MANAGING SYSTEM PARAMETERS FOR SNS MAGNETS AND POWER SUPPLIES

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Abstract

The Spallation Neutron Source (SNS), currently under construction at Oak Ridge, Tennessee, is a collaborative effort between six U.S. Department of Energy partner laboratories. Brookhaven National Laboratory (BNL) is responsible for the ring and transport lines requiring 312 magnets and 251 power supplies. The challenge is to maintain a closed communication loop among stakeholders for the variable parameters integral to these two major systems. This paper provides an overview of the organization and functional responsibilities used to define, update and communicate specific design parameters related to the SNS magnet, power supply, and other critical systems.

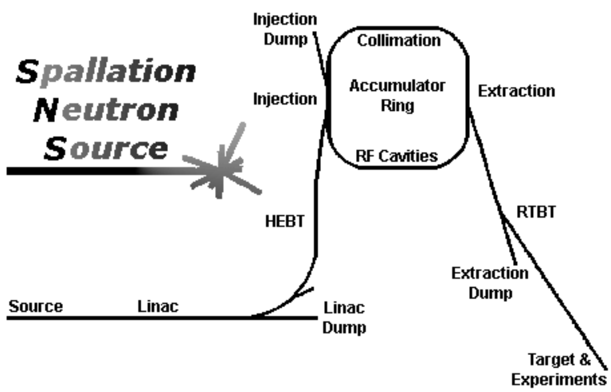

Figure 1: Schematic of the SNS Accumulator Complex

INTRODUCTION

Several factors contribute to make the SNS Project a unique challenge for physics, engineering and project administration staff at BNL. The primary factor, however, is the division of responsibility between the six partner labs.

Collaborating National Labs	Brookhaven Departments
Oak Ridge Management, Construction & Target	**Directors Office**
Berkeley Front End Source	**Collider-Accelerator Dept.**
Los Alamos Warm Linac	**SNS Project**
Jefferson Cold Linac	***Magnet Division***
Brookhaven Ring &Transport	***Central Shops***
Argonne – Instrument Systems	***Contracts & Procurement***
	Advanced Technology

Figure 2: Collaborators and Departments

As can be seen from Figure 2, BNL has overall responsibility for the electro-magnetic beam line equipment that makes up the high energy beam transport line (HEBT), the accumulator ring (Ring) and the ring to target beam transport line (RTBT) of the SNS machine.

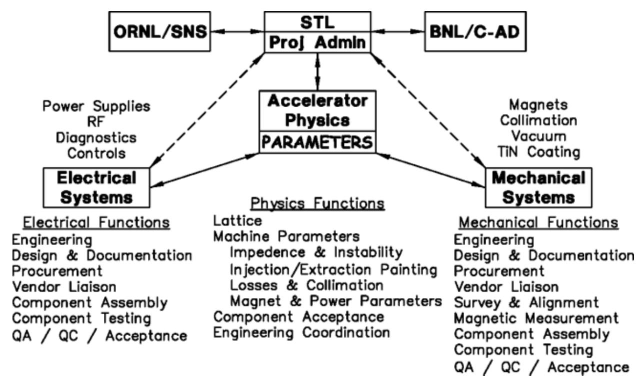

Figure 3: BNL/SNS Groups, Functions & Devices

MANAGEMENT

Like the other five partner labs, BNL's principal technical interface is with the SNS Project Office and the Accelerator Systems Division located at Oak Ridge where the internal lines of responsibility and communication are clearly drawn. The divisions of responsibility within the Project Office include the Project Director's Office, Accelerator Systems Division (ASD), Conventional Facilities Division (CFD), and the Experimental Facilities Division (EFD) encompassing the target area and related target systems.

The SNS project management structure at Brookhaven is shown in Figure 3. From this figure, it can be seen that Brookhaven's Senior Team Leader (STL) has project responsibility for administration, physics, and design efforts at BNL. Also shown in Figure 3 is a list of the primary functions performed by BNL's three main design groups; Accelerator Physics (AP), Electrical Systems (EE) and Mechanical Systems (ME).

