TRIUMF

ANNUAL REPORT
SCIENTIFIC ACTIVITIES
2004

ISSN 1492-417X

CANADA'S NATIONAL LABORATORY
FOR PARTICLE AND NUCLEAR PHYSICS

OPERATED AS A JOINT VENTURE

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NATIONAL RESEARCH COUNCIL OF CANADA

OCTOBER 2005

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 2004 the cyclotron was available for 92% of the hours scheduled, which is 4% better than last year. The total number of available hours was 5565, exceeding the 5176 hours available in 2003. The total beam charge delivered was 687 mAh, up 6% from last year, of which 437 mAh were delivered to BL1A for meson production and 108 mAh were delivered to BL2A for RIB production. Beam was delivered for the first time down BL2A3 to the east target station (ITE) of ISAC. Approximately 142 mAh were delivered at 85 MeV to rubidium targets in the solid target facility (STF) in beam line 2C4 for the production of radiopharmaceutical generators.

The cyclotron beam development shifts concentrated on reproducing, understanding and improving the ∼300 μA tune being developed to satisfy the users' requirements for beam in 2007 when ISAC is scheduled to begin operating at 100 μA. After several improvements in diagnostics and alignment of the centre region correction plates, the best 2004 high current result achieved was a stable beam with an equivalent current of 320 μA at 50% duty cycle with 64% cyclotron transmission and reasonable spills.

The annual downtime of 407 hours was only slightly higher than average, of which the inflector problems cost 138 hours of the total. Most impressive was the lowest ever rf downtime of 77 hours, which is about 1/3 of the long-term average. Site power and power supply problems were the next largest contributors to downtime, followed by beam trips which became a nuisance in 2A operation.

During the winter shutdown, the major beam line activities were the repair of four major vacuum leaks (M20Q1, upstream of Q14, 1AT2-M8 blank-off plate, O-ring at M20B2) in the T2 area of BL1A. Last year's crumbling block replacement program continued this year. However, because of the extent and complexity of the above jobs in mostly high radiation fields, we had to postpone the removal of the M11 septum and the repair of the small M15 vacuum leak. There were many other meson hall activities, which are covered in detail in the Beam Production section. The major vault and tank activities included jack-station maintenance, diagnostic maintenance activities, periscope improvements, installation of new inflector cables and connectors, and chore pad replacements in Q3 and Q4. Removing the STF in BL2C4 to repair limit switches and to correct a skew misalignment, that had caused problems for years, proved to be a very difficult job with mechanical obstacles and persistent water leaks along the way. A new and improved STF is being designed to replace the present one. The new STF will be a water vessel with no water joints to be made up in the vault. The target insertion will be done on rails located in the vessel and the insertion mechanism will be removable to the hot cell for MRO.

In the fall mini shutdown the vault activities included both X1 and X2A foils being replenished, vault BL monitors being gassed, 2C4 protect monitor being repaired, upper correction plate external cabling being repaired, and many other MRO jobs. In BL1A there was the repair of vacuum leaks at 1AVA8 and 1AQ14, a water leak at 1AQ15 and many other MRO jobs, which are covered in more detail in the support group sections. As well as vault and beam line activities, the support groups were also very busy in their own respective areas.

The efforts of the RF group are reflected in the low downtime of 77 hours compared to 234 hours last year. The major activities contributing to this reliability are the upgrade of the HVPS (which includes new thyrite varistor stacks, new water connections to the water-cooled resistors and a newly designed crowbar driver protection board), a new final combiner, major upgrades to the 9 in. and 11 in. transmission line system, and general upgrades in the rf power amplifiers.

In the Probes and Diagnostics group great progress was made on the HE probe refurbishment, including the completion of the probe detailed design and fabrication and testing of the major sub-assemblies. The group was also involved in ISAC work which is covered in that section.

The newly formed Diagnostics Electronics group had a very busy year. The major priority was given to fast signal acquisition from internal probes in the cyclotron. A real step forward in beam measurements in the time domain can be expected with the implementation of broadband signal acquisition and analysis. Improvements were made to the electronics processing the signal from the beam line capacitive probe to make the TOF measurements on the cyclotron more automatic.

The vacuum/cryogenics system operated reliably over the year. Upgrades were made to both B-20 cryogenerators to improve their reliability. Improvements were made to the B-20 cooling water system to improve turn around time during cryogenerator regeneration. Both cyclotron and beam line vacuum systems were efficiently maintained during the year.

In ISIS the CUSP ion source and injection line continued to operate well for the past year. A major effort was unexpectedly required to realign the I1 motor generator set that provides power to the ion source terminal. Variable aperture slits were successfully commissioned and now provide improved beam quality to the cyclotron. Some effort went into restoring the CRM ion source test stand to allow testing of CUSP ion sources by ISIS, Nordion and Dehnel Consulting, and to allow us to study our ion source characteristics.

The Controls group carried out many new developments on the CCS facility, secondary beam lines and other systems, which are too numerous to mention here. The low loss of scheduled beam time attributed to control systems is noteworthy and is a result of the new developments and maintenance efficiently carried out by the Controls group.

Operational Services, which includes Remote Handling, Magnet Power Supplies, Electrical Services and Mechanical Services, continues to play a vital role in the reliable operation of the cyclotron. Their services extend to the whole TRIUMF site and are appreciated site wide.

As part of the ongoing work for safety-critical monitoring for prompt radiation hazards, the reliable termination of beam production in response to beam spill, neutron, access, and emergency safety trip conditions was implemented during the 2004 shutdown. Each secondary channel area safety unit test procedure was written and approved. The operation of nine safety-critical pairs of radiation detectors was checked out on thirty-five maintenance days with no failures reported. The ISAC B1 level electrical room was made an interlock exclusion area and now must be locked up and unoccupied when beam line 2A is on.

BEAM PRODUCTION

Beam delivery for the year was reasonably successful with a total charge production of 687 mAh delivered to the high current proton lines (1A, 2A and 2C4), up 6% from last year although still 5% lower than the 2002 record of 723 mAh. Performance of the cyclotron was excellent for the most part (barring an emergency inflector repair in August) with a typical operating transmission of 64% and a measured tank beam spill around 1% of the circulating current. These parameters were achieved partly with the help of the rf booster that was sometimes unavailable due to developments in its control system, partly due to a more reproducible ISIS beam (with newly installed slits cutting back a high output source as needed), and partly because of the continuing tuning efforts of the operators. Thirteen weeks of shutdown left 6058 scheduled operational hours (in this 53 week year) of which 5565 were achieved for an availability of 92%, 4% better than last year. These totals, including 316 hours used for development and tuning, are shown in Fig. 180. Note that the 2 week periods preceding shutdowns were dedicated to lower intensity operation, usually involving beam delivery to ISAC with the proton irradiation facility (PIF, using BL1B and BL2C1) running in parallel. BL2C1 was also used at 74 MeV for ocular melanoma treatments for 6 patients during 4 proton therapy (PT) sessions. These PT sessions, with the high intensity source on-line, required the use of the ISIS pepperpot to limit the injected beam current during patient treatment times. Again this year there was no BL4 operation and no polarized source operation.

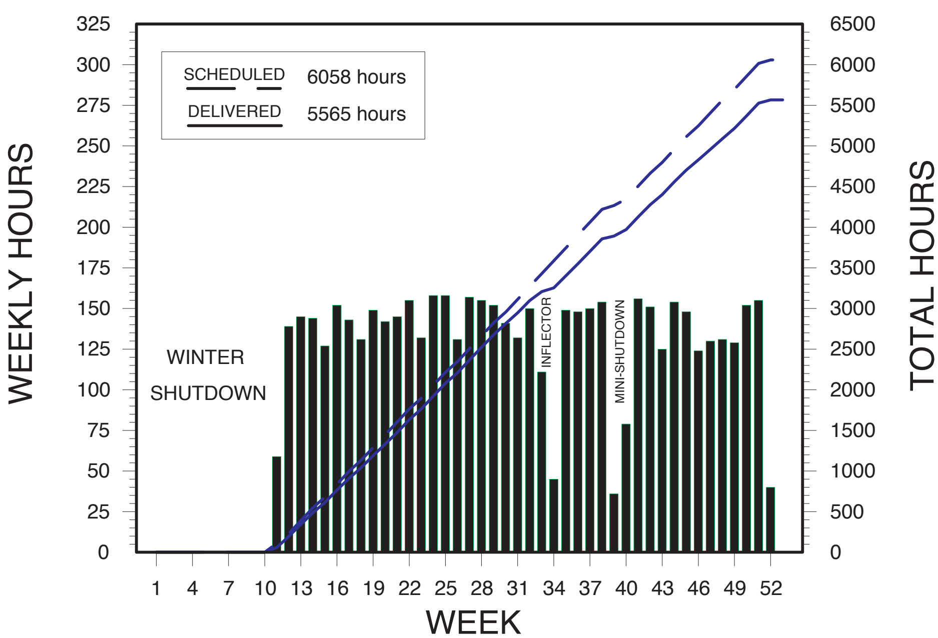

Fig. 180. Operational hours for 2004.

As Fig. 181 shows, the total beam charge delivered to meson hall experiments along BL1A was 437 mAh or 88% of the scheduled amount, down marginally from last year because of vacuum and target considerations described below. In addition to the BL1A charge, there were a significant 142 mAh delivered at 85 MeV to rubidium targets in the solid target facility (STF) in beam line 2C4 for the production of radiopharmaceutical generators and another 108 mAh, 30% more than last year's record, delivered to the two target stations on BL2A for the production of radioactive ion beams (RIB) for experiments in ISAC. A total extracted current exceeding 220 μA was sometimes shared by the three proton lines, although 200 μA or less was more normal for extended production periods. This was particularly true for the month when graphite targets were used at 1AT1 for the TWIST experiment, limiting BL1A currents to 100 μA.

The annual downtime of 407 hours (Fig. 182) was only slightly higher than average even though inflector problems cost 138 hours or 34% of the total. Most impressive was the lowest ever rf downtime, 77 hours or less than 2 hours per operational week, about one-third of the long term average. Site power and power supply problems followed at 9% and 8% respectively while beam trips, particularly a nuisance in 2A operation, came in at a costly 5%. The operational record and beam to experiments for the year are given in Tables XXVI and XXVII.

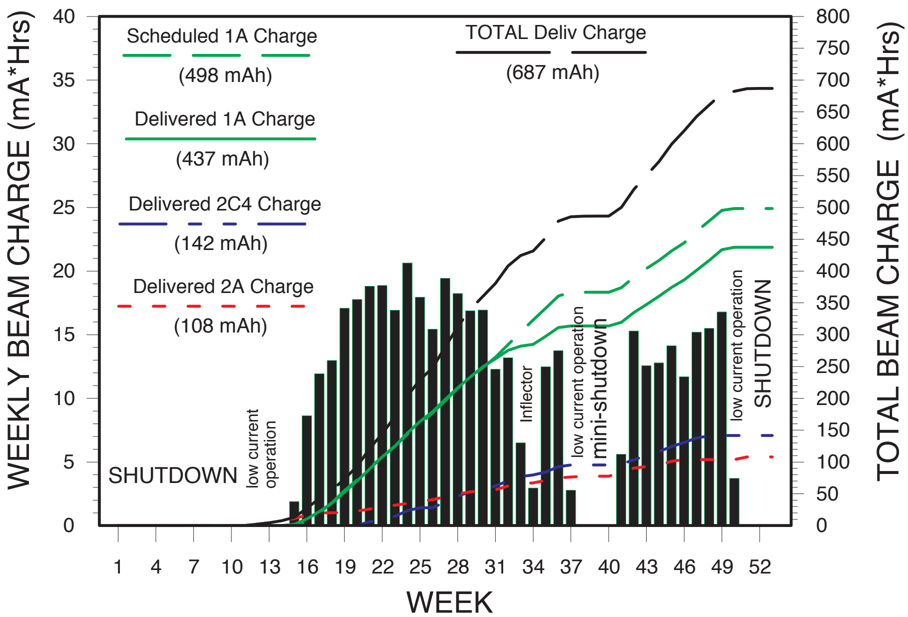

Fig. 181. Beam delivery for 2004.

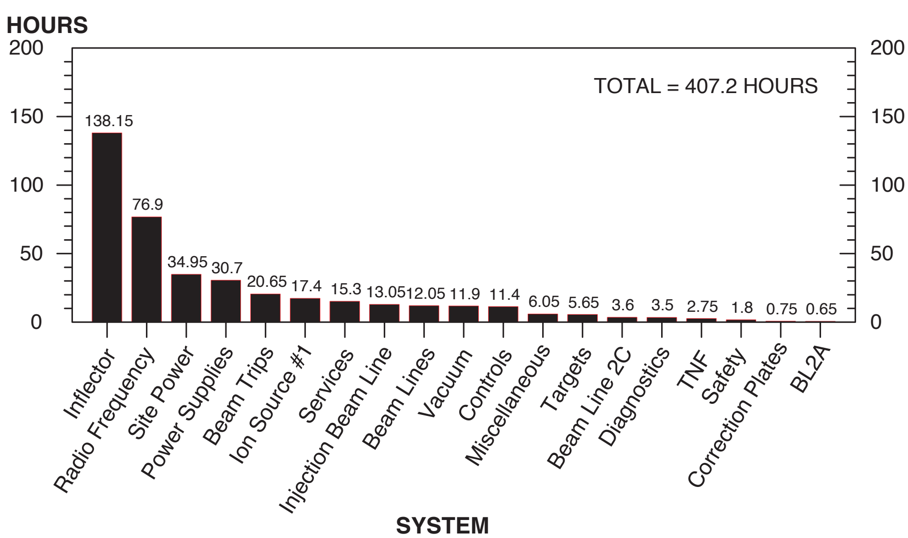

Fig. 182. Cyclotron downtime for 2004.

Table XXVI. Operational record for 2004.*

	Scheduled hours	Actual hours
Cyclotron off:		
Maintenance	528.0	535.25
Startup	178.0	178.30
Shutdown	2,140.0	2,155.50
Other	0.0	0.00
Cyclotron downtime	0.0	407.20
Overhead	0.0	62.75
Totals	2,846.0	3,339.00
Cyclotron on:		
Development	202.5	173.15
Cyclotron tuning	525.0	143.30
Beam to experiments	5,330.5	5,248.55
Totals	6,058.0	5,565.00

Actual / Scheduled = 5,565.0 / 6,058.0 = 91.9% availability

	Scheduled hours	Actual hours
Beam to experiments:		
1A Production	4,155.0	3,987.65
1A Development/tuning	10.0	35.20
1A Down/open/no user	807.5	854.15
1B Production	335.0	69.45
1B Development/tuning	0.0	3.50
1B Down/open/no user	23.0	298.60
Total 1A+1B production	4,490.0	4,057.10
2A Production	5,029.5	3,577.75
2A Development/tuning	0.0	18.25
2A Down/open/no user	301.0	1,652.55
2C1 Production/tests	1,431.5	192.95
2C1 Development/tuning	0.0	8.90
2C1 Down/open/no user	405.0	1,463.55
2C4 Production/tests	3,378.0	2,523.65
2C4 Development/tuning	0.0	18.00
2C4 Down/open/no user	116.0	1,041.50
1A Beam charge (μAh)	498,320.0	437,178.00
2A Beam charge (μAh)	148,903.0	107,875.50
2C4 Beam charge (μAh)	155,750.0	141,530.00

* There was no BL4 production this year and the polarized source was not used.

