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UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

JULY 2000

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

During the 1999 calendar year the cyclotron proper operated at a good level of reliability (91%). The down time of the cyclotron systems (435 hours) was also reasonably low, with the major offender being rf with 203 hours, followed by vacuum with 70 hours and the polarized ion source with 58 hours. This is below overall corresponding down time data of previous years, confirming that most of the cyclotron system actually behaved quite reliably. For the reliability of the high intensity beam line, however, the situation was quite different. At the beginning of July the beam line 1A beam dump developed a water leak to the beam line vacuum enclosure from the large main vessel containing the beam dump. The cause was a weld in the vessel which had deteriorated over the past few years. The vessel design was modified and a new vessel was built. The replacement of the old vessel was successfully accomplished in a period of about six weeks, on schedule and without problems. However, the loss of most of July and August for high intensity users could not be avoided. In terms of beam charge we delivered only 210 mAh towards 334 mAh scheduled for the whole year, with an availability of about 63%. During the remainder of the year BL1 was back to normal operation. The cyclotron has also been used to routinely extract and make use of four simultaneous beams.

During 1999 the Division was asked to plan for a much needed five-year plan refurbishing initiative for the cyclotron and the major ancillary systems in terms of long-term reliability and components in need of repair or replacement. Special attention was given to those systems such as vault beam lines, BL1A, rf, and probes, where the need for intervention is most urgent. The welcome allocation of refurbishing funds should allow us to increase the level of preventative maintenance for the critical systems during the coming years.

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 1999 achievements for these projects, in particular the completion and full power commissioning with beam of the RFQ and the routine delivery of 500 MeV 10 μA proton beam and low-energy beam operation in ISAC.

BEAM PRODUCTION

This report describes beam production for the full 1999 calendar year. With two shutdowns totalling nearly 24 weeks, only 4106 operational hours were scheduled of which 3723 were achieved for the relatively good availability of 91%. These totals include 135 hours used for development and tuning and, as shown in Fig. 111, 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 dedicated to the parity non-conservation experiment running in beam line 4A2 at 222 MeV.

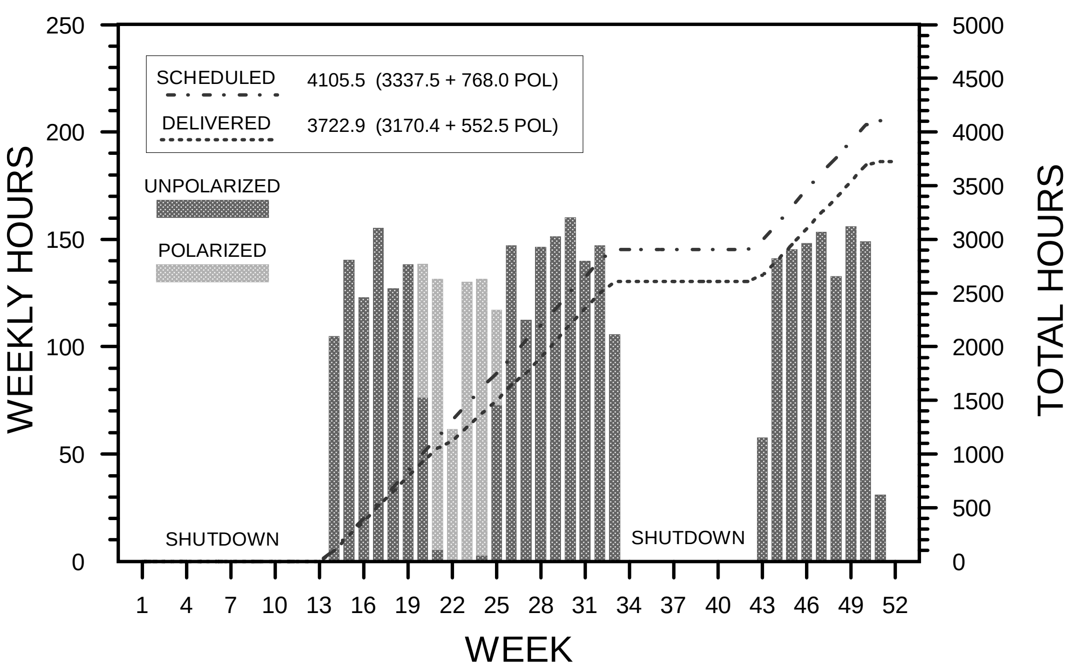

Fig. 111. Operational hours for 1999.

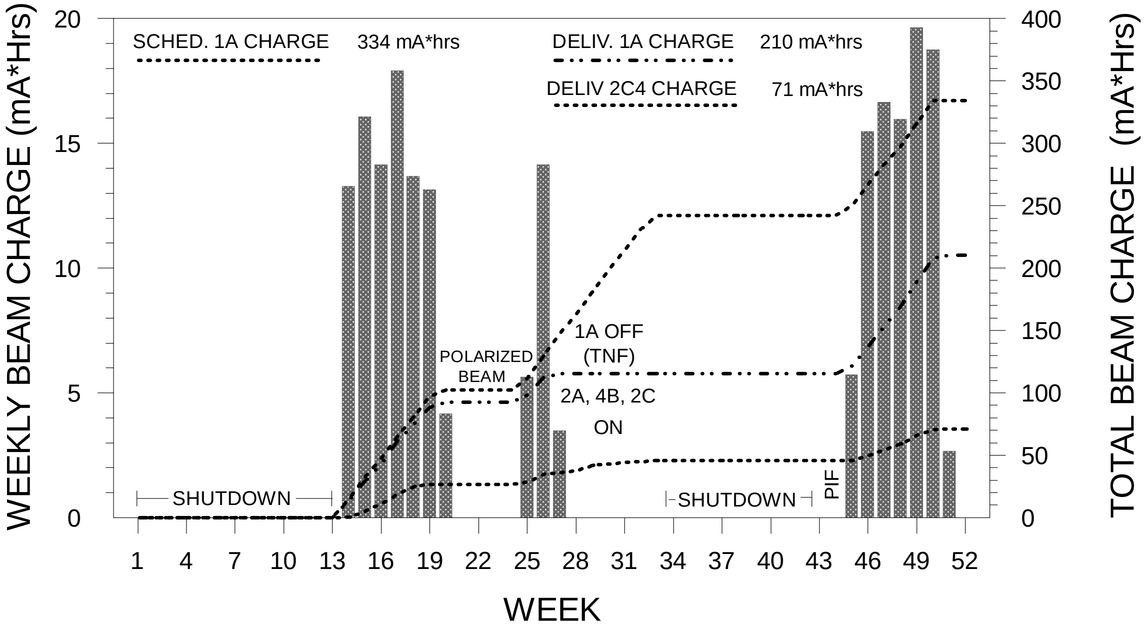

Fig. 112. Beam delivery for 1999.

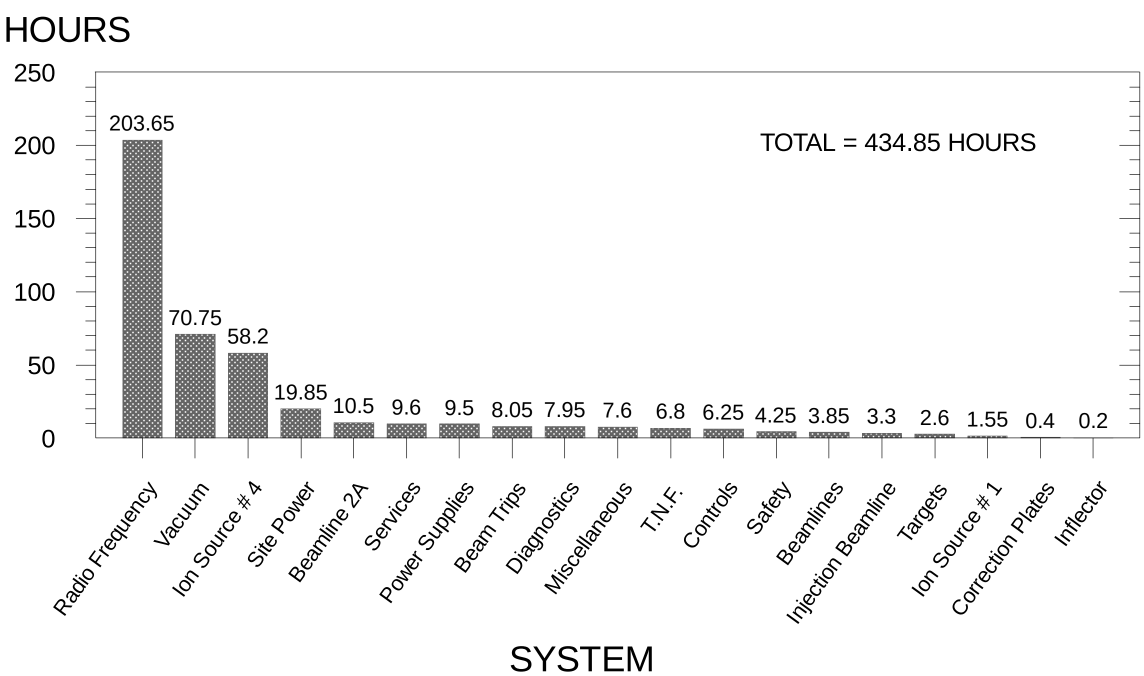

Fig. 113. Cyclotron downtime for 1999.

