TRIUMF

ANNUAL REPORT
1974

MESON FACILITY OF:

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

APRIL 1975

TRIUMF

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TRIUMF
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, B.C.
CANADA V6T 1W5

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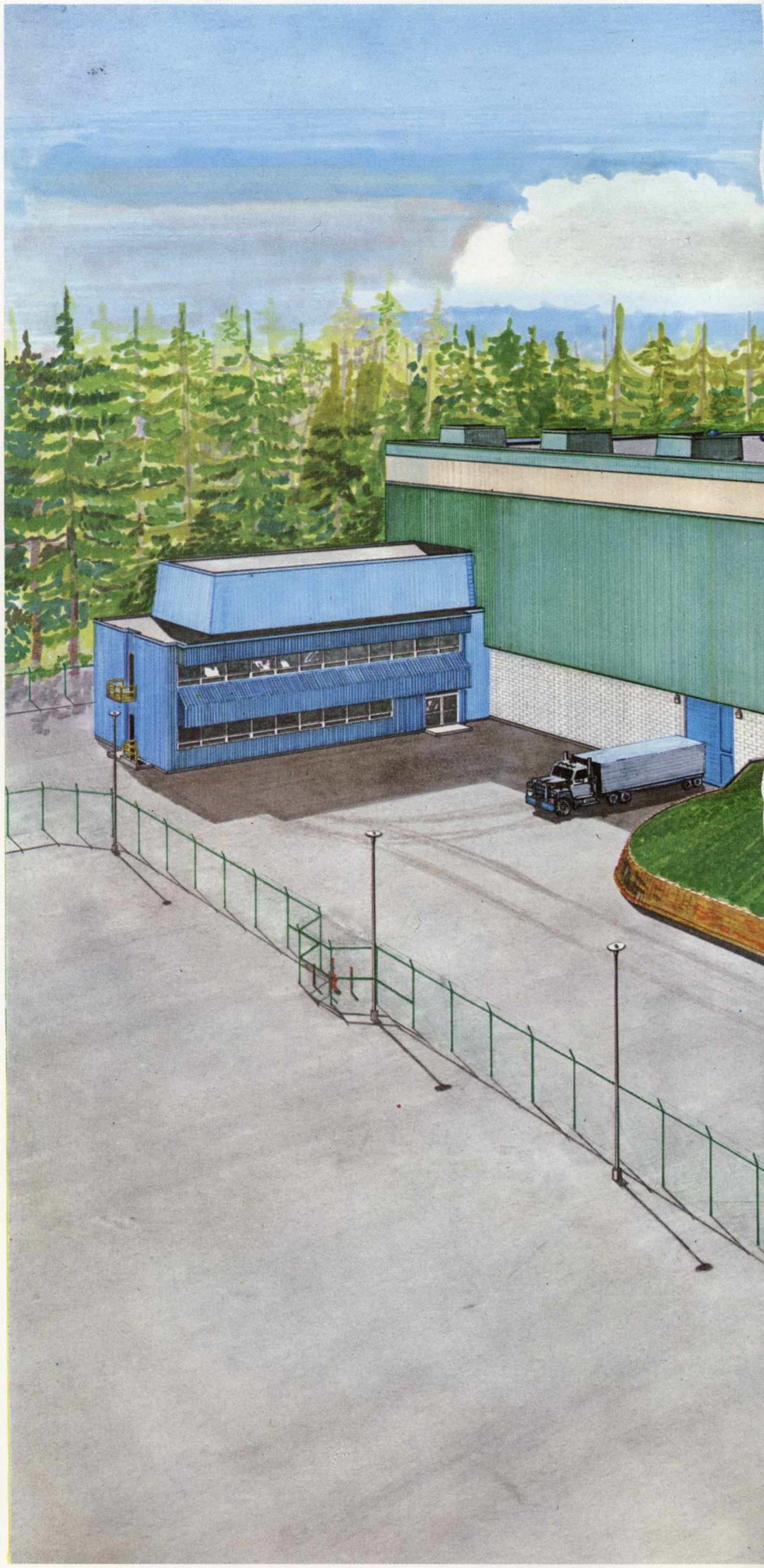


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ANDRE LIM

FOREWORD

This annual report may have difficulty in recording the great satisfaction about the technical achievement, at the end of 1974, of the first full energy extracted beam from TRIUMF and the immense excitement about the scientific programme just ahead. At this turning point it may be appropriate to give some measure of the achievement of TRIUMF in its six-year evolution from an idea into an operating facility. It has been my privilege to serve as Chairman of the TRIUMF Board of Management through that period.

The project has been pushed to completion by a small group of dedicated scientists and engineers with minimal support. It began with competent people and a major idea. First the four universities had to be brought together: the co-operation of the universities in such a large joint venture has been magnificent. But, as a university-based project, TRIUMF has not had the depth of technical back-up which such projects usually require. Further, the buildings provided by the universities—although constituting a major commitment on their part—have turned out to be inadequate for both the people and their research facilities.

The research funds have been generously provided by the Atomic Energy Control Board of Canada. But, the project was a large new step in Canadian university research, and it was built in an era of tight scientific budgets. The original financial agreements between the four universities and Ottawa were made after only 1/500 of the total project funds had been expended on design work.

In view of financial and technical restraints and the cramped quarters, the achievement is superb. The total construction costs exceeded the predicted costs by only 20% although the rate of inflation throughout the six-year construction period was an entirely unanticipated 10% per year. Few conventional projects in Canada have managed as well financially. In spite of its huge technical challenges and minimal technical back-up the construction schedule slipped by only a year or less. There were many heroic, and largely unsung, efforts which kept almost all of the major components of the cyclotron on schedule and which allowed the project to recover, without time loss, from several prolonged general construction strikes in British Columbia. In fact, the only major time loss occurred in the commissioning of the magnet earlier in the present year, occasioned by a major surprise in the magnetic properties of the steel. The recovery of the project from this blow is a tribute to the Director, J.R. Richardson, and to the many young people who worked unreasonably hard and who were extraordinarily ingenious.

The performance of the cyclotron and the ability of the people who built it and are planning to use it are very encouraging. In the years of science just ahead it is expected that TRIUMF will command the eyes of the world and merit the strong support of Canada.

W.M. Armstrong

W.M. Armstrong
Chairman of the Board of Management

HISTORY

TRIUMF was established in 1968 as a laboratory operated and to be used jointly by the University of Alberta, Simon Fraser University, the University of Victoria and the University of British Columbia. The facility is also open to other Canadian as well as foreign users.

The experimental programme is based on a cyclotron capable of accelerating two simultaneous beams of protons, individually variable in energy, from 180-500 MeV. The potential for high beam currents—100 μA at 500 MeV to 300 μA at 400 MeV—qualified this machine as a 'meson factory'.

Fields of research include basic science, such as medium-energy nuclear physics and chemistry, as well as applied research, such as neutron activation analysis, isotope research and production. There is also a biomedical research facility which will use mesons in cancer research and treatment.

The ground for the main facility, located on the UBC campus, was broken in 1970. Assembly of the cyclotron started in 1971. The machine produced its first full-energy beam in 1974.

The laboratory employs approximately 150 staff on the main site. The number of university scientists associated with the initial scientific programme is about 80.

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INTRODUCTION

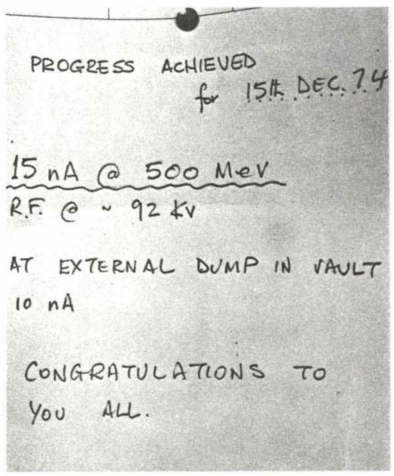
The story of TRIUMF in 1974 is one of dramatic success after a number of years of very hard work. In April the long period of wrestling with the exacting tolerances on the field of the main magnet was finished, and the installation of the internal parts of the cyclotron was begun. This activity proceeded until November 16 when H^- ions were injected and accelerated through some 15 turns. The number of turns and the energy of the ions was gradually built up over a period of a month until December 15 when, in a final leap of achievement, the number of turns and the energy was increased from 950 turns and 350 MeV to 1400 turns (minimum) and 500 MeV in a period of one hour. It is impossible to describe the great wave of joy and enthusiasm which swept through everyone associated with TRIUMF in the wake of this achievement. Suffice it to say that everyone now approaches the future with complete confidence in our ability to reach our technical goals, provided the necessary financing is made available.

The year 1974 also saw the heavy involvement of many more of the future users of TRIUMF in the setting up of the proton beam lines, both in the proton hall and the meson hall. Much of the work was done by scientists from the University of Alberta, Simon Fraser University, the University of Victoria, the University of British Columbia, and the BASQUE group from the United Kingdom.

Professor W.M. Armstrong, in his position as Deputy President of UBC, was an important driving force in the setting up of the TRIUMF project in 1968. He served for many years as Chairman of the Board of Management and has been a great source of strength for the project during this whole period. I particularly wish to express my appreciation to him, on behalf of TRIUMF, for his great help to us in making TRIUMF a viable facility. We were sorry to bid him goodbye at his last Board meeting in December, but we wish him continued great success in his new position as Chairman of the Universities Council of the Province of British Columbia.

It is with deep regret that I find it necessary to report the death of Dr. Harold Batho in June. Dr. Batho was a great source of inspiration to us all at TRIUMF, particularly in regard to the biomedical applications of the project. It is unlikely that these aspects of TRIUMF would have received the support that they so well deserve without his enthusiasm, persistence, and good sense.

J. Reginald Richardson
Director

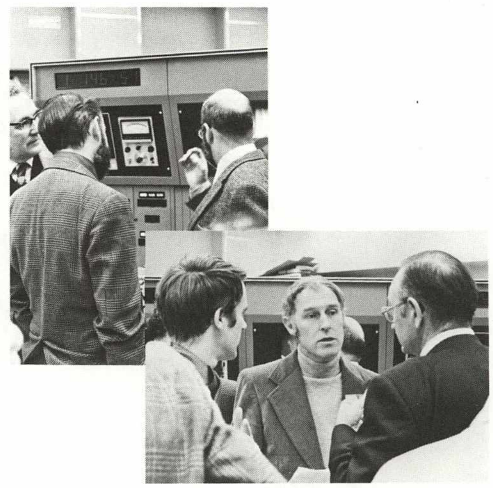


PROGRESS ACHIEVED
for 15th DEC. 74

15 nA @ 500 MeV
R.F. @ ~ 92 kV

AT EXTERNAL DUMP IN VAULT
10 nA

CONGRATULATIONS TO
YOU ALL.



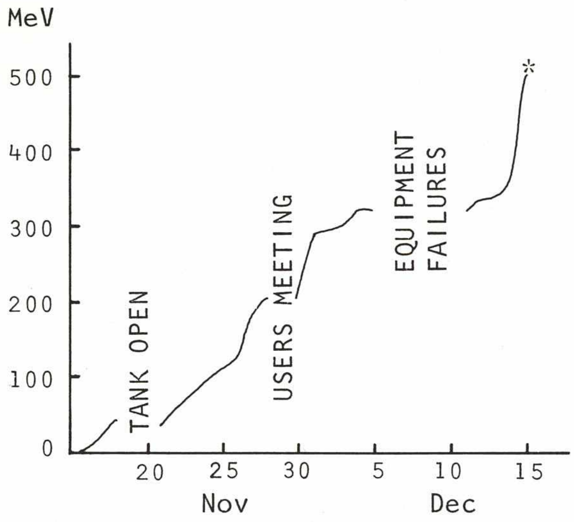
FIRST ACCELERATION OF PROTONS TO 500 MeV

The first acceleration of protons (H^- ions) at TRIUMF to the full design energy of 500 MeV was accomplished on December 15. Of course, there were many important steps leading up to this climax and only a few of them can be mentioned here.

The magnetic field survey and the concomitant tailoring of the magnet were completed in April after more than a year of intensive effort. By October the ion source and injection system (ISIS) had been completed, and a 6 μA beam of H^- ions was injected into the median plane of the cyclotron through the inflector and deflector on October 21. After some initial vacuum and bake-out problems, the resonators were brought up to a reasonably good voltage by the middle of November, and the facility was ready to attempt the acceleration of a beam.

On November 16, the first beam was accelerated to a radius of 42 in., which means, if the orbits were centred, to an energy of 6 MeV. On successive days the beam was worked out to larger and larger radii by adjusting the correction plates and trim coils. The log book reveals the following diary:

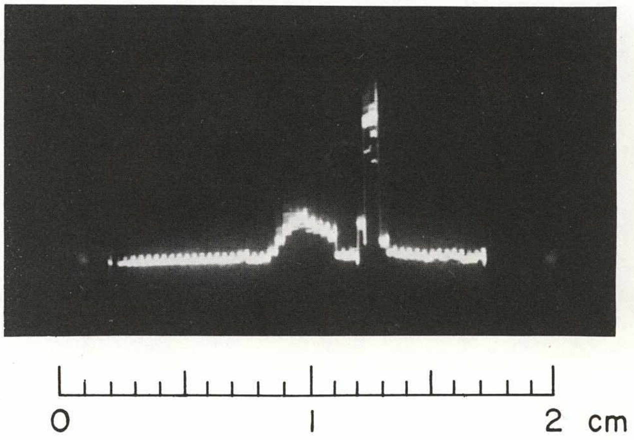
		Maximum radius of beam	Energy (if centred)
Nov. 17		42 in.	6 MeV
18		55 in.	10 MeV
		(Radiation in vault!)	
		85 in.	24 MeV
		Replaced low-energy probe	
22		150 in.	71 MeV
23		183 in.	113 MeV
		Replaced B-20 cryogenerator	
25		179 in.	109 MeV
		Vacuum problems	
26		195 in.	135 MeV
		Deflector sparking	
27		223 in.	195 MeV
28		231 in.	210 MeV
		Check $\nu_z^2 = 0.02$ at R=223 in.	
Dec. 1		259 in.	295 MeV
3		265 in.	315 MeV
4		Beam appears to be centred	
		300 kV supply in ISIS kaput	
11		Trying to re-establish beam	
		RF problems	
12		273 in.	345 MeV
		Sparking in ISIS	
14		278 in.	363 MeV
15	12:10	278 in.	363 MeV
	13:07	309 in.	500 MeV



Thus the last 140 MeV of energy was achieved in less than an hour when a suitable combination of trim coil currents was developed.

Beam extraction

Within an hour after the beam had been accelerated to 500 MeV, it was extracted and led through a combination magnet and focusing quadrupoles to a distance over 30 ft from the vacuum chamber. A fixed energy extraction foil had been placed for this purpose at a radius corresponding to an energy of slightly more than 500 MeV. The required combination magnet setting indicated that the beam energy was probably close to 507 MeV. The beam was examined with a scintillator and a multi-wire chamber, and finally an approximate current was read from a temporary beam dump. The high-energy beam was kept down to 10 nA in order to reduce the activation problems. The spot on the scintillator in front of the dump indicated a size of 1 × 1 cm^2 when focused by the quadrupoles. The extracted beam was extremely steady and was shown for several hours to visitors who had heard of the success of the operation.



Beam spot distribution as measured with a multi-wire chamber immediately after the beam had been extracted. The horizontal scan is on the right and the vertical on the left.

BEAM DYNAMICS

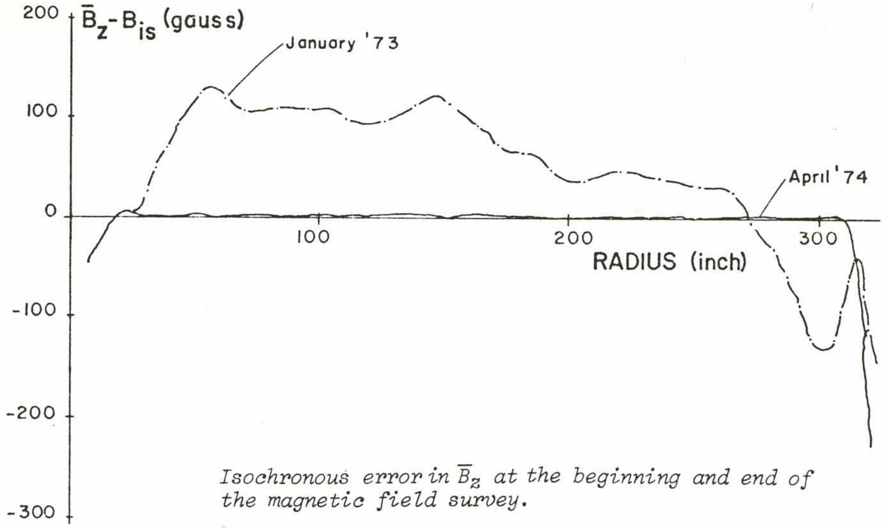
Magnetic field analysis and shim predictions

As described in last year's report, by the end of 1973 the vertical component of the magnetic field B_z had been shimmed to an acceptable state everywhere except near the very centre of the cyclotron. In the new year, therefore, attention was transferred to investigating the symmetry of the field by measuring its vertical gradient $\partial B_z/\partial z$. This should ideally be zero everywhere on the geometric median plane of the cyclotron; if it is not, then the ion orbits will be shifted vertically out of the median plane. To analyse the $\partial B_z/\partial z$ data new computer codes were brought into operation. The data were first checked for consistency and then Fourier-analysed at each radius. From this information the values of the horizontal field components B_r and B_θ were obtained by integration, allowing the deviations of the equilibrium orbit from the median plane to be estimated.

