SLAC-PUB-3716
June 1985
(A)

STATUS OF THE SLC DAMPING RINGS*

A.M. Hutton, W.A. Davies-White, J.-P. Delahaye(CERN), T.H. Fieguth,
A. Hofmann, J. Jager, P.K. Kloeppel(CEBAF), M.J. Lee, W.A. Linebarger,
L. Rivkin, M. Ross, R. Ruth, H. Shoaee and M.D. Woodley.

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

Electron beams of full design energy 1.21 GeV and nearly full design intensity 4×10^{10} particles/pulse (design 5×10^{10}) have been extracted from the Stanford Linac and successfully stored in the electron damping ring. Beams of less intensity have been extracted from the ring and reinjected into the Linac. The present intensity limits are not thought to be fundamental. The operating experience with the electron ring and the status of the construction of the positron ring will be discussed.

INTRODUCTION

The status of the SLC electron damping ring was presented at the last International Conference on High Energy Accelerators[1] at a time when the whole complex was just completed. In this paper, the considerable amount of operating experience which has been accumulated on the ring will be briefly presented, with special attention to those points which have led to design changes in the positron ring. During most of this period, the machine has been deliberately stressed to find weak or unreliable components resulting in considerable downtime. We felt that this policy would pay off in the long term when the damping rings must operate reliably for long periods as part of the SLC project. It is worth noting that few fundamental problems have been encountered with the basic concepts, and, while this paper will necessarily focus on changes, the design and construction of the positron damping ring complex will finally be very similar to that of the electron ring.

LAYOUT CHANGES

In the original SLC design[2] the two damping rings were to be vertically superposed in the same vault. This implied that both electrons and positrons had to be deflected south; the electrons descending 35 cm, the positrons rising 35 cm. The extraction scheme to accomplish this started with a pulsed vertical bend and a double Lambertson septum magnet, SBO, with opposing fields in the two halves. This concept was changed in January 1984 with the realization that installation of the second ring above the first would pose considerable scheduling problems and require an extended shutdown of the existing ring. The decision was therefore taken to put the second (positron) ring on the north side of the Linac, as shown in Figure 1. Extraction from the Linac could then be accomplished using a simple horizontal bend, pulsed for test purposes and DC in the final SLC configuration. Reinjection into the Linac uses a horizontal bending magnet which can only be operated DC in order to obtain the high field quality required to meet the SLC specification. A side benefit of this change is the removal of the SBO magnet which had been shown to have an unacceptably high skew quadrupole component during the Ten Sector Test[3].

This change required rebuilding the south injection lines LTR (Linac-to-Ring) and RTL (Ring-to-Linac) in the region close to the Linac to accommodate the changed vertical geometry. The LTR was rebuilt during the summer shutdown in 1984 while the RTL was completed during a one month shutdown in January 1985.

*Work supported by the Department of Energy, contract DE-AC03-76SF00515.

