OPERATIONS

USER FACILITY STATUS IN 1996

N. Anantaraman

During 1996, the K1200 cyclotron delivered beam for a total of 5235 hrs, distrubuted as follows: 4471 hrs for 34 PAC-approved experiments, 432 hrs for 20 short test runs and discretionary experiments, and 350 hrs for accelerator and equipment development. Included in the last category are 177 hrs for S800 development and 32 hrs for deflector development.

Of the 34 PAC-approved experiments, 25 used secondary beams produced by the A1200 fragment separator. The distribution of experimental stations where the experiments were performed was as follows: 4 with the A1200 in stand-alone mode, 3 at a special location in the east end of the Transfer Hall, 2 with the 4π Array, 11 in the N3 vault (some with, some without, the 92″ chamber), 4 in the N4 vault (3 of them with the Neutron Walls), 8 with the RPMS, and 2 with the newly commissioned S800 spectrograph. About 4% of the total beam time was used by non-nuclear science experiments.

Approximately 190 scientists took part in these experiments: 45 from within the NSCL and 145 from outside. They came from 52 institutions in 13 countries. The number of foreign visitors was 52. The number of students (mostly graduate students) participating in the experiments was about 57, consisting of 20 from the NSCL and 37 from other institutions.

The operation of the facility was generally smooth, except for two periods of unscheduled downtime. In May 1996, following a high-intensity ^{4}He run, the E1 deflector shorted out and it took nearly a week for the radioactivity in the K1200 cyclotron to cool down to a safe enough level for the cyclotron operators to replace the deflector. In November 1996, a week was lost when one of the expansion engines in the helium refrigerator failed, contaminants such as air found their way into the refrigerator, and the K1200 cyclotron warmed up to about 100K because it ran out of liquid helium. Since an inadequate supply of liquid helium was the basic cause of the latter downtime, the addition of the new helium refrigerator (reported elsewhere in this volume) should relieve similar problems in the future.

The experimental equipment capability of the laboratory increased considerably during the year. (a) Foremost among the new devices is the S800 spectrograph, which was commissioned in September 1996. This was the culmination of a long effort that began with basic design studies in the late 1970s and an active construction program for four years. The first experiment with this device, a thesis project, was run in early October. (b) An array of 38 position-sensitive cylindrical NaI(Tl) detectors, mainly for use in Coulomb excitation experiments, was commissioned in late 1995 and was installed in a dedicated setup on the F-beamline in the Transfer Hall in late 1996. The 38 cylindrical NaI(Tl) detectors are arranged concentrically around the beam pipe which also houses the secondary target. The intermediate-energy Coulomb excitation experiments are done with beams made in the A1200 fragment separator. The projectile-like particles are excited in the virtual photon field of a heavy target and the real deexcitation γ rays are observed in the NaI(Tl) detectors. Because of the high efficiency of the detector, it is possible to perform experiments with secondary beam intensities as low as 15 particles/sec. (c) For proton scattering experiments in inverse kinematics, an array of eight silicon-strip–silicon–CsI telescopes was built, and used in a 32″-diameter scattering chamber. The detector telescopes are mounted close to 90 degrees with respect to the beam, which corresponds to angles close to 0 degrees in the center-of-mass. The position sensitivity of the strip detector allows the measurement of the proton scattering angle while the silicon detector and the CsI detector determine the energy of the protons. (d) A β-NMR system was implemented to measure ground state magnetic moments of exotic nuclei. The system presently consists of a thin Pt catcher foil surrounded by two β telescopes placed at 0° and 180° relative to the holding field provided by the Hunter's Point magnet in the NSCL Transfer Hall. Each β telescope is composed of two thin (3 mm each) and one thick (2.5 cm) plastic scintillators, which are coupled to long (> 60 cm) light guides to remove the photomultiplier tubes from the fringe field of the Hunter's Point magnet. The catcher foil is also encompassed by a set of RF coils, arranged in a Helmholtz geometry, which provide an oscillating magnetic field required for the NMR measurements. Two 3″x3″ NaI detectors have been placed around the catcher foil position to allow for the isolation of specific β transitions using β–γ coincidences. This system was commissioned in April 1996 by measuring the resonance curve for ^{12}B ($T_{1/2}$=20 ms).