In order to be able to monitor B_z at the same time as $\partial B_z/\partial z$, the survey was broken into two parts, the first period being devoted to the inner part of the magnet and the second to the outer part (with some overlap). A further innovation was the use of pole shims 6 in. rather than 12 in. wide. These were first used near the centre to obtain adequate control of the radial variation of the field, and eventually along the entire pole edge. Measurements were therefore made of the changes in B_z and $\partial B_z/\partial z$ produced by specimen 6 in. shims placed at selected positions throughout the magnet. Also, new versions of the SHIMMING (field change superposition) code and the GLOBAL TRIMFIT (shimming prediction) code were produced to deal with the $\partial B_z/\partial z$ data, the changed radial ranges, and the 6 in. shims. The modified B_z TRIMFIT code predicted the symmetric shim changes needed in 342 positions to obtain the desired orbit time, vertical focusing (ν_z^2) and first, second and third harmonic field components at 150 radii simultaneously. The new $\partial B_z/\partial z$ TRIMFIT code predicted the asymmetric shim changes needed in 324 positions to reduce the average value of B_r and the first three harmonics of $\partial B_z/\partial z$ to zero at 150 radii simultaneously.

The first attempts at shimming for $\partial B_z/\partial z$ showed that improvements could be readily obtained in the harmonics and in smoothing out radial oscillations in the average value; however, it was not found possible to improve an extended region of negative $\overline{B}_r$ (about -12 G from 20 in. to 170 in. radius) by more than 4 G using the pole shims and trim coil #0 alone. Three tons of steel were therefore bolted to the lower magnet yoke, raising $\overline{B}_r$ a further 4 G; more steel than this could not be added, or the associated increase in B_z (already 15 G) would have been more than could have been counteracted by removal of pole shims. The remaining -4 G of $\overline{B}_r$ was corrected by powering some of the trim coils asymmetrically.

Over the outer part of the magnet it proved possible to reduce the initial $\overline{B}_r$ of effectively 10 G to an acceptable level using the pole shims and trim coils alone. The tolerance on $\overline{B}_r$ changes very rapidly with

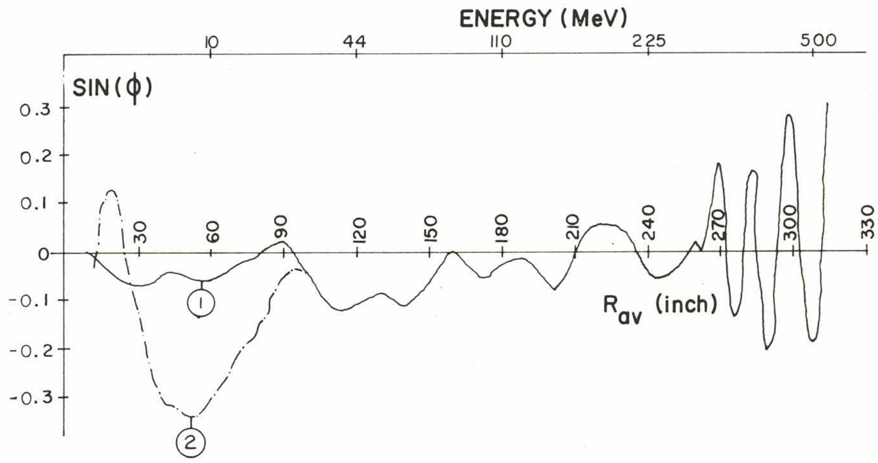


Isochronous error in $\overline{B}_z$ at the beginning and end of the magnetic field survey.

radius in this region because of the fluctuations in ν_z^2. Thus while the residual $\overline{B}_r$ was 0.7 G on average, locally where ν_z^2 dropped to its minimum value of 0.02, $\overline{B}_r$ had to be kept below 0.16 G. At the end of the survey it was estimated that the equilibrium orbit could be brought within ±0.5 in. of the geometric median plane everywhere except near the centre and near 220 in. radius (1 in. displacement). Inside 24 in. radius, following our experience on the central region cyclotron, electrostatic correction plates had already been designed to permit vertical steering of the beam on each turn. In view of the rapid oscillations in $\overline{B}_r$ and ν_z^2 beyond this radius it was decided to install additional plates out to 40 in. radius. With these extra plates it was estimated that the coherent vertical oscillations could be reduced to ±0.1 in. for all phases in the 45 deg wide range considered.

Because of 'cross-talk' from the B_r shimming it was necessary to continue monitoring and shimming the B_z field. For instance, as mentioned above, the addition of yoke shims raised the azimuthal average $\overline{B}_z$ by 15 G locally; however, by the end of the survey $\overline{B}_z$ had been brought to within ±0.5 G of isochronism, corresponding to phase excursions no greater than ±3 deg, out to a radius of 260 in. From there to 315 in. radius there remained ±2 G oscillations, which perhaps because of their relatively short wave-length, resisted all attempts at further reduction; these will give rise to ±12 deg phase oscillations between 300 and 500 MeV, twice the tolerance specified for normal operation. Isochronism nevertheless extends far enough to permit acceleration to 520 MeV with only 20 deg phase slip and 14% beam loss by field dissociation. The loss at 500 MeV is expected to be 7%.

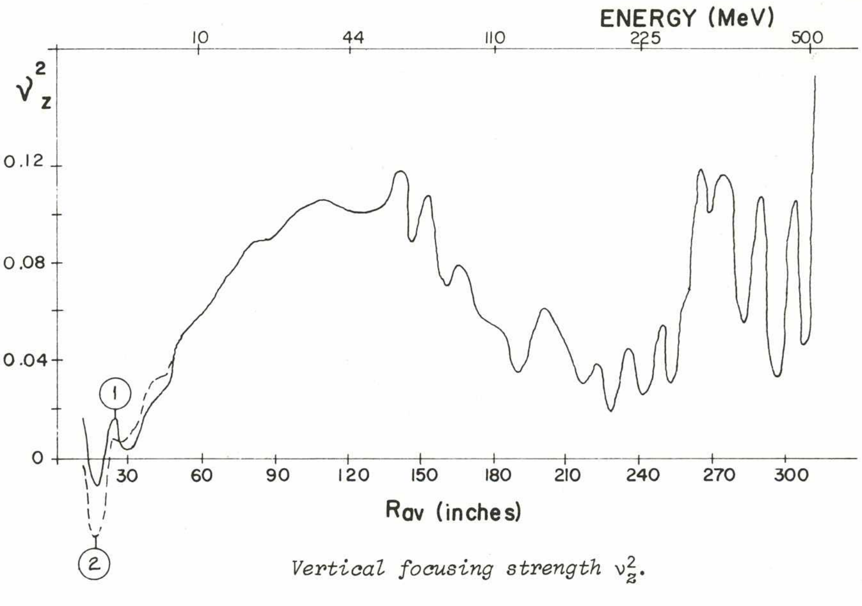
In the central region the trim coils were powered to produce a non-isochronous field designed to maximize the phase acceptance without exceeding the specified ±600 keV energy resolution. This field, which should start 30 G low on the first turn to favour the vertically-focused positive phases, and rise to 5 G high from the fifth to the tenth turns to reduce the radial spread introduced by radial-longitudinal coupling, has been achieved to within a few degrees of the required phase slip at all radii.



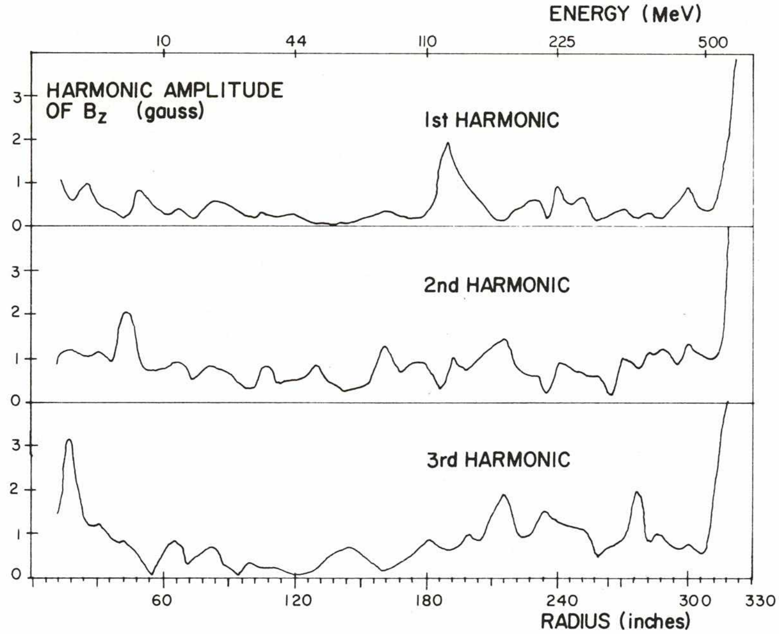
Phase excursions calculated in the final field configuration with proper trim coil correction for 1) an isochronous mode, 2) a special central region mode.

The strength of the vertical focusing is conveniently represented by ν_z^2, the square of the number of vertical betatron oscillations made per turn. Outside the central region, where the focusing is dominated by phase-dependent RF effects, ν_z^2 varied between a minimum of 0.02 at 220 in. and a maximum of 0.12. In view of the closeness of the minimum to negative and therefore defocusing values, a number of checks were made on the accuracy of the ν_z^2 value. Calculations were made using the raw, rather than Fourier-decomposed, field data, and independent integration routines were used; however, ν_z^2 could not be changed by more than 0.0006. The largest source of uncertainty that we are aware of is the calculation of field gradients, which contributes an error in ν_z^2 of about ±0.01.

The first, second and third harmonics of B_z were all reduced below the tolerance levels to be achieved by shimming (see table). Thus the first harmonic was reduced to below 1 G from 20-180 in. radius. This is still some way from the 0.05 G which must eventually be achieved near 60 in. radius with the aid of harmonic coils and measurements on the circulating



Vertical focusing strength ν_z^2.



B_z harmonic amplitudes in the final field configuration.

beam, but appears to be close to the limit of accuracy of field measurement techniques. The second and third harmonics have been brought below their respective tolerances of 0.5 G/in. and 0.1 G/in. in the critical resonance regions.

Resonance	Field Component	Radial Range
$\nu_r = 1$	B_{z1} <1 G [1]	30 - 120 in.
$\nu_r - 2\nu_z = 1$	dB_{z1}/dr <1 G/in.	255 - 312 in.
$\nu_r = 1$ $\nu_r + 2\nu_z = 2$	dB_{z2}/dr <0.5 G/in. B_{z2} <5 G	10 - 40 in. 280 - 312 in.
$\nu_r = 3/2$	dB_{z3}/dr <0.1 G/in.	287 - 309 in.
small vertical orbit displacement	$\bar{B}_r$ $\lesssim$1 G [2]	depending on ν_z^2
$\nu_r - \nu_z = 1$	dB_{r1}/dr <0.1 G/in.	200 - 280 in.
depolarization $(\frac{g}{2} - 1)\gamma = 2$	B_{r2}, $B_{\theta 2}$ <0.5 G	150 - 230 in.

[1]Assumes further compensation by central harmonic coils.
[2]Assumes further compensation by asymmetric trim coil currents in low ν_z^2 regions.

Most important tolerances on the nth harmonics of B_z, B_{zn}, and on B_r, B_{rn} and their derivatives for various radial intervals.

Preparations for beam commissioning

In spite of the care with which the magnetic field had been measured and analysed it was thought likely that small adjustments would still need to be made to the trim coil currents in order to accelerate a beam to full radius. This was expected because it was known that some small steel components (in the probe drive motors, for instance) would remain to be added after completion of the magnetic field survey and, of course, because of residual inaccuracies in the field measurements and analysis. The field changes $\delta B_z(r)$ and $\delta \overline{B}_r(r)$ induced by a selection of the trim coils had already been measured during the field survey. For the remainder of the coils data were generated from a function invented to give a smooth fit to the data for all the measured coils. These data were then used to compute the trim coil currents needed to minimize the phase slip of the beam and its vertical deviation from the median plane. In fact two 'standard' fields were produced by this means, one isochronous everywhere and one with phase programming on the initial turns to maximize the duty factor. The current settings for this last case were used as starting conditions when beam was first accelerated.

To assist in tuning the trim coils a number of interactive computer codes have been written; these take as input data the observed phase or height errors and calculate the currents required for correction in any chosen set of coils by least squares fitting techniques. For the phase a method was also developed to provide a local correction using two or three neighbouring coils; by contrast a single trim coil produces significant changes in the B_z field component and in the phase at all radii.

The linear motion code COMA, mentioned in the previous annual report, has been expanded to simulate the action of the various diagnostic probes. This code tracks particle trajectories inexpensively by multiplying matrices describing large segments of the magnetic field. The cost per particle turn is about 1% of that for our numerical integration codes, making it economically possible to track the paths of whole groups of particles with neighbouring energies, phases and positions. The particles are described in terms of their displacements from their equilibrium orbits in six-dimensional phase space and also by their absolute coordinates. The population distribution of any of the particle properties can be displayed as a function of radius for particles hitting any segment of a probe head. Also the population distribution at any point of any one particle parameter can be displayed as a function of any other parameter. These facilities have been used to verify the action of the vertical flag and in designing parts of the low-energy probe head.

By including suitable focusing impulses at the dee gaps it has been possible to obtain accurate results with COMA starting right from the point of injection and throughout the central region. Thus it was possible to use COMA to simulate setting the steering plates to correct vertical motion on the first few turns in the presence of dee misalignments and residual $\overline{B}_r$ components. The results could be displayed either as a spot on the scintillator or as a trace of current versus radius on the LE differential probe. It was determined that the vertical oscillations could be kept within ±0.5 in., even if only one of the two planned LE probes were installed.

The diagnostic probes used at energies in excess of 70 MeV operate by capturing the electrons stripped from the H^- ions in the thin material of the probe head; the protons continue to the tank wall. In addition the protons can produce high energy delta-rays in the probe heads, especially in material of high atomic number, and, at high power densities, thermionic electrons. The electrons may make several traversals of the head, this being especially true of the thin stripping foils, and a program PECS has been written to follow the paths of these electrons in the magnetic field. Electrons are generated randomly through the thickness of the head material with initial properties given by the kinematics of the generating process. For each electron the energy lost in traversing a portion of the material is obtained from tables, and the angle of multiple scattering is obtained by calling a random number generator that gives an angular distribution following the leading terms in the Molière formula. For the probe heads, which are much thicker than the stripping foils since they are self-supporting, large angle scattering is important, and many electrons can be back-scattered out of the head. To get reasonable results the head is divided into regions small compared to the thickness required to give an rms scattering angle of one radian. This code has enabled us to make more accurate calculations of the power distribution in stripping foils and should be useful in further probe head design.

Commissioning the beam

As explained in the ISIS report (p.19), the horizontal section of the injection line had been commissioned by March and the vertical section by October; considerable beam dynamics support was provided in these tasks. Beam transport computer calculations taking into account the stray magnetic field of the cyclotron showed that the field remaining in the horizontal section after shielding and compensation by ferrite was too small to cause appreciable steering effects or depolarization; in the vertical section the field causes a slight rotation of the beam which has to be taken into account in setting up the chopper. An interactive transport code was written to make possible immediate comparisons of the actual and theoretical effects of the various beam line elements. It proved to be of great assistance in setting up the injection line correctly and achieving 80% transmission; however, further work needs to be done on the vertical section to match the beam optimally to the cyclotron acceptance.

The commissioning of the beam in the cyclotron is described elsewhere in this report. It is sufficient to mention here that the interactive computer codes calculating the trim coil current changes needed to minimize deviations from the median plane played an especially important role in raising the transmission to high values. As expected, the vertical steering of the beam was found to be particularly sensitive where ν_z^2 is low, near 220 in. radius. At 223 in. a direct measurement of ν_z^2 was made by measuring the vertical shift in the beam when a known change in $\overline{B}_r$ was applied. The result was $\nu_z^2 = 0.02 \pm 0.01$, corresponding to a beam shift of 3 in. per gauss change in $\overline{B}_r$. This is in reasonable agreement with the value derived from the magnetic field survey, 0.035 ± 0.015. The smooth and gradual fall-off in beam current observed from 50 MeV onwards is consistent with stripping of the H^- ions by the residual gas molecules.

MAGNET

Magnet field tailoring

Simultaneous measurements of the vertical field component (B_z) and the radial field component (B_r) started in December 1973, were continued in January. The purpose was to reduce B_r, already reduced from 20 G to 5 G in 1973, to an acceptable value while maintaining B_z, which was already within tolerance. Another 14 ft^3 of steel had to be added to the bottom yokes to bring B_r within the limits of asymmetric pole shim adjustments and trim coil settings.

One problem that arose was that only long wave-length variations of B_z and B_r with radius could be corrected with the trim coils. To effectively attack short wave-length variations, half shims (6 in. radial width) had to be used.

By March only some corrections to the central region, using so-called 'bridge straps' had to be done as well as some reproducibility and stability checks.

