Report from the

10th Meeting of the Accelerator Technical Advisory Committee for the Japan Proton Accelerator Research Complex (J-PARC)

February 17 - 19, 2011

J-PARC Center

Tokai, Japan

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Introduction

The Accelerator Technical Advisory Committee (ATAC) for the J-PARC Project held its tenth meeting February 17 - 19, 2011, at the J-PARC Center in Tokai, Japan. This report of ATAC was presented to the Meeting of the International Advisory Committee (IAC) on February 21, 2011.

ATAC members in attendance at this meeting included: D. Findlay (RAL), J. Galambos (SNS, ORNL), R. Garoby (CERN), S. Holmes (FNAL), A. Noda (Kyoto U.), P. Ostroumov (ANL), U. Ratzinger (U. Frankfurt), T. Roser (BNL, chair), and J. Wei (MSU).

The ATAC wish to express its appreciation to JAEA and KEK management and support staff for their hospitality during this meeting, and to the J-PARC staff for their excellent and comprehensive presentations. The ATAC also congratulates the J-PARC team for a spectacular first year of operation, reaching or exceeding the performance goals for 2010. The Committee also greatly appreciates that the J-PARC team has carefully addressed all recommendations from the last review.

Overview of J-PARC operations and power projections

The J-PARC complex has now been fully operational, supporting experimental research programs both at the Materials and Life Sciences Facility and the Main Ring slow and fast extraction facilities, over the last year. The RCS is routinely providing 200 kW to the neutron target, and the Main Ring is providing 135 kW of fast extracted beam to the neutrino target and 3.6 kW of slow extracted beam with 99.5% efficiency to the Hadron Facility. Facility reliability is approaching 95%. These performance levels are both significantly improved from a year ago and consistent with goals outlined at that time. The 400 MeV linac upgrade is progressing very well and is on schedule for installation in 2012. Planning is well advanced for the next four years of operations, including the period of installation and commissioning of the 400 MeV linac upgrade.

Primary Achievements

- 200 kW of beam to the MLF on a routine basis
  - 10 neutron and 1 muon beamline in operation
  - 2 neutron beamlines in commissioning and 6 under construction
  - RCS capable of 300 kW; currently limited to 200 kW by neutron target
  - 420 kW of equivalent beam power from the RCS demonstrated on single shots
- 135 kW of beam at 30 GeV to the neutrino target on a routine basis
  - Several dozen events observed in T2K detector
  - Currently limited by losses/activation in injection/extraction areas

- 3.6 kW to the 30 GeV slow extraction program
    - First experiment completed (penta-quark search)
    - Significant improvement in extraction efficiency (now 99.5%) and duty factor (now 30%) over last year
    - 10 kW equivalent power demonstrated
    - Currently limited by extraction efficiency as beam intensity increases
- Successful summer 2010 shutdown strongly tied to MR performance improvements
    - 3-50 BT collimator shielding
    - New (fast) MR extraction kicker (8 bunch operations)
    - 6th rf station
    - Transverse bunch-by-bunch damper
    - Improvements to power supplies to decrease cycle time (3.6 to 3.2 sec)
    - Dynamic bump system
    - Transverse noise kicker
- Funding secured to support 200 days of facility operations for users
- Funding secured to complete linac upgrade
- Multi-year plan established through JFY2014
    - Goals unchanged from a year ago
    - Incorporates and depends upon the 400 MeV linac upgrade
    - 1 MW from RCS
    - 430-750 kW from Main Ring (fast extraction)
    - 100 kW from Main Ring (slow extraction)

Comments and Recommendations

- Goals established for JFY2011
    - 200 days operations for users at MLF and MR (FX/SX ~2/1)
    - 300 kW from RCS
    - 150 kW from MR (fast extraction)
    - 30 kW from MR (slow extraction)
- Residual activation is being monitored throughout the facility
    - High activation in RCS injection region (>500 μSv/hr @ 30 cm) and MR injection region (>5000 μSv/hr @ 30 cm) need to be addressed in moving to higher beam power.
    - Possible sources have been identified (multiple foil strikes in RCS; ringing of injection kicker in MR)

      Continue the activation-monitoring program as intensities are raised in the RCS and MR. Utilize the information for benchmarking of simulation codes and developing mitigation strategies as power levels rise.

