Canadian Light Source / Centre canadien de rayonnement synchrotron

CLS COMMISSIONING –PHASE III
BTS and Storage Ring

Technical Procedure 8.7.90.3 Rev 0

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1.0 Booster to Storage Ring Transfer Line Commissioning Plan

2.0 Background

This section of the report describes the principal components of the booster-to-storage ring transfer line (BTS) and the actions required to commission this line to meet its requirements as the final leg of the injection system of the Canadian Light Source (CLS). The section of the BTS transfer line, that was used to do booster extraction studies, has been described earlier[1]. In that report, the BTS up to the first BTS dipole magnet was described.

Requirements are to transport a pulse train of electrons from 2 to 136 ns in duration with a beam energy of 1.5 to 2.9 GeV and an average beam current up to 10 mA from the CLS booster to the storage ring. The beam will have horizontal and vertical emittances not exceeding 0.6 mm-mrad and an energy spread of 0.15% or less. The pulse train contains up to 68 bunches of electrons at a frequency of 500 MHz. The transfer line must focus the beam at the injection point of the storage ring such that the beam functions are matched to the machine functions of the storage ring.

This report also describes the requirements for safely commissioning and operating the BTS transfer line. Due to the levels of radiation produced by possibly mis-steered beams during transport, the BTS must be enclosed in a secure area. Up to and including the first BTS dipole, the BTS line is enclosed in the booster tunnel. From this point, it goes through the outer booster tunnel wall and into the storage ring tunnel. The tunnels serve to exclude access to the BTS environment while the injection system is in operation and to shield the environment external to the tunnels from the radiation that is produced. As well, access to the secure area is restricted until the residual levels of radiation have been measured and safe working conditions have been established.

3.0 Purpose

The purpose of this report is to provide an overview for the commissioning and operational procedures of the BTS required to safely and efficiently transport a beam of electrons suitable for injection into the CLS storage ring. The BTS is composed of many components that have to be tested and deemed ready for the commissioning process. Details of these components are found in the references provided throughout the report.

The report includes all aspects of BTS operation from the first dipole to the storage ring injection point. All the components required to transport a beam suitable for injection into the CLS storage ring are described. The first BTS dipole is located in the booster tunnel. After this dipole, the beam exits the booster tunnel and enters the storage ring tunnel. Hence, commissioning of the BTS from the first dipole begins with directing the electron beam into the storage ring tunnel. **Commissioning of transport into the storage ring tunnel**

requires detailed monitoring of radiation levels in the occupied areas and shielding walls exterior to both the storage ring tunnel and the booster tunnel, including the top of the tunnels, CLS office areas and public areas outside the CLS facility.

4.0 Abbreviations

RF	Radio frequency
BTS	Booster-To-Storage Ring transfer line
LTB	Linac-To-Booster transfer line
TRM	Transition Radiation Monitor
BPM	Beam Position Monitor (button monitor)
SLM	Stripline Monitor
ICT	Integrating Current Transformer
FCT	Fast Current Transformer
PCT	Parametric Current Transformer
QF	Quadrupole (horizontally) Focusing
QD	Quadrupole (horizontally) Defocusing
B	Bend magnet (dipole)
STH	Steering magnet horizontal
STV	Steering magnet vertical
ST	Steering magnet (both horizontal and vertical)

Other elements are defined in the CLS Names and Numbering Convention[2].

5.0 Required Equipment

The BTS is described in detail in references 3. A description of the BTS/storage ring interface is given in reference 4. The BTS line consists of four (4) "FODO" cells preceded by two quadupoles required to aid the beam matching. The initial quadrupoles can also be used to measure the beam parameters of the beam extracted from the booster[1]. Details of the elements are described below. Drawings and diagrams for the BTS are listed in Appendix A.

5.1 Pre-Focusing section

Immediately following the extraction septum of the booster are position monitors, current monitors, steering magnets and two quadrupole magnets. This part of the BTS line was described in reference 1.

5.2 FODO Cells

Each "FODO" cell consists of a (horizontally) defocusing quadrupole followed by a dipole and a focusing quadrupole. Four consecutive identical cells form the bulk of the BTS line. Thus the configuration of magnets is: QD B QF, QD B QF, QD B QF, QD B QF.

