Targets, Moderators, Calculations, Codes, Instruments

Thursday, December 15, 1977

9:00 a.m.	Informal Discussion
10:00	Summaries of workshop group discussion by designated persons.
12:30	Lunch
1:30	Discussion of Needed Actions,
	Review Draft Agenda for 2nd ICANS Meeting July 10-15, at Rutherford
	Preliminary discussion of Topic for 3rd ICANS Meeting, (February, 1979) (LASL)
3:00	Adjournment

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*Several functions of this workshop are combined with those which are simultaneously a part of the IPNS Proposal Review Meeting.

SUMMARY OF DISCUSSIONS

Although the meeting was called a workshop, the general consensus was that it might better have been called an information exchange since the various discussion sessions were devoted almost exclusively to this purpose. Nevertheless it was felt by all that this was a very useful function. The informal discussions in the various subject areas are summarized below.

A. Accelerator Problems

Participants

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A.1 Ion Sources

The two types of ion sources potentially capable of providing the beam intensity and duty cycle required for pulsed spallation neutron sources have been studied and evaluated. During the last year or so, significant advances have occurred in the development of direct-extraction surface-plasma H^- ion sources. Existing Penning-discharge versions of the surface-plasma source at Novosibirsk, where this type of source originated, at BNL, where it has been under development for several years, at LASL, where development started about a year ago and at ANL, where development is just getting underway, have shown that this approach to H^- production is clearly superior (for accelerator applications, where beam size and emittance are important considerations) to the brute-force approach in which several amperes of positive hydrogen ions, a gas or vapor target for double electron attachment, and a magnetic separator are required to produce a monoenergetic 50 mA H^- ion beam.

Problems which cause existing Penning surface plasma sources to fall short of the performance required for IPNS and SNS have been identified. The most serious appears to be the problem of extending the duty factor. A Russian source has exceeded the current and pulse rate requirements for IPNS but falls short of the required pulse length. Scaling down in current and pulse rate and up in pulse length will result in an average arc power ∿ 50% greater in the IPNS source than in the existing Russian source. More efficient cooling will have to be provided to dissipate this additional power to the source cathode and anode. Pumping requirements for the IPNS source will be formidable unless significant improvements in gas efficiency are achieved during the course of development of the Penning source.

The immediate objective of the H^- source program at Argonne is to produce an operational Penning source for direct H^- injection into the ZGS and Booster II as quickly as possible.

The beam intensities and duty cycles required for these applications were achieved during initial tests of the present source. During these tests, the arc and beam currents were quite noisy and gas consumption was excessively high. Efforts to eliminate these problems are underway. At Rutherford, Penning - discharge studies will be conducted while a complete source assembly and a test stand are being built, over the next six months or so.

Results of studies and development efforts at one laboratory will be communicated to the other on a quarterly or more frequent basis. More active collaboration will occur as occasions arise where studies or experiments initiated at one laboratory may be more expeditiously or conveniently conducted at the other laboratory.

A.2 Beam Loss in the Injector Linac

1. The high duty cycle, high mean current, performance required of the SNS and IPNS injector linacs demands that consideration be given to the problems of beam loss in these machines. A comparison can be made with the maximum design performance of existing machines:

	MEV	mA	μs	Hz	μ A(mean)
FNAL Injector	200	100	100	15	150
BNL Injector	200	100	200	30	600
LAMPF	800	17	500	120	1000
RL (SNS)	70	20	500	53	530
ANL (IPNS)	100	15	740	60	666

2. Heating due to beam loss
   - (i) Untrapped preinjector beam. Some 50% of the preinjector beam will be untrapped and create a heat load to the drift tubes. Assuming a 500 μA loss at a mean energy of 1 MeV, gives a 500 W heat load, which can be compared with the combined rf and magnet heat load in the first drift-tube of the RL linac of 130 W. It can be assumed that the beam loss will be distributed over a number of drift-tubes. Local heating of the drift-tube bores is unlikely to cause a problem.
   - (ii) Beam stop for accelerated beam. The 35 kW of beam power from the RL linac would require a carefully designed and expensive beam stop if it were proposed to dump this beam during linac commissioning. It might be acceptable to restrict the average beam current during commissioning.
3. Shielding. Beam losses in the BNL and FNAL linacs were estimated during their design at approximately 0.1% above 10 MeV. Biological shielding should probably be designed for a 1% beam loss, for which a concrete shield wall of 6 ft thickness

at 70 MeV should be adequate.

4. Activation. Continuous beam loss to give 100 mR/hr. at 1 m, after 1 hr. cooling, at 50 MeV, in copper, is of the order:

Loss at a point,	0.25 μA
Uniform loss over 30 m,	2.0 μA

Clearly, for hand-on maintenance of the linac, these losses are upper limits and should probably be reduced by at least an order of magnitude.