Table XXVII. Beam to experiments for 2004.

			Scheduled		Delivered	
Experiment*	Channel	Schedule #	Hours	μA h	Hours	μA h
614	M13	105	2,542	330,460	2,451.50	275,762
614	M13	106	1,108	124,570	1,048.60	117,473
(614)	M13	105	404	35,220	403.25	33,550
(614)	M13	106	101	7,070	80.30	5,612
782	M15	105	150	19,500	156.75	19,291
842	M9B	105	150	19,500	150.05	19,716
847	M15	105	273	35,490	276.60	35,300
877	M9B	105	123	15,990	139.65	17,113
881	M15	105	81	10,530	81.15	9,637
881	M15	106	79	5,530	58.30	4,080
891	M15	105	127	16,510	124.00	12,565
891	M20B	105	196	25,480	208.25	22,744
912	M15	106	127	16,390	110.60	13,718
917	M20B	105	427	55,510	446.85	51,536
917	M20B	106	273	26,730	239.25	23,729
932	M9B	105	150	19,500	169.90	20,095
938	M15	105	273	35,490	265.85	29,481
938	M15	106	127	16,510	127.45	16,616
939	M20B	105	254	33,020	275.80	34,569
939	M20B	106	277	31,390	238.70	26,373
943	M9B	105	273	35,490	273.45	30,649
944	M20B	106	151	15,100	151.50	14,839
945	M20B	105	150	19,500	147.30	17,971
945	M9B	106	79	5,530	73.45	5,495
945	M20B	106	127	16,510	127.45	16,616
949	M9B	105	300	39,000	278.85	24,210
949	M9B	106	381	49,410	368.55	47,875
950	M15	105	150	19,500	152.65	11,842
951	M20B	105	75	9,750	79.05	7,893
951	M15	106	69	8,970	69.30	8,966
953	M15	105	127	16,510	121.65	15,722
953	M15	106	127	12,700	120.25	11,970
958	M15	105	127	16,510	142.05	18,250
959	M20B	105	150	19,500	150.05	19,716
960	M20B	105	150	19,500	86.30	5,697
960	M15	106	127	12,700	125.25	12,255
962	M20B	105	150	19,500	155.80	20,191
968	M9B	105	438	56,940	371.20	31,995
968	M9B	106	277	27,700	249.35	24,672
969	M15	105	150	19,500	146.90	15,065
974	M15	105	277	36,010	198.50	20,750
975	M15	105	150	19,500	142.30	12,008
976	M15	105	46	5,980	54.95	6,125
976	M15	106	58	7,540	61.20	8,575
977	M20B	105	150	19,500	126.20	12,368
978	M20B	105	63	8,190	63.55	6,397
979	M20B	105	127	16,510	121.65	15,722
981	M20B	106	127	16,510	130.50	17,541
997	M20B	105	150	19,500	152.65	11,842
998	M15	105	127	16,510	143.20	17,180

Table XXVII (cont'd.)

Experiment*	Channel	Schedule #	Scheduled Hours	Scheduled μA h	Delivered Hours	Delivered μA h
999	M20B	105	123	15,990	139.65	17,113
1000	M15	105	300	39,000	303.10	38,162
1000	M20B	106	127	12,700	121.25	12,017
1000	M15	106	127	16,510	120.20	14,961
1001	M15	105	138	17,940	142.60	14,290
1002	M15	105	277	36,010	227.65	23,329
1003	M20B	105	127	16,510	142.05	18,250
1004	M20B	105	123	15,990	126.55	15,584
1005	M20B	105	150	19,500	142.30	12,008
1006	M20B	105	150	19,500	64.05	3,813
1011	M15	106	151	15,100	151.50	14,839
1012	M9B	106	127	16,510	120.20	14,961
1013	M15	106	67	4,690	60.75	4,688
1015	M15	106	150	15,000	128.10	12,655
1016	M20B	106	127	12,700	120.25	11,970
M9 test	M9B	105	173	5,190	174.85	10,315
Setup9	M9B	106	151	15,100	151.50	14,839
TBA15	M15	105	173	5,190	174.85	10,315
TBA20	M20B	105	231	12,730	226.70	15,898
TBA9	M9B	105	1,339	174,070	1,296.80	55,219
TBA9	M9B	106	194	17,390	165.85	15,243

* See Appendix D for experiment title and spokesman.

Winter Shutdown

Shutdown activities got under way at the beginning of the year, particularly in BL1A which was scheduled to be off until just before the Easter weekend. Work there was again long and involved, starting with the removal of 60 to 70 large shielding blocks to outside storage. One of the main 1A jobs was the repair of T2 area vacuum leaks, the main one at M20Q1 and another, trickier one discovered just upstream of Q14 that was sensitive to the loading of shielding blocks above it and which proved very challenging to fix because of alignment issues. A third leak was repaired by replacing the 1AT2-M8 blank-off plate and a fourth leak involved replacing a 20-year-old rubber O-ring at M20B2. After these were repaired the best vacuum that area has seen in years was achieved. While the area was accessible, a remote video survey of the front end of M20 was made in preparation for the future installation of new rad-hard components there. At M9Q1 it was discovered that water from a weeping solder joint was getting into hairline cracks on an insulator just below and causing a ground fault. This was fixed by epoxying the joint and insulator, but a residual ground fault was attributed to track marks left on the insulator.

To help reduce dose to the technical experts, volunteers were used to continue last year's crumbling block replacement program, this time starting with the removal of the 1AM10 smokestack monitor to access and replace six blocks in that area. The extent and complexity of the above jobs, most of them in high radiation fields, made it impossible to complete all the scheduled shutdown work so the removal of the M11 septum and the repair of a small M15 vacuum leak were postponed for yet another year. Still, there were numerous other meson hall activities, among them being the replacement of the M20VA5 valve, 1AT1 and 1AT2 water package upgrades and servicing, 1AT2 beam blocker servicing (both M9 and M20), the addition of a gate valve in M13 to remove the vacuum valve functionality of the existing beam blocker there, hose replacements and water leak repairs in M9, M20 and M13, replacement of the TNF resin can, routine filter changes, and so forth.

As in the previous year, the cyclotron was scheduled to start up a month earlier than BL1A in order to deliver beam to PT, PIF and ISAC while shutdown work in the meson hall continued. In the vault some jack-station maintenance took place before the lid was raised for 5 weeks of cyclotron repairs in residual fields similar to those of the previous year. Diagnostics activities there consisted of the usual probe maintenance as well as probe position measurements. Also some considerable effort was put into improving the periscopes by replacing radiation damaged pentaprisms and wiring. New cables and connectors were installed for the inflector and some maintenance of the inflector was done. RF inspections, chore pad replacement (Q3 and Q4 upper resonators) and thermocouple work went as planned. However resonator adjustments, transmission line improvements and correction plate work (where some subsequent shorts in the tank had to be located and repaired) were more involved than originally considered and pushed the schedule a little.

Remote handling work in the vault consisted of jack-station maintenance before the lid went up and alignment checks after the lid was down. In between were the usual remote installation and removal of shadow shields and copper beam blockers as well as assistance with probes work. Operations group activities consisted mostly of support work for rf resonator and correction plate work as well as overhead for lid cycling and tank inspections.

The main objectives of BL2C4 shutdown work were to remove the STF for limit switch repairs and to correct the misalignment that has caused tuning problems over the last couple of years. The latter proved to be a very difficult exercise with mechanical obstacles each step of the way including a persistent water leak at the seal between the STF target housing and the water column above it. Finally a mock-up in the hot cell and a different style clamp helped get the job done albeit a few weeks into the beam schedule. A new and improved STF is being designed to replace the present one in a couple of years. BL2C4 work ultimately contributed 50 mSv to the total shutdown dose of approximately 190 mSv distributed among 105 workers.

Beam Schedule 105

Startup was relatively straightforward although there was a problem with some upper correction plates that turned out to be environmentally damaged cabling. Quick repairs were made by cutting off the last metre and installing new connectors while planning for a more thorough job for the next shutdown. Beam was first injected and extracted in the middle of March with a notable change in the safety system logic that has reduced the number of beam-tripped devices to three (the ISIS vertical bends, beamstop 165 and the fast target) with the rf now notably removed from the list.

Availability of the cyclotron for this operating period was quite good at 91% of the 4267 scheduled hours and would have been even better had there not been an emergency lid up in mid-August to repair the inflector. An insulator had become dirty enough to prevent stable high voltage operation in a failure similar to that of the previous spring. Downtime totalled 299 hours, nearly half of which (137 hours) was for the inflector while rf was a distant second at less than 2 hours per week. The cyclotron tune was quite good with a typical transmission of 64% and measured spills around 2 μA for total extracted currents of up to 220 μA to the three active proton lines. Apart from these beam lines, which are discussed below, there was also beam delivery to 2C1 for both PT (three sessions, five patients) and PIF for two weeks at the end of the beam production schedule as part of lower current operation (placed to provide some cooldown prior to the fall shutdown). BL2C1 currents were less than 7 nA. BL1B scheduled at the same time had user problems and therefore had little use (at currents of less than 1 nA).

There was an unresolved problem in trying to tune 2C1 energies above 105 MeV that appears to have coincided with the emergency inflector repair in August. But, as there were no other pressing reasons for raising the lid and incurring the associated dose during the fall shutdown, it was decided, after confirming that lower energy tunes would suffice for this year, to wait until the spring, 2005 shutdown to resolve this issue.

BL1A ran for 2855 hours or 97% of its scheduled time, receiving 314 mAh or 86% of its scheduled charge. The high hourly availability was helped along by running unscheduled beam overnight during training shifts as well as keeping shorter than usual maintenance days. The impetus for this came from a new vacuum leak around 1AQ14 which would open up after about 6 hours of beam-off and slowly worsen until beam was restored at which time the vacuum would fully recover to its base pressure. However, that base pressure was slowly rising by 10 or 15 mtorr per week due to another vacuum leak around valve 1AVA8 (due to a tall vertical beam in the absence of 1AQ9). Preparations were made for emergency intervention if required earlier than fall shutdown and BL1A currents were for the most part kept to a conservative 130 μA as an extra precaution. As it turned out, the steady rise in pressure was kept in check enough by adding extra pumping to last out the schedule.

Later on the BL1A current was further lowered because of cooling problems with the BL1A triplet. This fault ended up in a horse race with the above vacuum problem to see which would curtail BL1A operation before the end of the beam schedule. The coolant flow through two circuits in the 1AQ15 magnet was restricted causing heating problems that could only be alleviated by reducing the current through this quadrupole. This, in turn, compromised the BL1A tune thus forcing lower proton currents in order to maintain normal beam spills in the 1AT2-TNF area. Even though some respite was obtained during the emergency inflector repair which offered the opportunity to check out and optimize the 1AQ15 flow, the subsequent deterioration of this cooling had the BL1A currents reduced to 50 μA as the fall shutdown approached. This was a large contributor to the above reduced percentage for current delivery. BL1A production was followed by BL1B operation which finished much sooner than scheduled allowing a welcome early start to the ambitious list of BL1A shutdown activities briefly described below.

BL2A ran for 2792 hours or 75% of its scheduled time, receiving a charge of 77 mAh at currents up to 65 μA but usually around 30 to 40 μA. Beam was generally available on demand and the lower availability reflects those times when RIB was not needed due to ISAC target problems or changeovers, stable-beam tuning or other procedures. The chief problem during 2A operation was beam stability. Far too many trips occurred while running as close to the target current limit as possible (to capitalize on exponentially increasing RIB production with current) only to be upset by an approximate 2 μA current variation. This instability may be inherent in the shadowing technique (with extraction 1) that itself was instigated to avoid BSM trips caused by high energy beam tails intercepted when the 2A foil is dipped in at slightly lower (non-shadowed) energies. Beam physicists are investigating the problem while the Controls group is developing stability programs that may help reduce the downtime – largely associated with the longish (2 to 4 minute) beam recovery ramp-up times following each trip).

BL2C4 ran for 1660 hours or 69% of its scheduled time, receiving 95 mAh or 83% of its scheduled charge. Shutdown repair problems, particularly in achieving leak-tight water seals as described above, delayed 2C4 startup by about 5 weeks resulting in the poor statistics as well as some of the higher individual shutdown doses. However, there was little 2C4 downtime once it got going at nominal currents of 60 μA. The shutdown goal of a realigned beam line and STF was achieved and some of the best operation in recent years has resulted (wider tuning windows, low collimator temperatures). Nevertheless, a redesign of the STF target is in progress in collaboration with ATG/Nordion.

Fall Shutdown

The scheduled fall shutdown saw a tremendous amount of meson hall work done over a three week period while the week of work in the vault was fairly limited. In BL1A there was the repair of vacuum leaks at 1AVA8 and 1AQ14, the repair of a water leak at 1AQ15 as well as flow improvements to that quadrupole magnet, the installation of new target ladders and water package servicing for 1AT1 and 1AT2, the replacement of monitor 1AM9 and servicing of others, the repair of BSM 56, and various routine maintenance jobs such as the replacement of active system filters.

In the vault both X1 and X2A foils were replenished (X2C foils were reloaded when the lid was raised in August), vault BL monitors were gassed, the 2C4 protect monitor wiring was repaired and the 2C4 scanning wire monitor alignment inspected, tank cryopump 2 was installed, the upper correction plate external cabling was refurbished, a vacuum leak at 2AVB1 was repaired, rf transmission line repairs were made at capacitor station 2, the water-cooled probe flow meter was replaced, and a 2C roughing pump was repaired.

Elsewhere a water leak in the main magnet power supply was fixed, AlALCW system control valves were serviced, site air and water filters were replaced, site power supplies were serviced (including a water leak repair at 1VB1), the 2A toroid was calibrated, diesel generator maintenance was done, and several water-pump motor couplers were upgraded. The total dose for all shutdown activities was about 26 mSv distributed among 50 workers. This was in addition to the 9 mSv accrued during the mid-August inflector repair.

Beam Schedule 106

The cyclotron availability for this period was 93% of the 1791 scheduled hours, a reasonably smooth finish to the year. The total downtime was 108 hours, the bulk of which was fairly evenly distributed among the RF, ISIS and Services groups as well as site power disturbances. It should be noted that the rf behaved extremely well with an average weekly downtime of only 1.5 hours. The cyclotron tune was reasonably good with a typical transmission of 64% and measured tank spills around 1% of the total current extracted to the three active proton lines as follows.

