

The SRS Multipole Wiggler Vacuum Vessel Protection System.

J.A.Balmer, M.J.Dufau, D.M.Dykes, B.D.Fell, M.T.Heron, B.G.Martlew, M.J.Pugh, W.R.Rawlinson, R.J.Smith, S.L.Smith, B.Todd, CLRC Daresbury Laboratory, Warrington WA4 4AD, UK.

Abstract

The UK Light Source, the SRS, is being upgraded by the addition of two multipole wiggler magnets. The vertical aperture of the multipole wiggler vacuum vessel, which is manufactured from a titanium alloy, is ± 7.5 mm. This paper reports the investigations into the effect of synchrotron radiation striking uncooled surfaces from the upstream dipole due to a mis-aligned electron orbit. It also describes the measures taken to protect the vessel, including a fast interlock system for beam dumping.

1 INTRODUCTION

The SRS Upgrade is a major project to install two new beamlines onto the SRS both based upon a high field multipole wiggler insertion device [1]. As the SRS is a congested 2nd generation light source several machine components have to be rearranged for the two new insertion devices to be installed, and the four RF accelerating cavities have to be relocated [2]. The shutdown for this work will be towards the end of 1998.

However some installation work has already taken place. In January 1998 one of the narrow gap titanium vacuum vessels [3] was installed in straight 14 so that experience could be gained running the SRS with a much-reduced aperture, i.e. 15mm instead of the previous minimum of 36mm.

If the electron beam is mis-steered then the synchrotron radiation from the upstream dipole could illuminate uncooled surfaces of the new ID vessel. The subsequent increase in heating, in the worst case, could cause the titanium vessel to melt in a few seconds. To prevent any damage to the vacuum vessels and machine components an integrated vessel protection system and method of operation was instigated.

2 IRRADIATING THE VESSEL AND UPSTREAM FLANGE

Orbits that may illuminate the MPW vessel or the upstream flange were determined from simple ray tracing. The assumed opening angle of the radiation, the vertical position of the intercepting surface and the distance from the source point determine the locus of beam position and angle at the source point which will just illuminate the considered surface. Figure 1 shows the ray tracing results carried out for dipole 13 and the ID vessel in straight 14.

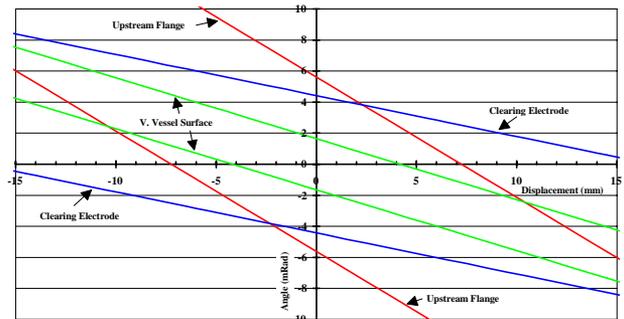


Figure 1: Position and Angles at The End of The Dipole Which Can Irradiate Machine Surfaces

To determine whether a beam could survive in the machine and irradiate a surface, random orbits were scaled until they were lost at the machine aperture. Figure 2 shows the position and angle recorded for 150 such orbits at the end of dipole 13.

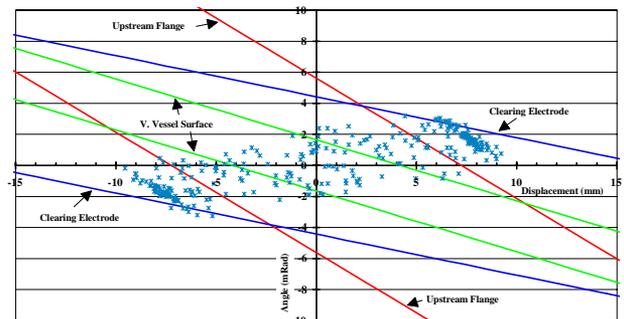


Figure 2: Survivable Random Orbits.

Clearly, from figure 2, it is possible to irradiate the vessel and the flange with survivable orbits. Further analysis shows that orbits at ± 2.6 mm at the vertical BPM could irradiate the ID vessel and orbits at ± 5.5 mm could irradiate the upstream flange of the ID vessel.

3 FEA ANALYSIS OF THE ID VESSEL

Finite element analysis (FEA) was undertaken to predict the temperature rise for both the internal glancing and direct incidence situations, in the worst case conditions. It was assumed that with an electron beam of 300 mA at 2 GeV, the heat load is 12 W per mrad and with the vertical beam size of 0.3 mm the divergence of the thermal gaussian is 0.25 mrad at the beam impact 1.24m from the source.

