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A B S T R A C T

The Spallation Neutron Source (SNS) completed construction in June, 2006. Since then the power has been ramped up and by October, 2008 has reached 620 kW with over 1200 MW-h of energy delivered to the target. During this period the complement of neutron scattering instruments has increased from the original 3–6 operational and 13 in varying stages of planning or construction. This paper will discuss the power ramp up history and availability with an emphasis on the target system components and operating experience.

1. Introduction

The Spallation Neutron Source (SNS) construction project was completed in June 2006. Since then the power has been gradually increased and additional neutron scattering instruments have been added. This paper will discuss the power ramp up history and goals and overall availability history up through October 5th, 2008. In addition the status of neutron scattering instrument development will be given and the availability and system experience for target systems will be reviewed along with the current planning for major target system component replacement.

2. Power ramp up history and goals

SNS reached 620 kW by the beginning of October, 2008 as shown in Fig. 1. The accumulated energy by that time was approximately 1200 MW h. The sequence of increasing power for neutron production periods between October, 2006 and October 5, 2009 can be seen in the figure. The periods with no power were planned maintenance shutdowns as can be seen in the figure. Fig. 2 shows how the actual integrated beam power for fiscal year 2008 compared with the internal SNS goals and with the commitment made to the Department of Energy. By the end of the fiscal year the commitment was exceeded, but the internal goal had not been made. Towards the end of the year the emphasis was changed from increasing power to ensuring high availability. The overall power performance goals for getting to 1.4 MW is shown in Fig. 3. With this plan, SNS would first reach 1 MW near the beginning of FY10. The emphasis however, will continue to be on improved availability and the rate of power increase will be slowed if needed to meet the availability goals.

The principal sources for unscheduled down time are shown in Fig. 4 for FY2008 and the first run period in FY2009. The largest contributor was the category of High Voltage Convertor Modulators with over 400 h of down time. The second highest was for Radio Frequency (RF) systems with about 225 h. Target systems were the cause of about 150 h due to one failure in the moderator refrigeration system.

3. Neutron scattering instrumentation

A model of the target building with the existing and planned neutron scattering instruments is shown in Fig. 5. There are six operational instruments as shown. Four instruments are scheduled to be completed in 2008 and three in 2009. In the period of 2010–2011 three instruments are planned and in 2012–2013 three more instruments are expected for a total of 19 instruments either operational or in varying stages of planning. Five of the total 24 beam lines remain uncommitted at this time. A summary of the beam line instrumentation status is given in Table 1. Temporary concrete and steel shutter plugs in beam lines 1 and 15 were replaced with operational shutters to support instrument development.

SNS had a goal for FY08 of attracting at least 75 "Unique Users." As shown in Fig. 6, this was exceeded with a total of 167 users. Also shown are the goal and results for the neutron scattering instruments at the High Flux Isotope Reactor (HFIR) at ORNL. The HFIR goal of 225 was exceeded with 274 users.

4. Target systems experience

Commissioning and initial operating experience up to 300 kW have been previously reported [1,2]. For the first run cycle in FY2008 of approximately 2000 h 100% availability was achieved. During the next run however, there was a failure of an oil filter seal

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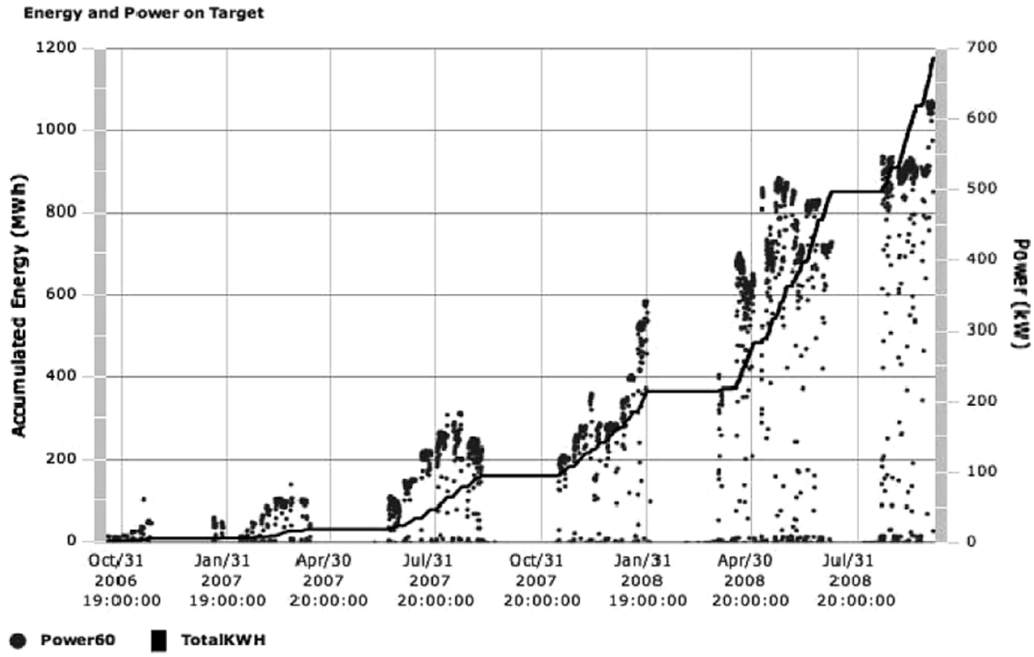