BL1A ran for 1133 hours or 94% of the scheduled time and received 123 mAh or 93% of the scheduled charge. The statistics were very good as a result of work done in the fall shutdown although there were still a few problem areas such as slightly rising (but not threatening) triplet temperatures and, more worrisome, a worsening beam line vacuum due to a leak associated with monitor 1AM9. There was also the continuing inability to tune π^+ mode which fortunately was not required. The BL1A current was limited to 100 μA for a month due to the use of graphite targets at 1AT1 but was usually 130 μA when beryllium targets were used. Nine weeks of BL1A production were followed by BL1B operation for PIF.

BL2A ran for 786 hours or 60% of the scheduled time at currents ranging from 20 to 65 μA. Beam was generally available on demand and the low availability reflects those times when RIB was not needed due to ISAC target problems or changeovers, stable beam tuning and other procedures. Beam stability was again an issue when running in a radial split configuration with BL1A but not so much a problem toward the end of the beam schedule when running as sole outside high-current user in parallel with PIF in BL1B and BL2C1. Some time was spent in trying to understand beam density issues with respect to target longevity and the line tune and its diagnostics. A more satisfactory beam spot was obtained by defocusing the last two quadrupoles.

BL2C4 ran for 858 hours or 89% of the scheduled time receiving 46 mAh or 111% of the scheduled charge at currents between 50 and 60 μA. It enjoyed continuing success although some problems with the water package conductivity toward the end of the last run will have to be attended to in the 2005 winter shutdown.

BL2C1 saw a single patient PT session and also ran for 65 hours (of 382 scheduled) primarily for PIF experimenters booked for the last 2 weeks. It was limited to energies less than 105 MeV as reported previously, another problem to be sorted out in the following shutdown. PIF users also ran in BL1B at three energies (225, 355 and 495 MeV) taking beam for 67 of a scheduled 231 hours – fairly heavy use as it goes. Following PIF was a two-day development shift after which most cyclotron systems were turned off just before the Christmas holidays.

Apart from the many tasks associated with beam delivery, various operators were again very involved with fire alarm and card access system improvements, AUTOCAD drawings, training, equipment repair, computer and console upgrades and maintenance, beam transport modelling, coordination software improvements and more as well as actively helping out with many shutdown jobs.

BEAM DEVELOPMENT

Cyclotron Beam Development

Cyclotron beam development concentrated on reproducing, understanding and improving the $\approx 300\,\mu$A tune being developed to satisfy the users' requirements for beam in 2007 when ISAC is scheduled to begin operating at 100 μA. The installation of emittance limiting slits in ISIS, improved diagnostics, better alignment of the centre region correction plates, and the discovery of improved ISIS tunes all contributed to the development effort.

Beam dependent heating of the beam scrapers attached to the leading edges of the trays holding the centre region correction plates was a problem. The upper scraper in quadrant 2 and the lower scraper in quadrant 4 both heated. In 2004, the lower trays were re-aligned, and for good tunes this has eliminated the lower quadrant 4 heating problem. The upper trays will be re-aligned in 2005, and that will hopefully eliminate the upper quadrant 2 heating.

Some work was done on low energy probes LE1 and LE2. First, a high resolution probe head with five vertical fingers, identical to the one installed on LE1 in 2003, was installed on LE2. Second, the vertical sag of the cantilevered probes was measured as a function of radius. After the sag in LE1 was partially corrected, the measured displacements were incorporated into the data analysis programs as correction factors so that the position of the beam centroids could be estimated more accurately.

After the above improvements, the position of the centroid of the beam was measured on opposite sides of the tank with LE1 and LE2. As shown in Fig. 183, the beam is higher on LE1 in quadrant 1 than it is on LE2 in quadrant 3. The reason for this median plane tilt is not entirely understood, however, a theoretical analysis done during TRIUMF's early construction suggests that it could be caused by dee mis-alignments. A median plane tilt could also be a contributing factor to the overheating of diagonally opposite upper and lower correction plate scrapers described above.

Decreasing beam losses in the centre region is advantageous when running high currents since it minimizes heating and the risk of component damage. This becomes increasingly important as the beam moves outward and becomes more energetic, so it was encouraging to find improved tunes with significantly better centre region transmissions beyond the first turn.

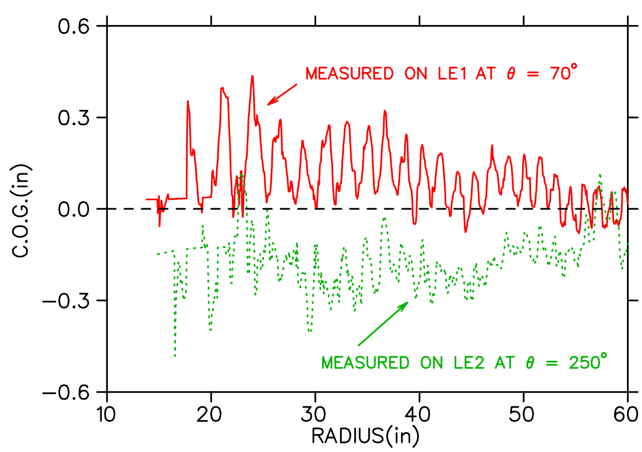

Fig. 183. Vertical positions of beam centroids measured on opposite sides of the tank with LE1 and LE2.

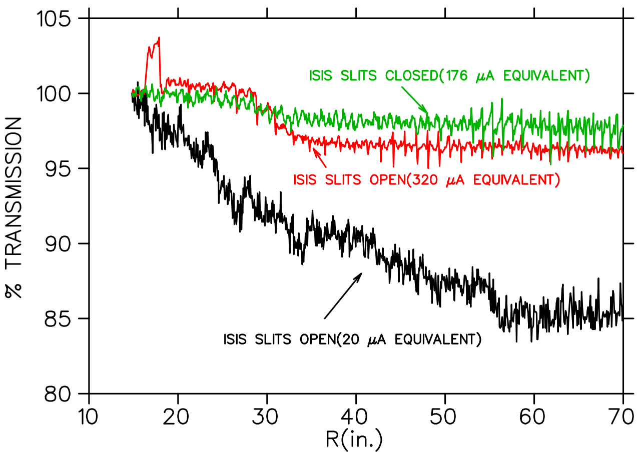

Fig. 184. Centre region transmission measured on low energy probe LE2.

This is illustrated in Fig. 184. On March 30 with 20 μA equivalent current the transmission measured on LE2 between the first turn and R = 70 in. was ≈85%, which was considered typical at the time. By June 15, after some judicious tuning, this increased to ≈96% even though the equivalent current was raised to 320 μA. Closing the newly installed ISIS emittance limiting slits to decrease the equivalent current to 176 μA increased the transmission to over 97%. This mode of operation is now being used for production runs. The ion source runs continuously at high current and the injected current is controlled with the ISIS slits.

The best 2004 high current result was achieved on June 15 when a stable beam with an equivalent current of 320 μA was obtained at 50% duty cycle with 64% cyclotron transmission and reasonable spills. In previous years we achieved similar results with duty cycles as high as ≈85%. This was difficult to do in 2004 because during development shifts the current handling capacity of the external beam lines was often limited by hardware problems and BL1, BL2A and BL2C were never all available simultaneously for high current extraction. Although many of the properties of high current beams can be studied at low duty cycle, it is impossible to develop a high current tune with good spills without working at high duty cycles. We hope we will be able to do this in 2005.

Because smoothly operating probes are essential for beam development, beam dynamics studies were done to assist the Diagnostics group in determining if the low energy probe heads could be made lighter for smoother motion and less vertical sagging. Thermal calculations based on calculated and measured beam spot sizes on the probe heads indicated that the weight of the heads could be reduced from 450 g to 190 g by making the radially outward part of the head thinner without decreasing the head's current handling capacity.

ISIS Beam Dynamics Development

During the winter shutdown, two sets of adjustable slits were installed in the horizontal section of ISIS. These proved useful for limiting the emittance of the injected beam and for controlling the current injected into the cyclotron without having to adjust anything upstream of the slits.

Considerable effort went into finding improved tunes for the vertical section of ISIS. The polarity of quadrupole Q340 in the lower section of ISIS was found to be reversed and was corrected. This enabled us to lower the voltage of quadrupole Q336 from 8.9 kV to 4.4 kV, thus reducing the risk of sparking. In addition, the 3 kV supplies attached to the last two periodic sections in ISIS were replaced with 5 kV supplies to provide more tuning room for high current beams. After retuning, the nominal settings for these sections was found to be ≈3.6 kV.

The transfer matrix elements in the vertical ISIS line, where the axial magnetic field of the cyclotron couples the transverse movements of beam, were measured and found to agree well with theoretical predictions. This will help us model the beam optics of the vertical section.

BL2A Beam Dynamics Development

ISAC requires a highly stable beam with a relatively large spot size on their target at the end of BL2A. To help achieve this, a development program aimed at obtaining a better understanding and improving the performance of BL2A was begun.

The beam envelopes along BL2A were measured with profile monitors and compared to theoretical predictions. During the course of this work, it was discovered that STRIPUBC, the program used to calculate the transfer matrices between the stripping foil and the BL2A combination magnet, was doing the vertical calculations incorrectly. This error has existed from the start, and so has implications not only for BL2A, but for all the primary beam lines. As shown in Fig. 185, good agreement between the measured and calculated envelopes was obtained after correcting STRIPUBC.

A feedback loop, which will sample the BL2A current and adjust the duty cycle of the ISIS pulser to keep the sampled current constant, is being developed. The software has been debugged and a number of successful simulations have been completed. A test with BL2A will be performed early in 2005.

In 2005 it is anticipated that a substantial portion of the beam development program will be devoted to improving the quality of the beam being delivered to the ISAC target.

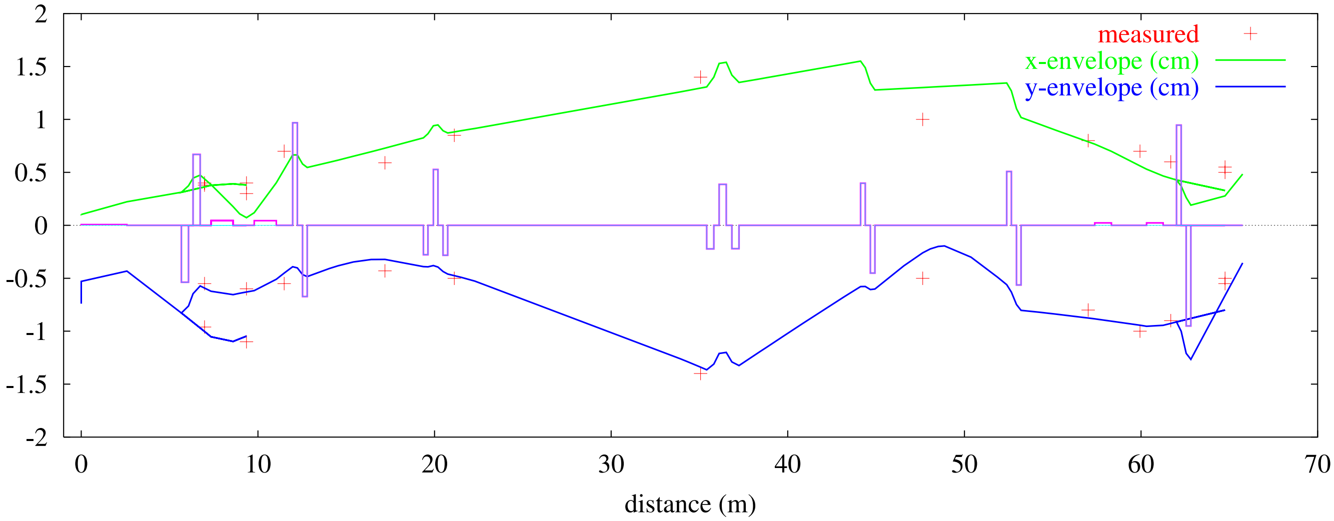

Fig. 185. Measured and calculated BL2A envelopes.

PROBES AND DIAGNOSTICS MECHANICAL MRO

In addition to normal MRO activities and ISAC work, more progress was made on the HE probe refurbishment. This included completion of the probe detailed design and fabrication and testing of the major subassemblies. The group activities are documented in the Diagnostics group meeting notes, which are available electronically via the Operations CYCINFO information service on the site computer cluster (accessible also through the TRIUMF home page on the WWW).

Cyclotron Diagnostics MRO

Prior to the lid-up, the low energy probes (LE1, LE2) were surveyed (via periscopes) for vertical alignment. The LE1 head was found to be low and so the track was adjusted to raise the probe 0.125 in. to bring it into better alignment. Both LE probes were inspected *in situ*. A new five-finger head was installed on LE2, replacing the crossed-wire head that had been installed in the mid-1990s for the alternative extraction studies. LE1 was removed from the tank for service; the re-circulating ball bearings were overhauled and modified slightly to reduce wear. Also, a problem was found with the mounting of the head, which is susceptible to cantilever forces. A new LE head design was developed to lighten the mass and improve the attachment. LE2 is scheduled for similar treatment in 2005.

The extraction probe for beam line 2C was removed for routine service in the winter shutdown. The grease on the vertical drive screw of PIP3 was found to have dried out resulting in stalling. The screw was cleaned and re-lubricated.

In a major effort, the vault wiring for the SE periscope was replaced during the winter shutdown. The NW periscope cables will be replaced in 2005. The NW periscope prism was replaced.

Beam Line Monitor MRO

All vault and standard beam line monitors were serviced during the shutdowns. The external wiring harness of 1BM5 was tied away from obstructions and the radiation damaged HT cable of 1VM3 was replaced. In addition, assistance was provided to beam line 2C4 service in which several alignment issues have been identified.

ISAC Diagnostics

The external wiring harness of the IMS:DB0 slits was re-routed to solve an interference problem. Conceptual designs were made for a scanning wire monitor to be an alternative to the harps in the target station exit modules because at the high ion-beam intensities possible with some ISAC ion sources, the harp monitors are saturated. As usual, a significant number of foils were prepared and loaded on the MEBT stripper.

HE Probe Refurbishment

The original HE and LE probe designs have ball-screw drives moving travelling intermediate members to perform cable-driven doubling of radial motion along a track that is raised and lowered to retract and insert the probe head into the cyclotron median plane. When not in use, the probes have to be raised at specific radial park positions. The replacement HE probe design utilizes a rack and pinion drive to move a travelling intermediate member moving along a vertically stationary track. The probe head alone is raised or lowered into the beam plane along a wide radial range of probe motion. Extensive tests of the lift mechanism were done in the lab to ensure reliability of the concept. The probe was assembled in the laboratory before the end of the year, but fabrication of the vertical mounts and laboratory commissioning will delay the installation in the cyclotron until the next opportunity available after March, 2005.

RADIO FREQUENCY SYSTEMS

RF Operation

The total rf downtime for the year was 77 hours. This is a great achievement compared to 234 hours in the previous year.

The main contribution to downtime was sparking with 44 hours. Crowbars caused 12 hours and the remaining hours were caused by various small failures like blown HVPS water cooled resistor and worn filament power supply breakers.

A great deal of activity was devoted to enhance the overall reliability of the rf system. A number of improvements were made in various areas starting from amplifiers all way through to the cyclotron resonators.

