TRIUMF

ANNUAL REPORT
SCIENTIFIC ACTIVITIES
2000

ISSN 1492-417X

CANADA'S NATIONAL LABORATORY
FOR PARTICLE AND NUCLEAR PHYSICS

OPERATED AS A JOINT VENTURE

MEMBERS:

THE UNIVERSITY OF ALBERTA
THE UNIVERSITY OF BRITISH COLUMBIA
CARLETON UNIVERSITY
SIMON FRASER UNIVERSITY
THE UNIVERSITY OF VICTORIA

ASSOCIATE MEMBERS:

THE UNIVERSITY OF MANITOBA
L'UNIVERSITÉ DE MONTRÉAL
QUEEN'S UNIVERSITY
THE UNIVERSITY OF REGINA
THE UNIVERSITY OF TORONTO

UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

OCTOBER 2001

The contributions on individual experiments in this report are outlines intended to demonstrate the extent of scientific activity at TRIUMF during the past year. The outlines are not publications and often contain preliminary results not intended, or not yet ready, for publication. Material from these reports should not be reproduced or quoted without permission from the authors.

CYCLOTRON OPERATIONS DIVISION

INTRODUCTION

Beam delivery for the 500 MeV cyclotron was very successful during 2000. The cyclotron was available for ∼5,000 hours, or ∼93% of the scheduled time. A record total beam charge of ∼600 mAh with an availability of 93% in terms of charge delivered to BL1A was achieved. The cyclotron recovered well from the low point of 1999 that had been caused by a failure of the high-intensity beam dump cooling vessel on BL1A. During 1999 the corresponding figures were about 4,000 hours and only about 350 mAh of total beam charge. Availability in terms of beam charge delivered by BL1A was only 63%.

A key element for the improved beam delivery was the utilization of the 4th harmonic auxiliary acceleration cavity (AAC), or rf booster, for beam production. This had been installed in the cyclotron tank during the KAON project definition study. Although this cavity had been studied previously during beam development periods and beam dynamics measurements confirmed the calculated behaviour, the cavity never achieved a level of reliability suitable for routine beam production until recently. During 1999 the rf feedthrough was modified to allow reliable operation. The cavity could be powered routinely to a voltage between 120–150 kV, reducing the electromagnetic stripping in the 400–500 MeV cyclotron region by 33% and the time structure of the accelerated high-intensity beam bunches from the 4 ns structure transmitted through the cyclotron region to the 2 ns requested by the CHAOS experiment. In previous years the 2 ns feature was obtained by limiting the cyclotron phase acceptance with radial flags at significant cost to the overall intensity.

The challenge to be addressed over the next few years is to increase the total cyclotron beam intensity from the 220 μA available at present to a total of 300 μA. This will allow an additional 80 μA to ISAC. That facility was designed for 100 μA but it has been operating up to 20 μA at 500 MeV.

The major remaining limitation to achieving 300 μA is caused by beam-related electrode overheating in the centre region. The precise location of overheating has not yet been determined. Once this is done additional cooling may solve the problem. A pulsed beam with 400 μA peak current, 200 μA average, was previously accelerated to 500 MeV in 1987. This would tend to exclude space charge or beam dynamics as limiting the increase in current.

A brighter H^- ion source is also being developed. The cyclotron developments before the KAON Project Definition Study were aimed at achieving higher intensity with the use of one or two AAC cavities, higher particle accelerating voltage and rf improvements, etc. The work for H^- extraction during the KPDS era stalled this effort. Cyclotron development efforts in the direction of higher intensity must now continue with the new ISAC requirements.

With the approval of the 2000–2005 five-year plan, the need for refurbishing cyclotron systems or components to maximize the future efficiency of the machine was recognized. Special budgets were assigned to the RF, Vacuum, Ion Source, Injection Line, Diagnostics, Controls, Power Supplies, and Beam Lines groups during fiscal year 2000–01 for this effort. All of these groups took initiatives in the refurbishing direction through acquisition of much needed spares and replacements for old or obsolete components. One of the most urgent requirements, the overhaul of BL1A in the vault, was started before year-end and was actively organized for the 2001 winter shutdown. The report for the refurbishing activities will be included in the 2001 TRIUMF Annual Report.

Members of the Division were again involved in both of TRIUMF's key projects, i.e., the collaboration on the CERN LHC construction and ISAC. The Cyclotron Division is proud of the achievements for these projects during 2000. A major milestone was achieved just before year end with ISAC-I accelerating its first beam to the design total of 1.5 MeV/u. Also, routine delivery of the 500 MeV proton beam to the ISAC target for exotic ion beam operation at low energy could be increased from 10 to 20 μA.

BEAM PRODUCTION

Beam delivery for the year 2000 was quite successful with production statistics back on track after the previous year's TNF replacement. Cyclotron performance was enhanced by the use of an improved rf booster (RFB) system that was brought back into service following a successful test at the end of 1999. This allowed the delivery of 2 ns pulse width beam (as requested by Expt. 778) without the large current reductions resulting from the alternative method of using the radial flags used in the past. At the same time the RFB helped improve the cyclotron transmission and reduce the tank beam spill. Four months of shutdown left 5331 scheduled operational hours, about average, of which 4935 were achieved for an above average availability of 92.6%. These totals include 240 hours used for development and tuning and, as shown in Fig. 127, were split roughly 6:1 between high-current beam production and low-intensity, polarized operation. While high-intensity periods served a variety of users, polarized operation was for the most part shared by the parity

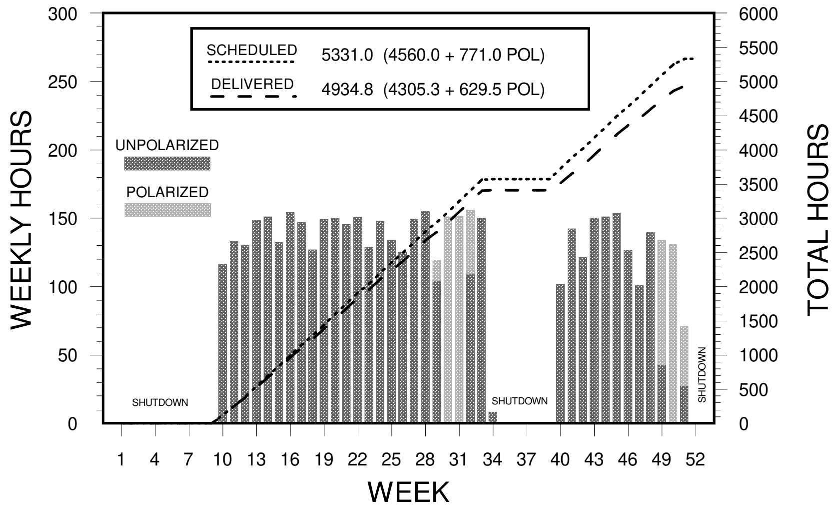

Fig. 127. Operational hours for 2000.

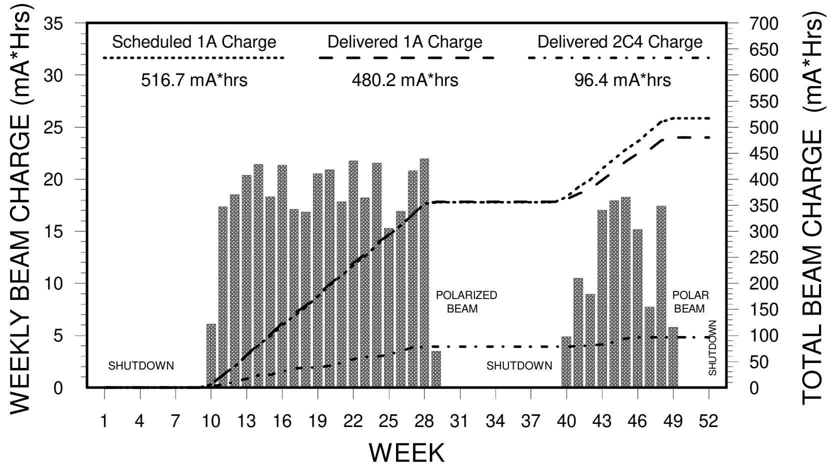

Fig. 128. Beam delivery for 2000.