On April 17 the magnetic field was declared acceptable in a joint meeting of the magnet and beam dynamics groups. The final survey indicated that the field was isochronous to a phase change of ±10 deg with the first harmonic reduced to a value <1 G. The axial restoring force appeared to be sufficient at its weakest spot (195 MeV) to give an oscillation frequency of $\nu_z^2 = 0.020$. B_r had been reduced to a value which should be correctable to negligibility by the trim coils. Based on the results of the last survey, the following cyclotron characteristics were predicted:

Maximum energy	520 MeV
Minimum extractable energy in beam lines I and IV	200 MeV
Beam loss due to magnetic dissociation	7% at 500 MeV

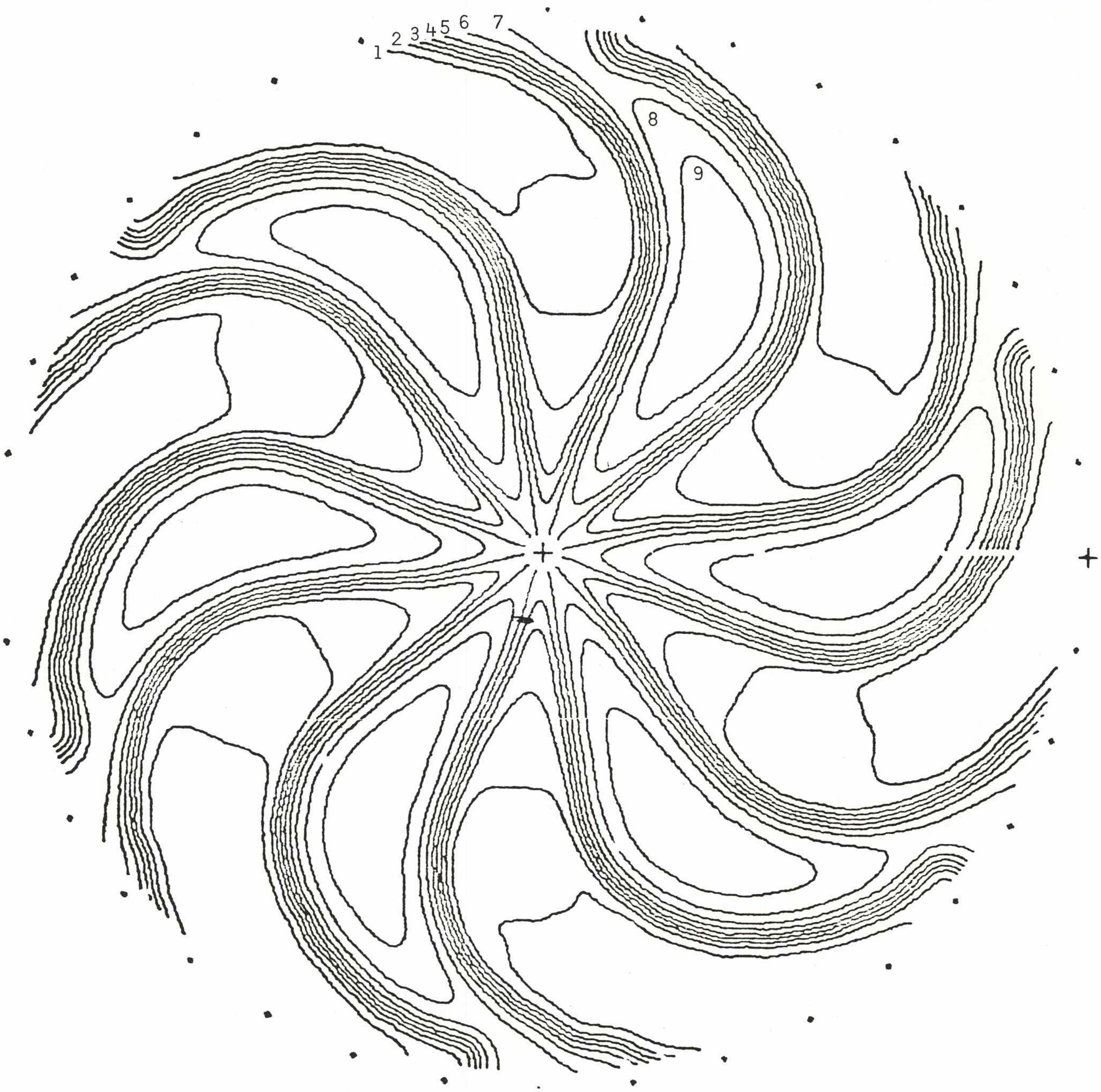
It took 492 days of 14 shifts per week to achieve this result, compared to the originally estimated 100 days. It also took many hands, of almost everybody on the project, to install, change and reinstall the many shims of great variety: 'pole shims', yoke shims', 'gap shims', 'block shims' and 'bridge straps'.

The main reasons for the prolonged survey were:

a) The difference in permeability between the full-scale magnet sectors and those for the 1:10 scale magnet model (see 1973 Annual Report)

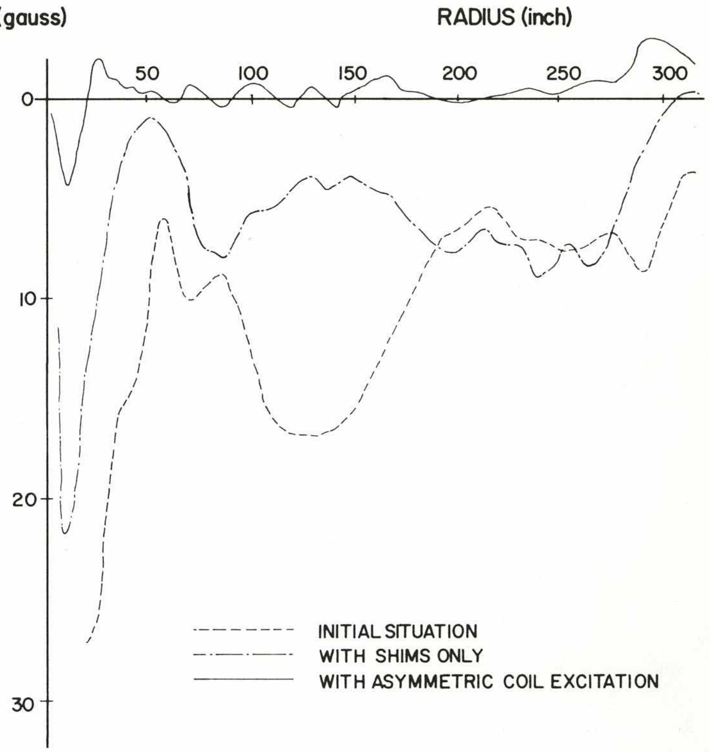
b) The sensitivity to B_r, as predicted theoretically and confirmed by central region cyclotron tests

c) The rather unexplained 'short wave-length' variations in the field which could not be corrected with the trim coils



Contour plot of the final magnetic field.

1 =1.00 KG
2 =1.50 KG
3 =2.00 KG
4 =2.50 KG
5 =3.00 KG
6 =3.50 KG
7 =4.00 KG
8 =4.50 KG
9 =5.00 KG



Various stages toward an acceptable $\bar{B}_r$ component.

d) The shaping of the complicated central region field, for which the 1:10 scale magnet model was too small and the CRC magnet too dissimilar.

Main power supply

After the initial troubles with the main magnet power supply early in 1973, it has given very reliable service. It was running for 1573 h in 1974, bringing the total to 2939 h. Of this approximately 2000 h was for the field survey. There have been no breakdowns during the year.

The field feedback loop in the current stabilizer is automatically shorted during trim coil adjustments by computer. Any change in a trim coil setting activates the shorting relay. This is to prevent the main magnet from compensating for trim coil current changes. The shorting reduces the stability from 5 parts in 10^6 to approximately 3 parts in 10^5.

Trim and harmonic coil power supplies

The number of trim coil power supplies was steadily increased as a result of the field measurements, as follows:

Late 1973 (End of survey 64)	58
Installed during 1974	29
Still on order	15
Total	102

This includes two powerful supplies for trim coil 0, which was installed to correct the central field. Turn-on of the coils is by computer; it takes only a few seconds to run all supplies up to their setpoints.

VACUUM SYSTEM

After completion of the magnet survey the vacuum chamber was prepared for installation of the resonators, cryopanels and beam and extraction probes. First the chamber was aligned, a lengthy procedure involving some 4000 optical observations and adjustments of some 500 tie rods. Then there were days of cleaning by a 'gas-masked' crew to remove all the dust and dirt that had collected inside the tank. From this point onward the vacuum chamber and vault have been treated as a 'clean area', i.e. anyone entering the vault has to wear special clean footwear and head coverings, and those working inside the chamber also have to don clean overalls and gloves.

Immediately after the resonators the vacuum system was installed. This consisted of the cryopanels, the cryoline, the cryogenerator, the turbomolecular pumps and the titanium sublimation pumps. The roughing system had been installed previously in order to provide a rough vacuum for alignment and magnetic field measurements. The cryopanels, of all-welded construction, have proved to be leaktight after several thermal cycles. Cold helium gas is circulated through the Philips B-20 cryogenerator and the two cryopanels connected in series via the cryoline. This cryoline is also of all-welded construction. The 20°K pipes are individually superinsulated with fibreglass and aluminum. The assembly of two 20°K pipes and two 80°K pipes are superinsulated with approximately 15 layers of fibreglass and aluminum.

Since it operates near 20°K the cryogenic pumping system is not capable of removing helium gas which might be present due to residual leaks in the cryosystem or hydrogen gas which is evolved from the metallic system. Titanium sublimation pumps were installed to pump the hydrogen. These pumps remove hydrogen gas by chemical absorption and hence have a high pumping speed only at low pressures. During the initial commissioning of the RF system large amounts of gas are driven off the resonator surfaces. This in effect means that a high pumping speed for hydrogen at high pressure is required, which is not compatible with the properties of the sublimation pumps; therefore, the sublimation pumps have been replaced with diffusion pumps for the time being. The cryogenic pumping system is also not capable of removing helium, and turbomolecular pumps were installed for this purpose.

No difficulty has been experienced with the main seal of the vacuum tank. All systems are functioning as expected. It is possible to pump from atmospheric pressure to below 10^{-6} Torr in 4 h. The best pressure obtained so far is 8×10^{-8} Torr with the RF system off. With the RF system on, the pressure varies between 2 to 5×10^{-7} Torr.

The performance of the vacuum system depends critically on the condition of the tank walls and equipment installed inside, such as the resonators.

It is still too early to judge the performance of the vacuum system under conditions of prolonged cyclotron operation. It appears that frequent defrost of the cryopanels and bakeout at 80°C are beneficial.

RF SYSTEM

As with the other components of the cyclotron, the results of several years of hard work were realized in 1974.

By the end of 1973 all but the centre resonator segments had been assembled, washed, baked, leak tested, wrapped and stored. In April the RF group undertook the immense task of resonator installation. Installation of the 80 resonator sectors began in May. A nucleus of twelve highly-trained technicians, assisted by up to 27 temporarily-employed helpers, were divided into three groups covering 14 shifts a week. Each shift had a tank crew, a vacuum testing crew and a resonator handling crew.

During the cleaning of the vacuum tank, the vault was sealed off and the vault fan was reversed to provide a supply of filtered air to keep the tank clean. The tank itself was shrouded with polythene sheeting, and transition air locks were provided for access at both ends of the accelerating gap. Clean precautions were instituted for all technicians employed in the tank and vault work, and the white-suited crews began the installation.

Several problems had to be overcome during installation: The tank lid was found to be displaced with respect to the bottom by about 3/16 in. Although adjustable in principle, the magnet shims at the centre prevented us from correcting this eccentricity, and the resonator mounting points had to be relocated from the carefully worked out positions which had been surveyed in with tolerances of ±1/32 in. Due to the complexity of the total assembly, there were also several interferences of certain cooling lines in the resonators and the resonator cooling header manifolds. About 25% of both lower and upper resonators had to be corrected.

Problems also arose with the metal C-ring seals in the resonator coupling blocks, and considerable effort was required to produce a seal in some cases. Each coupling and resonator was helium leak tested by pumping on the water manifold and sealing off all open coupling blocks.

Installation in the tank was carried on by the use of modified scissors lifts for installation of the upper resonators and special three-wheel carriages and winches for the lower resonators, as the service bridge was not yet operational.

Horizontal alignment of the central resonators with their latching system, which serves to connect the upper and lower resonators both mechanically and electrically, was difficult. It was finally achieved by the use of plumb lines, and the tank lid was lowered and a latch obtained seven weeks after the installation was begun (scheduled time was 40 days).

Electrical and power tests

Vertical alignment of the resonator tips was followed by Q measurements giving a Q of 6400, very close to the expected value of 6500. The Q was measured by the resonance peak width, by amplitude decay methods, and by measuring the phase change between the coupling loop and resonator currents as a function of frequency.

The transmission line, consisting of a matched 9 in. section and a standing-wave 12 in. section, was assembled and connected to the coupling loop through the special vacuum feedthrough. Tuning of the standing-wave section was facilitated by scanning 40 voltage probes on the line and displaying the standing-wave pattern on a CRT screen.

A major setback occurred when the tank lid was raised inadvertently with the resonators latched! The upper four centre panels, which were bent during the 10 in. lift, were removed, straightened and reinstalled in ten days. Due to the excellent mechanical properties of the panels and the expertise of Ebco Industries, the manufacturers, this accident proved not to be as disastrous as originally thought. The system was readied for power tests in the first week of August by the installation of some finger stock in gaps and copper foil seals at other positions to suppress RF leakage.

The resonators were excited at a level of 10 W through the transmission line and coupling loop, and adjustments were made to the resonators to tune both first and third harmonics at the design frequency. The expected vibrations in the cooling header lines were damped by the addition of copper mesh (commonly used for cleaning kitchenware and locally available under the trade name 'Chore Girl'). The panel vibrations were further damped by the installation of mechanical dampers at the resonator tips. A water smoothing tank, which was installed in the pump room, effectively removed the pump noise from the water system. This tank, which has the appearance of a mini-submarine, is appropriately placed in the water well at the lowest point of the building.

The first attempts at feeding higher power levels to the resonators under vacuum were plagued by severe hydrogen outgassing, a problem which was further compounded by the low available pumping speed for hydrogen above about 5×10^{-6} Torr. Four 10 in. oil diffusion pumps were installed on the vacuum tank to handle the hydrogen gas load, and this measure allowed voltages of over 50 kV to be sustained for reasonably long periods. However, as 60 kV was approached severe deterioration of of the vacuum was again experienced, which after many searches and speculations led to the discovery, early in November, that during the course of installation the water channels to one of the resonators had been left sealed off. The outgassing at higher power levels was caused by the real overheating of the uncooled resonator, which fortunately was not damaged by this mistreatment.

From this point the conditioning of the resonators to voltages suitable for acceleration proceeded much as expected, taking 10 two-shift days, compared with 120 h originally scheduled. Eventually 90 kV and higher could be held with no sparking for periods of up to five hours. It was found that sparks in the inflector/deflector or steering plates, or the exercising of various probes, could trigger resonator sparks, but as the vacuum improved the incidence of these secondary effects became less frequent.

During the tests and commissioning the RF voltage measuring probes near the resonator tips often failed when a spark occurred in their vicinity, a problem not encountered with the CRC, and they were eventually abandoned in favour of the current probes which are immune to such damage.

Other problems in the resonator system include failure of the radiation-hard, vacuum-resistant coaxial wiring to the latching microswitches. This wiring ruptured and shortcircuited at intervals along its length owing to overheating by RF. Leakage of RF into the beam gap in the central region segments caused sparking and overheating of the low-energy and centring probes. This was cured by fitting shielding strips in the gaps between the resonator panels.

Throughout the commissioning period the self-excited mode of operating the RF system once again proved its value. Some changes were made to the control system logic so that in the event of a resonator spark the RF power is automatically pulsed off and restored without the overdrive and power supply's crowbarring, which frequently occurred in the initial stages. The RF control system has now been refined to the point where operator intervention is not needed once the resonator voltage has been run up to the level required for operating the cyclotron.

The final part of the RF system to be tested was the pneumatic fine-tuning, allowing driven mode operation with the high stability of our frequency synthesizer.

RF power and control system

Reliability of the RF amplifier has proved to be satisfactory, the few failures that have occurred in close to 1000 h of operation since the start of resonator tests being understood and effectively corrected. During the one month of beam commissioning, the RF system caused only one cyclotron shutdown, of two shifts, owing to failure of a high-voltage pressurized capacitor in a combiner. The few such capacitors which remain in the system are being replaced by the more reliable vacuum type as they become defective.

Simultaneous injection of the first and third harmonics into the resonator array was achieved at low power in September. Assembly of the output stage and power supply of the third harmonic amplifiers has progressed steadily during the year.

Control of the RF system is available at the main cyclotron console, including frequency adjustment of ±3 kHz about the centre frequency of 23.050 MHz.

One of the most severe problems expected with the resonator system was detuning caused by vibration of the panels, mainly at their mechanical resonant frequency of 4.7 Hz. The fine-tuning system can handle only slow tuning drifts, below 1 Hz. The effectiveness of the mechanical dampers and water smoothing tank in reducing fast resonator vibrations is indicated by the small deviations of less than 500 Hz in the resonant frequency, a reduction of at least a factor of four. In the driven mode the power amplifiers can easily supply the additional power needed to maintain constant resonator voltage during the tuning fluctuations.