- Spares queues are being built up per prior ATAC recommendations
- Better understanding of beam loss mechanisms as compared to a year ago
    - Effective program marrying beam studies to simulations (RCS)
    - Simulations could benefit from increased study time to provide benchmarking in MR

Continue studies aimed at characterizing and understanding losses observed in the RCS and MR at the highest beam intensities possible.

- Plan established for improvement of RCS to 1 MW by 2014
    - Reliant on completion of 400 MeV linac upgrade
    - Requires 50 mA x 0.5 msec from linac at 400 MeV
    - New ion source
    - New RFQ
    - Upgrade to RCS injection/painting bump magnet power supplies
    - Improved painting schemes
    - New injection collimation systems
    - New diagnostics and corrector magnets
    - 12 rf stations
    - Plan supported by extensive studies and simulations
    - The ATAC finds the presented plan credible

- Plan under development for improvement of MR fast extraction to 750 kW
    - Reliant on RCS operations at 600 kW
    - Requires upgrade of collimator capacity in 3-50 BT (done) and MR (450 -> 2000 W)
    - New scenario based on decreased cycle time (1.2 sec)
    - Higher gradient rf cavities
    - New dipole/quadrupole power supply systems
    - Anticipated performance in 2014 is 430 kW, based on 2.2 sec cycle time (requires partial replacement with new power supplies)
    - The required power supply upgrade to support 750 kW operations may not be available for several years later
    - The ATAC notes inconsistency in presentation of future projections, some of which display 750 kW by the end of 2014, and current planning which provides 430 kW in 2014
    - The ATAC believes that the development of strategies for reducing the MR cycle time is a necessary investment to reach 750 kW and should be continued.
    - However, the MR plan presented is not sufficiently developed to be deemed “credible”.

R1: The plan for achieving MR operations at 750 kW should be further developed. While decreased cycle times should be part of the plan, other options or additions, for example operations at energies higher than 30 GeV or stacking of more than four RCS pulses in the MR should also be explored.

- Concepts have been identified for improvement of MR slow extraction to 100 kW by 2014
    - Ti chamber to reduce residual activation
    - Improved power supply regulation (<2×10-6 ripple)
    - New SX collimators
    - Transverse (noise) kicker
    - The ATAC does not feel a self-consistent plan, supported by simulations and beam experiments, exists for slow extraction of 100 kW beams

R2: Develop a strategy for achieving slow extracted beam powers approaching 100 kW that is supported by simulations. The strategy should take into account all known intensity dependent

effects, incorporate comparison with beam experiments, as possible, and accommodate losses up to a few kW in the extraction region.

- An operations plan for the period through 2014 has been developed that contains:
    - Estimates of peak performance in the RCS and MR by year
    - Estimates of the integrated beam power delivered from the RCS and MR by year
    - Estimates of the integrated hours of beam on target for users and accelerator studies by year.
    - Estimates of commissioning time required following the linac upgrade.
    - Estimates of the expected availability by year.
    - The plan includes input from the user community

  Update the existing operations plan as new information becomes available

- Significant progress has been made at defining the basic configuration and operational parameters for the period through 2014.
    - Parameter tables need to be updated as operational or development activities indicate the need for changes.
    - Extrapolation from current conditions should be guided by simulations and machine experiments.

  R3: The operations plan should be augmented by a J-PARC-wide technical upgrade plan that describes the configuration of the complex, associated performance goals through the upgrade period, and ensures that the necessary resources are available.

Linac status

Primary achievements

- Overall there is a marked transition from beam commissioning to beam operations. The linac routinely provides ≥200-kW operation of the RCS and it is adequate to support RCS operation at 420 kW.
- Significant increase of the linac availability compared to the previous years. The RFQ conditioning is no longer the major driver for maintenance stoppage and the ion source replacement time has been reduced from 3 to 2 days.
- Development and test of the new scintillator-based BLM, which is not sensitive to X-rays.
- Fabrication of the spare RFQ is complete.
- Continued beam studies to provide high-quality, high-power beams for injection into the RCS.