5.3 Septum magnets

The FODO cells are followed by two septum magnets. The first is the "thick" septum (SEP1400-01) and the second is the "thin septum" (SEP1400-02). These magnets bring the beam to the injection point of the CLS storage ring.

5.4 Timing System

Both the septum magnets are pulsed elements and require timing signals so that the magnets are ON when the beam passes. The timing signals (triggers) will be initiated with the booster extraction trigger.

5.5 Steering

To efficiently transport the electron beam through the BTS, steering elements are required. Steering magnets are grouped in sets consisting of one horizontal and one vertical element. Two sets of steering magnets are at the start of the line as described in reference 1. In addition, there is a set after the second FODO cell (ST1400-01) and two sets in the space between the fourth FODO cell and the thick septum (ST141400-02 and –03).

5.6 Diagnostics and Measurements

To monitor the transport of the electron beam along the BTS a variety of diagnostic elements are used. These include currents monitors, position monitors and beam spill monitors.

As well, for commissioning and setting up the transfer line, the beam will be allowed to proceed directly to a beam dump (BST1305-01) where the beam current can also be measured.

5.6.1 Current Monitors

An integrated current transformer (ICT) and a fast current transformer (FCT), are located just before the first FODO cell (ICT/FCT1305-01) to monitor current. Another ICT is located after the fourth FODO cell (ICT1400-01). The ICTs measure the total charge in the beam pulse train, while the FCT gives information about the pulse structure.

5.6.2 Transition Radiation Monitors

In the BTS line transition radiation monitors[5] (TRM) will be used to precisely measure the size of the electron beam and beam position along the transfer line.

5.6.3 Beam Loss Monitors

Beam loss monitors[6] can be used at several locations along the transfer line to detect beam spills that could indicate mis-steering or poor focusing.

5.6.4 Temperature Monitors

Thermocouples will be used to monitor the temperature of the magnet coils.

5.6.5 Beam Dump

The BTS line has a beam dump as described in reference 1.

5.6.6 Beam Function Measurements

Measurement of beam functions at the beginning of the BTS will be made as describe in reference 1.

6.0 Commissioning Plan

ATTENTION: Beam transport through the BTS line will be at a beam energy near 2.9 GeV. This is about ten times the energy of the beam in the linac-to-booster (LTB) transfer line (about 8 Joules per pulse in the BTS). For evaluating the potential background, the higher energy is offset somewhat by the lower peak currents at booster extraction. Consequently, the total beam power (that can be potentially mis-steered and lost) is comparable to levels encountered in Phase II commissioning.

Commissioning of the BTS brings the electron beam into the storage tunnel for the first time. Proceeding with beam into this area requires the radiation levels to be monitored by the Health Safety and Environment (HSE) department.

6.1 FODO Cells

Initially the dipoles (B1400-01,-02,-03 and -04) are set according to the beam energy determined by the booster ramping program and using the standard dipole setting procedure. The quadrupoles (QD1305-02, QD14000-01, -02 and -03 and QF1305-02, QF1400-01, -02 and –03) are also set to their nominal values[3] as determined from the beam energy. The values of the dipoles are then empirically fine-tuned by observing the beam at the BPMs. Fine tuning of the dipoles will also be required when the steering in the quadrupoles is minimized.

6.1.1 Steering

Steering through the first two FODO cells is adjusted with the two (2) sets of steering coils (STV1305-01, STH1305-01, STV1305-02 and STH1305-02). Steering is adjusted by oscillating QFs for horizontal steering and QDs for vertical steering. The beam is observed on TRM1400-01 following the third dipole. The dipole magnets can be adjusted by small amounts to minimize observed beam shifts. For machine protection, radiation levels will be monitored by beam loss monitors. **For personnel protection, radiation will by monitored as described in the Beam Commissioning Radiological Characterization Plan[7].**

Similarly, steering is removed in the following FODO cells using the horizontal and vertical steering magnets ST1400-01. (Again, oscillate QFs for horizontal steering and QDs for vertical steering.) At this point the beam should appear centered on both the TRMs following the FODO cells (TRM1400-02 and -03).

Properly focused and steered, the beam is now ready for transport through the septum magnets.

6.1.2 Current Measurement

The current at the start of the FODO cells can be measured using the beam dump as described in reference 1. For this purpose, dipole B1305-01 should be degaussed and set to 0 field. The current can also be measured using the ICT and the FCT (ICT/FCT 1305-01) located just before the first FODO cell .