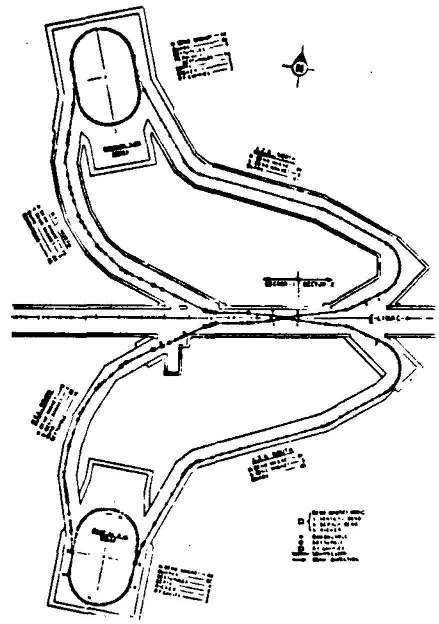

Figure 1. Layout of the Damping Ring Complexes

OPERATIONAL DIFFICULTIES

Most of the downtime has been caused by a few recurring mundane problems which we are only now getting under control. The worst problem, which has been responsible for over half the downtime, has been the water cooling circuits in the injection septum (and to a lesser degree, the extraction septum). The 1.37 mm I.D. copper tubes run at relatively high temperatures (80°-90°C) and apparently oxidize, causing blockage. We do not know if the oxidation is only due to heat, or if radiation is a significant contributing factor. Interim solutions have been to acid flush (MC200 or Diversey), adding of a nitrogen blanket on the water system and placing 10 u filters upstream. The long term solution is a detailed redesign of the septa to use all stainless steel cooling tubes of larger I.D.(1.62 mm) and a closed circuit, all stainless steel water system including heat exchanger, de-ionizer and de-oxidizer.

A major setback occurred in October-November 1984, when it proved impossible to store beam in the ring. Initially, it was believed that one (or a few) misaligned elements were causing the problem, but we were unable to pinpoint exactly where. A realignment of the entire ring was therefore undertaken, and it was then found that the vault floor (1 meter of reinforced concrete) had deformed into a dome shape with nearly 4 mm vertical lift in the center. Every magnetic element in the ring was misaligned and rolled, even the unloaded survey monuments were affected. This movement must have been caused by the excavation of the vault for the north damping ring, even though no movement was seen in the Linac. No clear explanation exists to explain all the facts, but blasting in the north side and hydrostatic pressure changes in the relatively recently compacted soil under the south vault have been proposed as theories.

Presented at the 1985 Particle Accelerator Conference, Vancouver, B.C., Canada, May 13-16, 1985

A third consistent problem has been with the stripline beam position monitors which are suffering damage primarily caused by beam loss. The resulting deformations have to date rendered 6 out of the 26 ring monitors unusable. The only solution in the long term is to replace all of the monitors with another design, and a new, more robust model has been developed[4] which will be installed in the north ring and retrofitted in the south ring.

OPTICS

The ring has always been difficult to model, and good agreement with the measurements has only been possible by treating the effective pole face rotations as variables. In fact, the sextupolar fields in the south ring are produced by shaping the pole faces of the bending magnets. Since the magnets are highly saturated (2.0T), the fringe fields are considerable, and the effective pole face rotation may well be different from the hard edge model. However, it has not been possible to reconcile the magnetic measurement data with the effective rotations used in the model since manpower has been insufficient to undertake the complete treatment by trajectory tracking using a field map. An additional problem is that the natural chromaticity is not positive definite, and the trim sextupoles must be run at maximum field in order to just make the ring stable.

These fundamental problems have not prevented a good empirical understanding of the ring optics which is described elsewhere[5,6,7].

Considerable effort has been devoted to reducing the coupling strength in the ring. The requirement is that the emittances should be coupled, but that the horizontal and vertical motions should be as uncoupled as possible. This condition can be met if the coupling strength is weak and the ring is operated very close to the coupling resonance. This is not yet possible, but the coupling is being successively reduced by finding the unwanted skew fields. A big improvement was made when a small systematic construction error was found in the 4 members of the QDI quadrupole family - insertion quads with rather high beta values in them. The location was determined rougly by kicking the beam horizontally and looking for vertical orbit differences. A more sophisticated modelling technique used matched horizontal and vertical bumps across the region of interest. The resulting orbit differences in the other plane are compared with those produced by a coupling term introduced successively into each element of the model. This technique has enabled us to pinpoint a quadrupole roll error of 1 mr, and the remaining errors are now known to be less than this.

ACCELERATOR PHYSICS STUDIES

Details of the considerable amount of accelerator physics studies are given elsewhere in this Conference[8], but some of the results have already had a direct influence on the design of the north damping ring. The most important results are mostly negative. With the orbits and chromaticity corrected, no fundamental problems have been encountered which would preclude operation of the damping ring at the SLC specification. The RF frequency swing of +/- 200 kHz is limited by the cavity tuning phase lock system but over this range, +/- 1.5% in momentum, the beams are stable. No instabilities have been seen unless deliberately provoked, and none are now predicted for currents up to the SLC specification. No ion effects have been seen, but these cannot yet be precluded at the total ring currents needed for the SLC. The clearing field electrodes, installed from the outset will therefore be maintained.