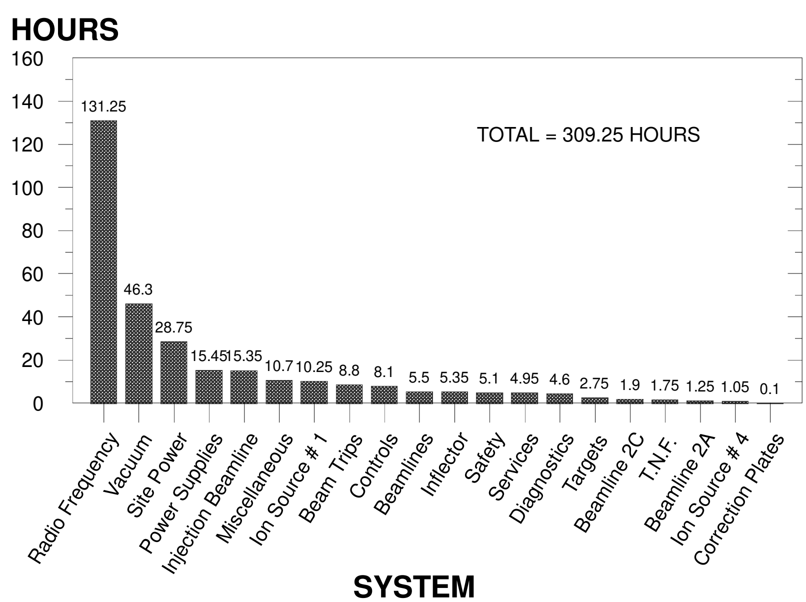

Fig. 129. Cyclotron downtime for 2000.

Table XVII. Operational record for 2000.

	Scheduled hours			Actual hours		
<u>Cyclotron off</u>:						
Maintenance	499.5			520.15		
Startup	100.0			94.00		
Shutdown	2762.5			2765.20		
Other	9.0			7.35		
Cyclotron downtime	0.0			309.35		
Overhead	34.0			105.15		
Totals	3405.0			3801.20		
<u>Cyclotron on</u>:						
Development	146.5	+	0.0 P	99.95	+	0.00 P
Cyclotron tuning	287.0	+	40.0 P	127.35	+	13.90 P
Beam to experiments	4126.5	+	731.0 P	4077.75	+	615.65 P
Totals	4560.0	+	771.0 P	4305.25	+	629.55 P
Actual/Scheduled = (4305.25 + 629.55)/(4560.0 + 771.0) = 92.6% availability						
<u>Beam to experiments</u>:						
1A Production	3871.5	+	0.0 P	3645.45	+	0.00 P
1A Development/tuning	0.0	+	0.0 P	27.50	+	0.00 P
1A Down/open/no user	128.0	+	634.0 P	273.50	+	528.00 P
1B Production	127.0	+	97.0 P	36.00	+	28.30 P
1B Development/tuning	0.0	+	0.0 P	3.15	+	3.70 P
1B Down/open/no user	0.0	+	0.0 P	92.35	+	55.65 P
Total 1A+1B production	3998.5	+	414.0 P	3681.45	+	341.30 P
2A2 Production	2736.0	+	575.0 P	2113.70	+	522.85 P
2A2 Development/tuning	0.0	+	0.0 P	19.05	+	1.70 P
2A2 Down/open/no user	1390.5	+	156.0 P	1945.20	+	92.80 P
2C1 Production/tests/tuning	423.0	+	155.0 P	115.95	+	17.50 P
2C4 Production/tests/tuning	3234.5	+	0.0 P	2492.00	+	0.00 P
2C5 Development/tune	8.0	+	0.0 P	3.70	+	0.00 P
4A2 Production	0.0	+	708.0 P	67.40	+	562.00 P
4A2 Development/tuning	0.0	+	0.0 P	1.40	+	17.85 P
4A2 Down/open/no user	69.0	+	0.0 P	78.35	+	12.85 P
4B Production	392.0	+	12.0 P	112.50	+	6.20 P
4B Development/tuning	12.0	+	0.0 P	12.40	+	3.20 P
4B Down/open/no user	3653.5	+	11.0 P	3805.90	+	13.55 P
Total BL4 production	392.0	+	720.0 P	179.90	+	568.20 P
1A Beam charge	516,730 μAh			480,184 μAh		
2A Beam charge	16,909 μAh			12,944 μAh		
2C4 Beam charge	133,310 μAh			96,386 μAh		

P = Polarized source on-line (although not necessarily polarized beam)

Table XVIII. Beam to experiments for 2000.

			Scheduled			Delivered		
Experiment *	Channel	Sched.#	h	h (pol)	μAh	h	h (pol)	μAh
614	M13	98	1279.0	0	161310	1101.05	0	123606
684	M9B	97	277.0	0	38780	259.90	0	36738
684	M9B	98	173.0	0	15115	108.55	0	7637
749	M20B	97	363.0	0	50820	362.35	0	52327
749	M20B	98	67.0	0	9380	60.10	0	4745
761	4A2	97,98	0	708.0	0	67.40	562.0	0
768	M15	97	127.0	0	17780	133.50	0	18649
768	M15	98	139.0	0	17850	74.20	0	9572
774	M15	97	273.0	0	33220	275.10	0	38811
774	M15	98	127.0	0	15240	127.90	0	14865
775	M20B	97	184.0	0	25760	192.10	0	27027
777	M20B	97	150.0	0	21460	147.30	0	21744
778	M13	97	2593.0	0	355350	2544.40	0	356448
778	M11	98	1279.0	0	161310	1101.05	0	123606
782	M20B	97	127.0	0	17780	99.45	0	13766
783	M15	98	268.0	0	35100	240.45	0	20361
784	M15	97	123.0	0	18230	120.55	0	17935
787/949	M11	97	127.0	0	17780	124.45	0	17612
791	M15	97	270.0	0	37800	271.30	0	38924
791	M20B	97	149.0	0	20860	147.30	0	20857
791	M20B	98	123.5	0	16620	118.45	0	11505
804	M15	97	358.0	0	50120	346.35	0	49407
804	M20B	98	64.5	0	7740	49.85	0	4204
806	2C4	97	3.0	0	0	0.10	0	0
806	4B	97	161.0	0	0	8.55	0	0
808	M20B	98	46.0	0	115	0.00	0	0
814	M15	97	150.0	0	21460	147.30	0	21744
822	M20B	97	127.0	0	17780	116.60	0	16444
833	M9B	98	148.5	0	18785	130.45	0	15764
834	M20B	97	273.0	0	38220	270.80	0	38538
835	M20B	98	127.0	0	15240	127.90	0	14865
835	M15	98	146.0	0	20440	131.95	0	18008
840	M9B	97	277.0	0	38780	273.45	0	39691
842	M9B	97	311.0	0	43540	313.90	0	45486
842	M9B	98	285.0	0	38290	206.15	0	27580
843	M15	98	127.0	0	17780	144.45	0	18077
844	M20B	97	150.0	0	21000	151.75	0	20718
846	M15	97	265.0	0	37100	269.65	0	39355
846	M20B	98	216.0	0	29080	206.15	0	27580
847	M20B	97	123.0	0	18230	120.55	0	17935
848	M20B	97	116.0	0	16240	122.35	0	18498
848	M20B	98	232.0	0	32480	241.85	0	32117
848/844	M20B	97	127.0	0	17780	128.10	0	18183
851	M15	97	277.0	0	38780	279.05	0	39549
851	M20B	98	69.0	0	9210	0.00	0	0
852	M15	97	127.0	0	17780	126.30	0	18905

Table XVIII (cont'd.)

