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THE CPS CONTRIBUTION TO MULTIBATCH FILLING OF THE SPS

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Summary

This note describes the modifications which have to be made to the CPS to allow it to perforn as an efficient injector for the transfer of up to 5 CPS batches per SPS filling.

The first proposed modification is to reduce to 0.65s the present CPS cycle of 1.25s for 10 GeV/c beams. This will be brought about by changes to the PSB main and auxiliary power supplies and by alteration of the PS main magnet inter-cycle and injection field. The estimated cost of this cycle time reduction is 4.7 MF of which over 75% would be spent on the PSB changes.

The second proposed modification is to complement the existing Continuous Transfer system with a faster fast bump. This will allow high efficiency shaving extraction over one or two revolutions, and used in conjunction with the CPS full aperture kicker will furnish beams for 3 and 5 batch filling. The estimated cost for this additional ejection equipment is 2.85 MF.

Introduction

The performance expected from the CPS when it was chosen as the injector for the SPS was the transfer of a single 10-12 GeV/c beam of up to 10^{13} particles, "continuously" extracted over 10 CPS revolutions. The Continuous Transfer (CT) system was designed accordingly. The CPS cycle time to accelerate the beam for the SPS influenced the amount of time remaining for 26 GeV/c physics but had no direct bearing upon the SPS cycle time; the then attainable time of 1.2s was considered satisfactory.

That the CPS met the performance requirements asked of it should not be regarded as defining its performance limits. The CPS can just as well serve as an injector for multibatch filling of the SPS but to be efficient in this new rôle, from the standpoints of both SPS filling time and time available for 25 GeV physics, it is necessary to bring about a substantial reduction in the cycle time to furnish 10 GeV/c beams. Furthermore, it is necessary to complement the existing CT system with new equipment designed to extract the beam over fewer CPS revolutions.

This note summarizes the actions required at the CPS both in respect of reduction in cycle time to 0.65s and modifications to the ejection system to cover up to 5 batch filling of the SPS. For more detailed information reference should be made to the listed technical papers published by the CPS Groups concerned. The note concludes with a budget estimate for the CPS contribution; this amounts to 7.55 MF at 1977 prices. The divisional effort required to execute the project is estimated at 25 man-years, spread over 3 years.

2. Reduction of CPS Cycle Time

2.1 Overall Situation

The CPS comprises three inter-linked machines - the 50 MeV Linac, the 800 MeV Booster and the 26 GeV PS. The cycle times of the Linac and Booster are not dependent on the energy to which the beam is accelerated whereas the PS cycle time is directly influenced. A first contribution to minimizing the CPS cycle time is to make the CPS-SPS transfer at the lowest possible energy; for the purposes of this proposal this is assumed to be 10 GeV/c. With this limitation and with modification of the main PS magnet inter-cycle field it is possible to obtain a main field cycle time of 0.65s. Any further reduction would involve major and costly changes to the power supply. Fortunately, this cycle time is sufficiently short to permit the transfer of up to 5 batches without extending the waiting time which in any case must be respected in the SPS cycle when operating at top energy and with long slow spill times.

Most of the remaining PS equipment is able to follow so that the work required to bring the PS machine to this cycle time is minimal. In order to obtain a CPS cycle time of 0.65s it is necessary that both Linac and Booster have the same or shorter cycle times. Concerning the Linac there is no problem because the new machine under construction, and due to enter service in 1979, has a design cycle time of 0.5s. The Booster, at present, has a cycle time of 1.2s which cannot be reduced to 0.6 - 0.65s without substantial investment.