One important, unexpected result was that the synchrotron radiation energy loss per turn was some 13% lower than predicted. This was traced to the fringe fields of the dipoles. Given the sextupole problem already alluded to above, it was therefore decided to modify the design of the north damping ring using permanent magnet sextupoles[9] for chromaticity correction and optimizing the pole faces of the bending magnets to reduce the fringe fields[10]. These hardware decisions led to a new optics design described elsewhere in this Conference[11].

ACHIEVEMENTS

The maximum performance achieved in the damping ring so far is summarized in Table 1. Recently, the beam intensity from the gun has been drooping, and, for operational reasons, the cathode will not be replaced until this summer. We are now confident that the damping rings will meet the SLC intensity sepcification and also the emittance specification[11]. What is still not established is the reproducibility of the extraction kicker which will determine the accuracy with which the beam can be centered in the Linac. This is important to reduce transverse wakefield effects in the Linac.

TABLE 1

SOUTH DAMPING RING OPERATION ACHIEVEMENTS

MAXIMUM CHARGE PER BUNCH STORED IN RING,
4×10^{10} e-/p (SLC Spec 5×10^{10}- 7×10^{10}).
LIMITATION: TIME TO TUNE UP SYSTEM. NO FUNDAMENTAL LIMITATION SEEN.

MAXIMUM CHARGE STORED IN TWO BUNCHES,
$2 \times 2 \times 10^{10}$e-/p (SLC Spec $2 \times 5 \times 10^{10}$-$2 \times 7 \times 10^{10}$)
LIMITATION: TIME TO TUNE UP SYSTEM. BUNCHES INJECTED SEPARATELY. NO FUNDAMENTAL LIMITATION SEEN.

MAXIMUM CHARGE RE-INJECTED INTO LINAC
1.5×10^{10} e-/p (SLC Spec 5×10^{10}- 7×10^{10}).
LIMITATION: LOW GUN CURRENT, LOSSES IN LINAC END OF RTL. RE-INJECTION OF 60 - 70% OF CHARGE ACCEPTED AT ENTRANCE OF LTR IS ROUTINE OPERATION

ELECTRON RING UPGRADE

The electron damping ring was built as an R&D project, and the running experience has been applied to modify the positron ring where necessary. The intention is now to stop running the electron ring from June 1985 to May 1986 to allow the necessary improvements to be carried out. The major items involved are: the septa; the ring beam position monitors, which will be of the new improved type[4] and increased in number; addition of some permanent magnet sextupoles to guarantee positive chromaticity in both planes; change of all the position monitors in the front end of the SLTR which are damaged or prone to damage; improvements to the instrumentation in the back of RTL to aid reinjection, and finally modification of some magnet alignment fixtures to improve the roll tolerance. With these changes the ring should be able to routinely reach the SLC specification.

STATUS OF NORTH DAMPING RING

The vault for the north damping ring , begun in February 1984, was completed on schedule in November 1984, despite some unexpected soil conditions (10 meter diameter boulder) which necessitated blasting. The cable tray and water piping are now installed in the vault, and cabling is just beginning. During the January 1985 shutdown, the survey monuments were all aligned with respect to the Linac ,and the girder feet set. In the NLTR, 65 out of a total of 68 magnets are built, measured and installed on concrete girders. About 3/4 are aligned, and half have all plumbing and wiring. The vacuum chamber installation will begin in about two weeks so that the first completely loaded girder can be taken down for installation in the first week of June 1985. In the NRTL, which will be installed later this summer, 54 out of a total of 56 magnets are built and more than half measured. Installation on the girders is just beginning. In the north ring itself, which will be installed this autumn, 38 of the 46 quadrupoles are completed, 40 bends cores are in the process of going through final numerical controlled machining to produce the correct pole face shaping[10]. The final prototypes of the permanent magnet sextupoles are being made with complete production of 72 sextupoles[9] foreseen for September. Including correctors, there are a total of 278 magnets in the whole north complex.