The NSC Program Advisory Committee met twice in 1996. The 20th meeting of the PAC (PAC-20) was held January 29, 1996, to consider 22 proposals for 3312 hours from 104 scientists at 33 institutions in 10 countries. The Committee recommended allocation of 2346 hours of beam time, including 144 hours held in reserve. PAC-21 met on July 11, 1996, to consider 26 proposals for 3736 hours of beam time from 145 scientists at 37 institutions in 10 countries. The Committee recommended allocation of 2362 hours of beam time, including 60 hours held in reserve. Of the total of 39 experiments approved by the two PACs, 22 were proposed by outside spokespersons, and 28 were collaborations between NSCL staff and users from other institutions. The Committee members for PAC-20 were Gary Crawley (NSCL), William Friedman (University of Wisconsin at Madison), Walter Henning(ANL), Alex Mueller (Institut de Physique Nucléaire, Orsay, France), Witek Nazarewicz (Oak Ridge National Laboratory), and Gordon Wozniak (LBNL). For PAC-21, Walter Benenson (NSCL) substituted for Gary Crawley and Robert Vandenbosch (University of Washington, Seattle) replaced Gordon Wozniak.

K1200 OPERATING EXPERIENCE

D. Poe, P. Miller and M. Garbek

Table I shows operating time statistics for the K1200 cyclotron for the year of 1996, and Table II shows the various beams which were run along with the number of hours for each. It also gives the percentage of total beam time for each beam. There were 118 different beams of 64 different types occurring in 6,241 hours of operation and 5,127 hours of research. This implies that there was one beam change for every 52.9 hours of operation and every 43.4 hours of research.

Table I: K1200 Time Distribution 1996

	Hours	Percentage
Operation		
Research	5127.00	71.86
Development	298.25	4.18
Overhead	815.75	11.43
	-------	-------
(R + D + O)	6241.00	87.47
Maintenance	168.00	2.35
Breakdown	726.25	10.18
	-------	-------
TOTAL	7135.25	100.00
Off	1639.25	
Startup	10.50	

EFFICIENCY = E = (R + D + O) / (TOTAL - Maintenance)

E = 6241.00 / (7135.25 - 168.00) = 0.896 = 89.6 %

There were 5,127 hours of research in 1996 versus 4,890.75 hours in 1995. The category of operation, or (research + development + overhead) was 6,241 hours. This represents the amount of time that the cyclotron was running. The efficiency is defined in Table I as the time that the cyclotron ran divided by the amount of time that we tried to run it, and is 89.6% versus 89.7% in 1995.

Since 1996 was a leap year it had 8,784 hours in it. Therefore, research was carried on 58.4% of the total time, and operation 71.0%.

All beams which were run for the first time in 1996 are listed in Table III. Notable among them were ^{48}Ca at 70 and 80 MeV/u, ^{110}Pd at 55 MeV/u, ^{86}Kr at 120 MeV/u, ^{9}Be at 40 MeV/u, and ^{58}Fe at 55, 75, 95 and 105 MeV/u. Solid beams are generally produced in the ECR either by sputtering plasma ions on a piece of the metal or by an oven.

New deflectors are being designed and built wherein the septa are held in place with a clamping strip rather than a series of screws. The idea is to eliminate warping in the septa since such warpage makes a septum appear artificially thick when viewed by the beam. This technique has so far been used only on the first segment seen by the beam, but we are planning to incorporate it in the other segments as well and to add water cooling to all segments. Beryllium oxide insulators are now used routinely in the first deflector segment and seem to work fine.