			Scheduled			Delivered		
Experiment *	Channel	Sched.#	h	h (pol)	μAh	h	h (pol)	μAh
852	M15	98	173.0	0	15115	108.55	0	7637
856	M9B	98	193.5	0	26660	206.95	0	23371
858	M9B	97	146.0	0	20440	147.00	0	20628
860	M20B	97	150.0	0	21000	143.30	0	20294
860	M20B	98	148.5	0	18785	130.45	0	15764
864	M9A	97	397.0	0	55580	409.10	0	57846
865	M15	97	69.0	0	9660	67.50	0	9093
866	M20B	97	127.0	0	17780	131.80	0	19106
867	M20B	97	300.0	0	42000	301.20	0	42205
868	M15	97	277.0	0	29640	261.20	0	29524
868	M20B	97	127.0	0	5640	109.45	0	8806
869	M9B	97	277.0	0	38780	279.05	0	39549
869	M9B	98	127.0	0	15240	127.90	0	14865
869 TEST	M11	97	24.0	0	3360	23.95	0	3350
875	M11	97	554.0	0	77560	532.45	0	75077
876	M20B	98	150.0	0	15000	108.55	0	7637
877	M9B	97	127.0	0	17780	123.80	0	17910
877	M9B	98	150.0	0	21000	143.10	0	19322
878	M9B	98	201.5	0	26220	177.95	0	15067
880	M9B	97	550.0	0	78470	521.25	0	75207
881	M15	97	150.0	0	21000	147.15	0	20786
882	M15	97	127.0	0	17780	99.45	0	13766
883	M20B	98	58.0	0	7660	57.75	0	5189
884	M15	98	81.0	0	11340	74.30	0	10107
886	M15	98	148.5	0	18785	130.45	0	15764
887	M15	98	69.0	0	9660	68.80	0	9215
949	M11	97	146.0	0	20440	147.00	0	20628
CHARGEX	4B	97	150.0	12.0	0	99.65	6.20	0
DRAGON TEST	2C4	97	150.0	0	3000	147.20	0	676
ISAC†	2A2	97,98	2736.0	575.0	16909	2113.70	521.15	12944
ISOPROD	2C4	97,98	3081.5	0	130310	2342.90	0	95710
PIF	1B	97,98	150.0	97.0	0	36.00	28.30	0
PIF	2C1	97,98	268.0	143.0	0	94.85	7.90	0
P.THERAPY	2C1	97,98	155.0	12.0	0	20.15	7.95	0
NIF	4B	97	81.0	0	0	4.30	0	0
TEST	2C5	98	8.0	0	0	3.60	0	50
YEN	M11	97	127.0	0	17780	131.05	0	17315

* See Appendix D for experiment title and spokesman.

† Total proton beam on target for all ISAC RIB experiments and tests.

non-conservation experiment running in 4A2 and ISAC via BL2A2. As Fig. 128 shows, the total beam charge delivered to meson hall experiments along BL1A was 480 mAh or 93% of that scheduled, one of the better results for the past ten years. In addition, 96 mAh were delivered at 85 MeV to the solid target facility (STF) in beam line 2C4 for the production of radiopharmaceutical generators, and 13 mAh, twice the 1999 charge, to the west target station in BL2A2 for the production of radioactive ion beams (RIB) for experiments in ISAC. Six patients were treated for ocular melanomas during five proton therapy (PT) sessions in beam line 2C1 operated at 74 MeV. The annual downtime of 309 hours (Fig. 129) was well below average with the rf, as usual, responsible for the greatest share of this time (42%) followed by vacuum problems (15%) and power bumps (9%). The operational record and beam to experiments for the year are given in Tables XVII and XVIII.

Winter Shutdown

The year started with a fairly heavy load of shutdown activities on the main accelerator side, most of which were completed successfully. In the meson hall this included extensive BL1A work for which significant block movement was required. Jobs there included 1AT1 target MRO and the location and repair of two T1 area air leaks, one in the M13 vertical jaws and one in BL1A. There was also the repair of monitor 1AM8 whose cables had become radiation damaged. Further downstream there was the repair of the M20T2 and M9B beam blockers, 1AT2 water package MRO, M9A rf separator work, and the investigation of a T2 area air leak. In the vault section of BL1A, the radhard valve was replaced, the upper coil of 1VB1 was resecured and a new turbo pump station was added. On the BL4 side, cooling hoses were replaced on 4VQ3.

While some of the above jobs were proceeding, there was a continuing cool-down of the cyclotron until late January when the cyclotron lid was raised. Work in the cyclotron tank was rather limited and included centre region inspections (rf surfaces, correction plates, inflector), an inspection of the cryopanels, an investigation of a malfunctioning HESW spill monitor thermocouple, as well as some probe maintenance (X2C, X1 and X2A). The lid was lowered after the usual commissioning tests, but during initial low-current tuning the HE2 probe stuck. It was decided to extend the shutdown by one week to raise the lid to repair this device. The final shutdown dose was 51 mSv distributed among 73 workers with no one exceeding TRIUMF guidelines.

Beam Schedule 97

Startup was a bit hectic as experimenters hoped to get some stable beam during the tune up to high currents. After some necessary commissioning time for a new ISIS rf control system, the beam was steadily stepped up to the nominal current of 140 μA to BL1A. The TNF vacuum held steady around last year's 200 millitorr value because of an elusive leak that was too difficult to repair. Performance was unusually good for the high-intensity portion of this schedule (19.5 weeks) with a cyclotron availability of 95%. The delivered charge to BL1A was 356 mAh or just over 100% of the scheduled charge (at 140 μA). As these numbers suggest, cyclotron downtime was small; a modest 6 hours per week with about half due to the usual short-lived rf instabilities. Also, there was one extended problem with a faulty combiner capacitor and some PA damage caused by debris in the cooling system. The higher percentage for the charge is a result of converting some of the scheduled tuning time to beam time and delivering somewhat higher than scheduled currents because of efficiencies realized by running the rf booster.

Although not contributing significantly to cyclotron downtime, there were some problems with the secondary channels that affected production there. These included more trouble with the M13 and M9T2 beam blockers and with the M20B and M9A separators. The latter needed an extensive rebuild because of continuing water leaks. Monitor 1AM8 also developed a bellows air leak and had to be removed and blanked off. The 1AT2 vacuum was so marginal that it was not clear it would last until the next shutdown. Several air leaks were eventually found to be originating from the defunct M8 channel. Some increased CuALCW system losses were also noted towards the end of the operating period and determined to originate from BL1A.

In addition to the charge delivered to BL1A, BL2C4 received 78 mAh or 85% of its scheduled charge with losses primarily due to problems resulting from a poorly manufactured resin can, a large water leak (split hose) in one of the line's quadrupole magnets (2CVQ1) and from reduced currents during an Eu foil irradiation.

BL2A2 started a few weeks later and received 9.9 mAh at currents of either 1 or 10 μA, with the exception of a limited amount of 20 μA development work. This was a little less charge than scheduled because of an extended target exchange (to calcium zirconate).

Three proton therapy sessions treated the same number of patients in BL2C1. This line was also used at energies of 70 and 116 MeV and currents of a few nanoamps to irradiate objects in the proton irradiation facility (PIF). There was not much activity in

BL4B apart from some brief Chargex tests. Early in the schedule the line was used for a few follow-up irradiations of tantalum foils at 200, 350 and 500 MeV for Expt. 806, as well as for a brief neutron irradiation for NIF in conjunction with PIF at the end of the low current run.

Scheduled development shifts focused primarily on tuning higher currents through ISIS in order to achieve the higher total extracted currents required when ISAC runs full steam. The highest total extracted was about 225 μA compared to a normal production total of about 200 μA. A test installation of a higher output source at the end of the low current schedule ran into geometry problems. Some time was also allotted for OPS training when operators had time to practice machine and beam line tuning and calibrations. There was also some work done by Safety to test the recently implemented neutron monitor trip function and another test with the 2A probe programmed to cycle radially in and out of the X1 shadow. This successfully sent a few hundred nA of pulsed beam to BL2A.

After high-intensity operation ended, BL1A was used for 3 weeks as a dump for about 300 nA of 219 MeV beam stripped before parity's BL4 extraction foil in order to reduce the vertical size of the beam to that experiment. After some initial problems with the I4 microwave tube that resulted in their using a reduced high intensity ion source for a few days, parity (taking 200 nA of 222 MeV beam in BL4A2) had a fairly good run, getting 94% of their scheduled beam during the three week period. BL2A continued to run up to 1.5 μA to the end of the beam schedule including some dedicated pulsed beam delivery after parity finished. A pulser program sent five second bursts of 500 nA twice a minute to the west target station as required by the GPS experiment in ISAC. Then there was a switch to BL1B for PIF operation at 500, 350 and 200 MeV as well as the short NIF run in BL4B at 283 MeV.

Fall Shutdown

There was no overriding need to raise the lid during this one month September shutdown. The main thrust of activity was in the meson hall where work there again required a considerable amount of shielding block movement. Water leaks were located and repaired at M15Q1 and at the rotary collimator. Small and elusive vacuum leaks were found and repaired at the M11 septum. At 1AQ11 the downstream indium seal was replaced and in M8 the main and neutrals ports on the bender were blanked off to achieve the best 1AT2 vacuum in years. An air leak was repaired in the M13 beam blocker's drive piston and work continued on rebuilding the M9 rf separator. A modified 1AT1 target was prepared for installation in October with two graphite targets and a 4 mm horizontal aperture in the protect monitor as requested for Expt. 614 running in M13, and with all targets raised back 2 mm to the standard position as requested for Expt. 778 now running in M11. The disparity between optimal 1AT1 vertical positioning was confirmed by Expt. 614, but was not a serious issue this running period.