ION SOURCE AND INJECTION SYSTEM (ISIS)

At the beginning of the year only the unpolarized ion source had been partially commissioned. This year the injection system common to both the unpolarized and the polarized ion source was commissioned, and the unpolarized ion source was commissioned to the level required to obtain a preview beam. The polarized ion source arrived from the University of Alberta and was commissioned inside its high-voltage terminal, without voltage on the terminal and no injection line installed. Work on improving reliability continues; a primary requisite is the improvement of the ISIS beam diagnostic devices (beam profile scanner and emittance measuring systems).

Unpolarized H^- ion source

The source filament lifetime has gradually been improved from 24 h to 65 h average, with a maximum of 99 h; it depends upon extracted beam current. The improvement is attributed to small changes in the filament shape and to improvement in the purity of the hydrogen supply. Component reliability and the inventory of spare parts has maintained a reasonably low fractional downtime, with two exceptions: The 300 kV power supply caused a rather lengthy shutdown in the middle of the beam commissioning period. This situation will improve with the delivery of a second supply, which will act as backup as well as the primary supply for the polarized source. The second is a sparking problem in the electrostatic quadrupole immediately following the first 45 deg bend in the injection system just before the common injection system.

Polarized H^- ion source

The polarized ion source itself is more than 95% complete and is in operable condition. However, there are a few power supplies which are being modified to make remote operation easier. It has been operated through the CAMAC controller and has produced a maximum beam of ∿500 nA of H^- current, with a polarization (by atomic substate measurements) of 75-85%. More typical beam currents are 300-400 nA.

Some difficulties have been experienced with leaks in two water-cooled solenoids; these have been temporarily repaired, but they will require redesigning in order to achieve a permanent solution to this problem. Considerable oil contamination has been experienced from the oil diffusion pumps. These were equipped with special jets which were supposed to reduce oil backstreaming to negligible amounts. Water-cooled baffles have been added to reduce oil backstreaming to reasonable levels. It is important to reduce oil contamination inside the ion source because insulating layers formed by the oil affect the polarized beam and reduce both its intensity and polarization.

The refrigeration system and closed-cycle water circulation system have been installed but not tested. The safety shorting bar has been installed. Windows and doors to the ion source room are undergoing manufacture and installation. After the room is clad in aluminum, the isolation transformer will be installed and the high-voltage cables connected. The 300 kV supply has been ordered but will not be delivered until April.

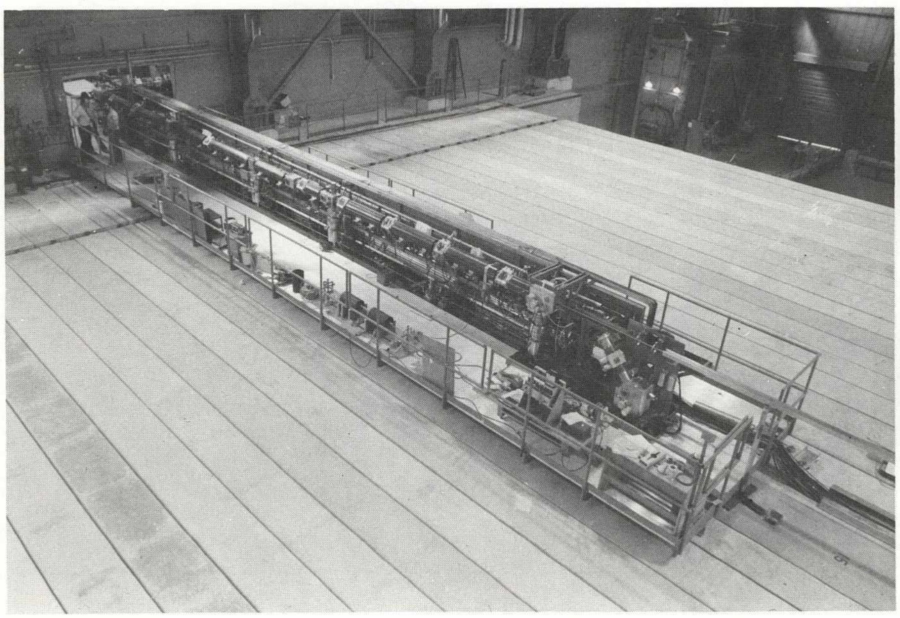
The support structure for the beam line that transports the beam to the common injection system is in place. Over 80% of all beam line components are on hand and are presently being readied for installation. The spin precessor has been completed and tested at the University of Alberta.

Common injection system

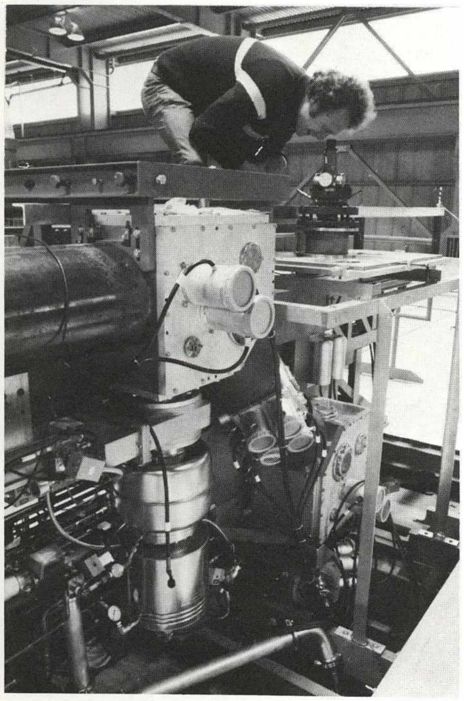
The horizontal section of the injection line was completed, and the vertical section modules were assembled, aligned and given vacuum and electrical tests in the vertical assembly station in the corner of the proton hall. To avoid transverse distortions the vertical modules were transferred in vertical orientation from the assembly area to their final positions in the beam line. They were then installed, optically aligned, vacuum tested and electrically tested. Mechanical alignment tolerances of better than 0.01 in. were achieved in the fixed modules, but some work remains to be done to achieve this tolerance for the removable section VRS.

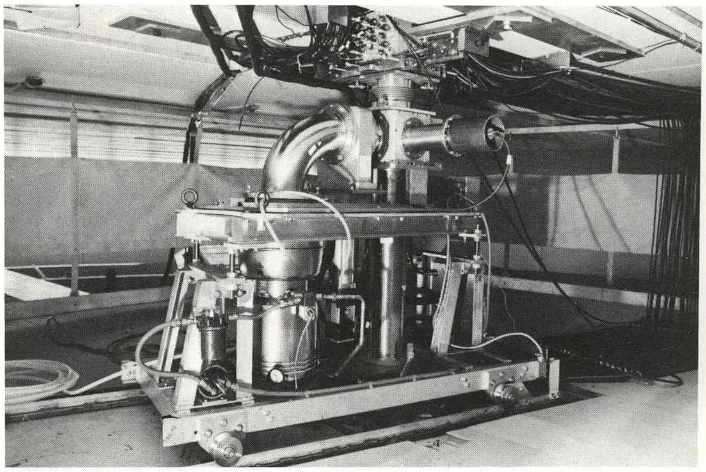
The fringe field of the cyclotron magnet (up to about 50 G transverse in some places), which seriously perturbs the beam trajectory in the ion source, acceleration tube and injection beam line, was successfully

View of horizontal beam line from crane.



Final section of vertical beam line just prior to its installation.





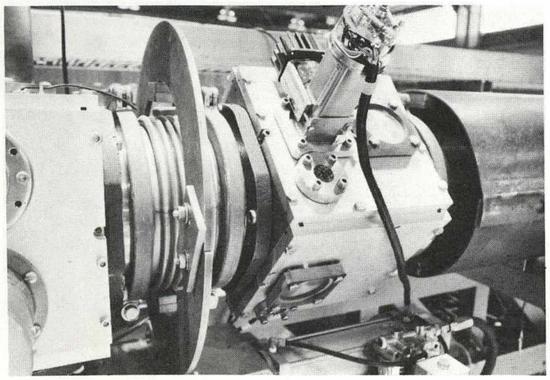
▲ *Vertical roll-out section of beam line between top of support structure and bottom of vault roof beams; this section has to be removed every time the cyclotron lid is raised.*

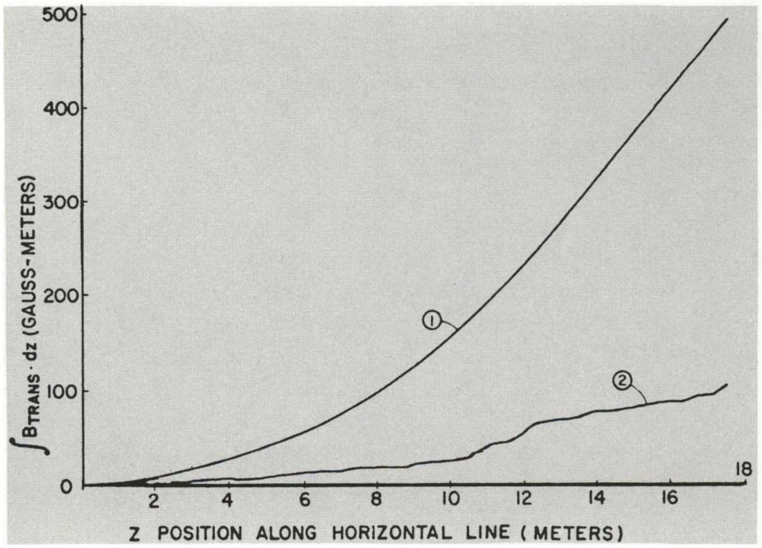
◀ *Non-dispersive electrostatic bend section connecting horizontal and vertical beam line sections at the time of alignment of vertical beam line.*

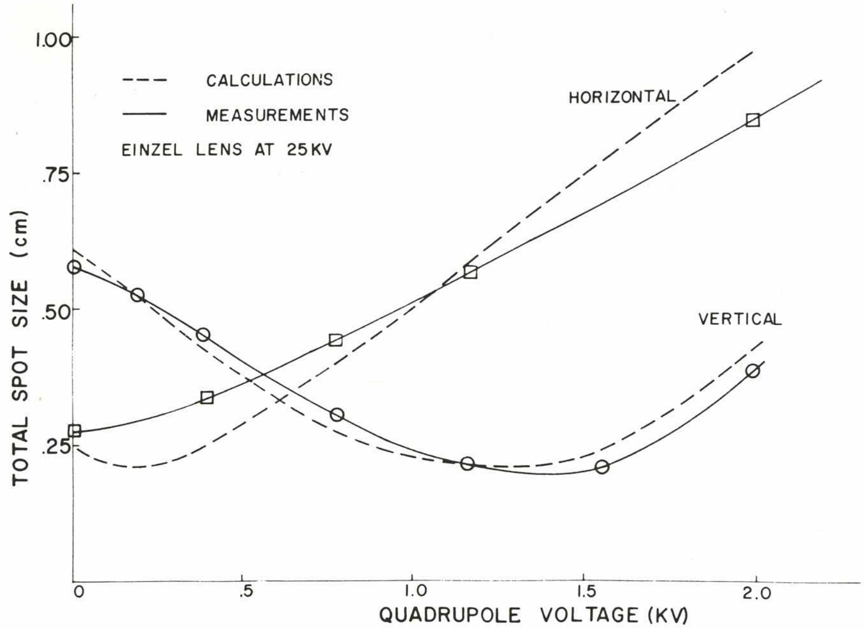
corrected by a combination of ferromagnetic cylindrical shields placed where feasible and ferrite dipoles suitably placed so that the line integral of the transverse component of the field over the horizontal section of the trajectory averaged out to zero. Measurements of the three components of field were made along the beam line using a three-axis Hall probe; these measurements were used to determine the correct placement of shields and dipoles, and were also used in calculations of the effect of the magnetic field on the polarized beam. The latter calculations indicate that it should be possible to inject the polarized beam without significant loss of polarization.

Transverse magnetic field along horizontal injection beam axis 1) with and 2) without compensation. ▶

Magnetic field compensating system: ferromagnetic shield and ferrite dipole compensating magnets. ▼







Computed and measured beam profiles in the 12 keV region as a function of quadrupole voltage.

Following closely behind the mechanical and electrical installation crews, the beam commissioning task force systematically commissioned the beam through the beam line, seeking to obtain proper agreement between the theoretical and experimental behaviour of the beam. Discrepancies between theory and experiment helped in the detection and correction of mechanical or electrical errors in beam line optics. Until the high current protection interlock system is completed, commissioning work has been restricted to low beam currents (up to 30 μA dc) to avoid damage to beam line components, and most attention so far has been to obtaining a good transmission (80% has been achieved). Proper centring of the beam through all optical elements and apertures and full agreement between theoretical and experimental beam profiles remains to be completed. Commissioning of the system to higher beam intensities will require the completion of this work, including the effects of space charge and may require improvements in the magnetic field compensation. The beam pulsing system to provide high instantaneous currents with low average current is available, and the chopping and bunching systems are in the final stages of commissioning.

Inflector

The design of the TRIUMF inflector is very similar to that used successfully in the central region cyclotron, except that space restrictions inside the stainless steel centre post presented a number of new problems. As the installation of the inflector must be done from the service bridge the connection of the upper inflector electrode assembly to the lower feedthrough assembly had to be designed for remote operation. The development of a connector design which would allow this and would also prevent the four 30 kV conductors from sparking under the combined effects of vacuum and magnetic field required several months of experimental effort in the CRC. Another unknown was the vacuum and pumping speed which would be obtained in the inflector region in the cyclotron at full RF power.

The inflector was first installed in the cyclotron in September and conditioned to the required operating voltages with the RF off. However, the conditioning process was slow as the pressure in the inflector region was higher than expected. This situation was improved by replacing the titanium sublimation pump in the pumping station below the centre of the cyclotron with an oil diffusion pump. At present the inflector conditioning is not a problem and the sparking rate is acceptable.

The first dc beam was successfully transported through the inflector to the low energy probe on October 21, and the first accelerated beam on November 16. Diagnostic slits at the entrance and exit of the inflector are used to optimize the beam transmission, and during normal operation no beam is lost in the inflector.

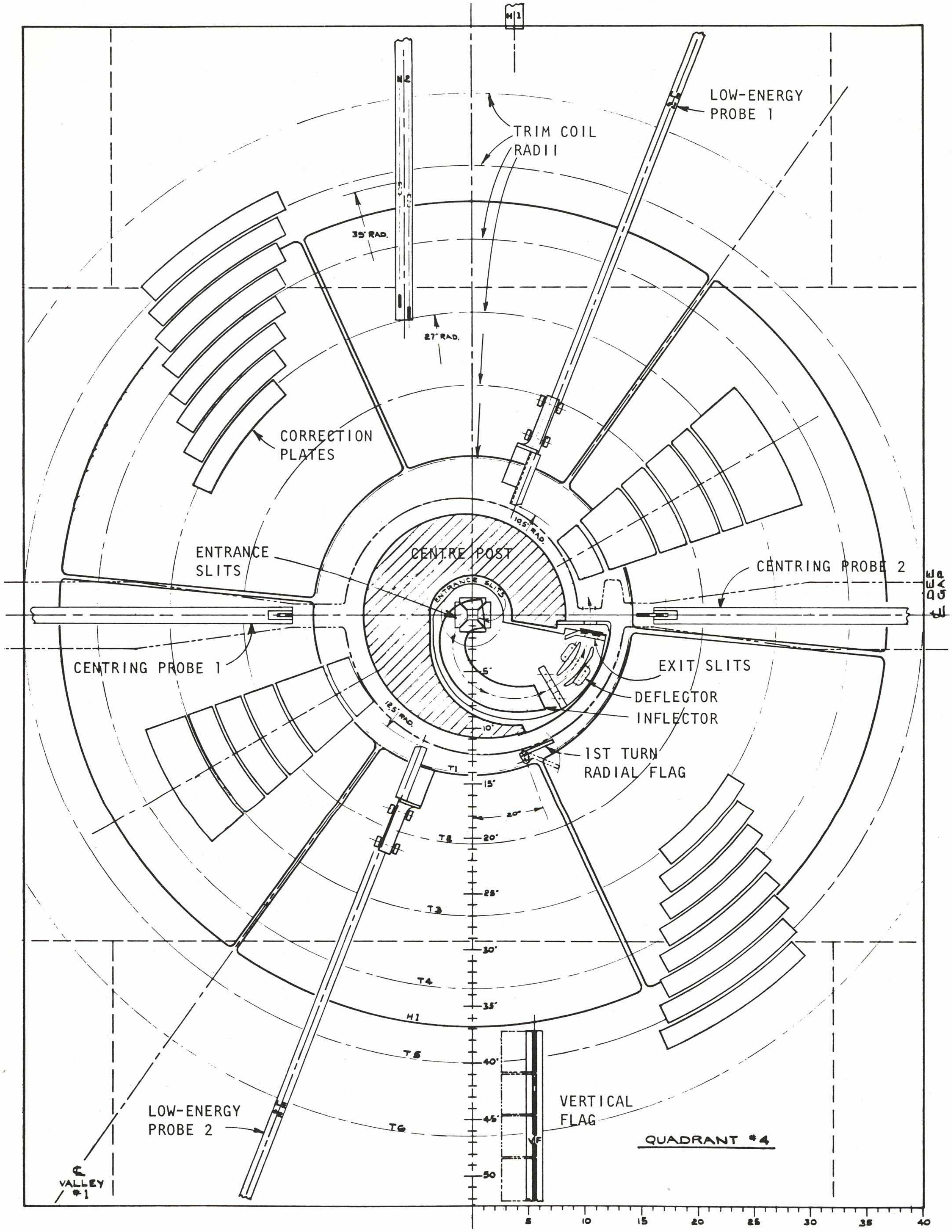
Correction plates

Twenty-eight pairs of correction plates were installed in the central region of the cyclotron to compensate for vertical beam losses and poor vertical emittance caused by electric or magnetic vertical perturbations.

