RELIABILITY EXPERIENCE AT THE SRS: Fault Analysis and Related Actions

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Abstract
The SRS at Daresbury Laboratory is a 2GeV 2nd generation synchrotron radiation source. The SRS is scheduled to operate almost 6000 hours per year for users. This places significant demands on the efficiency and reliability of all accelerator components and systems.
The SRS has been in operation for users for 20 years and has an excellent reliability track record, with efficiencies typically greater than 90%. However, the last two years have been particularly difficult with a number of unrelated faults reducing efficiencies dramatically.
This paper will briefly present the reliability of the SRS over the last five years. The last two years will be looked at in detail and the components and systems, which are responsible for most of the down time will be highlighted. As a result of recent efficiency figures a number of methods of improving our reliability are being investigated. These systems will also be presented.

INTRODUCTION

The SRS is a 2GeV, 2nd generation synchrotron light source operating in the UK. It was the worlds first accelerator specifically designed to use synchrotron radiation. The SRS was conceived in 1974 and was built between 1975 and 1980, becoming operational for scheduled experiments in 1981. In order to keep the costs of the SRS down and ensure funding, as much equipment as possible from the previous high-energy accelerator, NINA, was used.

Over the 21 years the SRS has been operating there have been several upgrades to improve the performance for experimenters. In 1986/7 a major upgrade took place to change the lattice, in order to reduce the emittance, by inserting a D Quadrupole magnet in each straight. The SRS was initially designed to use the main dipole magnets as a primary source of radiation and there have been several upgrades to install insertion devices in the straight sections. These include two superconducting wavelength shifters at 5T and 6T in 1982 and 1992 respectively. Also in 1997 a project was funded to install two 2 Tesla Multipole Wigglers (MPWs) in the SRS. At the end of 1998, two 2T MPWs and vessels were installed in the SRS and have been in routine operation since the start of 1999.

Funding has already been secured for a new synchrotron radiation source to replace the SRS called DIAMOND, and current build schedules indicate completion in 2006. DIAMOND will not begin operation with its full complement of beamlines, only 7 are planned for initial user operation. This will not be enough to satisfy the user community and clearly the SRS must run reliably for users for an adequate overlap period to be determined by the Research Councils and Office of Science and Technology.

SRS OPERATIONS

The facility produces synchrotron radiation for users and is scheduled to operate almost 6000 hours per year. This places significant demands on the efficiency and reliability of accelerator components and systems. In addition to the number of user hours scheduled, the SRS is subject to Service Level Agreements (SLAs) with our funding bodies. The overall reliability of the source must be in excess of 90% for dipoles and MPWs and 85% for the superconducting wiggler sources. An allowance of 1 hour is given for each multibunch refill. Due to the excellent lifetimes at the SRS, the facility can operate with only one fill per day.

The Main Control Room (MCR) is manned continuously by 3 shifts, each with 2 operators. A duty operations team leader and a deputy operate the SRS on a day-to-day basis. Each team leader works with the same deputy, increasing team working and efficiency. There are 6 operations teams in total.

RELIABILITY DATA

Figure 1 below, shows the annual operating efficiency of the SRS since 1984. The efficiency for 01/02 is based on April – December figures only.

