THE REFILL WIZARD - IMPROVING EFFICIENCY AT DARESBURY LABORATORY’S SYNCHROTRON RADIATION SOURCE

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Abstract
The SRS at Daresbury Laboratory is a 2 GeV 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. Although the SRS operates with only one refill per day, each taking about an hour, with such a demanding user schedule the length of time taken to refill can be significant when calculating the annual performance statistics. The duty operations team leader traditionally determined the refill sequence at the SRS without following a strict procedure. In December 1997, a very narrow aperture vacuum vessel was installed. Following this, if the correct refill sequence was not followed the potential for major component damage during injection was significant. The Refill Wizard, a series of tcl script programmes, was introduced to guide the operations team through the correct procedure at every refill in a step-by-step manner. The introduction of this operations software has led to increased efficiencies by making the refill process repeatable and predictable. This paper will discuss the significant advantages of such a system and will also highlight the unexpected disadvantages encountered during daily operations using the Refill Wizard.

1. INTRODUCTION

The SRS is a 2 GeV, 2nd generation synchrotron light source operating in the UK. It was designed to use the main dipole magnets as a primary source of radiation, however during its lifetime there have been several major upgrades to install insertion devices in the straight sections, these devices have relatively large apertures.

In 1997 a project was funded to install two 2 Tesla Multipole Wigglers (MPWs) in the SRS. The MPWs were designed to provide high flux at 10 keV, therefore the vertical aperture was carefully assessed to determine an optimum gap with respect to lifetime. It was concluded that the internal beam stay clear region in the straight sections could be reduced from 36 mm to 15 mm with a reduction in lifetime of approximately 15% [1]. In December 1997, a prototype MPW vessel was installed in the SRS to gain operational experience refilling the machine with such a small aperture. At the end of 1998, the two MPWs and vessels were installed in the SRS and have been in routine operation since the start of 1999.

With the introduction of the two narrow aperture vessels the potential for major component damage during injection was significant. In order to prevent damage the correct refill sequence had to be followed. This paper describes how the SRS was traditionally refilled, the solution employed to prevent damage to the narrow gap vessels and its subsequent effects on SRS operations.

2. 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. However, with such stringent requirements placed on the reliability of the source and the limited time allowable for refills, it is critical that each refill is completed quickly and efficiently. Unless Beam Studies time is scheduled the duty operations team leader is responsible for conducting all SRS refills.

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. The additional cover enables annual leave and sick leave to be covered easily. In addition each member of the team can carry out project work.

3. REFILL OF THE SRS PRIOR TO THE INTRODUCTION OF THE WIZARD

Prior to the introduction of the narrow gap vessels each team leader had complete autonomy and carried out refills to suit their own personal style. This method of refill produced very different procedures and refill times varied from one operations team to another. However, provided that the time taken was within that allowable in the SLAs there was very little drive to standardise the system.

