SUPPORTS AND INSTALLATION SYSTEM OF THE RHIC SUPERCONDUCTING MAGNETS

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Abstract

The Relativistic Heavy-Ion Collider that is currently under construction at Brookhaven National Laboratory is composed of hundreds of superconducting magnets. A careful study was done in order to support and install these magnets inside the RHIC tunnel systematically and efficiently. A basic systems-approach was pursued and primary consideration was given to develop a system that would not be only both economical and efficient but also well-suited to a fast-paced production environment. This report will present a description of the design of the magnet stands and the magnet transport and installation system, the procurement and fabrication phase, and then finally, the experience gained in implementing the system. In summary, the system turned out to be very efficient and cost-effective far beyond our expectations.

1 MAGNET STANDS

Although the original plan was to provide three vertical supports for the 6-ton, 33-ft. long arc dipoles, i.e. two end stands and one in the center, after a thorough finite-element study, I recommended eliminating the center support since the results showed a reasonably acceptable vertical sag. (The dipole cold mass, however, still retained its 3-point vertical support inside the vacuum vessel). Without the center support, the savings would be significant owing to the fact that there would be a few hundred dipoles.

The recommendation was accepted, but in addition, it was also decided that all the magnets may have the same stands. Therefore, although, there were a few design alternatives that were considered and studied, for an optimized, cost-effective design geared towards production quantities, the most attractive choice was a *casting.*

1.1 Design, Fabrication, and Procurement

The primary structural requirement was to support the magnet dead weight as well as the axial forces that might result from a worst-case scenario triggered by a magnet quench, vacuum failure, etc. The dipole was estimated to weigh 6 tons; the worst-case axial force was estimated to be also about 12,000 lbs. Based on these loads, a conceptual casting design was made, and a finite-element study was undertaken. I chose ductile iron, specifically ASTM A536 Gr 80-55-06, owing to its superior strength and corrosion resistance over gray iron.

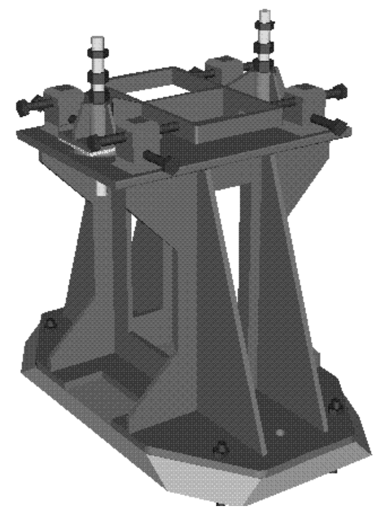

Figure 1: Magnet Stand (Solid Model)

The solid model of the casting is shown in Fig. 1. The figure shows also the adjusting slider and the x-y-z adjusting screws that would enable the surveyors to position the superconducting magnets accurately.

When the design was approved after the final design review, detailed fabrication drawings were made, and then the procurement process began. Without going into details, which would be irrelevant for this report anyway, the magnet stands were finally fabricated and delivered well on schedule by a reputable company in Orange, Massachussets, U.S.A., called Rodney Hunt Co. who did an excellent job for us.

1.2 Installation

The installation of the magnet stands was done by the Collider Ring Division's Survey Group. First, they laid out the Rhic ring, and then using a template of the magnet stand footprint they installed the 3/4-inch Hilti-Drop-In anchors, and subsequently, the anchor bolts. At some locations, special “maxibolts” from Drill-Co, another company from Long Island, New York, were added in order to absorb the expected greater pull-out loads due to a large unbalanced force on the warm-to-cold transition. Next, the magnet stands were positioned into place, leveled, and then set to a specified elevation. Subsequently, the base was grouted to the tunnel floor.

The installation group added the additional hardwares, i.e. the adjusting sliders and the x-y-z jacking screws. After this last step, the stands were ready to accept the magnets.

By the end of June, 1995 all of the required magnet stands were fully installed.

2 TRANSPORTERS

Having completed the design of the magnet stands, the next step was to design the magnet transporters. There would be no overhead cranes available inside the Rhic tunnel for magnet installation, so the transporters would serve also as the main installation mechanism to install the magnets into the stands.