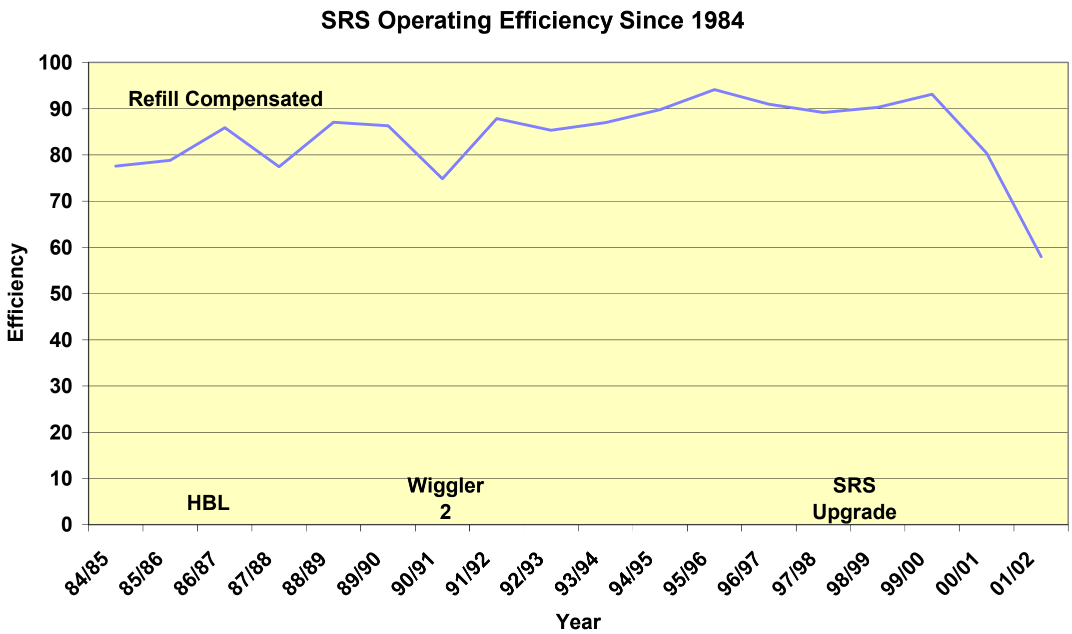

Figure 1: SRS Efficiencies 1984-2002

The SRS has proven to be an extremely reliable source of synchrotron radiation for experimenters over the last 21 years. However, the last two years have been extremely difficult and the graph clearly illustrates the dramatic reduction in efficiency. The efficiency figures for the last two years are discussed in more detail.

April 2000 – March 2001

Table 1 below summarises the performance over the year 00/01. Parameters to note are the number of fault hours, in an average year this is typically 400-450 hours. In this particular year, 1064 fault hours were recorded, although interestingly the mean time between failures did not increase.

Table 1: Summary of Year 00/01 Operating Statistics

SUMMARY TABLE			
	Multibunch	**Singlebunch**	**Total**
Scheduled Hours	4734	673	5407
Achieved Hours	3672	403	4075
Start-up and Commissioning			288
Number of User Fills	302	33	335
Shutdown Hours			2352
Injection Hours			271
Fault Hours			1064
Mean Time Between Failure (hours)			29
MB Operating Efficiency (%) with Injection Allowance			77
SB Operating Efficiency (%) with Injection Allowance			51
Beam Studies			312

Figure 2 shows the contribution of each of the accelerators major components to the 1064 fault hours.

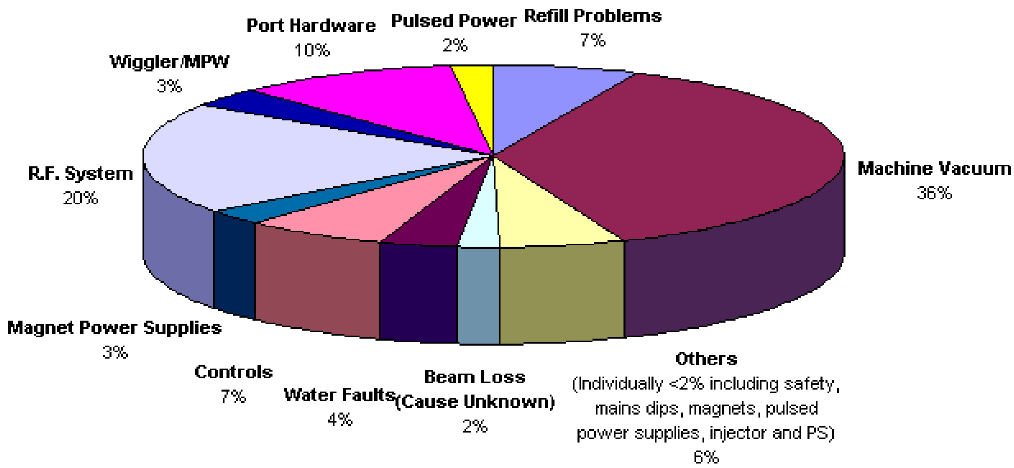

Figure 2: Fault Breakdown 00-01

The reason mean time between failure did not increase is that machine vacuum dominated the fault attributions, due to two major vacuum accidents. The first was a failed ion pump feedthrough, which let up a sector of the storage ring to atmosphere. The second was a water to vacuum leak from an RF cavity tuner. Feedthroughs and bellows are always high-risk items in a vacuum system. The length of time taken to recover from these two vacuum incidents caused the majority of the increased downtime.