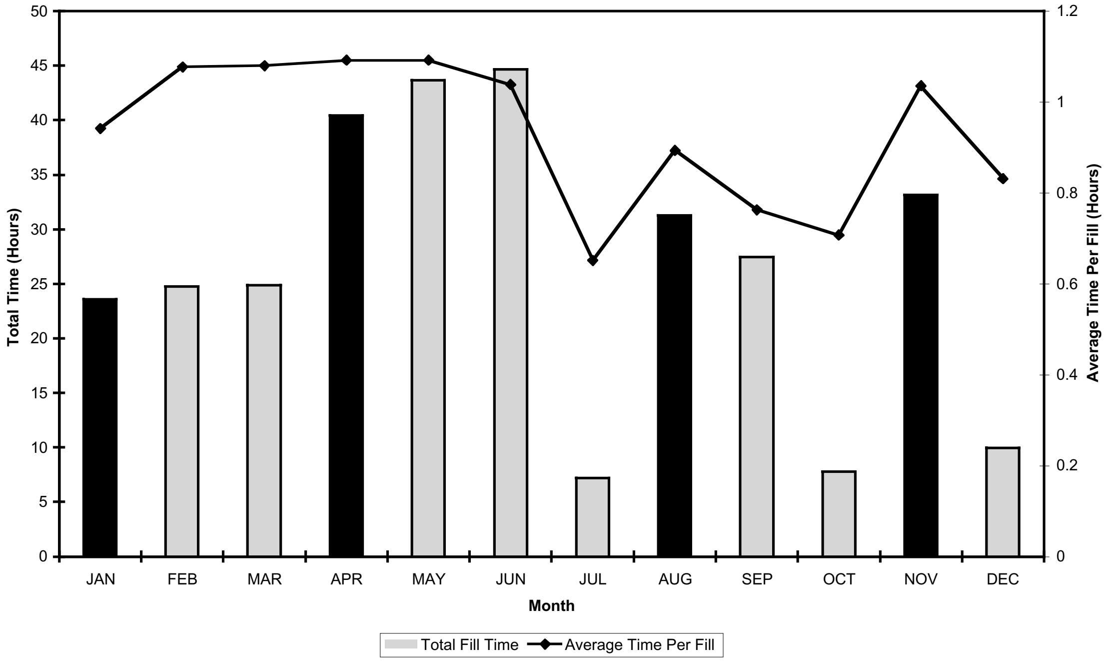

Fig. 1: Multibunch Refills in 1997

The graph shows the refill statistics for multibunch operations in 1997. Total time spent refilling per month is shown on the left and the average time per fill for each month shown on the right.

The average time taken for a multibunch refill in 1997 was 58 minutes.

4. THE INTRODUCTION OF THE WIZARD

In December 1997 the first narrow gap vessel was installed into the SRS storage ring. During the design phase of the project it became apparent that the possibility for major component damage during refill was significant due to very high power levels in the photon beam and various vessel protection systems were put in place. However, this did not eliminate the possibility of human error and it became necessary to ensure the correct refill sequence was followed. A system was required which allowed the operations team to refill the SRS in a step-by-step manner. The solution employed was The Sequence Manager, more commonly known as ‘The Wizard’.

4.1 The Wizard

The Wizard is a programme, which can read and execute a text file in a particular order. The file the wizard uses is the SRS Refill file, which is just a text file that contains a list of executable Tool Command Language (tcl) programmes. Tcl is a general purpose, robust command language that can be easily integrated into new applications. Tcl programmes are scripts consisting of tcl commands, which are processed by an interpreter.

The complete SRS Refill text file is given in Appendix 1. As the wizard reads each line of the text file in order the associated tcl programme is executed. An example is shown below:

The SRS Refill text file final line is:

Run Goodbeam,2,GoodBeam.tcl

Run Goodbeam appears in the wizard window. Goodbeam.tcl is the name of the programme to be executed. The number 2 indicates a level of priority. The wizard runs at level 5, therefore those lines that have a number less than 5 must complete successfully to allow the next line in the file to be executed. If a line fails to complete there is the option to run the script again or to debug. The debug function allows the operator to move on to the next line even though the previous tcl script has not been completed correctly. This function is useful where the fault is likely to be communications problem, rather than a real fault. All lines in the SRS Refill file are at level 2, except one, the line reads ‘Cycle OCEMs,6,CycleOcems.tcl’. As this number is higher than level 5, at which the wizard operates, the sequence will continue even if this tcl script does not execute properly. This particular script runs a degauss cycle on the magnet power supplies. Communications between the magnet power supplies and the control system is carried out using RS232, which is relatively slow and an error message was generated regularly. The debug command allowed the operator to continue with the refill in these circumstances, however the fault occurred often and caused unnecessary delays in refill. By changing its priority to 6 the wizard ignores the error message and continues with the sequence, eliminating the unnecessary delays. Before using this technique the implications of the script not running must be carefully considered. In this case the implications are minor if the degauss sequence does not run and injection into the storage ring is not achieved, some time is lost fault finding and rerunning the sequence from the degauss cycle.

Since it is a text file based it is easy to edit and add new tcl scripts. Several scripts have been written by the Accelerator Physics group rather than relying on specialist controls programmes. An example of a tcl script Goodbeam.tcl is shown in Appendix 2

5. THE EFFECT OF THE WIZARD ON OPERATIONS

The wizard was introduced as a safety feature to prevent significant damage to the two narrow gap vessels and flexibility has been deliberately reduced, this caused considerable concern in the operations group. It was perceived that the reduction in flexibility would reduce efficiency by preventing the duty operations team leader from intervening at particular points during the refill. However, flexibility can still be maintained, by understanding what each of the tcl scripts are doing. Scripts can be modified and run individually or arranged in a text file in a particular sequence for the wizard to execute.

In addition to its safety role the wizard has provided some significant benefits. Since the installation of the two new narrow gap vessels during December 1998, there have been two full years of refill statistics using the wizard. The two graphs below show multibunch refills in 1999 and 2000.