Beam Schedule 98

Cyclotron performance deteriorated in the final quarter with a number of problems reducing the availability to 86% for this period. The delivered charge to BL1A was 124 mAh or only 77% of the scheduled charge. This was primarily due to current restrictions during the first month because of inflector problems and because of a BL1A vacuum leak towards the end of the high-current portion of the schedule. Cyclotron downtime jumped to an average of 14 hours per week, half of it due to rf problems (including a phase mismatch following an IPA tube change) and most of the remainder due to the BL1A vacuum leak at 1AQ11 and some large power bumps late in the year.

Startup tuning was again interrupted with an emergency lid up, this time to repair the inflector whose positive electrode was failing to hold adequate high voltage. The lid was lowered and the main magnet turned on just as beam delivery was scheduled to begin. The reinstalled inflector required a significantly different tune to achieve standard high-current operation and, as this tuning progressed, an intermittent instability arose that hampered production for three weeks until the problem worsened and was finally traced to a bad cable or connection. Cyclotron performance improved considerably afterwards and for the remainder of the high intensity period the rf booster was again in operation.

There was some ongoing trouble with the BL1A tune including difficulties with formerly routine π^+/π^- changes. These, it seemed, were due in part to constraints of the new 1AT1 target that included a non-working target profile monitor, and 1AM8. Towards the end of the high-current run, the former (2 mm low) target ladder was installed to help clarify tuning problems. Unfortunately its profile monitor was also useless because of, it was then assumed, a faulty common signal cable between the target ladder and the electronics rack. Subsequent tuning went well, however, and the development shift went on to reduce front end and beam line 1A spills by lowering the extraction energy slightly. This gave rise to a cyclotron development shift at the end of the beam schedule that found disparities in some probe shadowing positions and recommended some measurements be taken next shutdown. Towards the end of the high-current run, a vacuum leak developed in the 1AT1 volume that was eventually tracked down to the 1AQ11 indium seal that had been repaired in the fall shutdown. The original repair failed because the mating surfaces were not parallel and a compensating wedge-shaped seal was installed. There were also ongoing problems with the M13 and M11 beam blockers that were addressed.

In addition to the BL1A charge, there were 18 mAh delivered to the solid target facility in BL2C4 until a target failure occurred towards the end of its scheduled beam. The cause of a miniscule pinhole found in the centre of the rubidium target cassette is thought to be too high a beam density produced by too narrow an extraction foil. For various ISAC experiments, BL2A received nearly 3 mAh at currents ranging from 1 to 10 μA on calcium zirconate and SiC targets. BL2C1 was used at 74 MeV for two proton therapy sessions during which a total of 3 patients were treated. Because these took place during the high intensity schedule, the ISIS pepperpot was required to limit the injected beam during patient treatment times. There were no BL4 users but for the last couple of days of high-current operation PIF users ran BL2C1 at 70 MeV.

The last three weeks of the year had the I4 source again on-line for polarized delivery to the parity experiment that was continuing to test experimental set-up improvements. Beam was also delivered to BL2A2, taking 2 μA at 500 MeV, and PIF, running a few nanoamps at 200, 350 and 500 MeV in BL1B and 70 and 116 MeV in 2C1. When PIF finished there was a switch back to BL1A for use again as a dump for about 200 nA of vertically pre-stripped beam. The polarized source and the parity experiment ran quite well, the biggest problem being a couple of large power bumps that caused about a day of downtime. After parity finished there were two days of development and cyclotron device tests prior to shutting the various systems down prior to the Christmas holidays. The last week of the year was uneventful but a major refurbishment of the BL1 vault section and considerable tank work are included in a busy winter shutdown schedule starting in the new year.

High-Current Beam Development

TRIUMF currently operates with a maximum extracted current of 220 μA. A beam development program has begun to increase this to 300 μA, so that BL2A to ISAC can eventually operate at 100 μA without limiting the current available to other users. Additional centre region cooling and/or the installation of an improved high-brightness CUSP source will be required to achieve 300 μA.

Some beam development time has been devoted to studying high-current, low duty cycle tunes. This is the first step towards a 300 μA c.w. tune. In addition, by gradually raising the duty cycle and watching the temperature increases recorded on thermocouples located at strategic locations within the machine, we can better estimate the amount of additional cooling that will be required for running at 300 μA c.w.

TRIUMF's existing CUSP source has been optimized for 200 μA operation by making the extraction apertures small. To date, no attempt has been made to enlarge these apertures, and the current at the fast target has been limited to 470 μA.

Allowing for some decreased transmission at higher currents, it is estimated that at least 600 μA will be required to obtain 300 μA of extracted current.

During a 45 minute test at 97% duty cycle with an average extracted current of 230 μA and 58% transmission, temperature readings on the centre region thermocouples remained within allowable limits while approaching their equilibrium values. In 2001, development work will continue in order to improve the tunes and to reach higher currents. In addition, the new high-brightness CUSP source, currently being evaluated on an off-line test stand, will be installed and tested.

RADIO FREQUENCY SYSTEMS

RF Operations

The total cyclotron rf downtime for the year was 131 hours. The combination of sparking, crowbars and out of drivens caused 95 hours of this downtime. The next major downtime was an accumulation of 26 hours caused by the failure of a PA tube, an IPA driver tube, and a combiner capacitor.

The refurbishing of the rf system was delayed this year due to the loss of rf personnel. A start was made on the fabrication of the third combiner, assembly of the two preliminary combiners and the control system for the 92 MHz booster.

RF Support

The RF group was also dedicated to the following major projects in ISAC.

1. Assembly, installation, alignment and commissioning of the DTL tanks and bunchers for the successful rf and beam tests.
2. Commissioning of the 35 MHz spiral rebuncher.
3. Design, manufacture and signal level tests on the HEBT high beta buncher.
4. Prototype testing and design of the HEBT low beta buncher.
5. Prototype testing and design of the MEBT choppers.

These activities are reported in the ISAC section.

RADIO FREQUENCY CONTROLS

The 92 MHz rf booster rf control system was scheduled for replacement in 2000. The new system is a digital signal processor based system housed in a VXI mainframe. This will bring the system up to date with most of the rf control systems in the cyclotron and all of the rf control systems in ISAC. Local supervisory control of the digital signal processor is by an Intel Pentium processor communicating with the VXI mainframe via the IEEE 1394 FireWire standard. Design of the new system was completed and commerical hardware was purchased in 2000. However, due to the diversion of manpower towards ISAC, the implementation of the control system is delayed until 2001.

Incremental software upgrades were performed on both the main rf control system and the ISIS rf control system. The main rf system has developed some intermittent instability when running in the self-excited mode. Efforts are in progress to track down the source(s) of the instability. In the case of the ISIS system, software changes were made in order to provide more robust communication between the rf control system and the central control system.

CYCLOTRON PROBES AND DIAGNOSTICS

In addition to MRO activities, the major efforts throughout the year were focused on upgrading the beam line 2A extraction probe foil mechanism for high-intensity operation, and improving the ISAC target station and preseparator area diagnostics for serviceability in a highly contaminated environment. All other work was limited to essential repairs of the cyclotron probes and beam line monitors. The Diagnostics group biweekly meeting notes are available electronically via the Operations CYCINFO information service on the site computer cluster (accessible also through the TRIUMF home page on the WWW). The cyclotron shutdown activities are summarized in detail in the Diagnostics group meeting notes of March 17, 2000, and October 27, 2000.

ISAC Diagnostics

Completion of the west target station for operation and service at design beam intensities requires full remote handling capability. As part of this work the exit module service trays were modified so that they can now be removed at the hot cell without need for hands-on assistance at the containment box. Also, the commissioning profile monitor at ITW:harp5B was replaced with a properly engineered one of a smokestack design using the new style of multi-wire pc board. A new design for the diagnostics box DB0 at the preseparator was made to improve the reliability and to make the mass selection slits removable with remote handling techniques. The assembly was well under way at year end with installation scheduled during the winter shutdown.

A stripping mechanism retrieved from Brookhaven was recommissioned and techniques were developed for handling the very thin foils required for stripping of low energy ions in MEBT. The Diagnostics electronics support provided electronics modules, cabling and system integration for the diagnostics of the new ISAC installations of LEBT and MEBT.