The first 12 pairs are located every half-turn along the first five turns, right after the dee gaps. In this arrangement they can be used most efficiently to compensate for vertical dee misalignments, as had been shown during the central region cyclotron beam tests. The outer 16 pairs consist of two sets of 8 pairs each, 180 deg apart in azimuth, and are located radially between 25 in. and 45 in. Their main function is to compensate for short-wave B_r fluctuations which could not be eliminated with shims or asymmetric excitation of trim coils. If not compensated these fluctuations would introduce large vertical coherent oscillations for different phases and seriously limit the phase acceptance of the cyclotron. A layout of the plates system is shown on the following page.

Opposite voltages up to ±3 kV can be set on the upper and lower plates of each pair through a system of feedthroughs and special wire-ways attached on the upper and lower side of the dee structure. The individual voltages and polarities can be controlled from the main control room.

During the initial operation of the system it appeared that the plates always were able to provide an important increase in the beam intensity transmitted to higher radii. In one instance, where the dees were misaligned by more than 3 mm, they proved to be essential for accelerating a beam. The voltage stability on the plates presented a few problems due to interactions with the RF leakage along the wire-ways. Proper RF shielding along the wire-ways is expected to make the system more reliable.



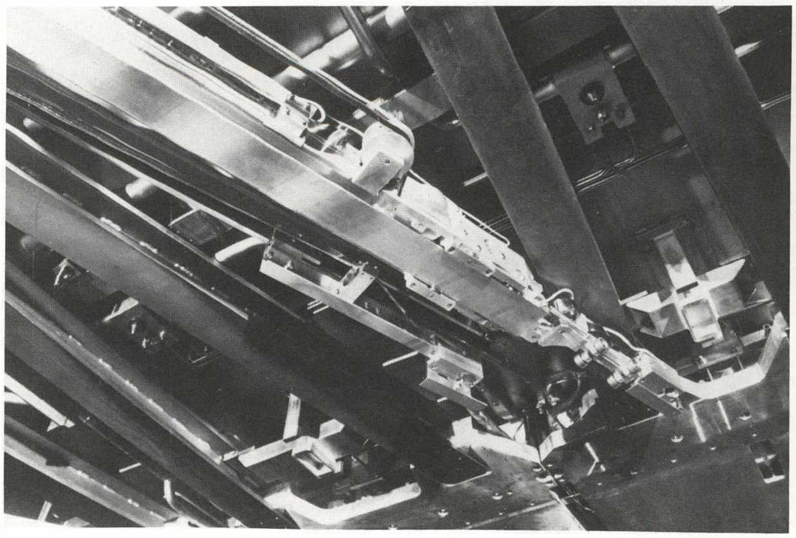
Layout of correction plates system.

BEAM PROBES

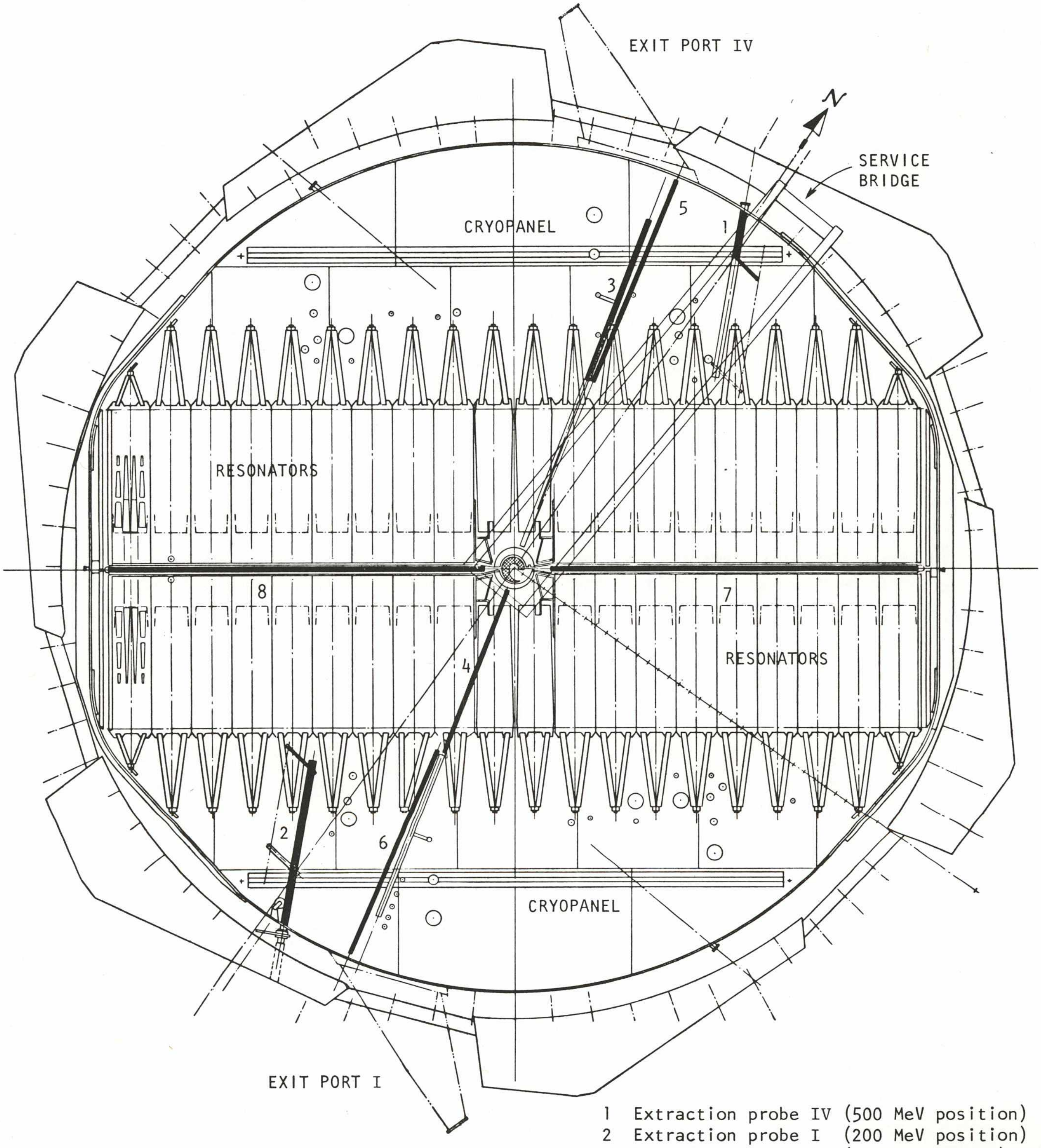
During the second half of 1974 at least one of each of the diagnostic probes was installed in the cyclotron and used during the initial beam commissioning. Success with the probes systems varied and several anticipated problems, as well as some unexpected ones, were encountered during the probes commissioning. Some of these have been solved and others require further study during the coming year. However, we were fortunate in that the beam commissioning program through to a full-energy extracted beam was delayed by only a few days due to breakdowns with the probes systems.

The location of the probes relative to the resonator array is shown in the following plan view of the cyclotron. The centring probes which cover the full radial range of over 300 in. along the dee gap were the first to be installed during the resonator installation period in June. The probe head, which is typically a flag of 2 in. radial flag, is driven by means of an endless beryllium copper tape. These probes have not operated reliably as yet in the cyclotron, primarily due to the large friction forces necessitated by keeping good RF contacts on the tape.

The first low-energy probe, which covers the radial range out to 144 in., was installed in Valley IV in July. Mechanically this probe has worked reliably. However, this probe is cantilevered in the region between the upper and lower resonator arrays, and it was found that at certain radii there was sufficient RF leakage to produce sparking to the probe arm as well as serious outgassing of some probe components. This problem was improved by better RF shielding but is still not eliminated completely. The probe head consists of a three-finger differential head with a 1.5 in. diam lithium glass scintillator mounted on the total current head. The scintillator is viewed through a rotary mirror by a TV camera



The low-energy head is on the right, mounted on a trolley which runs along the top of the lower resonators. The high-energy head on the left is driven along a track by means of an endless copper tape.



1 Extraction probe IV (500 MeV position)
2 Extraction probe I (200 MeV position)
3 Low-energy probe 1 (outer position)
4 Low-energy probe 2 (inner position)
5 High-energy probe 1
6 High energy probe 2
7 Centring probe 1
8 Centring probe 2

Plan view of the cyclotron showing the various diagnostic and extraction probes.

mounted below the cyclotron and displayed at the control console. The currents on the head are processed through amplifiers and a multiplexing system, and can be displayed as histograms on a Tektronix 611 storage scope, as analog signals on Keithley electrometers, or on a 6-channel chart recorder which can be driven synchronously with the probe for radial beam plots. This probe is the principal diagnostic tool for the optimizing of the beam through the inflector and the cyclotron central region, and the experience with the central region cyclotron resulted in this stage of the commissioning going quite quickly.

The next major period of installation activity in September resulted in the commissioning of the high-energy probe which covers the radial region from 142 in. to 315 in. (65 to 520 MeV), movable radial slits between 4 and 30 MeV, and a vertical flag for restricting the beam height at 4 MeV. The high-energy probe head consists of five horizontal fingers which strip the H^- ion and pick up the two electrons. This probe was the most important diagnostic tool and received much activity during the trim coil optimization on the way to a full-energy beam. As vertical centring of the beam was very critical the beam centroid was calculated from the currents in the five fingers and would be displayed as a function of radius on the chart recorder.

The commissioning of the extraction probe for beam line IV was delayed due to difficulties in aligning the all-metal gate valve on the vacuum tank, and initial extraction was made using a fixed stripping foil (the kitchen variety) mounted on the extraction probe track at a radius corresponding to 500 MeV. After achieving an extracted beam in this manner the extraction probe mechanism was successfully installed and operated in the last week before Christmas.

In the probes laboratory the second of the low- and high-energy probes are undergoing mechanical tests, and the second extraction probe for beam line I is being assembled for installation in February of 1975.

As the mechanical assembly and installation of the various probes was taking place, an equally major effort was going on in parallel by the controls and software personnel to commission the controllers for the synchronous and stepping motors, the encoder readouts for position information, the limit switch logic for mechanical protection, and the diagnostic amplifiers and display systems. All operations involving probes are now controlled from the main control console. These systems have worked reliably.

HANDLING FACILITIES

Elevating system

The servicing and handling of active components is the responsibility of the remote handling group. In so far as the cyclotron is concerned, these activities all have to be performed with the upper part of the cyclotron raised, by means of the elevating system described in earlier reports. The system has made 110 'push-ups' during 1974, bringing the total number to 311. The failure rate has been virtually nil: one broken wire and one loose screw, which were quick to repair.

The speed of the reference synchro was increased by 1.5% for raising and 2% for lowering. This has the effect of reducing the number of motor re-starts, resulting in less wear of motors and starters. The average running time after a start was increased from 20 sec to 1.5 min. The time to elevate the upper yokes 48 in. was reduced from 41 to 35 min as a beneficial side effect.

In last year's annual report the lubrication of the jacks was reported as unsatisfactory. Due to higher priorities no improvement has been made to date, other than the installation of 24 plastic kitchen pails to collect the excessive amounts of grease: the jacks used 1/4 ton over the year!

Handling of active components

In spite of limited money and manpower resources during the final assembly of the cyclotron, substantial progress was made in establishing a good base for handling and servicing radioactive components. Three general areas of activity were handling of cyclotron components, handling of beam line components, and an interim hot cell facility.

Cyclotron components: The service bridge went through its shakedown, and several minor changes were made in the carrier drive and lifting mechanism. Some very beneficial experience was gained during resonator installation, now being applied to new trolley designs. Peripheral indexing at 1 deg intervals was added for the service bridge, and an offset installation mode was established for inflector and central region servicing. The original trolleys are still being used but will be replaced early next year. Cable trays have been installed on the bridge and facilities for servicing have been provided for in the service bridge tunnel. A dummy magnet section and dummy centre post have been provided in the vault for future testing of remote equipment on the service bridge outside the cyclotron, and a half-length dummy service bridge has been built for assembly and test of service bridge trolleys and fixtures outside the vault.

Beam line components: A radiation-hard 8 in. remote operable vacuum flange and seal design was standardized for all beam lines. The target handling flask design was completed, and indexing bridges were designed for accurate locating and simplified service of the T2 and LD_2 targets and associated collimators, blockers, etc.

Interim hot cell facility: Installation of a temporary hot cell has been started. It will consist of shielding blocks and water windows and will be equipped with three manipulators. It will be used primarily for training and familiarization with future service requirements. The hot cell will initially be used for servicing targets but it can accommodate units as large as a resonator. By replacing the water windows with lead glass windows the hot cell should be usable for target servicing until the beam in beam line I goes into regular operation at currents higher than 1 μA. A technical lab with modest fabricating capabilities is being established in the hot cell area. The manipulators are used equipment, made available by LLL (Livermore, California) and AECL (Chalk River, Ontario). These contributions are greatly appreciated at this time of tight money: without them the facility would have been even more modest.

CONTROL SYSTEM

Beam commissioning control system

The initial beam commissioning control system has been completed. Three computers are dedicated to machine operation, as outlined in previous annual reports. One computer serves as an interface to the control console as well as supporting CRT display. A second is used to scan machine parameters checking operation limits. This computer is the principal control communication link to the cyclotron. Device drivers, such as extraction foil motion programs, reside there. A third computer supports remote commissioning consoles and bypasses the other two computers. This allows an alternate and direct link to site devices. The current number of devices under control are summarized in the following table.

The overall reliability of the system is good. There is about one control system failure per week with about a half-hour mean time to repair. Such equipment reliability has allowed the team to devote their time to new device installation. The programming staff also devote a full-time effort to new device support.

Development efforts

With the cyclotron operational the demand for system modifications and new operation procedures has increased. This is especially true in beam diagnostic efforts. The demand for system change must always be moderated by system security considerations. In general, new system modules are inserted in the controls program only during shutdown periods. Two approaches to allow more dynamic interaction with the control system have been developed:

Component	Digital Status (devices)	Analogue Status (devices)	Digital Control (devices)	Analogue Control (devices)	Comments
Magnet	100	100	100	100	Main magnet, combination magnets have D/A converter in power supply. Trim and harmonic magnet supplies are referenced by an external converter.
RF	7	140	2	2	80 thermocouple signals from resonator cooling lines are monitored. Run-up and shut-down are hardwired automatic. Central control system monitors operation of stages of RF.
ISIS	240	240	210	200	These numbers include two ion sources. A third ion source will be installed next year.
Probes	12	40 (including currents)	12	12	The principal task of probe control is the direction and monitoring of stepping motors. Independent shaft encoder measurements are used to establish the probe position.
Vacuum and Ancillaries	20	10	0	0	The vacuum system can be run up or recycled from the control room. The cooling water system status is monitored at the control room.
Safety	1	16	1	0	Radiation monitors are logged on the scan cycles.
Beam Lines	180	180	170	160	160 beam lines devices are anticipated.

Control functions of TRIUMF. Status information is kept on a logging facility as well as displayed in control room; control system allows operator control of the facility and automatic run-up procedures.

Development and experimental computers are interfaced to the control system via a CAMAC-to-CAMAC link from any crate in the control system. This technique has been used to supplement experimental data with machine parameters in studies using TRICL and BASIC as the host language. Since requests for control changes are routed through the remote console computer it is possible to restrict access to only selected components.

A second method, including more computer sources on the CAMAC executive system, is under development. The present two-source system will be expanded to include four computers, two of which operate in a high-level language allowing cyclotron physicists rapid real time access to the control system. Limited CAMAC drivers will provide system security.

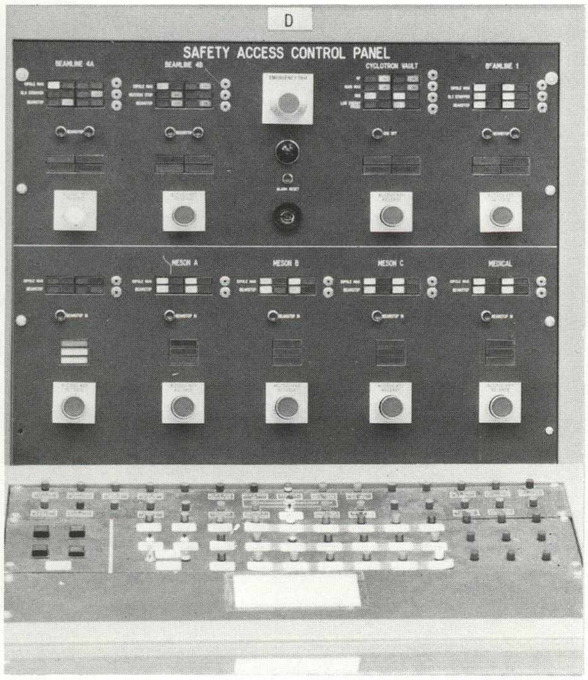
SAFETY

Much of the TRIUMF Safety Group effort in the early part of 1974 was directed towards finalizing documents for submission to the Atomic Energy Control Board in support of a licence application to operate the cyclotron. The activities of the TRIUMF Safety Advisory Committee (TSAC) were brought to a successful conclusion following meetings with the AECB's Accelerator Safety Advisory Committee in June, which resulted in TRIUMF obtaining an operating licence, limited to 1 μA.