As Fig. 112 shows, the total beam charge delivered to meson hall experiments along BL1A was 210 mAh or only 63% of that scheduled. This percentage is much lower than the cyclotron availability largely because of a TNF failure part way through Beam Schedule 95 that brought a halt to BL1A delivery, although the cyclotron continued to accelerate beam to other proton lines. In addition to the BL1A charge, there were 71 mAh delivered at 85 MeV to the solid target facility (STF) in beam line 2C4 for the production of radiopharmaceutical generators as well as 7 mAh to the west target station in ISAC for the production of radioactive ion beams (RIB). Seven patients were treated for ocular melanomas during five proton therapy sessions in beam line 2C1 which was operated at 74 MeV. The annual downtime (Fig. 113) was 435 hours, about average with respect to the scheduled hours and with the rf, as usual, responsible for the greatest share of this time. The operational record and beam to experiments for the year are given in Tables XIII and XIV.

Table XIII. Operational record for 1999.

	Scheduled hours			Actual hours		
Cyclotron off:						
Maintenance	361.5			310.70		
Startup	174.0			128.20		
Shutdown	4007.0			4014.00		
Other	0.0			0.50		
Cyclotron downtime	0.0			434.85		
Overhead	88.0			124.90		
Totals	4630.5			5013.15		
Cyclotron on:						
Development	47.0	+	0.0 P	27.35	+	0.00 P
Cyclotron tuning	167.0	+	40.0 P	82.40	+	25.65 P
Beam to experiments	3123.5	+	728.0 P	3060.65	+	526.80 P
Totals	3337.5	+	768.0 P	3170.40	+	552.45 P
Actual/Scheduled = (3170.40 + 552.45)/(3337.5 + 768.0) = 90.7% availability						
Beam to experiments:						
1A Production	2794.0	+	0.0 P	1820.50	+	0.00 P
1A Development/tuning	82.0	+	0.0 P	42.70	+	1.50 P
1A Down/open/no user	49.5	+	603.0 P	993.90	+	456.50 P
1B Production	186.0	+	125.0 P	72.30	+	28.30 P
1B Development/tuning	0.0	+	0.0 P	2.15	+	1.35 P
1B Down/open/no user	12.0	+	0.0 P	129.10	+	39.15 P
Total 1A+1B production	2980.0	+	125.0 P	1892.80	+	28.30 P
2A2 Production/tests/tuning	2034.5	+	0.0 P	1230.80	+	0.00 P
2C1 Production/tests/tuning	833.0	+	165.0 P	197.45	+	15.40 P
2C4 Production/tests/tuning	1892.0	+	0.0 P	1803.30	+	0.00 P
2C5 Development/tune	8.0	+	0.0 P	7.30	+	0.00 P
4A2 Production	0.0	+	728.0 P	0.00	+	466.70 P
4A2 Development/tuning	0.0	+	0.0 P	0.00	+	26.15 P
4A2 Down/open/no user	0.0	+	0.0 P	46.40	+	33.95 P
4A3 Production	314.5	+	0.0 P	232.60	+	0.00 P
4A3 Development/tuning	11.0	+	0.0 P	5.80	+	0.00 P
4A3 Down/open/no user	1003.0	+	0.0 P	1074.75	+	0.00 P
4B Production	1762.5	+	0.0 P	1503.65	+	0.00 P
4B Development/tuning	0.0	+	0.0 P	45.85	+	0.00 P
4B Down/open/no user	32.5	+	0.0 P	151.60	+	0.00 P
Total BL4 production	2077.0	+	728.0 P	1736.25	+	466.70 P
1A Beam charge	334180 μAh			210403 μAh		
2A Beam charge	10463 μAh			6994 μAh		
2C4 Beam charge	81735 μAh			70841 μAh		

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

Table XIV. Beam to experiments for 1999.

			Scheduled			Delivered		
Experiment *	Channel	Sched.#	h	h (pol)	μAh	h	h (pol)	μAh
497	4A2	95	0.0	728.0	0	0.00	466.70	0
614	2C1	96	90.0	0	0	46.70	0	0
677	M15	95	115.0	0	13800	92.75	0	10155
684	M15	95	162.0	0	18960	123.40	0	12538
704	4B	95	1762.5	0	0	1503.65	0	0
741	4A3	95	148.5	0	0	142.40	0	0
746	M15	95	127.0	0	15240	126.90	0	14810
749	M20B	96	127.0	0	13970	128.60	0	13975
766	M9B	95	381.0	0	45240	221.15	0	23258
766	M9B	96	145.0	0	13600	131.95	0	11344
774	M15	95	273.5	0	33850	249.50	0	28230
775	M20B	95	127.0	0	15240	126.90	0	14810
777	M20B	95	150.0	0	18000	125.10	0	13835
778	M13	95	1207.0	0	147470	998.30	0	115009
778	M13	96	799.0	0	92150	817.20	0	94829
798	M20B	95	275.5	0	35140	260.60	0	31757
783	M15	96	98.0	0	12740	120.80	0	15901
791	M15	96	145.0	0	13600	131.95	0	11344
793	4A3	95	72.0	0	0	47.55	0	0
793	4A3	96	59.0	0	0	15.30	0	0
804	M15	96	127.0	0	13970	128.60	0	13975
814	M15	96	69.0	0	7590	74.00	0	8927
834	M20B	96	255.0	0	31070	264.80	0	33831
835	M20B	95	273.5	0	33850	249.50	0	28230
838	M9A	95	552.5	0	68380	532.65	0	64086
840	M9B	96	290.0	0	35620	299.40	0	38558
842	M9B	95	273.5	0	33850	249.50	0	28230
842	M9B	96	139.0	0	16220	136.45	0	14965
843	M15	95	104.0	0	12480	0.00	0	0
843	M15	96	139.0	0	16220	136.45	0	14965
844	M20B	96	139.0	0	16220	136.45	0	14965
845	M15	95	150.0	0	18000	145.15	0	17519
846	M15	95	206.5	0	25480	190.20	0	23282
847	M20B	95	104.0	0	12480	0.00	0	0
847	M20B	96	145.0	0	13600	131.95	0	11344
848	M20B	95	127.0	0	14760	91.05	0	8858
849	M15	96	140.0	0	18200	145.55	0	19668
849	M20B	96	133.0	0	17290	155.40	0	20628
850	M15	96	81.0	0	9830	89.85	0	9963
851	M20	95	150.0	0	18000	145.15	0	17522
856	M9B	96	127.0	0	13970	128.60	0	13975
857	M9B	96	98.0	0	12740	98.80	0	13235
949 TEST	M11	95	69.0	0	8280	68.40	0	7890
BELLE	M15	95	69.0	0	9660	70.40	0	8475
ISAC RIB †	2A2	1999	2022.5	0	10263	1189.90	0	6754
ISAC TESTS	2A2	96	12.0	0	200	13.40	0	240

Table XIV (cont'd.)

Experiment *	Channel	Sched.#	Scheduled h	Scheduled h (pol)	Scheduled μAh	Delivered h	Delivered h (pol)	Delivered μAh
ISOPROD	2C4	1999	1892.0	0	81735	1803.30	0	70841
LS37	4A3	96	23.0	0	0	17.40	0	0
PIF	1B	1999	186.0	125.0	0	72.30	28.30	0
PIF	2C1	1999	294.0	125.0	0	128.00	11.95	0
P. THERAPY	2C1	1999	449.0	40.0	0	20.10	3.45	0
TEST	M11	95	275.5	0	35140	260.60	0	31757
U of A	M11	96	145.0	0	13600	131.95	0	11344
Xe 127	2C5	96	8.0	0	150	7.30	0	150

* See Appendix D for experiment title and spokesman

† Total for all ISAC RIB experiments; 100 μA and Talbert target tests follow under ISAC TESTS.