2.2 Changes Envisaged

2.2.1 Booster

The implications of the shorter cycle time on the magnet supplies and magnets, both main and auxiliary, have been given detailed study(1). The main magnet voltage must be raised by using an extra rectifier-inverter group, the rating of the a.c. filter capacitor must be increased, the higher harmonic filters must be modified and, above all, a new reactive power compensator must be added. These changes will ensure that the main supply can operate at the higher repetition rate with the same high reliability and low disturbance to the CERN 18 kV network as at present. The main magnet can operate at the higher repetition rate with an appropriate cycle shape. A number of auxiliary power supplies require reinforcement or replacement but the magnets which they feed are adequately rated. Modifications are also necessary to the Booster timing, controls, instrumentation equipment and data treatment. Possibly some modifications may be necessary to the cooling system.

The effect of the higher repetition rate on the Booster RF system has been examined[(2)]. The conclusion drawn is that no additional cavity is necessary for Booster cycles of 0.6s and beam intensities corresponding to a CPS-SPS transfer of up to 10^{13} protons per batch.

As the Booster main magnet is excited by a static power supply connected to the 130 kV Services Industriels de Genève (SIG) network, the Booster repetition rate can influence the power transients of rotating plant connected to this network. Tests have been performed[(3)] in conjunction with the SIG to determine the influence which Booster repetition rates up to 1.8Hz would have on the water wheel alternators at Verbois. These have shown a transient loading of no more than 1.5% of the nominal machine rating, this being negligibly small compared with the transients arising from synchronization or turbine cavitation at light load. The conclusion drawn at CERN from these tests is that there would be no power supply network problem arising from a Booster cycle time of 0.6s - formal SIG confirmation on this point is still outstanding.

2.2.2 PS

The PS main magnet cycle can be shortened to 0.65s for 10 GeV/c cycles; this time is sensibly independent of the accelerating system (9,5MHz or 200MHz) in the PS[(4)]. This shorter cycle time is achieved by raising the magnet field between cycles to about 500 gauss and minimizing the dead time. No additional heavy hardware is necessary for either the PS main magnet or its power supply; modifications would be limited to the power supply controls and the peaking strip which gives the cycle start pulse.

The mixing of 10 and 25 GeV/c cycles within a super cycle perturbs the regularity of the magnetization curve and the magnet injection conditions. This could lead to a small deterioration of the injected beam in some CPS sub-cycles. Further studies are necessary to evaluate this problem and determine the solution.

Not all the auxiliary magnet power supplies of the PS are able to cope with this higher repetition rate. Certain of the capacitor discharge type must be rebuilt or replaced. Modifications are also needed to the septum magnet 16 power supply.

Some additional spares must be provided for PS components which will have a higher pulse count and receive more radiation damage as a result of multi-batch filling of the SPS. This principally concerns ejection septa, both magnetic and electrostatic.

3. The Ejection System

3.1 Modifications to Ejection Hardware

The CT ejection system was foreseen for single batch transfer of a PS beam extracted over 10 revolutions. During the commissioning of the SPS the transfer of two batches of PS beam extracted over 5 revolutions has been made successfully; it is considered that the existing CT equipment can operate reliably in the one and two batch modes for beams up to 10^{13} protons per batch.

The requirement to transfer 3 and 5 batches to the SPS is too onerous for the present fast bump of the CT system on account of the high absolute and inter-step voltages which would arise in the pulse generator. Furthermore, the relatively slow rise time of the fast bump, whilst acceptable for ejection over 10 revolutions, would give excessive amplitude modulation for ejection over 3 or 2 revolutions. The only solution is to complement the existing system with new hardware to produce a faster fast bump for 3 and 5 batch transfers. In order to limit the quantity of hardware and avoid having to enlarge the horizontal aperture of the "shaving" electrostatic septum magnet, it is proposed to make the 3 and 5 batch transfers as "mixed" ejections. The definition of a "mixed" ejection is one in which (n-1) revolutions of the ejection are shaved by the CT scheme and the n^{th} revolution is fast extracted without passing through the shaving electrostatic septum. Tests have been carried out with the present CT system, but at reduced PS intensity, to prove the validity of this principle(5).

On the assumption that the "mixed" transfer is adopted, the new hardware is restricted to faster transmission line type dipoles and 2-step pulse generators, which can also be readily converted to single step(6). This hardware would follow closely the well-tried design of the PS full aperture kicker and associated pulse generators.