Comments and recommendations

- Ion source can support extended runs up to 2 months; the maintenance time has been reduced to 2 days. Possibilities for further reduction of the maintenance time are being investigated.

- The Linac team consistently records downtimes and analyzes possible causes. Troubleshooting of the HVDC power supplies resulted in the development of technical modifications of the HVDC system, which are being implemented.
- There is a substantial improvement in the availability of the RFQ but the RFQ discharge problem is a relatively large contributor to beam downtime. So far the RFQ discharge rate does not appear to be increasing, despite an increase in operational vacuum levels. However, it is unclear how the discharge problem will scale with higher beam currents and full duty cycle.

R4: Consider testing RFQ operation at higher currents approaching the design values as soon as possible (e.g. in beam study time if feasible), to identify any potential discharge issues early.

R5: Continue thorough investigation of the Linac trips related to SDTL and BLM. It is likely that these trips can be eliminated without significant investment of resources.

- The status of the klystrons approaching their design lifetime is being constantly monitored. The klystron efficiency has been observed to be decreasing, but there are no failures yet. There are spares available for about half the klystrons. The procurement of 4 klystrons per year is foreseen.

R6: Consider alternate klystron replacement options such as partial rebuilds of failed units.

- Work on redundancy of the Front End systems is being pursued. The copper parts of the spare RFQ have been successfully brazed and low-level RF measurements of the RFQ assembly are being performed. Main electrodynamics parameters of the RFQ (resonant frequency, field flatness, frequency separation of dipole modes) have been measured. To have a confidence in correctness of the dipole mode tuning, it would be useful to measure frequencies of all modes as a function of the end-tuner penetration and to apply bead-pull measurements for dipole modes. Consider how the spare RFQ will be used after the high power RF tests.

R7: Build a test stand with ion source, LEBT and RFQ capability as soon as possible that would allow developing the required confidence before installing the spare RFQ in the operational machine. Such off-line beam tests of the spare RFQ can be combined with the development and tests of a high-intensity ion source and high intensity RFQ for the future upgrade.

- Despite of limited time for the machine study the Linac team has performed several useful beam studies. Quantitative beam loss measurements in the ACS upgrade area of the linac as a function of the vacuum pressure in the upstream sections have been performed. These experiments clearly demonstrate that an appreciable beam loss increase in the ACS area is caused by the stripping of H-minus beam on residual gas. Important information on linac parameters and the bunch longitudinal profile has been obtained by phase acceptance scan of the SDTL.
- There is still an unexplained beam halo observed at the high-energy end of the linac. Beam studies on the effectiveness of L3BT collimation should be done. Additional collimation is being considered in the MEBT2 section of the linac.

R8: Consider implementation of scraping in the low energy region (MEBT-1).

- The residual activation levels built up while supporting 200 kW operations are quite modest, and not a concern at present. They do not appear to be a limitation for the immediate power ramp-up plans.

3 GeV RCS, including operations after Linac upgrade

Primary achievements

- Routine operation of the Rapid Cycling Synchrotron (RCS) at 200 kW.
- Establishing a good understanding of beam loss issues at injection, including optimisation of foil geometries.
- Making important beam dynamics measurements at the equivalent of 400 kW with 180 MeV injection.
- Resolving problems with the connectors for the fast extraction kickers.
- Demonstrating that except at the injection and collimation regions of the RCS induced radioactivity in the machine structure is markedly low.
- Demonstrating that after resolution of the extraction kicker connector problem the reliability of the RCS has proved to be markedly good.

Comments, suggestions and recommendations

- Since November 2010 the RCS has run routinely at a beam power of 200 kW (with 17 mA in the linac and a pulse length of 0.38 ms). It is likely that the RCS would have run at higher powers except for worries over risks to the target (for which there is no spare) and over less than optimal behaviour of the liquid hydrogen moderator due to the presence of trace amounts of frozen water and hydrocarbons.