The second major loss of time was the RF system. Problems arise frequently with the ageing Klystron Power Supply and this can also be seen in previous years statistics, however this year there was significant time lost due to thermal problems caused by aging waveguide components.

April 2001 – December 2001

The average efficiency to date for this financial year is 58%, it is hoped that with three months reliable running that this can be improved upon, but approximately 60% is all that is now achievable. Again this dramatic reduction in efficiency could only have been caused by a vacuum accident. In this case, a heat leak between the super conducting wiggler vessel and the cryostat froze standing water inside the vessel absorber, which fractured. This led to a major shutdown, as one complete sub sector and two ports required removing from the storage ring to be cleaned and baked. This lost approximately four months from the user schedule. A fault analysis for this year is shown the figure 3 below, clearly machine vacuum due to the failed absorber dominates the chart. The other systems have been expanded to give a clearer picture of the faults during the year.

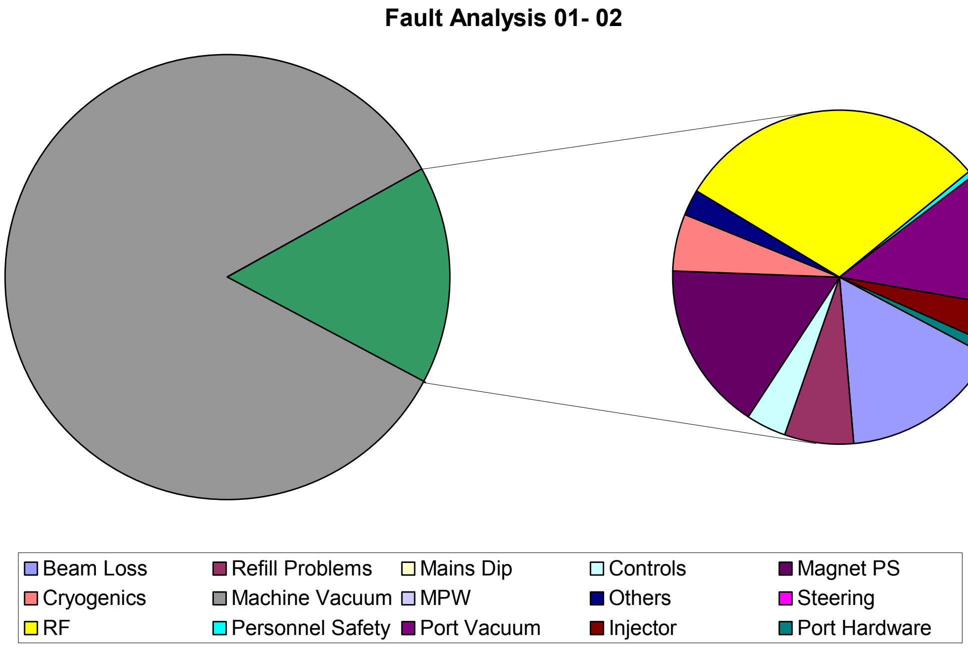

Figure 3: Fault Breakdown 01 – 02

If the expanded chart is considered, RF is responsible for the most downtime. An area of concern in these statistics is the beam loss cause unknown, responsible for 44.9 lost hours, there has been a successful drive over the last few years to reduce this figure. However, during this year it has increased again. Although faults are logged as beam loss cause unknown, this is usually because at the time the fault occurred there was no means of diagnosing the problem. If the fault continues to occur it is usually traced using portable monitoring equipment. Unfortunately the previous statistics do not get changed to reflect this.