Table II: Beams Run in K1200 Cyclotron in 1996

Ion	**E/A** $\left(\frac{\text{MeV}}{\text{u}}\right)$	**Hours**	**%Time**
$^{4}\mathrm{He}^{1+}$	40	28.50	0.5%
$^{4}\mathrm{He}^{1+}$	60	28.00	0.5%
$^{4}\mathrm{He}^{1+}$	70	9.00	0.2%
$^{4}\mathrm{He}^{2+}$	140	4.25	0.1%
$^{4}\mathrm{He}^{2+}$	155	169.50	3.1%
$^{5}(\mathrm{H\text{-}He})^{1+}$	30	17.50	0.3%
$^{6}(\mathrm{D\text{-}He})^{1+}$	22	4.75	0.1%
$^{9}\mathrm{Be}2+$	40	105.50	1.9%
$^{11}\mathrm{B}^{2+}$	32	168.25	3.1%
$^{12}\mathrm{C}^{2+}$	22	99.75	1.8%
$^{12}\mathrm{C}^{3+}$	60	109.25	2.0%
$^{13}\mathrm{C}^{3+}$	48	18.00	0.3%
$^{13}\mathrm{C}^{4+}$	80	195.00	3.6%
$^{14}\mathrm{N}^{3+}$	40	114.50	2.1%
$^{14}\mathrm{N}^{5+}$	100	19.00	0.3%
$^{16}\mathrm{O}^{3+}$	25	25.00	0.5%
$^{16}\mathrm{O}^{4+}$	40	4.00	0.1%
$^{16}\mathrm{O}^{4+}$	60	110.25	2.0%
$^{16}\mathrm{O}^{8+}$	140	0.75	0.0%
$^{16}\mathrm{O}^{8+}$	200	4.00	0.1%
$^{18}\mathrm{O}^{4+}$	35	14.25	0.3%
$^{18}\mathrm{O}^{5+}$	60	45.00	0.8%
$^{18}\mathrm{O}^{6+}$	80	1111.25	20.4%
$^{18}\mathrm{O}^{6+}$	100	50.75	0.9%
$^{20}\mathrm{Ne}^{6+}$	70	199.75	3.7%
$^{20}\mathrm{Ne}^{6+}$	80	91.00	1.7%
$^{20}\mathrm{Ne}^{6+}$	100	187.75	3.5%
$^{22}\mathrm{Ne}^{5+}$	55	1.00	0.0%
$^{22}\mathrm{Ne}^{6+}$	80	3.00	0.1%
$^{36}\mathrm{Ar}^{12+}$	80	24.75	0.5%
$^{36}\mathrm{Ar}^{12+}$	100	123.75	2.3%
$^{36}\mathrm{Ar}^{15+}$	150	37.75	0.7%
$^{36}\mathrm{Ar}^{17+}$	180	4.00	0.1%
$^{36}\mathrm{Ar}^{18+}$	200	0.50	0.0%
$^{36}\mathrm{Ar}^{6+}$	22	12.25	0.2%
$^{36}\mathrm{Ar}^{9+}$	50	42.00	0.8%
$^{40}\mathrm{Ar}^{10+}$	60	20.75	0.4%
$^{40}\mathrm{Ar}^{12+}$	80	243.75	4.5%
$^{40}\mathrm{Ar}^{12+}$	100	149.25	2.7%
$^{40}\mathrm{Ar}^{8+}$	40	2.75	0.1%
$^{40}\mathrm{Ar}^{9+}$	40	134.75	2.5%
$^{48}\mathrm{Ca}^{12+}$	60	148.50	2.7%
$^{48}\mathrm{Ca}^{12+}$	70	275.75	5.1%
$^{48}\mathrm{Ca}^{13+}$	80	127.00	2.3%
$^{56}\mathrm{Fe}^{9+}$	20	16.00	0.3%
$^{58}\mathrm{Fe}^{14+}$	55	13.50	0.2%
$^{58}\mathrm{Fe}^{15+}$	75	109.25	2.0%
$^{58}\mathrm{Fe}^{18+}$	105	31.25	0.6%
$^{58}\mathrm{Ni}^{15+}$	75	3.50	0.1%
$^{81}\mathrm{Kr}^{17+}$	45	112.75	2.1%
$^{86}\mathrm{Kr}^{18+}$	35	58.00	1.1%
$^{86}\mathrm{Kr}^{18+}$	45	5.00	0.1%
$^{86}\mathrm{Kr}^{22+}$	70	34.50	0.6%
$^{86}\mathrm{Kr}^{23+}$	80	76.25	1.4%
$^{86}\mathrm{Kr}^{27+}$	100	75.50	1.4%
$^{86}\mathrm{Kr}^{28+}$	120	38.75	0.7%
$^{86}\mathrm{Kr}^{29+}$	120	10.00	0.2%
$^{96}\mathrm{Mo}^{16+}$	22	28.75	0.5%
$^{110}\mathrm{Pd}^{25+}$	55	146.00	2.7%
$^{129}\mathrm{Xe}^{19+}$	20	33.50	0.6%
$^{129}\mathrm{Xe}^{30+}$	60	76.50	1.4%
$^{132}\mathrm{Xe}^{22+}$	22	38.00	0.7%
$^{197}\mathrm{Au}^{29+}$	20	141.75	2.6%
$^{238}\mathrm{U}^{35+}$	20	106.00	1.9%
Total		5440.75	100.0%