  It would obviously be good to remove any perceived barrier to operation at increased powers due to target and moderator worries — as funds, opportunities and user schedules permit.

- It is noticeable again from the absence of any mention of them that most of the RCS systems must have run well, e.g. the main magnet power supplies and the high-power RF drivers, and these successes again deserve to be noted.
- A good set of investigations of beam dynamics issues at injection has been made — involving measurement, simulation, and foil configuration changes. These have resulted in the establishment of a notably improved understanding of the behaviour of the beam at injection, and have pointed the way towards installation of an improved collimation system to further reduce localised beam losses.

  R9: Machine schedules should be arranged so that sufficient time is made available for a sustainable machine development and study program.

  Measurements of beam profiles and time dependences of foil losses could usefully be compared with simulations.

- Linac beam halo may be contributing to beam losses at RCS injection. However, in practice there may be a reluctance to use the L3BT collimation system for fear of activation caused by overly thick stripper foils.

R10: Study the optimum operational balance between scraping off beam in the L3BT collimators versus the collimators in the RCS. The exercise could include varying the thicknesses of the collimation foils.

- Measurements have been made, at higher beam power, of the beam transmission through the RCS for different painting configurations. For the equivalent of 400 kW with 180 MeV injection it has been shown that the powers deposited in the RCS collimators are well within their ratings.

  R11: Similar measurements should be made with as high a repetition rate as possible.

  As powers deposited in collimators increase, it would make sense to consider procuring entire replacement collimator assemblies so that in the event of failure a whole assembly could be replaced without incurring a significant radiation dose to personnel.
- Simulations for 1 MW with 400 MeV injection have been carried out (50 mA, 0.50 ms, 0.56 beam chopper duty factor). These suggest that beam losses on the RCS collimator could be increased in order to reduce more troublesome beam losses between the RCS and the main ring (MR) with its 54π-mm-mrad acceptance (lower than the acceptance of the RCS by a factor 6), although it is recognised that extensive further work on injection into the MR is necessary.

  Continue work on reducing beam halo to facilitate sustainable injection into the MR.
- Substantial work has been carried out on schemes for upgrading RCS hardware to accommodate injection at 400 MeV. On the basis of the beam dynamics and particle tracking studies carried out so far, the schemes look good. The resources required to carry out the schemes are considerable, however, and efforts should be made to ensure that the resources required would indeed be available.
- It is noted that in moving towards operation of the RCS at 1 MW it is likely that a method for reducing kicker impedances will have to be developed, and that a bunch-by-bunch feedback system for the RCS will become necessary. It is also noted that in moving towards 1 MW attention is likely to have to be paid by accelerator staff to the problem of optimising beam spot sizes and shapes on the neutron-producing target.
- The RCS team should be congratulated on a successful programme to resolve problems with the connectors for the fast extraction kickers.
- The levels of induced radioactivity in the RCS away from the injection and collimation regions are sufficiently low that they will not prevent operation of the RCS at higher beam power.

Main Ring, including operations after Linac upgrade

General

Rapid start of user experiments after establishing of stable LINAC operation was achieved, although some key equipment required modifications and improvements to increase the performance of the facility. Up to now the neutrino experiment using fast extraction with a maximum beam power of 135 kW and the hadron experiments using slow extraction with a beam power up to 3kW have run for 6 and 2 months, respectively.

J-PARC is to be congratulated that the MR is already providing physics output from both the neutrino experiment and the hadron experiments. It is also noteworthy that more than half of the users come from outside Japan, demonstrating that J-PARC is a truly international research facility.

Scheme to Realize Proposed Power at MR

A possible scenario to provide 0.75 MW beam power from the MR was proposed requiring an increased MR repetition rate of 0.8 Hz. The increase of the MR repetition rate is required by the lower than expected limit for the MR circulating beam intensity. 8 bunches out of 60 bunches from the RCS are transferred to the MR with a total beam power of 75 kW taking into account the 3.5 % beam loss of at the 3-50 BT collimator. Accelerating to 30 GeV then realizes the beam power of 0.75 MW for fast extraction to the neutrino experiment. The planned RCS simulation studies including space charge effects to evaluate the beam loss for the case of dynamic collimation with the use of local bump should be pursued.