Winter Shutdown

While ISAC conducted a series of stable beam tests, the year started with shutdown activities proceeding on the main accelerator side. The lid remained down for the first month to allow for an adequate cyclotron cooldown prior to February's tank work that included the following groups: RF (centre region inspections and the installation of a new rf booster feedthrough); Engineering Physics (inflector and correction plate maintenance – a wider scraper on the UQ2 correction plate assembly was installed); Vacuum (replacement of the inner tank seal and cyclotron vacuum pump maintenance); Remote Handling (general assistance and the installation of additional tank neutral beam blockers to reduce activity in the area of the BL2 exit horn); and Diagnostics (general probe maintenance including X2C, X2A and slit 4 repairs). Other vault work included lighting and walkway improvements and beam line 2C plumbing changes. The Plant group was very busy with water system maintenance with both the active and non-active copper systems undergoing extensive pump rebuilds to improve reliability.

In BL1A, TNF tests indicated a small water leak at the target itself in addition to the much larger collimator leak bypassed last fall. Repairs were left undone due to fiscal and manpower constraints and because the water loss rate was manageably small. So although this new leak prevented vacuum pumping there, beam could still be delivered to TNF in the same manner as during the previous year when the vacuum volume was back-filled with helium and appropriate air monitoring was put in place. Meanwhile, plans were initiated to replace the TNF water vessel and repair the collimator in the next shutdown. One other postponed job was the repair of the M9B beam blocker – there was not enough time at the end of the busy Beam Lines schedule to take care of it, especially in view of the large amount of shielding block movement required. All the shutdown work was done with doses managed within the sliding time guidelines with the final statistics showing a total dose of 58.6 mSv distributed among 97 workers.

Beam Schedule 95

The first six weeks of high intensity production saw fairly respectable performance with beam usually run simultaneously to the four primary proton lines. (ISAC started about a week late after repairing target station water leaks.) About 92 mAh or 90% of the scheduled charge was delivered to BL1A experiments over a period of 827 hours or 92% of the scheduled time. BL2C4 received an additional 26 mAh. Downtime was relatively modest, averaging ten hours per week, two-thirds of it rf related. The total extracted current was not usually greater than 160 μA (120 μA to BL1A and 40 μA to BL2C4) because of a restricted tune set up to provide 2 ns pulse-width beam to the CHAOS experiment in M13. A good cyclotron tune was difficult to achieve at times because the Q4 radial flag used to produce the narrower pulses became stuck. Fortunately this device was found to work properly at the end of the high intensity run and it was able to be moved as required for parity tuning. The TNF water loss rate remained small and no problems were encountered there. BL2A2 received 1 μA of 500 MeV beam most of the time including one day as sole user when a special pulsed mode of operation was set up to help minimize the buildup of unwanted background decay modes. For this trial, the ISIS pepperpot was used to limit the maximum beam available to ISAC in the same manner as for proton therapy. Unfortunately the last couple of weeks of ISAC beam were marred by a failing target with calcium flakes shorting out the extraction electrodes and production was halted about a week before a scheduled ISAC shutdown. BL4 operation during the high intensity period was mostly dedicated to the long-running charge symmetry breaking experiment, occasionally punctuated by single-shift TISOL target tests in BL4A3. There were some tuning difficulties in the former resulting from an as yet unexplained lack of reproducibility in the tune energies. Finally, BL2C5 took about 75 μA during a three hour test of the Cs target and BL2C1 treated a single patient with 5 nA of 74 MeV beam.

The following five weeks of polarized operation were not as successful. Apart from a Proton Irradiation Facility (PIF) run in the first week and a proton therapy session in the fourth week, both of which went well, parity was the sole user suffering through a host of problems in the first few weeks. The cyclotron availability was only 72% during this period with nearly 175 hours of downtime, two-thirds of it rf related (sparking, IPA, and rf control system problems). The polarized ion source (I4) had vacuum and its own rf problems, and parity had additional trouble with the target vacuum, beam monitors and data acquisition system. During the first few weeks of the run, the beam was often less than optimally stable and more than the usual amount of nursing was required. Fortunately the last two weeks of polarized operation were much more successful than the first few so that parity was eventually able to accumulate half a run's worth of useful data on what may have been the end of the long running 222 MeV experiment. ISAC was in shutdown mode for the whole of the polarized schedule with a busy target hall work load in preparation for the resumption of high intensity beam. The beam shadowing configuration necessary for the parity extraction foil saw BL1A used as a dump for a few hundred nanoamps, thereby limiting any maintenance work there.

The high intensity production period following parity ran into trouble right from the start with indications that the TNF vacuum volume had unexpectedly filled with water up to the beam plane during polarized operation. Ninety litres of water were drained, then beam ran successfully for a week of 120 μA, 2 ns pulsewidth delivery. M13 users had previously made convincing arguments to lower the 1AT1 target by 2 mm but this never happened because on July 6 the TNF water loss rate became unmanageable (increasing by a factor of ten) and it was decided to cancel BL1A operation. Table XIV lists only those meson hall experiments scheduled beam to the end of week 27 in Schedule 95. The rest of that beam schedule was spent delivering beam to the other three primary proton lines in a variety of ways. For much of the time this included BL2C4 as the main high intensity user taking 20–40 μA at 85 MeV while 1 μA was circulated beyond the 2C foil to high energy probes at 500 MeV. This created beam quality problems for some modes of BL4B operation to the extent that 2C4 running was sometimes curtailed. It was also necessary to establish additional beam trip criteria to protect the machine against extraction probe 2C foil failures. This worked out well enough although it was thought that a 2 μA graphite dump located after the 1VB1 straight-through port in the vault might provide a better solution for the future. BL2A eventually came on line to take 1 μA to ISAC and later the current was carefully increased to 10 μA on a niobium target. This continued very successfully for two to three weeks at the end of the beam schedule with only a few interruptions, notably from the BL2A PLC. There were also several trips from a sensitive BSM in the 2A tunnel that diagnostic tests determined could be avoided with a wider extraction foil. At the end of the beam schedule there was a successful full-power test of the redesigned rf booster feedthrough promising that the RFB could see a return to routine operation.

With only about 23 mAh delivered to BL1A experiments in the second half of the high intensity schedule, charge availability was a very poor 48%. However, the cyclotron was in operation for 90% of the scheduled time and the TNF failure allowed an earlier start to some planned BL1A maintenance. A moderate water leak was traced to the 1AQ11 magnet which, since it could not be easily fixed in place, was removed from the beam line and taken to the hot cell for repair. This was successfully completed and the magnet reinstalled. At the same time a nearby crumbling 1A tunnel block was replaced and the new TNF vessel design was finalized and sent out for manufacture while work started on replacing the TNF collimator.

Summer/Fall Shutdown

Much lower circulating beam currents than planned had the advantage of providing a cooler machine than would have been available had BL1A delivery proceeded as scheduled. This allowed the lid to be raised in the second week of the shutdown with a shields-in survey indicating general fields about 10% less than for the previous spring. There was only a small amount of cyclotron tank work including probe inspections and repairs (the water-cooled probe had failed during the last running period), rf centre region and RFB area inspections, correction plate testing and inspections, and the replacement of an extraction 4 gate valve actuating cylinder.

The bulk of the shutdown work concerned continuing repairs in BL1A. After the repair of 1AQ11, further tests on the BL1A magnet cooling system showed there to be water losses from M9B1 and M20Q1. There was also the outstanding job of repairing the faulty M9B beam blocker. These jobs, along with the TNF repair, required a large number of concrete shielding blocks to be removed from BL1A and the assistance of an outside contractor was obtained to store some of them outside the meson hall.

The M9B1 water leak was located and successfully repaired but a smaller one believed to be somewhere in the convoluted piping to M20Q1 could not be found and plans were made instead to consider an alternate supply route in the future. The air leak at the M9B beam blocker was identified but there was not enough time to repair it as new parts needed to be fabricated; instead, the blocker was wedged out of the beam path and plans were made to repair it next shutdown.

The TNF vessel (that contains the water-cooled dump) was replaced with a new stainless steel one. This difficult job and the collimator repair were both successful – there are no longer water leaks there. Work then proceeded on restoring the integrity of the TNF vacuum tank – leaks were found and repaired on the TNF side of the 1AW2 window seal as well as at an indium-sealed blanking flange on a beam line stub projecting back from the old radio gas target area. Corrosion resulting from the previous water leaks seemed to have been a factor. A third, more elusive, air leak, that may have been intermittently present for a number of years, had to be left alone, preventing the vacuum tank from pumping down below 100 to 300 millitorr. Commissioning the rebuilt TNF and 500 MeV facility systems was completed in time for a quick 1A beam test before delivery to BL1B at the beginning of Beam Schedule 96. The total shutdown dose was 47 mSv distributed among 65 workers.

