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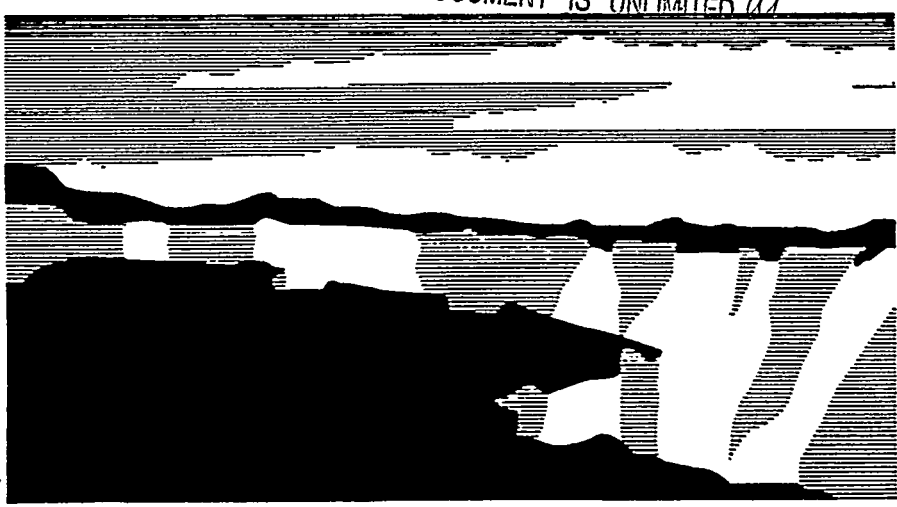
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PROGRESS ON THE PSR/LANSCE UPGRADE*

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ABSTRACT

A two-phased improvement program for the spallation neutron facilities at LANSCE is underway and scheduled to be completed early in 1998. The primary goals are a beam reliability or availability of 85% or greater, a capability for routine and sustained beam operations for eight months per year, access to the experimental room (ER-1) closest to the neutron production target with beam on, and 100 μ A average beam current from PSR. Many reliability improvements are included in the project along with implementation of direct H⁻ injection into PSR and a major upgrade of the target/moderator system.

1. Introduction

The winding down of the nuclear physics program at LAMPF (the Los Alamos Meson Physics Facility) presented an opportunity to redeploy these high-intensity accelerator assets at modest cost for a revitalized neutron science program. To this end, the US Congress allocated funds in two phases commencing in 1994 to upgrade the spallation neutron facilities at the LAMPF site and to facilitate the transition to the new LANSCE (the Los Alamos Neutron Science Center). This paper will discuss the objectives, plans, results and progress on both phases of the PSR/LANSCE improvement (upgrade) project undertaken with these funds [1].

2. Goals and Requirements

The primary objective of the upgrade is to improve the research productivity of the neutron facilities and establish LANSCE as a premier center for neutron science. Much of the effort is aimed at improving the reliability and availability of high-intensity neutron beams. Other issues raised by the neutron scattering community are also addressed including a) the need for personnel access to the experimental room (ER-1) while beam is on, b) operation for a

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[†] Presented on behalf of the entire LANSCE Upgrade Team.

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significantly larger fraction of the time than the present 3-4 months per year, and c) routine operation of the proton storage ring (PSR) at the design current of 100 μA .

2.1 Reliability/Availability Issues

A key issue for the upgrade is to address the user concern with relatively poor beam reliability and availability at the Manuel Lujan Jr., Neutron Scattering Center (MLNSC). A very significant improvement to ~85% beam reliability/availability (with respect to scheduled beam time) is needed to make the facility attractive to the majority of potential users.

Data on past performance shown in Figure 1 reveal that the average beam availability in the years 1989 through 1993 was 69%. During this same period the availability of PSR (proton storage ring) equipment (including the H⁻ ion source, pre-accelerator and low energy beam transport) was 84% and the availability of the linac was 83%. Of perhaps more significance is length of downtime intervals. In the years 1992 and 1993, for which we have data on the length of downtime intervals, the beam to MLNSC was down 33.4% of the schedule and most (~2/3) of this was due to intervals longer than 8 hours. In fact, the beam was off 20% of the scheduled time for periods of 8 hours or longer. Downtimes longer than a shift are particularly disruptive to the short experiments (around 3 days) typical at a spallation neutron scattering facility.