Slow Beam Extraction

Slow extracted beam has been provided to experimenters with a beam power of up to 3 kW although demonstration up to 10kW was made. The extraction efficiency for the 3 kW operation is a world record 99.5 %. The duty factor of the beam, however, was 3.6 % reflecting the big ripple in the excitation currents of the magnets. The duty factor has been improved to 17 % by additionally short-circuiting trim coils and to 30% with further additional application of transverse 20 MHz RF to increase the beam emittance. Application of transverse RF, however, is suffering from multipacting, which will be mitigated with a solenoid field. To reach a high duty factor for slow extraction the current ripple of the main power supplies has to be reduced by orders of magnitude. This is unlikely to occur by 2014.

The position of collimators may need to be adjusted to avoid beam loss during the last three turns before extraction.

R12: Schedule sufficient beam time for machine studies in the MR.

Linac energy upgrade

Primary achievements

- The series production of the ACS modules has been started, 4 units have been finished already. The fabrication capacity is one module per month. The klystron production is on schedule.
- One out of these four modules was successfully power tested; shunt impedance is above design.
- Installations for linac upgrade have started in 2010 summer shutdown and will be continued during summer shutdown of 2011 (3 months). It was deduced from simulations, that no cavities can be installed in advance, as they would increase the energy spread above RCS injection needs.
- Beam simulations along the linac from RFQ exit to RCS injection were done, including alignment and setting errors.
- For the intensity upgrade a SNS type rf driven source plasma generator will be tested at JPARC, involving cesium. A RFQ3 design for 60 mA (50 mA) beam current is underway.

Comments and recommendations

- The linac energy upgrade is progressing very well. No showstoppers have been seen so far. The planning and time schedules are convincing.
- Recommendation R30i from ATAC10 should be included during the power testing of ACS modules, to assure that neighboring modes will not be a danger at all power levels.
- Detailed beam simulations including alignment and setting errors were presented. In future the RFQ should also be included.
- The intensity upgrade is still in the design phase. It is quite behind of the energy upgrade.
- The choice of using the SNS source plasma generator will not necessarily lead to a 60 mA H^- source. Cesium will be needed now and vacuum conditions down along the LEBT have to be checked to get no cesium contamination of the RFQ.
- The physics design of the high-current RFQ3 is not yet finalized. The proposed design may require additional studies. The design shows a pronounced voltage ramping by more then a factor of two. It is not clear why such a novel design is needed for the still modest design current of 50 mA. Of particular concern is the reduction of the focusing strength at the end of the RFQ, which may result in excessive tune depression and emittance growth due to the space charge of the bunched beam. In addition, a longer RFQ resonator should be considered to reduce peak surface field. A longer RFQ will require appropriate techniques to control the dipole modes.

  R13: Consider decoupling the energy upgrade from the intensity upgrade. The front end might still need more R&D than is presently scheduled before construction of components should start.

  Beam studies from source *to RCS injection including all upgrades should be continued.*

Ring RF, including high gradient cavity

Findings

General:

Eleven cavities are operational in the RCS (12 after the Summer 2012 shutdown) and 6 in the MR (8 after the Summer 2011 shutdown). The RF systems give satisfaction in both rings and do not detrimentally impact on accelerators' performance. The number of major faults during the last 12 months was limited (9 in the RCS and 7 in the MR) and they mostly concerned the electronics. The cavities did not contribute to the down time of the accelerators, although (because?) they remain under close monitoring.

RCS cavities

Buckling is a pending issue for the RCS cavities equipped with uncut cores. "Type C" coating has been identified as a solution, and systematic replacement of the cores of all RCS cavities is in progress at the rate of approximately 2 cavities per year, finishing during the summer 2013. The non-modified cavities equipped with other types of cores still suffer from this phenomenon (e.g. cavity # 1 operating now with 2 gaps whose cores will be replaced during the summer 2011).