Conclusions from Data Analysis

A feature of the recent drop in efficiency is that most of the faults are completely unconnected and not systematic. Therefore directing resources into one particular area is not likely to show a dramatic change in the statistics. However, there are some conclusions that can be drawn.

One of the major problems at the SRS is our ability to diagnose a problem quickly, due to the lack of transient diagnostic tools available to us. The SRS was not designed with the array of diagnostics available at modern machines to assist in fault diagnosis, therefore tracing a fault can, in extreme circumstances, take several intermittent beam losses. Funding for transient monitoring of SRS parameters has been included in recent capital investment proposals.

The SRS at Daresbury has been providing beam for users for 21 years, some of the equipment predates the SRS and was used on NINA. As with any facility technical risk assessment is carried out routinely and there has been modernisation throughout the operation of the SRS. However, some equipment is over 20 years old and as at that time there were no commercially available accelerator systems, these systems were designed in house. As a result, they have to be repaired in-situ rather than being quickly replaced with a spare. The programme of technical risk assessment and periodic replacement to replace obsolete and inefficient to maintain equipment must continue.

Succession planning is becoming increasingly important, due to the age profile of the Laboratory staff and the restructuring of the Departments to participate in new projects. Close immediate support from some of the technical groups is being reorganised due to new project commitments.

The user schedule is very demanding and this has resulted in the reduction of shutdown time and beam studies. Figure 4 below shows a typical, three-month period.

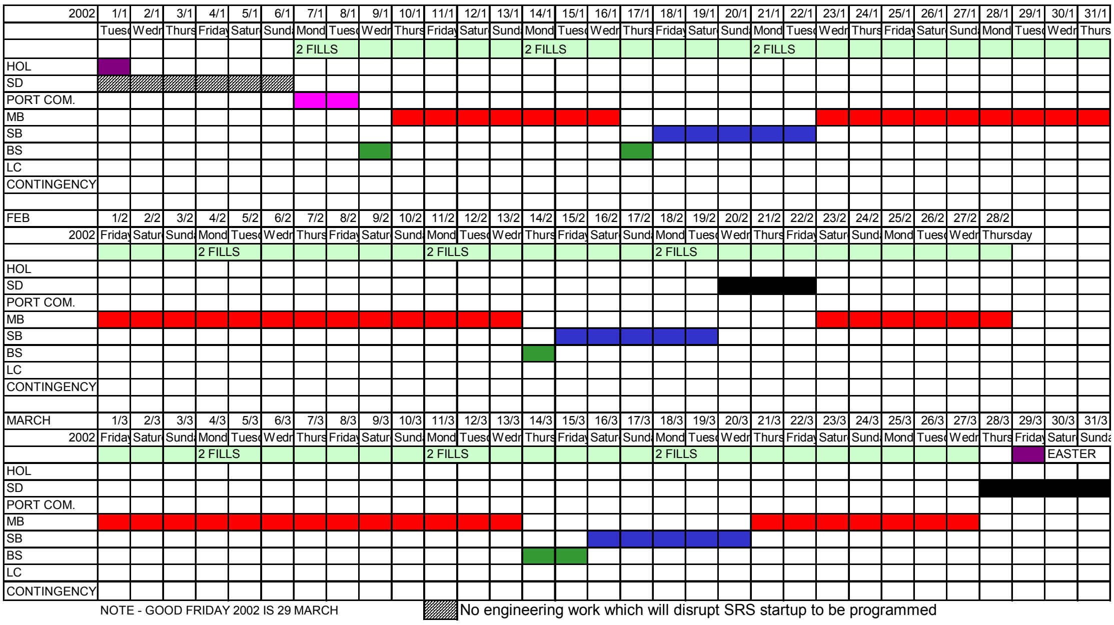

Figure 4: Typical SRS Schedule

In the last few years there have been several new projects planned and funded (insertion devices and beamlines), long shutdowns have been put in place to carry out the new projects at the expense of the short monthly maintenance shutdowns. Also, due to the tight timescales for the delivery of new projects, much of the monthly shutdown time which remains is taken up with preparation work for large projects and which reduces the amount of time and resources available for general maintenance.