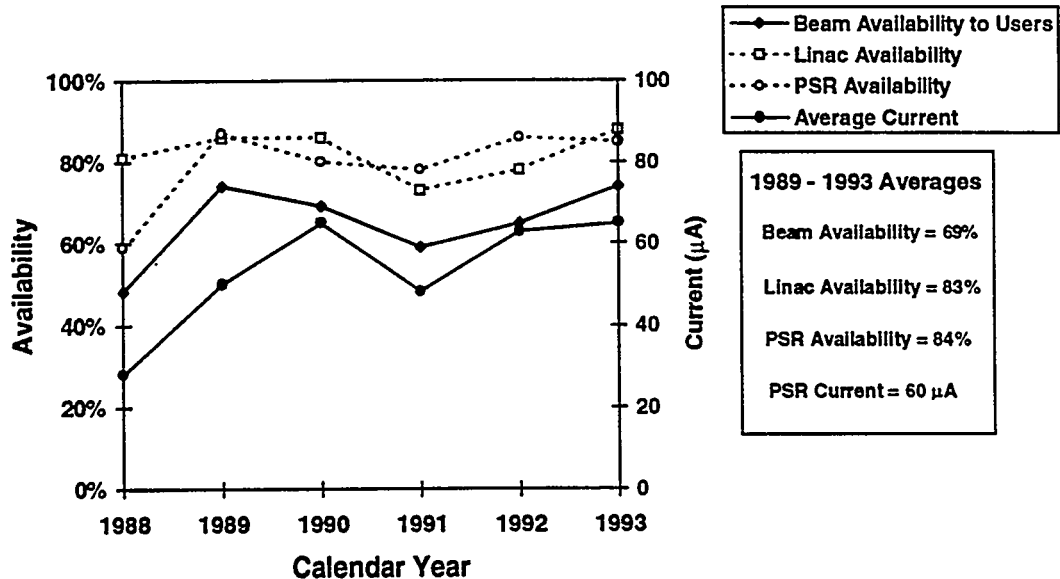


Figure 1. PSR/MLNSC Beam Statistics 1989-1993

Yet another aspect of the general issue of beam availability is the limited amount of beam time per year that has been available in the past. A viable neutron science program requires beam for more than the 3-4 months per year that has been reality for much of the time that PSR has been in operation. While this underutilization is primarily the result of limited budgets for accelerator operations, the goal of operating for about eight months per year is more than just a question of additional funds for accelerator operations. The long down-times between beam

cycles have been utilized to advantage for cool-down of activated components before servicing of both the PSR and the target/moderator systems. In the future, it will be necessary to carry out yearly maintenance activities in much less time. Thus, another important goal of the upgrade is a capability for routine and sustained beam operations for up to eight months per year.

2.2 Personnel Access to ER-1

Safety concerns over the high radiation levels possible in experimental room ER-1 under unmitigated worst-case beam spill accident scenarios have prevented personnel access to this room while beam is on either to the neutron production target or in the beam channel passing over ER-1. As a result of this safety policy, entries are scheduled on a daily basis through negotiations with all affected users on the floor at the time. While the downtime for such entries is scheduled and thus removed from the calculations of beam delivery equipment availability it still has a serious impact on user effectiveness and satisfaction. Access to this area with beam on is very high on the list of goals for the upgrade project.

2.3 Beam current from PSR

The original design goal for PSR was 100 μA of average current at a low (12 Hz) repetition rate. Average beam current in PSR is limited, not by our ability to generate and accumulate the beam intensity, but rather, by beam losses in the ring and the resulting radioactivation of certain ring components. In fact, average currents of 95 μA for periods of one hour or so were demonstrated years ago. As a result of the accumulative effects of beam losses, PSR has a long-term, practical limit of $\sim 70 \mu\text{A}$ average current at 20 Hz.