MR cavities

A 6th RF station has been installed as foreseen during the summer 2010.

The latent problem is corrosion at the cut. (e.g. cavity # 5 is operating with 2 gaps because of impedance reduction: cores will be replaced during the Summer 2011).

As a remedy, Silica coating has been applied to cavities # 3, 4 and 6 in November 2010. In the case of cavity # 2, treated also in November 2010, this has been combined with the installation of an RTV rubber shield to avoid circulation of water in the cut.

All cavities will be Silica coated after the summer 2011, with RTV in cavities # 1, 2 and 5.

The impedances of cavities # 6 and 3 show a slight decrease. No conclusive explanation exists. It is tentatively attributed to the fact that these cavities have already suffered from some damage, which was recovered by polishing.

As a matter of precaution, the cooling circuit of the cavities will be isolated from the magnets during the summer 2011.

Beam commissioning

A second harmonic RF voltage is used for longitudinal painting at injection in the RCS since 2009. In 2010 it has been successfully applied before ejection in the RCS and at injection in the MR to improve the bunching factor.

Feed forward beam loading compensation on harmonics 2 and 4 has been successfully implemented on the 11 RCS cavities, reducing by more than an order of magnitude the equivalent impedance of the cavity for the beam. This technique will be extended to the MR during the JFY2011.

R & D for future cavities

The R & D for future cavities progresses on two fronts:

- A core module made up of three concentric rings (to remove thermal stress and eliminate buckling) in a chemically inert cooling fluid (to get rid of corrosion in water) has been tested at high continuous RF power (up to 10 kW). RF and thermal measurements fit very satisfyingly with computations, leading to the need of 83 l/min of "Fluorinert" for a heat transfer coefficient of 750 $W/m^2/K$. The next step is to construct a one gap resonator equipped with 6 core modules and to test it with a 60 kW RF amplifier.

- A new technique of production of the MA core is being developed to reduce heat dissipation and increase impedance. Based on the use of a thinner ribbon annealed in the presence of an axial magnetic field, a prototype of such an "FT3L" core has been measured as having twice the impedance of a classical "FT3M" core of the same size. Using the same RF power, a 2 m long cavity with 4 gaps and 6 FT3L cores/gap, would provide 60 kV instead of 40 kV in the present FT3M equipped cavities. Cooling could be done by water, air or Fluorinert. A set-up is being assembled in the J-PARC Hadron Hall for producing 20 MR-type cores and 2 RCS-type cores before the summer 2011. A single gap cavity could be installed in the MR during the summer 2011.

Comments & recommendations

Present RF systems

Important efforts continue to be made for addressing the remaining imperfection of the MA-loaded cavities. The satisfying operational result of the accelerator complex shows that it is worthwhile. Moreover, there are reasons to believe that long-term solutions have now been found. It will unfortunately take a few years to get a convincing proof.

> *The Committee is concerned about the persistent reduction of impedance of certain MR cavities. This confirms the need to continue the systematic monitoring of the cavities characteristics.*

The excellent performance of the feed forward beam loading compensation on the RCS cavities and the observed beneficial effect of a second harmonic RF in the RCS and in the MR to increase the bunching factor are very encouraging for the future operation at much higher beam power.

> *The Committee congratulates the RF team for these remarkable results and encourages their publication.*

R & D for future cavities

FT3L based cavities are a potential solution for getting, within the available straight sections, the RF voltage required by the MR for delivering a beam power of 0.75 MW.

> *The Committee is impressed by the progress of this development and fully supports its continuation.*

Concerning the cooling fluid, a lot of experience has been gained with water, which is used in all installed RF systems at JPARC. It is possible that long-term solutions have now been found, but the demonstration will take many years. The investigation of other cooling fluids is therefore worth continuing, as a back-up solution for future cavities. Similarly, multi ring cores could become an attractive option if experience shows that “Type C” coating does not fully avoid buckling.