6.2 Septum Magnets

Initially the septum magnets (SEP1400-01 and SEP1400-02) are set to the beam energy determined by the booster ramp. Septa timing is adjusted so that the peak values occur during the passage of the electron beam.

6.2.1 Steering

Steering through the septum magnets can be fine tuned with steering magnets ST1400-02 and -03. The beam can be observed on the TRM between the septa (TRM1400-04) and on the TRM after the second septum (TRM1400-05).

For personnel protection, radiation will be monitored as described in the CLS Safety Report. For this purpose, the beam current should start at a small value and should only be raised to the design value with the permission of the HSE Manager.

Passage of the beam through the two septum magnets brings the beam to the CLS storage ring injection point.

6.3 Beam Parameters

6.3.1 Beam Emittance

Both the horizontal and vertical emittances are measured as described in reference [3]. To check the emittance of the beam extracted from the booster, quadrupole QF1305-01 and position/profile monitors TRM1305-02 and TRM1305-03 are used.

7.0 Machine Protection

To avoid excessive beam spills along the BTS, the machine protection system must be enabled before the line can be operated. Systems that are continuously monitored include temperature control, power supply status and vacuum levels.

7.1 Vacuum Failure

The vacuum in the beam pipe must be lower than a predetermined value before beam is allowed to pass through. During the course of operations if that value is exceeded, the gun will be automatically turned off.

7.2 Temperature Control

Temperature of the magnet coils will be monitored to ensure reliable operation of the magnets. Cooling channels blocked by debris can cause the temperature to increase. A shorted coil could cause the temperature to decrease. In the case the coil temperature is outside established “normal” values the gun will be turned off at the operators discretion and the magnet in question will be checked by maintenance staff.

7.3 Power Supplies

Power supply failures may result in the mis-steering or defocusing of the beam in the BTS. Consequently, the failure of any magnet power supply, or a sudden variation in voltage drop across a magnet, will result in the gun being turned off.

7.4 Beam Loss Monitoring

Beam loss monitors at various locations in the BTS tunnel(s) will indicate abnormal levels of radiation. “Normal” levels of radiation, in the tunnel, will be established as discussed in section 8.1. Monitoring of radiation levels can indicate problems with the beam steering that may result in excessive radiation at specific sites. Disabling of the machine will be at the discretion of the machine operator.

8.0 Personnel Protection

Operation of the BTS cannot proceed until the personnel protection system[8,16] is enabled, verified and validated. The primary purpose of the personnel protection system is to ensure that personnel are not exposed to unacceptable levels of radiation. A secondary function is to ensure that personnel are not exposed to conventional hazards such as power supplies and chemical hazards.

For these reasons, all accelerators and transport lines are enclosed in secure areas. No personnel are allowed in the secure area during operation of the machine. This is ensured by a lockup procedure as described in references [8,16]. Once the lockup is complete the storage ring can be enabled. Estimates of radiation levels are discussed in references [7] and [9].

8.1 Radiation Safety

During commissioning and routine operation of the transfer line, radiation levels both inside and outside the transfer line tunnels (booster tunnel and storage ring tunnel) will be monitored. Monitoring will ensure that radiation levels are in compliance with the guidelines described in reference [7].

Radiation levels inside the tunnels will be monitored to indicate possible errant beam conditions during commissioning or setup and to establish "normal" background levels during routine operation.

Residual radiological surveys will be carried out to indicate levels of background radiation after the BTS is turned off and re-entry to the secure area is required. Re-entry will be permitted once the radiation levels are deemed safe. At re-entry, extra monitors such as personal dosimeters and hand-held radiation monitors will be used to monitor doses received and check the background radiation levels at all locations in the tunnels. Once radiation levels are established access times to different areas can be determined and regulated.

8.1.1 Commissioning Considerations

8.1.1.1 Radiation Outside the tunnels

Radiation levels outside the BTS tunnels will be measured at each stage of commissioning. If levels exceed acceptable levels[7], commissioning will proceed with the beam current reduced to bring the radiation levels to an acceptable level. If required, additional shielding will be added to allow operation at higher currents.

8.1.1.2 Radiation Inside the tunnels

Each time the shielding tunnels are opened after operations, residual radiation levels inside the BTS tunnels will be measured by the HSE department and safe working conditions established. All personnel entering the tunnel areas are required to wear personal dosimeters.

