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OCTOBER 2002

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CYCLOTRON OPERATIONS DIVISION

INTRODUCTION

The good performance achieved during year 2000 in terms of cyclotron availability and beam production was maintained during 2001, with 92.4% availability for scheduled cyclotron hours and 95% for scheduled BL1A beam charge. The recently installed beam line 2A and 2A extraction probe were very reliable, and did not cause significant downtime for ISAC. While the 2A maximum operating proton beam current was gradually increased to 40 μA, attention had to be paid toward reducing the occurrence of 2A beam spill monitor trips caused by occasional beam deviations, related to sudden beam energy variations at extraction, produced by beam instabilities at cyclotron injection. Extracting the 2A beam in the shadow of the 1A stripping foil helped reduce the amplitude of these transverse beam perturbations. In addition, increasing the horizontal aperture of two protect monitors down 2A increased the energy acceptance of the beam line, making its protection systems less sensitive to small energy instabilities. The facility which experienced most problems was beam line 2C4, for the production of ^{82}Sr. Most problems originated from the fact that after the winter 2001 shutdown maintenance, the solid target facility (STF) could not be properly realigned. The entrance channel defining the beam acceptance was found rotated horizontally by 20 mrad. To avoid the lengthy realignment work of the STF in the cyclotron vault and the corresponding high dose exposure, it was decided to redirect the incident proton beam with the help of a newly installed powerful steering magnet, so it would match the rotated target channel acceptance. Installation and adjustment of the new magnet could be performed during shutdown or maintenance periods.

Toward year-end, high intensity beam delivery was hampered by water leaks and became very unpredictable to say the least. A small water leak in the quadrupole triplet downstream of T2 increased gradually during the fall. The rather complex intervention on this leak could have taken place only during a major shutdown. It was therefore decided to operate with the increased leak rate up to the point where reduced water cooling could have jeopardized the integrity of quadrupole coils. The danger limit for thermal damage was reached right at the end of the high intensity schedule, not causing, therefore, interruptions to the high intensity beam production. The triplet water leak triggered a shift in site priorities. Part of the planned T2 area refurbishing was actually scheduled for the 2002 winter shutdown. In addition to the triplet repair, it became necessary to proceed with the removal of the obsolete M8 secondary beam line and with the installation of the new shielding configuration around M8 and triplet to prepare for the future triplet replacement. The design work for the reconfiguration of the area had actually been brought ahead during 2001, so that most of the new shielding blocks (concrete and iron) could actually be manufactured and procured before year-end.

No cyclotron developments had been budgeted for during the 1995–2000 five year plan and all cyclotron accelerator resources not immediately required for operations or maintenance were assigned to ISAC projects. One important exception, however, came as a byproduct of work on ISAC rf cavities and could go ahead since it did not require significant funding or manpower resources. This is a reliably operating 4th harmonic rf booster cavity. The booster had been conceived and prototyped during KAON studies, but had never been operated reliably because of an inadequate rf coupler. The coupler problem was solved and reliable operation of the booster could start. The cavity would provide two important features: (1) it would allow the reduction by about a factor of two of the time length of a single rf beam pulse, to about 2 ns (as requested by the CHAOS experiment); (2) it would also allow the reduction of the H^- beam electromagnetic stripping losses by about 30% because of the two-fold increase in energy gain per turn at high cyclotron beam energies. This would allow the total extracted current to be increased in future from ~200 μA to 300 μA without increasing total beam losses or cyclotron activation beyond levels previously reached at 200 μA without booster operation.

With the new five year plan, which started in April, 2000, the drastic policy of not allowing developments and improvements to the cyclotron was modified. Developments in the direction of an increase of the total intensity of the cyclotron beam were authorized. Development beam shifts were scheduled again and a beam physicist was assigned to cyclotron beam studies. The 300 μA goal, which will allow us to satisfy ISAC beam requirements without reducing the beam intensity delivered to present users, was given priority. A 250 μA intermediate step was given higher priority in order to satisfy immediate ISAC requirements. By year-end a tune of 250 μA peak had been achieved in a ~50% duty cyclotron mode with >60% cyclotron acceptance. A 300 μA peak had also been achieved at 50% duty cycle, but only with 50% acceptance. An analysis of beam losses through the cyclotron showed that, for the 300 μA beam, a significant loss of intensity occurred in the cyclotron centre region around the second or third turn. Electrode overheating was also localized to the first quarter turn after injection. The insertion of a water cooled beam scraper to protect the overheating electrodes, together with a close inspection of the centre region at the second or third turn radius, were planned for the coming winter shutdown.

A cyclotron refurbishing program, started in April, 2000, continued in 2001 as planned in the current five year plan. A major accomplishment was the overhaul of the vault section of BL1A and the radiation hardening, or rearrangement to locations not directly exposed to cyclotron radiation, of electric cables, water hoses, and other non-radiation-hard components. Another major undertaking was the replacement, before year-end, of three large distribution power transformers (1250 kVA, 1250 kVA, and 750 kVA) after it was determined that the quality of the insulation had diminished below acceptable standards. The Ascarel insulating oil (PCB) was an environmental risk in case of failures, earthquake, or fire damage. The replacement of the transformers with new environment-friendly units was flawless and occurred during the Christmas break week, causing minimum disruption to the laboratory.

Another completed refurbishing initiative was the procurement and installation of eight new regenerators in the two 20 K B20 cryosystems serving the cyclotron tank cryopanels. New compressors were also installed in several injection line cryopumps. Modifications were introduced in the cyclotron high energy probes and in beam line monitors for reliable operation. In the central control system, obsolete or inefficient components were replaced with recent upgraded technology. A new waster load and refurbished combiners were produced for the main rf amplifier system. New reliable polarity switches were installed for some of the beam line power supplies.

Refurbishing work will continue over the remaining three years of the five year plan. High priority items include: (1) completion of the work in BL1A extension between T2 and TNF with the installation of the new replacement triplet; (2) refurbishing of the BL2C4 isotope production station; (3) replacement of the vacuum control system; and (4) replacement of the control system for resonator tip tuning and completion of the rf amplifier refurbishing. High priority should also be given to the area around the T1 target including the replacement of the M11 septum magnet.

The first two years of the plan have been addressing very urgent requirements. In a few cases they were very timely indeed. It is essential that the priority for cyclotron refurbishing be enhanced and maintained at a high level.

BEAM PRODUCTION

Beam delivery for 2001 was quite successful with production very similar to the previous year. Cyclotron performance continued to be enhanced by the use of the rf booster which was on during most of the high current running, partly to satisfy the occasional demand for 2 ns pulse-width beam but also to improve the cyclotron transmission (typically between 60% and 65%) and reduce the tank beam spill. Eighteen weeks of shutdown left 5075 hours scheduled for beam operation. The cyclotron was actually available for 4680 hours, with an above average availability of 92.4%. Totals include 230 hours for development and tuning and, as shown in Fig. 132, were split roughly 10:1 between high current beam production and low intensity operation, namely the proton irradiation facility (PIF) production in 1B/2C1. As Fig. 133 shows, the total beam charge delivered to meson hall experiments along BL1A was 481 mA h or 95% of that scheduled, one of the better results for the past ten years, although the total charge was lower than some years because of current limitations while using graphite targets at 1AT1. In addition to the BL1A charge, there were 84 mA h delivered at 85 MeV to the solid target facility (STF) in beam line 2C4 for the production of radiopharmaceutical generators, as well as 37 mA h, triple the previous year's charge, to the west target station in BL2A2 for the production of radioactive ion beams (RIB) in ISAC. A maximum total of 210 μA was extracted down the three operating proton lines. Seven patients were treated for ocular melanoma during four proton therapy (PT) sessions in beam line 2C1 operated at 74 MeV. The annual downtime of 372 hours (Fig. 134) was well below average with the rf, as usual, responsible for the greatest share of this time (48%) followed by power failures (14%) and power supply problems (9%). The operational record and beam to experiments for the year 2001 are given in Tables XV and XVI.

Winter Shutdown

Cyclotron shutdown activities began early in January. The extent and complexity of some of the tasks, especially those in high radiation fields, as well as competing demands for key personnel in other areas, contributed to a revision of the original shutdown schedule, extending it about two weeks in order to achieve the desired goals.