RF Power Amplifiers

Acquisition of data concerning the voltages and currents of the power amplifiers (PA) is via CAMAC. A new interface box with the capability to handle up to 112 inputs was installed to provide the good rf filtration and over-voltage protection required for the controls input modules and the ADCs. Also installed were new wiring within the rf room and new shunts for PA screen current measurement. All this was accomplished in the framework of our co-op student project.

Modifications were made to the spare soft-start SCR boxes. Diodes, SCRs, and snubber networks that have higher break-down voltage ratings and new heatsinks were installed. A spare filament power supply was refurbished to provide a tube conditioning voltage of 12.0 V. Because the filament connectors of the original PA tube were very weak and were prone to water leaks, new connectors were designed. A total of sixteen connectors are being installed.

A new, more robust, hairpin inductor less susceptible to water leaks was designed and will be tested in 2005. Meanwhile, a new hairpin cooling concept was tested in the PA1 amplifier. Broken input capacitors' gearboxes were refurbished in PA3 and PA4.

The original elapsed-time counters for the filaments were located at the back of each PA and were non-resetable mechanical meters. Two (of eight) have stopped and there were no spares due to their obsolescence. The new electronics-type counters are compact, easy to read, and have a maximum range of 999999.9 hours. They can be reset to zero, which is very useful when a new or rebuilt tube is put into service. All eight counters were mounted on a 19 in. rack panel above the main console (see Fig. 186) and commissioned in May.

Anode HVPS

New thyrite varistor stacks with additional air cooling were installed in the main HVPS to improve protection of the chokes (see Fig. 187). Horn spark gaps on the chokes were readjusted to the specified rating. New flexible couplings for the water-cooled resistors were installed because the old ones often cracked and gave a lot of trouble with water leaks. Both the old and the new type of connections are shown in Fig. 188.

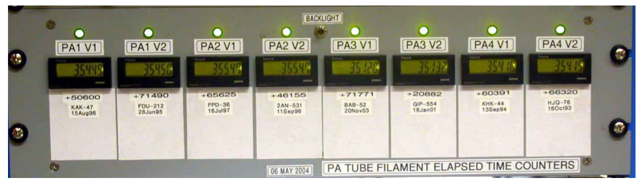

Fig. 186. New PA filament elapsed time counters.

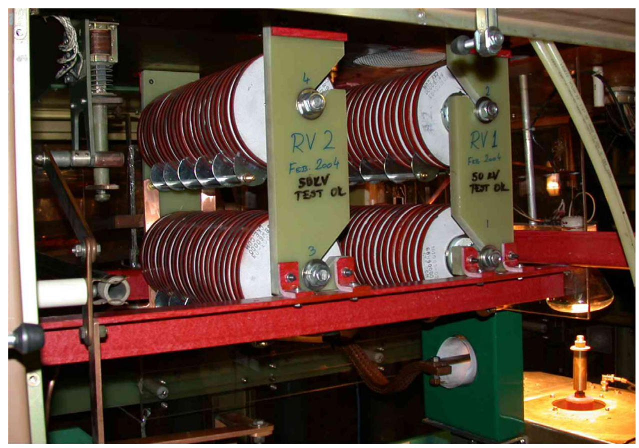

Fig. 187. New thyrite varistors in anode HVPS.

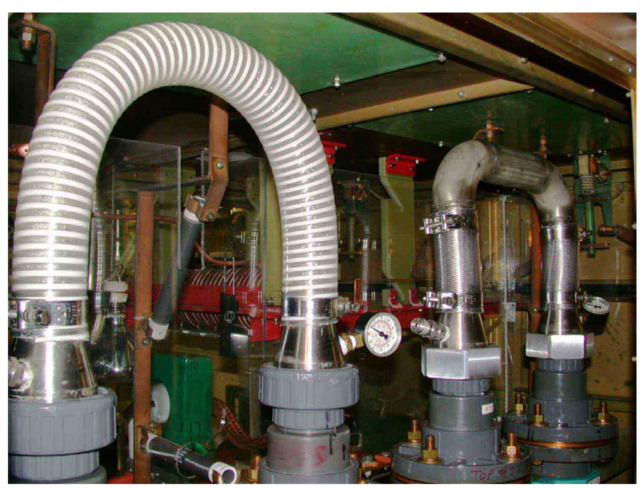

Fig. 188. Old and new (left to right) flexible couplings in the HVPS resistor cooling circuit.

A water filter, purging valves, and pressure release valves were incorporated into the return cooling line. Broken check valves were replaced. New controls were installed for the automatic water supply valve.

The original HVPS diodes in the 24 stacks of 12 series connected high power diodes, with their accompanying RC networks, became obsolete. Two new spare rectifier diode stacks with new diode types were assembled and successfully tested.

The crowbar-driver protection board accepts crowbar firing signals from eight PA tube cathode shunts and is supposed to suppress transients and potentially high voltage spikes, not allowing them to get to the crowbar driver logic board. It also provides signal sources for monitoring continuity of the cathode shunts and interconnecting cables. The old board contained signal diodes that were low-rated in both forward current and reverse breakdown voltage capabilities. These shorted almost every time when the crowbar was fired from a cathode shunt because of the excessive energy of the transient. A shorted diode means a completely shorted input and the PA tube is no longer crowbar-protected! A new crowbar protection board was designed and built. It performs much better transient clamping by means of 2 × 20 A Schottky diodes for both positive- and negative-going transients. The existing coaxial cables to the old board were removed and replaced with new cables fitted with SMA and BNC connectors and, for ease of maintenance, bulkhead adapters instead of direct soldering. The board was installed (Fig. 189) and commissioned in the September shutdown.

RF Combiners and Coaxial Switch

The final rf combiner (#3) was replaced with a new unit (see Fig. 190) that was tested into a dummy load up to 700 kW, limited only by the load cooling capability. All 3 combiner waster loads were relocated on top of their corresponding combiners and new water cooling circuits were installed. All sharp edges of the 12 conical adapters to transmission lines were chamfered, and an installation procedure for the cones was established to prevent fingerstocks damage.

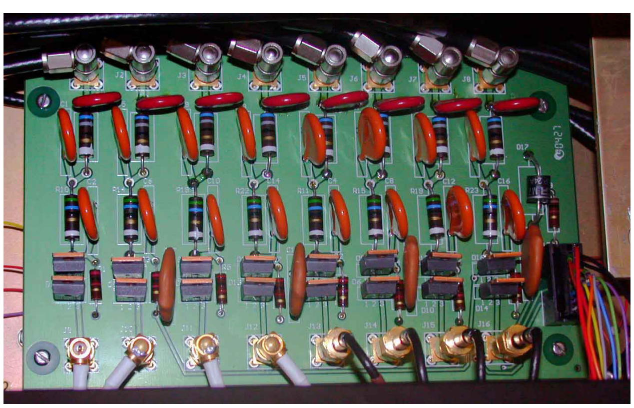

Fig. 189. New HVPS crowbar driver protection board.

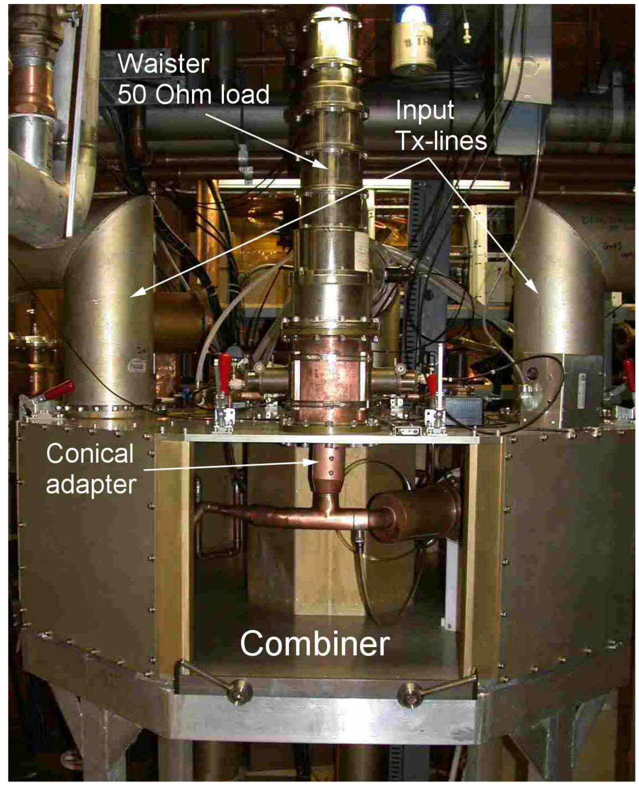

Fig. 190. New final combiner with dummy load on top.

The rf amplifier system provides up to 1 MW of rf power at the output of combiner #3, which is connected to the cyclotron through a 9 in. transmission line. To simplify troubleshooting the system a 4-port 9 in. coaxial rf switch was purchased in 1995. The idea was to install it at the final combiner output in order to switch rf power either to the cyclotron or to the dummy load. Unfortunately, the manufacturer's power rating did not suit our requirements covering only the range up to 700 kW.

Over the last year the switch was modified by incorporating a water-cooling circuit inside the switch port of the inner conductors and the rotor-blade contacts were air-cooled by 3 blowers attached to the switch. Teflon insulators were replaced with polypropylene ones to prevent substantial deflection due to cooling-water pressure. An inside view of the switch while it was being modified is presented in Fig. 191.

In April the rf switch was tested on a soda-solution dummy load (see Fig. 192). Maximum power at that time was limited to 700 kW by the capability of the heat exchanger of the dummy load.

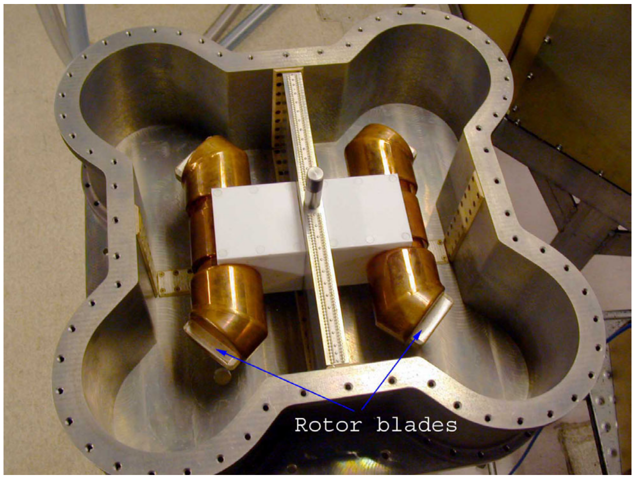

Fig. 191. Inner structure of the rf switch.

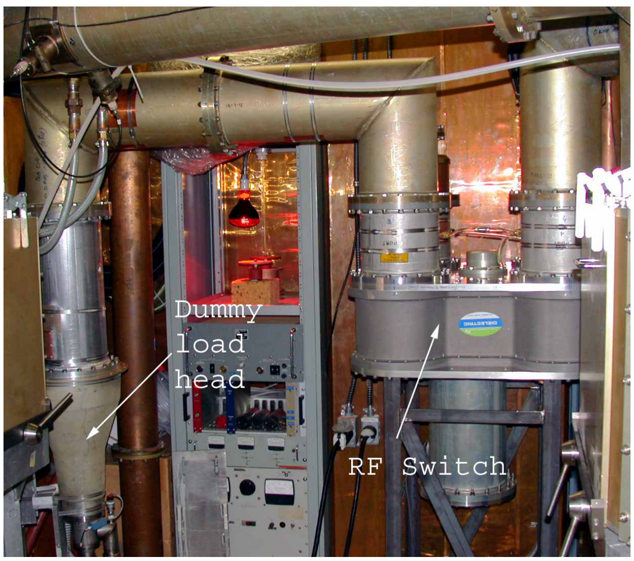

Fig. 192. RF switch with dummy load test set-up.

In June the switch was successfully tested at full power in the cyclotron. This time we extended the length of the transmission line (including the switch) by about 5 m in order to move a transmission line resonance away from the operating frequency. The measured temperatures at the rotor (knife) contact and the water-cooled stator contact group are presented in Fig. 193, and show a minor temperature rise which will not affect the reliability of the operation of the system. The rf switch and soda solution load are being upgraded now with commissioning planned for 2005 winter shutdown.

Transmission Line

The entire section of 9 in. transmission line from the final combiner to the 11 in. matching section was overhauled during winter shutdown. All junction bullets and elbows were serviced and new O-ring water seals were installed. Old rubber gaskets, installed some 20 years ago, were found hardened (carbonized), especially in the vault area where they are exposed to radiation. The transmission line water cooling circuit was redesigned. The original design was based on a plastic return pipe buried inside a centre conductor of the transmission line. This pipe was found to be completely disintegrated due to radiation damage. The new design uses an external copper return pipe and requires new combiner adapter cones and centre-conductor water plugs with plastic pipes going out of the transmission line (see Figs. 194 and 195). The new design separates the cooling circuit for active branch from that of the non-active branch.

To reinforce structural stiffness of the transmission line at the water breakouts where water pressure creates a high axial force, new dielectric spacers were fabricated initially of delrin and later of polypropylene. These new spacers were installed at the output of the final combiner, at active/non-active water junction, at 9 in. to 11 in. transmission line junction, and on the

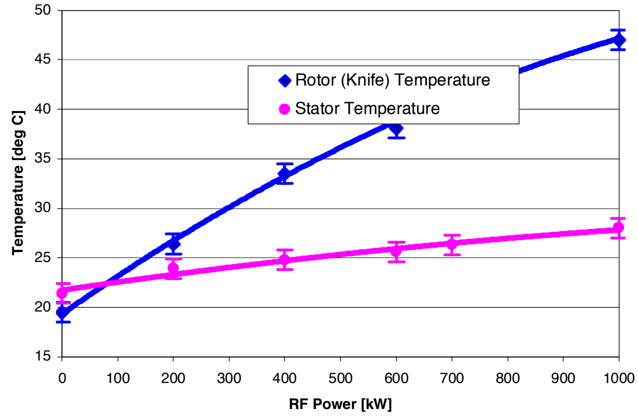

Fig. 193. RF switch temperatures vs. rf power.

Fig. 194. Parts for new transmission line cooling design.

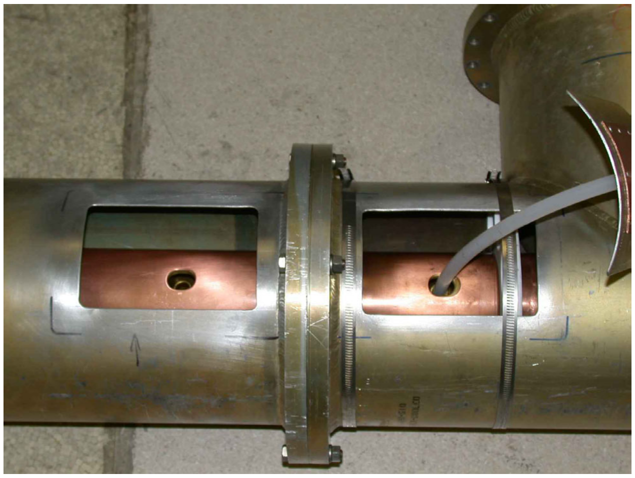

Fig. 195. Water outlets at transmission line junction.

coaxial switch. The new cooling circuit incorporates pressure and flow regulation valves and an interlocked flow switch. Matching section capacitor stations #1 and #3 were replaced with fast-detachable plug-in modules in the winter shutdown. This new approach uses external, quick-detachable cooling lines.