Probes MRO

The 2A extraction probe was inspected. An rf-lossy insulating limit-switch actuator on the L-arm had overheated, resulting in intermittent operation of the L-arm limit. A new actuator made of G10 material (which is more tolerant of rf fields) was installed. The commissioning L-arm with a rotating foil cartridge of the beam line 4 style was found to suffer damage from beam heating, so a current limit of 15 μA was imposed for beam schedule 99. The design of the high-intensity L-arm similar to that on extraction 1 was completed. This L-arm utilizes a flat cartridge that holds up to 9 disposable foils and will be available in the spring of 2001.

The 2C extraction probe was cleaned, inspected and relubricated. No heat or mechanical damage was found. New foils were installed. The standard load of 2C foils lasts about 6 months.

Extraction probe EX1 was removed for routine service. All support bearings were inspected and cleaned. New drive tapes and cables were installed. No problem was found with the L-drive ball screw and a problem reported with the L motion was attributed to a fault in a stepping motor translator module in the control system. The cable-tensioning brackets were showing signs of wear, but this problem was left to a future service.

High-energy probe HE2 was removed and repaired with a minor modification, the problematic recirculating ball bearings that are prone to jamming were replaced with rollers. This change was successful but must be considered to be a temporary measure. A refurbishment project has been approved in the 5-year plan to replace one of the high-energy probes. The probe's functional requirements have been specified, but Design Office resources are required to make progress on the design.

Monitor MRO

All vault and standard beam line monitors were serviced during the shutdowns. To remedy the chronic problem of recurring leaks in aging ferro-fluid feedthroughs, a refurbishment program has been funded to replace the standard beam line monitors. Orders have been placed for the materials required and the work will be spread out over several years beginning in the summer of 2001. Smokestack monitor 1AM8F developed a leak in a bellows and was removed from service in the fall shutdown. It will be repaired and reinstalled during the winter shutdown.

Probes and Diagnostics: Developments and Upgrades

The beamspill monitors installed in BL2A have been calibrated in terms of known losses and fields nearby. This was necessary to permit operation at currents greater than 10 μA. Pairs of non-intercepting beam-position monitors had been placed at the beginning and end of the long drift through the wall of the cyclotron vault. They consist of inductive pick-up loops above, below, and to either side of the beam. They were designed by L. Rezzonico of PSI and use the same signal processing as at PSI. The linearity was checked and the units calibrated in terms of voltage output per mm displacement of beam. At the present time the voltages are displayed in the cyclotron control room, but there has been no call to upgrade the display to show actual position. This may change when higher beam currents are run.

Experiment 614 requires that the position of the proton beam not move by more than 1 or 2 mm with respect to the target 1AT1 for the length of a run that might last several days. It had been shown previously that the beam position was stable to 0.1 mm but only for a one hour period. The standard monitor had plates separated by 5 mm in both horizontal and vertical directions. The beam spot is taller than it is wide and it was possible to get sufficient signal from upper and lower plates to show that the experimental criterion was met in the vertical plane. However, it was necessary to build a new monitor with left and right plates separated by 4 mm in order to confirm long-term stability in the horizontal plane. This was installed and personnel from the experimental group monitored the readings from the four halo plates of the T1 protect monitor for several days and, with the help of Operations, calibrated that monitor. The beam position was stable to within 0.1 mm in both planes during most of that time, with brief excursions up to 1 mm. The latter may have been associated with re-optimization of the cyclotron tune.

The radioactive ion beam in ISAC is sometimes modulated in intensity in order to reduce background signals from competing decays. It is sometimes desirable to modulate the proton beam hitting the isotope production target in order to reduce the amount of undesirable isotopes created in the first place. This has been done by pulsing the beam in ISIS and this affects all other users of the cyclotron. Shortly before the fall shutdown an attempt was made to modulate the current in BL2A by moving its extraction foil into and out of the shadow cast by the extraction foil for BL1A. This would also modulate but not necessarily null the beam current in BL1A, and should not affect any beam lines at lower energy. The experiment was successful. The foil X2A was run into and out of the beam at different rates of acceleration and no evidence of vibration or jitter was seen. The rise and fall times of the BL2A current agreed with those expected from the acceleration of the foil carriage, except that the fastest transition time measured was $\geq$0.3 s. The source of this limitation on bandwidth was not determined convincingly. The experiment ended by cycling the extraction probe continuously for 3.6 hours. There was no slippage between the motor controller and an absolute position encoder. The probe mechanism was inspected carefully during the shutdown and no sign of damage was seen. We believe that cycling the radial position of X2 is one method to modulate the current in BL2A with minimal perturbation to other users.

The positions of the extraction and diagnostic probes in the cyclotron are determined first by surveying the position with respect to other cyclotron components, such as the centre post, at the time that the probe is installed and then operating the probe with the control system keeping track of the readings from shaft encoders. Drifts in encoder readings are checked occasionally by running the probe to a limit switch whose position was determined during the initial survey and by comparing the encoder reading with an absolute encoder for those probes where one has been installed. There has been growing concern that discrepancies have arisen between relative probe positions despite these procedures. A series of measurements was made in which each of several probes in turn was made to shadow, i.e. just touch, the orbit of a well-tuned beam. Such cross calibrations have been made previously. The new measurements imply that the radial position displayed by extraction probe X1 disagrees from the mean position of other probes shadowing the same orbit by as much as 1.3 inches and that this offset has increased since the time of the last check. A careful taping of the positions of the four probes that are operated through ports in the tank wall will be conducted during the forthcoming winter shutdown.

Several useful equipment items have been purchased. A digital phosphor oscilloscope with enhanced memory features has been purchased for the control room. A precision programmable pulse generator will make the calibration of diagnostic instruments in the field easier. For example, pulses matching those from a toroid or a particle detector can be generated. An

Ethernet hub installed in BL1A has allowed us to read monitor output on any X Window terminal.

VACUUM AND ENGINEERING PHYSICS

Vacuum

The cyclotron vacuum system performed well during the year. The only significant downtime was due to the failure of a seal ring in one of the B-20 cryogenerators. There were also a few brief interruptions due to unexplained pressure rises in the tank. The data available seemed to indicate a heat load from the tank, presumed to be due to rf leakage. Continued and closer observation eventually traced the problem to a leak in the cryoline vacuum jacket. The suspect area was treated with leak sealer and will be repaired during the winter, 2001 shutdown. In the course of investigating this problem, it was noticed that the consumption of liquid nitrogen in the B-20 heat exchanger increases dramatically with the time between defrosts. Economic operation will require routine defrosts in the future.

There were a few problems with the beam line 1A vacuum during the year. The pressure in both T1 and T2 rose during the spring and summer, although never to the point of disrupting beam production. The T1 area leak was traced to an indium seal that was replaced during the fall shutdown. The leak in the T2 volume was found to be in the M8 area. There was evidence of more than one leak and the decision was made to remove the slit box, blank the line at the exit of the first bender, and replace the seal in the blank flange on the zero degree port of the bend box. The M8/T2 repair was successful and the pressure is now very good there. The 1AQ11 seal is unreliable due to a component misalignment. The seal failed again in November and was replaced. By December it was failing again. The beam pipe will be realigned during the winter, 2001 shutdown to solve this problem.

Engineering Physics

The inflector, correction plates and thermocouple systems performed normally until September when an insulator in the inflector system failed. The lid was raised and all the insulators for the inflector and deflector were replaced. It was very difficult to achieve a good machine tune after this repair and it was not possible to operate at the scheduled beam current. There was some suspicion that the inflector was not positioned correctly. The major problem was eventually traced to a high voltage breakdown in the inflector negative cable system. A spare cable was connected and the situation was much improved. While full current can now be run, the inflector still seems to be more sensitive than it was. It will be removed in the winter, 2001 shutdown and the alignment checked.

ISIS AND POLISIS

The CUSP ion source and injection line continued to operate well for the past year with only minor downtime due to spurious interlock faults caused by aging equipment. As for the past few years, there were no major activities undertaken during 2000 as ISIS personnel were involved in the completion of ISAC projects. These include the high energy beam transport (HEBT) systems, the drift tube linac (DTL) optics, and the lithium beam line.

The polarized H^- ion source I4 supplied beam for the engineering runs for the parity experiment scheduled for July 19–August 8 and December 6–20. In the summer, I4 actually began operation July 23, due to a delay in installing a new 29 GHz microwave tube. The first week of the run was single user, followed by shared beam with ISAC. When sharing with ISAC, a typical beam inventory was:

- I4: 25 μA;
- Fast target: 12 μA;
- Circulating: 2 μA (17% transmission with some bunching);
- BL1 shadowing: 0.5 μA;
- ISAC: 1.3 μA;
- Parity: 0.2 μA.