In the cyclotron vault a long-anticipated electrical and cooling services upgrade to the front end of BL1 took place with modifications to the combination magnet (CM1), the first three quadrupole magnets (1VQ1, Q2 and Q3) and the dipole magnet (1VB1). In order to minimize dose exposure from residual activation, work

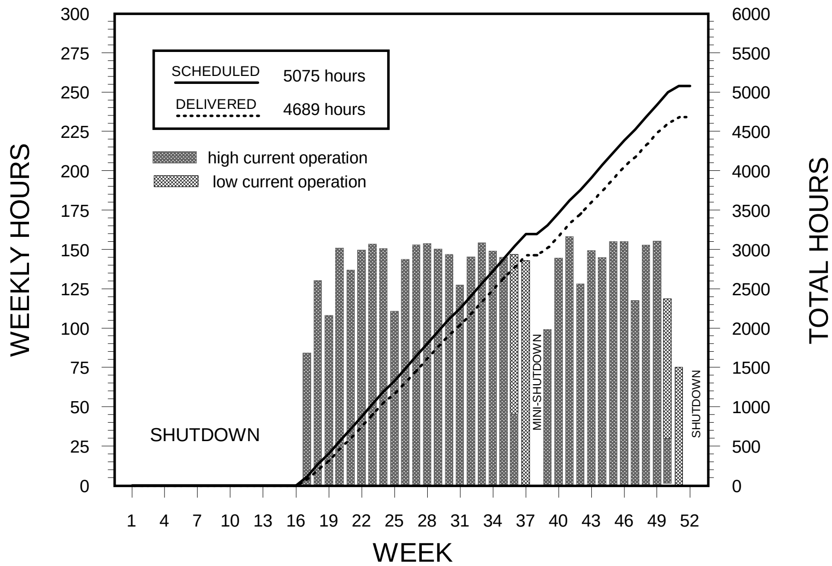

Fig. 132. Operational hours for 2001.

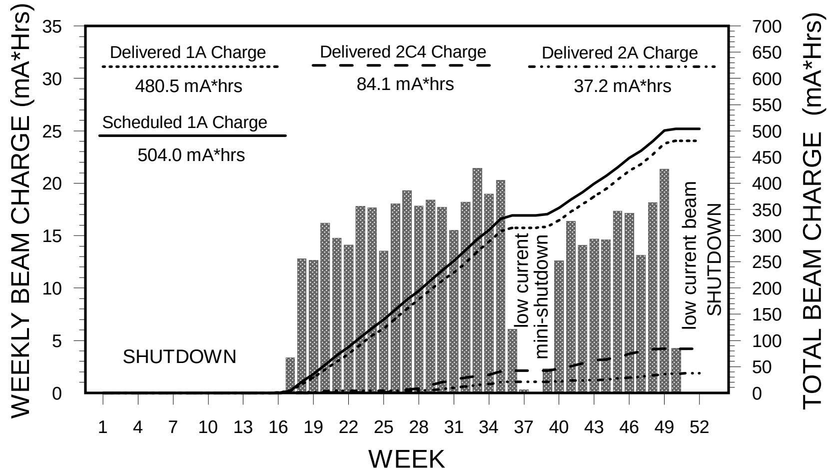

Fig. 133. Beam delivery for 2001.

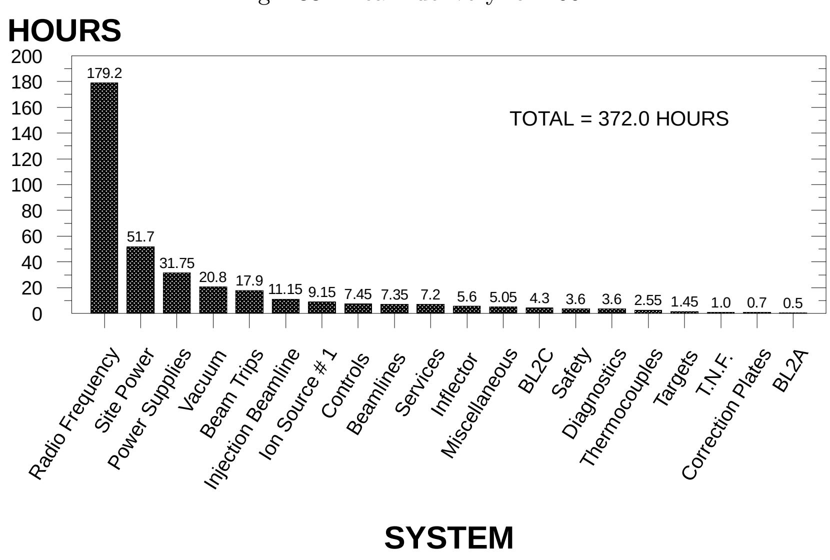

Fig. 134. Cyclotron downtime for 2001.

Table XV. Operational record for 2001.

	Scheduled hours			Actual hours		
Cyclotron off:						
Maintenance	391.0			414.80		
Startup	221.0			172.40		
Shutdown	3028.5			3027.00		
Other	0.0			6.50		
Cyclotron downtime	0.0			372.00		
Overhead	20.5			54.35		
Totals	3661.0			4047.05		
Cyclotron on:						
Development	146.0	+	0.0 P*	136.45	+	0.00 P
Cyclotron tuning	278.5	+	0.0 P	94.05	+	0.00 P
Beam to experiments	4650.5	+	0.0 P	4458.45	+	0.00 P
Totals	5075.0	+	0.0 P	4688.95	+	0.00 P
Actual/Scheduled = 4688.95/5075.0 = 92.4% availability						
Beam to experiments:						
1A Production	4245.5	+	0.0 P	4052.35	+	0.00 P
1A Development/tuning	4.0	+	0.0 P	7.65	+	0.00 P
1A Down/open/no user	147.0	+	0.0 P	178.85	+	0.00 P
1B Production	242.0	+	0.0 P	36.00	+	0.00 P
1B Development/tuning	0.0	+	0.0 P	4.40	+	0.00 P
1B Down/open/no user	12.0	+	0.0 P	179.20	+	0.00 P
Total 1A+1B production	4487.5	+	0.0 P	4088.35	+	0.00 P
2A2 Production	3356.5	+	0.0 P	2706.20	+	0.00 P
2A2 Development/tuning	0.0	+	0.0 P	14.70	+	0.00 P
2A2 Down/open/no user	1294.0	+	0.0 P	1737.55	+	0.00 P
2C1 Production/tests	648.0	+	0.0 P	148.45	+	0.00 P
2C1 Development/tuning	0.0	+	0.0 P	2.15	+	0.00 P
2C1 Down/open/no user	783.0	+	0.0 P	1146.90	+	0.00 P
2C4 Production+tests	3215.5	+	0.0 P	1947.55	+	0.00 P
2C4 Development/tuning	0.0	+	0.0 P	128.75	+	0.00 P
2C4 Down/open/no user	4.0	+	0.0 P	1084.65	+	0.00 P
1A Beam charge	503,957 μA h			480,546 μA h		
2A Beam charge	45,111 μA h			37,172 μA h		
2C4 Beam charge	153,750 μA h			84,117 μA h		

P = Polarized source on-line (although not necessarily polarized beam)
*There was no BL4 production this year; nor was the POL (I4) source used.

Table XVI. Beam to experiments for 2001.

			Scheduled		Delivered	
Experiment *	Channel	Schedule#	h	μA h	h	μA h
334	M9B	99	208.0	27040	204.60	24978
614	M13	99	746.0	104210	718.70	100351
614	M13	100	1547.0	165847	1485.70	164545
677	M20B	100	123.0	17220	124.80	17702
744	M9A	100	700.0	79775	693.95	78483
746	M15	100	150.0	19550	154.20	19950
751	M15	99	150.0	21230	144.50	18513
768	M15	99	277.0	24920	244.65	21916
775	M20B	99	150.0	8640	119.15	6653
775	M20B	100	146.0	16790	136.55	15603
777	M15	99	92.0	11040	89.45	9912
777	M20B	99	150.0	19500	153.10	19349
782	M15	99	150.0	19500	153.10	19349
783	M15	99	150.0	19500	124.15	15602
784	M20B	99	150.0	21000	150.20	22300
791	M15	99	119.0	14930	102.50	11768
791	M20B	99	127.0	15240	129.45	14958
791	M15	100	128.0	14195	136.25	15028
804	M20B	99	150.0	18000	147.45	16250
804	M15	100	69.0	7935	69.55	7805
822	M15	100	150.0	16500	135.60	14893
833	M9B	99	273.0	38220	257.75	36652
833	M9B	100	150.0	19550	154.20	19950
834	M20B	99	300.0	39000	299.25	36915
842	M9B	99	173.0	23990	167.60	21334
842	M9B	100	146.0	16790	136.55	15603
846	M20B	99	300.0	36000	298.20	34671
846	M20B	100	127.0	14605	122.85	14412
847	M20B	99	300.0	42230	287.65	38578
848	M20B	99	127.0	16510	129.90	16330
848	M20B	100	150.0	15230	156.10	16176
851	M20B	99	127.0	16280	125.50	15263
852	M15	99	150.0	19500	149.80	18553
852	M15	100	277.0	17717	219.80	17262
860	M20B	99	119.0	14930	102.50	11768
862	M11	99	1122.0	125870	1039.15	111848
865	M15	100	81.0	9315	84.55	9555
868	M15	99	150.0	21000	133.95	18573
868	M20B	99	150.0	21000	133.95	18573
869	M9A	99	694.5	74630	611.50	62219
876	M20B	99	123.0	17220	123.80	18079
877	M9B	99	150.0	21000	150.20	22300
878	M9B	99	150.0	21000	143.15	20065
881	M15	99	150.0	18000	145.40	16821
881	M15	100	150.0	15230	156.10	16176
883	M20B	99	150.0	19500	124.15	15602

Table XVI (cont'd.)

