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BNL-75476-2006-CP

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Presented at the 10th Biennial European Particle Accelerator Conference (EPAC)
Edinburgh, UK
June 26 - June 30, 2006

June 2006

Collider-Accelerator Department

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AN OVERVIEW OF THE SNS* ACCELERATOR MECHANICAL ENGINEERING

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Abstract

The Spallation Neutron Source (SNS*) is an accelerator-based neutron source currently nearing completion at Oak Ridge National Laboratory. When completed in 2006, the SNS will provide a 1GeV, 1.44MW proton beam to a liquid mercury target for neutron production. SNS is a collaborative effort between six U.S. Department of Energy national laboratories and offered a unique opportunity for the mechanical engineers to work with their peers from across the country. This paper presents an overview of the overall success of the collaboration concentrating on the accelerator ring mechanical engineering along with some discussion regarding the relative merits of such a collaborative approach. Also presented are a status of the mechanical engineering installation and a review of the associated installation costs.

INTRODUCTION

The decision by the Department of Energy (DOE) to design and build the SNS as a collaborative venture was almost certainly based on the fact that no American laboratory had the breath of knowledge and expertise to tackle a project of this magnitude alone. Each of the partner laboratories were given a particular responsibility with Lawrence Berkeley, Los Alamos, Thomas Jefferson, Brookhaven (BNL), Argonne & Oak Ridge responsible for the front-end, warm linac, super-conducting linac, accelerator ring, beam-line instruments and target respectively. BNL was chosen to design and build the accelerator ring because of its wide experience designing similar electro-magnetic accelerating components and the fact that there was a strong physics and engineering team already in place at the laboratory.

RING LATTICE

The accelerator ring lattice is shown in Figure 1 and consists of three distinct areas a high energy beam transport (HEBT) beam line, an accumulator ring (Ring) and a ring to target beam transport (RTBT) beam line with each area having an associated service building situated above ground housing the various utilities required e.g. cooling water pumps, magnet power supplies, communication & controls etc. BNL had responsibility for design, manufacture and delivery of all the lattice components in the HEBT, Ring and RTBT.

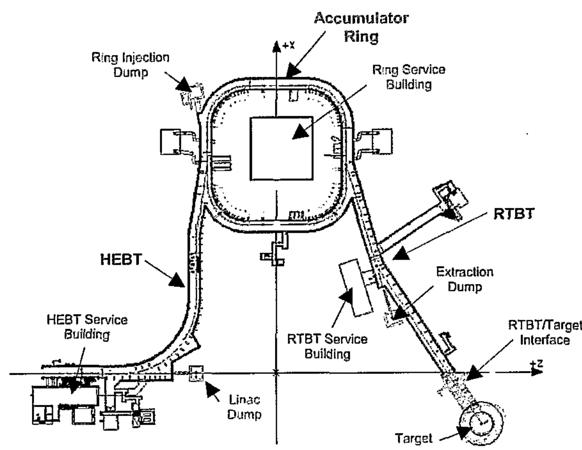

Figure 1: Accelerator Ring Lattice

The lattice components consist of [1]:

- 312 magnet assemblies
- 267 vacuum chambers
- 45 diagnostic structures
- 7 collimators
- 4 RF cavities
- 272 support stands

MECHANICAL ENGINEERING

History

The original project goal was to have the partner laboratories not only design, manufacture and deliver technical components but also have responsibility for installation in the facility, essentially delivering a turn key system similar to what commercial companies supply in industry. This of course would have been a major under-taking bearing in mind that the staff required to facilitate the installation were spread across the country and would have needed to be available to spend long periods of time at the SNS site during the installation phase. Also, this proposal by definition dictated that the number of mechanical engineering staff required in Oak Ridge to be small consisting mainly of operations type engineers with virtually no provision for design or installation. A project decision was made in early 2001 to transfer the installation scope from the partner laboratories to Oak Ridge with the understanding that valuable technical support would be available from the laboratories once system testing and commissioning was underway. This decision prompted a hiring program to boost the accelerator systems division mechanical engineering (ME) group from a staff of approximately twelve to its present level of thirty five consisting of engineers, designers and technicians. Engineering design responsibility for a few key areas was also transferred to Oak Ridge namely the interfaces at the linac & extraction dumps the RTBT/target interface and design of remote vacuum clamps and utilities for predicted activated regions in the machine. The SNS ME group also became responsible for design of several diagnostic devices e.g. wire scanners and target HARP.