Fig. 1. Energy and power on target 10/2006–10/5/2008.

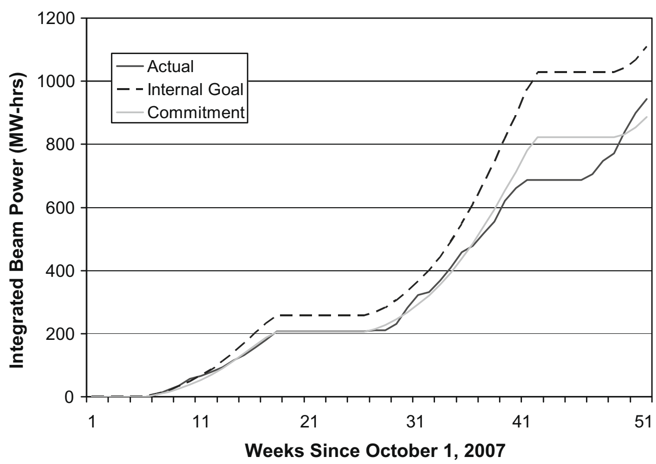

Fig. 2. SNS power delivery goals for FY08.

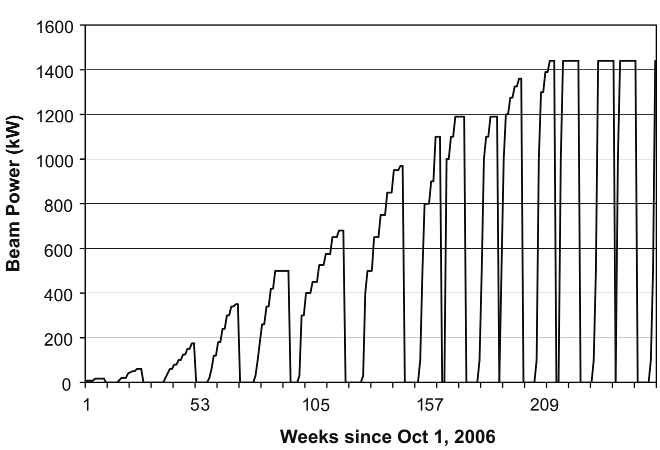

Fig. 3. SNS power performance goals for 2009 and later.

in the oil recovery system downstream of the compressor in the helium refrigeration system. This required approximately 150 h of down time for recovery. In the current run (as of October 5, 2008) the only significant down time for target systems was approximately 4 h caused by a moderator temperature cable failure which required re-wiring.

5. Target and proton beam window operation

Operational limits on the peak beam current density on the target were established as a function of the beam power for the ramp up to allow more peaked profiles at lower power. The limits were set to avoid premature target failure due to cavitation damage. The peaking factors and peak fluence for each run cycle were tracked for the target and proton beam window and used to estimate the radiation damage levels. By the beginning of October, 2008 the peak damage level of the 316L stainless steel mercury vessel was estimated to be 3 dpa with a peak total fluence of 4×10^{18} protons/mm^2. A level of approximately 5 dpa is expected to be reached by the end of this run cycle in January. The original design limit for the mercury vessel was 5 dpa, We currently plan to run until a leak is detected and will now allow up to approximately 8 dpa on the water cooled shroud which would allow operation until approximately July, 2009.