The primary parameters in the design of the transporters were the following:

- Structural integrity: The transporters should not only be strong, durable and rugged enough to carry repeatedly the prescribed load, they should be designed to assure safety of the personnel who would be installing the magnets,
- Adjustability and maintainability: The transporters should be modular, adjustable, and maintainable since they would be subjected to repeated load cycles as hundreds of Rhic magnets were going to be installed; In addition, they would have to be usable in the future, when a necessity might arise to remove and replace some ring magnets,
- Cost-effectiveness: The transporters should be simple, and easy and convenient to use in order to minimize actual magnet installation time, thus maximising the number of magnets that could be installed in a given day to save installation labor cost. Considering the difficulties facing us then, the design objective was to install at least 2 magnets in an 8-hr. day.

Another aspect that also controlled the transporter design was the fact that there are only 3 specific locations, namely 4:00 o’clock, 8:00 o’clock, and 12:00 o’clock, that would allow us to install/remove magnets. These entry/removal points are all located in the inner part of the ring.

2.1 DIPOLE MAGNET TRANSPORTER

As I mentioned earlier, the arc dipole magnets were the heaviest magnets, about 6 tons in weight, to install as a unit. Each one was also about 35 ft. long, including all the cryo pipes and wires protruding at both ends, and it would be a major challenge to transport and maneuver it inside the tunnel.

But the arc dipoles were also the first ones to be available for installation. Hence, the dipole transporter was the first one to be designed and fabricated.

After the final design review, we fabricated the transporter in-house. Then we proof-tested the whole assembly by loading it with a fully assembled arc-dipole plus 25% more extra load. During the test, the actuators performed as expected and it was approved and commissioned for service by the safety representative.

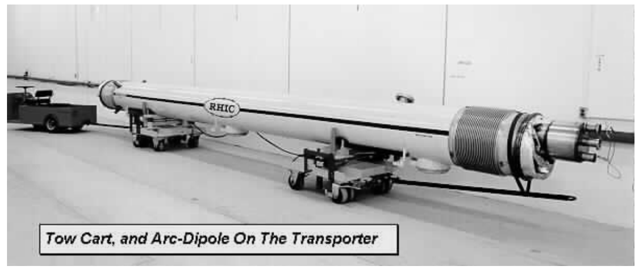

Figure 2: Arc Dipole On Transporter

Figure 2 above shows a dipole cradled by the transporter being pulled by a small electric Taylor-Dunn cart inside the Rhic tunnel. The cart had been modified and re-geared in order to limit its speed below 6 mph for personnel safety. The two transporter carts shown at each end of the magnet are mirror images of one another, and both have electrically-driven actuators that are simultaneously controlled from a main control box; These mechanical screw actuators would allow vertical adjustability. Furthermore, alathane wheels were used for their durability and ruggedness.

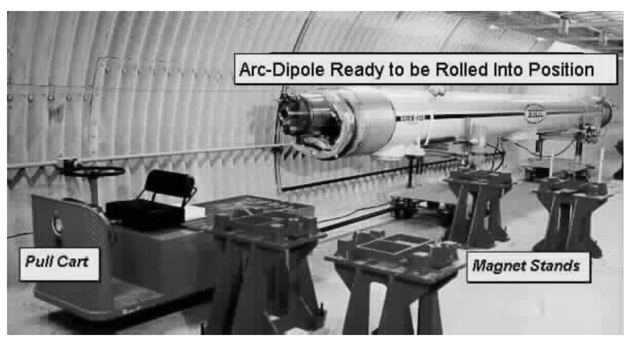

Figure 3: Dipole Installation

Figure 3 above shows the arc-dipole in its raised position a little above the magnet stands. From this position, the wheels would be rotated 90^{o} and then the whole assembly would be pushed carefully to a nominal position directly over the stands. The mounting holes on the magnet support base would be aligned with the vertical mounting bolts on the stands and then the magnet would be lowered down until it would hit a prescribed nominal vertical position. The magnet would now be safely resting on its support and the transporter assembly could now be rolled out. The entire process of trucking and transporting a magnet from the storage area to the ring and then completing the whole installation would take a little over an hour. In an 8-hr. day, six (6) arc-dipoles could be fully installed, or three-fold from the original design objective!