Experiment *	Channel	Schedule#	Scheduled h	Scheduled μA h	Delivered h	Delivered μA h
883	M15	100	146.0	16790	145.45	16159
884	M15	99	127.0	15240	113.75	12684
885	M15	99	150.0	21000	143.15	20065
889	M15	99	150.0	19500	149.45	18362
890	M15	99	127.0	16510	129.90	16330
891	M15	99	277.0	33240	282.25	32808
894	M20B	99	148.5	17820	128.65	14864
894	M20B	100	277.0	17717	219.80	17262
895	M15	99	273.0	38220	274.00	40379
896	M15	99	148.5	17820	128.65	14864
896	M20B	99	127.0	15240	113.75	12684
898	M20B	100	150.0	16500	135.60	14893
911	M11	100	135.0	18900	136.50	19339
912	M20B	100	150.0	19550	154.20	19550
915	M15	100	127.0	14605	122.85	14412
916	M20B	100	128.0	14195	136.25	15028
917	M20B	100	296.0	34040	299.55	33519
918	M15	100	146.0	16790	136.55	15603
DEV	M15	99	58.0	6960	58.00	6338
HallD	M11	99	300.0	42230	278.45	37086
HiTime	M15	100	123.0	17220	124.80	17702
ISAC RIB†	2A2	99,100	3356.5	45111	2706.20	37172
ISOPROD	2C4	99,100	3215.5	153750	1947.55	84117
M11test	M11	100	127.0	14605	115.55	13122
PIF	2C1	99,100	569.0	0	128.95	0
PIF	1B	99,100	242.0	0	36.00	0
P.THERAPY	2C1	99,100	79.0	0	19.50	0

* See Appendix D for experiment title and spokesman.

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

started with the cyclotron lid down and began with the removal of the BL1V shielding to more freely access and remove beam line components for refurbishing. Shielding blocks were used to construct a bunker in the vault basement to provide a workplace for individual quadrupole upgrades. This work was done and the quads were reinstalled after the tricky CM1 upgrade was completed *in situ*. Buckling up the beam pipe's vacuum joints was delayed when measurements indicated a 2 mm horizontal displacement of the quads with respect to their initially measured positions. This may have resulted from a relatively strong earthquake on February 28. Alignment was brought back to tolerance by pushing the beam line platform slightly with the help of a bracing structure and jack.

Another vault job was the removal of the STF in BL2C4 to attempt repairing the target position limit switches. This was attempted at the end of the shutdown and resulted in some dose exposure because of the fiddly nature of the work.

Shutdown lid-up work was scheduled in two batches to fit in with BL1V upgrade work requirements. The Probes-Diagnostics group serviced the BL2C, BL1 and BL2A extraction probes (the latter equipped with a modified L-arm to hold nine disposable foils); upgraded the HE1 probe trolley and replaced the vertical drive ferrofluidic feedthroughs on both HE1 (because it failed) and HE2 (preventative). The group worked with the Alignment group to measure probe positions to verify proper indexing. The Engineering Physics group removed the inflector for servicing and found some noticeable play in and misalignment of the deflector electrodes as well as a smaller but measurable misalignment of the inflector electrodes that was thought to account for the tuning anomalies of the previous running period. Further centre region work included correction plate inspections and continuity checks as well as rf surface cleaning in a small area roughened by sparking.

The third main area of activity was in the meson hall where shielding blocks were shuffled to complete a number of MRO tasks including 1AT1 and 1AT2 water package servicing; M9 T2 beam blocker rebuild; monitor work (1AM9's leaking gas package repaired and 1AM8 rebuilt); O-ring and active system water filter changes as well as work on the M11 and M13 beam blockers. The 1AQ11 vacuum leak at its downstream indium seal was repaired. Its platform was realigned after being discovered out of position a few mm high and south. Leak checking was done in M11 to find a large leak near M11B2 that was subsequently repaired. After a lengthy battle with water leaks, a rebuilt M9A rf separator was installed.

There was much more work done by many other groups; listed above are mostly jobs undertaken in high dose exposure areas. Because of the long shutdown and the number of such jobs, a few workers had to get permission to exceed their 30-day and/or quarterly sliding dose guidelines. No one exceeded any regulatory limits. The final total shutdown dose was 130 mSv distributed among 102 workers.

Beam Schedule 99

Startup was delayed a few days to repair the HE1 ferrofluidic feedthrough which failed (air leak) after the main magnet was turned on. Once tuning started it was confirmed that the realignment of the BL1 vault quads and of the 1AQ10-11 doublet was adequate. Although the first two weeks of production saw quite a lot of rf downtime with a variety of IPA problems, beam delivery improved considerably after this was sorted out and the performance for schedule 99 was quite good with a cyclotron availability of 92% and a BL1A charge delivery of 315 mA h or just over 93% of that scheduled. As mentioned above, the BL1A currents were lower than usual due to the use of graphite targets at 1AT1 as requested by Expt. 614 (TWIST) in M13. The second such target held up very well, being removed after 170 mA h and 11 weeks with currents ranging up to 130 μA, whereas the first one lasted only nine days and 25 mA h at currents below 120 μA before falling apart. BL1A currents were raised as high as 150 μA for the remaining month of the high intensity portion of the schedule with a Be target at 1AT1. After one development shift's further exploration of some earlier probe position measurements, the 1A energy was reduced by about 7 MeV to correspond to 500 MeV. BL1A had little downtime itself although it was home to a couple of steadily increasing water leaks. One of these was located at the M11 header in the 1A tunnel and it was temporarily patched until proper repairs could be made during the September mini-shutdown. Another leak that grew quickly during August was identified as originating somewhere in the 1AQ14-15-16 (triplet) cooling circuit.

In addition to BL1A's charge, BL2C4 received 43 mA h, less than half of its scheduled charge, primarily due to problems arising from a misaligned STF when it was reinstalled. The resulting kink in the line made tuning impossible until a corrective steering magnet was added and commissioned towards the end of June. After this intervention the line received about 75% of the remaining scheduled (55 mA h) charge. A few trips resulted from running the new steering magnet too close to its thermal limit and plans were made to replace it with a water-cooled one during the September mini-shutdown.

BL2A2 fared somewhat better, receiving 80% of its total scheduled 26 mA h at currents of up to 40 μA. Startup with the niobium target was plagued by excessive sparking in the ISAC west target station and only 60% of the charge scheduled for that target was delivered before production ended in late May to switch to a tantalum target. With the new target, BL2A received 87% of its scheduled 20 mA h charge before stopping in week 36 for the next target change (to SiC). For a while there was a bothersome number of spurious 2A tunnel radiation trips until, during a beam development shift, it was shown that the frequency of these trips could be substantially reduced by extracting in the shadow of the extraction 1 stripper which would reduce stray high energy beam bursts.

BL2C1 was used at 74 MeV for three separate proton therapy (PT) sessions during which a total of six patients were treated. 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). Two weeks of low current (BL2C1 and BL1B) operation were scheduled at the end of the high intensity period to allow the cyclotron fields to decay prior to the September mini-shutdown. PT went well but subsequent production was pretty spotty as many of the scheduled PIF users cancelled because of travel problems in the wake of September 11.

Scheduled development shifts focused primarily on higher current in order to achieve the higher total extracted currents required when ISAC runs full steam, with particular attention to both tune reproducibility and centre region effects. In these shifts, 300 μA equivalent was attained with up to 170 μA run down BL1A albeit with machine acceptance seemingly limited to 50% instead of the normal 60%. Some time was also allotted for OPS training during which shift operators had time to practice machine and beam line tuning and calibrations or assist with development work.

Fall Mini-Shutdown

This week of extended maintenance started two days early after the PIF run finished prematurely. There was no plan or need to raise the cyclotron lid; the main jobs included routine diagnostic, beam line, vacuum, targets and plant MRO. As well, the 2C4 corrective steering magnet was replaced with a water-cooled one and the failure-prone M13 beam blocker was repaired again. Individual doses received ranged up to 0.77 mSv and totalled around 3 mSv for these jobs. Measurements of copper active low conductivity water (Cu ALCW) system loss rates confirmed increases in the leaks at the 1A downstream triplet and M20Q1. After a careful evaluation of the problem, upcoming repair was deferred to the winter shutdown. Cyclotron systems were started up on time to meet the demands of the following beam schedule.

Beam Schedule 100

Cyclotron performance was somewhat better for these 13 weeks with an availability of 93% and a delivered 1A charge of 166 mA h or 100% of that scheduled, typically at currents of 120 μA (with carbon targets at 1AT1) but including a couple of weeks at 140 μA when Be targets were requested. Cyclotron downtime was just under 10 hours per week, quite reasonable considering it included 30 hours of power outage and recovery resulting from a wind storm during a PIF run at the end of the beam schedule. The rf booster was off for a few weeks in the middle of the high intensity period because of PA problems; otherwise it was on to help the cyclotron run more efficiently.

By far the most troublesome aspect of the 1A operation was the growing Cu ALCW system leak, presumably due to a worsening of the 1A triplet leak. This approached critical levels with respect to possible overheating of the quadrupole coils, causing some anxiety as well as localized flooding and ground fault trips on the associated power supplies before the water was finally able to be turned off at the beginning of the low current portion of the schedule. Tests at that time confirmed that the triplet leak had grown to 45 or 50 litres per hour while leaks at M20B1 (new, 20 l/h) and M20Q1 (5 l/h) accounted for most of the remaining measured losses from the Cu ALCW system. Because of these leaks the triplet repair, the removal of the M8 front end elements and the replacement of some of that area's metal and concrete shielding were given higher priority for the winter shutdown.