Short term access to the BTS tunnel will be done with a “button access” as described in the lock-up procedure[8]. One person will be stationed at a single access point to ensure that all personnel entering the area eventually leave the area. Personnel entering the tunnel carry radiation monitoring equipment. Button access disables the linac.

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9.0 Storage Ring Commissioning Plan

10.0 Backgrond

This section of the report describes the principal components of the storage ring and the actions required to commission the storage ring to meet its requirements as the final accelerator system of the Canadian Light Source.

Requirements are to inject a pulse train of electrons from 2 to 136 ns in duration with a beam energy of 2.9 GeV and an average beam current, in the pulse train, up to 20 mA. The beam will be accumulated (stacked), using consecutive pulse trains, up to an average circulating current of 500 mA (initially 200 mA).

At injection, the beam is expected to have horizontal and vertical emittances not exceeding 0.6 mm-mrad and an energy spread of 0.15% or less. The pulse train contains bunches of electrons at a frequency of 500 MHz. At the injection point of the storage ring the beam functions should be matched to the machine functions of the ring. At the injection point these functions are: $\beta_x \approx 9$ m, $\alpha_x \approx -0.2$, $\beta_y \approx 5$ m, $\alpha_y \approx -0.3$, $\eta_x \approx 0.14$ m, $\eta_x' \approx -0.0$, $\eta_y \approx 0$ m and $\eta_y' = 0$.

Before the beam is stacked, beam studies will be carried out with a single shot injected from the booster. Current should be adequate to establish the beam orbit, correct the orbit and measure the beam parameters.

Once the measurements and adjustments are made at low current, the beam can be stacked to the (initial) design current of 200 mA. Machine parameters and life time measurements will be made for various beam currents.

This report also describes the requirements for safely commissioning and operating the storage ring. Due to the level of radiation produced by possibly mis-steered beams during injection and stacking or by synchrotron radiation from dipole magnets, the storage ring is enclosed in a tunnel. The tunnel serves to exclude access to the storage ring environment while the ring is in operation and to shield the environment external to the tunnels from the radiation that is produced. Access to these secure areas is restricted until the residual levels of radiation have been measured and safe working conditions have been established.

11.0 Purpose

The purpose of this section of the report is to provide an overview for the commissioning and operational procedures of the storage ring required to safely and efficiently inject and stack in the CLS storage ring. The storage ring is composed of many components that have to be tested and deemed ready for the commissioning process. Details of these components are found in the references provided throughout the report.

The report includes all aspects of operation from the storage ring injection point to storing of accumulated current. Thus, all the components required to inject, store and stack a beam in the CLS storage ring are described.

12.0 Equipment Required

12.1 Storage ring

The storage ring is described in detail in references 10 and 11. The primary components are 24 dipole magnets, 72 quadrupole magnets, 36 sextupole magnets and a single superconducting (SC) RF cavity. The magnets form a lattice with 12 symmetrical cells. Each cell has two dipoles, six quadrupoles and 3 sextupoles, forming a “double bend achromat” (DBA). Drifts at the ends of each cell join to form long (5.2 m) straight sections. Two of these straights are used for the injection kickers and the RF cavity, a third straight is used for diagnostics and the remaining straights are used to accommodate insertion devices (IDs) for producing synchrotron radiation. The total circumference of the storage ring is 170.9 m.

The dipole magnets are powered by a single power supply. The quadrupole magnets are powered by individual power supplies. There are, however, three families (Q1, Q2 and Q3).

For injection, there is an injection septum and four injection kickers that bring the orbit in the ring near the injection septum.

12.2 Timing System

Timing signals are required for both injection septum and the injection kickers. At injection, both the injection septum and the injection kickers must be fired at the appropriate time to inject the beam into the ring efficiently. Details of the timing system are given in reference [12]. Timing signals will also be used to gate the diagnostic electronics.

12.3 Orbit Correction

The orbit of the beam in the booster is corrected by 24 horizontal and 24 vertical corrector magnets. In addition to these magnets, some sextupoles can also function as corrector magnets and skew quadrupoles. The correctors are used to keep the deviations from the ideal orbit small, as well as to position the beam for efficient injection. Skew quadrupoles are used to control the coupling between the horizontal and vertical motion.