Thus we have eliminated the troublesome cooling lines buried inside the 11 in. transmission line centre conductor. At present we have all of the capacitor stations upgraded; they are independently cooled and interlocked with individual flow switches. The new water distribution set-up is shown in Fig. 196.

During the September shutdown some critical transmission line junctions were inspected. Severe finger-contact damage was detected on the transmission line centre conductor at the matching section capacitor #2 (see Fig. 197). Broken parts were repaired and new stainless steel clamps were built to replace weak copper clamps, ensuring reliable rf contact for copper sleeves at the transmission line centre-conductor junctions.

Cyclotron

We continued the program of the replacement of copper chore pads with fibreglass ones. The aim of this program is to protect the delicate resonator cooling circuit bellows. This year another 20 resonators in the upper octants #3 and #4 were serviced and leak tested.

Ground arm tip (GAT) positions of #10 resonators are not adjustable like the other resonators. From the measurements last year we recognized that some of them are offset with respect to the adjacent resonators. To reduce an impact on the electric field distribution it was decided to compensate this misalignment with hot arm repositioning, aiming for a constant rf gap along the dees.

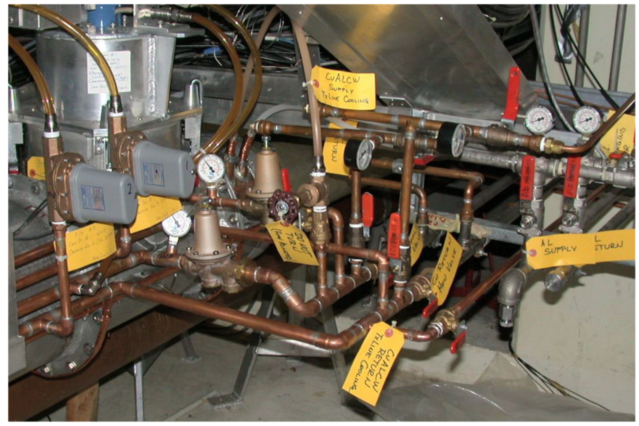

Fig. 196. Capacitor stations water distribution.

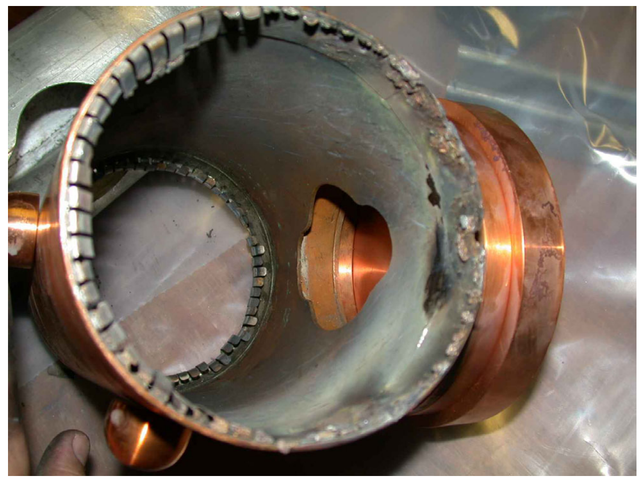

Fig. 197. Burnt transmission line finger contacts at capacitor station #2.

An attempt to measure some of the GAT positions inside the tank was made. However, the planned survey was not completed due to an issue of high dose. The measurements that were completed confirm last year's numbers. These data are the essential part of the dee-voltage monitoring program: the rf gap distances will be included in the calibration factor for the voltage distribution along the dee gap. At present this information is used in the GAT tuning process for minimization of rf leakage patterns. All of the troublesome thermocouples (TC) in the tank were assessed. A few problems were traced down to poor contacts in the connectors and were fixed. Three thermocouples, one on the rf booster, rf deflector, and high-energy spill monitor, were found damaged. A decision was made not to touch them because of the high radiation level in the area. All the above-mentioned devices have other thermocouples in their proximity, which can cover temperature monitoring. The correction plate (CP) trays from quadrant #3 were pulled out of the tank and serviced. All insulators were replaced, burnt marks cleaned, and deformations straightened out. CP trays in Q2 and Q4

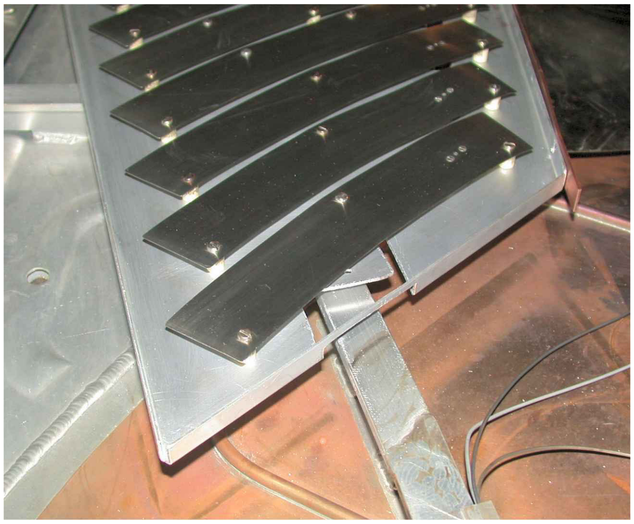

Fig. 198. Modified Q4 correction plates tray.

are known for significant temperature response because of the accelerated beam hitting the CP trays. This time both lower trays were realigned by means of modified supporting spacers. CP Q4 required tray modification to meet the desired elevation (see Fig. 198). Four thermocouples attached to the CP copper beam-scrapers were rearranged to protect them against direct beam exposure.

At the end of the winter shutdown we had found a number of shorts in the correction plates HV feeding cables. The problem was traced to radiation damage in the last part of the cable length near the cyclotron (see Fig. 199). A few broken cable ends were trimmed and new connectors installed, while many other cables remained marginal. During the September shutdown a number of upper vault cables were trimmed back ~10 m, where a breakout panel was installed with new sections of cabling to the cyclotron feedthroughs. A replacement program is being planned for the next winter shutdown for the lower CP feeding cables.

RF Booster

The RF Controls group replaced an old rf booster control system with a newly developed hardware and Windows PC-based software. The system interface now looks much the same as for the ISAC rf systems. The motor attachment of the rf booster tuner was modified to ensure reliable operation at the extremes of the tuning range. The coupling-loop window was checked for moisture conditions that had been observed in the past. This inspection showed dry transmission line and ceramics surfaces, as a result of forced air ventilation provided for this area in 2003.

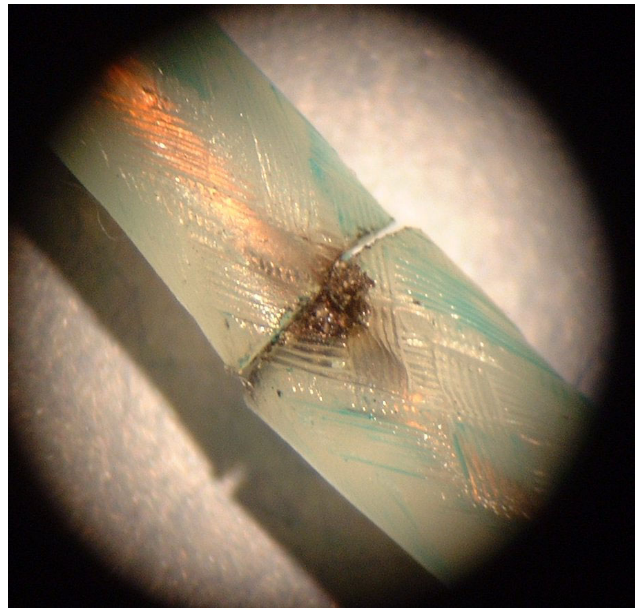

Fig. 199. Broken CP HV cable fragment.

Cyclotron Simulations

A cyclotron electrodynamics study was carried out using the 3-D structure simulator software, HFSS (high frequency structure simulator, Ansoft Corporation). This work is aimed at better understanding the rf modes excitation and eventually to suppress cyclotron sparking. The centre post, the flux guides, the quasi-circular vacuum chamber, and the rf structure have been incorporated into the simulation. Fundamental accelerating mode and rf leakage into the beam gap have been studied in details. The rf parameters have been computed and are in close agreement with the parameters measured on the cyclotron (see Table XXVIII). Vertical asymmetry at the dee gap, caused mainly by resonator misalignment, leads to rf leakage fields into the beam-gap tank volume outside the resonators. A number of parasitic modes were identified in the frequency range of 10–40 MHz. Field distribution of one of the nearest parasitic modes is shown in Fig. 200.

Table XXVIII. Calculated and measured rf parameters of the cyclotron.

Parameter	HFSS	Measured
Resonant frequency (MHz)	23.106	23.060
Quality factor	5814	5500
R_{shunt} (kΩ)	38.6	36.0
Power (kW) for dee-gap voltage of 180 kV	840	900
Sensitivity to all ground arm tip displacement (kHz/mm)	83	––

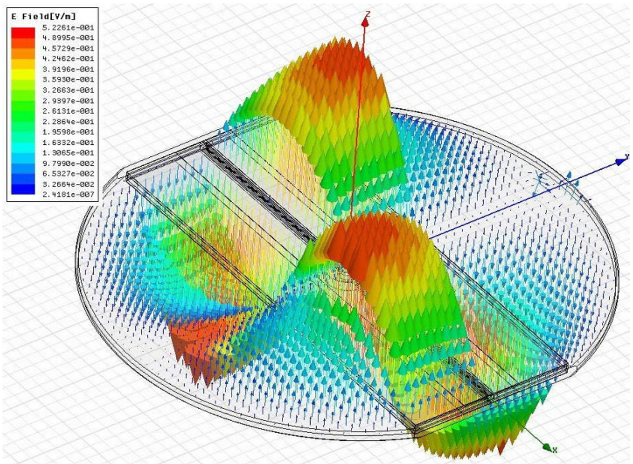

Fig. 200. Medium plane E-vector plot for one of the parasitic modes.

RF Support

The RF group was also dedicated to the following major ISAC projects, which are reported in the ISAC section.

- Operation and maintenance of the ISAC linac.
- ISAC-I rf amplifier remote controls development.
- SCRF cavities and accessories design, test, and characterization.
- Cryomodule alignment (WPM) system commissioning.
- Cryomodule #3 assembly and tests.
- ISAC-II transfer line rebuncher system development.

RADIO FREQUENCY CONTROLS

The RF Control group, in cooperation with the RF group, has continued fine-tuning the main cyclotron rf control system with the goal of reducing rf downtime in the cyclotron. By adjustment of the levels of the smaller sparks, which are ignored, and using a more aggressive recovery of rf voltage on the larger ones, the rf downtime was reduced significantly while reducing stress to the rf power components.

The booster rf control system was commissioned. Internal tuning controllers were added to facilitate the automatic power up sequence.

The rf control system for the ISAC-II superconducting rf module was tested successfully. Each module consists of 4 superconducting rf cavities, each of which are individually amplitude and phase regulated with tuner feedback control. Phase instability that was traced to fan noise in the power amplifier was fixed. Cross-talk within the phase feedback loop was eliminated and the phase loop is now, like the amplitude loop, unconditionally stable. Additional control was added to the tuner controller with the result that powering up a superconducting cavity can now be fully automatic. Remote interface to EPICS was completed and tested.

CYCLOTRON DIAGNOSTICS

Tank Broadband Diagnostics

The major priority was given to fast signal acquisition from internal probes of the cyclotron. The fastest beam signal currently available for operation is the time-of-flight (TOF) signal with a frequency spectrum extending to a few MHz. With such a limited band this signal represents only the envelope of the multi-bunch beam structure; the rf structure is not retained. The TOF signal is routinely used by Operations to optimize the transit time of the beam through the cyclotron. However, the signal appears not to be sufficiently stable when applied to more delicate measurements of the beam isochronism and the beam energy gain per turn as a function of the orbit radius.

An investigation was undertaken to identify the nature of the noise in the TOF signal derived from the HE2 probe. We observed that the stability $\Delta t/t$ of the TOF remains nearly constant with the radius to a level of 10^{-4}. This implies that the absolute accuracy worsens with the radius as a power of $\sim$3. We conclude that fluctuations in the TOF signal are not related to the signal acquisition instrumentation but rather are generated by the beam itself. While studies of beam instability may be considered as a long term program, interpretation of data may still be unambiguous if adequate statistical analysis, such as data smoothing by cubic splines, is applied. This procedure was implemented in Matlab as a test.

An attempt was made to improve the accuracy of the TOF measurements by increasing the dwell time at each radius and averaging over multiple samples. Though a benefit was noted, the slowness of the procedure makes it impractical unless the data acquisition instrumentation and/or algorithms are improved.

A real step forward in beam measurements in the time domain can be expected with the implementation of broadband signal acquisition and analysis. Applications for these diagnostics include measurement of the TOF, direct bunch phase measurement with respect to the rf, and the shape of the longitudinal bunch. Significant efforts were made in this direction concentrating simultaneously on two devices: the phase capacitive pickups and a new broadband head for the HE3 probe. Only the two outermost pairs (upper and lower) of the capacitive pickups remain of some seven pairs initially installed in the tank. The others were decommissioned because the strong signal induced by the cyclotron rf system, rendered extraction of accurate beam information impossible. There is a hope, however, that modern methods of signal analysis can improve the accuracy of measurement to the required level even in the presence of the strong rf background.

The four pickups were inspected visually during the September shutdown and their signals observed in the time and frequency domains. All four are still usable and beam induced spectra were observed up to ∼2 GHz. Signal-to-noise ratio (SNR) was ∼0.1 at the fundamental, more than 5 at the second harmonic and drastically increasing above the 7th harmonic. Inspection revealed that some of the coaxial signal cables were partially damaged. A decision was taken to replace the four cables with foam dielectric, low loss, phase stable cables. The cables were installed in the winter shutdown along with two similar cables for the HE3 probe equipped with a new broadband stripline head (see Fig. 201).

The new head is essentially a 50 Ω, parallel-plate transmission line made of a tantalum foil 0.3 mm thick supported by a frame made of BN ceramic. The entire structure was designed with the high-frequency structure simulator program (HFSS) from Ansoft and was optimized to provide a broadband 50 Ω match (VSWR <1.2) over a frequency interval from dc to over 2 GHz. The 3 mm inter-plate spacing of the transmission line was chosen as a compromise between two objectives: minimizing transverse geometrical dimensions and reducing the current leakage due to knock-on electrons that was estimated to be ∼2%. In contrast to capacitive pickups, this broadband monitor intercepts the beam and therefore can be used only for cyclotron tuning at low beam currents. A 3D thermal simulation with ANSYS Workbench has shown that the probe can be operated up to at least 1 μA average. A high peak current at low duty cycle is essential for a good SNR. Minor modifications made to improve the mechanical rigidity of the frame during the mechanical design had a negative impact on the rf performance between 1 and 2 GHz (VSWR increased to almost 2).