Only one pumping laser was used, instead of the normal two, reducing the H^- polarization to about 70%. The other pumping laser was borrowed by ISAC for the β-NMR experiment. The argon ion photodetachment laser used to produce coherent intensity modulation of the H^- beam gradually died during the run, ending up at 5–6 W.

For the winter run, a new tube was installed in the photodetachment laser. The maximum H^- beam intensity modulation was 0.1%, about half of what was expected. Perhaps the H^- beam was off-axis. As in the summer, the beam was shared between multiple users, and required some bunching. A Pockels cell circularly polarized the light from the single pumping laser, thus increasing the H^- polarization to about 80%. The resulting increase in unwanted helicity-correlated beam parameter modulations was not important for the engineering run.

PRIMARY BEAM LINES

The year 2000 began with a cyclotron shutdown and, with it, the relocation of shielding blocks from over the 1AT2 region to outside the main cyclotron building. This was necessary to allow repairs to be made near the 1AT2 target.

The bellows unit of the M9 beam blocker was removed, repaired, and reinstalled. A vacuum leak at the connection of the first quadrupole of the M9 channel to the 1AT2 monolith was repaired by replacing an indium seal at that point. The window of M8, a suspected source of a vacuum leak, was also blanked off.

Blocks from over the 1AT1 region were then removed to allow access to that area. Because the blocks from over 1AT2 had been removed, those from the 1AT1 area could be stacked where the others had been. In the 1AT1 area the jaws of the M11 channel were repaired, as was the "in" limit switch of the 1AT1 profile monitor.

Attention was then turned to the cyclotron vault. O-ring seals were inspected and replaced as required. In the vault section of beam line 4 a water leak was repaired by replacing a hose. In that of beam line 1, the vent valve of its combination magnet required repair. It was noted that a coil of the 19.8° dipole was not firmly constrained. With parts made in the machine shop it was possible to correct this problem.

In May, after running was resumed, the M13 beam blocker required repair. A temporary repair was made so that operation could continue until the next shutdown. At the end of the month an interlock problem at the first dipole of the M11 channel necessitated that the 1AT1 area be opened so that the problem could be corrected.

A vacuum leak at the neutrals port of the M8 channel had been suspected for some time. It had been planned to correct this problem during the September shutdown. However, the vacuum had deteriorated to an extent that other sources of leaks had to be considered. To reach this region it was again necessary to move shielding blocks from that region to outside the building. This was done in mid-August. Because other problems had arisen in the 1AT1 area, it was decided to tackle it first, thus allowing more time for the 1AT2 region to cool.

In the 1AT1 region, quadrupole 1AQ9 immediately downstream of the target had developed an interlock problem. This was traced to a faulty thermal switch and an adjustment was made to the wiring of the thermal switches. The first quadrupole of the M15 channel also had an interlock problem that was traced to a broken wire. In addition, a water connection had developed a leak. A special wrench had to be obtained before repair could be effected. Because a vacuum leak was discovered in the area, the 1AT1 target was reinstalled and pumping began. There appeared to be a recurrence of a vacuum leak at the bellows of the M11 septum. The region was sprayed with sealant and liquid epoxy but the pressure remained high. Efforts to locate the leak were suspended to allow repair of the M13 beam blocker to proceed.

As noted above, this beam blocker was temporarily repaired during the January shutdown. Its piston assembly was removed and sent to the machine shop for modification. The modified assembly was installed and its limit switches set.

Attention was now turned to the 1AT2 area. Because of the high residual radiation levels, a comprehensive radiation survey of the area was made first. Then, considerable time was spent planning how work in the area could be accomplished with a minimum risk of exposure to the persons involved in the repair.

Once adequate shielding had been arranged, all vacuum joints upstream of the M8 neutrals port were checked for leaks. None were found and it was concluded that the leak at the neutrals port had become worse. Close-in shielding around 1AT2 was replaced leaving access to the neutrals port. The M8 slit assembly was removed and the neutrals port blanked off.

Attention returned to the vacuum leak in the 1AT1 area. It was finally traced to an indium seal in the bellows at the downstream end of the 1AQ10/11 quadrupole doublet. Experience has shown that it is not unusual to make several attempts to effect a seal with these indium joints. True to form, the joint was made vacuum tight on the second attempt. This repair was deemed to be temporary; a permanent redesign of the joint support will be fabricated and installed in the January, 2001 shutdown.

In both shutdowns this year the Beam Lines group has been pressed both in manpower and time. Its duties have been well executed and group members deserve commendation for having accomplished the required work efficiently and within the time scale allotted.

2C

The production of the radioisotope ^{82}Sr in the solid target facility (STF) on 2C4 continued to be the major user of 2C beam time. This year, there was more operating time than the previous records of 121 days in 1996 and 123 days in 1997. There were 135 days of ^{82}Sr production in 2000 for a dose of 95.50 mAh and a yield of 31.87 Ci at the end of bombardment. The beam intensity was reduced to typically 40 μA because of scheduling difficulties, cyclotron intensity problems and imposed restrictions from previous target failures. This was a significant increase over 1999 production of 118 days for a dose of 70.73 mAh and a yield of 26.80 Ci. There were seven natural rubidium targets used for the 2000 production.

The STF was also used for production of a ^{148}Gd source that will be used for set-up of the DRAGON facility in ISAC. This involved irradiating a europium foil encased in aluminum foil at 28 MeV on the target, for 628 μAh in twenty shifts. Beam was extracted at 70 MeV and was restricted to a maximum intensity of 5 μA, extracted on a narrow extraction foil (0.015 in. wide) that was used to reduce the beam spills and halo from the nominal foil (0.200 in. wide). A 0.100 in. foil was added to the 2C extraction probe during an emergency raising of the cyclotron lid in late September. This foil will be a compromise with more current than the narrow foil and less spill than the nominal foil at 70 MeV. The 0.100 in. foil was used for the only ^{127}Xe production run at 105 MeV into the cesium target on 2C5, but more tuning is required to reduced the beam spill in the 2C exit horn. The 0.100 in. foil was also used at 85 MeV for the irradiation of the rubidium target, RA20, that failed with a minor leak. The foil created a very symmetric beam spot, but increased the beam density so that the containment foil was damaged where the beam hit the target. Two short irradiations of Ta foils at 110 MeV were done on the STF. 2C1 was scheduled for 29 shifts of proton therapy and 12 shifts of proton irradiation facility (PIF).

CONTROLS

The Central Control System (CCS) continued to run reliably throughout 2000. Year 2000 (Y2K) catastrophes failed to materialize and there were no other large problems in the CCS. Cyclotron downtime due to CCS causes, as recorded by the Operations group, was listed as 8.1 hours. This is 2.6 hours more than the previous year, but the 8.1 hours represents a small fraction (2.6%) of the overall cyclotron downtime. More than 7 hours of downtime was due to hardware failures such as power supply faults.

There has been progress on general CCS goals. Replacing aging VAXes with Alpha computers has advanced, the network infrastructure has moved to a gigabit Ethernet backbone and local 10/100 Mb Ethernet switches, and the overall goal of replacing aging components has continued, albeit slowly. An additional goal of improving the reproducibility of beam tunes has also received some attention and will be of increasing importance.

CCS Facilities

There are a number of software topics to mention, including new developments and enhancements to existing items. An unusual event was the Y2K apprehension, which proved to be unfounded, and the new year came in without incident. Logged data and cyclotron messages were organized and put on CD for long-term storage. This makes retrieving old data much easier than the previous system that employed magnetic tapes. Support for the new network hardware included development of SNMP routines for gathering hub information and installation of Perl 5 for SNMP support. The beam line 2C controls and user interface continues to run reliably using Vista software. Configuration of the BL2C controls was changed by replacing the VAX with an Alphastation 600, and reorganizing and tidying up the software. With the change to the Alpha, the performance of the user interface was dramatically improved. A new data logging program, data_logger, was started. It provides for faster data retrieval than the existing program called cycscan. Development has continued on exploring a Windows NT connection to the CCS.

Numerous existing software packages were modified during 2000. Several of these packages received almost constant additions and enhancements due to their heavy use and the requests for new functionality. The five most heavily affected packages were the XT display pages (XTpages), the scans, Xstrip, the console panels, and the device (system and thumbwheel) support routines. Changes to these packages are too numerous to note here.