The Inconel 718 proton beam window has also reached approximately 3 dpa with a peak total fluence of 6×10^{18} p/mm^2. The damage is nearly the same as the target because the beam is more peaked at the proton beam window and this compensates for a much lower rate of damage due to neutrons at this location compared to the target. Both the target and proton beam window have operated without any problems at up to 620 kW. The target is monitored for leaks from the mercury vessel as shown in Fig. 7. There are two independent systems in a helium filled gap between the mercury vessel and an outer water cooled shroud. The first is a set of mineral insulated cables which have sections of the insulation removed so that any mercury in these regions would electrically short the wires together. The other system is a heated thermocouple junction which can detect water or mercury and dis-

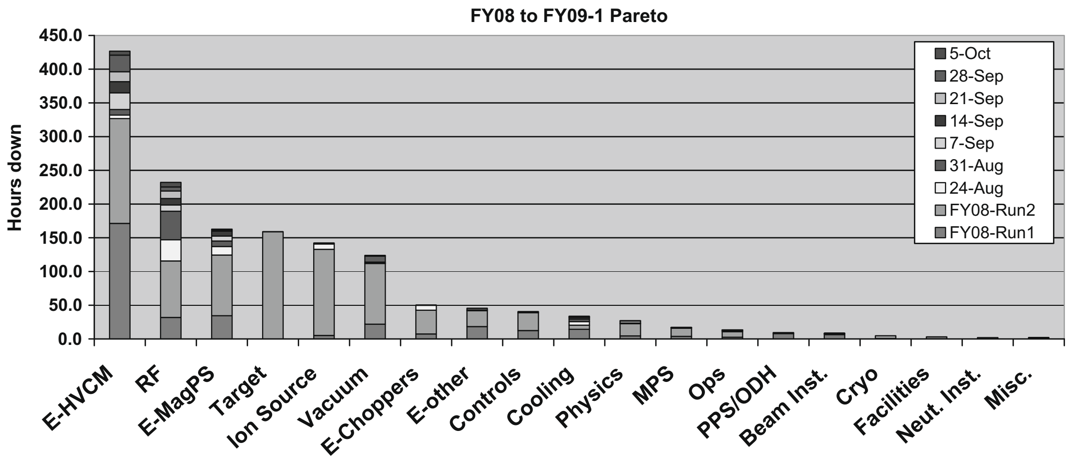

Fig. 4. Down time – Pareto chart for FY2008 and first FY09 run period.