Beam Schedule 96

Beam production was much better with 100% of the scheduled charge delivered to BL1A experiments, although there were occasional problems with beam stability in both ISIS and the machine. The first week of production involved low currents to PIF with both BL2C1 and BL1B, sometimes simultaneously, used to extract beam at a variety of energies to samples located in the 1B area. This provided the opportunity to sort out a couple of minor problems in the 500 MeV facility before the targets were loaded there. Start-up to high currents went fairly well. The TNF air leak resulted in some higher activity at the vacuum pump exhaust stack which has been carefully monitored. The decision was made to continue pumping at TNF rather than revert to running in a helium atmosphere. After a problem with the T1 protect monitor was corrected, the 2 mm low target ladder at T1 was installed and worked well for the experimenters in M13. A 2 ns tune, also required by them, resulted in lower extracted currents during November but these climbed towards the usual 140 μA during December when the tight pulse timewidth requirements relaxed as M13 proceeded with lower energy particles. The schedule and year finished with a couple of important and successful tests more fully described elsewhere. The first was the two-stage 100 μA test in ISAC, first to the West Target Station dump and then to the Talbert target installed there. The second was another rf booster (RFB) test. This time, high intensity beam was run for a day with the RFB on and everything was well behaved. Apart from transmission improvements, it was shown that 2 ns pulse widths were obtained without having to use the radial flags so normal high currents of this quality beam could be extracted. The RFB is expected to see routine use next beam schedule.

In addition to 94 mAh delivered to BL1A, there were 25 mAh delivered to BL2C4 and 3.4 mAh delivered to 2A. BL2A ran 1 or 10 μA at 500 MeV fairly steadily; the chief downtime was an operator staffing problem. There was one proton therapy session (one patient) using BL2C1 at 74 MeV, and a 75 μAh 2C5 (cesium target) run. Except for one shift of beam to 4A3 every other week, BL4 remained idle for most of this schedule. Cyclotron downtime was reasonably low at 56 hours, half of it rf and one fifth from tank vacuum problems, some of which may have resulted from rf leakage on the cryopanels. The rebuilt TNF fared well and successful production during this operating period helped boost the year's charge delivery to 63% of that scheduled. Production ended on December 21 when systems were turned off in preparation for the Christmas holiday and the winter shutdown. There were no site problems as Y2K arrived.

BEAM EXTRACTION

Extraction at High Energies

Beam line 1A was not in use for several months in 1999 and the majority of the beam circulating at high energies was extracted into beam line 2A. The widest foil in the X2A carousel was 0.2 in. This beam line is not completely achromatic and measurements of beam profiles at 480 MeV had shown two peaks and evidence of a tail, these were tentatively ascribed to the distribution of energies extracted rather than to transverse phase space. Occasionally, high current operation could be inhibited by mysterious beam loss in the pipe.

The foil width is more than three times the turn spacing. The radial betatron tune is $\sim 3/2$ and one naively might expect all the beam to be extracted within two or three turns, but COMA simulations for a 2π mm mrad radial emittance showed that some particles can jump past the foil and hit it on a later turn when the betatron oscillation has a negative phase. A very few particles can just miss the inner radius on first approach and then make 7 more turns before hitting with an energy 3.5 MeV higher than the average. These few amount to $\ll 1\%$ of the beam extracted into BL2A, but could account for the high radiation fields sometimes observed. These particles would be intercepted at lower energy if the foil width were ≥ 0.3 in. but such a width requires a special carousel with fewer options. The number of high energy particles is sufficiently small that they can be removed before extraction by shadowing the X2A stripping foils with one of the internal probes of the cyclotron.

Extraction at Low Energies

Some years ago "brush" foils were developed to extract beams of tens of microamps at 65–85 MeV. These extractors consist of a closely packed array of 30 μm carbon monofilaments clamped at one end in a stainless steel frame. It was found that such an array lasts longer than solid foils under these conditions. The monofilaments are intended to overlap but there must be gaps since a solid foil 0.4 in. wide would intercept all the beam when fully inserted, whereas the brush foils transmit 3 to 5% even when new. The monofilaments curl after irradiation and on one occasion a brush foil was removed after only 5000 μAh and it was found that the strands had parted in one spot leaving a gap 0.01 in. wide.

The turn separation in the region of the brush foil is $0.29 \cos\phi_{\rm rf}$ inch. A matched and homogeneous beam approaching the foil will consist of particles with different amplitudes and phases of radial betatron oscillation and different phases with respect to the rf. Some of these particles will hit the foil once only and would be transmitted for acceleration to higher energies if there were a small gap at the point of impact. Other particles would pass through that 0.4 in. radial region more than once in the absence of a foil and, when a foil is present, they are less likely to find two gaps and survive for further acceleration. A narrow slot in the foil, therefore, would transmit a beam consisting of a series of closely spaced narrow rf phase bands and with a smaller betatron amplitude (but with the same divergence). The spacing of the phase is less than the resolution of our monitors and so we would measure a homogeneous distribution at higher energy. Close to the foil, however, the mismatched beam will rotate in radial phase space showing narrower widths every half precession cycle until it decoheres. This behaviour has been observed by a differential probe.

A gap is not necessary to cause beam modifications. We modelled a "porous" foil, i.e. one that transmits, say, 5% of the beam incident at any point, and COMA simulations showed a behaviour similar to a foil with a gap. Trajectories passing twice through a porous foil have only a 0.25% probability of transmitting a particle.

Pseudo-Tomography in the Cyclotron Beam Lines

The large TRIUMF site is divided into regions with different electrical grounds. The target entrance module is at ISAC ground but a beam profile measured there is needed to tune the BL2A proton line from the cyclotron control room. The monitor itself, which is at ISAC target ground, is optically isolated from the signal processing electronics which must be at cyclotron/BL2A ground in order to be read out in the control room.

The monitor is installed and removed by a crane since radiation fields are high. It also moves vertically to scan the beam. The vertical distribution is measured directly by a horizontal wire, but the horizontal distribution is calculated by means of a tomography-like program using signals from three wires at 45° to each other. This program had been used off-line for similar monitors in ISAC and the core was arranged to run in real time in the control computers of the cyclotron for use with BL2A equipment.

RADIO FREQUENCY SYSTEMS

RF Operations

The total cyclotron rf downtime for the year was 203 hours. The combination of sparking, crowbars and out of drivens caused 136 hours of this downtime. The next major contributor was 54 hours due to the failure of an IPA amplifier component for which we had no spare because it did not appear on the spare parts list. Great progress was made on the 92 MHz booster feedthrough. Shields were installed to prevent electric field buildup at the junction of the ceramic to metal joint. The new design was tested on two occasions with very few multipactoring problems as compared to previous conditioning periods.

RF Support

The remaining manpower load of the RF group was dedicated to the following major projects.

1. Assembly, installation, alignment and commissioning of the full complement of 19 RFQ rings for the successful rf and beam tests.

2. Manufacture, assembly and test of the 35 MHz spiral rebuncher.
3. Assembly, alignment and test of the first DTL tank. The detailed work on these projects is reported elsewhere.

RADIO FREQUENCY CONTROLS

The ISIS first harmonic (23 MHz) and second harmonic (46 MHz) bunchers, the 5:1 selector (4.6 MHz), and the rf chopper (11.5 MHz) rf control systems were replaced by a state-of-the-art system using digital signal processors housed in a VXI mainframe. Each individual frequency is synthesized by phase-locked loops using a sample voltage from the cyclotron dee. Each frequency is amplitude and phase regulated by a pair of in-phase and quadrature-phase proportional-integral-differential feedback regulators realized using a single digital signal processor. With signal bandwidths of 20 kHz for each channel, the new system provides better regulation than the old system. A SDLC link to the Central Control System allows the amplitudes and phases of the frequencies to be controlled by the CCS.

CYCLOTRON PROBES AND DIAGNOSTICS

The major efforts throughout the year were focused on improving the beam diagnostics for the ISAC west target station and the ISAC mass separator system, and providing diagnostics for the 100 μA beam test of the target provided by Amparo Corp. All other non-ISAC related 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 May 28, 1999, and November 12, 1999.