The causes of the slow losses at PSR are well understood as is the remedy, direct injection of H^+ into PSR [2],[3], [4]. What has been missing until the upgrade project is the resources and priority to carry it out. Phase II will include the PSR injection upgrade. It is aimed as much at the reliability and availability improvements that flow from reduced beam loss rates as it is at the opportunity to raise the average current.

3. Phase I

Phase I has focused on the most urgent, short lead-time reliability/availability issues plus measures to assure access to ER-1 with beam on the neutron production target. Measures to mitigate the causes of the longer downtime intervals received the highest priority. A long list (2-3 times more than could be implemented with the combined resources of phase I and II) of meritorious improvement projects was considered and items were selected for the upgrade primarily on the basis of cost/benefit considerations.

3.1 Technical Goals

Specific technical goals for phase I were adopted early in the project and are enumerated below:

- Capability for routine and sustained 8 months/year operation of LANSCE (by end of Phase II)
- Beam availability to LANSCE users > 80% (w.r.t. schedule) by 1996
- Less than 10% down-time from intervals > 8 hours by 1996
- Personnel access to ER-1 with PSR beam on to the MLNSC target
- Reduced beam delivery operating costs
- Reduced radiation exposure

3.2 Main Accomplishments

Phase I was 90% complete as of July 1, 1995 and on time for the start-up activities preceding the beginning of 1995 beam operations. After about 50 days of scheduled beam operations for the MLNSC users the accumulated beam availability was 78% and down-time from intervals longer than 8 hours was 8.5%. While the statistics for 50 days are too limited to claim complete victory, we are encouraged that beam availability is close to the goal set for phase I. The reduction by more than a factor of two in the down time from intervals longer than 8 hours is very encouraging but is also the aspect most limited by the available statistics.

It would be inaccurate to suggest that the hardware improvements alone are responsible for the improved performance. Due credit must be given to the operating and maintenance staff who gave highest priority to improving availability in all of their activities. Both the upgrade and operating teams had improved reliability/availability as a main goal.

The complete list of improvements successfully implemented in phase I is too long to include in this paper. However, the more significant ones are enumerated below:

- Several H⁻ Source, Injector and Chopper reliability improvements
- Better understanding of RFQ-Injector Options for the H⁻ beam and the difficulties in chopping such beams to meet existing WNR time structure requirements [4]
- Soft-vacuum upgrade for Tank 1 of the 201 MHz Linac
- Several Linac RF Reliability/Availability improvements
- DC Beam Switching (H⁻) to Line D (the beam line transporting beam to PSR and WNR)
- Several PSR Reliability/Serviceability improvements
- PSR Pulsed-Power improvements
- Extraction line BPM upgrade
- Some PSR controls converted to EPICS
- Design Studies for the PSR Injection Upgrade and the Target/Moderator Upgrade
- Improved operability and serviceability of the MLNSC target/moderator cooling systems
- Improved Target Cell Shielding permitting access to ER-1 with beam on the MLNSC target
- LANSCE Hazard Classification and Safety Assessment Document completed and submitted to DOE
- Completed design of an improved, site-wide Radiation Security System (RSS interlocks)

The improvements range from deferred maintenance items and deferred incremental improvements to complete systems redesigned for reliability and maintainability. The reconfiguration/redesign of the highly radioactive extraction septum region in PSR for ease of maintenance and replacement is an example of the latter. Several design studies for systems to

be implemented in phase II were also carried out. The overall flavor is one of a concerted attack on a broad front.

4 Phase II

Phase II consists principally of two longer-term, large projects i.e., direct H^- injection for the PSR and a major upgrade of the MLNSC target/moderator system. The PSR injection upgrade aims at a large reduction (factor of 3-5) in beam loss rates in PSR while the target upgrade seeks to reduce the time to replace the target/moderators from the present 10 months to 3 weeks. The target upgrade also seeks to increase the intensity limit (arising from target constraints) from the present 70 μA to 200 μA .