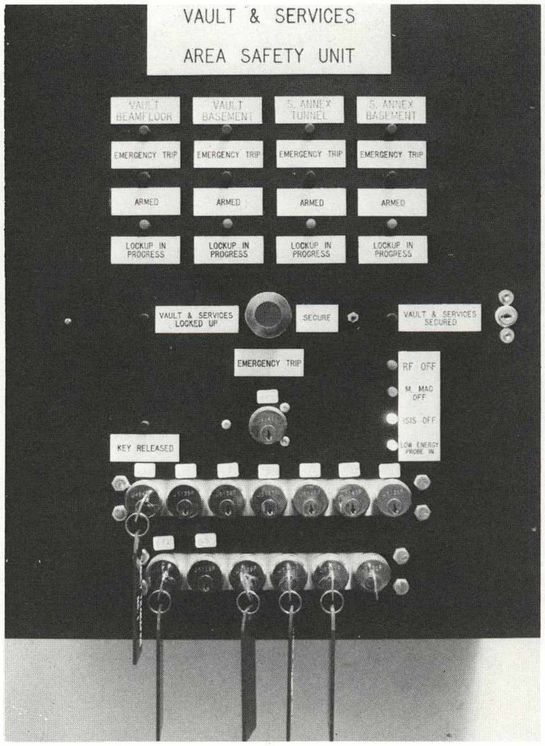
In September the Director appointed the TRIUMF Safety Executive Committee (TSEC). It has the responsibility of making rules for the promulgation of safety at TRIUMF in accordance with the policy developed by TSAC. TSEC meets every two weeks and is actively involved in reviewing experiments before they are mounted on the floor.

Safety interlock system

The safety interlock system for the cyclotron vault was successfully tested and commissioned on November 11, five days before the first injected beam. This portion of the system accounts for about 50% of the total logic required for the complete system. The safety interlock system has performed well since its commissioning, and there have been no failures in the system. At the end of the year the detailed design of the rest of the interlock system was well in hand, and installation was started on the proton hall interlock system.



The safety access panel in the control room.



Area safety unit at the vault entrance.

Machine protect system

The machine protect system was designed, installed and partially commissioned in August. This system is tied with the safety interlock system, although there is a high degree of separation in that most of the logic decisions are made in a bank of relays rather than in the PDP-14. The machine protect system consists of the interlocks that are required between major systems. These systems consist of the cyclotron magnet, power supply, the RF system, the vacuum system, ISIS, the cyclotron elevating system, probes, the service bridge, the inflector and correction plates, targets and proton line magnet power supplies, and the cooling system. In addition each system has its own internal interlocks.

Radiation protection

During the initial cyclotron tuning period six beamspill monitors and four neutron monitors were installed with control room readouts. The beamspill monitors proved to be a useful tool for beam optimization, and the first indication of an extracted beam came as a radiation warning alarm from the monitor which was mounted inside the temporary beam dump in the vault.

Radiation levels at several locations have been logged to assess the effects of beam losses and to make crude extrapolations to the radiation levels expected when the cyclotron operates at full power.

By the end of the year 240 individuals were on the permanent film badge service for neutron and gamma monitoring; an additional 60 film badges cover contractors' employees, visitors and other short-term demands. These badges are routinely picked up at a control point at the entrance to the security fence. No individual at TRIUMF received any radiation in 1974 according to the records of the Radiation Protection Bureau.

Accident record

There have been no accidents during the year other than the usual occasional minor injuries, although a number of near-accidents, such as heavy loads that 'nearly' tumbled down, hopefully served as a stern warning to be more careful.

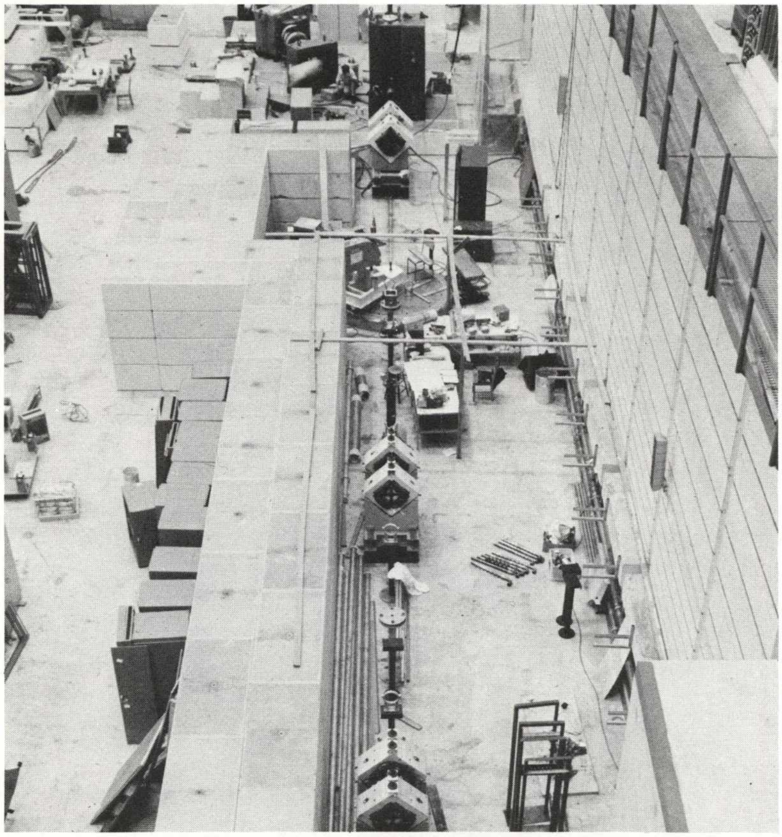
SHIELDING

At the beginning of the year the production of shielding was still very much dominating the scene on site. The second layer of roof beams was placed over the vault in February and the third, and last, layer in April. The east and west vault walls were increased in thickness from 3 to 16 ft and were completed in March. This was just in time to clean up the proton hall before unwrapping the carefully cleaned resonators prior to their installation in the cyclotron.

Most of the effort during the rest of the year has gone into the layout and detailed design and procurement of the movable block shielding for the experimental beam lines and areas. In October Turnbull and Gale was awarded a contract for 3200 tons of shielding blocks and beams, to be manufactured on the southwest corner of the site. Because of budgetary constraints only enough shielding has been ordered to operate the beam lines at currents of the order of 100 nA. However, most of the special shaped shielding blocks around primary beam targets and primary and secondary beam lines, which require the bulk of the design effort, were included in the initial orders to achieve an orderly development of the facility.

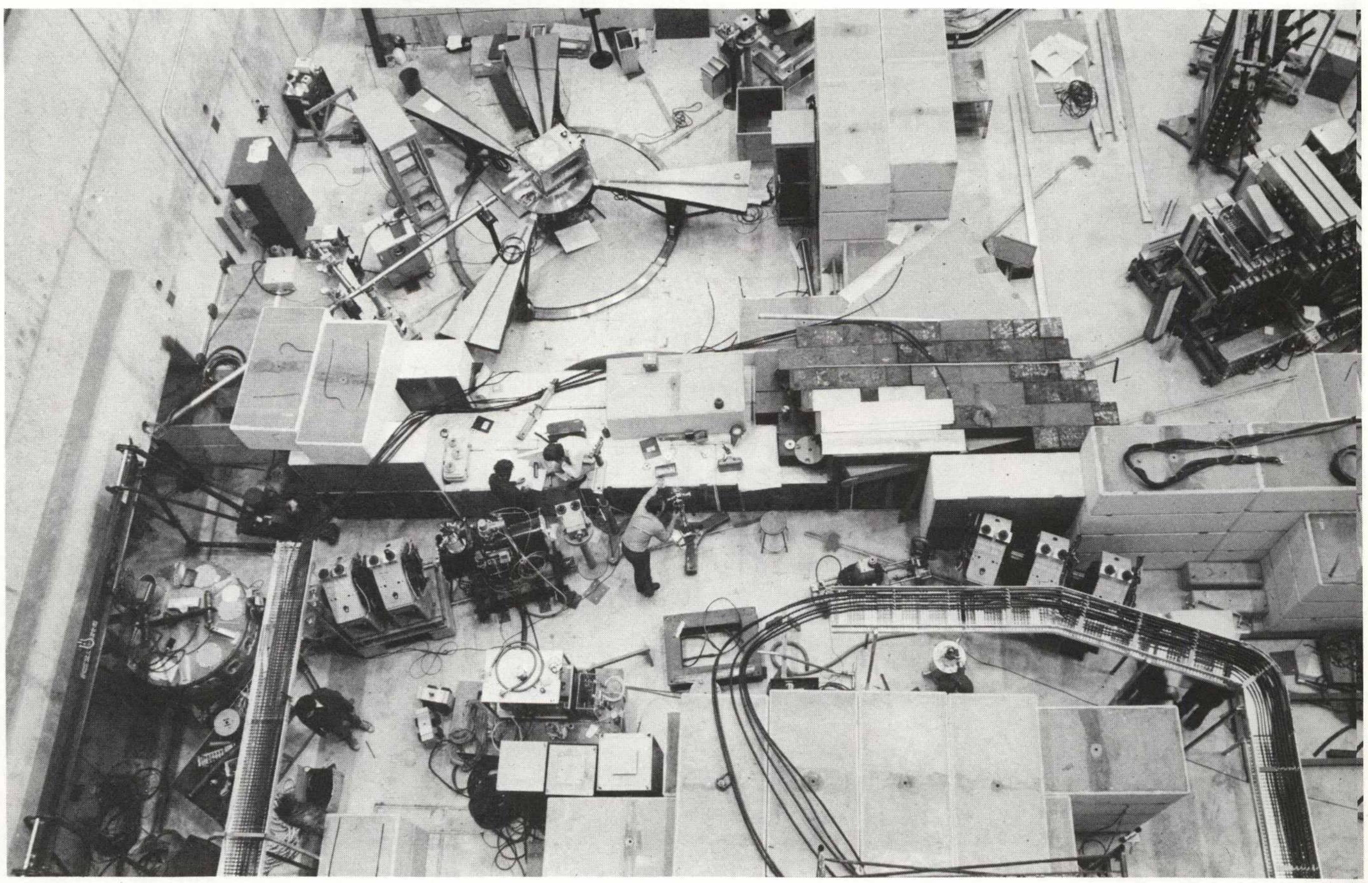
The following table shows the inventory of standard and special shaped shielding blocks that will be on hand at the completion of the contract. This is sufficient only for a 4 to 8 ft thickness of concrete over and around the proton beam lines in the experimental areas; this, in turn, limits the possible beam intensities to the order of 100 nA.

		Proton Hall	Meson Hall	Cyclotron Vault	Cyclotron Periphery
1'×2'×3'	Iron	12	3	-	-
2'×3'×6'		4	8	-	-
Special		10	11	-	-
1'×2'×3'	Heavy Concrete	60	40	-	38
2'×3'×6'		130	70	30	175
Special		25	25	-	68
1'×2'×3'	Standard Concrete	70	70	10	-
2'×3'×6'		190	160	50	-
4'×6'×12'		22	18	13	-
4'×6'×18'		15	28	-	-
4'×6'×30'		5	-	-	-
Special		5	8	6	41



◀ *Looking downstream beam line I in meson hall.*

▼ *Beam lines IVa and IVb entering proton hall through the shield wall on the left.*



PROTON BEAM LINES

Progress with the installation of beam lines has been formidable, considering that at the year's beginning most of the magnets and power supplies still had to be delivered and there was no sign yet of any installation. As in the previous year manpower and shop priorities were assigned to beam lines only after the needs of cyclotron installation and commissioning had been met. Largely through the efforts of scientists from the participating universities and the BASQUE experimental group, assisted by summer students, beam lines were completed at about the right speed to be ready for beam when the cyclotron would be ready to deliver.

A team from the University of Victoria and the main site had started measuring beam line magnets in 1973. At the end of the magnet survey the team inherited the Hewlett-Packard computer and other field-measuring equipment, and the dipole and quadrupole measuring effort was stepped up. By the end of the year some 24 quadrupoles and 3 dipoles had been measured for the proton beam lines and some 8 quadrupoles and 4 dipoles for the secondary beam lines.

The 10 μA beam dump, at the end of beam line IVb, was installed in February, underground outside the proton hall. The remainder of the proton beam line installation had to wait until the end of June after the resonators had been moved out into the vault for installation in the cyclotron.

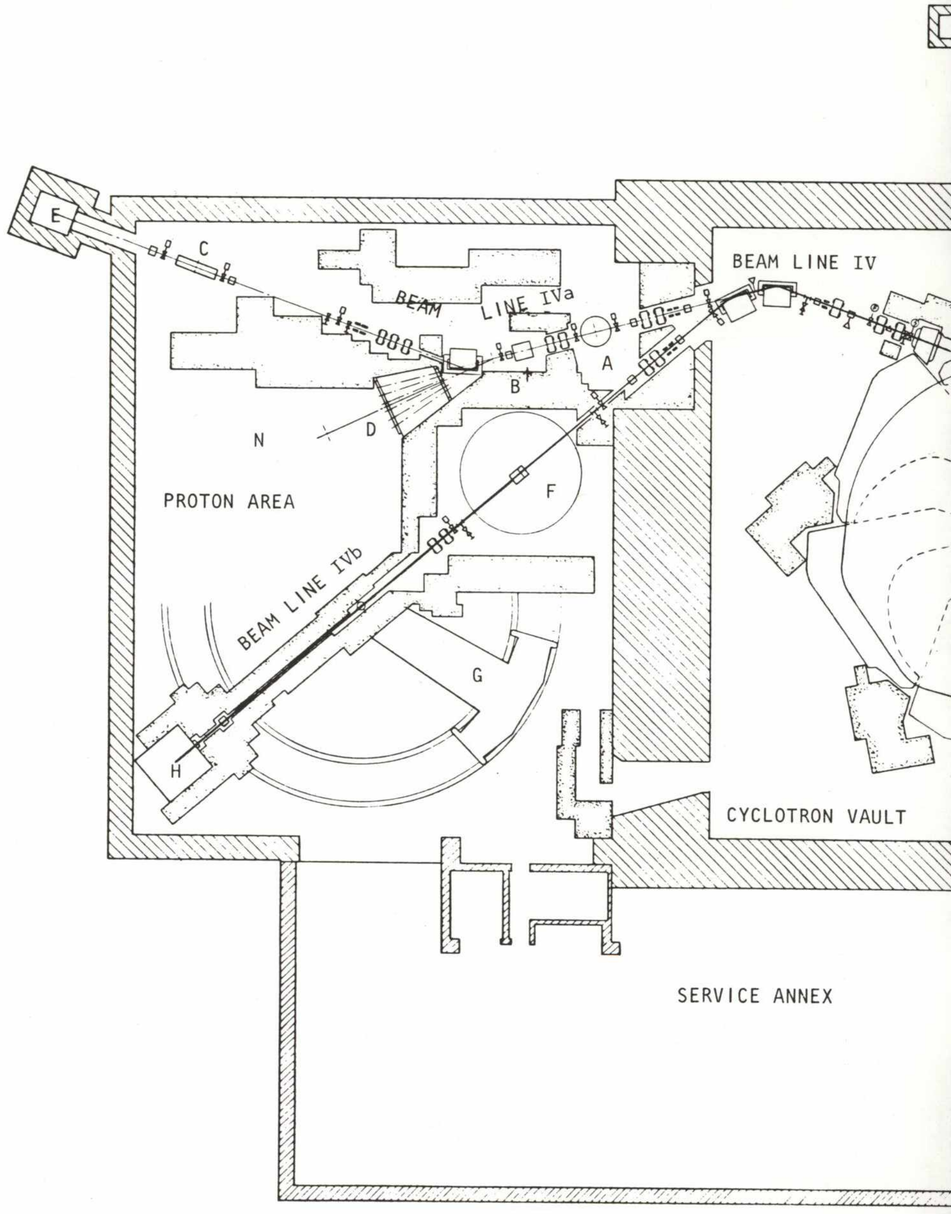
Installation of quadrupoles and bending magnets located in the vault was started immediately after completion of the main magnet survey and was completed in July. The 100 nA beam dump was moved to its final location in the southwest corner of the proton hall in July, and all quadrupoles in beam line IVb were installed by October. In December the vacuum system was completed and the necessary beam monitors installed. Three feet of shielding was placed around the whole line and by the end of the year beam line IVb was ready to receive a beam, with only remote control and interlocks still to be done.