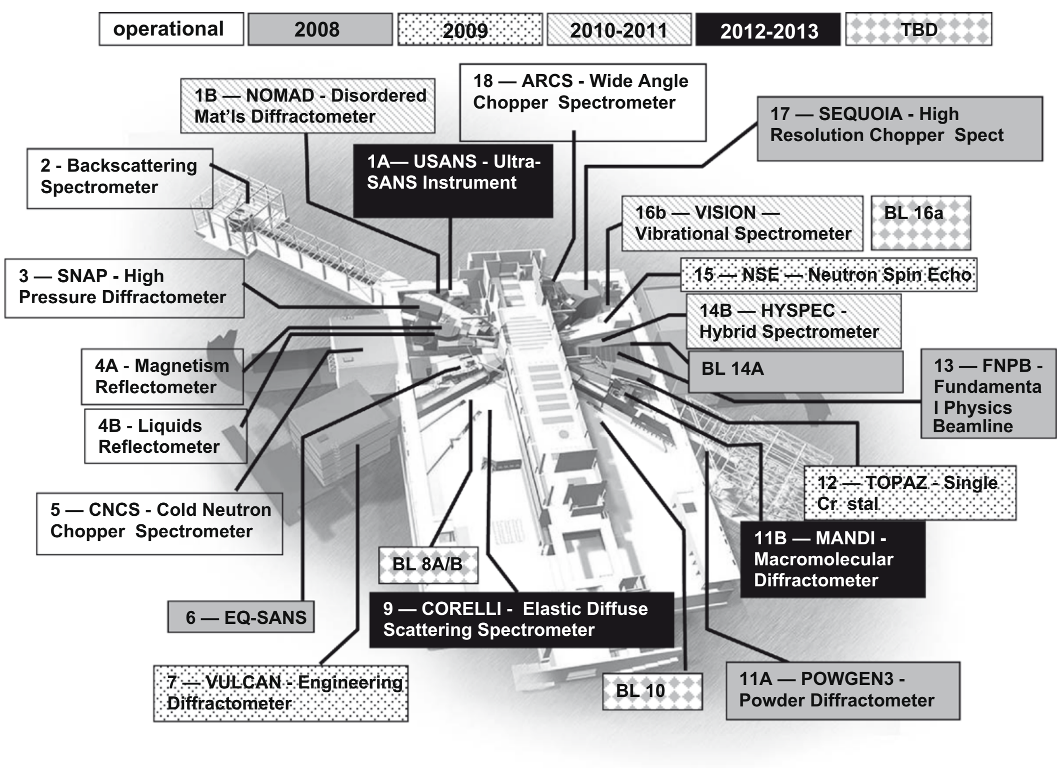

Fig. 5. SNS instrument plan.

tinguish between them. Neither system has showed any indication of leakage.

The mercury process loop has been very reliable after repairs to fix pump grease and gas seal failures were completed in December, 2006. There does not appear to have been any mercury leakage based on the background mercury vapor levels and leak detectors in the cell collection basin. A spare mercury pump has been procured which incorporates improved seal designs for the grease and helium. This pump is not planned to be installed unless there are indications of problems with the first pump.

The first spare target has been delivered. A procurement plan has been implemented to provide up to four target modules per year with at least two vendors. The third target is expected to be delivered in December, 2008. Contracts for spare targets have been placed with METALEX (the original vendor) and two additional vendors (Major Tool and Machine and Oak Ridge Tool and Engineering). The new units will be the same design as the first two. Use of 316LN was investigated, but a supplier for the quantity needed was not found and a decision to continue to use 316L was made. The thick plate material (100 mm) for the target front body will be HIPP'ed to avoid porosity problems found in the plate material for the first two targets.

A second proton beam window assembly has been delivered. The first window is expected to reach 10 dpa near the beginning of FY2010 and the current plan is to replace it at that time.

Table 1
Instrument status.

Beam line	Instrument	Planned year of commissioning
1A	US-USANS – Ultra-SANS	2012–2013
1B	NOMAD – Disordered Materials Diffractometer	2010–2011
2	Backscattering Spectrometer	Operational
3	SNAP – High Pressure Diffractometer	Operational
4A	Magnetism Reflectometer	Operational
4B	Liquids Reflectometer	Operational
5	CNCS – Cold Neutron Chopper Spectrometer	Operational
6	EQ-SANS	2008
7	VULCAN – Engineering Diffractometer	2009
8A	Uncommitted	
8B	Uncommitted	
9	CORELLI – Elastic Diffuse Scattering Spectrometer	2012–2013
10	Uncommitted	
11A	POWGEN3- Powder Diffractometer	2008
11B	MANDI – Macromolecular Diffractometer	2012–2013
12	TOPAZ – Single Crystal Diffractometer	2009
13	FNPB – Fundamental Physics Beamline	2008
14A	Uncommitted	
14B	HYSPEC – Hybrid Spectrometer	2010–2011
15	NSE – Neutron Spin Echo	2009
16A	Uncommitted	
16B	VISION – Vibrational Spectrometer	2010–2011
17	SEQUOIA – High Resolution Chopper Spectrometer	2008
18	ARCS – Wide Angle Chopper Spectrometer	Operational

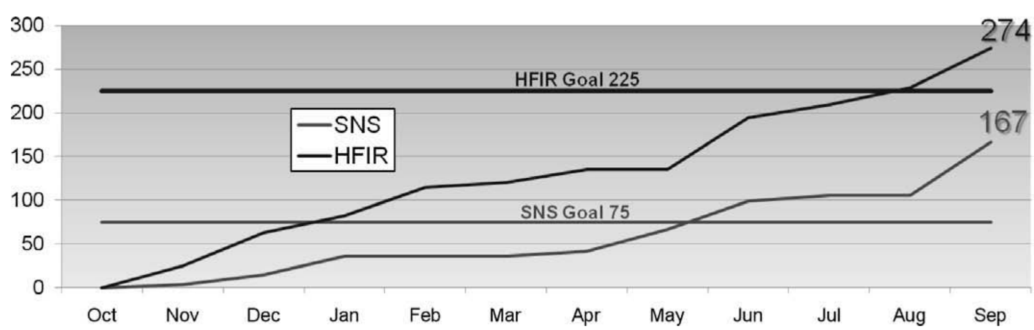

Fig. 6. FY2008 "Unique Users" exceeds goals for SNS and HFIR.