3.1 Irradiating the ID Vessel

This case is schematically illustrated in figure 3, and represents the worst heat load condition at a glancing angle. The temperature distribution is shown in figure 4. The steady state temperature rise is > 1400 deg. C, whilst this is below the melting point for the vessel material, it is clearly unacceptable.

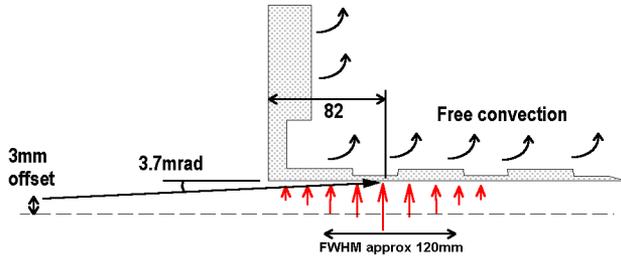


Figure 3: Schematic of Glancing Irradiation of ID Vessel

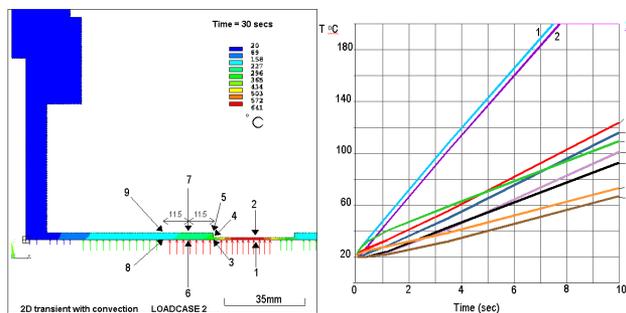


Figure 4: Temperature Distribution For Vessel Irradiation

3.2 Irradiating the Upstream Flange

This case is schematically illustrated in figure 5, and represents the worst heat load with the SR beam striking the flange. The temperature distributions are shown in figure 6. Calculations indicate that the material would melt in under 4 seconds.

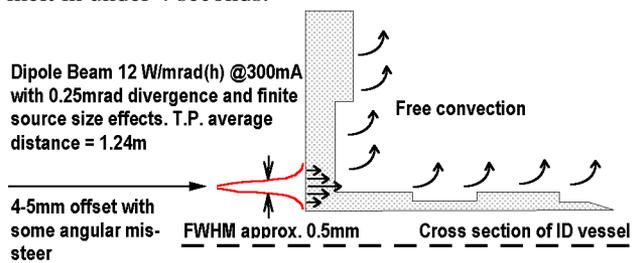


Figure 5: Schematic of SR Beam hitting ID Vessel Flange.

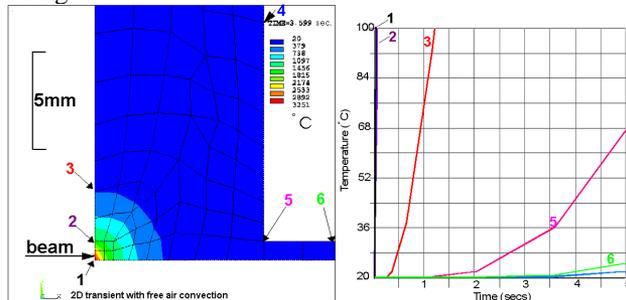


Figure 6: Temperature Distribution For Flange Irradiation

4 PROTECTION SYSTEMS

The solution involved a number of different systems, including changes to the engineering of the vacuum system, operational software changes, hardware protection systems and software protection systems.

4.1 Engineering Changes

It has been decided to insert a water-cooled copper flange on the upstream side of each ID vessel. A photograph of one of the flanges is shown in figure 7. This solves the problem of SR beam hitting normal to the ID vessel flange.



Figure 7: Water Cooled Flange

4.2 Operational Software Changes

The existing orbit bump application software has been modified to prevent application of bumps that could produce harmful effects. All bumps applied now have pre-defined limits in both the horizontal and vertical planes. A bump reset is now performed only by cycling the magnets or by applying fixed steering file settings.

The introduction of improved software for the energy ramp servo has been necessary to provide precise control of the orbit from EBPM readings whilst the stored beam energy is ramped from injection levels (600MeV) to 2.0GeV.

Ramping the stored beam is permitted only when the horizontal and vertical jaw positions are within defined limits. This restriction gives limited protection, but does trap some orbits which would irradiate the MPW vessel if the jaws were left fully open.

