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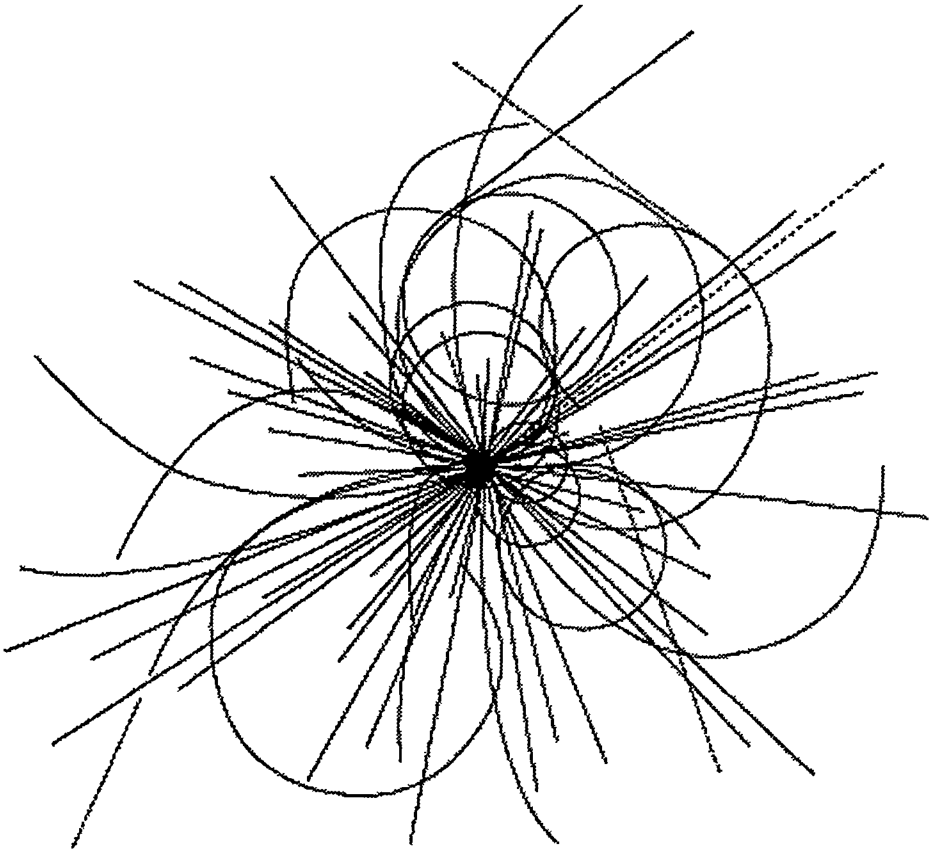

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Equipment Acquisition Plans for the SSCL Magnet Excitation Power System*

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EQUIPMENT ACQUISITION PLANS FOR THE SSCL MAGNET EXCITATION POWER SYSTEMS

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INTRODUCTION

The particle beam production capability of the Superconducting Super Collider Laboratory (SSCL) consists of the injector accelerator systems and the collider accelerator systems. The basic parameters of these accelerators are given in Table 1.

Table 1. Technical Parameters of the Injector and Collider Accelerators.

	INJECTORS				
PARAMETER	LINAC	LEB	MEB	HEB	COL
Length/Circumference	150 m	540 m	3960 m	10 890 m	87 120 m
Injection Momentum	N/A	1.2 GeV/c	12 GeV/c	200 GeV/c	2 TeV/c
Maximum Momentum	1.2 GeV/c	12 GeV/c	200 GeV/c	2 TeV/c	20 TeV/c
Cycle Time	100 ms	100 ms	8 sec	515 sec	Continuous

The Linac is a linear accelerator composed of an H^- ion source, the radio frequency quadrupole accelerator, the drift tube linac accelerator and the cavity coupled linac. The Low Energy Booster (LEB) is the first of three injector synchrotrons which collectively raise the momentum of the proton beam from 1.2 GeV/c to 2 TeV/c. Both the LEB and the Medium Energy Booster (MEB) have resistive magnets in their lattice while the High Energy Booster (HEB) has superconducting magnets. The HEB is a bi-directional accelerator in which protons are first accelerated in one direction (CW) filling one CW collider (COL) ring followed by operation in the reverse direction (CCW) filling the other collider ring. As noted above, there are two collider rings with superconducting magnets, each operating independently. During experimental times, the proton beams in the two accelerators are brought to the same orbit, causing collisions between protons.

One of the key subsystems of all of the accelerators are the magnet excitation power systems. These power systems, along with auxiliary support subsystems, are provided by the Electrical Engineering Department in the Accelerator Systems Division (ASD/EE). The power systems provide well regulated and repeatable current to dipole, quadrupole and other multipole magnets in the accelerators and their interconnecting beam lines. These magnets may be individual magnets such as those of the pulsed power and correction element power supplies or may be strings of magnets which are typical of the ring magnet and beam line power systems.