> *The Committee acknowledges the quality of the work accomplished and supports the continuation of the development of the single gap cavity equipped with multi ring core modules and using Fluorinert cooling. This development is performed by a group separate from the J-PARC rf group. The Committee acknowledges the existence of regular communication between the two rf development teams and encourages its enhancement, which could develop into a joint proposal for a future prototype.*

(R14 was converted to a comment)

R15: Before starting to build a multi-gap cavity using air or Fluorinert cooling, a complete engineering design should be made describing, in detail, cost, the infrastructure needs (space, electricity, water, air…), the maintenance requirements and the compatibility with safety rules in confined areas.

MR power supply upgrade

Primary Achievements

The present MR magnet power supplies operates with cycle periods of ~ 3.2 sec and ripple amplitudes of ~ 10^{-4}. These pose limitations on the available power for FX and SX. The nominal 750 kW FX scenario requires ~ 1.2 sec cycle time and ripple magnitudes ~10^{-6} for SX operation

Investigations of the present MR power supply system show only marginal possible reductions of the cycle time from 3.2 to 2.6 sec, without sacrificing control further. Ripple reduction prospects of the present system power supply include:

- Shorted trim coils, which are effective in the flattop region, but only provide about 10 times reduction, whereas the SX requirements are ~ 100
- Feedback cancelation, which are effective throughout the cycle (appropriate for FX), but only provide ~ 1/3 ripple reduction, as compared to a factor of 30 needed.

These improvements are not sufficient for a long-term solution.

A new MR PS system is proposed that would:

1. Reduce the number of magnets per power supply to reduce the inductive load
2. Use an IGBT technology
3. Use a capacitor based energy storage scheme

Simulations of the system look promising to meet the requirements, but the design is only conceptual.

Comments and Recommendations

The power supply ripple and cycle time requirements should be clearly specified for the designers, based on beam and overall operational power scenario considerations.

While promising, the new proposed IGBT power supply with capacitive energy storage is quite conceptual at present. There are possible issues with increased space requirements, additional cabling requirements, uncertain component lifetimes, and overall development time. It is not obvious that this proposal is the best solution, as it was the only one presented to the committee. Before initiating such a major upgrade a comparison should be done with the more conventional option of flywheel energy storage and separate high voltage ramp and low voltage flattop power supplies. The proposed solutions should be reviewed by an appropriate panel of experts.

While detailed planning has not yet evolved for the deployment of the new power supply, the prototype testing and initial installation should protect the reliability of operations. Limited testing time of a single prototype may not provide adequate reliability data.

> *Consider initial deployment of this technology in a manner that would allow "roll-back" to the old power supply if there were unforeseen issues. This could be accomplished with an individual quadrupole family power supply, which would not need re-cabling.*

Impedance, instabilities and controls

Primary Achievements

- A single-shot beam with intensity corresponding to 420kW beam power if the repetition rate were 25Hz was achieved in the RCS. In this mode, measured beam intensity reduction is 0.5%, and no beam instability was observed.
- At the 420kW-equivalent intensity, instabilities were observed in the horizontal direction at times more than 10ms after the injection if the chromaticities were corrected.
- An operational scenario was proposed simultaneously meeting power requirements on the RCS and MR without exceeding RCS and 3-50BT collimator limit of 4 kW. This scenario required tune manipulation in the RCS with quadrupole correctors and effective reduction of RCS collimator acceptance with a dynamic bump.
- The horizontal damper reduced the beam loss at injection energy in the MR when 8 bunches were injected at the intensity corresponding to 135 kW at 30 GeV.
- Transverse broad-band beam break-up instabilities were observed with the 135kW-equivalent beam in the MR. The instability frequency extended up to 40 – 70 MHz.

Comments and recommendations:

- The committee commends the efforts in pursuing 420kW-equivalent beam study in the RCS, and beam studies to define the path towards 1 MW beam power in the RCS and 0.75 MW beam power in the MR under realistic operational conditions and collimation constraints. The plan to increase the time of machine studies from the present 20 days to 50 days per year can significantly enhance the understanding of the beam dynamics and accelerator systems performance. Present beam loss studies and computer simulation comparisons indicate that beam dynamics of space charge and phase space painting is relatively well understood. More systematic studies are needed in understanding the nature of collective instabilities and impedance sources including possible electron cloud effects.