ISAC Diagnostics

The west target station entrance module profile monitor, which had been installed for beam line 2A commissioning and was described in the 1998 Annual Report, was replaced with a scanning wire monitor. The monitor scans three wires vertically: one wire reads a true vertical signal; the horizontal profile is derived from two wires which are crossed at 45° to the vertical. The monitor was successfully operated during 100 μA tests in December.

The exit module multiwire monitors ITW:harp3A and ITW:harp5A, and external monitor ITW:harp5B, described in the 1998 Annual Report, were removed to have beam shields installed to protect the pc boards during insertion through the radioactive ion beam. New collimators were installed to provide optical ground planes to prevent steering effects from the quadrupole fringe fields. The amplifier and display controls were improved to provide greater dynamic range.

The contacts on the "radiation hard" limit switches for DB0 and DB10A were found to be unreliable, so these switches were replaced. The Faraday cup wiring was redone to reduce noise picked up from the stepping motors. The DB0 harp was replaced with a vertical scanning wire; a similar device was installed in DB10A.

The Diagnostics electronics support provided control modules, cabling and system integration for the diagnostics of the new ISAC installations of LEBT and MEBT.

Probes MRO

The water cooled probe developed an air leak in the retraction bellows and was replaced with the spare unit. All other cyclotron probes were inspected but none were removed for service. During commissioning, the outer HE2 vertical potentiometer was found to be bad due to radiation damage. It was replaced and the new pot was calibrated. Four new pots have been ordered; the remaining pots on HE2 and HE1 will be replaced in 2000.

The 2A extraction probe radial drive mechanics were modified to prevent problems with the ferrofluidic feedthrough caused by its proximity to the cyclotron fringe fields. The new design relocates the motor and gear box into the vacuum space, moving the ferrofluidic seal into the centre of the magnetic shield can. A steel cover on the outside end has reduced e/m noise radiating from the R stepping motor that was causing an offset on the 2C toroid. A special large foil cartridge with a 0.400 in. wide by 1.25 in. long pyrolytic graphite foil was installed for the 100 μA test. The EX2A vault local crane rail was commissioned.

The 2C extraction probe was cleaned, inspected and re-lubricated. No heat or mechanical damage was found but the nominally rad-hard Fomblin grease is failing sooner than anticipated.

Extraction probe EX4 was removed for routine service. The R drive ball nut and screw were in need of cleaning; new Z and L cables were installed. The R drive tapes were found to be in good condition. All R support bearings were found in good condition; they were cleaned. The main member V groove was cleaned, but it should be noted that this member is still in need of replacement. The EX4 gate valve air cylinder was replaced by the Remote Handling group.

The Lytton encoders on the original cyclotron probes: EX1, EX4, HE1,2, LE1,2 etc. are in poor condition and will begin to fail at a increasing rate. There are no spares or direct replacements available. The stepping motor control system could be replaced with newer hardware similar to that used in the newer diagnostics such as the 2A extraction probe.

Monitor MRO

All vault and standard beam line monitors were serviced during the shutdowns. In spite of this, problems persist with recurring leaks in aging ferro-fluid feedthroughs, some of which fail between semi-annual maintenance. The TISOL protect monitor cabling became radiation damaged and was replaced.

VACUUM AND ENGINEERING PHYSICS

There were a number of problems with beam lines and cyclotron vacuum this year. Early in the year it was noticed that water was still being lost from the TNF water package to the vacuum space. By early July the leak became so large that further operation was not possible, and beam line 1A was shut down. A crash program to manufacture a new vessel was undertaken, and the new vessel was installed and commissioned in time for the start of Schedule 96 in November. The collimator between the former radio gas target and the 500 MeV irradiation facility was replaced at the same time. The cooling line on this collimator had failed in December, 1998.

One of the B-20 cryogenerators suffered a major bearing failure in March. This came as a total surprise. The lubricating oil is sent for analysis on a regular basis and there was no indication of impending failure. This machine was rebuilt but suffered a seal failure on two occasions when it was placed back in service. On the second occasion it was apparent that a thrust bearing was out of adjustment. As of year end, the cold head from this machine is being mated to a spare reciprocating assembly to form our second machine.

The group continued to assist the ISIS and Beam Lines personnel who installed and commissioned beam lines to the LTNO and β-NMR experiments. The group also assisted with the mounting and successful running of the Expt. 839 high current target test.

The Engineering Physics personnel worked on a number of ISAC projects. Among the tasks were revisions to the target high voltage enclosure and connections, fabrication of rf components, MEBT magnet assembly, completion of the yield station and substantial completion of a collection station.

ISIS AND POLISIS

ISIS

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 the past year as ISIS personnel were involved in the completion of ISAC projects. These included the low energy beam transport systems (LEBT), the medium energy beam transport systems (MEBT), the β-NMR beam line and the lithium beam line.

POLISIS

Parity violation experiment

The optically pumped polarized ion source (OPPIS) I4 provided very high quality H^-beam for several weeks to Expt. 497 during the spring run.

OPPIS injector for RHIC

The project to upgrade the KEK optically pumped source at TRIUMF was completed very successfully, and the source was shipped to BNL for installation at RHIC. Figure 114 shows the achieved H^- current and polarization dependence on the optically pumped rubidium cell target thickness. The upgrade has produced more than an order of magnitude increase in source current, as well as improved polarization and increased pulse length.

Progress was achieved in experiments with the sodium-jet ionizer cell (see Fig. 115). The polarized atomic H beam enters the cell and H^- ions at the exit can be accelerated to higher energy if the cell is negatively biased. Acceleration reduces current losses. Polarization is also improved, since the beam energy during spin-transfer collisions in the Rb cell can be optimized to just below 3.0 keV. Sodium losses are very low in a jet-type target, which allows the cell aperture diameter to be kept relatively large (20 mm) so as to prevent direct exposure of the biased cell parts to the

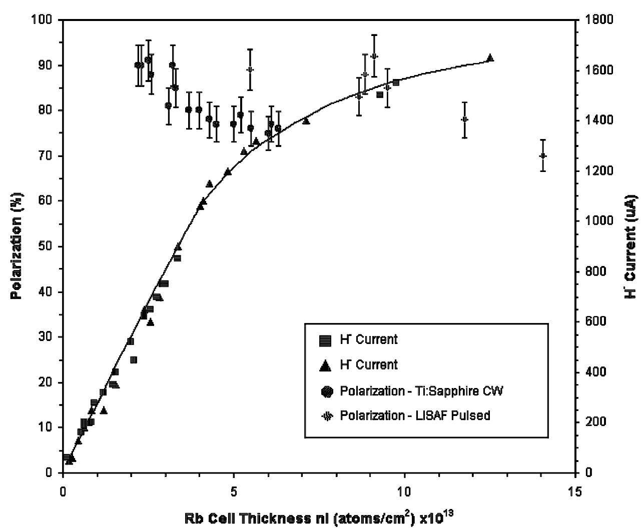

Fig. 114. H^- current and polarization vs. Rb thickness.

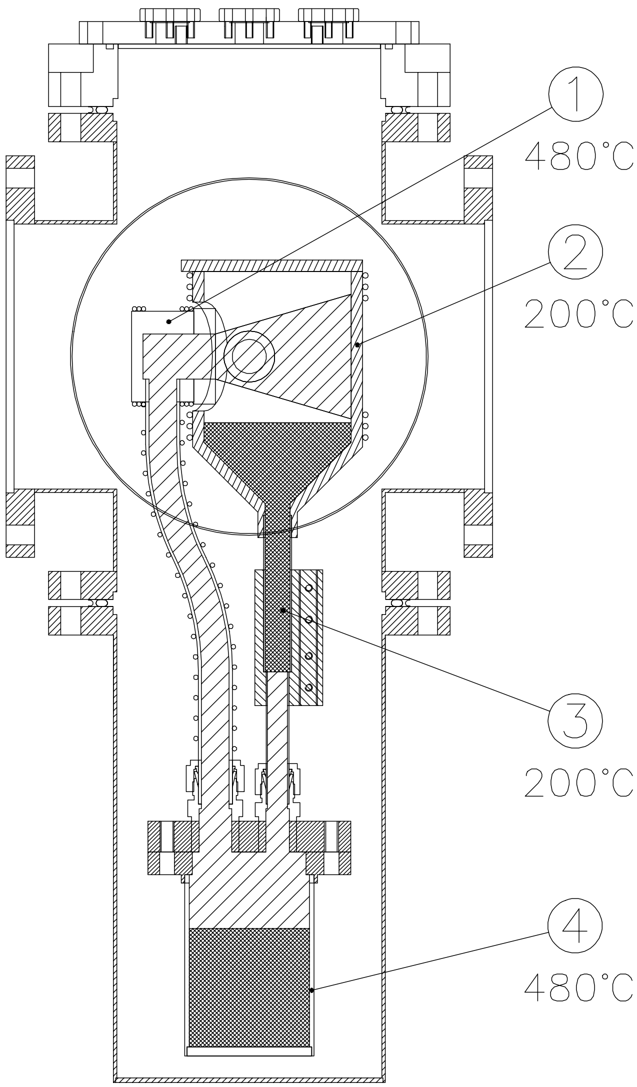

Fig. 115. Sodium-jet negative ionizer cell: 1–nozzle; 2–collector; 3–return line; 4–sodium reservoir.

atomic beam. A pulsed bias of 32 kV was applied to the cell, producing a 35 keV polarized H^- ion beam ready for injection to an RFQ. The focusing effect of the acceleration gap and improved beam transport efficiency helped to obtain an H^- current of 1.6 mA.