The output current from the power systems may be: continuous steady state as used in the Linac; ramped (programmed) as in the LEB, MEB, HEB and COL synchrotrons and some of the beam lines; pulsed as in the injection and extraction kicker subsystems; or may be half sine wave as in the pulsed septum and Lambertson magnets. In all cases the output current is required to be

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continuously adjustable over nearly the full range of current (i.e. from a few percent up to 100% of the maximum output current).

Two unique electrical subsystems also provided by the ASD/EE, while technically not magnet excitation power systems, are the quench protection subsystem and the energy extraction subsystem. This equipment is required for protecting the superconducting magnets in the HEB and COL from being destroyed when they unexpectedly transition from the superconducting state to the normal (resistive) state with high levels of current flowing in their coils (quenching). This situation is made worse with strings of superconducting magnets when energy from other magnets in the string can feed into the quenched magnet. For economic reasons, superconducting magnets are not made with sufficient copper conductor in their coils to support full current conduction when the current leaves the superconductor filaments and flows instead in the copper surrounding the superconductor. The quench protection subsystem detects this transition condition and applies stored electrical energy to heaters imbedded in the superconducting coils to drive the entire coil normal, distributing the magnetic energy through the entire coil volume. At that time, bypass diodes, in parallel connection to the magnets, become forward biased diverting the current from the coil and thereby protecting the coil. The energy extraction subsystem protects the bypass circuit from damage by inserting resistors in the circuit reducing the current in the magnet coils and absorbing the magnetic energy stored in the magnet string.

What follows is a brief description of the major electrical technical equipment used in the accelerators and the present laboratory plans for the acquisition of the equipment.

PULSED POWER SUPPLIES AND KICKER MAGNETS

A number of pulsed power supplies and specialized fast rise and fall time magnets are needed for various injection and extraction operations of the several accelerators. Table 2 lists some of the critical features of the kicker magnet subsystems.

Table 2. Kicker System Critical Performance Criteria.

Accelerator System	Rise Time µ sec	Fall Time µ sec	Pulse Length µ sec	Peak Current Amperes
LEB extract	0.08	N/A	2.5	1400
MEB inject	0.06	2	2.0	1400
MEB extract	2	N/A	15	2000
MEB abort	2	N/A	15	2000
HEB inject	0.4	1.7	13	3200
HEB extract	1.7	N/A	35	6000
HEB abort	1.7	N/A	35	10000
COL inject	1.7	4	35	3500
COL abort	4	N/A	300	15000

These magnet and power supply subsystems will be developed by the technical staff of the laboratory in accordance with the system level technical specifications to the extent ranging from preparing detailed fabrication designs to preparing detailed technical performance specifications. In the case where detailed designs are being prepared, for example the LEB extraction magnets, the laboratory will develop the detailed magnet fabrication and assembly drawings, contract for the fabrication and assembly of the hardware and take delivery of the completed magnets. Acceptance will be by testing and inspection. For example, the subcontractor will measure the leak rate of the vacuum envelope and will perform high potential testing of the coil assembly.

In those cases, such as the modulator and charging power supplies, where equipment is acquired through performance specifications, the laboratory staff will prepare detailed technical specifications for the equipment with the fabrication and assembly design being prepared by the subcontractor, subject to the review and approval of the laboratory technical staff. As part of the work, the subcontractor will fabricate and assemble the modulators. Acceptance of the completed equipment will be based on tests and inspection.

Table 3 lists the main components which the laboratory plans to purchase in support of the pulsed power work and the calendar year in which the equipment is expected to be delivered. These components will be purchased both by performance specifications and by fabrication and assembly documentation.

Table 3. Pulsed Power Major Components.

Component	CY 93	CY 94	CY 95	CY 96	CY 97
HV Cable RG 220	20 000 ft	20 000 ft	100 000 ft		
Modulator & Charging PS					
Assembly					
MEB extract			12		
HEB inject				18	
HEB abort				20	
HEB extract				20	
COL inject					20
COL abort				40	20
Ferrite Core 1x6x6 inch	200	200			
Ferrite Core Magnet Assembly Gap: 5x8x500 mm				12	18
Laminated Iron Core Magnet Assembly 5x5x1500 mm				80	40

CORRECTION ELEMENT POWER SUPPLIES

The principle function of the correction element power supplies is to provide the accelerator operators the capability to correct the orbit of the proton beam due to misalignment errors in the main dipole and quadrupole magnets and for betatron tune correction. Although these errors may be small, the accumulated effect is to reduce the brightness of the beam which in turn reduces the luminosity of the colliding beams or the production capability of the laboratory. Table 4 shows the correction element power supplies and the calendar year in which the order is expected to be delivered. Acquisition of this equipment will be through detailed performance specifications.