Straight section space can be found in the PS for the faster dipoles compatible with the present CT installation except that one quadrupole must be added. Some small rearrangement of auxiliary magnet locations is necessary to make room for one of the new fast dipoles. An extension of approximately 150m^2 is necessary to the Centre Building Hall B359 for the installation of the 2-step pulse generator.

3.2 Synchronization

The problem of the synchronization of the CPS and SPS for multi-batch transfer differs somewhat according to whether 9.5 or 200MHz is used in the PS. On the assumption that a 200MHz system is installed, and in the absence of any deliberately created hole in the beam, there is no space for the rise of the fast kicker for ejection of the n^{th} revolution of a "mixed" transfer. Synchronization between the machines is then not a problem as there is no bunch position or identification to be respected in the CPS. The penalty paid for this ease of synchronization is beam loss on the ejection septum 16 but this should be less than ½%. About 1% of the beam not fully kicked during the kicker rise will remain in the PS but this can be collected on a dump target. At this stage it is felt that the septum 16 losses are acceptable and that this mode of operation is admissible.

Synchronization of the two machines is more difficult if advantage is to be taken of the bunch structure of a 9.5MHz beam or a hole in a 200MHz beam to minimize septum 16 losses. Two possibilities are considered to exist; these are a controlled radial beam displacement in the PS or a homing system which predicts the evolution of revolution frequency(7). Neither has been given detailed study because it is assumed that the beam which will be used for multibatch filling will be a continuous 200MHz beam.

4. Cost and effort

Table 1 gives a summary of the estimated costs; the total is 7.55 MF. The costs are grouped according to the two main activities, namely reduction of cycle time and beam extraction. The costs are budget estimates and, in general, are not based on firm offers from industry or other CERN Divisions. Nevertheless, they are considered to reflect to within 10% the true cost of the project in 1977 prices, assuming this to be executed before 1980.

The PS effort is estimated to be about 25 man-years; about one third of this effort would be engineering staff and the rest technical/manual staff. In addition some 12 man-years of temporary labour support would be required.

The overall time scale for implementation depends on factors exterior to the project itself such as divisional staffing and parallel work load. The minimum time scale is about 2½ years, determined by the sequential effects of delivery delays from industry and scheduling of machine shutdowns for installation.

TABLE 1

Task	Item	Costs KFs PSB	PS	Total
Faster Cycling	Power supplies	1600	600	
	Magnets	----		
	Timing, controls, instrumentation	350		
	Cabling, cooling, miscellaneous installations	500	50	
	Temporary labour	450	120	
	Civil Engineering	400	---	
	Contingencies	300	80	
		3600	1100	4700
Beam Extraction	Pulse generators		1150	
	Pulsed magnets		650	
	Septa		180	
	Timing and controls		70	
	Miscellaneous installations		90	
	Temporary labour		125	
	Civil Engineering		465	
	Contingencies		120	
			2850	2850
			Total	7550

References

1. The PSB Magnet Current Supplies : Implications of a Shorter Pulse Repetition Time. F. Völker, PS/BR/Note 76-25.

2. Beam Dynamics Constraints on Booster Cycle Time. F.J. Sacherer, CERN/PS/BR 76-8

3. Essais de pulsation de l'alimentation Booster à des taux de répétition jusqu'à 1,82 Hz (Effects sur les machines de Verbois) B. Godenzi, F. Völker, CERN/PS/BR 76-17

4. Interim Report of PS Multipulsing Working Group, D. Boussard et al. PS/AE/Note 76-11

5. Status of the Multipulsing Investigation. D. Fiander, PS/AE/Note 76-17

6. A Design Proposal for a 2-Step Fast Bump for a Multipulsing Project. D. Fiander, PS/AE/Note 77-1

7. Synchronization and Tolerances for Multipulse Injection PS-SPS. D. Möhl