In addition to the BL1A charge, there were 41.5 mA h delivered (82%) to the STF in BL2C4 which ran reasonably well with the water-cooled corrective steering magnet. Towards the end of the schedule, there were tuning problems which were ultimately attributed to a worn stripping foil and although this reduced the beam intensity, it did not significantly compromise the total charge required for the two rubidium targets irradiated for processing at MDS Nordion.

The completion of the final 2A2 target change (to SiC) lasted a few days longer than anticipated. The beam line ran quite successfully at currents ranging from 5 to 15 μA to provide various ISAC experiments with nearly 16 mA h of incident beam or 85% of that scheduled. BL2A2 beam delivery continued during the last two weeks of the schedule in parallel with PT and PIF.

BL2C1 (at 74 MeV) was used for a proton therapy session with one patient treated. As for all of the other PT sessions this year, the high intensity source was on-line, so the ISIS pepperpot was required to limit the injected beam current during patient treatment; BL2C1 was also used as a lower energy complement to PIF operation at 200, 350 and 500 MeV in BL1B. Samples were irradiated with currents of 1 nA or less. Because of heavy user demand and a significant loss of time due to power failures, 2C1 operation (at 70 and 116 MeV) and 1B operation ran simultaneously in the common experimental area, creating, at times, a rather hectic pace; but everything was completed on time.

A couple of development shifts during this period again involved centre region studies for injection at higher current. Scans were done with low energy probes to analyze differences between a 250 μA equivalent tune with 62% cyclotron beam acceptance (obtained by empirically extrapolating normal 200 μA conditions) and the 50% tune resulting from the 300 μA development shifts. Centre region studies were also dedicated to identify electrodes subject to excessive heating for the higher injected currents. There was also a BL1A tuning shift to confirm a theoretical tune for BL1A with the T2 target out and the last triplet off should the necessity arise.

Cyclotron systems were turned off before the Christmas weekend just as holidays and winter shutdown were beginning. One final major operation was undertaken before year-end, namely the replacement of the three main service annex (pcb-oil) transformers. This was well-planned and executed, and completed in a couple of long days so that power was available upon people's return to work in 2002.

BEAM DEVELOPMENT

The high current beam development work, aimed at increasing TRIUMF's extracted current from 200 μA to 300 μA so that 100 μA can be supplied to ISAC without limiting the current to other users, continued during 2001.

The maximum output of TRIUMF's cusp ion source was increased from 470 μA to 700 μA by increasing the radius of the source's extraction aperture and by installing permanent magnets at the exit of the source to compensate for the steering produced by the stray cyclotron magnetic field. We were then able to accelerate 300 μA at 50% duty cycle to 500 MeV with an ISIS transmission of over 90% and a cyclotron transmission of 50%.

Although the ISIS transmission obtained with 300 μA was similar to that obtained with lower currents, the 50% cyclotron transmission was lower than the 63% obtained during 180 μA production tunes and the 62% obtained with a 250 μA development tune. Radial scans with the low energy probe LE2 indicate that the difference in transmission is largely due to additional vertical losses on the second or third turn ($\sim R \approx 17$ in.) when running 300 μA. This is probably the result of the increased space charge. Although the lower transmission shouldn't prevent TRIUMF from running 300 μA at 100% duty cycle, one of our goals is to better understand the loss mechanism and to determine the best injection optics for this current.

A major obstacle to high current operation was the centre region heating resulting from these beam losses. This can damage components and is thought to contribute to the centre region rf sparking which commonly occurs during high current operation. During the first few turns the negative phase ions are defocused and may be lost on the beam scrapers. However, these scrapers are water cooled, therefore these losses should not cause any problems. Radial losses occur when far off phase ions don't gain enough energy crossing the injection gap to keep them from spiralling into the vertical walls of the rf resonator quadrants surrounding the centre post. Although the quadrant walls are water cooled, they are reinforced with vertical stainless steel ribs which extend radially outward and intercept a portion of the lost beam. Since stainless steel is a poor conductor of heat, these ribs can overheat. Thermocouple measurements and calculations indicated that ribs #2 and #3, located 55° and 75° after the injection gap are most prone to overheating. A water cooled beam stopper was designed to shield these ribs from the lost beam. The stopper will be installed during the January, 2002 shutdown and will be tested when cyclotron operation resumes.

Since excessive spills are one of the major problems associated with high current production, understanding and controlling the injected emittance is important. Future plans call for the installation of a dedicated emittance measuring rig and emittance limiting slits in ISIS. In addition, work should go forward on an improved low emittance cusp source.

Considerable effort was devoted to developing a 300 μA equivalent tune with ISIS and tank spills low enough to allow operation at 100% duty cycle. We are close to achieving this goal, however, some additional tuning will be required to find a fully optimized solution. By the end of 2002, we hope to be able to satisfy the immediate users' demand of a total internal 250 μA production beam to be partially extracted to the three high intensity beam lines (1A, 2A and 2C4).

RADIO FREQUENCY SYSTEMS

RF Operations

The total rf downtime for the year was 180 hours. The combination of sparking, crowbars and out of driven accounted for 85 hours. The next major downtime component of 55 hours was caused by an instability in the gain of the IPA (intermediate power amplifier) driver stage. After changing out tubes and various components, the problem was traced to a poor filament connection on the tube socket fingerstock ring. The evidence indicates that this situation was there for a long time and was the cause of many problems with the IPA. The next downtime cause (17 hours) was the repair of a water leak in a transmission line capacitor station.

The 150 kW tube in the rf booster amplifier developed a grid to cathode short and was replaced by a spare one. Along with the tube replacement, all the amplifier circuits were serviced and tested. A kapton bypass capacitor was found severely damaged by a water leak in the amplifier cooling circuit. This could explain many of the rf booster instabilities experienced in the past.

RF Refurbishing

A substantial effort was dedicated to rf refurbishing.

The IPA amplifier can now be switched to a resistive load for troubleshooting. The load, as incorporated in the present amplifier design, is shown in Fig. 135.

Fabrication and assembly of three powerful (up to 1 MW output power) combiners are now complete (see Fig. 136). Signal level measurements have been performed on two combiners. The new combiners will replace the original ones, which are very difficult to maintain and adjust. Moreover, the new combiners will enable cyclotron operation with two PAs instead of four during repairs to one or both other units.

Fig. 135. IPA resistive load.

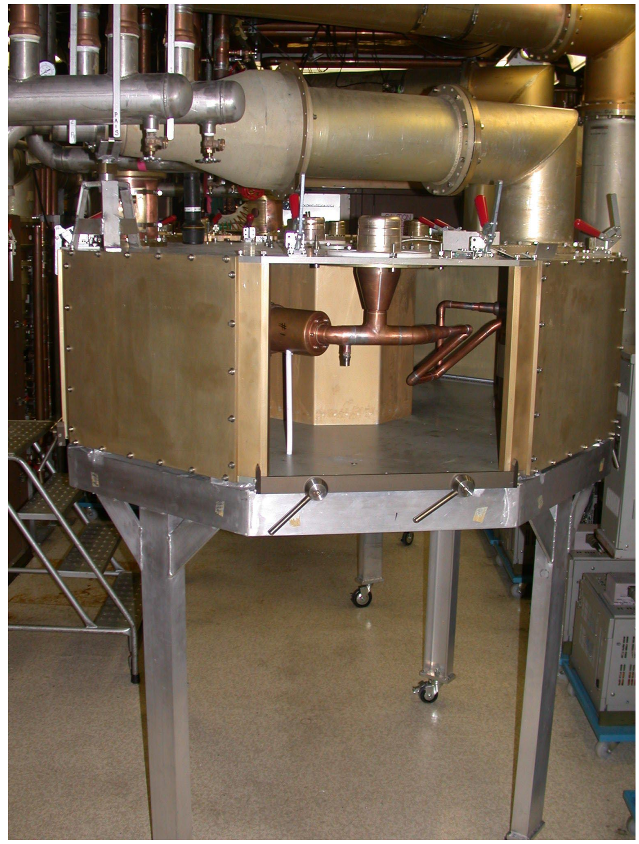

Fig. 136. New 1 MW rf combiner.

The 500 kW resistive load has been developed at TRIUMF and is close to being fully assembled (see Fig. 137). Its design has incorporated some parts from the old “Continental” resistive load: 9 in. transmission line matching taper, water pump and valves. The load is meant for power testing the combiners and PAs.