12.4 Diagnostics and Measurements

A variety of diagnostic elements are used to monitor the orbit and characterize the quality of the electron beam in the booster. These include current monitors and position monitors. Also a variety of beam loss monitors will also be used.

12.4.1 Current Monitors

A parametric current transformer (PCT) is located in the diagnostic straight in the storage ring.

12.4.2 Beam Position Monitors

There are 48 BPMs in the storage ring not including those associated with IDs. These are located symmetrically in each cell, four to a cell. Fast BPM electronics will be used to track the beam around the first turn during early stages of commissioning. Later, as part of a global orbit correction system, the BPMs will be used to help keep the beam position stable in position to about one micron.

12.4.3 Tune Kicker

A stripline-like kicker will be available to “kick” the beam to make tune measurements.

12.4.4 Beam Loss Monitors

Beam loss monitors will be used at several locations around the storage ring to detect beam spills that could indicate mis-steering or poor focusing.

12.4.5 Temperature Monitors

Thermocouples will be used to monitor the temperature of the magnet coils.

13.0 Commissioning Plan

The first stages of commissioning involves beam energies and currents levels that are familiar from previous commissioning of the booster and BTS. Radiation levels will be monitored as the beam enters new areas of the storage ring tunnel.

ATTENTION: During storage ring commissioning all ports in the tunnel must be blocked to prevent radiation from leaving the tunnel. In areas where photon beam lines have been installed, the “front-end” shutters[13] must be closed. The safety shutters will be of the safety interlocks system.

ATTENTION: Once stacking of the beam current commences, power levels associated with the beam increase linearly with beam current. At full stored current (200 mA) a 10% beam loss is equivalent to the loss of the entire beam in the single shot current (20 mA). Note: the radiation hazard from high stored beam currents is largely from the synchrotron radiation that is produced. Since, in this mode, current is not continuously injected into the storage ring, any loss of beam will be a single event equivalent to a few minutes of operation.

13.1 Injection

Once the beam is centered in TRM1400-05, and the beam machine functions are deemed satisfactory, the beam is ready for injection into the storage ring. The septa should be set to the nominal values for the beam energy. The storage ring dipoles and quadrupoles will also be set to their nominal values. With the magnets on, any beam making it through the septum will initially be lost diffusely over many meters of the ring.

Once all the magnets are set, the beam should be seen on the PCT and the BPMs beyond the injection septum. Some small adjustment of the dipole fields may be required. If no beam is observed, the injection septum field should be slowly scanned until the beam is observed. Some adjustment to BTS steering magnets (ST1400-02 and -03) may also be required. The timing of the septum excitation pulse can also be adjusted to optimize the current in the PCT. The beam loss monitors in the vicinity of the injection septum can also be used to optimize the injection process. Current measurements in the PCT should confirm 80% or greater electron beam transmission through the injection septum. Once the injection efficiency is satisfactory, the storage ring commissioning can proceed.

Until the efficiency is satisfactory, the HSE manager must approve of operations with low injection efficiency. Commissioning may proceed if the radiation levels outside the storage ring tunnel are sufficiently low. [If required, this can be achieved by operating at low average beam currents and/or low repetition rates.]

13.1.1 Steering

As mentioned above, steering through the septum is accomplished through a combination of scanning the injection septum and using both the horizontal and vertical channels of the BTS steerers ST1400-02 and -03.

13.1.2 Current Measurement

The current transmitted through the septum is measured with the sum signal of a BTM. This should be compared with the current previously measured in the BTS transfer line. Average current in the storage ring is measured with the PCT.

13.1.3 Timing

The timing signal for the injection septum is adjusted to optimize the beam transmission through the septum. Timing signals can also be used to trigger the FCT and the beam loss monitors.

13.1.4 Beam Loss Monitors

Two types of beam loss monitors[6] are located at many locations around the storage ring. With two monitor types both prompt and slow beam losses can be detected.

13.2 First Turn

Once the injection is optimized, the beam is ready to be tracked once around the storage ring. For this purpose, the magnets should be at their nominal value as described above. The orbit corrector magnets should be available and all set to zero strength.