5. Radiation damage. Assuming 0.1 neutrons produced per proton lost at 70 MeV, and of the order 1.4×10^{-8} Rads per n/cm^2, then for a uniform loss of 5 μ A of beam current over the 150 ft length of the RL linac the dose at the 70 MeV end is of the order 10^7 Rad/year at 10 cm. This should be acceptable for most linac components and materials. However, all semi-conductor electronics must be located outside the shielding wall.

6. Linac radial acceptance. Present information suggests that H^- ion beams can be produced with emittance values no worse than these emittances should be well within the linac acceptance and with something to spare. The RL linac will operate in the FFDD focusing mode giving a normalised acceptance of 10π mm. mr.

7. Longitudinal acceptance. Beam loss will be sensitive to any instability in phase between tanks. Instabilities of up to 17° have been observed in the RL linac, probably due to electron reactive loading. Fast phase control will be introduced for this linac. Electron loading effects are unlikely to be a problem in a modern linac with a clean vacuum system.

Note: There was no spokesman from either LAMPF or ANL on the topic of linacs.

A.3 Beam Loss and Activation in the Synchrotron

This discussion was attended by the entire study group. Graham Rees presented the thinking of the SNS group on this subject.

Philosophy

The enormous quantity of protons to be handled in both machines dictate a new operational philosophy from that previously used at either Nimrod or the ZGS. The HIS proposes to accelerate 2000 times the protons handled by the ZGS. The SNS group plan to set a hard limit on the beam loss at 2 x 10^{11} eight hundred MeV protons per cycle during 50 Hz operation. During tune-up and troubleshooting, this limit would be adjusted for energy and repetition rate to be an equivalent loss rate. This pointed out the necessity of making operational mode changes simple and diagnostic procedures clearly defined so that on shift operators could handle most of them without staff help after stable operation is achieved.

Injection Losses

Uncaptured or conditionally stable captured 70 MeV (100 MeV) beam will represent from 30 to 50% of the injected particles. It is important to dispose of these particles in a controlled way. SNS suggested kicking the unbunched beam into catching targets very early in the acceleration cycle. HIS ideas included injecting directly into the rf bucket by chopping in the linac or more exotic, an intermediate storage ring. Since chopping in the linac would introduce tails on the bunches, it was agreed that kicking in the circular machine would likely be better. Even better, it was agreed, was a very efficient capture process. It would seem that work on the capture process and a conservative injection scheme ought to take first priority.

SNS plans a vacuum system capable of producing 3 x 10^{-7} Torr vacuum to minimize vacuum scattering. Experience in the ZGS indicates that vacuums at least that good will be required to minimize proton-residual gas instabilities.

Acceleration Losses

SNS plans a system of vertical deflecting foils which would drive vertically scattered protons into catching targets. These targets would need to be water-cooled and the water could be used in a way to moderate the resulting neutrons.

Radially lost beam is harder to collect, but SNS plans an outer edge collecting system much like the vertical systems just mentioned. They noted the importance of an orbit trimming system to maximize the available orbit.

These collecting targets must be long to be effective, therefore, long straight sections are desirable in this type machine.

Extraction Losses

It was felt that a conservative philosophy was important here, too. This can best be done by designing apertures and fast kicks at least twice as great as that required by the theoretical beam size.

Remote Repairability

Neither group had come to grips with this question as yet, but quick magnet disconnect schemes in use at CERN were briefly discussed.

A.4 Magnets and Vacuum Chambers

The ring magnets for the high intensity synchrotrons discussed have several special requirements which they must satisfy. These are 1) 60 Hz operation, 2) operation in high radiation fields, 3) incorporation of an rf shield between the useful beam volume and the inside of the magnet gaps, and 4) good vacuum in the useful volume of the magnet gaps.

The 60 Hz operation demands that eddy currents in the magnet structure be minimized for reasons of their causing errors in the gap fields and their producing excessive power losses. The cores for the magnets will be laminated. The questions of concern for a laminated core are:

1) What are the core losses and how are they affected by the way in which the core is tied together?
2) What are the mechanical and vacuum properties of a laminated core with an an externally attached vacuum shell?

The present design for IPNS is an unimpregnated, laminated core. The RL core will probably be bonded with epoxy resin, particularly since the dipoles are curved. ANL will be constructing a test core to look at the above questions in a dry core. The laminations used and basic core design are those of Booster II. RL has done some measurements of the vacuum properties of a stack of disks. Their results showed that a laminated core inside a vacuum system will require large pumping capacities to reach reasonable pressures. They expect that cryogenic pumping would also be necessary in the magnet gaps.