Table 4. Correction Element Power Supplies.

Accelerator/Power Supply	CY 93	CY 94	CY 95	CY 96	CY 97	CY 98	CY 99
LEB							
4 Quadrant							
70 V, 25 A		90					
130 V, 15 A		76					
130 V, 25 A		48					
190 V, 100 A		18					
70 V, 3.5 A		12					
MEB							
4 Quadrant							
100 V, 15 A			250				
Unipolar							
800 V, 600 A			2				
HEB							
4 quadrant							
30 V, 100 A					254	200	
300 V, 100 A					8		
COLLIDER							
4 quadrant							
30 V, 100 A					700	800	700
200 V, 100 A					100	100	

RING MAGNET POWER SUPPLIES

The ring magnet power systems furnish the excitation power to the main dipole and quadrupole magnets in the four synchrotrons. In the LEB, HEB and COL, both dipoles and quadrupoles magnets are powered in long series-connected magnet strings. In the MEB, the dipoles and the two quadrupole circuits are independently powered. The main parameters of the ring magnet power system circuits are given in Table 5. The COL circuit is subdivided into 10 independent circuits per ring to minimize the recovery time from magnet quenches.

Table 5. Ring Magnet Power System Specifications.

PARAMETER	LEB	MEB D	MEB QF	MEB QD	HEB	COL
Maximum Current	4000 A	5200 A	4500 A	4500 A	7000 A	7000 A
Cycle Time	0.1 s	8.5 s	8.5 s	8.5 s	250 s	cont
System dI/dt	125 kA/s	1690 A/s	1500 A/s	1500 A/s	70 A/s	4 A/s
Power Supplies	3	8	1	1	4	20
Pulse Number	24	24	24	24	24	12
Total Ripple Voltage	<1%	<1%	<1%	<1%	<1%	<1%
Ripple Current	50 ppm	50 ppm	50 ppm	50 ppm	10 ppm	1 ppm

The design of the ring magnet power systems are based line commutated power conversion systems operating as current regulated power supplies. The design emphasizes common hardware in all power systems with variations between the injector power supplies and the collider power supplies. In all cases except the LEB and the MEB QF and QD power circuits, one of the power supplies will operate in the current regulated mode with the remainder in the voltage regulated mode. In these cases, the power supplies are operated in the voltage regulated mode imbedded in the current regulation circuit.

The major components of the system will be acquired through performance specifications prepared by the SSCL according to the delivery schedule in Table 6. Equipment design and fabrication/assembly will be by the subcontractor.

Table 6. Acquisition Schedule for the Ring Magnet Power Supplies.

COMPONENT	CY 93	CY 94	CY 95	CY 96	CY 97	CY 98	CY 99
15 kV SWITCHGEAR		4	12		5		
15 kV RECT XMFR		6	20	4			
5 kV SWITCHGEAR					10	6	4
5 kV RECT XMFR					10	6	4
POWER CONVERTER		6	20	4	12	20	12
THYRISTOR ASSY		36	120	24	48	120	72
OUTPUT FILTER		2	10	4	9	8	7
CURRENT XDUCR		1	3		12	20	9
AC HARMONIC FILT		1	3		1	5	5

At the present time, the technical requirements have been determined for all of the technical components of the system and the prerequisite procurement documents have been written for much of the equipment. Most of the equipment is of conventional design and construction. However a few components are special and require some explanation. The 15 and 5 kV rectifier transformers are multiphase units that are designed for both three phase bridge type circuits (used in the Injector synchrotrons) and for dual six phase star circuits as used in the COL. The transformers are characterized by tight tolerances on impedance, phase angle and turns ratio. The power converter equipment contains thyristor gate drive equipment and the interconnecting ac and dc busses. In the case of the HEB and COL power converters, those units also contain interphase transformers to assist in minimizing unbalanced current and voltage ripple. The thyristor assemblies support three thyristors and the necessary voltage snubbers. These units are water cooled and are housed in the power converter assemblies. The output filters are required to reduce the output voltage ripple to the level needed to meet the magnet circuit current ripple requirements.

There are two types of current transducers. One type IS the conventional current magnitude devices that measure the output current of the power circuit. Three current ranges are planned: 4000 A, 5200 A and 7000 A. The transducter has a D/A converter for the digital reference signal, an analog difference circuit with a gain of stage 32 and an A/D to produce a digital difference signal for the current regulation system. The AC harmonic filter will be acquired for both 15 kV and 5 kV utilization voltages. These units are the band pass type and are required to reduce harmonic voltages on the AC system to acceptable levels and to improve the power factor.