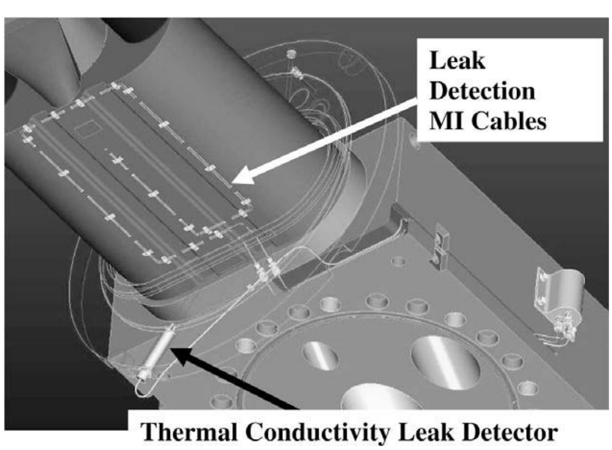

Fig. 7. Target module leak detection systems.

Fig. 8. Cryogenic moderator system refrigeration system showing the new vacuum enclosure used for a vertical orientation of the heat exchanger.

6. Cryogenic moderator system

The helium refrigeration system originally had a problem with a loss of capacity with time such that the system had to be warmed up about every 3 weeks [2]. The problem was suspected to be a gravity driven instability in the heat exchanger. The heat exchanger was removed and installed in a vertical cold box as shown in Fig. 8 [3]. This has eliminated the problem and the system can be run for over 4 months with no loss of capacity.

During the second neutron production run in FY08 there was a seal failure on one oil filter assembly in the oil recovery system of the compressor. This resulted in 150 h of downtime for repair and recovery. This operation required warming the hydrogen system, removing one of the oil filters and replacing the seal with an improved design, loading hydrogen back into the system and cooling down to operating temperature.

The moderator system has three loops, one for each hydrogen moderator. The loop for the bottom downstream coupled moderator exhibited abnormal behavior including transient pressure and flow fluctuations and an increased accumulator bellow travel. An investigation has led to the conclusion that the supply tube which should enter the moderator was fabricated to be too short and stops about 30 mm before entering the moderator. The result is that most of the supply can immediately go to the concentric return path with very little net flow to the moderator. At 500 kW the accumulator bellows motion would indicate an average hydrogen temperature at or above 35 K. Neutron spectrum measurements at 1 kW agree with predictions but at higher power the spectrum looks like that of a water moderator which would be expected with the higher hydrogen temperature. A repair plan based on inserting a flexible line to extend the supply tube is being developed to be implemented during the next shutdown starting in January.

A contract for the second Inner Reflector Plug has been awarded. Fabrication is expected to take approximately 18 months. The design incorporates features which are expected to simplify fabrication. The basic moderator design and layout will not be changed.

7. Water cooling loops and utilities

The four cooling loops have had nearly 100% availability for all run cycles. The system performance has been consistent with design and there have been no water leaks either within the core vessel or in the external loops.

When funding allows the procurement of heavy water, the reflector and core vessel cooling loop will need to be drained and the system refilled with heavy water. Since there is no gravity drain for reflector plugs or core vessel, procedures for drying these components are needed. In the February to March 2008 shutdown a drying test was conducted using heated air and vacuum. The test was very useful and identified a number of recommendations. The amount of water remaining after draining and drying was estimated by comparing the tritium concentration before draining to that after refilling with fresh water. With no improvements to the process the amount left would degrade 99.8% heavy water to approximately 97%. At present SNS has approximately 25% of the heavy water needed. It does not appear that there will be enough funding in FY09 to procure the remaining balance.

8. Summary

- SNS has met the 2008 power ramp up and new user goals.
- The facility is expected to reach and exceed 1 MW in 2009.
- New neutron scattering instruments are being added accorded to plans.
- Target systems are maturing and achieving excellent availability.
- The first target could be replaced at any time between now and July 2009.
- The first proton beam window should be replaced by late FY09 or early FY10.
- The first Inner Reflector Plug could be replaced in summer 2010 if moderator repairs are not successful.

Acknowledgements

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