The main focus of the AP group is directed at physics issues related to the machine lattice, parameters, and overall performance. AP is also responsible for component acceptance and for maintaining close two-way communication with the BNL/SNS engineering staff.

The EE group is responsible for major sub-systems that include the magnet power supplies, RF systems and diagnostics (along with specific areas of support, such as controls).

The ME group is responsible for all magnets and beam-line hardware between the upstream linac and the downstream target. Specifically, the ME group is responsible for magnet, vacuum and the collimation sub-systems.

PARAMETERS

Currently, BNL's direct line of communication to the Project Office for all physics and engineering issues is through the Accelerator Systems Division at Oak Ridge. However, during the initial design phase of the project a significant amount of effort was spent in collaboration with the Conventional Facilities Division (CFD) to define specific conventional parameters that were critical to the evolving design of the facilities. During the early stages, this was a challenging interaction, since many of the BNL/SNS design parameters in the CFD scope of work were not yet fully known by the BNL design teams. Throughout the project, communications were regularly conducted with ORNL via telephone and video conferencing. Frequent site visits were made by various SNS staff members for design reviews.

An exploration of both the parameters required for the various accelerator systems and the impact of the iterative process follows.

Facilities and Infrastructure

It was difficult during the early phase of accelerator engineering to accurately predict some of the conventional facility requirements needed to support the electro-mechanical equipment of the ring and transport lines. A wide array of parameters such as size, space, headroom, access doorways, crane requirements and capacity, clean power, utility power, ground breaks, cooling water, environmental temperature controls, compressed air, etc. were necessary for CFD to properly design the SNS facility. Considering the fact that estimates of these variables could be revised significantly as a result of changes during the early iterative design process, frequent communication of the revised parameters was very important.

Heating Ventilation & Air Conditioning (HVAC)

The HVAC systems were designed specifically for the tunnels and service buildings by CFD with inputs from the partner labs. For BNL the heat load contribution included thermal radiation from magnets, power supplies, return water manifolds, power cables, control racks, electronics, etc. As the design of the BNL equipment evolved, so did the understanding of how much heat was to be removed by radiation (ambient air) and conduction (cooling water). During the early design stages, data often had to be extrapolated by controlled testing of specified components and first articles at BNL.

Cooling Water Systems

Cooling water systems were also designed by CFD with inputs from the individual partner labs. It was imperative that BNL identify equipment cooling requirements during the early design stages so that CFD could size and specify all of the various individual facility cooling water sub-systems. This was not an easy task during the design phase when other, seemingly more important, engineering questions begged to be answered. Some of the critical questions related to the cooling water system included:

- What is the applicable baseline operating condition for the accumulator?
- What are the acceptable margins for each cooling systems? Is the cooling achieved by an open-loop (as used for magnets and power supplies) or a closed-loop (as used for the collimators)?
- What are the design parameters (temperature, pressure, flow) for the individual components (magnets, collimators, power supplies and RF) using a worst case scenario?
- What are the extreme maximum and/or minimum cooling parameters to be assumed?

Of course, some of the load parameters were never accurately known until much later when BNL and/or Oak Ridge had the opportunity to test actual prototype and production units.

AC Power

The responsibility to define facility AC power belonged to CFD. As with the other systems, specific inputs were given to CFD by the partner labs. Power was one of the more difficult parameters to define in the early design stages since it was directly affected by all facility and machine design changes. It became clear early on, that this parameter required continual surveillance and numerous iterations in order to stay abreast of all design changes and growing demands. Although the total power requirement is divided between facility needs (lights, outlets, HVAC, crane, cooling pumps, etc,) and machine power (vacuum, power supplies, RF, and controls), the BNL staff remained challenged to keep their sights trained on the machine side of the equation; that is, the AC power requirements for the accumulator ring and transport lines.