Mechanical Systems

Design of the mechanical components at BNL was a major task that relied on close collaboration with the accelerator physics (AP) groups both at BNL and SNS. The AP groups were responsible for specifying parameters for the magnets and collimation systems to a level where the mechanical engineers could start the engineering design. Because of the complexity and high dollar value of the components the search for suitable vendors extended outside the USA resulting in procurements being placed across several countries in Europe and the United States. Competitive bidding internationally of the large procurements almost certainly helped keep costs to a minimum with the down side being that from a project management standpoint tracking of the various stages of the manufacturing process became more troublesome. To mitigate this extensive use was made of conference calls with vendors to monitor progress, typically weekly in early morning to off-set the time difference and to a much lesser extent vendor site visits. In hindsight more vendor visits by a cognizant engineer would have been beneficial inspecting equipment first hand and tackling technical issues face to face generally pays dividends, however this is a balance between perceived technical advantages, cost and schedule work load of the engineers. A typical procurement is shown installed in the tunnel in Figure 2.

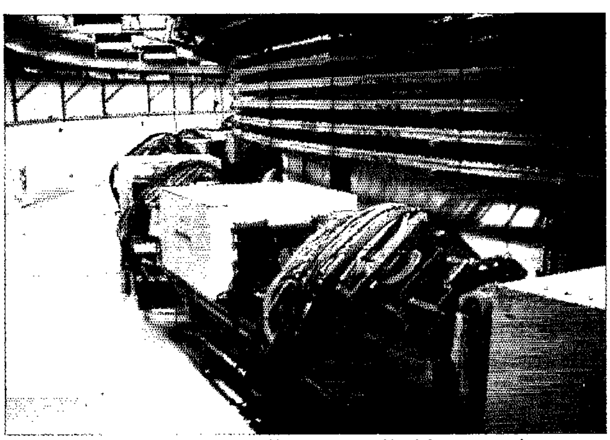

Figure 2: Half-cell Arc Installed in Tunnel

Water Systems

An area that is generally thought to be of low technical risk is the water system however if the overall design is not addressed early enough in the project design phase then serious problems both technically and cost may arise during the commissioning phase. The gross cooling water system was the responsibility of the Conventional Facilities Division (CFD) with input from the partner laboratories that were designing the technical equipment. It was therefore important for BNL to identify specific cooling requirements for the various magnets, collimators, power supplies etc. as early in the design process as possible to enable CFD to size the various sub-systems and consequently the whole system, this was an iterative process that was not resolved until many of the first article components had been tested fully at BNL. At this point it was obvious that some of the sub-systems were marginal and that upgrades may be required to satisfy the full cooling load. Another area that required remedial work was flow balancing of some of the larger assemblies components which would generally be done with the first article or prototype but schedule pressure to deliver the components for installation resulted in this work being carried out at Oak Ridge during the early commissioning stages.

Vacuum Systems

The vacuum system was designed at BNL stainless steel is used extensively for the vacuum chambers and is chemically cleaned and assembled in a clean environment and in some cases baked to reduce outgassing rates. No elastomer or organic materials are used and all vacuum seals are metal. To avoid the e-p instability due to beam-residual gas ionization an ultrahigh vacuum of $1x10^{-9}$ Torr is required [2]. In specific identified areas quick release type vacuum clamps are used in an attempt to minimize radiation dose to personnel during maintenance periods. The issue of working in high radiation areas was thought to require further work by both BNL & SNS engineers consequently design work was undertaken to address this.

Drawings & Documentation

During the many engineering meetings held between the BNL and SNS engineers there was a general consensus on the level of engineering drawings required assuming suitable funding could be found to support this. It was agreed that a complete set of detail and assembly drawings would be furnished electronically by BNL to the SNS project including all 3-D models. A rigorous document change process was in place to identify drawing modifications. The subsequent ease with which the accelerator components were built and installed and the extremely low number of interface issues between the sub-assemblies highlights the level of engineering oversight and quality of the engineering drawings.

On a more general note the SNS ME group received engineering drawings from all the partner laboratories for the various mechanical systems this has resulted in a database that has drawings in six different CAD formats. The SNS team at Oak Ridge has consolidated all its engineering design using two packages ProE© and Autocad© for 3-D and 2-D respectively and it is unfortunate that this consolidation was not done across the partner laboratories in the early stages of the project, a lesson to be learned for future collaborations.