In all cases, the performance requirements of the equipment will be by the SSCL staff. The subcontractors will be responsible for the detailed design and fabrication. Acceptance will be by performance testing and inspection.

QUENCH PROTECTION EQUIPMENT

As explained in the introduction, the quench protection equipment is designed to protect the superconducting magnets from damage during quench operations.

The QPS procurement strategy is for the SSCL to procure non-critical items under performance specifications, procure commercial off-the-shelf assemblies under source control drawings, and design and produce fabrication drawings for procurement of assemblies or chassis that are critical to magnet protection, in particular those having intricate functionality not normally seen in industry. Use of a system integrator to assemble and comprehensively check out fully configured QPS systems (above ground) is under consideration. Test requirements for procured items will be defined in detail by the SSCL. Testing of major components will be the responsibility of the contractor. Embedded software will be designed and produced by SSCL. The quantities of major components required for the QPS are listed in Table 7 along with the planned delivery schedule.

Table 7. Quench Protection Equipment Acquisition.

COMPONENT	CY 93	CY 94	CY 95	CY 96	CY 97	CY 98	CY 99
Heater Firing Unit	180	360	360	360	360	360	240
Volt to Freq Convert	40	65	65	65	65	65	45
Quench Prot Monitor	40	65	65	65	65	65	45
Bypass Diode Assy	160	320	320	320	320	320	170
Uninterruptible Power Supplies	40	65	65	65	65	65	45

ENERGY EXTRACTION EQUIPMENT

The Energy Extraction equipment consists of 7000 A dc circuit breakers and temperature dependent resistors capable of absorbing up to 1000 MJ of energy stored in the HEB and COL superconducting magnets. The circuit breaker is controlled from the QPS. On the initiation of a quench in one of the magnets, the circuit breaker opens and switches the current into the resistor. At the same time, the power supply is turned off and the current begins to decay with a 36 second time constant. Table 8 lists the major equipment required for the energy extraction system and the calendar years for delivery. The requirements for this equipment will be detailed by the SSCL with design, fabrication and assembly by the subcontractor. Acceptance is by inspection and performance testing.

Table 8. Energy Extraction Equipment Delivery Schedule.

COMPONENT	CY 93	CY 94	CY 95	CY 96	CY 97	CY 98	CY 99
DC CRKT BRKRS			10	33	33	20	
RESIST ASSY			10	33	33	20	

BEAM LINE POWER SUPPLIES

A number of current regulated power supplies are required for the beam transfer lines interconnecting the various accelerators and the test beam facility. These power supplies are mainly programmed types for the purpose of energy conservation with a few being continuous duty types. These power supplies will be free standing units and will have current regulation requirements of 1000 ppm and better. Table 9 lists the major units with ratings greater than 200 kW to be purchased and the year of delivery. Additional units less than 200 kW will also be purchased.

Table 9. Beam Line Power Supplies Delivery Schedule.

COMPONENT	CY 93	CY 94	CY 95	CY 96	CY 97	CY 98	CY 99
100 V, 3000 A				8			
100 V, 5000 A					8		
250 V, 1000 A					4		
500 V, 700 A				5			
300 V, 2500 A					2		
125 V, 6000 A						6	
170 V, 2000 A						2	
65 V, 3000 A			1				
200 V, 1000 A			12	13			

All of the beam line power supplies will be purchased to technical specifications prepared by the SSCL. The subcontractor will provide the design and will fabricate and assembly the equipment. Acceptance will be by performance testing and inspection.

CONTROL AND REGULATION EQUIPMENT

Most of the equipment described above will be complete with regulation and control hardware ready to be installed and connected to the control system. A serial fiber optic interface for connecting the power supplies to the host control system is being developed at the SSCL. The specifications for this hardware will be included in the power supply technical specifications and will provide the interface protocol and functional diagrams. The detailed design will be performed by the subcontractor.

For other equipment such as the ring magnet power supply, the control and regulation equipment will be designed by the SSCL and will be acquired by purchasing components at the module level. Some special equipment will be required which will be designed by the SSCL. The design of this hardware is based on digital regulation and control schemes. Single board computer hardware and operating system software with a VME back plane will be purchased. Detailed application software will be written by the SSCL.

SCHEDULE

At this time, extension of the collider completion schedule is being considered by the DOE and laboratory management. However, to provide a consistent schedule, the delivery dates given above are based on the present integrated project schedule with the completion of the project in 1999.

CONCLUSIONS

A comprehensive listing of forthcoming procurement activities for special technical electrical equipment for the SSCL has been given. Some high level technical specifications have been provided to assist readers in evaluating the scope of these acquisitions.