Table III: Beams run for the first time in the K1200 Cyclotron in 1996

Ion	E/A[MeV/u]
$^{9}Be^{2+}$	40
$^{13}C^{3+}$	48
$^{16}O^{8+}$	140
$^{20}Ne^{6+}$	70
$^{22}Ne^{5+}$	55
$^{22}Ne^{6+}$	80
$^{36}Ar^{8+}$	40
$^{36}Ar^{15+}$	150
$^{36}Ar^{17+}$	180
$^{48}Ca^{12+}$	70
$^{48}Ca^{13+}$	80
$^{58}Fe^{14+}$	55
$^{58}Fe^{15+}$	75
$^{58}Fe^{17+}$	95
$^{58}Fe^{18+}$	105
$^{86}Kr^{28+}$	120
$^{86}Kr^{29+}$	120
$^{110}Pd^{25+}$	55

RADIOACTIVE BEAMS AT THE NSCL

Mathias Steiner [1]

The A1200 Fragment Separator is being used as a production facility for radioactive beams (RNB) in a wide variety of nuclear-physics experiments. The following table is intended to provide an overview of the radioactive-beam effort during the last two years.

The information provided is far from complete, but should be helpful for users planning an RNB experiment. It should be kept in mind that count-rate and beam-quality requirements vary widely, and that any beam/target/wedge combinations shown may not be adequate for other experiments using the same secondary beam. If a desired RNB is not in the table, the reader may use the values provided for nearby nuclei to judge the reliability of codes like LISE [1] or INTENSITY [2] in predicting production rates for a given situation.

The table lists the date any experiment was run, the experiment number and its title in abbreviated form, the principal investigator, primary beam, energy, and maximum achieved intensity. The nature and thickness of target and wedge are also shown, followed by the spectrometer's momentum acceptance (full width). Finally, the secondary beam and its energy are listed, along with the observed rate, normalized to beam current in units of particles per second and particle-nanoamperes of beam. A short comment is added for some beams, giving further information. Abbreviations and slang used: *Rx XSec* means reaction cross section; *CEX* is Charge Exchange; *Slits* refers to a set of horizontal slits just downstream of the A1200 focal plane, used to clean up secondary beams before transmission to experimental stations; *Purity* is the rate of desired fragments, divided by the total count rate; *Att* refers to the beam current attenuators used to adjust the cyclotron current; *Beam Angle* indicates that the primary beam impinged on the production target at an angle.

References

1. D. Bazin, unpublished (further information on *www.nscl.msu.edu/~bazin*)
2. J.A. Winger et al. NIM **B**70(1992) 380

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[1] and dozens of people involved in the many experiments summarized in the table.

Date	Expt #	Title	P.I.	Beam	Energy	Target	Wedge	P Acc	RNB	Energy	Rate	Comments
					MeV/u	mg/cm^2	mg/cm^2	%		MeV/u	1/pnAs	
4-95	94014		Loveland	**40Ar**	40				**38S**	7		Energy, rate very low
5-95			Thoennessen	**13C**	100				**11Be**	84	1325	
6-95		Test Run	Glasmacher	**40Ar**	80	Be 285	PE 233		**38S**			99.5% pure
7-95			Galonsky	**15N**	60	Be 790	PE 525		**9Li**	28		85% pure
8-95		Ion-Chamber Test		**13C**		Be 587	PE 525		**11Be**	53		Plenty of it
8-95	94025	Neutron-Wall Expt	Zecher	**15N**	60	Be 790	PE 525		**9Li**	28		85% pure
11-95	95022			**110Cd**	55	Be 94	none		**108Ag**	46		
1-96		Low-Energy 11Li Test	Kruse	**18O**	35	Be 379	none		**11Li**	24		Very low rate
1-96	95034	Coulomb Excitation	Glasmacher	**48Ca**	80	Be 379						
							PE 233	1.0	**44Ar**	46	1800	
							PE 233	1.0	**46Ar**	38	1	
							PE 233	1.0	**40S**	42	10	
							PE 233	1.0	**42S**	43	8.4	
				40Ar	100	Be 790	PE 233	1.0	**38S**	42	521	
								3.0			1375	3% to 1% =2.64
2-96	96009	12B Beta-NMR	Mantica	**14N**		Au 100	none	1.0	**12B**	38	101	
2-96		Isospin Depend. Flow	Westfall	**58Fe**	75	Be 94	none	0.5	**58Mn**	65	30k	CEX, not fragments
							Al 70	0.5			23k	No focal-plane slits
											9,000	Slits; 94% pure
				58Ni	75		none	1.0	**58Cu**	68	5700	
							Al 100	1.0		55		Purity 16% w/ slits
3-96		Fusion	Loveland	**40Ar**	40		none	0.5	**38S**	25	1260	
4-96	96017	Coulomb Excitation	Ibbotson	**48Ca**	70	Be 285	none	1.0	**36Si**			No rate calibration
								1.0	**34Si**			
4-96	96009	Beta-NMR part 3	Mantica	**18O**		Nb 340	Al 465	1.0	**11Be**			
4-96	96017	Coulomb Excitation	Glasmacher	**48Ca**					**44S**			
4-96		11Be Gamma Rays	Glasmacher	**18O**	80	Be 884	Al 425					
5-96		Total Rx XSections	Warner	**18O**	80	Be 285	PE 550	1.0	**14Be**	64	0.22	
						Be 285	PE 550	1.0	**12Be**	58	49	
						Be 285	PE 550	1.0	**11Be**	60	125	
						Be 285	PE 550	1.0	**9Be**	65	2250	
						Be 285	PE 550	1.0	**10Be**	62	7230	