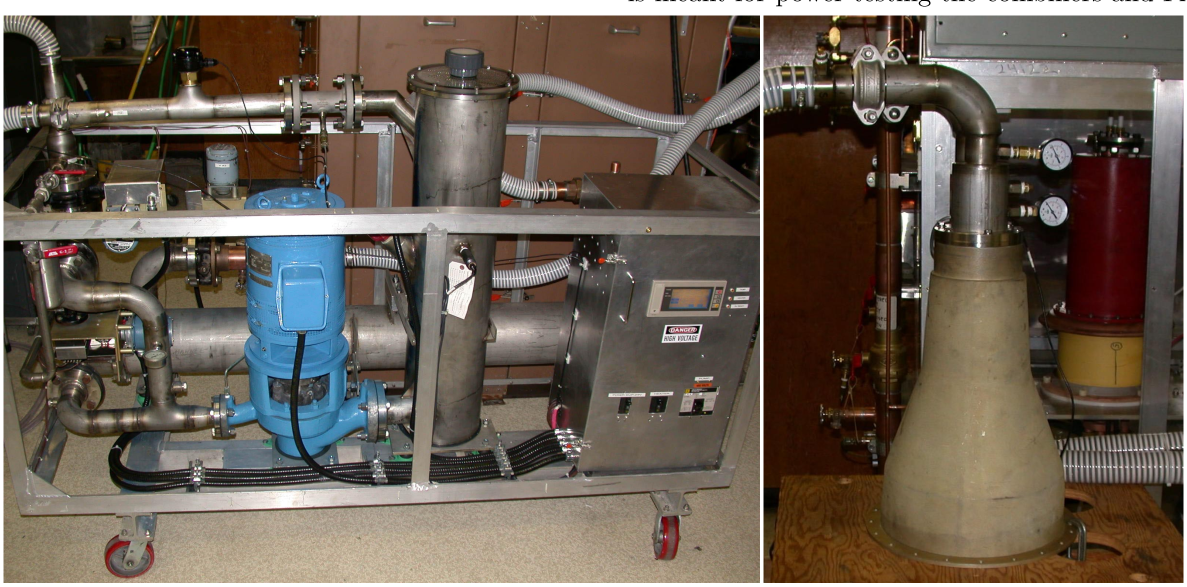

Fig. 137. 500 kW resistive load.

RF Support

RF separator

The rf separator for the M9 muon beam line experienced many water leaks in the plates and centre conductors. New plates were fabricated but they also developed water leaks. During the last rf tests some material from nearby solder joints was deposited on the coupling loop and surrounding area causing damage to the surfaces. The damaged surfaces were cleaned up and the assembly was sent out for copper plating to shield the solder joints from rf fields. Water leaks have now been repaired and the whole separator assembly has been vacuum leak checked and is being re-installed in the beam line.

ISAC

The RF group was also responsible for the following projects in ISAC-I, as reported in the ISAC section of this Annual Report.

- Testing, installation and commissioning of the high-beta buncher and low-beta buncher in the HEBT line.
- Testing, installation and commissioning of the bunch rotator and dual frequency chopper in the MEBT line.
- Study of the rf quality of copper plated surfaces.
- Partial installation of a phase measuring system for the DTL rf systems.

RADIO FREQUENCY CONTROLS

Cyclotron

An upgraded rf control system was built and ready for use with either the separator or the third harmonic buncher.

ISAC

The entire ISAC rf system was commissioned successfully. This includes a prebuncher, 1 RFQ, 5 DTLs, 6 bunchers, 1 chopper and 1 bunch rotator. They range in power from 100 W to 25 kW. Four different frequencies of 11 MHz, 23 MHz, 35 MHz and 106 MHz are necessary to drive these 15 cavities, which are then individually amplitude and phase regulated.

ISAC-II

The rf control system for the superconducting prototype cavity was designed and built. Due to the extremely high Q anticipated, the design is based upon a self-excited loop. Frequency and phase control are achieved by modulating the phase of the drive signal.

CYCLOTRON PROBES AND DIAGNOSTICS

In addition to normal MRO activities and ISAC work, there were a number of major repair jobs completed this year. A large inventory of aging diagnostics is in need of attention, so a refurbishment program is attempting to remedy the chronic problems. The most severe of these are high duty-cycle devices such as key cyclotron probes and monitors. Of particular concern are those with bearings and ferro-fluidic feedthroughs that have been in service since the first years of operation. This year, non-routine repairs were done on the following devices: 1AM8, HE1, 2C4 wire scanner, and 2C4 protect monitor.

For more details, 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, including the report on the ISAC DB0 installation, are summarized in detail in the Diagnostics group meeting notes of April 27, 2001.

Probes MRO

In order to permit higher proton beam currents to the ISAC production targets, the 2A extraction probe commissioning foil mechanism consisting of a rotating cartridge of reusable foils which had a beam current limitation of about 15 μA was changed to a standard disposable foil pack similar to that in use on beam line 1.

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 six months.

Extraction probe Ex1 was removed for routine service. A minor realignment was done on the L-arm to remedy a fault with the L-arm latch pin actuation. An improved latch pin design will be installed at the next service.

The high energy probe HE1 was removed and the recirculating bearing was replaced with a brass roller as was done with HE2 in the previous shutdown. Design concepts for a new high energy probe were advanced this year, and some detailing has been done. The radial drive ferro-fluid feedthrough (f/t) failed at the end of December, 2000, and was replaced during the winter shutdown. The replacement f/t failed at startup, necessitating an emergency repair. There is a concern about the other ferro-fluid f/ts. In particular, the slits and flags f/ts will be inspected during the winter shutdown in 2002.

Monitor MRO

All vault and standard beam line monitors were serviced during the shutdowns. The refurbishment program described in the last Annual Report was begun and, through the efforts of a co-op student, the monitor replacement assemblies have been advanced almost to completion. Some parts are required from monitors in service, and the gas pack heads await windows being manufactured by the shop electron beam welder. The work should be completed in the coming year.

The apertures for halo beam line 2A monitors 2AVM7 and 2AM8 were opened to 60 mm to reduce the number of spurious radiation trips caused by proton beam instabilities.

An unplanned service of the 2C4 protect monitor was done which included the replacement of radiation damaged cabling. New scanning wire monitors have been built for beam line 2C and will be installed during the winter shutdown in 2002.

VACUUM AND ENGINEERING PHYSICS

Vacuum

The cyclotron vacuum system operated normally for the most part. There was a failure in the B20 cryogenerator that required extensive repairs, but the impact on beam production was minimal. As part of the cyclotron refurbishment program, the four 20 degree regenerators in each of two cryogenerators were replaced at a cost of $80 k. This restored the refrigeration capacity to the design level and the used units are useful spares. Towards the end of the operating period it was noticed that the tank pressure was higher than normal on the south side of the dee gap. Residual gas analysis indicates a small air leak which will be addressed in the spring, 2002 shutdown.

A large part of the Vacuum group effort was directed to the various ISAC vacuum systems. The group experienced some change during the year with the retirement of one member and the transfer of another within TRIUMF.

Engineering Physics

The inflector, correction plates, and thermocouple system operated normally during the year. During routine maintenance of the inflector, some misalignment of both the inflector and deflector plates was noticed and corrected. The deflector plates were actually found to be loose, and this was also corrected. There are some minor issues with the correction plates and thermocouples that will be addressed in the winter, 2002 shutdown.

Most of the engineering physics effort was directed to various ISAC hardware issues.

ISIS

The CUSP ion source and injection line continued to operate well for the past year with only minor down time due to spurious interlock faults caused by aging equipment. As for the past few years, there were no major activities undertaken as ISIS personnel were involved in the completion of ISAC projects. These include the low energy polarimeter, the Osaka beam line, GPS1, 8π, and the target conditioning box.

ISIS had requested refurbishing funds ($75 k) for the replacement of fifteen aging cryopump compressors over a three year period. The existing compressors were installed as part of a major upgrade from diffusion pumps to cryopumps many years ago. The intent is to stagger the installation of the new compressors over a three to five year period such that future replacement costs would not fall into one year. This year, five compressors were installed and funds became available to purchase an additional five compressors that will be installed later in 2002. The remaining five compressors will be installed in 2003–2004.

The successful operation of the new ISAC facility will require the development of higher current targets. In order to be able to provide sufficient proton beam to ISAC without curtailing other users, an ion source low emittance beam current of 500 to 600 μA will be required to increase the current capability of our cyclotron to 300 μA at 500 MeV. An examination of the ion source optics led to a revised design of the extraction system. The extraction lens was modified and, with compensation for the stray cyclotron magnetic field in the source region, an H^- current of 700 μA was achieved at the 12 keV Faraday cup (arc power: 120 V/10 A). This beam, although with slightly larger emittance, was successfully transported to the cyclotron and used for 300 μA, 500 MeV 50% duty cycle development tests.

An upgrade of the optically pumped polarized ion source was undertaken to replace the aging ECR rf system and to increase beam current such that this source could be used, in a non-polarized mode, as an emergency backup for the CUSP source in case of failure. Once upgraded, the source could provide, in a polarized mode, useful beam intensities ($\sim$10 μA) for ISAC, combining ISAC modest intensity beam requirements in pre-shutdown periods with the requirements of polarized beam users, therefore maintaining access to the polarized beam facility during periods of time before shutdowns. In collaboration with BNL, a new HV power supply was specified and procured to meet the warranty requirements of the klystron tube. Work on the power supply continues at BNL with delivery to TRIUMF expected in early 2002.