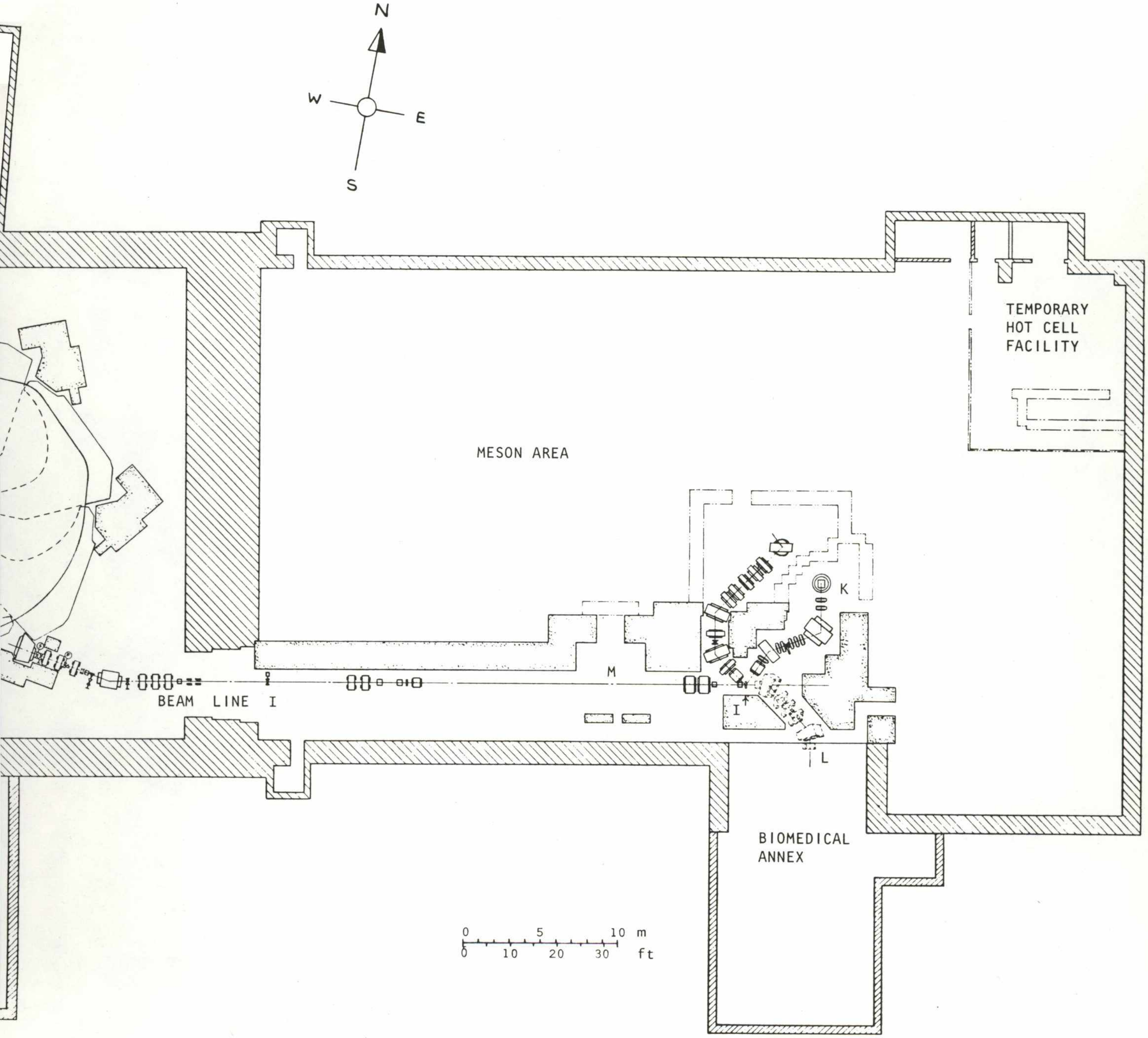
Also in the second half of the year the bending magnet and quadrupoles in beam line IVa were installed, along with a scattering chamber and BASQUE equipment discussed elsewhere in this report.

Beam line I installation lagged only a little behind beam line IV. The T2 target was installed first, along with the bending magnet and quadrupoles in the vault. By the end of the year all quadrupoles and some of the vacuum system had been installed.

A factor that is often underestimated is the effort and time required to install the essential electrical services and cooling system. This, to a large extent, determined the maximum rate of progress.

A 60 in. scattering chamber
B Super-conducting solenoid
C Time-of-flight mass identification facility
D Neutron collimator
E 10 μA beam dump
F Proton target with scattering stand (PT1)
G Proton spectrometer
H 100 nA beam dump
I Meson target (T2)
J Stopped π/μ channel
K MSR facility
L Medical channel
M TINA and π production experiments
N BASQUE experiments




N
W
E
S
TEMPORARY
HOT CELL
FACILITY
MESON AREA
K
M
BEAM LINE I
I
L
BIOMEDICAL
ANNEX
0 5 10 m
0 10 20 30 ft

The majority of the beam line layouts and experimental facilities were not changed from those reported in 1973. The unfortunate exception was the high resolution channel planned for beam line I, which because of the limited budget for experimental facilities had to be temporarily suspended. The power supplies and magnets which had been ordered for this facility were lent to other facilities, pending the channel's being restarted, hopefully in 1975.

Because the cyclotron installation absorbed most of the efforts of main site technical staff, progress had to rely extensively on the efforts of scientists with technical help provided by the participating universities.

Meson production target T2

All the target components, the cooling package, purge package, and control electronics have been fabricated and assembled at the University of Victoria. The 30-ton lead-shielded vacuum vessel, housing the target, 10 μA temporary proton beam dump, meson channel blockers and target beam monitor, is finished and positioned at the end of the beam line in the meson hall. Modifications to the 10 μA dump are in hand to enable an ^{123}I generator to be inserted immediately in front of the beam stop. The target controls and cooling system are presently being tested prior to final installation and commissioning at the main site next year.

Liquid hydrogen targets

Two liquid hydrogen target assemblies are under construction in the UBC Physics Department. Both are standard up to the design of the individual flask assemblies, and both incorporate a Crydone Model 1020 refrigerator with a capacity of 10 W at 20°K. One refrigerator was purchased by TRIUMF, the other has been loaned by the Atomic Energy Research Establishment, Harwell for the BASQUE experiment. The target for the BASQUE experiment will be fitted with a mylar flask 11 cm in diameter, 36.6 cm long, to be used in the neutron-proton scattering experiment. The second target, to be used initially in the pion production experiment, will be fitted with a stainless steel flask 3 cm in diameter, 8 cm long. These target assemblies are completely contained systems requiring no liquid nitrogen and, being completely automated, require only occasional surveillance. The control system is being built at the main site.

Liquid D_2/H_2 target

Fabrication of the components of the target system at the University of Victoria is now virtually complete, and the remaining work will be mainly in testing and installation. To date about half of the liquid D_2 loop (the heat exchanger and pump section) has been vacuum checked and low temperature cycled. The vacuum pump set is operational and the vacuum test vessel and the gas storage and safety tanks have been leak checked. The local control (NIM) modules are built and the relay logic control box is nearing completion.

The heavily shielded vacuum vessel to house the target in beam line IVa is on order for delivery in late February.

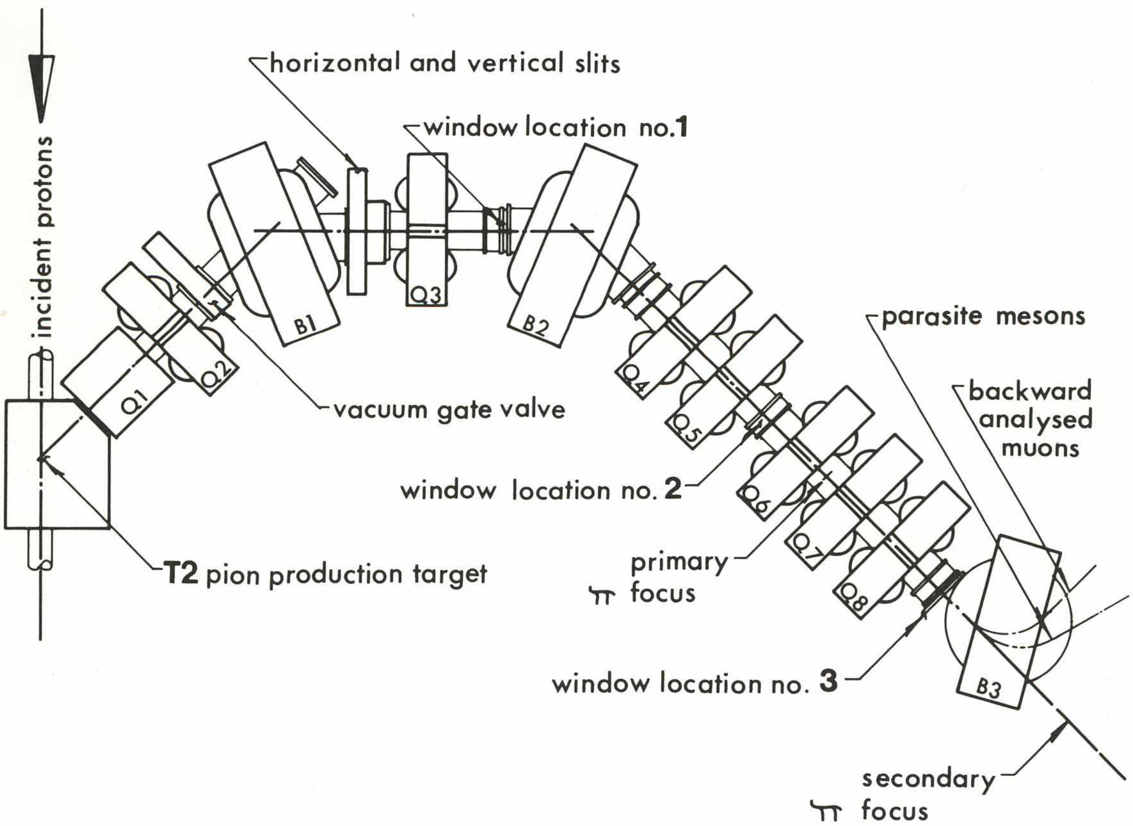
Thermal neutron facility

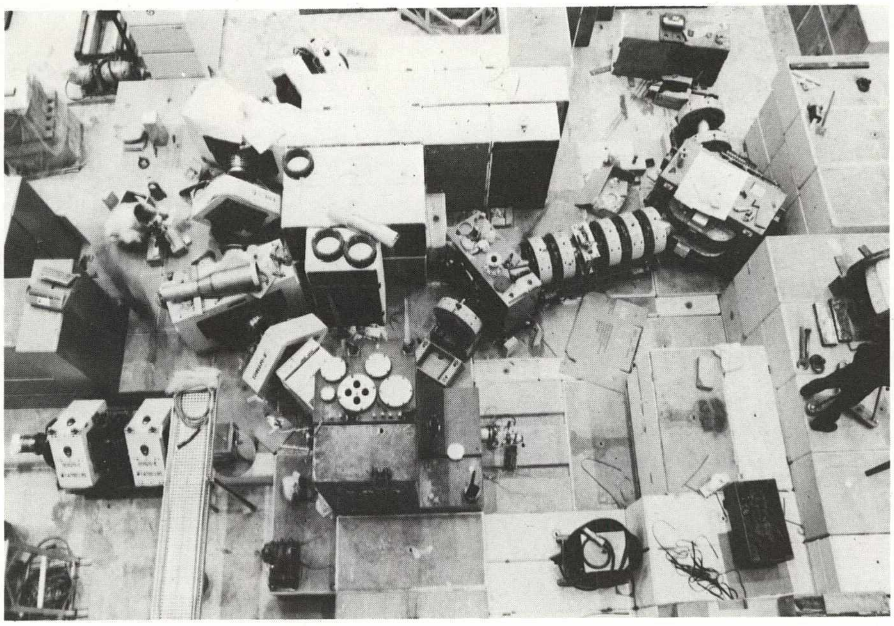
Design effort for the thermal neutron target has been virtually zero, due to lack of funds. The multi-group neutron diffusion code EXTERMINATOR II was obtained from the Reactor Physics code center at the Argonne National Laboratory and put into operation on the Simon Fraser University computer. It estimates flux distributions in two dimensions, which allows a more realistic modelling of the geometry of the proposed TNF target-moderator assembly compared to the one-dimensional code used previously. The code is being used to estimate leakage and flux depression effects of detailed design variations.

Stopped π–μ channel

Although primarily designed to provide stopping π and μ beams of either polarity, the stopped π/μ channel also will be used for low-energy π-scattering experiments until other channels come into operation.

Channel design has been completed. Detailed mechanical layout coupled with TRANSPORT, M BEND and MP FLUX calculations have resulted in a channel layout which provides both a primary and a secondary π-focus as well as a separate stopped-μ experimental area, as shown below. Almost all channel magnets as well as mechanical, electrical and vacuum components have been received and tested, and are presently being installed.





Beam line I enters from the left, hitting T2 whose target shield is in the foreground. The stopped π/μ channel then goes to the left and the MSR to the right.

To facilitate removal of closely spaced components near T2, the quadrupoles Q1 and Q2 have been mounted on a removable rolling stand which may be relocated laterally to within ±0.003 in. Other channel magnets up to the pion focus were set on 2 ft thick concrete blocks with the stainless steel vacuum components supported within the magnets. The quadrupole triplet beyond this focus has been mounted on air pads so that it may be moved quickly when changing from π to μ experiments.

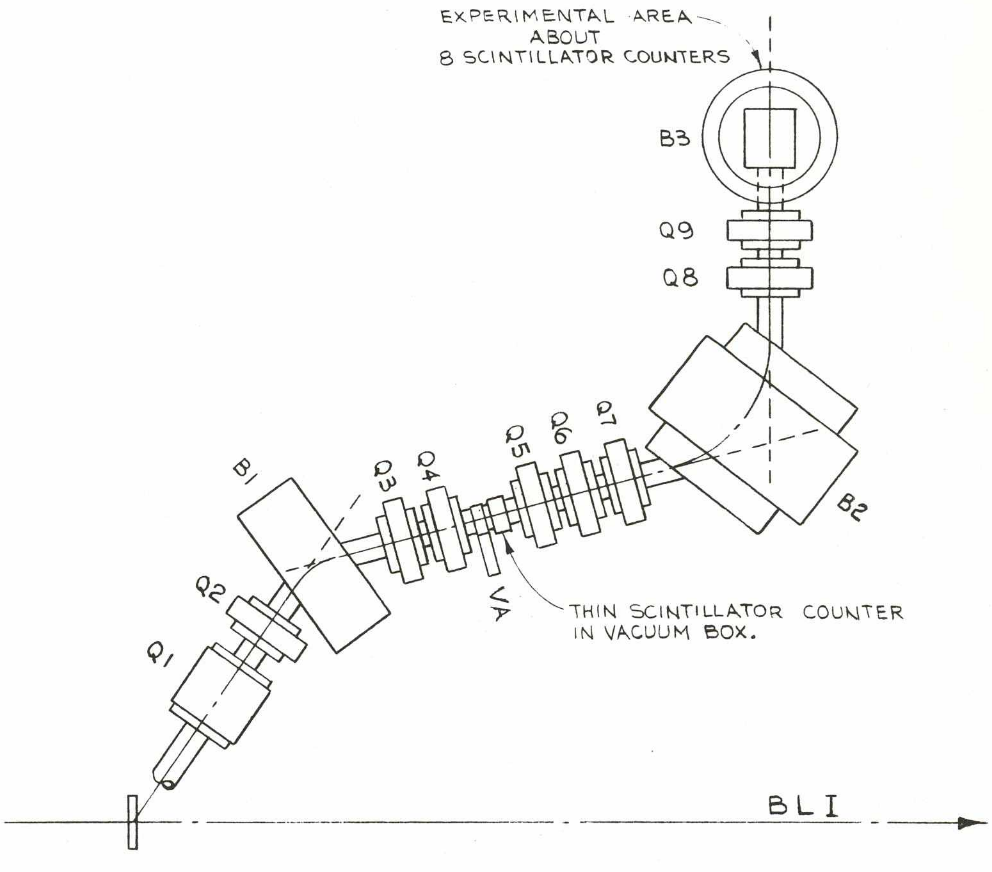
Tests of the dipole magnet B3 obtained from Chalk River showed that the magnetic field is inadequate when the gap is larger than 5 in.; thus the channel will be operated with the corresponding μ-loss until the magnet coils are uprated.

MSR channel

The MSR beam line is a second stopped muon line at TRIUMF (i.e. in addition to the stopped π/μ channel). It exits at 55 deg from T2 and has been designed with the capability of providing both muons from decay in flight and 4 MeV positive muons from decay in the outer regions of the production target. This latter technique provides an essentially monochromatic μ^+ beam (with its concomitant high stopping density) which is basically 100% polarized. The beam line in its present arrangement, as shown in the following drawing, consists of one radiation-hard quadrupole (Q1), two bending magnets (B1 and B2) and eight laminated coil quadrupoles (Q2-Q9). In addition, the drawing shows a magnet (B3) which is required for MSR studies. All the beam line components shown have been installed, with the exception of B3. Other than Q1, all the beam line components (B1, B2, Q2-9) have been obtained on long-term loan from the United States. For this TRIUMF would like to express its sincere thanks to Prof. K.M. Crowe of Lawrence Berkeley Laboratory, for two large power supplies (1000A, 90V), a bending magnet (B2, 'Cal Tech') and the quadrupoles Q2-Q9, and to Prof. R. Wilson, Harvard University, for a bending magnet (B1, 'Patty Jane'). Since the elements Q2-Q9 and B2 are the property of the USAEC, thanks should also be directed to that agency for its spirit of international co-operation. Needless to say, TRIUMF has been in no position to spend the necessary funds to purchase anew the major components of a second muon channel.