Date	Expt #	Title	P.I.	**Beam**	Energy	Target	Wedge	P Acc	**RNB**	Energy	Rate	Comments
					MeV/u	mg/cm^ 2	mg/cm2	%		MeV/u	1/pnAs	
						Be 470	PE 550	1.0	**14Be**	64		
						Be 470	PE 550	1.0	**12Be**	59	106	
						Be 470	PE 550	1.0	**11Be**	68	596	
5-96		Total Rx XSec cont.	Warner	**20Ne**	80	Be 94	PE 233	0.5	**17Ne**	59		17Ne / 15C = 0.15
						Be 367	PE 233	1.0	**13O**	54		Purity <= 1.5%
						Be 285	PE 233	1.0	**13O**	54		Purity = 1.7%
						Be 94	PE 233	0.5	**13O**	54		Purity = 2.0%; low rate
						Be 285	PE 233	1.0	**9C**	65		Purity = 1.5% after slits
						Be 285	PE 233	1.0	**10C**	55		Clean after slits
						Be 94	PE 550	1.0	**10B**	50		Clean after slits
						Be 367	PE 233	1.0	**10C**	50		
						Be 367	PE 233	1.0	**9C**	56		Purity = 2.7%
5-96	95024	Coulomb Excitation	Cottle	**20Ne**	70	Be 470	PE 233	1.0	**18Ne**	31		28/sec @ Att#5 [1/100]
				22Ne	70	Be 470	PE 550	1.0	**20O**	31		
6-96	95039	(p,p') Inv. Kinematics	Suomijarvi	**48Ca**		Be 367	Al 70	0.5	**40S**	31	141	
6-96	96026	11Be Magn. Moment	Mantica			Nb 216	Al 425					Beam angle 3 degrees
7-96		11Li Production	Kruse	**18O**	60	Be 790	none	1.0	**11Li**	35	1.2	
						Be 790	none	1.0	**11Li**	32	1.1	
						Be 790	none	1.0	**11Li**	41	2.1	
						Be 790	none	1.0	**11Li**	48	2.7	
						Be 790	none	1.0	**11Li**	56	1.5	
						Be 790	Al 425	1.0	**11Li**	30	0.84	
						Be 790	Al 425	1.0	**11Li**	25	0.57	
7-96		Coulomb Excitation	Glasmacher	**40Ar**	80	Be 367	PE 233	1.0	**32Si**	55	18k	
							PE 233	1.0	**34Si**	55	1880	
									34Si	62	1040	F.P. slit width 19mm
7-96		Neutron Wall	Kruse	**18O**	80	Be 2165	none	1.0	**11Li**	35	1	Mapping yields, 2 tgts
						Be 2165	none	1.0	**11Li**	57	5.4	
						Be 1550	none	1.0	**11Li**	57	7.4	
						Be 1377	PE 1g	1.0	**6He**	25	616	
						Be 1924	PE 1g	1.0	**8He**	25	8.7	
						Be 1924	none	1.0	**11Li**	25	3.3	