Next the injection kickers must be activated. The kicker values should be set to the nominal value determined by the beam energy. The kicker timing must be adjusted so that the beam is injected when the kicker is at its maximum value. The kicker amplitudes are adjusted to kick the beam onto the storage ring axis. The horizontal orbit correctors and the vertical orbit correctors are now adjusted so that the beam is seen on the BPMs located in each cell. Dipoles and steering magnets can be adjusted to bring the beam around from cell to cell.

Since no beam will be accumulated, radiation levels should not be too severe even if the beam is completely lost. Nevertheless, radiation levels will be monitored to ensure safe operating conditions. The beam loss monitors should be helpful in steering the beam around the first turn.

13.2.1 Steering

Steering the beam around the first turn is accomplished with twenty-four horizontal/vertical orbit correctors and twenty-four sextupole correctors. The single turn produced by sequential use of the steering magnets will not necessarily produce a closed orbit.

13.2.2 Current measurement

The beam current can be measured using the BPM sum. After one turn is completed both the injected beam and the first turn should be observed in the BPMs.

Successful completion of the first turn around the storage ring should result in near 100% transmission of the beam current.

13.2.3 Focusing

Focusing of the beam is accomplished with three families of quadrupoles. Although these quadrupoles will be set to the nominal value determined by the beam energy, small adjustment may aid in transporting the beam around the first turn.

13.2.4 Timing

The timing of the septum and injection kickers will be adjusted during injection. Once the beam has made it around one turn the timing and kicker amplitudes can be adjusted to ensure that the kickers form a closed "bump"[4].

13.2.5 Beam Loss Monitors

A large number of beam loss monitors around the booster will aid in tracking the beam around the first turn.

13.3 Beam Storage without RF

After the first turn is successfully accomplished, the beam orbit can be adjusted to allow the beam to store for many turns. This will first be attempted with no RF power supplied to the cavity. Under these conditions it should still be possible to store the beam for many hundreds of turns.

Since tracking the beam around the first turn does not necessarily produce a closed orbit, the dipoles and all the orbit correctors have to be adjusted to form a closed orbit. Successive passages of the beam can be observed on the BPMs. The storage may be further optimized by adjusting the three quadrupole families either as families or perhaps individually.

Radiation levels during this stage of operations will be similar to those produced during tracking around the first turn. The two types of beam loss monitors will be useful in identifying whether beam losses are prompt or occurring over time.

When the storage is optimized the beam will be lost over hundreds of turns.

13.4 Beam Storage with RF

NOTE: Once storage times are longer than 1 second, the timing system will be adjusted to produce single shots of beam so that longer storage times can be observed. At the same time, this will reduce the potential of radiation hazard outside the ring.

Once the storage is optimized with no RF, the RF power will be turned on. With the RF on, all of the injected beam should be stored for minutes and eventually hours.

The beam storage will be optimized by iterative adjusting the RF system, the beam orbit and the beam tunes.

13.4.1 RF System

To capture a single shot of beam, the cavity voltage is set to the nominal value (2.4 MV). The RF frequency can be adjusted to optimize storage.

13.4.2 Orbit Control

Once the beam is stored, the beam size will quickly damp. The damping times are less than 4 ms. With a damped beam, it will be possible to measure the position of the closed orbit using the BPMs. Once the beam positions are known, the orbit can be corrected using the global orbit correction scheme[11,15].

13.4.3 Tuning

Once the beam is stored and damped, the tunes can be measured using the stripline kicker. The stripline is used to excite the beam while a BPM is used to measure the response. Tunes can be adjusted using two of the families of quadrupoles (Q1 and Q2). The optimum tune for best storage may vary from the nominal tunes[3] of (10).26 horizontal and (3).22 vertical. As indicated by the brackets, only the fractional part of the tune is measured.

13.5 Stacking the Current

Stacking the beam current will create the potential for radiation levels higher than previously encountered. Stacking should initially proceed with a few shots and the total stored current only increased after radiation measurements have been made. Radiation levels outside the storage ring tunnel will be closely monitored. Repeat Note: the radiation hazard from high stored beam currents is from the synchrotron radiation that is produced. Since, in this mode, current is not continuously injected into the storage ring, any loss of beam will be equivalent to a few minutes of operation in the previous commissioning.

The beam current is stacked by sequentially adding additional shots of current to that already stored. The kickers must be adjusted so that the stored beam is brought close enough to the injection septum for more beam to be injected without getting so close that the stored beam is lost. Careful adjustment of the kicker amplitudes and timing is required. This may be done initially with stored beam in the storage ring but no new beam injected from the booster.