In order to increase the source output current, a new biased sodium vapour jet ionizer cell and solenoid magnet were designed. This combination increases the acceptance of the ionizer cell while reducing the emittance of the beam for better transport efficiencies. The new components have been bench tested and will be installed in 2002. The recommissioning of the ion source is expected to take place in the first quarter of 2002.

PRIMARY BEAM LINES

BL1A Vault Section

With the exception of the combination magnet, elements of the vault section of beam line 1 were installed in the early 1970s using components that were not radiation hard. Further, the routing of many cables repeatedly crossed the median plane close to the beam line resulting in radiation damage to insulation. Although the system has operated reasonably well through the intervening years, radiation damage to power and water circuits and wiring for monitors, valves, and other components has required frequent repairs. Because of the compact construction and proximity of shielding, repairs have been both dose intensive and difficult. Consequently, it was decided to refurbish this section of the beam line as a high priority for the refurbishing program.

This major upgrade began in January of this year. Refurbishment of the combination magnet (1VCM1), the first three quadrupoles (1VQ1/2/3), and the 19.8° dipole (1VB1) was of primary concern. To improve the servicing layout, a decision was made to move all services to the south side of the beam line and to replace existing rubber cooling hoses with flexible stainless steel ones. An estimated three months of activity was foreseen.

The work began with a detailed radiation survey of the area. This showed radiation levels somewhat higher than anticipated; thus additional shielding was required for work done locally. The exact location of each element was measured, cabling was labelled, and photographs of the existing installation were taken as reference.

Work on the combination magnet involved a reconfiguration of the cooling water services to eliminate as many soft-solder connections as possible. These were replaced with individual runs of swaged connections from new supply and return headers located at some distance from the beam line. This work was done *in situ* because of the complexity involved in disassembly of the magnet and because of dose considerations.

The work was further complicated because of limited access due to the presence of a cyclotron support post that also had a hot spot (4.5 R/h on contact) at beam height on its southwest face. Local shielding was provided with lead blankets for the post as well as lead sheets that provided shielding from the magnet itself. Lead chevrons were placed in the magnet gap.

Disassembly of the cross connections proved to be easy. However, the stub lengths of the bottom coil subheader were too short for the required compression fittings and it was necessary to remove them and replace them with longer stubs. This proved to be difficult and the lower headers were taken to the Machine Shop where the extensions were brazed on.

The time required for, and dose obtained by, personnel during this operation were effectively doubled because of the problems encountered with the lower section of the coil.

To service the remaining three quadrupoles and monitors, a bunker was constructed in the lower vault using shielding blocks removed from beam line 1A and smaller blocks from the cyclotron shielding. A shielding wall with removable plugs (borrowed from the Remote Handling group) was installed. The resulting much-reduced radiation field facilitated working on the magnets.

Inspection of the quadrupoles showed that coils had withstood the radiation. These were left in place. Intercoil connections were replaced with circular 0.75 in. solid copper bus material, custom formed for each connection. They were also modified to eliminate any beam-plane transition and to permit connections to quadrupole 1VQ3 from the bottom. Those for quadrupoles 1VQ1/2 cross the median plane but the power cabling was routed behind new shielding that was installed by the combination magnet; their power connections are now accessible from the top. All power cabling is on the south side of the beam line in a tray that also has terminations for sacrificial wiring to the buss bars. The former can be replaced in sections from the upper vault.

Because quadrupoles 1VQ1 and 1VQ2 had a common beam tube and were mounted on a common stand and quadrupole 1VQ3 was on its own stand, the latter was used to test the above improvement strategy. Work proceeded well and a test of the refurbished magnet indicated that the methodology of repair was satisfactory.

Following the successful refurbishment of 1VQ3, the remaining two quadrupoles were stripped of their services and their captive beam tube was cut with a large tubing cutter. Quadrupole 1VQ2 was then removed to the bunker and refurbished in a similar manner to quadrupole 1VQ3.

Quadrupole 1VQ1 does not have direct crane access and it was necessary to construct a cantilever beam to lift the quadrupole to the 1VQ2 location where direct crane access was available. This quadrupole was then refurbished in the bunker.

All three quadrupoles were then meggered and tested at 300 A to establish that there were no hot spots and that their magnetic fields were the same as before the refurbishment. They were reinstalled and their alignment was checked. Comparison of before and after alignment data showed that all three quadrupoles were approximately 2.5 mm further south than had been the case before the quadrupoles were removed. Because all three quadrupoles showed the same displacement, and quadrupoles 1VQ1/2 shared a common support whereas quadrupole 1VQ3 had its own support, it was concluded that the beam line platform had moved during a moderate earthquake that had occurred in the interim. Repeated measurements using a Leica Total Station and optical measurements confirmed that the support platform appeared to have a southward rotation, the rotation being centred on the 19.8° dipole that lies downstream of quadrupole 1VQ3. Consequently, the west end of the platform was moved north 2.5 mm using a hydraulic jack bolted to the floor on the southwest corner. This was done in small steps while watching the alignment points. Using this method, the quadrupoles were realigned to their initial positions.

Buss bars for the combination magnet were relocated under the beam floor in the vault basement. A short length of cabling that can be easily replaced connects the magnet to its buss bars.

Cabling for controls, monitors, and valves was installed in an elevated cable tray to the north of the beam line. Beam plane crossings were eliminated. Interlock cables for these elements were replaced and the termination box was made larger to ease servicing.

BL1A West-East Section

A troublesome vacuum leak had been detected downstream of the 1AT1 target of beam line 1A. Its location, however, had been difficult to pinpoint. This leak was finally traced to an indium seal at the downstream exit of the 1AQ10/11 doublet. It was found that quadrupole 1AQ11 was slightly tilted; one edge of its support stand was sitting on a lifting lug. This was corrected and the vacuum joint replaced. No further problems have been encountered with this connection.

It had been known for some time that there was a water leak in the quadrupole triplet 1AQ14/15/16 that lies downstream of the 1AT2 target. In October, 1999 a total system loss of 10 l/h had been noted. Of this, 6 l/h were ascribed to the triplet. The total leak rate began to increase quickly in August of this year. By the end of September it reached 26 l/h (of which 13 l/h were attributed to the triplet) and by the end of October the total leak rate had increased to approximately 40 l/h. However, because the radiation level in the area in which these elements are located was extremely high, a decision was made to keep a close watch on the leak rate and try to continue to operate until year-end. It had already been planned to enter the area and fix any leaks in the upcoming January, 2002 shutdown. By the end of the year the total leak rate had increased to 70 l/h, a rate that was at the limit of what could be sustained. When beam was shut off in December, water losses of 45 l/h were attributed to the triplet, 20 l/h to M20B1, and 5 l/h to M20Q1. These are to be attended to during the January, 2002 shutdown.

In addition to the above shutdown activities, a diverse number of MRO projects were undertaken in the meson hall and in ISAC. The former involved normal filter changes, servicing the M11 and M13 beam blockers, and ongoing support of the secondary channel separators. ISAC work was centred on DRAGON, HEBT, and DBO.

The vault upgrade work at the beginning of the year was nominally a project of the Beam Lines group. Ultimately, however, the services of 43 persons were required to accomplish the tasks. Without the excellent cooperation of all those involved, the work could not have been accomplished on time. The Beam Lines group would like to thank those who assisted throughout the shutdown. In particular, J. Tanguay and K. Trithart, by devising the 1AVQ1/2/3 service details, made a significant contribution to the success of the project.

Beam Line 2C Production

The production of the radioisotope ^{82}Sr in the solid target facility (STF) on 2C4 continued to be the major use of 2C beam time. The solid target facility was removed in the spring shutdown for servicing but it was reinstalled misaligned with respect to the proton beam. Isotope production was delayed by five weeks while efforts were made to compensate for the misalignment by tuning. A steering magnet was added approximately 2 m upstream of the target and various software protections were added to allow for routine isotope production in this configuration. There was less operating time this year, 107 days compared with 135 days last year because of the tuning difficulties but there was a production of 81.15 mA h and a yield of 31.12 Ci at the end of bombardment, compared with last year's production of 95.50 mA h and a yield of 31.87 Ci. This improved make-rate is a result of optimizing the production schedule with shorter target irradiations with consistently high beam currents. Five targets were irradiated this year compared with seven targets last year.

The beam extraction foil that is used for isotope production is a 0.20 in. wide curtain of 0.001 in. diameter pyrolytic graphite fibres. There were only two production foils on the 2C extraction probe; 75.77 mA h were run on one foil because the other foil with 8.38 mA h created a larger beam halo. The foil with higher dose appeared to be failing at the end of the run. Nominally the dose would be shared between the two foils so the highest dose that had been previously run on a 0.20 in. foil was 50 mA h. Three 0.20 in. wide foils will be installed in the next operating period because the foils can only be changed when the cyclotron lid is raised. An increased operating period with only one lid up each year is now preferred.

There were 36 days scheduled for proton therapy and 23 days scheduled for the proton irradiation facility on 2C1.

CONTROLS

The Central Control System (CCS) performed well during 2001 and was responsible for only 7.45 hours of downtime. Most of the downtime was due to hardware failures such as power supply faults. The level of failures can be expected to rise as the existing control system ages unless new equipment is substituted for old. In addition, repairing existing hardware is becoming more difficult as replacement parts are not always available. Cyclotron control refurbishing is meant to alleviate this.