Date	Expt #	Title	P.I.	**Beam**	Energy	Target	Wedge	P Acc	**RNB**	Energy	Rate	Comments
					MeV/u	mg/cm^2	mg/cm2	%		MeV/u	1/pnAs	
						Be 1524	none	1.0	**11Li**	25	2.8	
						Be 1377	none	1.0	**11Li**	25	3	
8-96	95047	40P Production	Winger	**48Ca**	70	Ta 422	none	0.5	**40P**	54.6	1.4	Scanning BRho
						Ta 422	none	0.5	**40P**	53.6	1.5	
						Ta 422	PE 233	0.5	**40P**	39.9	4.6	Wedge in
						Ta 422	PE 233	3.0	**40P**	39.9	9.1	
						Be 254	PE 233	3.0	**40P**	39.9	16.2	
10-96	96027	15C Magn Mom	Mantica	**18O**	80	Nb 214	none	3.0	**15C**	75	42	
12-96	95026	Elastic Scattering	Kolata	**18O**	80	Be 978	PE 550	1.0	**11Li**	51	26.5	
1-97	96021	Structure of 16C	Raimann			Be 1170	PE 233	3.0	**14C**	48		
									15C	46		
									16C	43		
1-97	96037	Coulomb Excitation	Glasmacher	**40Ar**		Be 564	none	1.0	**22O**	64	6.2	3.2221Tm
									28Ne	62	0.16	
									26Ne	71	16	
									24O	60	0.02	3.4 Tm
									22O	71	3.4	
									28Ne	69	0.16	
									26Ne	79	1.7	
									18C	60	0.78	
1-97	96020	8B Breakup	Davids	**12C**	100	Be 1900	PE 233		**8B**			7Be contamination
1-97	95012	Total Rx XSec	Crawley	**55Mn**	90	Be 103	none	1.0	**50Ca**	35	0.084	Rate maximized
2-97	96048	44Ti Lifetime	Goerres	**46Ti**	70	Be 202	none	0.25	**44Ti**	51	22k	44Ti = 6% of total
7-96	96019	7Be(d,n)8B	Powell	**12C**	60	Be 587	Al 300	3.0	**7Be**	25	1800	8B contamination 5%
4-97	95046	17Ne Magn.Mom.	Anthony	**20Ne**	80	Nb 104		1.0	**17Ne**	75.4	1.25	Peak of Distribution
						Nb 104	Al 540	1.0	**17Ne**	50	0.4	Strong 15O contam.
3-97	96046	17Ne Total Rx XSec	Borcea	**20Ne**	80	Be 564	PE 233	1.0	**17Ne**	45	50	15O/17Ne = 250
						Be 564	PE 233	3.0	**17Ne**	45	500/sec	Pure after RPMS
5-97	95049	11Be GDR Studies	Beene	**13C**	100	Be 986	PE 525	1.0	**11Be**	80	9400	Pure

LIQUID HELIUM PLANT EXPANSION

H. Laumer, J. Chacko, J. Eicher, R. Fontus II, J. Gonzales, P. Gupta, D. Harris, H. Hilbert, C. Heckman, A.J. Malyadri, B. Nurnberger, D. Pendell, D. Sanderson, R. Swanson, and B. Welton

During the past year, the cryogenic system has been expanded to approximately double the available liquefaction capacity for helium. As mentioned in the 1995 annual report, a used helium liquefier was purchased in the fall of 1995. This plant consists of, essentially, two liquefiers of 300 watt capacity each; they are linked to one final expansion engine (which is shared). The first step was the construction of a building to house the compressors of nominally 108 g/sec capacity. During the first half of 1996 the utilities (electrical power and cooling water) required by the compressors where installed, and at the same time the compressors where put in place. The motor starters needed extensive rewiring of control switching gear. The heat exchangers associated with the compressors where cleaned. Shaft seals where replaced and oil piping was inspected and replaced as needed. The gas handling system, consisting of makeup gas control valve, gas recovery control, pressure control valve, and charcoal adsorber vessel where installed. The charcoal vessel was charged with activated charcoal and the drying process was initiated and completed over a two month period. The final motor alignment for compressors was carried out after both motors where disassembled, cleaned, baked, and had new bearings installed. The gas piping, linking compressors to the liquefiers, as well as the cross connect piping, to interconnect the old operating system so that complete interchange between old and newly installed compressors is possible, was installed. The compressors were first turned on 9/13/96.