Initially, current may by limited due to out-gassing causing by synchrotron radiation hitting the vacuum chamber walls. Out-gassing will eventually diminish with continued exposure to the beam.

13.5.1 Stacking End-to-End

The pulse train from the booster is nominally 136 ns long. Three such pulse trains can be stacked end-to-end to form a single pulse train in the storage ring of 412 ns. One possible scenario to fill with this pattern is to have the timing system slip or advance 136 ns from shot to shot over three shots then return to the starting value.

13.5.2 Stacking On-Top

If pulses are injected at the same relative time in the injection cycle the current will be increased on top of the previously stored beam. Combinations of “end-to-end” and “on-top” stacking will be used to bring the average circulating current to the limit of the installed RF power corresponding to about 300 mA.

During this stage of the commissioning, the beam power levels will continuously increase as more current is injected. **This phase of the commissioning process will produce the largest amounts of radiation.** This radiation not only poses a potential safety problem but can also cause severe damage to the vacuum system if it is mis-steered onto one location. For this reason the beam current **will not be increased until the beam orbit is well defined. This will involve implementing the global orbit control system[13]. Deviation from the defined orbit, as detected by the BPMs, will result in a controlled "dump" of the beam. This can be accomplished by turning off the RF power which in turn causes the beam to be lost at the minimum aperture on the inside of the ring. This location is designed to safely absorb the beam power.**

During stacking, it is expected that virtually none of the stored beam will be lost. However, small amounts (<2mA equivalent) of injected beam may be lost.

13.6 Beam Optimization

Once the beam is efficiently injected and stacked, some time will be spent optimizing the processes. This will mainly involve fine tuning of the various elements. During this process, radiation levels should be observed to be within the normal operation levels outlined in the safety report.

13.7 Insertion Devices

Insertion devices are designed to produce high fluxes of synchrotron radiation. These devices will be initially commissioned with low currents and well-established orbits, as mentioned above. With low currents circulating, the front end shutters[14] can be opened and the radiation in the photon beam line measured. This will be discussed in the beam line commissioning plan. Commissioning with IDs will be described in detail in the beamline commissioning plan[15].

14.0 Personnel Protection

Operation of the storage ring will not proceed until the personnel protection system[16] is enabled, verified and validated. The primary purpose of the personnel protection system is to ensure that personnel are not exposed to unacceptable levels of radiation. A secondary function is to ensure that personnel are not exposed to conventional hazards such as power supplies and chemical hazards.

For these reasons, the storage ring is enclosed in a secure area. No personnel are allowed in the secure area during operation of the booster, transfer line or storage ring. This is ensured by a lockup procedure as described in reference [16]. Once the lockup is complete, the storage ring can be enabled.

14.1 Radiation Safety

During commissioning and routine operation of the storage ring, radiation levels both inside and outside the storage ring tunnel will be monitored.

Radiation levels in any occupied area outside the storage ring tunnel will be monitored to ensure that radiation levels are in compliance with the guidelines described in reference 7.

Radiation levels inside the tunnel will be monitored to indicate possible errant beam conditions during commissioning or setup and to establish “normal” background levels during routine operation.

Residual radiological surveys will be carried out to indicate levels of background radiation after the storage ring is turned off when re-entry to the secure area is required. Re-entry will be permitted once the radiation levels are deemed safe. At re-entry, extra monitors such as personal dosimeters and hand held radiation monitors will be used to monitor doses received and check the background radiation levels at all locations in the storage ring tunnel. Once radiation levels are established, access times to different areas can be determined and regulated.

14.1.1 Commissioning Considerations

14.1.1.1 Radiation Outside the Tunnel

Radiation levels outside the storage ring tunnel will be measured at each stage of commissioning. If levels exceed acceptable levels[7], commissioning will proceed with reduced current to bring the radiation levels to an acceptable level.

14.1.1.2 Radiation Inside the Tunnel

Each time the storage ring shielding tunnel is opened after operations, residual radiation levels inside the tunnel will be surveyed by radiation safety personnel and safe working conditions established. All personnel entering the tunnel area are required to wear personal dosimeters.