The goals set out for the year were largely accomplished. These included starting to replace the existing secondary beam line controls, replacing the last VAX that has a production role with another Alpha, completing the phase out of the FDDI network infrastructure for switched Ethernet, and starting the replacement of the existing disk systems. Typically, the new replacements offer much better performance and improved functionality but there are some tradeoffs because the new equipment is often less expensive and not as well engineered, particularly for long term maintenance.

CCS Facilities

There were numerous software changes in applications and infrastructure. The requests for enhancements and other modifications are almost continuous on the heavily used applications such as the display pages (XTpages), the logged data playback/live update (Xstrip), and the event scans and interlock trips (Scans). The work on these applications is important and consumes a significant amount of the available resources.

Infrastructural changes occurred in a variety of areas such as security, network statistics, printing, and the low level acquisition software. Security issues have been addressed on a number of fronts, with network access and functionality being reviewed and tightened. Secure connections are now the common login. Improvements in the statistics on network usage have been pursued. Better data have been helpful but the new switched Ethernet needs more diagnostic capabilities (to be explored in the next year). There was also an issue when printing from Windows/PCs. It is common for control system users to display their X Window output on a Windows/PC. Printing the displays seen in this environment was improved nicely when a freeware print product (Xwpick) was enhanced on site.

CCS hardware also changed in numerous ways. The changes came in the form of improvements to existing equipment, replacements of old equipment by new, and the installation of additional new items. An example of an enhancement is the upgrading of the memory on the database computer. Replacements came in several areas. Examples are, the fibre channel disk storage taking over from the DSSI storage, the network where the FDDI has been phased out and switched Ethernet has completely replaced it, and in computer upgrades such as an Alphastation 600 which was replaced by an Alphaserver DS10 and a VAX that was replaced by the Alphastation 600. An example of supplemental equipment is the addition of a colour laser printer. Along with these changes is the removal of numerous pieces of equipment such as the FDDI hardware, battery charger systems, and VAXes.

Time and effort was spent on monitoring the system, and on diagnosing and correcting problems. This year was not without its hardware faults but these are felt to be reasonable given the size of the CCS and the age of many of the components. The X Window terminals have problems about once per month but there are 50 terminals and the older ones are more than 10 years old. It is remarkable that these X terminals function so well given their age; consider working on a 10+ year old PC. Power supplies continue to reinforce their image of being a weak link, with 2 CAMAC crates and an Alpha server suffering power supply failures. A variety of other components also had problems, for example printers, DACs, ADCs, crate controllers, the old DSSI disk systems hungup, the 3 way valve controller, switches, etc. A problem that had a larger impact was when the UPS system failed to perform on one occasion. The UPS has in general been a tremendous and reliable asset.

The refurbishing goals have been met in part. Old DSSI disk storage systems, one in the Development Cluster and one in the Production Cluster, are being replaced. The new fibre channel storage is operational in the Development Cluster and providing significantly improved performance, functionality, and reliability. The fibre channel hardware for the Production Cluster has been purchased and will be installed next year. A newly designed ADC module has been slow in coming to fruition. The basic design and prototyping have been largely completed but the final debugging and production boards have suffered from lack of sufficient site priority.

Secondary Beam Lines

Work on replacing the existing secondary beam lines controls was started and has progressed very well. M13 (TWIST) was designated as the first beam line to be converted. The existing CAMAC hardware with some changes has been integrated into a serial CAMAC branch from a VME crate. A pair of Sun Sunblade 100s has been configured for development and production running. Using EPICS software this set-up has been used to replace the existing functionality and provide new features. The initial requirements for TWIST have been met but requests for enhancements are anticipated when TWIST starts intensive data-taking next year. Other beam line controls, starting with M20, will be converted to this configuration. Additional support will be needed in the area of diagnostics and a tape drive will be added to provide the required backup.

Other Systems

Support for other systems has been provided as needed. Beam line 2C controls have run smoothly and have received only minor attention. One exception was when the beam line was changed to provide extra beam steering using 2CSM4. At that time, machine protection scans were added to constrain operational parameters.

The proton therapy operator interface software was moved from a VAX to an Alpha. This configuration was tested and the first treatment has been completed. As a further upgrade, we hope to have UPS provided for various proton therapy components in the next year.

Help was given for the TWIST experiment. Additional data gathering has been provided. In one case, a data transfer of cyclotron parameters was set up on an ongoing basis. In another case, target scans were done while monitoring the protect plates and other readbacks. This and other support will likely continue during TWIST's duration.

Miscellaneous

With the VMS support being phased out in the Data Analysis Centre computing, a number of programs are now being supported by the Controls group. One example is the Dose program used by the Safety and Operations groups for keeping track of pencil dosimeter use. Help has been given on the porting of Dose and the program should be moved over and operational by the end of the spring shutdown, 2002. Another example is the Eyeplan program used by the B.C. Cancer Agency for treatment planning. Support for porting of Eyeplan will be given in the next year. In other areas, work has already started and will continue on a variety of security issues and in hardware and software readout of a VME based current-to-voltage and digitizer board used with multiwire chambers.

OPERATIONAL SERVICES

Remote Handling

ISAC

Support work for ISAC development was the predominant activity for Remote Handling for the year, expending over two-thirds of the Group manpower, with completion of the east target station vacuum tank, construction of new target, exit, entrance and dump modules, and assembly of ion beam optics elements.

Remote Handling activities for the year included design and installation of a new remotely accessible spent target storage vault, refinement of the remote crane system and hot cell facilities. A catastrophic electrical failure in the ISAC target module #1 required replacement in the hot cell of the entire target/extraction column assembly.

Cyclotron servicing

The spring shutdown required routine Cu-blocker removal, shadow shield installation, video survey, and radiation surveys. The 2C extraction probe was removed again this year for work by Diagnostics, along with HE1 and HE2.

During the year, the remote cyclotron servicing system controls and trolleys were reworked and maintained. Heavy workloads postponed cyclotron elevating system maintenance for yet another year.

Beam lines servicing

The principal spring shutdown activity was in support of the beam line #1 front end refurbishment. Assistance was given with magnet services upgrade for 1VCM1, 1VQ1,2,3 and 1VB1, and new indium vacuum seals installed in the section after completion of the work.

A recurrence of a vacuum leak at 1AQ11 required replacement of the indium seal and realignment of the flange and joint support assembly.

Work began on the scheduled decommissioning of beam line M8. A current area shielding layout perspective drawing was completed, a proposed shielding revision approved, and new shielding designed and specified. Over 32 tons of concrete shielding and 100 tons of steel shielding blocks were completed by year-end.

Hot cells and targets

Servicing for the T1 and T2 cooling packages required filter changes, demineralizer pressure transducer replacement, resin can exchange, water release, and a change of the water flow nozzles in an attempt to recalibrate control rack signals.

The T1-Mk1 target was removed from the beam line for replacement of a leaking Pb-coated "C"-seal in the hot cell. This leak released over 17 l of water into the target vacuum vessel. New 10 mm pyrolytic graphite targets were installed at positions #2 and 5, and the T1-Mk2 target had a new 10 mm graphite target installed at position #2. One of the two target beam blocker air pressure amplifiers was rebuilt. The T1 profile monitor had air flow control valves installed.

The M9 beam blocker was moved into the hot cell for replacement of the actuators with revised design, larger bore air cylinders. Assistance was given to 2C beam line for resin can change/disposal, and with a target holder latching problem. Similar assistance was provided to TNF for resin can servicing.

Hot cell housekeeping required a change of the ventilation roughing and pre-filters, as well as disposal shipping of hot cell garbage, and redistribution of active component storage.

Magnet Power Supplies

2001 saw the final commissioning of power supplies related to ISAC-I for the experimental areas. Difficulties were encountered with the old M8 supplies which suffered multiple water leaks, specifically on MD1 and MD2, Q10 supplies.

During the spring shutdown, M13 polarity switches were replaced as well as the cabling to these switches.

Precision DCCT current monitoring equipment was installed for the remaining power supplies for M13 to achieve the desired stability and reproducibility of that channel required for Expt. 614.

A new steering element was introduced for BL2C to compensate for target misalignment. This involved the pulling of new power cables from a trim coil junction box as well as running new interlock cables.

As part of the BL1A upgrade, new interlock terminations for the front end magnets were done.

A satisfactory heat sink has been generated to replace the original Wakefield and this will be used to retrofit the supplies in future.

The balance of the group's activities was providing experimental support as well as MRO for the power supply system.

Coordination was provided for the BL1A front end refurbishing as well as the PCB transformer replacement project.

Electrical Engineering Services

Electrical Systems

ISAC-I continued to be the focus of the engineering efforts. About 50 engineering and large installation work orders in support of accelerator and experimental programs were carried to completion.

Major refurbishing projects included:

- The rewiring of the dc feeder at the front end of BL1A in the cyclotron vault with new terminations, cabling, buss bars, and cable tray installation;
- The replacement of three Askarel (PCB coolant) transformers during the Christmas shutdown.