The liquefier plant was placed in the east high bay addition. Since this plant was shipped in three sections, it had to be welded back together. A transfer line to link the liquefier to the 2500 liter Dewar supplying the S-800 spectrograph had to be constructed. A channel was cut in the high bay floor to receive the steel jacket which carries a liquid nitrogen cooled shield, which in turn supports the liquefier output supply and cold gas return from the S-800 spectrograph magnets in multilayer, vacuum insulated, pipes. This Dewar can also still receive the output from the old CTI-1400 liquefier. The expanders associated with this plant where taken apart and all usual maintenance was performed. The motor controllers to maintain expander speeds needed extensive trouble shooting to get to operate reliably. There are helium leaks to the cold box vacuum chambers of two of the three components. One cold box can be operated by continuous evacuation of helium with an oil diffusion vacuum pump, backed by the usual roughing pump. The other cold box has a roots blower for backing the diffusion pump to achieve a residual vacuum, which does not noticeably affect the capacity of liquefaction. The rate of helium leak was measured to be 1.2 atm. cc/sec of helium gas. The first liquid helium was produced on 12/3/96. There are still modifications to be made to the expanders to improve the lifetime of tappet push rod and piston rod seals, but the expected production capacity of 200 l/hr has been demonstrated. The liquid helium requirements of the S-800 spectrograph and the beam line magnets leading to it are being satisfied by operating one cold box and the wet expander of the newly installed system. There is, therefore, spare capacity of about 100 l/hr available at the present time.

The liquid helium stored in magnet cryostats and storage Dewars has exceeded our gas storage capacity for some time. We have obtained a 35,000 gal gas storage tank from the SSC equipment dispersal so that our total recovery gas storage capacity is now 75,000 gal at 250 psig. This still can not hold all liquid inventory; but since it is very unlikely that all liquid will be turned to gas at the same time, it is adequate for routine operation. The new gas tank was received on 6/26/96 and put in service on 7/25/96.

ELECTRONIC SYSTEMS REVIEW

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Introduction

This paper will briefly discuss the current and planned electronic systems managed by the NSCL Electronics Department. The systems to be considered include the S800 construction, the CCP electronics, power supply R&D, the NSCL Control System (NCS), and finally the rf systems. Although the staffing level needed to pursue all that has been assigned is barely adequate, we believe the level of progress has been adequate and will continue to be so.

S800 Construction

As mentioned in last year's annual report, the S800 electronic systems are largely extensions of existing technology developed for the NSCL. This year, the installation of the system was accomplished. The systems required a minimum of development after installation and are now routinely used as needed for S800 experiments. At this time, the system does not appear to need any further enhancements or upgrades. A few minor electronic installations need to be performed such as installation of the carriage limit switches. These sorts of tasks are waiting on the final mechanical implementation and will be performed swiftly thereafter. From an electronic perspective, this project is complete and is now handled as a routine maintenance item.

Coupled Cyclotron Project (CCP) Electronics Systems Progress

Last year's annual report [1] gave a terse overview of the CCP project from the electronics department perspective. Some of the effort needed that was outlined there has been started. Delays in the initial funding of the CCP have caused some of the work to be performed in a less than optimal fashion, leading to increased effort from what was projected. Now with continued funding, the work should proceed roughly in step with the projected estimates and schedules.

The necessary changes to the existing control locations described last year were accomplished this year during a 6-week shutdown. The shutdown was needed to provide for a more efficient construction process for the CCP so the small disruption to the operating program was considered reasonable. In order to facilitate the shutdown, a few of the normally scheduled shutdown periods were moved together thereby not changing the overall operating time available per year in a significant way. During the shut down, a significant portion of the existing K1200 rf and magnet controls were rearranged which resulted in opening up the needed space for the CCP electronic systems associated with the K500 cyclotron upgrade. To reduce the needed manpower and disruptions to operations, the initially intended locations for equipment was rearranged somewhat. The new arrangement arrived at is actually preferable to the previous design. With these changes, all of the K500 electronic systems may now be installed and developed without further disruption to, or requiring minimal coordination with, the laboratory experimental program.

Other work associated with the needed changes to the electronics infrastructure was also accomplished during this past year. A needed balcony extension was designed and installed to hold ECR related power supplies and controls. The K500 injection line power supplies have been moved there and the controls installation is now in progress. The balcony extension will eventually accommodate all of the ECR power supplies and controls and the overall layout and infrastructure for this transition to begin has been prepared. Additionally, the existing K500 rf control balcony was completely stripped of equipment, cleaned, and extended to accommodate the CCP needs. The balcony will now accommodate the K500 Main Magnet power supply, a large programmable logic controller I/O drop suitable for servicing the entire K500 cyclotron needs, a new 500 kW, K500 rf anode power supply, and some other smaller equipment.

Some power supplies associated with the K500 cyclotron were worked on this year. After reviewing the options, it was decided to refurbish the existing K500 Main Magnet supply and this work is in progress. The K500 trim coil power supplies and controls have been refurbished and tested. Finally, the design for the new rf plate supply is ready and the construction funding is scheduled for next year.

