklift truck is roughly 29.2 ft × 10.5 ft × 10.3 ft (not extended) (Reference 9).
- Single Failure Proof: This feature is not available with forklifts.
- Efficiency: The rate at which reactor experiments can be assembled is expected to be low when using a forklift due to the lower capacity, larger footprint, lower precision, and lower coverage area.

Figure 5-1. Forklift (left), Reach-Stacker (Right)

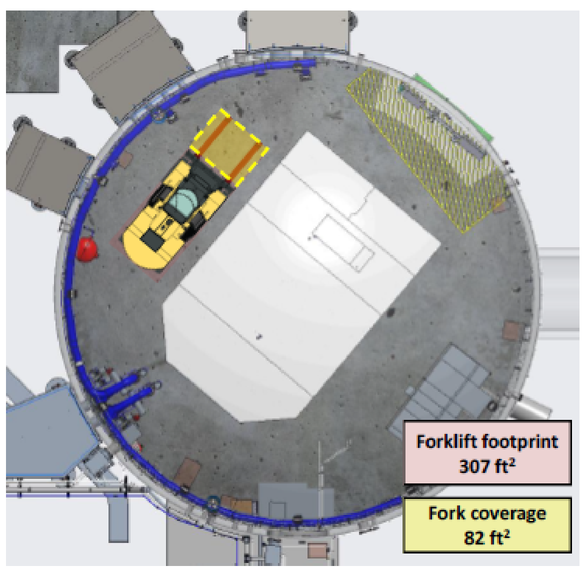

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Figure 5-2. Forklift in DOME

5.3. Mobile Cranes

A mobile crane is shown in Figure 5-3 for reference. The Liebherr LTC 1050-3.1 mobile crane is considered when assessing the feasibility of mobile cranes in DOME. The pertinent features of this mobile crane is listed below.

- Lifting Capacity: The nameplate capacity of a boom type mobile crane would likely need to be in the 50 to 100 ton range to accommodate the height and reach required for Dome applications.
- Lifting Hook Height: The capacity of the mobile crane would be around 19.7 ton at 23 ft horizontal extension offering a 23 ft radius coverage at that capacity and at a 36 ft vertical extension (Reference 11).
- Lifting Coverage Area: The maneuverability of a mobile crane inside DOME will be very difficult when considering the relatively small space available (see Figure 5-4).
- Lifting Precision: Mobile cranes have reduced precision.
- Footprint: This type of mobile crane is designed as a compact crane but will occupy a significant amount of space: The size of the mobile crane considered is 34 ft x 14ft 5in without considering the extended side.
- Single Failure Proof: Mobile cranes do not adhere to ASME NOG-1 standards. Therefore, a mobile crane could not be used for critical lifts unless additional work was done to show that failure of the lift is not credible or would not exceed 10 CFR 835 dose limits.
- Efficiency: The rate at which reactor experiments can be assembled is expected to be low when using a mobile rate due to the lower capacity, larger footprint, lower precision, and lower coverage area.

Figure 5-3. 50t Mobile Crane

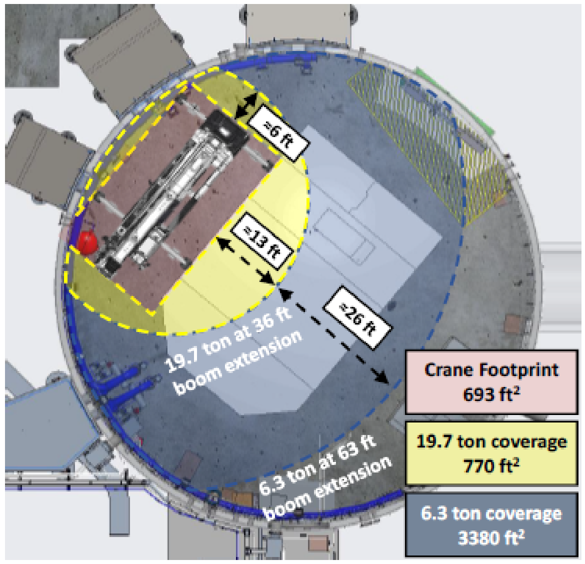

Figure 5-4. Mobile Crane in DOME

5.4. Free Standing Bridge Cranes

A free standing bridge crane is shown in Figure 5-5 for reference. The pertinent features of a free standing bridge crane are listed below.