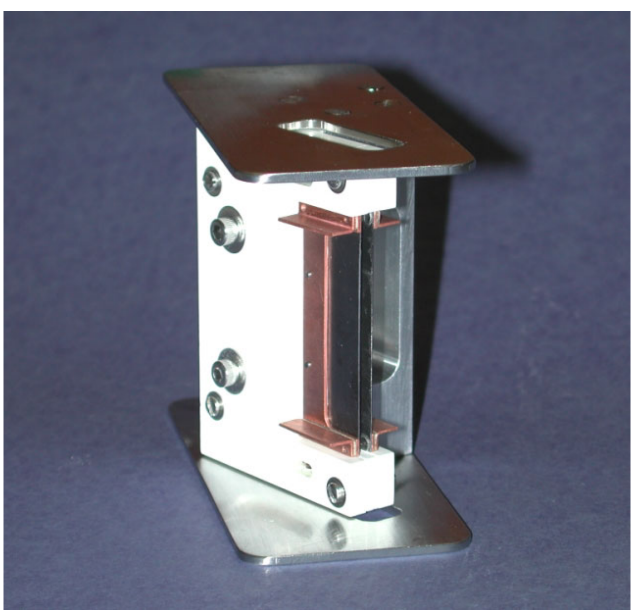

Fig. 201. The new stripline head for the HE3 cyclotron probe.

The head was built and installed in collaboration with the Probes group on the existing drive mechanism of the former HE4 probe which replaced HE3 in the tank at the end of the winter shutdown. Diplexers permit acquisition of the dc, low frequency TOF (<3 MHz), and broadband signals.

Beam Line Diagnostics

The signal from the capacitive probe in beam line 1A is used to optimize the overall TOF of the beam through the cyclotron. The raw signal from the probe is a train of pulses at 23.055 MHz modulated by the 1 kHz pulse structure. A CAMAC module was in place to count the number of rf cycles from the start of the ISIS pulser signal to the trailing edge of the capacitive probe signal but the system was never fully commissioned. A prototype module was built which unambiguously detects the leading and trailing edges of the beam pulse from the capacitive probe signal. Applying these new signals to the counter module now allows the machine TOF and the apparent lengthening of the extracted beam pulse to be determined. Since the measurement is automatic, it eliminates the need for the operators to set up the oscilloscope and allows the new parameters to become a part of the shift log. The design was tested with beam and a printed circuit card version will be made.

Diagnostics MRO

In addition to numerous routine checkups and calibrations of diagnostic electronics, several time consuming and dose related jobs were performed over the year. The water cooled pop-in-probe (WCP) cooling flow meter was replaced in the vault. The radiation damaged wiring harness of the SE periscope was replaced completely. An oil-free vacuum test station, consisting of a turbo pump, a scroll pump, gauges, and a test box, is being constructed in the Probes laboratory. Our rf design software was updated and printed circuit card layout software purchased. A USB to GPIB interface was purchased for connecting our notebook computer to various test instruments using LabVIEW.

CYCLOTRON VACUUM AND CRYOGENICS

The cyclotron vacuum/cryogenic system continued to operate well for the year. Minor problems with vacuum equipment caused almost no downtime during beam production. Cryogenerator #1 is still not very reliable, and it is used for a one to two week interval to make time for overhauling cryogenerator #2.

The lubrication delay device was modified on cryogenerator #1; the lubrication can be turned on manually in the case of a device failure. Major repairs were made to the crank case assembly of cryogenerator #2 to fix a loose displacer rod on the first cylinder. The temperature sensors wiring and some of the sensors were replaced on both cryogenerators. New cables were made and installed connecting the sensors to the new Lakeshore temperature monitor. The monitor readouts are available through the main control system. The helium gas copper lines were replaced with stainless steel lines on both cryogenerators as well as on the gas manifold system.

Cyclotron cryopumps were maintained and serviced regularly throughout the year. Cryopumps 2, 4, 5 and 6 were refurbished. The limit switches were repaired on the gate valves of cryopumps 5 and 6.

In December the main seals of the cyclotron were tested OK by venting the seal space. The Varian ion gauges that were installed in 2003 are operational and readouts are available through the main control system. One of the two inflector ion gauges failed. Both gauges have been replaced with dual filament models for redundancy. The ion gauge power supply was checked and repaired as well as the cable for the inflector ion gauge.

An air leak was registered by the residual gas analyzer (RGA) in December as soon as the rf system was shut off. Helium leak detection with the RGA confirmed the leak in an O-ring seal of the coupling loop.

The cyclotron tank vent valve system failed during the summer emergency shutdown. The tank was vented with nitrogen through a manual valve on the RGA line. Failure of the vent valve was caused by low pressure in the air line due to leaks in other devices using the same air supply. The air leaks have been repaired.

Improvements to the B20 cooling water system were made by removing an inefficient heat exchanger and switching to the city water system.

Beam Line Vacuum

On BL1A the vacuum of the beam line was compromised due to the leaks in the 1AT2 area at 1AQ14 and 1AVA8. The roughing system was modified to accommodate the increased load. The leaks at 1AVA8 were repaired during the summer shutdown by replacing O-rings and refurbishing the valve.

A few leaks developed in the vault section of BL2A because of radiation damage to O-ring material. The O-rings were replaced. All key brass block valves were replaced with refurbished ones. The ion gauge head 2AVIG1 was replaced.

The vacuum system of BL2C worked well. The BL2C radiation hard valve and its N_2 supply were repaired.

The front-end vacuum of BL4 was maintained and kept under nominal vacuum to protect the cyclotron vacuum in case of gate valves failure.

Vacuum and Cryogenic Support

The Vacuum group has been involved in ISAC projects assisting with vacuum designs, vacuum equipment installation, mechanical assemblies, leak checking, cryogenic designs, etc. The details are presented in the ISAC Vacuum section of this Annual Report. The supply of liquid nitrogen and liquid helium was also looked after by the Vacuum group.

ISIS

The CUSP ion source and injection line continued to operate well during the past year with only minor downtime due to a failed turbopump, light-link power supply module, and some vacuum leaks. Although many ISIS personnel were involved in other TRIUMF projects, some extraordinary maintenance as well as a few significant projects were undertaken during the past year.

A major effort was unexpectedly required to realign the I1 motor generator set that provides power to the ion source terminal. The ion source optics were cleaned, realigned and reinstalled. The second of two new CUSP ion source bodies was installed and commissioned in March. This source ran well albeit with shorter than expected filament lifetime during a brief test run. The beam production schedule dictated that, for reliability, the other source be reinstalled. The source was tested off-line later in the year in the CRM and will be installed in the I1 terminal in early 2005.

Last year we reported the design and manufacture of four new sets of motor-driven variable aperture slits. One set of slits (y-direction only) residing between the two 45° vertical bend elements were installed in the September, 2003 shutdown to limit the dispersive energy tails of the beam from reaching the cyclotron. Of the other three sets, two sets of slits were installed into the first common periodic section of the ISIS beam line to define the emittance of the beam injected into the cyclotron. This entailed moving some diagnostic and beam trip elements with appropriate interlocks revisions as well as some minor refurbishing of the optics. The final assembly replaced the existing 5:1 slits and provides enhanced beam current control. The slits were successfully commissioned and provide improved beam quality to the cyclotron.

The inflector/deflector system experienced a major failure in August and accounted for 138 hours of downtime. The failure was due to sputtering from a sharp metallic edge on an insulator in the "cross" providing high voltage to the inflector/deflector. This area had previously been serviced in May, 2003 when all insulators were replaced. The insulators in this region will be inspected and replaced in January, 2005. The inflector/deflector proper was serviced during the winter shutdown and ran well for the entire schedule.

A new equipment rack was installed next to the existing inflector/deflector power supply equipment rack to allow for present and future refurbishing. The oil filled ballast resistors were replaced with new air insulated resistors. New high voltage cables and positive lock connectors at the feedthrough end were installed. New power supplies will be installed in the latter half of 2005.

The prompt radiation safety trip system has been revised to include redundant safety-critical gamma and neutron monitors. Each of these safety-critical trip functions requires three independent ISIS beam control devices. To provide these additional beam control devices we have designed a system of four high-voltage relays to service the four vertical bend electrodes and two beamstops. Each trip function will use two high-voltage relays to switch two electrodes to ground potential and to insert a beamstop. The design is complete and procurement, assembly and off-line testing is under way. Installation will take place in January and February, 2005 with commissioning scheduled for March.

Some effort has gone into restoring the CRM ion source test stands. The first chamber of the 1 MeV cyclotron was restored to operating condition. This has allowed the testing of CUSP ion sources by ISIS, Nordion and Dehnel Consulting. In addition, Dr. Yong-Seok Hwang joined us in August on sabbatical from Seoul National University in South Korea, to study our ion source characteristics.

ISIS has provided assistance to numerous ISAC projects during the course of the year. These include assembly of electronics racks for the TITAN RFQ and high-voltage power supply commissioning. For Expt. 991 an extension of the LEBT was required and ISIS procured, assembled and installed the major mechanical and electrical components including power supplies. A great deal of mechanical effort was directed for the assembling of the ISAC-II cryomodules. Work also continued on the transfer line vacuum and diagnostics systems.

Last year we reported the successful development effort to achieve 412 μA equivalent extracted current at 25% duty cycle. This year our development focused on producing 300–350 μA equivalent tunes at higher duty cycles and with improved cyclotron beam losses. This work, as well as centre region work, is described in greater detail in the Cyclotron Beam Development section of this Annual Report.

PRIMARY BEAM LINES

The winter shutdown began on January 5 following the Christmas holidays with replacement of the 1AT2-M20Q1 indium ring. Vacuum leak checking also showed leaks at the collimator B-1AQ14 and 1AS1-1AM10 vacuum joints. The 1AT2-M20Q1 indium ring was removed, remnant indium removed, and new ring installed. A video survey of the front end of the M20 channel was made to aid planning for its refurbishment during next year's shutdown. A loose nut on the power connection to M20Q2 was carefully tightened to avoid cracking the connector. The location of the ground fault on the M20Q1 magnet was determined. After a successful power test the shielding over the channel was replaced.

M9Q1 was uncovered to investigate its interlock and electrical problems. The former was caused by a broken wire in the Klixon sensor chain, which was repaired, and the latter by a water leak from a Pyrotenax end cap. After its repair no further water leakage was detected at the insulator.

An unexplained vacuum excursion occurred causing another round of leak checking. Three leaks were detected. Load tests determined there was a correlation with tightening/loosening the remote-handling bolts on the buss links of the 1AQ14/15/16 triplet downstream of 1AT2. Indium remnants were found on the impression on the collimator B side on the ring indicating that indium had not been totally removed during 2003 triplet installation. The indium was removed and a blanking plate with a rubber O-ring was installed to allow further leak checking. Tests showed that the 1AQ14 flange did not close parallel to the collimator B flange. A new procedure was employed to close this joint and a new indium ring was installed. Another leak test with block loading resulted in no change in the vacuum. The leaks at 1AT2-M8 blank-off plate and 1AS1-1AM10 joint were, however, still present.

A new beam-spill monitor was installed on the upstream side of the triplet; the bridge and service-chase blocks were installed. The 1AT2-M8 blank-off plate was removed and inspected. The threads of a spring eye were found to be stripped and the knife impression was found to be deep. The leak was repaired by reducing the tension on the springs.

The entire layer of blocks surrounding monitor 1AM10 and the monitor itself were removed to replace crumbling blocks in that region. A broken, lower spring pin explained the vacuum leak at this location. However, because the leak was small and its repair would increase the total shutdown dose, no repair was made.

More shielding was removed to gain access to the crumbling blocks south of 1AM10. Those that were structurally sound were left in position. Others, however, could not be safely lifted; it was necessary to jackhammer them until they could be removed. All high density blocks were replaced with low density ones except for the high-density suitcase blocks along the south wall of the trench, which were replaced with steel suitcase ones. Because the area was uncovered, the opportunity was taken to replace the cabling to the beam-spill monitor upstream of 1AS3.

Replacement of crumbling blocks north of the 1AM10 area was difficult because many had services attached to them. Removal of the blocks surrounding the crumbling ones had an added bonus of allowing inspection of the services running through the 1AS2/M20 service chase, partially exposing the M20Q5/Q6 and sextupole region of the M20 beam line to allow inspection of the rubber cooling lines. Some were radiation damaged and all hoses of the M20Q5/Q6 and sextupole were replaced; replacement of the M20VA5 valve was also done.

With the work completed at M20 and the crumbling blocks replaced, reinstallation of the beam line shielding began. The smokestack was chain-falled into position, the 1AM10 vacuum can–smokestack joint established, and the 1AT2 vacuum was pumped down. Leak checking found the joint leak tight. The 1AT2 vacuum was vented to install the 1AM10 monitor. A full-power test of the triplet magnets showed no problems and the triplet was covered with its remaining shielding blocks. A new beam line pipe was fitted to the M20Q9-10 doublet to allow a new window and gate valve assembly to be installed.

The Beam Lines group replaced the supply and return hoses of the M9AQ3/4/5 and M20Q5/6/7/8/9/10 magnets as well as those of M20B1. A vacuum leak discovered at the joint between M20Q8-M20B2 was cured by replacing an O-ring. Finally, the remainder of the M20B2 channel was covered with shielding and the shielding blocks that had been stored outside were replaced over beam line 1A.

Following the shutdown, operation continued normally until mid-July when it was noted that the vacuum in beam line 1A was deteriorating. At the same time over-temperature warnings began from quadrupole 1AQ15, the centre quadrupole of the triplet downstream of the 1AT2 target. By the end of July it was necessary to reduce the current to the quadrupole to maintain its operation and reduce the beam line 1A current from 130 μA to 100 μA to prevent excessive beam spill in the beam line. By the middle of August the beam line current was reduced to 60 μA to maintain operation of the beam line. Then the inflector began sparking and it was removed for cleaning. The opportunity was taken to open the triplet area for assessment of the 1AQ15 problem.

Thermal scans of the quadrupole revealed that two of its cooling circuits were running hotter than the others. One of these was significantly hotter and it was decided to backflush the magnet. A thermocouple was attached to each of the hotter circuits and to one of the circuits that was operating normally, which served as a control measurement. Signals from these thermocouples were fed to the control room where their temperatures were monitored continuously. This was completed as the repaired inflector was being installed in the cyclotron.

Normal operation continued with a beam line 1A current of 100 μA until the end of August, although the beam line vacuum continued to worsen. In early September quadrupole 1AQ15 began tripping again on over temperature with the result that the beam line current had to be reduced to 80 μA and then to 50 μA just before the September shutdown.