4.1 Technical Goals

Specific and, where applicable, quantitative technical goals for phase II are enumerated below:

- Beam Availability > 85% by 1998
- Less than 5% downtime from intervals > 8 hours by 1998
- Access to ER-1 with WNR beam on
- Add capability for more neutron beam lines and neutron scattering instruments
- 100 μA routine operating current @ 20 Hz by 1998

4.2 PSR Injection Upgrade

Beam losses at PSR and the resulting radioactivation of ring components are the dominant factor limiting average beam current, a major factor in equipment repair times and a significant cause of equipment failure. Reducing the beam loss rate is key to any significant increase in the performance of PSR whether it is increased reliability, availability or higher average beam current that is desired.

Stored beam losses in PSR are primarily caused by nuclear and Coulomb scattering in the foil when traversed by stored protons. [2],[4] Large angle scattering leads to immediate loss whereas smaller angles lead to growth of beam halos which can be lost later as synchrotron motion moves the protons to higher momenta and thus larger displacements. Stored beam loss can be reduced by keeping the stored beam off the foil as much as possible. The present two-step injection process (H^- to H^0 in a stripper magnet then H^0 to H^+ in the stripper foil) leads to significant emittance growth in the bend plane of the stripper magnet and a large mismatch at the injection foil. Both factors severely limit the use of various injection "painting" methods to keep the stored beam off the foil.

Direct H^- injection does not suffer the emittance growth from a stripper magnet and offers the capability to focus the beam for optimal painting. Our implementation of direct H^- injection shown in the layout of Figure 2 makes use of a low field magnet (low enough to avoid field stripping of the H^-) to merge the incoming H^- beam with the stored H^+ . A stripper foil after the merging magnet strips the H^- primarily to H^+ which is captured in PSR. A small amount of H^- and H^0 beam is present just after the stripper foil. The residual H^- strips to H^0 in the fringe

field of the first down stream dipole magnet. Both H^0 beams, the one produced in the foil and the one resulting from field-stripping the residual H^- are converted to H^+ in another foil and transported to a beam dump.

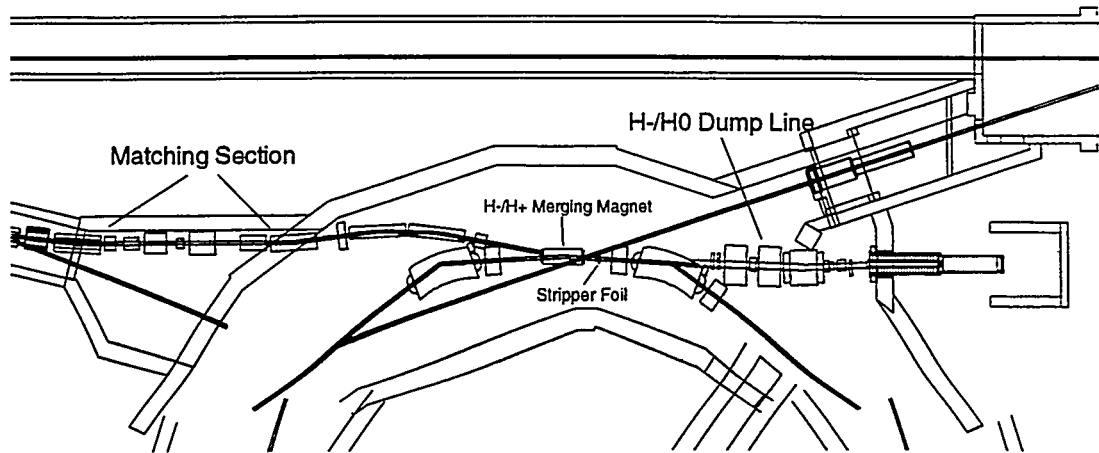


Figure 2. PSR Injection Upgrade (Direct H^- Injection Beam Line) Layout

Simulations of an optimized direct H^- injection as configured in layout of Figure 2 and with a programmed closed orbit bump in the vertical plane show a factor of 10 reduction in the number of foil hits per turn. [5]. Some of the gain from reduced foil hits is given up in making the foil thicker (by \sim a factor of 2) to reduce production of excited states of H^0 in the stripper foil and their contribution to "first turn" losses when the excited states strip part way into the first bend magnet downstream from the stripper foil. The final foil thickness is chosen to minimize the sum of stored beam and first turn losses. Thus, the overall reduction in total beam losses, compared with the present injection system, is estimated to be 3-5.