- Lifting Capacity: Free-standing bridge cranes have adequate capacity for DOME applications.
- Lifting Hook Height: The maximum hook height in the DOME would be limited to 34 feet 10 inches. This is because the bottom of the polar crane corbel is at 41 feet 10 inches and a free standing bridge crane rated for 40t will need about 7 feet between the hook height and the lowest structure above the bridge crane (Reference 8).
- Lifting Coverage Area: The free-standing bridge crane only covers the central area of the DOME (see Figure 5-6).
- Lifting Precision: Free-standing bridge cranes can have slow feed rates and precise positioning.
- Footprint: A top running bridge crane would require the installation of crane rails and their vertical support posts, with plant equipment designed to be positioned around them.
- Single Failure Proof: Free standing bridge cranes that adhere to ASME NOG-1 standards are commercially available, enabling critical lifts.

- Efficiency: Bridge cranes have a high lift capacity, which can reduce the total number of lifts needed. However, the limited hook coverage means that another crane will be needed to make lifts that are outside the reach of the bridge crane (see Figure 5-6). This will slow the rate of work within DOME.

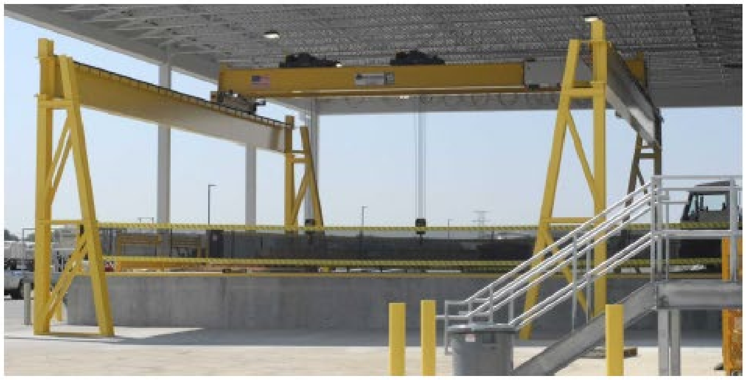

Figure 5-5. Free Standing Bridge Crane

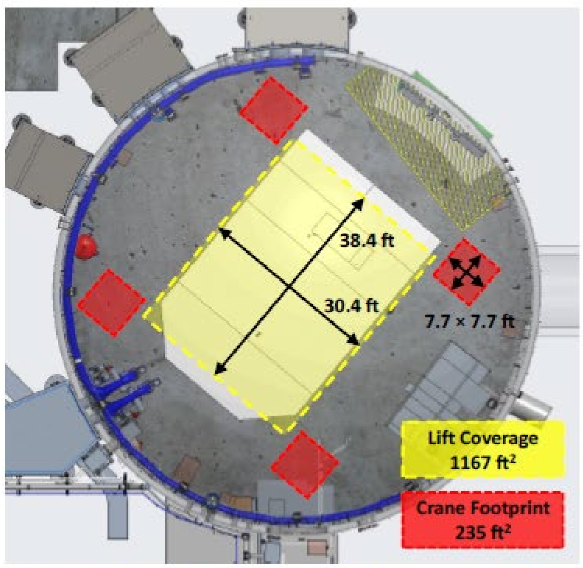

Figure 5-6. Free Standing Bridge Crane in DOME

5.5. Polar Crane

The pertinent features of the polar crane are listed below.

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- Lifting Capacity: The 75 ton capacity of the polar crane is sufficient for DOME applications (Reference 1).
- Lifting Hook Height: The polar crane has a hook height 38 feet 5 inches (Reference 4).
- Single Failure Proof: The polar crane can be refurbished to ASME NOG-1 standards, enabling critical lifts.
- Lifting Precision: Polar cranes can have slow feed rates and precise positioning.
- Lifting Coverage Area and Footprint: The polar crane would reach a wider area and use less floor space than all other lifting options in the DOME facility (see Figure 5-7).
- Efficiency: The rate at which work can be performed is maximized by the polar crane.

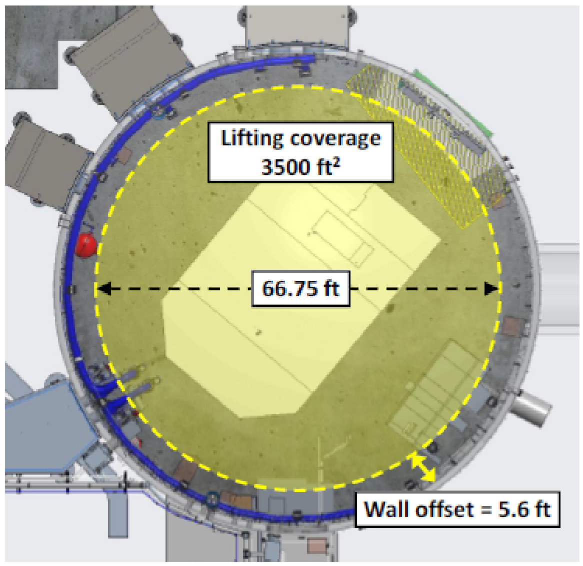

Figure 5-7. Polar Crane in DOME

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