Due to the vacuum and overheating problems the September shutdown was extended to allow all the necessary repairs to be made. A vacuum leak in the 1AVA8 area was tackled first. Leak checking indicated problems with the gate valve and both of the body-valve O-rings. Examination of the damaged O-rings showed that the beam was tall vertically in this region and it was speculated that this could be related to the present mode of operation of the beam line. After the replacement of these O-rings back-flushing of the two problem circuits of the 1AQ15 magnet began. Flow rates through the two hottest and control circuits were measured; that of the hottest circuit was found to be one-third that of the control circuit. After backflushing with boosted water pressure, the flow rate through the hottest circuit was doubled and found to be close to that through the next hottest circuit.

The coil interior bore of these hot circuits was examined to see if any obstructions could be removed. A black residue of unknown composition was found on a rod after its removal from the bore. Because backflushing with water had improved the flow rate, air pressure was used in an attempt to flush out the residue and further improve the flow rates. More black sediment was released and water flow in the circuit was increased. When the triplet was powered it was found that the temperature of the hottest circuit had decreased 30°C to approximately the same temperature as the other hot circuit. That circuit too was air backflushed and sediment was removed as well. Another full-power test found that the operating temperature for this second-hottest circuit had also been reduced.

Having completed the repair of the triplet the final job was the replacement of the collimator B-1AQ14 indium joint with a new tapered indium ring to which a thermocouple had been attached to monitor its temperature. The new ring is thicker at the top than the bottom to compensate for the vertical misalignment between the 1AQ14 and the collimator B flanges. When the vacuum was re-established a leak check found this joint leak tight.

With the conclusion of the September shutdown normal beam line operation was resumed. Temperatures of the water circuits of 1AQ15 remained normal although toward the end of the running period a slight increase in the temperature of the hottest circuit was noted. Another backflushing of this quadrupole will be scheduled during the spring, 2005 shutdown.

Beam Line 2C

The solid target facility (STF) on BL2C4 was removed during the spring shutdown to repair the target position limit switches and to correct the skew misalignment that had been introduced in 2001 when the STF was previously removed. The alignment was corrected but the limit switches could not be fixed so other indicators were used to determine target position. Reinstalling the STF was very difficult because the flanges between the STF and the vertical water column did not come together when the clamp was tightened. The original clamps and alignment mechanisms were removed and a modified chain clamp was installed on both sides of the latching mechanism between the STF and the vertical water column. This work continued after the shutdown on maintenance days so BL2C startup was delayed by a month and beam production started on May 19. The dose for the STF repairs and the clamping difficulties was 51 mSv to the repair crew and the volunteers with 5 people exceeding the shutdown and sliding quarterly limits.

Strontium-82 production in the STF was very good in 2004 despite the delayed startup. 48.48 Ci were produced from 134.3 mAh in 137 days compared with 41.66 Ci produced from 116.1 mAh in 170 days in 2003. The yields in 2004 with 40 days less operation were similar to 2003 because the 2C beam current was increased to 55–60 μA. Increased currents were allowed because aligning the STF increased the beam acceptance and extra extraction foils were added in the summer when the cyclotron was raised for inflector repairs. Nine natural rubidium targets were irradiated in 2004 compared with eight targets in 2003. A dose of 180 mAh for 2005 is projected as demand for strontium-82 continues to increase. There were 30 days scheduled for proton therapy on BL2C1 and 42 days scheduled in the proton irradiation facility (PIF) on BL2C1. PIF operation was compromised because energies above 108 MeV could not be extracted. The BL2C extraction probe and beam line are designed to work from 65 to 120 MeV. It is assumed that the BL2C exit horn beam stop is in the way; this will be corrected in the 2005 shutdown.

A number of meetings were held to discuss the shutdown difficulties and a redesign of the STF. The new STF will be a water vessel with no water joints to be made up in the vault. The target insertion will be done on rails located in the vessel and the insertion mechanism will be removable to the hot cell for MRO. A new vacuum box to facilitate changing the target protect monitor will be attached to the BL2C4 beam line. The beam pipe including the new vacuum vessel will not be attached to the STF water vessel so that the vacuum box can be removed to the vault for servicing. A budget of $360 K based on the preliminary design has been approved and will be funded by MDS-Nordion.

PROMPT RADIATION HAZARDS

During the 2004 shutdown the electrical room on the B1 level of ISAC was made an interlocked exclusion area. It now must be locked and unoccupied whenever beam line 2A is on. This was necessary because a combination of measurements and calculations had shown that dose rates in that location could exceed the 1 Sv/h policy limit of TRIUMF given a point loss of the total beam for which beam line 2A is licensed. Dose rates at ground level over beam line 2A are within the 1 Sv/h policy limit.

An interim proposal to reliably terminate beam production in response to beamspill, neutron, access, and emergency safety trip conditions was implemented during the 2004 shutdown. Three existing ISIS devices, beamstop 165, the fast target, and components in bend 3/4 were all interlocked to stop beam delivery in response to any of the four trips. The rf system was removed from all safety trips.

A template set of annual area safety unit test procedures was drafted. Specific annual test procedures for each secondary channel area safety unit were written and approved.

There were four safety-critical radiation monitor trips in 2004, but all were associated with power bumps and not with beam delivery.

The operation of the nine safety-critical pairs of radiation detectors was checked on thirty-five maintenance days. No failures were reported.

CONTROLS

Introduction and Summary

The Central Control System (CCS) ran smoothly during 2004. New developments and maintenance were done as needed. Reliability and performance remained good. The CCS continues to evolve with enhanced functionality and the replacement of aging components, supported in part by the refurbishing program.

The loss of scheduled beam time due to CCS faults during 2004, as recorded by the Operations group, was 11.4 hours. Of this time, 85% was the result of three events: two hardware failures and one software bug. The remaining 1.7 hours were the result of 12 other lesser events. Problems with the site network and the UPS were of concern but did not lead to significant controls downtime.

The goals established in 2003 were mostly attained and numerous unforeseen requirements that arose during 2004 were also met. In the area of planned goals, a number of tasks are worth noting. The hardware and software to support the new ISIS slits, including console support, were completed. Control system support for the rf spark detector was completed for the present state of the detector system. A system to control and display rf power signals was developed and commissioned. In the area of X Window displays, LCD monitors replaced the old CRT displays in the main console and a new X Window terminal configuration capable of replacing the VXT X Window displays is now running smoothly. The old safety touch screen has also been upgraded to this new X Window configuration and it now uses a touch sensitive LCD monitor. An upgrade to OpenVMS version 7.3-2 was done as anticipated. Changing the cyclotron device numbering from octal to decimal is almost completed.

Not all projects were completed as anticipated. The task of decommissioning the old DSSI disk system in the Production Cluster was mostly done but not completed and should be finished during the 2005 shutdown. Work on replacing the old terminal servers also did not progress as well as expected. Work on establishing a reliable terminal server replacement is continuing.

CCS Facilities

Numerous changes were made to the Central Control System hardware. Changes resulted from adding new and removing old equipment, doing regular maintenance, and as a result of trouble shooting problems. An example of a new addition is the crate that was added at the vacuum test stand to support developments. Other areas include items such as cooling tower motor control, inflector power supply control, rf thermocouple readback, M13 gate and window valve control, and correction plate control. One major change, physically removing the development cluster DSSI disks, is now complete. Other disk changes were made including restricting access on the fibre channel systems and installing new disk drives. An HP Integrity Server using the Intel 64 bit Itanium chip was acquired and set up. To allow this Itanium system to connect to the CCS, a PCI-X to PCI expansion chassis was purchased and configured with the Itanium box.

There were many software developments in the CCS. A few examples are cited here. The safety displays and scans were modified as requested by the Safety group. Further support for the new ISIS slits was provided. The main magnet run up procedure was modified to incorporate new requests from Operations. Important changes were made to the message handling software to allow a better reaction to the message storms that occur when crucial hardware components fail. Changes were also made to most of the major applications in the CCS such as XTpages, Xstrip, the scans, the logged devices, PSU, and Xasset. The standalone rf booster application was normalized by including its functionality in XTpages and some developments were done on dual speed ramping of the ISIS pulser. A significant effort was put into examining improved beam stability by providing feedback with the pulser duty cycle. The goal is to increase stability to beam line 2A and to reduce the number of overcurrent trips. If testing in the new year indicates that improvements to 2A stability can be attained then the software and a standardized user interface will be made operational.

Many CCS users are familiar with the existing system and thumbwheel scheme of specifying a device. A significant effort was put on modifying this cyclotron device numbering system to move from octal numbering to decimal numbering. The related hardware and software components have now been largely changed. A system for simultaneously supporting both numbering systems was established and the phase has been occurring transparently and without interruption.

When problems arose with the quadrupole magnet 1AQ15, a variety of activities took place to support continued running while providing new machine protection.

The computers in the CCS were upgraded to Multinet version 4.4. To support the new Itanium computer, a field test version of OpenVMS was acquired and a number of applications were ported to this hardware platform. The low level software that does the data acquisition is being ported and modified to support symmetric multi-processing. We expect to have Itaniums in both the development and production clusters and connected to the fibre channel disk systems by the end of next year.

Secondary Beam Lines

There were a number of developments on the secondary beam line controls. A new valve controller for the M20 window and gate valve was built and installed. The backup procedure for the Sun server computers was enhanced. Improvements were made to the control system functionality including such things as a multiplet tuning feature, M11 bender ramping controls, beam line save/restore, new EPICS tools, new display pages, and new scripts. The version of EPICS was upgraded and in the new year the latest build of EPICS will likely be installed.

Other Systems

There are several other areas that also received support during the year. Both the neutron irradiation facility and the proton irradiation facility had changes. The CRM (centre region model) also had activity as the emittance facility was re-activated to support ion source developments. In the new year a variety of other developments are anticipated in the CRM. There were some activities for proton therapy and the environment that supports the dose program for the Safety group was changed to allow more instances.

OPERATIONAL SERVICES

Remote Handling

Cyclotron servicing

Annual remote handling winter shutdown activities for cyclotron maintenance included removal and storage of the interim Cu-blockers, installation of the tank peripheral personnel shadow shields, remote vacuum cleaning, as well as video and tank seal inspection. In the 2004 shutdown the 2C extraction probe and one low energy diagnostics probe were removed for servicing and reinstalled.

Routine maintenance of the elevating system of the cyclotron was performed at the beginning and end of the shutdown. The screw jacks and gear reducers at station #8 were removed for service rebuilding during the year.

During the summer months routine maintenance was performed on the major-use trolleys of the cyclotron servicing system and the remote handling service bridge. High voltage sparking of the ISIS inflector in August required an emergency cyclotron tank lid-up for repair. Two beam stop Cu-blockers in the tank were remotely removed and four others repositioned to reduce personnel exposure during tank access for the inflector removal and repair. The remote handling building access shield door was opened again in September to facilitate vault access for servicing of probes by the Diagnostics group.

The cyclotron elevating system station #8 jacks and gear reducers, which were removed during the winter shutdown, were rebuilt and overhauled. A new, TRIUMF original specification, spare reducer, compatible for either left or right hand operation was acquired from the manufacturer in England. Canadian distribution of this critical TRIUMF component has been discontinued and future supply might be problematic. Replacement reducers from a North American supplier have proven problematic in routine exchange maintenance due to dimensional differences in construction.

Hot cells/targets

In the winter shutdown, the M9 beam blocker was removed for replacement of the vacuum seal gland of the actuator rod. The 1AT1/1AT2 water packages were serviced and the BL2C solid target was brought to the hot cell for repair work and clean-up of the damaged sealing-flange faces.

During the year significant remote handling assistance was provided to the BL2C beam line solid target facility with its hot cell operations. A target mechanism required repair due to bent guide pins on the assembly, Rb targets were loaded into a transport flask, and a 1AT1/1AT2 style resin can was modified for use at the BL2C cooling package. In routine servicing, the BL2C cooling package filters were changed, conductivity cells cleaned, and the resin can to the reservoir lines flushed.

The 1AT2-Mk1 target was serviced in the second quarter. The travel positions of the target cassette were measured and noted, the cassette and profile monitor elevations were changed 3 mm from 1834.5 to 1837.5 mm. The 1AT1-Mk2 target was also serviced with a 4 mm wide by 5 mm high aperture protect monitor replacing the original 5 mm by 5 mm aperture monitor. Target cassette and monitor elevations were changed 2 mm from 1828.0 mm to 1830.0 mm. A "new" (1980 vintage body, 1984 vintage graphite) 2 mm by 45° uncooled pyrolytic graphite target was installed at position #2.

In the spring, work began on three new graphite target assemblies. After production of one target the brazing oven failed and required repair. Of the three targets produced, only one appeared to be satisfactory, the other two evidenced brazing voids in the pyrolytic-to-saddle bond. Redesign of this challenging target production began with Engineering group involvement.

Another rubidium target was swapped in the BL2C hot cell in October with the currently used target-holder float experiencing a weld failure. Again in November a rubidium target was exchanged in the BL2C hot cell. The soda-lime trap on the BL2C cooling package became blocked due to excessive moisture in the trap and required removal for cleaning.

A new graphite target was installed at position #5 on the 1AT1-Mk1 target. Fittings on this ladder are exhibiting signs of wear, causing difficulties in achieving leak-tight joints during target replacements. This target was installed in the beam line in November when the 1AT1-Mk2 target was moved to storage. Subsequent inspection of the Mk2 target in the hot cell noted that the 2 mm 45° graphite target had eroded approximately 0.2 mm back from the top of its 10 mm height.

The BL2C resin can was exchanged due to deteriorating cooling water electrical resistance. Some difficulty was experienced with conductivity and flow in the cooling package and additional adjustment was required before operation could continue. This package will require some rework in the winter shutdown.

A radiation damaged, rubber pneumatic air hose on the M20 beam blocker at 1AT2 ruptured during beam operation in November. These will be replumbed with metal tubing in the winter shutdown.

Another iteration of graphite target brazing was completed in December. Seven graphite targets were produced and look promising before machining. At this same time, as a trial, Diagnostics group requested that we experimentally braze a Ta/Cu/TICUSIL assembly in the oven. This was achieved at 943° C for a 35 minute period. The Ta/Cu bonding was adequate for this use, and could improve with better preparation.

Miscellaneous hot cell facility work included: rebuilding of one air pressure amplifier for the meson hall target areas, dilution and release of 280 l of the 1AT1/1AT2 cooling package water, TNF resin can transfer, thermal cycling tests for the ceramic insulator development program, and barrel scans performed by the Radiation Protection group for active waste disposal. A new target cassette alignment jig (determining beam direction) was also manufactured.

Beam lines servicing

Beam line activities for the winter shutdown centred around the 1AT2 target area. Leak checking with periodic shield block repositioning identified three separate leaks: the 1AT2 target monolith to the former M8 beam line blank-off plate, the collimator B to 1AQ14 joint, and the 1AS1 to 1AM10 vacuum joint. The indium seal at the 1AT2/M20Q1 joint was successfully replaced, and the M20 front-end inspected and documented in preparation for the future M20 refurbishment. The actual location of the M20Q1 ground fault was also determined. Survey of the area revealed a loose connection at an M20Q2 SuperCon electrical connector. This event could have contributed to another catastrophic failure similar to last year's M9Q1 failure. The connector was carefully re-tightened, giving allowance for the radiation damaged materials.