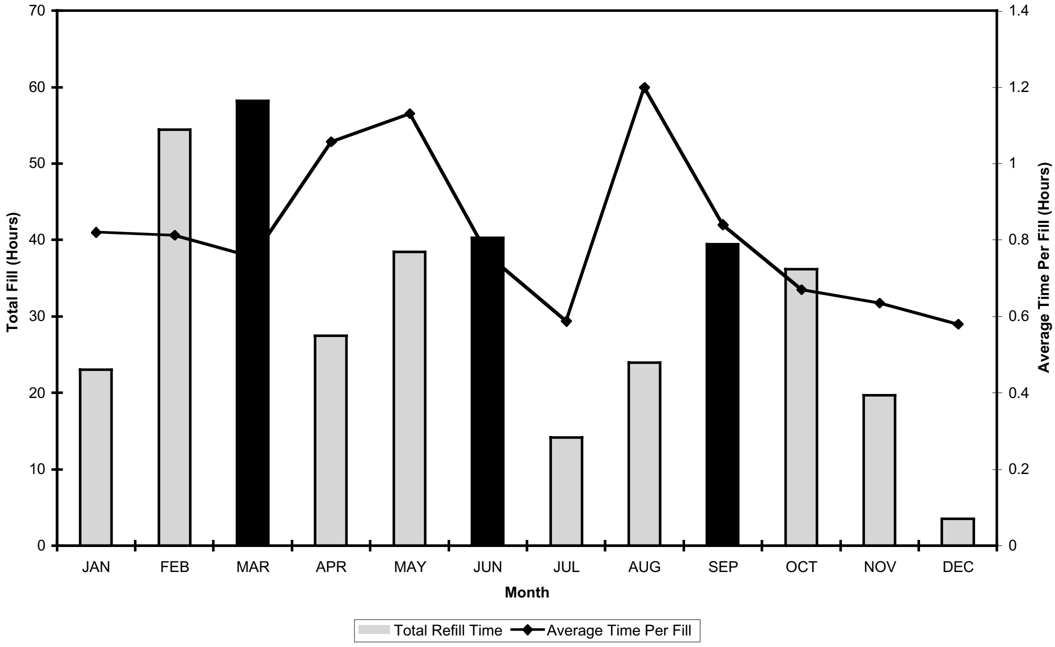

Fig. 2: Multibunch Refills in 1999

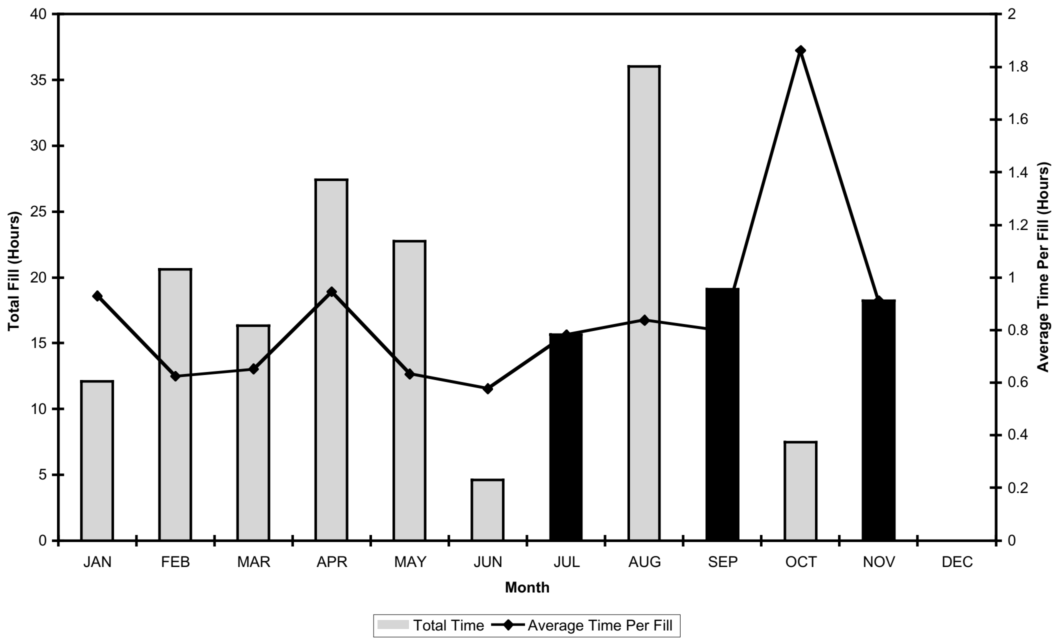

Fig. 3: Multibunch Refills in 2000

The average time taken to refill the SRS in 1999 and 2000 was 48 minutes and 47 minutes respectively. The refill times for 2000 include a significantly longer superconducting wiggler ramp (approximately 5 minutes longer), due to control system changes. The figure for 2000 also includes the high average refill time in October due to problems with the RF system.