Software upgrades occurred on Oracle (to version 8i), and VMS (to version 7.2-1). New timers were added for beam lines 2A and 2C. Additional 2A timers will be added in the following year to support the new 2A foil cartridge. The PCI/CAMAC interface software has been modified to be autoconfiguring. Enhanced support for the pulser was added including a new XT page 5P. The histogram program now has max/min/current value markers, more colour features, and default gain setting. XRC, the X Window based remote console program, was modified to support register status and control. Improvements were made to the adjusted current calculations and the beam line 2A energy calculation. The user interface to the cables database was moved from a Web implementation to an X Window based one. The X Window program, called Xstrip, that strips out logged device data and displays it, had numerous enhancements. Xstrip has become a commonly used tool and as such will warrant further enhancements. XT pages can now dynamically call Xstrip and during the next year XRC will also be modified to call it.

There were a number of changes to the hardware configuration of the CCS. VAX computers are being phased out and Alphas are being used in their place. With the replacement of the beam line 2C VAX this year, the production cluster is now only Alphas. The proton therapy VAX was in the process of being phased out at year end and when it goes, only Alphas will need to be supported for new developments. Two VAXes are still in use for diagnostics and development, but they should be replaced during 2001. At the end of the year there were 3 DS10s, 2 Alphastation 600s, and one Alphaserver 2000 in use for production, developments and diagnostics.

The existing computers received some modifications. Such things as memory, cache, disk, and DSSI interfaces were upgraded and a CD burner was added.

The proton therapy computer and the PC server each received a DLT tape drive for doing backups. The existing FDDI based network is being phased out and a gigabit Ethernet backbone and switched 10/100 based Ethernet is being installed. We expect that by the end of 2001 all of the CCS network traffic will be running through the new system. A number of changes also occurred in the CAMAC. The last four of the old CAMAC crates that were used for trim and harmonic power supply control were replaced with two new crates. By replacing old DACs and digital controllers, fewer crates were necessary. After these changes were made, the DACs for the trim and harmonic power supplies were calibrated. UPS power was extended to more equipment and further UPS work will be done in 2001. Because even the UPS can fail, a number of the UPS units were connected to the CAMAC system so that they can be monitored. Beam line 2A and the site services received 32 channel expansions to their ADCs.

Each year there are numerous hardware failures and 2000 was no exception. The network hub that is being phased out had a power supply problem and another power supply was purchased for that system. Motor controllers had problems. The VXT X Window terminals continue to fail frequently, but in most cases they can still be repaired and put back into service. The DSSI disk systems hung up on 2 occasions for unknown reasons. There have been problems with an HP 5Si and an HP 4050 printer. One of the UPS systems had a problem. There is a large number and variety of CAMAC equipment that for the most part runs very reliably, but there were a variety of CAMAC module problems. These included such items as crate power supplies, DACs, a parallel branch coupler, a crate controller, an active extender, battery chargers, fans, etc.

A refurbishing budget was established this year. The planning had included a number of goals where the largest had been to develop and deploy a new ADC module. Unfortunately, the design has been delayed due to higher priority jobs for the group undertaking this design. An aging disk system due for refurbishing in the following year was moved ahead and the ADC project has been delayed one year.

The issue of beam reproducibility has gained a higher profile. Tools to understand beam related problems are being enhanced. The ability to switch from one tune to another more quickly will be further investigated in the next year.

Other Systems

As mentioned earlier, beam line 2C controls have been enhanced in several ways. The old VAX has been replaced by a much faster Alpha. The software directory structure was reorganized and significantly cleaned up. A change to a newer version of the Vista software has been initiated and should be completed during the next year. Support continued for the parity experiment. This was made more difficult by the departure, after almost 10 years of service at TRIUMF, of the person most familiar with the parity/ion source 4 controls. Proton therapy (PT) also received support as necessary during the year. A new PT summary panel display was developed for the Cyclotron Operations group. During the winter shutdown, replacement of the PT VAX by an Alpha was initiated. The Alpha should be operational during the spring, 2001 startup.

Miscellaneous

Security on the computer systems has been of increasing concern. A number of actions have been taken on site to enhance the situation but increased attention and resources will need to be given to security in the future.

Unfortunately, two members of the Controls group left TRIUMF during 2000. They were both very valuable contributors to TRIUMF's ongoing success and left with a combined 25 years of experience at the laboratory. Their contributions were appreciated and will be missed.

OPERATIONAL SERVICES

Remote Handling

ISAC

For another year the principal activity for Remote Handling personnel was in support of ISAC projects. Module construction continues with target modules #2 and #3, and manufacture of spare components. The south hot cell and support facility is still under development and commissioning continues on the remote controlled crane system console.

The addition of a technician-in-training for hot cell operations, dedicated to the ISAC program, will greatly ease work loads during target changeover and shutdowns. Conversely, the loss of a senior technician to the ISAC division will distribute the workload in other directions.

Cyclotron servicing

A single main shutdown was scheduled for the beginning of the year. Routine Cu-block removal, shadow shield handling and radiation surveys were performed. The major remote handling job for the shutdown was the removal and replacement of the 2C extraction probe for work by the Diagnostics group. An unplanned intervention was required in March for repair, including removal of the high energy probe #2, Cu-block removal and the installation of some shields to enable in-tank activities. Another event in September, involving the cyclotron beam inflector, again required

Cu-blockers to be removed and a small complement of shadow shields to be installed. The only effort provided for the cyclotron elevating system for the year was an alignment check and inspection service of the guide bushing at station #2.

Beam lines servicing

The ISAC radioactive ion beam lines between the preseparator magnet and both the west and east target stations were rebuilt to a revised design incorporating additional shielding. Assistance was given with the replacement of the 1VRR1 rad-hard valve in the cyclotron vault, and a vacuum leak repair at the 4BP7-SEM (Faraday cup). At the T1 area of beam line 1A a 1AQ9 thermo-interlock cable was replaced, and cooling water leaks at M15Q1 and the 1A rotary collimator were repaired. A vacuum leak in the M11 septum bellows was investigated. An indium seal downstream of the 1AQ11 magnet developed vacuum leaks twice in the last four months of the year. One occurred during a scheduled beam run and required an interim patch until a proper repair can be completed. At the T2 area the major task was the disconnection of the M8 secondary beam line vacuum volume from the main system. A blank-off plate was installed downstream of M8B1 replacing the slits box, and the blank-off at the M8B1 neutrals port was replaced. Also in the area, an indium seal was replaced in the M9Q1-T2 joint to repair a vacuum leak, an M9Q2 thermo-interlock cable was replaced, and 1AM10 and 1AM11 beam monitors were vacuum leak checked.

Hot cells and targets

Maintenance of production targets and services occupied the majority of the workload for this year. The cooling packages at 1AT1 and T2 were serviced and refilled, a pressure transducer at T1 was replaced along with a valve relay, and a mechanical flow test performed to calibrate feedback readings. The T2 cooling package had both flow and pressure transducers replaced, as well as a water conductivity cell. At T2 the air cylinder drive for the M20 secondary channel beam blocker was rebuilt using a revised design with 50% more elevating thrust. The T1 target had a "home position" microswitch replaced on the Mk1 assembly. The Mk2 target had a new protect monitor and new graphite targets installed. It was then placed in service in beam line 1A for Expt. 614 which uses these graphite targets. The Mk2 target trombone assembly was lowered to match the corresponding alignment of the Mk1 target. Work continues on the development program for vacuum brazing of new graphite targets. Assistance was given with servicing of 2C resin cans and filters, and with modification of an existing filter housing. The 1AM8 monitor was serviced in the targets storage pit for a leak check of a worn bellows. Hot cell housekeeping for the year included disposal of seven 2C spent resin cans and uranium rods used in the ferficon experiment. These items were all sampled and gamma spectra measured by TSG prior to shipment. A broken wrist-actuation tape was replaced on one hot cell master-slave manipulator. The beam line M8 slits, removed this year, were packaged for storage in the east cell. ISAC work included assistance with manufacture and construction of the new hot cell doors as well as removal and storage of the 100 μA Mo target used for a high-current experiment at the ISAC west target station.

Magnet Power Supplies

The year 2000 saw the installation of power supplies for the ISAC DTL, HEBT, DRAGON and TUDA lines. With the exception of DRAGON, where supplies from the decommissioned M8 channel were used for high power applications, the supplies are switch-mode supplies. Polarity reversal capability was also supplied for 100 A service for steering magnets.

For the existing TRIUMF facility, the majority of the work was MRO with calibration of trim and harmonic supplies as well as beam line 1A supplies occurring during the winter shutdown.

Failing Entrelec switches are being replaced, as well as cab-tire cabling related to these switches. The insulation of this wiring has become brittle and is being replaced with RW 90 cabling.

Wakefield heatsinks are being replaced with a new copper design that should provide better service.