The proton polarization was optimized using a Lamb-shift polarimeter and measured after beam acceleration to 300 keV with a nuclear polarimeter based on the ^{6}Li(p,^{3}He)^{4}He reaction. At low Rb vapour thickness, a polarization of 85% was achieved in dc mode with a single 4.0 W Ti:sapphire laser. At higher density the polarization dropped, but the use of a pulsed Cr:LiSAF laser recovered a polarization of over 80% at a beam current of 1.6 mA.

Optical pumping development

High laser power at 795 nm ($\geq$15 W/cm^2 within the 3 GHz absorption bandwidth of Rb) is required to polarize high thickness Rb vapour in the large diameter cell of a high current OPPIS. For pulsed sources, pulsed lasers easily supply enough power. Good results had been obtained previously with a flashlamp-pumped Ti:sapphire laser, but the lifetime of the upper level in Ti:sapphire is only 3.4 μs and laser efficiency is low in long pulse operation. An excellent replacement for the pulsed Ti:sapphire laser is the Cr:LiSAF laser. It has a 67 μs upper level lifetime and maximum emission is at 850 nm. At 795 nm, close to the end of its tuning range, peak power of 300 W was obtained in a 400 μs pulse, with a relatively low 70 J input energy from a single flashlamp. This performance was obtained by cooling the LiSAF crystal to 10°C. A three plate birefringent filter and 0.2 mm thick uncoated etalon reduced the laser bandwidth to 12 GHz.

The peak emission wavelength of 850 nm is particularly suitable for direct optical pumping of cesium vapour. Cesium has a higher radiation trapping limit on density than Rb and therefore can make a thicker or more compact target than Rb, useful for increasing the source current and developing polarization schemes based on spin exchange. Thick Cs vapour can also be polarized through spin exchange with a polarized alkali-metal vapour. An experiment was carried out where Cs and Rb were loaded together into the source and heated to between 80 and 150°C. The pumping LiSAF laser was tuned for Rb and a probe laser at 852 nm monitored the Cs polarization, using Faraday rotation. Cesium polarization of 72% was measured at a Cs thickness of 12×10^{14} atoms cm^{-2}, which is much better than can be achieved by direct optical pumping of Cs at this density. The Rb thickness was measured to be 4×10^{14} atoms cm^{-2} and its polarization was near 100%. The results show that optical pumping of a Cs-Rb mixture is very promising for use in a pulsed, high-current OPPIS, in schemes where very high thicknesses are required. A very thick polarized Cs target could be used to polarize atomic hydrogen through spin exchange.

PRIMARY BEAM LINES

During the past year the Beam Lines group was primarily involved with ISAC-related tasks. Most of the group worked full time on projects related to facility installations. Because of this commitment to ISAC, only minimal support was available to beam line 1A and other primary beam lines.

Some idea of the scope of the projects undertaken by the group may be gained from the following list.

1. Alignment of the platen of the radio frequency quadrupole.
2. Installation of the remote handling hot cell turntable.

3. Installation of the stands, quadrupoles and services of the MEBT.
4. Installation of the basic components of the yield station.
5. Installation and alignment of components of the DRAGON facility.
6. Concepts and general assistance for the DTL triplet design.
7. Installation and alignment of the stands for the β-NMR facility.

In addition to the above, assistance was provided to other groups to enable them to meet their deadlines in the areas of general services, vacuum systems and component assemblies.

As for the existing beam lines, the most serious problem that arose during the year was the failure of the TNF water vessel. This vessel encloses the beam dump at the end of beam line 1A in the meson hall. Because of this failure there was no beam delivery to beam line 1A from early July through October. During that period a new vessel was fabricated and it was installed in late October. In addition, a copper collimator upstream of the TNF was also replaced because of a leak in its cooling lines.

During the construction of the new water vessel, other water leaks in the 1AT2 region were discovered. A water leak at 1AQ11 was found and, in order to repair it, it was necessary to remove the 1AQ10/11 doublet from the beam line and make repairs in the warm cell. A cracked copper header was found to be the source of the leak. Fortunately, it was repairable in the warm cell. Following repair, the two quadrupoles were reinstalled in the beam line.

Further investigation of water leaks in the 1AT2 area revealed that, in addition to a known leak in the triplet downstream of the 1AT2 target, there were two other leaks – one at the first dipole of the M9 channel and the other at the first quadrupole of the M20 channel. For the former, the solution was to replace the existing supply and return lines with more durable stainless steel tubing and flexible hose. In the case of the latter, the source of the leak was again in the lines between the magnet and the headers. However, in this instance the exact location could not be determined because the lines are hidden under the shielding of beam line 1A. It is proposed to fix this leak using unused lines from the M8 channel, with some of this work being started in the next shutdown.

In addition to the water leak at the M9 dipole location, a significant vacuum leak there was repaired. A failed bellows unit was replaced with a temporary cap while a new replacement was fabricated. The new unit is now available for installation.

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, the high current beam schedule was increased so that production was similar to 1996 and 1997 levels. There were 118 days of ^{82}Sr production in 1999 for a dose of 70.73 mAh and a yield of 26.87 Ci at the end of bombardment. This was a significant increase over 1998 production of 85 days for a dose of 55.32 mAh and a yield of 21.9 Ci. There were seven natural rubidium targets used for the 1999 production. 2C4 ran in June and July as the sole high current user or against 2A while 1A was off for TNF problems. 2C current was limited during this period because 5% of the circulating beam passed through the 2C extraction foil so the current limit on the high energy probes was reached at 30 μA extracted. The current could be increased when 2A took some of this beam. The STF water package was modified to increase the production of ^{11}C for the cold positron facility. The STF water package was also modified so that radioactive air in the cool water reservoir could be captured in an air ballast bag and allowed to decay before release. This was required in case a rubidium target ruptured in the cooling water.

2C1 was used for approximately 38 days with the time being shared by the proton irradiation facility (PIF) and proton therapy. Seven proton therapy sessions were scheduled. The cesium target on 2C5 operated four times at 105 MeV with intensities up to 25 μA to produce ^{127}Xe. It was run for a total of 17 hours with a dose of 238 μAh. A rad-hard ball valve was added to the plumbing connection between the 2C5 beamstop and STF water package, and the 2C targets safety TRIMAC was modified accordingly. Commissioning without beam has started on the NaI target in 2C3.

CONTROLS

The Central Control System (CCS) ran well during 1999, providing the required operational functions while incurring only a minor amount of cyclotron downtime. The beam downtime attributed to the CCS as recorded by the Operations group was 5.5 hours. None of the problems leading to this downtime took more than 1 hour to repair. With improved hardware and software diagnostics, many problems are now discovered before the trouble escalates to preventing beam delivery. Nonetheless, minor and more major failures will happen periodically. In addition to the problems causing downtime, there were also numerous problems, such as console X terminal display failures, that occurred but did not prevent cyclotron operation.

The CCS's evolution and renewal continued. The program of slowly replacing old and obsolete equipment progressed with one VAX being removed while a new Alpha was readied for installation. A small amount of aging CAMAC and network equipment was replaced and/or phased out. During the next year, we expect to see the site network and its infrastructure improved. A variety of software components were upgraded and there has been a trend to PC use for many of the office related activities such as email, and to provide X Window terminal support.

One serious problem that could have resulted in downtime was narrowly avoided. This occurred when a third party software product was sold by the company that developed it to another company and the licensing which was about to expire was repriced creating an unbudgeted expense.