Short term access to the storage ring tunnel will be done with a “button access” as described in the lock-up procedure[16]. One person will be stationed at a single access point to ensure that all personnel entering the area eventually leave the area. Personnel entering the tunnel carry radiation monitoring equipment. Button access disables the linac.

15.0 References

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2] D. S. Lowe, “CLS Naming and Numbering Convention”, CLS Technical Design Note 0.2.1.1, July 7, 1999

3] J. C. Bergstrom, "The Booster-to-Storage Ring Transfer Line: Preliminary Design Study", CLS Technical Design Note 4.2.69.1, October 24, 2000

4] R.M. Silzer, "Injection into the CLS", CLS Technical Design Note 5.2.69.1 Rev 0, August 1, 2002

5] J. Wishart, "Preliminary Design of the Transition Radiation Monitors to be Installed in the Linac-to-Booster Transfer Line", CLS Design Note 2.2.38.2 (formerly 2.1.46 rev2), May 8, 2000

6] J. Vogt, "The CLS Beam Monitor System", CLS Technical Design Note 8.2.48.4 Rev. C, (to be issued)

7] K. Krueckl, "Beam Commissioning Radiological Characterization Plan", CLS Design Note 11.12.53.1 Rev C, August 14, 2002

see also: M. Benmerrouche, "Safety Report", Canadian Light Source, University of Saskatchewan, 2002

8] M. Benmerrouche, "Booster Lockup Procedure", CLS Design Note 3.7.37.1 Rev 0, November 1, 2001

9] E. L. Hallin, M. Benmerrouche and L. O. Dallin, "CLS Source Parameters for Shielding Calculations", CLS Design Note 0.2.35.1 (formerly 2.1.31c), December 20, 2000

10] L. O. Dallin, "Canadian Light Source Main Ring Lattice", CLS Technical Design Note 5.2.69.2 Rev. 2, August 1, 2001

11] L. O. Dallin, "CLS Lattice Performance Analyses", CLS Technical Design Note 8.2.69.1 Rev. 0, November 27, 2000

12] J. M. Vogt, "CLS Design Specification Timing System", CLS Design Specification 7.4.39.2 Rev. 2, January 30, 2000

13] L. O. Dallin, "SR1 Dynamic Orbit Correction", CLS Technical Design Note 5.2.69.4 Rev. A, June 13, 2000

14] J. De-Tong, "CLS Front Ends Conceptual Design", CLS Design Note 6.2.26.2 Rev0, June 6, 2002

15] E. Hallin, "Beamline Commissioning Plan", in preparation

16] K. Krueckl, "Storage Ring Lockup Procedure", CLS Design Note 5.7.31.1 Rev. B, August 22, 2002

References and more details are available at http://www.lightsource.ca/

16.0 Appendix: Diagrams and Drawings

BTS:

The BTS is shown in the following drawings:

BTS1/ME/0034800 Rev 0

The equipment necessary for the commissioning of the BTS is identified in the process flow diagrams (PFDs) for the following systems:

OPTICS: BTS1/PFD/OPT/0057401 Rev A

VACUUM: BTS1/PFD/VAC/0057411 Rev A

WATER: BTS1/PFD/PPG/WTR/0057421 Rev A

PNEUMATIC: BTS1/PFD/PPG/PNU/0057431 Rev A

STORAGE RING:

The storage ring layout is shown in the following drawing:

Storage Ring 1 (SR1) General Plan View: SR1/ME/0034900 Rev K

The injection straight is shown in drawing:

SR1 Injection Straight General Arrangement Plan View: SR1/ME/0043100 Rev A

Diagnostics are shown in drawing:

ACCL, LTB1, BR1, BTS1, and SR1 Electron Beam Diagnostic Equipment Locations Layout: BLDG/ME/MON/0050910 Rev H

Many other storage ring drawings are available.

The equipment necessary for the commissioning of the storage ring is identified in the process flow diagrams (PFDs) for the following systems:

OPTICS: SR1/PFD/OPT/0057501 Rev A, 02 Rev A and 03 Rev B

VACUUM: SR1/PFD/VAC/0057511 Rev A, 12 Rev A and 13 Rev A

WATER: SR1/PFD/PPG/WTR/0057521 Rev A, 22 Rev A and 23 Rev A

PNEUMATIC: SR1/PFD/PPG/PNU/0057531 Rev A, 32 Rev A and 33 Rev A