The transformer procurement and replacement was carried out over a period of 12 months under the overall project coordination of TRIUMF. Five firms worked alongside TRIUMF staff. Beaver Electrical Machinery Ltd. performed the initial testing and feasibility study, VECO Canada Ltd. provided the engineering services, Partner Technologies Ltd. of Regina manufactured the replacement transformers, PVK provided the electrical installation, and Trans-Cycle Industries of Kirkland, Ontario carried out the removal and disposal of the PCB liquid and the transformer carcasses.

The three Askarel transformers had been in service for 30 years. Dielectric property tests and dissolved gas analyses revealed significant deterioration of the winding insulation and clearly indicated the need for their urgent replacement. The reliability and continuity of service of these transformers are too important for cyclotron operation to risk keeping them in service in those conditions. The removal of these units from the site also eliminates a significant risk and liability associated with the operation of PCB chemicals.

The electrical department responded to about 250 trouble calls and was involved in about 130 minor installation requests. Typical maintenance activities included servicing lighting systems, motors, air conditioning controls, panel boards and transformers, HV switchgear, breakers, and capacitor banks. About 10 motors were replaced, including four in the cooling tower complex. Lighting maintenance took a good share of the electrical crew time with the replacement of about 400 ballasts and a large number of fluorescent tubes. Continuing engineering support was provided to TRIUMF users and MDS Nordion. Completed major tasks included electrical services for TWIST, the M9 He polarized targets, and the CP42 power supply upgrade. Improved dc cabling was also installed for CP42. M13 polarity switch wiring was replaced as part of the polarity switch replacement program. Engineering support was also provided to the new MDS Nordion project, TR30-2.

Electrical maintenance requirements have increased significantly since the addition of the ISAC-I facility and will increase even further with the ISAC-II buildings. It is vital to the service continuity and reliability that we add to the staffing level to cope with the increased workload.

A number of system components have aged. The regular replacement program of obsolete equipment was sidelined during the construction of ISAC-I. It is important to restart it to continue to deliver the continuity of service and reliability we are accustomed to.

Power Delivery

A severe windstorm that swept the UBC campus on December 15 caused extensive power outages and operational disruptions. Some equipment damage resulted and the electrical crew was busy around the clock to clean up and repair the damage.

Power management continued as a routine activity. The monthly averaged peak power demand increased a mere 1.8% to 6857 kVA from 6736 kVA a year earlier (Fig. 138). The maximum peak power demand was reached in August with 8871 kVA, a good 5% higher than last year. After steady increases over the last three years, the electricity consumption bucked the trend. It decreased 2.3% to 51.99 GWh in 2001 from 53.21 GWh in 2000 (Fig. 139). The largest consumption also occurred in August (6.0 GWh). The power factor (PF), averaged over the calendar year remained unchanged at 96.1% (Fig. 140).

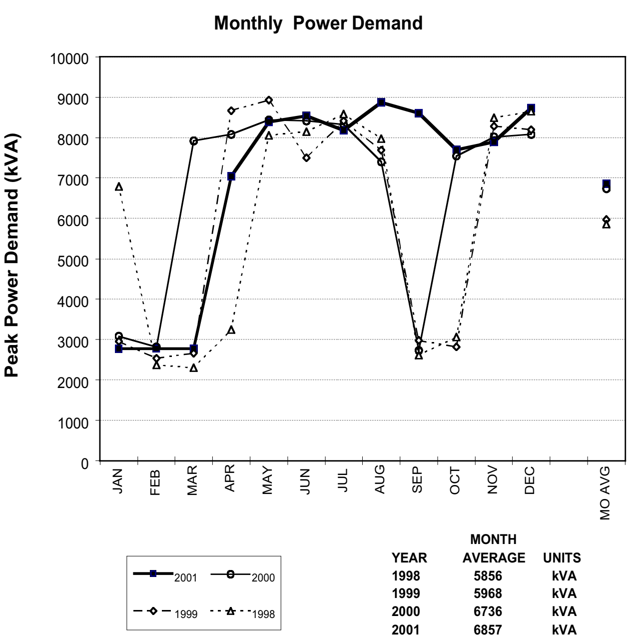

Fig. 138. Electrical system power demand – four year comparison.

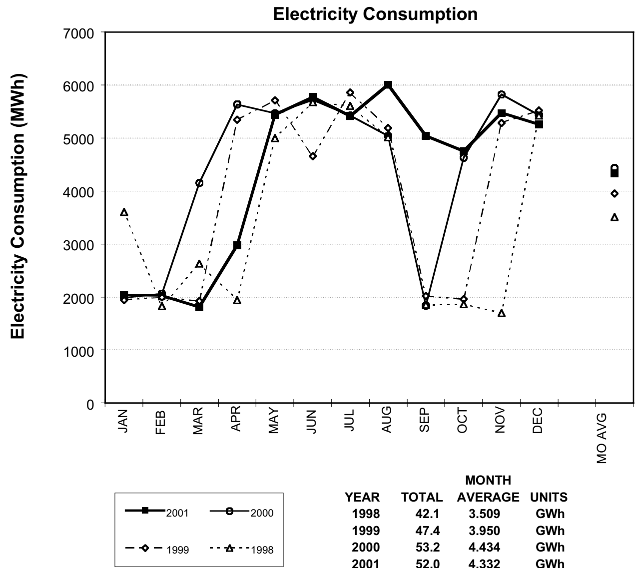

Fig. 139. Electrical system energy consumption – four year comparison.

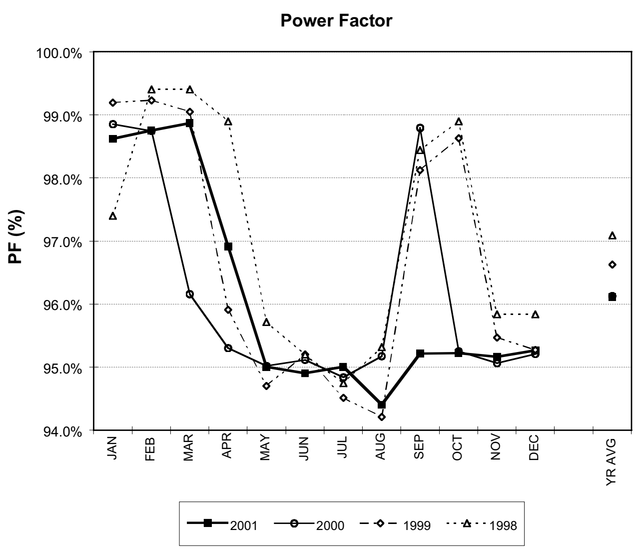

Fig. 140. Electrical system power factor – four year comparison.

Mechanical Services

ISAC

The 2001 effort was concentrated on ISAC. The experimental hall completion included a wide range of work, including cooling water, compressed air, and vacuum lines to HEBT and experimental areas, completion and commissioning of the DRAGON hydrogen exhaust system, gas tubing and alarms. Other ISAC jobs included a third controlled temperature water loop for TRINAT, a mechanical hoist in the penthouse hay loft, the connection and the commissioning of alarms for six fume hoods, spent target vault ventilation and exhaust, high level alarms for the three filling points for the decontamination sump, and vacuum roughing lines to the CDS room. One ISAC development job was the modification of the experimental hall roof top heating units to act as exhaust fans for summer operation, and the installation of a test area of open floor grating on the mezzanine. This is intended to reduce the air temperature on the mezzanine in summer, by moving more outdoor air through the building, and allowing it free convection access to the mezzanine. Other development jobs included modification to chilled water supply lines to the electrical room to allow more efficient operation of chiller 2 in winter, venting the decontamination and sanitary sumps for odour control, and DDC operational improvements. A list of MRO work was carried out.

Engineering assistance was provided for the ISAC-II building project, and the Superconducting RF Laboratory at B.C. Research.

Main site interventions

The single largest project was the abandonment of the underground diesel storage tank. This job was required by the University of B.C. for environmental protection, and included test drillings in the nearby area to search for possible pre-existing diesel oil leakage into the ground water (there was none), pumping out and disposal of the nearly 5000 gallons of oil (more difficult than imagined because of high sulfur content of the old oil, and some water contamination inside the tank), excavation of the top of the tank, cutting a manhole in the top, power washing the inside, filling the tank with low strength (excavator ready) concrete, and finally backfilling and repaving the area. Other significant jobs were the transformers T1, T2, T3 replacement, the combination magnet CM1 reservicing in the vault, the refurbishment and re-commissioning of the M8 building HVAC, and new upgraded HVAC for the auditorium. Other MRO work included the board room HVAC, the el. 264 electrical room Buffalo AC unit replacement, a new boiler water feed line, new laminar flow diffusers for the main office building clean room and lab, M13 gas lines, RH control room AC, tricky temporary and, later, permanent repair of a water leak in a beam line 1A copper pipe, the startup of Expt. 614 power supply AC, and new exhaust ductwork for M11. A fire suppression system was installed in the kitchen and a new pressure gauge and flow switch installed in the remote handling building sprinkler system. A maintenance software package was purchased and installed to systematize procedures and record keeping for Plant group. The application and startup of this system will carry on into 2002.

Engineering assistance was given to MDS Nordion and ATG for various jobs, including the new expansion project. This work included site water shutdowns because of related intervention on the mains.