With the added load that ISAC represents, we are having to develop expertise in switch-mode power supply technology. To this end, a training course for power supply staff is being arranged.

Electrical Engineering Services

Electrical Services is involved in both new installations for ISAC and MRO activities for existing systems. Supervision of outside contract labour for installations for ISAC and assisting with TRIUMF electrical staff as required presents a formidable challenge.

In parallel with these activities is MRO which represents a significant task because of the age of existing installations and the multiplicity of fault reports that arise and have to be addressed to keep the facility functional. Old installations that are substandard are being addressed and this is foreseen to require a significant workload. Staffing levels are a concern because of the aging and ever increasing size of the electrical system.

Electrical Systems

Activities involved new installations for ISAC and maintenance of the existing systems. The department processed about 40 orders between large installations and minor construction tasks. These required the provision of both infrastructure and experimental support. About 200 trouble calls and numerous minor requests were attended to. Typical maintenance activities included servicing lighting systems, motors, air conditioning controls, panel boards and transformers, HV switchgear, breakers, and capacitor banks. Continuing engineering support was provided to the TRIUMF users. Design support was provided for the TWIST experiment, the refurbishing of the Batho biomedical facility, and for the site surveillance system. The site lighting upgrade is still in progress and will continue in the next fiscal year.

Services provided for new electrical installations for ISAC included DTL, HEBT, DRAGON, TUDA, LTNO, hot cells, and various other installations. Some of these installations are still in progress. The major installations for ISAC-I are foreseen to be completed in early 2001. Providing support for experiments will be an ongoing task, as will the maintenance of the new installations.

In the last few years efforts have concentrated on the new projects, with the result that the upkeep of the existing systems suffered.

Major site installations outside ISAC included the refurbishing of the Batho biomedical facility and the new maintenance support facility for ATG in the meson hall.

Power Delivery

A "bumpless" switchover was successfully completed at the beginning of September in cooperation with the Utilities Department of the University of British Columbia. This was accomplished by paralleling the two 12 MVA substation transformers for a period of time. In the future, shutdown of TRIUMF power can be limited to the time when servicing the main switchgear is required, typically every five years. Future annual maintenance of the substation equipment may be carried out without power shutdown to TRIUMF.

Power management continued as a routine activity. The monthly averaged peak power demand increased almost 13% to 6736 kVA from 5968 kVA last year (Fig. 130). Again this year May saw the largest power demand (8436 kVA). The electricity consumption jumped another 12% to 53.2 GWh from 47.4 GWh (Fig. 131). The largest consumption was reached in November (5.82 GWh). The power factor (PF), averaged over the calendar year, dropped 0.5% to 96.1% from 96.6% (Fig. 132). The power factor during operational months remained around 95.1%. This trend is expected to continue next year as more ISAC systems are brought into operation.

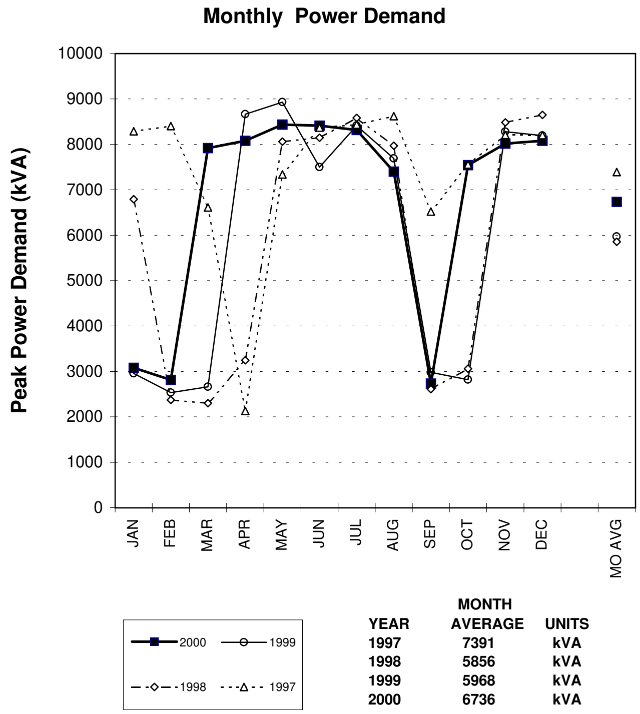

Fig. 130. Electrical system power demand – four year comparison.

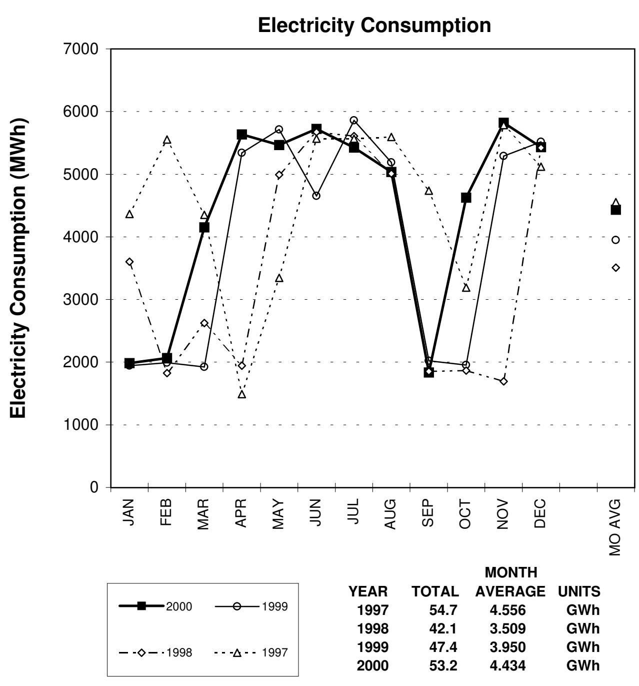

Fig. 131. Electrical system energy consumption – four year comparison.

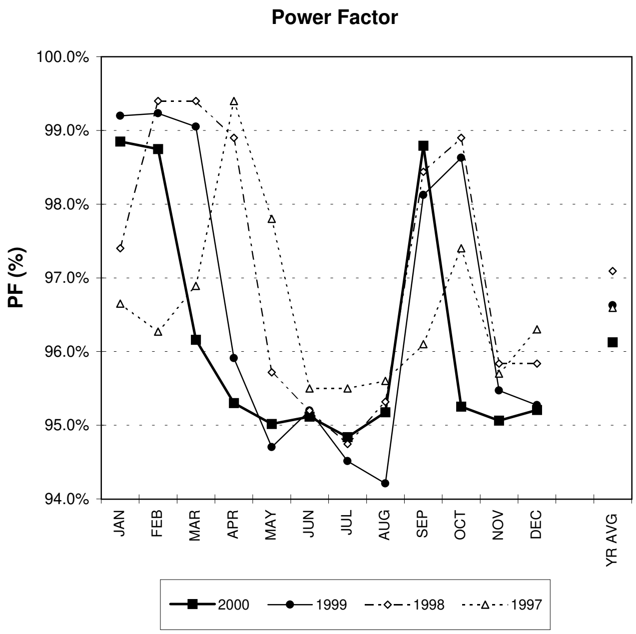

Fig. 132. Electrical system power factor – four year comparison.

Mechanical Systems

ISAC

A majority of site mechanical service engineering effort went into ISAC related projects. Notable jobs included: assembly and services for fume hoods, new compressor for chiller CH-1, new transmitter and remote for EH crane, piping services for MEBT, HEBT, DTL, DRAGON and TUDA, DRAGON hydrogen vent, air conditioning for TUDA shack, assembly of TRINAT cooling water return system, high level alarms for decontamination sump filling points, charcoal filter for target hall vacuum pump exhaust, perimeter drainage sump pump piping, and laminar flow diffusers for TRINAT. Preliminary engineering and cost estimates were provided for ISAC-II, and an estimate was given for a new target hall for a U.S. laboratory. Assistance was provided for the ISAC OPS training program. Estimates were given for a superconducting rf test facility to be located in the CRM area of the main office building.

Calculations for HEBT buncher water flow were provided and consultation provided for DTL cooling problems.

TRIUMF

Larger jobs included: medical annex HVAC overhaul and modifications to suit new occupants, reroofing, boiler burners overhaul, replacement of machine shop water pipes, new stainless gas lines in MESA, connection of TNF vacuum pump exhaust to the BL1A exhaust system, sorting out troublesome hot water circulation in the chemistry annex, and various air conditioning repairs. Annual safety inspection and testing was given for the site fire sprinklers, lifting equipment and active exhaust HEPA filters.