The need to operate in high radiation fields makes the core described above (unimpregnated) desirable. If the core were impregnated with epoxy and located inside the vacuum system, a large gas load in the vacuum space would be generated by beam loses striking the epoxy. The current coil designs of IPNS and SNS are different. SNS is severely limited by their power supply; they have to build a coil for operation at around 14 kV. To meet this requirement they must use an epoxy-based system. They feel that this will be acceptable if sufficient shielding is provided and the losses are kept down.

ANL is investigating MI conductor for their HIS coils. This conductor presents several problems. One is the induced voltage in the outside shield conductors. These voltages are the same as those on the conductor itself. To eliminate this problem, ANL now is considering the insertion of insulating gaps in the shield conductor. This gap must be sealed, however, to prevent loss and/or contamination of the insulation.

The second problem is the eddy currents in the shield conductor. ANL is in the process of developing codes to calculate these currents and their effect on the fields in the magnet gaps and the effects of the added power dissipation in the coils. ANL will also be able to test an MI coil in their test core and empirically determine some of the aspects of MI coils.

The ANL coils are now designed to have a voltage drop of about 1900 V maximum. This is roughly the potential to ground during operation for a power supply feeding the ring magnets at 16 points. If a fault occurs, one might expect higher voltages and probable breakdown of the insulation. The magnesium oxide insulation does not seem to be irreversibly damaged by this and, therefore, no serious problem is anticipated.

The rf shield proposed at this time by ANL is a radially segmented conducting cylinder which is electrically tied together along one side. The present RL design incorporates conducting strips of 2 mm thick stainless steel running along the inside surfaces of the vacuum chambers.

The last area of discussion was the method for providing the vacuums of 1×10^{-6} to 1×10^{-7} Torr required in the beam volume. RL now is proposing to build ceramic chambers made from sections about 10" long and joined together by a glazing process at about 1100°C. This chamber is designed so that it does not touch the pole surfaces, thereby eliminating vibration problems from the rapid cycling magnets. RL is running some tests now to define any problem areas related to radiation damage and to the effects of beam losses and thermal cycling.

The present ANL design uses the magnet core and outer vacuum jacket to provide a rough vacuum around the coils and inside the magnet gaps. The test core will help to evaluate the attainable pressures for this type of design. Hard vacuum chambers will then be located inside the magnet gaps. The detail of this chamber have not been developed yet, and will depend heavily on the results of the test magnet work.

There is an alternate core design being considered at ANL by M. Foss. This involves the accelerator bending magnets and the chokes needed for the power supply to be incorporated in a single magnet structure. This magnet-choke contains a dc core (solid steel) and an ac core (laminated steel), and a dc coil (could be easily rdiation hardened) and an ac coil (is relatively small). This magnet-choke appears to have a cost advantage of about 6% over a discrete geometry.

SUMMARY

The most difficult problems at this time are related to the required vacuums and the need for radiation hardened magnets. RL is involved now in R & D on a ceramic vacuum chamber. ANL is now doing R & D on aspects concerned with radiation hardened coils and cores which must operate in a 60 Hz system. The results of this work will, hopefully, allow us to proceed to more realistic designs for the ring magnets at both laboratories.

Collaboration

It was agreed to exchange information. At present, no areas are identified where specific help is required, but R & D work being done at both labs is of mutual interest and the results will be exchanged.

A.5 Summary of Discussion on Power Supplies

Present: Messrs. Roger Bennett and Barry Ward of Rutherford Laboratory and Charles Potts and Walter Praeg of ANL.

1. Ring Magnet Power Supply

Barry Ward described briefly the NINA 50 Hz power supply which is available for use at the Rutherford Laboratory for their 800 MeV proton synchrotron. The ac excitation of the resonant magnet network was provided for NINA by a pulse circuit, supplying a current pulse on the choke primary winding during the rising portion of the magnet current.

The current in NINA was stable within ± 0.01%. For the new synchrotron, a 395 A sinewave current is superimposed on a 660 A dc current. Both current components must be regulated within 0.01% and this will give a variation of injection field of about 0.5 G. The injection field is 1760 G, the peak field 7 kG. The losses are approximately 1 MW for dc and 1 MW for ac.

The objections to a pulsed supply are field perturbations and resonances excited by the pulse. Rutherford is now looking into continuous ac excitation by various means and including the possible use of a motor alternator set.

The question of phase-lock to the mains, of detuning an account of mains frequency changes and temperature were discussed.

W. Praeg mentioned that Argonne made a brief feasibility study for an IPNS-RMPS in 1975 to obtain cost estimates. Engineering design is anticipated to start in about a year.

With the success of the Booster II RMPS, where a 2300 A dc current is modulated by a 1853 A 30 Hz current by phase control of a 24-phase dc power supply, it is planned to use a similar but 36 or 48-phase system to generate the IPNS magnet current. The Booster II power supply and its phase control circuits were then discussed in more detail.