Engineering Interfaces

As discussed earlier several interface areas were thought to require designs that addressed the expected higher residual radiation levels. The linac dump was chosen as the obvious first candidate due to the fact that it would be required during linac commissioning. An Inconel 718 beam window separates the machine vacuum from the dump flight-tube, a remote vacuum clamp and co-axial bellows assembly that allows remote retraction of the vacuum bellows and flange completes the assembly [3]. This design was used as a basis for vacuum clamping mechanisms on the HEBT, Ring and RTBT collimator assemblies and the RTBT/Target interface area. The RTBT/Target interface was thought to be an area where the residual doses would be high and in conjunction with the tunnel geometry it was necessary to design these components to be able to withstand forty years dose and have the ability to remove and replace components without personnel receiving high radiation doses [4]. Consequently, the large twenty five ton quadrupoles that make up the final four magnets in the RTBT are designed with mineral insulated coils and all utilities are designed to be handled semi-remotely using long tools, etc. Large Ø17" remote vacuum clamps are utilized based on the linac dump principle and the co-axial bellows design was modified to a much larger form. The quadruplole coils were designed and wound at BNL and assembled into the magnets prior to delivery to ORNL for fitting of the remote connections. Figure 3 shows a quadrupole assembled in the tunnel prior to the upper shielding being installed.

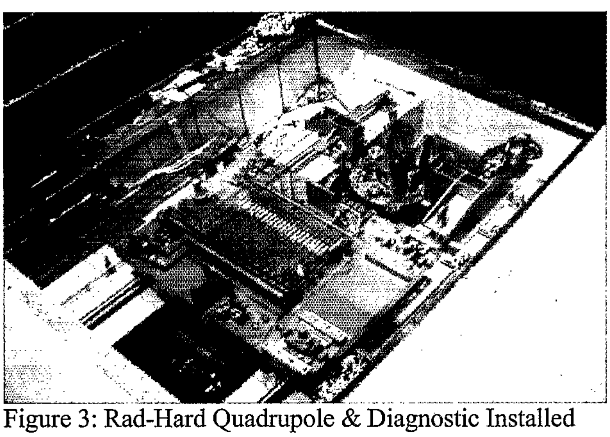

Figure 3: Rad-Hard Quadrupole & Diagnostic Installed

Installation

The final component installation was completed several weeks prior to beam on target date of April 28, 2006. The integrated project schedule identified milestone dates for the various commissioning activities from the linac through to the RTBT/target interface and this in itself dictated the sequence of mechanical installation leaving the final five target interface components which were considered to be the most complicated to install. Pre-alignment and setting of the large quadrupoles, validating vacuum integrity on remote clamps, proving co-axial bellows assembly etc. along with crane scheduling issues with the target division who were themselves under pressure to finish installation contributed to a stressful last eight weeks.

Estimations made based on the resource loaded project schedule identified some 50 man years of craft and technician labor would be required to complete the installation [5] with the actual being in the order of 40 man years [6].

SUMMARY

The timely success of the accelerator design, manufacture, installation, commissioning and subsequent beam to target highlights the success of the collaboration with BNL. Transferring the component installation scope to Oak Ridge although contentious at the time was almost certainly the correct decision it allowed the SNS engineering teams to get fully involved and gel technically into a very competent engineering function that is more than capable of running and maintaining the accelerator. It would have been beneficial to have system lead engineers from SNS involved earlier in the component design process especially in areas such as handling but issues like this are difficult to predict until the design process is underway. It is imperative that projects of this magnitude choose to consolidate design packages early in the project cycle the cost of re-drawing components over the life of the project by far exceeds the initial cost for training.

The two engineering teams exhibited a wide range of experience and personalities and meetings at times were contentious partly due to the schedule and budget restraints but overall it was enjoyable and fulfilling to be part of team that designed and built the accelerator portion of the SNS.

REFERENCES

[1] McGahern W. et al. "Managing System Parameters for SNS Magnets & Power Supplies", EPAC'04.

[2] Hseuh H. C. et al. "Design of the SNS Accumulator Ring Vacuum Systems", PAC'99.

[3] Murdoch G. et al. "Beam Dump Window Design for the SNS", PAC'03.

[4] Holding M. et al. "Engineering the SNS RTBT-Target Interface for Remote Handling", PAC'05.

[5] Hechler M. et al. "The Installation Status of the SNS Accumulator Ring", PAC'05.

[6] Bivens J. ORNL, Private Communication

* SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.