  R16: Perform more systematic studies in understanding the nature of collective instabilities and impedance sources, and develop mitigation plans accordingly.

- The committee commends the efforts in significantly enhancing beam diagnostics including fast beam loss measurements, high-frequency beam position measurements, fast transverse beam profile measurements, and longitudinal wall-current-monitor measurements. Understanding and control of transverse beam profile in the RCS is crucial in optimizing beam phase-space manipulation to meet various design requirements under operational conditions and constraints.

  R17: Further enhance beam diagnostics and analysis capabilities, in particular beam profile measurements in the RCS and 3-50BT.

- Kickers are identified as major sources of beam coupling impedance. Test stands are available for off-line R&D. We encourage the project teams to pursue more systematic measurements and analysis including both longitudinal and transverse impedance measurements, and kicker performance calibration including rise time and flattop flatness under various kicker and power supply network design optimization scenarios. Similar efforts on the SNS ring extraction and injection kickers may be referenced.

  R18: Pursue more systematic measurements and analysis including both longitudinal and transverse impedance measurements, and kicker performance calibration including rise time and flattop flatness under various kicker and power supply network design optimization scenarios.

- Instabilities were observed in the MR at relatively low beam intensities. Instability behaviors were similar to those at many other high intensity accelerators. Chromaticity maneuver and bunch-to-bunch dampers may not be adequate to mitigate the effects.

  R19: Consider more instability damping measures including using octupole magnets and momentum broadening rf cavities in the MR.

- Maneuver of the transverse tunes along the ramping cycle of the RCS was identified as one of the key procedures to meet design requirements. We encourage actual implementation of ramping quadrupole correctors both to manipulate the tunes and to correct the β-function beating. We also encourage resonance correction with nonlinear correctors.

  R20: Consider implementation of ramping quadrupole correctors in the RCS for tune maneuver and β-beating correction. Evaluate benefits of nonlinear correctors.

Appendix: Meeting Agenda

Thursday 17 February 2011

09:20	Project Status	NAGAMIYA, Shoji
10:00	Accelerator Overview	ANDO, Ainosuke

Status & Commissioning (Linac)

11:30	Linac Status (00h30')	HASEGAWA, K.
12:00	Beam Study Results of Linac (00h30')	IKEGAMI, M.

Status & Commissioning (RCS)

13:30	RCS Status (00h30')	M. KINSHO
14:00	High Power Study of RCS (00h30')	H. HOTCHI
14:30	Beam Loss in RCS (00h30')	K. YAMAMOTO

Status & Commissioning (MR)

15:20	MR Status and Beam Study Results (00h40')	KOSEKI, Tadashi
16:00	MR Slow Extraction (00h30')	M. TOMIZAWA

Friday 18 February 2011

Status & Commissioning (MR)(contd.)

08:40	Instability: Observation and Study Results of MR (00h30')	TOYAMA, Takeshi

Ring RF

09:10	Ring RF Status (00h40')	YOSHII, Masahito
09:50	Alternative Solution (00h30')	MORITA, Y

Towards 1MW RCS and 0.75MW MR-FX with Linac Energy Upgrade

10:40	Schedule & Commissioning of Linac Upgrade (00h30')	N. OUCHI
11:10	RCS with 400MeV Injection (00h30')	N. HAYASHI
11:40	MR-FX 0.75MW Scenario (00h20')	IGARASHI, Susumu

Towards 1MW RCS and 0.75MW MR-FX with Linac Energy Upgrade

13:00	MR Power Supply at Present (00h30')	S. NAKAMURA
13:30	MR Power Supply in the Next Step (00h30')	Y. KURIMOTO
14:00	High Gradient RF Cavity (00h30')	C. OHMORI
14:30	Instability: Dynamics of High Intensity Beam (00h30')	Y. SHOBUDA

Saturday 19 February 2011

11:00	Report to project team	T. ROSER