ACTIONS

Since observing this down turn in efficiency and identifying some of the causes a number of actions have been put in place to reverse the trend.

Capital Investment

Although the SRS has undergone modernisation there are still key areas, which would benefit from capital investment. Senior managers, together with group leaders have identified where investment would have the most significant impact.

The first of these investments a new Storage Ring Klystron Power Supply has been funded and will be installed summer 2002. This should significantly reduce the RF contribution to the fault statistics.

Maintenance

Although significant investment is required in some areas, the statistics could be improved by small amounts of money and regular planned maintenance. This is particularly apparent in the areas of electrical and mechanical services, where it is not unusual to lose a couple of hours beam time per month, due to blocked filter or a failed cooling fan.

Over the last three years a number of new projects to install insertion devices have been secured. As a result increasing pressure is put on the technical groups to fulfil both the new project and general maintenance requirements.

In order to temporarily redress the balance between new project work and maintenance, a new monthly meeting has been set up at group leader level to discuss the months operating statistics and faults. Actions can then be placed on the various technical groups to solve any current operational problems.

Pressure to include more shutdown time in the schedule will be applied at the next scheduling meeting. The additional shutdown days will be used to carry out SRS regular maintenance only and not new project preparatory work. Alternatively a solution is being considered where each technical group provides some resources to the operations group for the duration of a shutdown. These staff will carry out maintenance work under the direction of the operations team, while the rest of the technical group will continue with project work. If this system is to work, detailed regular maintenance schedules need to be drawn up by each group leader for the equipment they are responsible for.

When we recover from our high new project workload, we will be able to return to our regular maintenance procedures.

Risk Assessment

One of the difficulties of operating an older machine is that it evolves over a period of time and equipment, which was required for one configuration, may not be required on the present machine. Some of these items may be high risk, i.e. unnecessary bellows, water connections, etc. As a result we are in the process of carrying out a comprehensive technical risk assessment of the SRS. This will identify any high-risk items on the SRS and place responsibility for mitigating that risk on to individual technical group leaders.

This risk assessment is to use formal techniques to evaluate risk. All SRS Control Parameters, the facility inventory and updated schematics are being used to aid the process. A set of guide words are employed with each parameter to consider the risk:

Mechanical Assembly	Mechanical Services	Electrical Assembly	Electrical Services	Vacuum Systems	Control Systems
Power Supplies	Motor Systems	Radiation	Personnel Safety	Spares	Air
Water	Cables	Information	Obsolescence	Knowledge	Responsibility

The following is an excerpt from the Linac Risk Assessment. The likelihood of the risk occurring and the impact of the risk to operations are assessed and each assigned a number from 1 to 5. These two numbers are then multiplied together to give a risk exposure. Resources can then be targeted at high risk areas.

Risk Gun	**Likelihood**	**Impact**	**Risk Exposure**	**Discussion**	**Action and Responsibility**
Between 1 and 2 weeks loss of operations due to mechanical failure of the conflat gun assembly and ceramic tube	Low 1	High 3	Low 3	The spare assembly is the original using wire seals, which was replaced due to poor reliability.	Procure new conflat spare. J Manning
Operational delay and inefficiency due to present reliance on two highly experienced shift staff. One due to retire in months and the other in up to 4 years	Medium 2	High 3	Medium 6	The RF group has always exploited the skills of shift staff that were responsible for the original engineering of LINAC systems. With retirement approaching, succession planning both on and off shift is necessary	Assign technical staff to understudy our existing experts immediately. D M Dykes/C L Hodgkinson

CONCLUSIONS

Although efficiency has reduced in the last two years, there is no indication that there is any systematic failure, which would indicate that the SRS's useful life is limited. However, to ensure efficiency remains high and maximise the performance of the SRS, a number of significant capital investments are required.

The very poor efficiency figures over the last two years has been due to three completely unconnected vacuum accidents, which require long recovery programmes. A full risk assessment of the accelerators is being carried out to high risk areas and actions placed to mitigate the risk.

Diagnosis of problems still remains a problem, although both the Operations and Controls Groups are investigating methods of overcoming some of the difficulties.

ACKNOWLEDGEMENTS

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