The M9 front-end was uncovered to investigate an electrical problem at M9Q1. It was eventually determined to be a leaking solder joint at a Pyrotenax endseal that leaked water into hairline cracks on the insulator beneath. This joint was cleaned and epoxied with a fibreglass reinforcement sleeve.

A vacuum excursion concentrated work on the collimator B to 1AQ14 magnet vacuum leak and its correlation with the electrical buss links solidly mounted to the trench shielding. Heavily loaded shielding causes the magnet to be disturbed by movement of the solid buss links on 1AQ15. The indium joint seal was removed and inspected. A vacuum leak at the M8 blankoff was found to be due to a stripped thread spring eye on one side. This was replaced and a good vacuum achieved.

The work of crumbling block replacement occupied a full five weeks of shutdown. Many crumbling blocks needed to be jack hammered down in size to relieve crumbling expansion pressure against adjacent blocks. Badly crumbled blocks required packaging into metal containers. All suspect "high density" blocks found to be still structurally sound were relocated up from ground level to prevent future standing water damage. Many hand-stack blocks at the south wall opening to the former Bio-Med treatment room were removed and replaced at this time.

Additional shutdown work included new cabling to BSM #61, refastening of the triplet Pyrotenax brackets in the trench, repair of rusted M9/M20 beam blocker control power conduit, re-hosing of the M20 sextupole magnet, installation of new O-rings at Marmon joints in the 1AS2 service chase, repair of a water leak at M9AQ5, replacement of an O-ring at M20Q8, and replacement of the M20VA5 valve. The 1AM10 monitor and monitor smokestack were also replaced after shielding was installed at the area.

Following the major winter shutdown work, activities in the second and third quarter were much quieter, with the majority of effort going into design and planning for the M20 front-end replacement work. New magnet stands, vacuum boxes and remote handling of services were organized for the replacement of the M20Q1/Q2 magnets.

During the mini-shutdown in September a vacuum leak in the 1AVA8 vacuum gate valve between the 1AT1 and 1AT2 volumes required replacement of the all three O-rings.

In the same shutdown a major effort was directed to the 1AQ15 cooling flow problem that was first identified in August. Individual "control" and two problematic circuits were isolated from the magnet cooling header. Tests were performed to determine flow characteristics and found to be significantly lower on the two problematic circuits. As yet unexplained foreign material was flushed from both problematic circuits. After both forward and reverse back-flushing of these circuits, flow was greatly improved. Further investigation of the magnet coils revealed an obstruction at the end of circuit #11 coil. This was mechanically opened-up in diameter. Again a foreign substance was removed from the interior of these coils. Further examination of these materials will be performed in the fall. After work was completed on these circuits the magnet was normally replumbed and power tested successfully to run at 917 A as required for the normal beam line 1A 140 μA beam tune.

Late in the year a decision was made to concentrate the winter 2005 activities on repair of the 1AQ9 magnet thermal switch problem. This decision was taken because the inability to operate this magnet results in higher beam spills downstream, thus further exacerbating radiation damage to 1AVA8 and other organic vacuum seals, as well as some loss of beam tuning beyond this location. This decision will also address the concern of the failed M11 septum magnet, and allow additional time to work on crumbling shielding blocks upstream of 1AT2. Work progressed toward preparation for the new work, with as little impact as possible on the continued effort to complete refurbishment of the M20 front end.

Magnets and Power Supplies

Most of the work in 2004 related to MRO activities in support of the cyclotron, primary and secondary beam lines, and the ISAC facility. Copper chill plates for heat sinks in the series regulated power supplies are being installed to replace leaking pass banks as in previous years. As last year, we prepared trim and harmonic supplies which had to be modified for trim and harmonic bay 1 which will be brought up to code during the spring, 2005 shutdown.

Power supplies for ISAC were purchased for the S-bend dipole supplies as well as some quadrupole supplies for ISAC-II straight section. Further units are to be purchased once the budget is finalized.

Experimental support was provided in the repair of a laser power supply in the ISAC-I laser shack. This was necessary to allow the developmental work to proceed.

A new power supply engineer has joined the group to replace a retiree and is providing good support as he becomes familiar with the existing system. Documentation upgrades are under way which will facilitate trouble shooting and data management.

As part of his workload the group leader also provides coordination of meson hall activities during the winter and fall shutdowns.

Mechanical Services

Efforts to improve the reliability of breathable compressed air met with success with the modifications made to the hand-me-down Sullair compressor (ex-MRS compressor) that fixed a few problems. With the addition of the new breathable-air-monitor air dryer (thanks to ISAC-II) the compressor has passed the breathable air certification and is now acting as a backup site machine. Its large capacity was obtained for a fraction of the cost of a new machine. Until the Sullair was proven to be reliable, the existing Nash compressor was directly connected to the chemistry annex and shown to be capable of running that building by itself. At present the Nash now acts as a backup for the Chemistry Annex. Another new development of note is the new services umbilical installed into a trench between the proton hall extension and the main office building (MOB). When connected it will provide CuLCW to the MOB, along with electrical and control functions. Lastly in compressed air, the MOB air dryer was repaired.

Piping MRO work included replacement of corroded heating water lines in the MOB and Chemistry Annex and city water lines in the service annex. Repairs were undertaken for the sprinkler system, the CuALCW de-ionizing resin, the rf room piping hangers, the rf vault transmission line pressure regulating valve, and the M15 vacuum pump exhaust line.

HVAC MRO work included air conditioning repairs to the MOB board room, AHUs 1 and 5, trailers Gg and Hh, Me140 and 141 pneumatic controls, and the MESA clean room buffalos. An air conditioning duct was attached to the rf floor UPS for direct cooling. The MOB kitchen fan exhaust stack was raised to 15 feet to help reduce cooking smells in the building.

Several meson hall lifting beams were sent out for testing and recertification.

Electrical Services

The centrepiece of the design and engineering effort continued to be the ISAC project and is covered under a separate heading. On the rest of the site, priority was placed on the implementation of the re-design of the power distribution for the Trim Coil Bay 4, the completion of the VFD addition (phase 2) to the cyclotron cooling towers, the supply of emergency power for M15 cryogenic loads, and the phase out of the old CP42 UPS unit. All radioisotope production facilities UPS loads were integrated under the TR30-2 UPS machine installed in 2003. In all about 48 entries of various importance were logged in the engineering log-book of which about 30 belonged to ISAC. Other completed jobs include rationalization of services in the MHESA detector laboratory, services for a new crane in the meson hall extension clean room and TR13 nearby, services for a new elevator in TR30-2, and conduit services for the TSG in the vault area. Continuing engineering support was provided to TRIUMF users on electrical matters, and to Nordion and the ATG group for maintaining electrical services for the isotope production facilities. The upgrade of the rf system distribution system was postponed as spare breakers were finally located in the United States.

Typical maintenance activities included servicing lighting systems, motors and associated controls, air conditioning controls, panel boards and transformers, HV switchgear, breakers and capacitor banks, and the fire alarm system. A dedicated electrical crew looks after the electrical installation and maintenance needs of Nordion and the radiochemistry isotope production facilities. Approximately 130 calls were answered from the rest of the site (about 35 from ISAC-I) for other than lighting maintenance. Motors for about 120 HP total were replaced. The fire alarm system annual inspection, carried out during the summer, revealed a few deficiencies that needed attention. Early last March the main emergency power centre, MCC-B suffered the first short circuit of its life when minuscule water infiltration from a conduit run above found its way into the unit. The short circuit occurred on the line side of the breakers. As a result the whole MCC-B tripped leaving the UPS without its natural power back-up. The short circuit destroyed the two breakers feeding the substation main protection breaker relays and caused significant damage to nearby cubicles. The repair was carried out expeditiously, but the source of the water could not be located. The fault also revealed a weakness in the distribution wiring to the UPS for such rare events like this fault that shuts down the emergency power bus while the normal power bus remains functional. To protect against these rare events we plan to add a second feeder line from the normal power bus at the next opportunity.

As equipment ages it becomes crucial to keep up with technology changes. This year brought to light the question of maintainability and reliability of the UPS and spare parts for the power distribution centres. Both are strategically important to the continuing operation of the experimental program. A strategy was developed to cope with this problem and start phasing out obsolete power distribution centres this fiscal year. In addition to increased trouble calls, the main UPS suffered a couple of serious faults, one of which was associated with early battery wear. Plans are under way to replace this unit in the near future.

Power delivery

Power delivery continued to be very reliable without major unscheduled outages. In early fall the site was shut down to allow for the replacement of a damaged power pole and cracked HV insulators.

Scheduling coordination with Power Tech High Voltage laboratory continued regularly to ensure that the impact on our operation from their short circuit tests is minimized.

The monthly averaged peak power demand increase was more contained this year. It was a mere 2.7% from 7358 to 7560 kVA (Fig. 202). The annual maximum peak demand (8914 kVA) was reached in July and was 2.4% higher than the maximum last year. The electricity consumption jumped about 3.5% from 56.4 GWh to 58.4 GWh (Fig. 203). The largest monthly

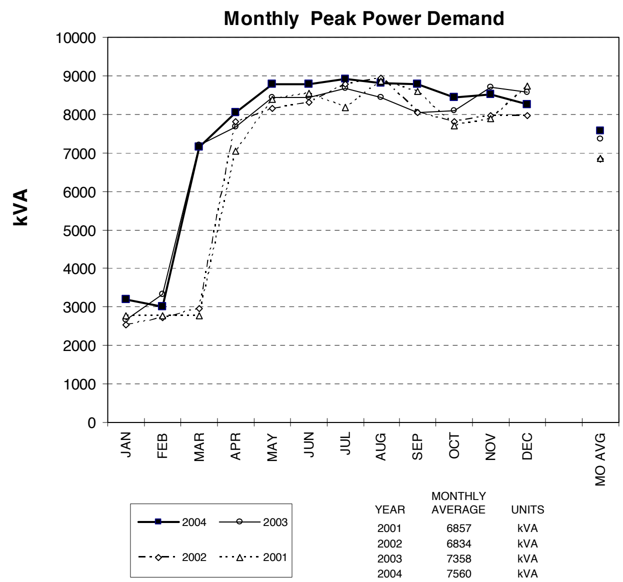

Fig. 202. Monthly peak power demand – four year comparison.

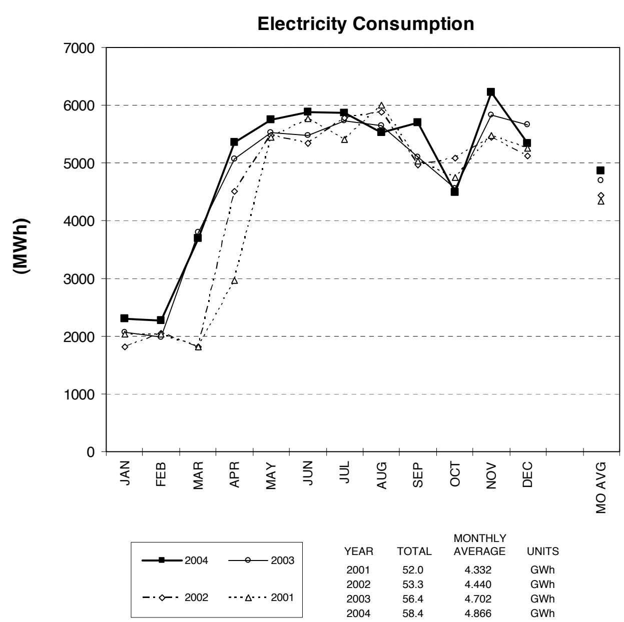

Fig. 203. Electricity consumption – four year comparison.

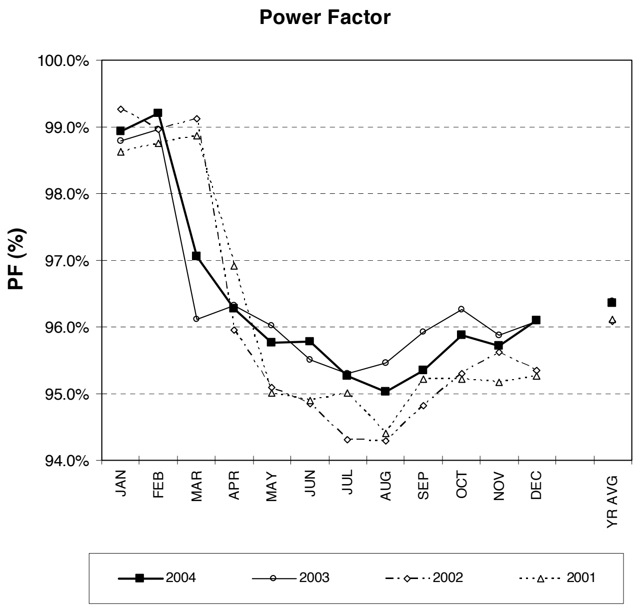

Fig. 204. Electrical system power factor – four year comparison.

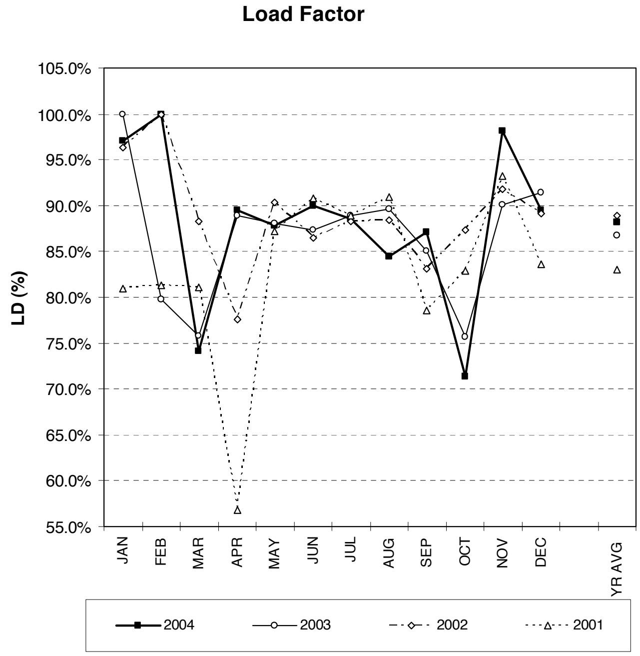

Fig. 205. Electrical system load duration – four year comparison.

consumption was recorded in November (6.22 GWh) and was approximately 6.6% larger than last year's maximum. These increases are in line with the increased activities in both ISAC (primarily ISAC-II) and Nordion.

The power factor (PF), averaged over the calendar year, remained flat at 96.4% (Fig. 204) despite increased activities. This effect can be attributed to the work of the additional capacitor banks in ISAC. The average load duration – the indicator of how well we use our power demand – has increased just slightly by 1.6% to 88.1% (Fig. 205).