From a design point of view, the primary engineering inputs needed to define the ring power requirement were determined directly from the integrated power demands of the individual magnet power supplies. For the magnet system there are 251 power supplies feeding 312 magnets in the ring and transport lines. Furthermore, for performance optimization, the 312 magnets are connected in various series/parallel string arrangements to meet the AP requirements for magnetic field. For economies of scale and efficiency, BNL decided early on to develop a family of power supplies consisting of 21 individual models covering the numerous string arrangements for the SNS ring and transport lines.

For the individual power supplies, design specifications remained fluid until all of the external factors (magnets, cables, etc.) were known. Power supply related hardware responsibilities were split between BNL and ASD. BNL was responsible for all the magnet power supplies while ASD was responsible for the cables, tray and conduit.

For magnets, the design parameters were tabulated into two categories; fixed magnet parameters and operating parameters. The fixed parameters included the magnet core length, gap height, ampere turns, resistance, inductance, weight, etc. Operating parameters included beam energy, peak field, gradient field, integrated field, operating current, voltage drop (for magnet coils, buss, connections and power cables) and the coil cooling requirements.

One of the design iterations that directly affected the machine's power needs included a decision by the SNS Project Office to have BNL provide a sufficiently robust design so that the baseline 1.0 GeV machine operating parameter could, at some future date, be increased to 1.3 GeV with minimum impact to the beam-line hardware. To keep equipment costs in check, it was further decided that power supply operating margins at 1.3 GeV should not exceed 10% of the calculated nominal operating value. Since they had to contend with shared hardware responsibilities, wherein magnet cables, tray and conduit were the responsibility of Oak Ridge, this became a particularly difficult task for the BNL design team.

Components	Models	HEBT	RING	RTBT
Magnets (n = 312)				
Dipoles	8	9	36	1
Septums	3	~	3	~
Injection Kickers	4	~	8	~
Extraction Kickers	6	~	14	~
Quadrupoles	6	40	53	32
Sextupoles	2	~	20	~
Correctors	11	18	61	17
Power Supplies (n = 251)				
High power	1	~	1	~
Medium power	12	30	11	28
Low Power	6	18	122	19
Pulsed	2	~	22	~
Vacuum chambers (N = 267)	16	83	123	61
Diagnostics (n = 159)	32	60	71	28
Collimators (n = 8)	6	3	3	2
RF Cavities (n = 4)	2	(2 by ORNL)	4	~
TOTALS	117	261	552	188

Table 1: Equipment, Quantities and Location

PARAMETER TRACKING

Tracking parameters associated with magnets, collimators, power supplies, vacuum vessels, diagnostics devices, RF devices and control modules was handled by the individual BNL design engineers during the early life of the project. The final responsibility for comprehensive tracking of parameters lies with ASD as they accept, store and track both device specific information and system level parameter values in the project production database.

Significant difficulties were experienced in disseminating fundamental changes in component parameters to all those who were actually affected or even interested. Personnel changes during the life of the project exacerbated this problem. A system for tracking magnet parameters was developed in the form of an Excel spreadsheet that was later linked to an Access database for reporting purposes.

CONCLUSIONS

It will remain difficult to accurately predict the individual design values for the numerous machine parameters needed to define a new accumulator ring, such as the Spallation Neutron Source. However, experience suggests that a good way to circumvent this shortfall is by actively promoting good communication between all the design teams and by providing an internal mechanism for periodic reviews and documentation. A subscriber based notification system for parameter, spreadsheet and other technical document changes, would greatly enhance the communication and review process.

The recent BNL/SNS experience indicates that real productivity gains and avoidance of duplicate or unnecessary effort can be achieved if appropriate information management technology is brought on board in the early phase of accelerator design and development. As a complex system involving multiple disciplines, accelerator design is an ideal candidate for application of this technology. The effective and efficient management of the parameters associated with particle accelerator design and development is a process that requires the application of both classical principles and current tools.

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