2.2 ADJ-LENGTH MAGNET TRANSPORTER

The arc-CQS (CQS: Corrector, Quadruple, Sextuple) magnets are much shorter and lighter than the arc-dipoles. Aside from the arc-CQS's, there are also several other magnets with various different lengths in the insertion region. Therefore it was decided to design and fabricate an adjustable-length transporter in order to accommodate all the CQS's and the insertion magnets.

It should be noted, however, that based on the concept of the dipole transporter, the installation group also made a dedicated CQS transporter/installer out of a lift table that fitted well in between the stands of the arc-CQS. Although this lift table transporter would have limited use in the removal/replacement of arc-CQS's, it certainly served very well in the installation phase like the dipole transporters.

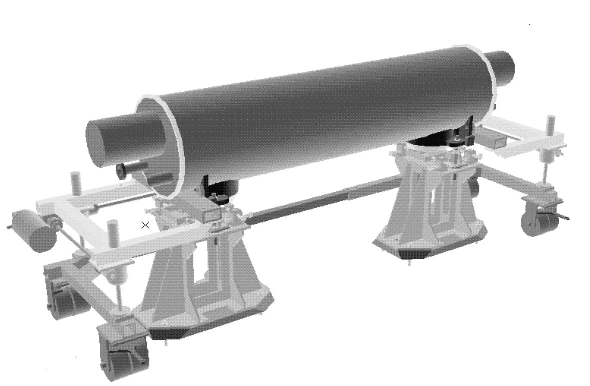

Figure 4: Adj-Length Transporter (Solid Model)

The adjustable-length transporter would have a load-carrying capacity of about 1/3 that of the dipole transporter. But unlike the dipole transporter that fits "in-between" the stands, this new transporter would have to go "around" the magnet stands since the stands of the shorter magnets were very close to one another. Figure 4 shows the conceptual layout of the adjustable-length transporter as a CQS magnet was installed into position. Again, this transporter was fabricated in-house, and upon completion, it was first proof-tested before it was put in service.

Unfortunately, a short insertion dipole turned out to be significantly heavier than the arc-CQS. Although the mechanical actuators and other components were designed to handle the excess load, the horsepower of the drive motor was not sufficient enough. After replacing the drive motor, however, the whole system worked well as planned.

3 MAGNET INSTALLATION PROCEDURES

The final selection and sorting of the magnets was done by the Rhic Accelerator Physics (RAP) group. All magnets were serialized and assigned to specific locations inside the Rhic ring based on a general project-wide nomenclature and naming convention.

A database was created to automate the generation of traveller sheets that went with each magnet. The database was published on the Rhic Accelerator Systems webpage for easier access and was updated at least once a week as new magnets were accepted and assigned to their respective locations in the ring.

The magnet acceptance crew would print out the necessary information relevant to a particular magnet. They would attach this information to the magnet before turning it over to the installation crew. This process was done at the magnet storage area where the magnets would be loaded unto the transporter on top of a flatbed truck and then moved to one of the three loading docks in the inner periphery of the Rhic ring as indicated in the traveller sheet. It should be noted that a given magnet would have to be at a specific orientation as it was pulled out from the flatbed towards the tunnel since there was no room inside the tunnel to turn it around.

4 CONCLUSION

The experience in installing the superconducting magnets in the Rhic ring had shown that a basic systematic approach in planning and designing the support and transport system proved quite beneficial in the long run. Computer modelling and simulation contributed significantly in visualizing basic concepts especially in checking and verifying interferences. Costly proto-typing was essentially avoided.

We started installing arc dipoles in August, 1994, and by the end of February, 1996, all 264 arc-dipoles were installed; Installation of the arc-CQS started around March, 1995 and as of April, 1997, 98% were already installed. The main constraint now is simply the availability of magnets that are ready for installation.

For further information, check the Rhic collider ring installation webpage at the following address:
http://www.collider.bnl.gov/installation/installation.html