The reduction in refill times has been achieved by allowing the precise timing and order of events to be modified in a systematic manner. The wizard locates and executes all of the small programmes that the operations team had to search around for, prior to its introduction. By using a single wizard in this way the interaction between the various front end controls systems and the operations team has been simplified. A significant benefit has been the ease with which the operations team can change between various operating conditions. A selection box appears at the launch of the wizard, at which point the operations team can select which insertion devices are available, the wizard then selects the appropriate scripts for that particular refill. This can save a significant amount of setting up time, when an insertion device has to be withdrawn unexpectedly due to a fault.

Another benefit is that there is no confusion over file names. For instance, the latest steering file is already applied as are the best settings for obtaining injection. Occasionally in the past incorrect files were used because of poor communication, this is no longer an issue.

In addition to the reduction in refill times, the overall reliability of the source for users has been improved by correct sequencing. For example soft starts on particular power supplies have been routinely introduced to prevent overload trips. In another case, a line has been added to the wizard, which checks the MPWs can wind out before allowing beam dump. This improves efficiency by keeping the stored beam until the correct technical groups have been contacted and are ready to correct any fault immediately on beam dump. Beam stability has also been improved by keeping the magnets on for the maximum amount of time prior to refill, ensuring optimum thermal stability.

The introduction of a step-by-step refill sequence has made the training of new operations staff much easier. In addition, as all operations team leaders now refill in the same way, when a member of the operations team is on leave, to replace that member with a stand-by causes much less disruption to the two man team.

Although the wizard has been proved to provide significant benefits to the operation of the SRS, there have been some unexpected disadvantages. All of these disadvantages are associated with the lack of flexibility and also the operators are now divorced from the procedures happening in the background.

The operations staff who operated the SRS prior to the wizard gained significant understanding of the accelerators. This knowledge was necessary to refill the machine. The refill wizard has simplified the refill to the extent that this knowledge is no longer necessary during routine operations. Although the wizard has made it easier to train new operations staff, the length of time taken to acquire the same knowledge of the accelerators and controls systems is much longer, as there is no longer a requirement for it on a day-to-day basis. This reduction in expertise is noticeable when serious problems arise with the operation of the accelerators.

Due to the sequential nature of the wizard there are cases where the wizard has actually increased the refill time. The wizard has been developed to refill the SRS from the beginning; therefore these situations usually arise when a fault condition has occurred at some point during the refill. A significant part of the sequence may need to be repeated increasing the time taken to re-establish injection. This is due to conditions written into the scripts, which assume refill from a controlled beam dump.

If the refill fails continually, it is more likely that a member of the Accelerator Physics Group is required to solve the fault. Fault finding and correction now relies upon the understanding of what each of the tcl scripts do, where each of them are located and the interaction between tcls and other files. However, it is usually clear where the fault lies and so solving such problems is usually faster than in the past.

6. CONCLUSION

The refill wizard was developed and introduced as a safety feature. It has fulfilled its role of protecting the narrow gap vessels from damage for the last 3 years. Although received sceptically at first, due to the deliberately reduced flexibility during refill, the wizard has performed well and provided some additional benefits. The refill wizard is an excellent memory aid and minimises most of the repetitive tasks. It almost eliminates the possibility of operator error, particularly during busy periods in the MCR. As a result of using the wizard, refill times have reduced by approximately 10 minutes (17%) even though more actions are taken by the operations team due to the introduction of 2 additional insertion devices. The user community have benefited from increased reliability of components and beam stability due to correct sequencing during refill. However, the reduction in flexibility does inevitably cause some frustration to the operations teams, particularly when the beam is lost part way through a fill and the time taken to recover is much longer due to the sequential nature of the wizard. The wizard simplifies the refill to the extent that new operators are able to refill the SRS very quickly. However, the detailed knowledge that was required to refill the machine is no longer required on a day-to-day basis, which could prove to be a disadvantage in the long term.

Since the introduction of the wizard the benefits to operations have far outweighed the minor disadvantages. The SRS Refill Wizard has proved to be a major improvement to the safety, efficiency and reliability of the SRS.

7. ACKNOWLEDGEMENTS

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References

[1] James A Clarke, Neil Bliss, David Bradshaw, Cheryl Dawson, Barry Fell, Neville Harris, Gary Hayes, Michael Poole and Ron Reid, ‘Design of a 2 T Multipole Wiggler Insertion Device for the SRS’, Journal of Synchrotron Radiation (1998), Volume 5, pp. 434-436.