CCS Facilities

The CCS hardware has changed in a number of ways. For CCS CPUs with a PCI bus, the previous computer-to-CAMAC link has been replaced with redesigned electronics and software. This new configuration is simpler and supports more Executive Crates per computer bus slot than the old hardware. Further enhancements to this interface are under consideration. The last of the primary VAXes in the Production Cluster was removed, leaving only the Beam Line 2C MicroVAX still in use there. Three other VAXes continued to be used; one for proton therapy, one for software development, and one for diagnostics. A plan exists to replace the existing beam line 2C VAX with an Alpha early in the new year and to replace the proton therapy VAX before the end of 2000. Several PCs were bought to replace X Window terminals and when another disk was purchased, a major reorganization of the existing disks proceeded.

CCS software was also evolving. There were numerous instances of changes but only three examples will be cited. The primary display program known as XTpage was enhanced to support an additional level of security beyond the existing access control list on its executable image. The new feature allows restricted access by username to commands on a per page basis. In another development, previous requests for comprehensive control of the ISIS pulser were combined with new requirements from ISAC target users to specify a pulser control page. In still another area, changes were made to the safety vertical and touch screen displays to reflect safety system changes and ergonomic requests from Operations. Some of the infrastructural software was also changed. Alpha OpenVMS went to version 7.2, Multinet to version 4.2, Oracle to version 8, and the network hub firmware was upgraded.

There was a significant increase in the use of PCs by Controls group members. The PCs were commonly used as X Window terminal replacements, for accessing the new mail server, for running Web browsers, and for a variety of other functions. A better tape backup system and procedure was set up for the PC servers. This backup procedure should be extended to the rest of the Controls group PCs in the next year.

The existing X Window terminals, of which there are approximately 50 supported by the Controls group, have functioned very well but are now failing frequently. No replacement strategy or funding has been established but the hardware failures are increasing greatly and repairs are not always possible. In addition to the reliability issue, the performance of this existing hardware is well below the current technology.

There were a number of problems in addition to the numerous X terminal failures. The stepping motor control system frequently needs attention and is badly in need of replacement. This is a critical system in that it runs most of the extraction and other probes in the cyclotron. Network problems also arose during the year. There was a hub power supply failure, DECnet area routing issues, and a serious bug in a new version of the TCP/IP software. The CAMAC system ran very well but due to its large size and aging equipment there were numerous CAMAC related hardware problems, particularly after power outages. Errors occurred in the SDLC link to ISAC, there were a number of CAMAC power supply failures, a difficult problem with the A2 line in the Executive crate, and a host of failures in ADCs, DACs, and other modules. An unusual problem occurred when the breaker on a uninterruptable power system (UPS) circuit failed. The vastly improved UPS on site has resulted in a significant improvement in the CCS performance through power outages and this UPS breaker problem was an isolated event. Unfortunately, not all of the CCS is on UPS.

Other Systems

Support was provided as necessary for beam line 2A and ISAC activities. One development involved using the ISIS pulser to turn the beam on and off for given durations in order to test specific characteristics of an ISAC target. Another instance involved monitoring thermocouples during ISAC's Talbert test.

Beam line 2C support continued at a modest level. One of the software staff went for Vista control system (VSYS) training and subsequently started planning for meeting Vista Y2K requirements, the move from a VAX to an Alpha, and the upgrade to VSYS version 4.2. The switch to an Alpha should occur early in the new year, during the shutdown.

Year 2000 issues were investigated in advance of year end. One small bug was found during testing and was corrected. Although testing had occurred on the CCS, because the cyclotron would be off over the New Year period, Y2K problems were not anticipated to be a concern.

Proton therapy and the parity experiment both received support as necessary.

Miscellaneous

Another collaboration with the TRIUMF librarian started and continued into the new year. This effort was to improve the user interface and database characteristics of the software application which supports journal and book invoices and acquisitions logging, withdrawals and returns from TRIUMF's library, and other functions.

OPERATIONAL SERVICES

Remote Handling

ISAC

Remote Handling personnel were heavily involved in ISAC related activities. Work continues towards completion of the first hot cell, development of the remote target hall crane system and initial commissioning of targets and beam optics modules.

The original CaO and the new Nb surface source production targets were both successfully replaced in the hot cell. The water cooled proton beam window upstream of the ISAC ITW vacuum tank on beam line 2A was re-fit with metal seals.

The target hall crane is now fully operable in remote mode, complete with all safety interlocks, from the ISAC remote handling control room. Improved CCTV viewing, position feedbacks and assembly of a permanent control console are under way.

New, revised design target modules #2 and #3 were constructed by Remote Handling personnel. Module #2 was adapted during construction to support a unique 100 μA beam heated Ta target, used successfully for a thermal heat transfer experiment.

Cyclotron servicing

For the spring shutdown Remote Handling performed a full installation of tank peripheral shadow shielding, removed the 2C extraction probe for service, and assisted with the replacement of the vacuum tank inner seal. During this shutdown an actuator seal spool was replaced on the extraction-IV gate valve and a new Cu beam spill blocker positioned in the tank.

Beam lines servicing

During July and August a cooling water leak on the supply header of 1AQ11 downstream of the 1AT1 target required the remote removal of the 1AQ10/11 doublet from the beam line to the warm cell facility for repair of a failed Cu plumbing joint.

An extensive water leak into the sealed vacuum system of the 1A beam dump at the TNF facility halted beam operation in mid summer. A weld failure in the aluminum dump cooling vessel was found to be responsible. A new stainless steel cooling storage vessel of an improved design was fast tracked through the design office and an outside fabricator, and installed remotely in September. A previously leaking water cooled Cu beam collimator upstream of the dump was also newly built and replaced at this time.

During the attempts to commission the TNF system, a significant air to vacuum leak was discovered at the 1AW2 water cooled window on the upstream side of the vacuum vessel. The fault was found to be severe corrosion of the indium vacuum seal due to the water flooding. This required remote removal, cleaning and replacement with a new cooled window unit. The same corrosion caused a failure of a blanking flange seal at the former TNF radio gas beam line port. Access to this area required extensive dismantling of the TNF area steel and concrete shielding.

Hot cells and targets

It was a busy year for the Remote Handling hot cells facility.

Assistance was given to adapt a resin filter can and shielding flask to filter the TNF cooling water during the initial leak in January.

In February the first ISAC CaO target was transferred from the target hall to the warm cell facility in the meson hall for inspection, disassembly, photo documentation and gamma spectrometry analysis.

During the spring months, the 1AT1 and T2 cooling packages were drained, serviced and refilled. The 1AT2/M20 beam blocker was serviced and the supply air pressure increased to assist operation. The 1AT2-Mk2 target was replaced in beam line operation by the Mk1 target assembly.

In the summer the 1AT1-Mk1 target ladder was realigned at a 2 mm lower position by request. The TNF area active storage site was monitored and rearranged in preparation for the TNF cooling vessel replacement. The hot cells lab area was utilized by TSG to perform active materials storage barrel scans. The warm cell was prepared and used for repair of the 1AQ11 magnet water leak.

The fall months were occupied with the replacement of the TNF water vessel and collimator. The 1AT2 water package was serviced, the 1AT1 target assembly was replaced and repaired, and the 1AT2 target exchanged. Design began for an upgrade of the 1AT2/M20 beam blocker actuator.

Magnet Power Supplies

1999 saw the installation and commissioning of power supplies for ISAC MEBT as well as the purchase of supplies for the DTL and the DRAGON facility. Preliminary work was done to define the power supply requirements for HEBT and TUDA which will be purchased next fiscal year.

M8 power supplies were decommissioned and moved to the ISAC facility.

For the existing TRIUMF facility, activity was mostly routine MRO with experimental support provided as required. Leaking heat sinks from transistor pass banks continue to be a problem and these are being replaced on an ongoing basis.

We experienced a number of failures with the Entrelec polarity switches installed in beam line 1A and M13 and these will have to be replaced. Welding cable which had been installed on M13 power supplies is experiencing deterioration of insulation and will be replaced with standard RW90 4/0 cable during the spring shutdown.

Planned shutdown activity includes calibration of all trim and harmonic power supplies as well as those for beam line 1A.

Electrical Systems

The electrical department continued to be actively and heavily involved in the ISAC installations. In addition there was the handling of plant maintenance, including the power distribution system and lighting, and support to the other TRIUMF users. The department proceeded with 51 installations, which were required to provide infrastructure support as well as experimental support, and responded to 149 trouble calls as well as numerous minor requests. Lighting ballast replacement was a continuing activity.