4.3 MLNSC Target Upgrade

Beam operations are at significant risk from target/moderator failures because of the long down time (\sim 10 months) needed to make major repairs or replacement. Target failure rates are difficult to predict but the best educated guesses are life-times of order 5 years at present intensities and for 6-8 months of beam operations per year. The liquid hydrogen moderator has failed twice. The most recent failure (September 1995) occurred five years after installation and with no more than 15 months of beam operation. The vulnerability to infrequent but costly failures is clear.

The present target/moderator system takes about 10 months of down-time to replace because many pieces of equipment and shielding must be removed piece-by-piece by personnel working in the target cell. Three to four months of radiation cool-down with beam off are needed before it is practical to have people working for extended periods of time in the target cell removing components.

The present approach for the target upgrade is a design concept of concentric cylindrical vertical inserts enabling quick access to the failed components. It is illustrated below in Figure 2. The paper presented by Gary Russell at this conference will discuss the target upgrade including this concept in more detail.

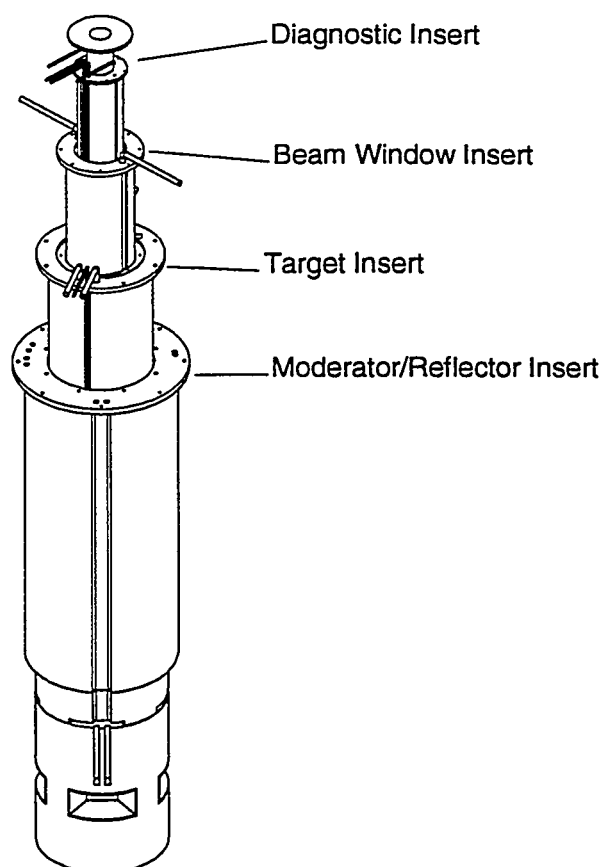


Figure 2. Concept for MLNSC Target/Moderator Assembly Inserts

4.4 ER-1 Access

The added shielding in the MLSC target cell along with RSS-rated beam current limiters in the H^- beam lines to PSR were sufficient protection (under the existing authorization basis) to permit access to ER-1 with PSR beam on to the MLNSC target. The problem of access while WNR beam is on remains to be solved in phase II. The RSS interlock system will be upgraded to full compliance with the latest LANL and DOE standards. With these in place, the case will be made with the regulators that the residual risk from a worst-case beam spill accident is acceptable. Prompt-radiation accidents leading to doses of 25 rem or more in an hour in ER-1 require simultaneous failures of several systems including 3 functionally distinct safety systems.

4.5 Schedule and Status

The target date for completion of phase II is February 1998. One of the drivers is the need for 8 months of down time in one stretch to install the target upgrade. Other than this requirement, phase II will work around the planned beam schedule of 5 months operation in calendar year 1996 and 3-5 months in 1997.

Phase II began in July of 1995 with detailed planning of the work. Design studies of direct H⁺ injection and the target upgrade began in phase I. Detailed design work is underway in phase II. A first baseline detailed plan for phase II is expected to be finished by November of 1995. An external review of the PSR injection upgrade design is scheduled for October 30-31, 1995. Reviews of the target upgrade and the project cost and schedule are planned for early in 1996.

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