APPENDIX 1 – SRS REFILL TEXT FILE

Check MPW6 is OK,2,MPW6Check.tcl
Check MPW14 is OK,2,MPW14Check.tcl
Open MPW14 Gap,2,OpenMPW14Gap.tcl
Unlock MPW6,2,MPW6Unlock.tcl
Open MPW6 Gap,2,OpenMPW6Gap.tcl
Switch off servos,2,ServosOff.tcl
Dump The Beam Using the RF,2,BeamDump.tcl
Set Wigglers to zero,2,WigDown.tcl
Run Injection sequence,2,OpsSequence.tcl
Check DISPs,2,CheckDisps.tcl
*** Open Undulator Gap ***,2,OpenUndulatorGap.tcl
Show refilling,2,ShowRefilling.tcl
Reset Steering,2,ResetSteering.tcl
Set-up Transfer Path,2,TransferPathSetup.tcl
Cycle OCEMs,6,CycleOcems.tcl
Set Injection Steering,2,InjectionSteering.tcl
*** Set Timing mode ***,2,SetTiming.tcl
Check cavity impedance calibration,2,ImpedanceCal.tcl
Switch on RF,2,RFOn.tcl
Set OCEMs/RF for Injection,2,InjectionSetup.tcl
*** Start Stacking ***,2,StartStacking.tcl
*** Store Beam ***,2,StoreBeam.tcl
Start Ramp steering system,2,RampSteerOn.tcl
Arm Vessel Protection system,2,VesselProtection.tcl
Start Orbit Trip,2,OrbitTripOn.tcl
Start Ramp,2,StartRampRF.tcl
Switch Off DSHN,2,DSHNOff.tcl
Initialise MPW14,2,SendMPW14TrakMap.tcl
Close MPW14 Gap,2,SetMPW14Gap.tcl
Initialise MPW6,2,SendMPW6TrakMap.tcl
Close MPW6 Gap,2,SetMPW6Gap.tcl
*** Ramp Wigglers ***,2,RampWigglers.tcl
Stop Ramp Steering system,2,RampSteerOff.tcl
Apply User Steering,2,UserSteering.tcl
*** Check H Orbit ***,2,HOrbit.tcl
*** Steer Line 5U ***,2,SteerLine5.tcl
*** Steer All TVMs ***,2,Steer.tcl
*** Run Global Servos ***,2,GlobalServos.tcl
Show User Beam,2,UserBeam.tcl
*** Record Fill Structure ***,2,RecordFillStructure.tcl
Run Goodbeam,2,GoodBeam.tcl

APPENDIX 2 – GOODBEAM.TCL

```
# Goodbeam.tcl
# --------------
#
# This file runs the injector down
#
# Revision history:
# ------------------
# 25th Nov 1998 BGM Script rewritten for MPW upgrade
# 8th Feb 2000 BGM Added SI parameters
# 20th Mar 2000 SFH Corrected error - SI.HTRBs now switch OFF

package require Sequence

sequence::init true
sequence::completion 1 "Script interrupted"

sequence::heading "GOODBEAM SEQUENCE \n\n"

catch {sequence::setProp BM.ACPI.01 CCV 0.0}
catch {sequence::setProp BM.DCPI.01 CCV 0.0}
catch {sequence::setStatus BR.RFON.01 OFF}
catch {sequence::setStatus {FR.PULS.01 FR.PULS.02 FR.HTV.01} OFF}
catch {sequence::setStatus {BI.HTRB.01 BI.HTRB.02 BI.SEPT.01} OFF}
catch {sequence::setStatus {BE.HTRB.01 BE.HTRB.02 BE.HTRB.03} OFF}
catch {sequence::setStatus BE.BUMP.01 OFF}
sequence::remark "\nBooster magnets running down. Please wait 60 seconds...\n"
sequence::wait 60000
catch {sequence::setStatus {BM.ACPI.01 BM.DCPI.01} OFF}
catch {sequence::setStatus {LG.HTV.01 LG.RFHT.01} OFF}
catch {sequence::setStatus LR.KHTV.01 OFF}
catch {sequence::setStatus LR.HTRB.01 OFF}
catch {sequence::setStatus LR.DHTR.01 OFF}
catch {sequence::setStatus TM.DIP.02 OFF}
sequence::remark "\nLinac Off and Booster magnets Off\n"
sequence::wait 2000
catch {sequence::setStatus SI.POSN.01 ON}
catch {sequence::setProp SI.POSN.01 CCV 0.0}
catch {sequence::setStatus {SI.HTRB.01 SI.HTRB.02 SI.HTRB.03 SI.HTRB.04} OFF}
sequence::remark "\nSeptum retracted and Heaters off\n"
sequence::wait 2000

sequence::completion 0 "OK"

exit
```