The most relevant maintenance activities included the replacement of the main electrical distribution panel in the main office building, the replacement of four water pump motors in the service annex basement and on the rf floor, the removal of M8 power supplies for use in ISAC, the replacement of the dc wiring in M13, additional UPS power distribution, upgrade of the outside lighting, and new cafeteria services. Installations included the power distribution for the ion source test stand, services for the ATLAS clean room, a new power distribution for the remaining trailers south of the accelerator building, and the carpenter shop. The fire alarm system device database was completed in August, and the “as-built” drawings were updated in October at the same time as the annual inspection.

Power Delivery

Power management continued as a routine activity. The monthly averaged peak power demand edged up almost 2% to 5968 kVA from 5856 kVA last year (Fig. 116). The largest peak was reached in May with 8932 kVA. The electricity consumption jumped a solid 12% to 47.4 GWh from 42.1 GWh (Fig. 117). The largest consumption occurred in July (5.86 GWh). The power factor, averaged over the calendar year, dropped a marginal 0.5% to 96.6% from 97.1% (Fig. 118).

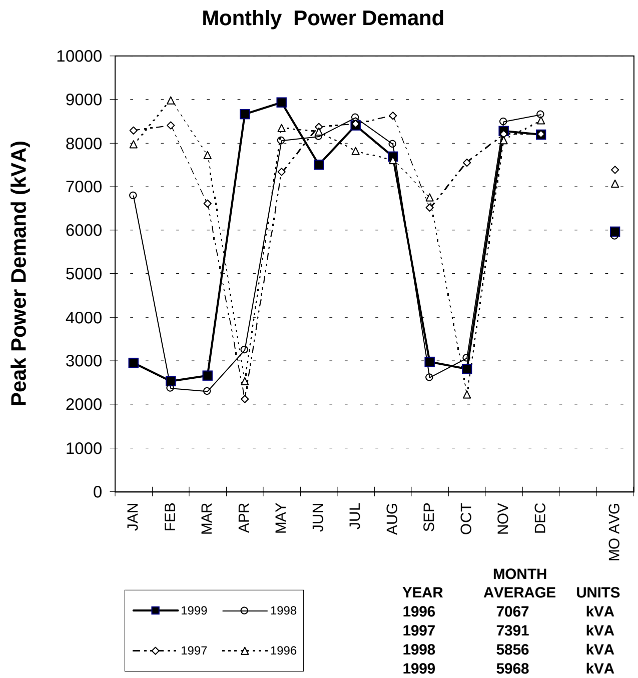

Fig. 116. Electrical system power demand – four year comparison.

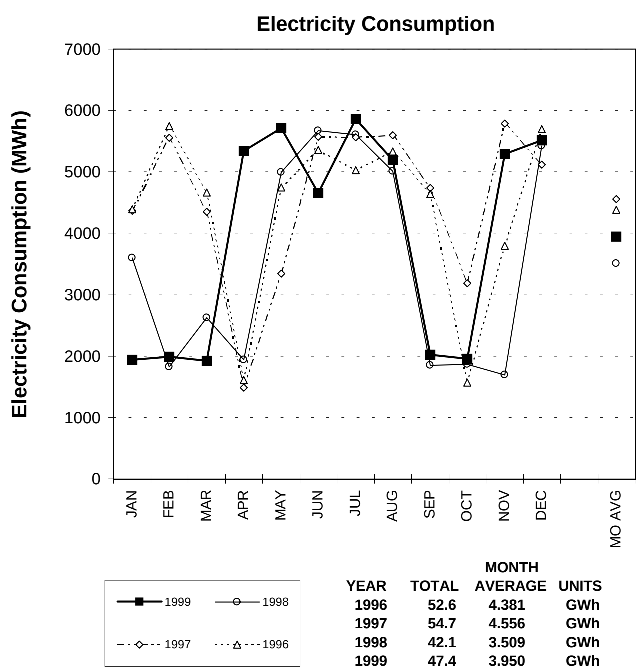

Fig. 117. Electrical system energy consumption – four year comparison.

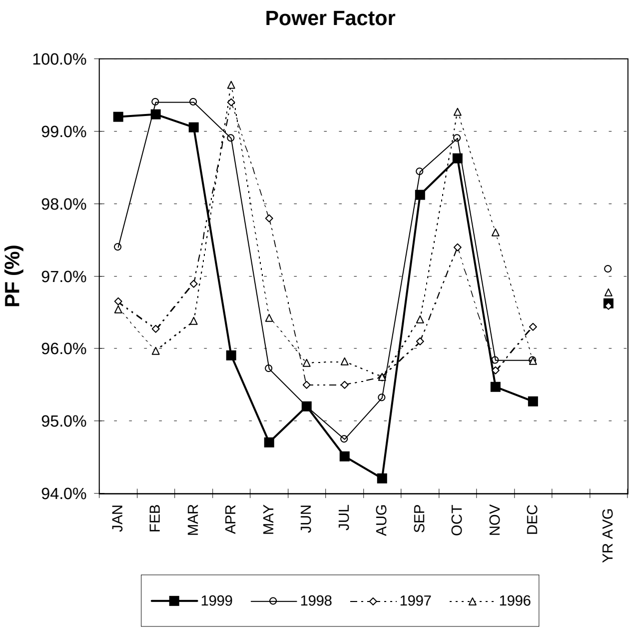

Fig. 118. Electrical system power factor – four year comparison.

The decrease would be just above 1.2% when we consider the operational months alone. This trend was anticipated to occur with the beginning of the ISAC experimental program, and is expected to be accentuated next year as more ISAC facilities are brought into operation.

Mechanical Systems

The TRIUMF site mechanical equipment underwent several large repair and upgrade projects. Three of the five major low conductivity water systems had their pumps substantially reworked. The AlALCW main circulation cast iron pump was replaced with an all-stainless pump due to corrosion problems from the very high resistivity water. A new smaller motor was installed as the pump was sized smaller in order to avoid the severe valving of the former pump. (System operating demand is smaller than originally designed.) The two CuALCW circulation pumps were upgraded because of increasing demand: the 3600 RPM Goulds pump received a larger impeller and motor, and the 1800 RPM Leitch pump was sped up to 3600 RPM, the impeller cut back, and the motor hp increased. The CuLCW pumps had their impellers cut back to reflect reduced demand, and to avoid severe valving. In all three systems, bypasses were installed around the pumps to better allow for flow demand changes over time. The pumps are slightly oversized, and new demands can be met by reducing bypass flows, and vice versa. Other replacement jobs during the year were due to failures: old Chemistry Annex 35 ton water chiller system for air conditioning, air conditioning systems for the Gerber and telephone exchange rooms, rf room heating coil, refrigeration compressor for the control room air conditioning water chiller, and pipe lengths corroded through with age. A screen was installed on the cooling water supply to the rf room to protect against unwanted solids. Other jobs included repair of the vault crane horn and jog speed, the demolition of the old TRINAT room, annual sprinkler and crane inspections, and annual site radioactive exhaust HEPA filter acceptance tests. Studies were undertaken for various proposals including new testable charcoal and HEPA filter exhaust systems for the old chemistry annex, and use of the medical annex and MESA for a TR13 and hot cell lab.

ISAC mechanical project work was aimed toward readiness for beam production and included the completion and commissioning of the nuclear exhaust zoning system and the high active, or target, cooling water system. In the case of the exhaust system it entailed final connections to the target caves and hot cells and installation of related HEPA filters, control systems, dampers, and alarms. The inter-zone doorways were given gauges and labels to allow personnel to ascertain correct zoning operation before entering. Upon mechanical completion, the system was balanced to obtain the prescribed zone differential pressures. The system responded exactly as intended with increasing depressions provided as one moves from the outside world into three sequential zones. The high active water cooling system was completed and commissioned for use in RIB production. Various scenarios of filling, venting, operation, mechanical and electrical failure modes for ensured backup pump operation were demonstrated. At completion, detailed operating instructions were issued and reviewed with operations staff. Other work may be classified as providing mechanical services to various areas of ISAC: water, gas and exhaust for room 06 fume hoods; completion of HVAC system for the new Design Office; completion of TRINAT clean room HVAC and cooling water; and compressed air into the RH room. The largest effort was in the experimental hall where temperature regulated and non-regulated water, compressed air, and vacuum roughing and exhaust lines were run and connected for LEBT, MEBT, β-NMR, GPS, and mezzanine power supplies. Starts were made for the DTL and DRAGON services. Design work and orders were completed for the TRINAT floor cooling water return pressure control system. Engineering assistance was provided to various areas including: orifice hole re-sizing for Chalk River flow switches, flow rate calculations for drift tube spiral and MEBT buncher, and rough modelling of thermal expansion of the DTL end plates. Cost estimates were provided for a proposed target hall washroom and ISAC-II.