During the next year, the push will primarily be directed at building and installing the electronic systems needed for the K500. This list includes, the rf transmitters, rf power supplies and controls, and various other controls, instruments, and power supplies. Additionally, the power supply development effort for the A1900 and coupling lines needs to begin. The current schedule calls for the K500 rf system to be tested in November of 1998. We would like all of the K500 electronic systems to be complete by this time as well. Previous experience indicates that once the rf system appears ready, overall cyclotron beam tests begin which requires that all other systems be ready as well.

Power Supply R&D

We are currently investigating the use of MOSFET power block and IGBT power block devices as an upgrade option to our existing 4-Quadrant power supplies. Associated with this effort, the internal controls for these supplies as well as the overall assembly and maintenance effort is to be reduced. Assuming the development is successful, it is likely that the designs developed will be used for the A1900 and Coupling line magnet power supplies as well. As a parallel effort, we are also trying to identify economically viable outside manufacturing resources to reduce the drain on inside resources.

Control Systems

The laboratory control system made significant progress this past year. Some representative developments will be described here.

Interfaces to the system were standardized and implemented as previously envisioned. Data to and from the system may now be accessed through both custom and industrial interfaces.
Included are OCX controls for Visual Basic and Delphi programmers, a standard API for generic language interface (FORTRAN, C, C++, PASCAL, etc.), interfaces to commercial controls software (VISTA, Labview, Wonderware), as well as interfaces to general purpose software through DDE (Microsoft WORD, Excel, Access, etc.). VISTA is currently used to control instruments and beamlines for the experimental program while Labview is currently being applied by the operations and cryogenics groups to supply general controls for the entire facility. Workstations requiring control system data may acquire it via a standard network connection, standard network protocols, a security setup, and NSCL installed software. Although, connections originating from outside of the building network domain have special security applied to them, most control applications may acquire data over standard Internet connections remotely. For example, an individual could use the same software they use at the laboratory to monitor, and sometimes control, devices from home (or any other location) over a standard phone modem maintaining an Internet connection through any provider. We believe the laboratory control system interface to be one of the most versatile and modern systems in the world today.

The VME based portion of the control system also began a significant upgrade this year. We intend to replace the aging processors (68010 based) in these crates with modern processors and software. We have acquired a Power PC based VME processor board and the PSOS+ operating system. We intend to have a system that abstracts the hardware and operating system as much as possible and is written in ANSI standard C and C++ exclusively outside of the abstraction layer. Additionally, we wish to have local small (< 5MB) solid state disks that may be accessed via FTP to upgrade and develop new software over a standard Ethernet based network connection. A TELNET based shell interface will allow software modules to be loaded, unloaded, and monitored to facilitate development and maintenance efforts on crates in operation. This effort is currently in progress and we expect a great deal of progress on these goals during the next year.

RF Systems

The K1200 rf systems reliability continues to be excellent. Although we did experience a failure of a TH555 recently, it had accrued approximately 43,000 filament hours and 35,000 rf hours. An in house spare immediately replaced the failed tube and a new spare ordered which is now available. The other TH555 tetrodes have accrued between 45,000 and 50,000 filament hours and between 36,000 to 40,000 rf hours. Other then the tube failure described; there are no significant issues to report on the existing K1200 rf system.

Significant work began this year on the CCP upgrade to the K500 rf system. The electrical and mechanical design of the new transmitters was completed and parts ordered. The electrical design of the cyclotron resonators has been completed and the mechanical design begun. Design and installation of the needed vault utilities was started. Additionally, a great deal of effort has begun on the rf electronics necessary to achieve the level of performance demanded by the CCP. Existing systems were extensively studied, mathematically modeled, and documented. New electronic designs and devices were studied and are now being prototyped. We hope to have the overall system and the most critical modules designed and prototyped over the next year. The most critical modules consist of 1) The Amplitude Regulator, 2) The Phase Regulator, 3) The Phase Detector, and 4) The Amplitude Detector (may be part of Amplitude Regulator). Detailed results of these studies and prototypes may be found in the internal NSCL RF Notes as they become available.

Conclusion

In general, the electronic systems developed and implemented for the current operation of this facility have been found to be well suited and highly reliable. The critically needed rearrangement of the facility to accommodate the CCP electronic systems has been accomplished and the design and development of the electronic systems for the CCP is well underway. The facility control system continues to straddle state of the art industrial developments and a major upgrade to the VME portion of the backbone of this system is in progress. We hope to have a great deal of progress to report on all fronts for the next year.

References

1. John Vincent, et. al, “Electronic Systems Review”, NSCL Annual Report, pp 154-156, 1995