A change in the philosophy of SRS operation has required the introduction of sequencing software to control the precise order of events that occur when refilling the SRS. It utilises the universal scripting language Tcl/Tk 8.0™ with a custom library to interface this to the control system. Each step of the refill process is defined by a Tcl scriptlet, written in consultation with Accelerator Physicists. This software has allowed an efficient refill procedure to be established and provides additional safety by ensuring that correct settings are applied in each operating mode.

4.3 Beam Position Protection System

The MPW vessel is mounted within the magnet support system located and isolated by vacuum bellows, fixing its position. ESRF type buttons with titanium bodies were fitted within a pocket at the rear of each flange, such that they and their cabling are prevented from fouling the MPW magnets. This allows the magnet poles to move past the rear of the flange as the gap is closed. Thus the beam position within the MPW vessel itself is measured vertically. Figure 8 shows the location of the buttons within the vessel and also shows an end view taken during electrostatic analysis using the QuickField™ 4 finite element analysis (FEA) package.

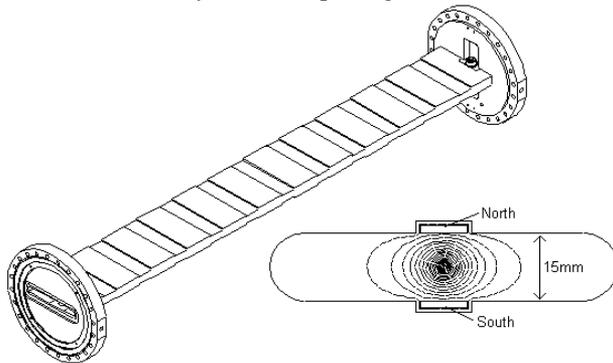


Figure 8: MPW Vessel Showing Vertical EBPM Layout and The Simulated E-Field Distortion.

For the EBPMs within the MPW vessel, a commercial system manufactured by BERGOZ Instrumentation using the switched button amplitude measurement technique has been installed. This system has a fast position update rate (1kHz as standard), produces smoothed DC outputs representing beam position and has sufficient side-band rejection to allow single bunch beam mode operation. This system lends itself to the simple introduction of a position based beam trip in the event of a mis-steering of the beam leaving the upstream dipole.

Since the EBPM response is very linear, the system has been set up to provide a DC output representing 1 Volt per mm. A pair of simple windowing comparator systems is used on both the upstream and downstream MPW EBPMs to provide active interlocks along with a lower level audible alarm in the event of a slow position drift towards the trip level.

The active interlock interrupts the low-level RF drive to the Klystron amplifier thereby tripping the beam. A beam position signal, which exceeds a pre-set limit, results in a normally open contact tripping the beam in 20mS, thus protecting the MPW vessel. To allow filling of the storage ring, a simple over ride relay operating from the storage ring dipole DC current, over rides the interlock chain, becoming automatically active at beam energies above 0.65GeV (450Amps).

4.4 Temperature Protection System

A temperature interlock system has also been installed in an attempt to give protection against slower temperature rises due to the photon beam striking the MPW vessel surface at a glancing angle in the horizontal plane. Thermocouples have been installed along the top and bottom of the ID vessel following the line of optimum heating in the event of a mis-steer, to improve their response time.

The system comprises of 24 K-type thermocouples feeding a DL3000 DT Data Logger, which compares the temperatures against the trip temperature level, which has been set at 50 °C. If any part of the vessel reaches the trip limit, the RF will immediately be tripped off.

4.5 Software Protection System

The software interlock and diagnostics provide a secondary safety system for the prevention of damage to the MPW vessel. This continuously monitors the orbit position from the existing 16 horizontal and vertical electron BPMs and if there is a drift in position over a period of time it will trip off the RF system.

5 SUMMARY

The MPW vessel within the SRS has been protected by the active interlock system for approximately 5 months, during which time there have been a number of beam trips. In most cases these have been caused by noise within the system or malfunctions within associated sub-systems. On several occasions, the interlock has performed its action due to genuine large orbit excursions during ramping and stored beam operation. Over the whole period of operation, the thermal interlocks have never shown any increase in temperature that could be attributed to beam irradiation. Work has continued to improve reliability and eliminate spurious tripping to the point that the this system no longer has any significant impact on machine performance and reliability.

REFERENCES

- [1] J.A.Clarke and M.W.Poole, "Upgrading the SRS with Additional Insertion Devices and its Implications for the Storage Ring Layout", Proc 5th EPAC Sitges, June 1996.
- [2] D.M.Dykes, "RF System Changes Associated with the SRS Upgrade", Proc 5th EPAC Sitges, June 1996.
- [3] J.A.Clarke et al, "Progress with the SRS Upgrade Project", these proceedings.