2. Injection Bump and Ejection Septum Magnet Power Supplies

Papers describing these pulsed power supplies were briefly mentioned. Copies of these papers were given to Messrs. Bennett and Ward, together with papers describing the transient protection of the ZGS-RMPS and ripple filter design.

3. Collaboration

It was agreed to exchange information. No areas where specific help would be useful to the participants were identified at this time.

A.6 Stripper

ANL presented observations on its experience with strippers to date. Paralene foils have, in early tests, shown life-times of ∿ 10^{18} -10^{19} p/cm^2 at 50 MeV. Actual foil lifetimes in BST-II have been << less, except for the present foil in use which has worked for over a week at various operating conditions. No clear reason can be given for its longevity, except that it coincides with the first period of operation in which beam is extracted. Beam is also carried "over-the-top" of the B-field so that non-extracted beam is now dropped radially outward. Whether or not the non-extracted beam has been the culprit is not clear.

The use of other materials was also brought up. ANL is having carbon foils (∿ 50 μ g/cm^2) and silver foils (0.15 μm thick) prepared for testing in BST-II. Results should be available within the month.

Since the use of paralene foils has some problems of using proprietary materials, it may be advisable that ANL provide paralene for early test.

A.7 Injection and Capture

Both HIS and SNS plan to use stripping of H^- ions to produce a large circulating current of protons for acceleration in the synchrotron. In both proposals the stripper is located near the inside aperture limit and bumper magnets are used to create synchrotron orbits near the stripper. These bumper magnets are turned off after injection so that the stripper is hidden from the accelerated protons.

SNS plans to inject the H^- from inside the ring, using the field of one of the bumper magnets to bend the beam to the correct injection angle. Care has been taken to locate the stripper at a favorable location in the lattice so that manipulation of the H^- beam during injection is not required. Due to difficulties of achieving good matching conditions for the external beam the energy spread of the beam must be limite Therefore SNS plans to use smaller accelerating bucket sizes and to capture about 50% of the injected beam. Care will be taken to localize the lost beam into a specia dump area.

Injection for the HIS proposal is very similar to the H^- injection method already used in Booster I and II. The H^- beam is injected from the outside and bent outward in a regular ring magnet to be headed in the direction of an inside closed orbit located near the stripper. Pulsed bumper magnets will be used to create these orbits and control their outward rate of movement away from stripper. Pulsed steering magnets in the H^- injection line will be used to keep the injected particles headed in the most favorable direction. The whole scheme is designed to create a nearly uniform transverse density to minimize space charge effects. A small energy ramp of the H^- beam will also be used for the same reason. The HIS accelerating buckets are large enough to contain a large energy spread. Adiabatic capture will be used in an effort to capture more than 70% of the injected beam. Localized beam dumps for absorbing the uncaptured beam will also be considered.

A.8 RF Systems

The IPNS and SNS RF System proposals were reviewed. SNS plans a 2 or 3 gap cavity with the gaps driven in parallel by conventional power amplifiers similar to the FNAL design. Beam loading would be controlled with a feedback scheme similar to that employed by the CERN ISR. The IPNS plans call for a single gap cavity driven by a low output impedance cathode follower type amplifier. The cavities would be resonated near the center of the frequency range and not be required to track.

The SNS frequency range is somewhat higher than IPNS but ferrite data, cavity/power amplifier designs, and low level rf systems are all likely areas for collaboration. In addition the Argonne Booster II accelerator has the capability of injecting with rf on but with the cavities out of phase. Since this is the injection mode planned for SNS some experience can be gained from Booster II experiments.

A.9 Extraction

The proposed extraction systems for the SNS and HIS accelerators are similar in a general sense. Both systems will utilize a bumped orbit to position the beam optimally for extraction using fast kicker magnets and a septum magnet. However, for the SNS the beam is to be removed vertically whereas for the HIS radial extraction is proposed. The dispersive properties of the beam handling after extraction impose some additional complications for the SNS cheme. The kick angle for the SNS extraction scheme is about half that necessary for the HIS extraction although the apertures necessary for high intensity beams force the kicker designs to present some degree of difficulty in engineering and operation.

Critical review and discussion of the proposed methods has already contributed to the spirit of collaboration. The suggestion was made that the HIS scheme should examine the dispersive properties of the bumped orbit and consider also the possibility of vertical extraction. Concern was also expressed as to the consequences of back voltages on the thyratrons for the power supply circuits proposed for the SNS kickers.

SNS plans to build a prototype supply for the kicker magnets to test their circuit design. Results of investigations along these lines as well as experience at Argonne with the Booster II kicker magnet operation will provide information as input to both efforts.

B. Targets, Moderators, Calculations, Codes, Instruments

Participants

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