The 714 MHz klystron has already been run successfully at full 45 kW CW into a dummy load, and the two 2-cell RF cavities are completely built and undergoing fine dimensional adjustment before final brazing and high power testing. The septa parts for the north ring are all completed, but the assembly (a long complicated process including 7 different brazing operations) has not yet begun. Two new septa to replace those in the south ring are in the final stages of assembly. The kickers presently installed in the south damping ring are actually destined for the positron (north ring). In the electron ring, the kickers need to inject and extract two bunches at a time and have a 60 ns flat top. The first of these kickers is being installed in the south ring during this Conference to evaluate its performance under actual operating conditions.

The installation and commissioning schedule for the whole damping ring complex is shown in Table 2.

TABLE 2

DAMPING RING SCHEDULE

June 3, 1985	Begin NLTR installation
August 1985	Begin NRTL installation
Sept. 30, 1985	NLTR and NRTL installation complete
October 1985	Begin NDR installation
November 1985	First tests of NLTR with electrons (3 weeks)
December 1985	Begin SDR upgrade
December 31, 1985	North Damping Ring Complex installation complete
Jan.-Feb. 1986	First tests on NDR and NRTL with electrons
March 1, 1986	Begin SLTR,SRTL upgrade
May 15, 1986	South Damping Ring Complex upgrade complete
	Begin commissioning of South complex
	Continue commissioning of North complex
Sept. 30, 1986	SLC Spec bunches of electrons and positrons delivered to Sector 30

CONCLUSION

The electron damping ring has been demonstrated to perform as designed and, when some equipment weaknesses are corrected, should be capable of routinely providing bunches to the SLC specification. The positron damping ring construction is well under way and will be completed by December 1985.

ACKNOWLEDGEMENTS

The commissioning of the electron damping ring and the design and construction of the positron damping ring have involved a large number of people too numerous to mention. Their assistance, crucial to the project, has often been in addition to their regular jobs. It is a pleasure to acknowledge this kind of dedication in the face of very tight schedules and manpower shortages.

REFERENCES

1. G.E. Fischer, W.A. Davies-White, T. Fieguth, H. Wiedemann, Proc. 12th Internat. Conf. on High Energy Accelerators, FNAL, Batavia, Illinois, 1983, p.37 and SLAC-PUB-3170, July 1983.
2. H. Wiedemann, Proc. XIth Int. Conf. on High Energy Acc., Geneva, 1980, p. 693 and SLAC Report AATF/79/8, Sept. 1979,
3. J.C. Sheppard, J.E. Clendenin, R.K. Jobe, V.G. Luth, A. Millich, M.C. Ross, J.T. Seeman and R.F. Stiening, Proc. of 1984 Linear Accel. Conf., Darmstadt, W.Germany, GSI-84-11, 439 (1984).
4. J.-C. Denard, K.L. Bane, J. Bijleveld, A.M. Hutton, J.-L. Pellegrin, L. Rivkin, P. Wang, J.N. Weaver, This conference (X17).
5. M.J. Lee, J.C. Sheppard, M. Sullenberger, M.D. Woodley, presented at the Europhysics Conference, Computing in Accelerator Design and Operation, Berlin, West Germany, 1983 and SLAC-PUB-3217 (1983).
6. J. Jager, M.J. Lee, M. Woodley, SLAC-PUB-3408 (1984).
7. J. Almog, J. Jager, M.J. Lee, M. Woodley. This conference, (L55).
8. L. Rivkin, J.P. Delahaye, K. Wille, M. Allen, K. Bane, T. Fieguth, A. Hofmann, A. Hutton, M. Lee, W. Linebarger, P. Morton, M. Ross, H. Schwartz, J. Seeman, J. Sheppard, R. Stiening, P. Wilson, M. Woodley. This conference (Y42).
9. J. Spencer. This conference (H53).
10. R. A. Early, J.K. Cobb. This conference (H33).
11. J.P. Delahaye, L. Rivkin. This conference (H51).