The MSR beam line is to be primarily utilized for the study of muon precession experiments, for which the acronym 'MSR' (or 'μSR') has been coined. In MSR studies muons (either μ^+ or μ^-) are stopped in a target of interest, placed in a perpendicular magnetic field. Depending on its interaction with the medium, the muon in a perpendicular field precesses either at some characteristic 'free' frequency, or (for μ^+ only) at the frequency of the muonium atom (μ^+e^-). One then speaks of μSR for $\mu^\pm$ precession and MSR for muonium precession. The analysis of the amplitude, phase and relaxation of this precession signal (which is only possible because of parity violation in the decay sequence $\pi \to \mu \to e\nu\nu$) has wide applications in a large interdisciplinary area of research, encompassing chemistry, solid state physics and nuclear physics.

For μ^+SR studies, the maximum rate which can be accepted is limited by decay of the muon to 4.5×10^5 μ^+/sec. The present design of the MSR beam line should be capable of providing this flux at 100 μA proton current on T2, in either the Arizona or conventional mode of operation. Even at 1 μA (or less) the number of μ^+ stops is sufficient to permit



the collection of a statistically meaningful number of events in a few hours running (current experiments at LBL are operating with a data rate of ∿1500 μ^+ stops/sec). For some targets (notably low pressure gases) the Arizona mode of μ^+ operation is essential. However, for μ^-SR studies conventional muons must be used. In this mode of operation the B1 coils presently limit the channel to pion energies <120 MeV/c. This low momentum is a major factor in limiting the maximum μ^- flux to an anticipated $\sim 2 \times 10^5$ μ^-/sec at 100 μA. Such a low μ^- flux is a severe restriction on μ^-SR studies, particularly in heavy nuclei, where the μ^- lifetime is dominated by the nuclear capture process. Hence, it is expected that we will replace the magnet coils on B1 in the near future to allow for pion energies up to ∿160 MeV/c, which should improve the number of μ^- stops by as much as a factor of ten.

Prof. T. Yamazaki and Dr. K. Nagamine, University of Tokyo, as well as two graduate students (R. Hayano and N. Nishida) are spending the 74/75 academic year at TRIUMF. They have contributed generously to the budding μSR programme here. As well as providing the precession magnet, a dilution refrigerator capable of temperatures <0.1°K will be permanently 'loaned' to TRIUMF for collaborative experiments on both the MSR and the stopped π/μ channels. In addition, the Tokyo group has made a major financial contribution through the Toray Foundation, and TRIUMF is indeed grateful for their support.

The core of the MSR (μSR) data acquisition system (DAS) is a PDP-11/40 based GT44 (Graphics) computer system, with 64k of memory, two large discs (1.2M words each), magnetic tape and a 17 in. CRT, all utilizing the DEC RSX11-D software operating system. This is a real-time operating system which allows for many simultaneous users; it is hoped that several users will in fact utilize the system. It is now installed in the MSR beam shack. Other than the computer itself, the major components of the DAS are a CAMAC crate and type-A controller, an EG&G time-digital converter (TDC 100) and an MBD-11, which is a microprogrammable branch driver made by Bi-Ra of Albuquerque. In essence, the TDC digitizes the time difference between a μ stop and the detection of its decay electron, and the MBD-11 functions as a peripheral precessor for I/O between CAMAC and the PDP-11. In addition, the DAS consists of several fast timing discriminators with their accompanying logic circuitry. The bulk of the fast electronics was purchased with funds from a President's Emergency Grant (UBC) and from a Cottrell Grant (Research Foundation, California). We are grateful to both of these organizations for their generous financial support.

Medical facility

Due to their strong interaction with the nucleus negative pions stopping in matter convert a significant fraction (30 MeV) of their rest mass into locally deposited energy, with the result that an unusually large amount of energy is deposited in the stopping region. The Medical Facility has been constructed in order to study the possibility of using negative pion beams for more effective treatment of cancer. It is funded jointly by the British Columbia Cancer Treatment and Research Foundation and the Health Resources Fund of Health and Welfare Canada.

The medical beam line originates at target T2 in the meson hall. It emerges from T2 in the forward direction, inclined 30 deg above the proton beam. It consists of nine magnets arranged in the sequence QBSQQQSBQ. The first and last quadrupoles have 8 in. apertures while the two sextupoles and the quadrupole triplet are of 12 in. aperture. The two bending magnets have a 6 in. gap and each bends the beam 45 deg. The first two magnets are in an intense radiation environment which requires them to be constructed exclusively of metal and ceramic materials to make them 'radiation hard'.

By the end of 1974 all beam line elements had undergone acceptance tests (partly by the University of Victoria) and had arrived on site except the two dipoles and the first quadrupole, and these are expected in January. It was necessary to obtain new bids on the dipole contract in mid-year when the original manufacturer was unable to supply the steel due to a general shortage of steel in North America. However, with the assistance of the Department of Industrial Development, Trade and Commerce in Victoria, we were able to obtain the 9 in. steel plate from Japan in record time so that the dipoles could be manufactured locally on a schedule commensurate with the rest of the beam line.

During this year design of all secondary beam line components was finalized and much of the fabrication was completed. This includes the magnet power supplies, magnet stands, specially-shaped shielding blocks, the moving slit system and the vacuum line and associated equipment. The pion star counter and the MWPC (built at the University of Alberta) for beam diagnostics were essentially complete and ready for the first beam measurements. The 32K Nova II computer system which will control the beam line has been set up at the B.C. Cancer Institute, and most of the CAMAC interfacing and software development is complete.

The interior finishing of the biomedical laboratory got under way in the fall and will be completed in January. The mobile animal quarters, which were delivered in September, have provided temporary laboratories for staff while the biomedical lab was being completed.

The development of the biological experiments has progressed well, and most of the test systems to be used in the pre-clinical research program are ready to go. Most of these experiments, however, must await high beam intensity. The gel technique developed here for the cultured cell pion experiments was adopted by one of the Los Alamos groups, who have used it successfully in their preliminary biological studies. This is an example of the excellent spirit of co-operation that exists between TRIUMF and the other meson facilities.

Proton spectrometer

The decision to build an initial medium resolution proton spectrometer that later would be extended into a high resolution spectrometer was made at the beginning of 1974. The order was placed in January for the steel fabrication of the yoke, those for the coils and power supply already having been placed. The University of Alberta agreed to purchase the steel and supply it to a local manufacturer. Delivery of the steel was to be in May-June. The final 15 in. plate was in fact received in December. This late delivery has meant that the steel yoke will not arrive on site until mid-to-late February 1975, a delay of approximately 19 weeks from that first scheduled.

The contracts for the coils and power supplies for the above dipole were fulfilled in October, and testing of the power supply to full load using the coils is being prepared.

The arrival of the University of Alberta personnel engaged in the proton spectrometer at TRIUMF on August 1 marked the start of the spectrometer facility. The main central bearing plate was laid on August 9 and the track and centre post were levelled and grouted by the 20th. A survey after completion showed that over the first 130 deg of the track, the variation in height and level was within ±0.005 in. but then fell at a uniform rate over the remainder of the arc to be ±0.015 in. below the 0 deg line.

The contract for the main support arm was placed on July 11 and was delivered to the TRIUMF site in two parts on November 7 and 11. The assembly of the support arm was finalized by November 19, and since that time the air flotation system has been assembled and the support arm is complete.

The design and detail drawings for the vacuum vessel have been completed but not yet tendered. The design of the vessel has included features to enable a cart to traverse the magnet to simplify the magnetic field measurements.

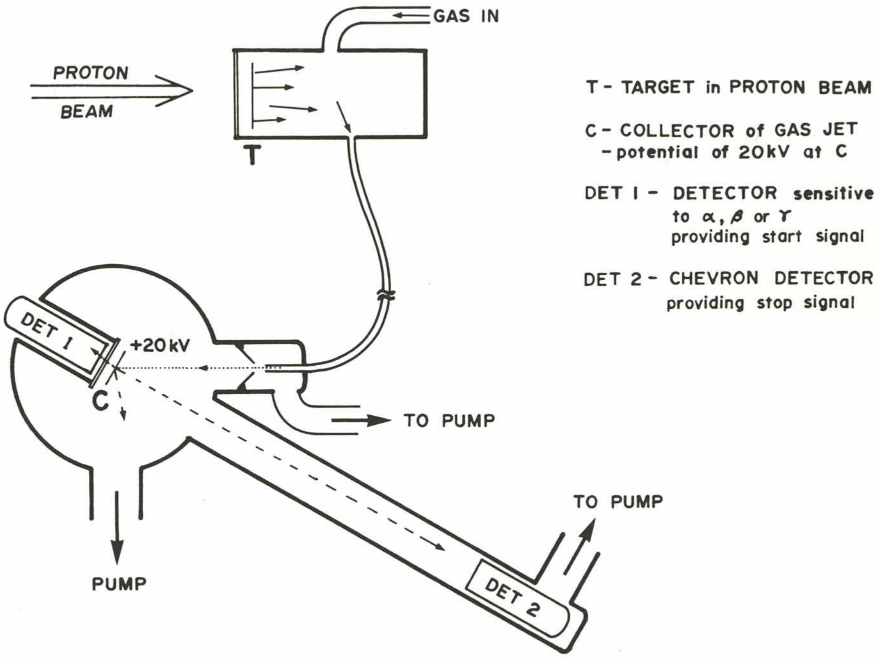
Scattering chamber

After completion of its construction and testing at Simon Fraser University, the 60 in. diam scattering chamber was transported to the TRIUMF site and installed in beam line IVa during 1974. Its design features have been discussed in earlier annual reports. The chamber is functioning in its new location and is maintaining vacuum in the first section of beam line IVa.

The main effort is now directed to interfacing its operation with that of the beam line and that of the data-collecting system for the initial experiments which will use the chamber. These T=0 experiments are the study of fragments emitted in proton-induced reactions (Exp. 3) and the study of proton-induced fission (Exp. 6).

Time-of-flight mass identification facility

A time-of-flight, heavy mass identification facility to be positioned at the collection end of the gas jet facility was funded and is under construction at Simon Fraser University. This facility will allow precise determination of the mass of radioactive species produced by high-energy proton-induced reactions and transported to a collection site by the gas jet recoil transport system. The timing and data collection system will also be used for improved mass determination of fragments produced by fragmentation and fission reactions in the SFU scattering chamber.



The principle of operation is based upon measuring the time of flight of a heavy fragment of a radioactive decay process occurring at the collection end of the gas jet, over a known distance under a predetermined acceleration field (see diagram above). This time, which is related to the fragment's mass, is generated with a start signal provided by the associated decay process, e.g., α-, β-, or X-ray emission, registered in an appropriate detector and the stop signal provided by the interaction of the heavy fragment in a chevron detector at the end of the flight path. Isotopic identification can be achieved by using an X-ray detector for start signals.

Crucial to the precise mass determinations is the achievement of pressures in the range of 10^{-6} Torr in the time-of-flight chamber, given that the carrier gas of the jet system is flowing through a small hole into the system. Pumping stations, detector systems, and the high voltage system producing the acceleration potential have been ordered. The entire system has been designed and is under construction; operation is expected early in 1975.

Experimental facilities on beam line IVb

Development of the experimental area on beam line IVb began in June, soon after the last of the cyclotron resonator panels were removed from the proton hall for installation in the machine. The first equipment installed at the PT1 target position was the University of Alberta scattering stand and four large movable booms which rotate about the PT1 point. The booms are designed to carry detector telescope arrays and moderate quantities of lead shielding. Measurements indicate that the boom motions allow positioning each detector assembly anywhere in the horizontal plane with a precision of ±0.05 deg in angle. Remote or local positioning of the booms is possible and the angle of each boom is displayed automatically by the on-line computer in the counting room.

University of Alberta experimentalists have played an active and continuing role in the layout and installation of the shielding walls and roof beams which enclose the area around PT1 and along IVb. The first shielding installation followed closely the erection of the scattering stands. The moving of concrete blocks from the storage area in the meson hall to their position on IVb has been a lengthy and laborious job.

The pulling of cables from the target site on IVb to the counting room in the U of A trailers was a job which consumed an entire month at the end of the summer. The cable tray contains 110 high-quality coaxial signal cables, numerous multiconductor control cables, and a CAMAC branch highway cable. To minimize the possibility of noise pickup on these 200 ft long cables the cable tray is a continuous metal enclosure which is isolated from building ground connections except at one grounding point. To minimize cross-talk between signal and control cables, these two types of cables are separated in the tray by a solid metal divider.

In preparation for the first proton beam on line IVb, a simple vacuum system was installed. The high vacuum of the cyclotron extends down IVb to a 0.001 in. Havar foil window located in the 4 in. beam pipe just upstream of the target position PT1. At the target position is mounted a scattering chamber with four interchangeable solid targets and an automatic target positioning ladder. The scattering chamber is joined on either side to the 4 in. beam pipe and maintained at rough vacuum. Ten feet downstream of the target chamber is a second foil window. Downstream of this window is the 8 in. beam pipe leading to the 100 nA beam dump. The 8 in. line is maintained at rough vacuum by a second pumping system.

In addition to holding solid targets for scattering experiments, the scattering chamber will accommodate beam profile monitors for beam development work. By making it a simple matter to change from a beam diagnostics set-up to a scattering experiment set-up, it is hoped that the first external proton beam can be used for the two different purposes during different shifts of the initial operation.

Instrumentation

The TRIUMF Instrumentation Advisory Committee has held eight meetings in 1974, with meetings occurring on a monthly basis since August. Its primary activity this year has been to establish the nature of the TRIUMF Instrumentation Pool and the availability to experimental users of instrumentation from this Pool. In addition it has continued to update the list of TRIUMF standard experimental instrumentation, the principal addition this year being a list of 'slow NIM' equipment. Statements on both the operation of the Pool and the current list of standard instrumentation were distributed to TRIUMF users at the Users Group meeting in November. The Committee also defined a colour code for coaxial cables at TRIUMF.

The present list of standard equipment includes:

1. RACKS

Premier Metal Housings (Montreal)	Type 000003070

2. POWER SUPPLIES, BINS AND CRATES

NIM bins	
Bin and power supply: B.L. Packer	Bin NB10 200W power supply 1001
CAMAC crate	
Crate: GEC Elliott	VC0011/CP1
Power supply: B.L. Packer	1031 BC (300W)
Photomultiplier high voltage:	Power Designs 1570
High voltage distribution:	TRIUMF supply

3. PHOTOMULTIPLIERS AND HOUSINGS

2 in. 12-stage, bi-alkali photomultipliers:	RCA 8575R or RCA 8850R
Housings:	N.P.W. England Ltd.

4. NIM MODULES

<u>Fast NIM</u>

Discriminators, quad updating:	LRS 621 L
AND (coincidence) gates:	
Dual 4-fold majority logic	LRS 364 A/L (preferred) (LRS 365 A/L accepted)
Dual 4-fold variable width	TRIUMF BO 24
Quad 2-fold overlap	TRIUMF BO 42
OR gates and logic fan-out:	
Logic 8-fold fan-out	TRIUMF 14X2951
OR gate: Dual 4-fold	TRIUMF 14X3001
Linear mixer (fan-in): Dual 8-fold	LRS 127 D/L
Linear fan-out: Dual 8-fold	LRS 128 L
Linear gate:	Borer 330
Linear gate and stretcher (integrator):	EGG LG 105/N
Level converter (NIM Fast⟷Slow):	TRIUMF 14X2991
Gate pulse and delay generator:	EGG GG202
Scaler (visual display): 100 MHz, 6 digit:	ORTEC 772
Variable delay units (cable-switched):	
Passive '64 nsec'	TRIUMF BO 07 Borer 361
Variable attenuators (50Ω):	LRS A101 L

4. NIM MODULES (cont'd)

High resolution ADC:	
10-bit amplitude encoder (requires scaler for read-out):	EGG EA 101/N
High resolution TDC:	
10-bit time encoder (requires scaler for read-out):	EGG ET 102/N
Spark chamber TDC (routing unit):	
Clock generator (up to 200 MHz) and scaler required. Dual unit:	TRIUMF BO 0100

<u>Slow NIM</u>

Gated biased amplifier	ORTEC 444
Research amplifier	450
Timing filter amplifier	454
Delay line amplifier	460
Delay amplifier	427A
Linear gate	426
Linear gate and stretcher	442
Constant fraction discriminators	453, 463
Fast coincidence	414A
Universal coincidence	418A
Time-to-pulse height converter	437A
Gate and delay generator	416A
Precision pulse generator	419

5. CAMAC MODULES

Coincidence buffer (pattern unit):	Dual 12-fold	EGG C212
Multi-ADC:	Octal 8-bit units	LRS 2248 or NE 9040
Multi-TDC:	Quad 9-bit	LRS 2226A
Scalers:	Quad 24-bit, 100 MHz	LRS 2550B

SITE, BUILDINGS AND SERVICES

As all the available resources—financial and otherwise—had to be rallied to complete the cyclotron, buildings and site had to take a back seat. So despite some very vocal protests about deep potholes in the parking lot and clouds of dust around the TRIUMF buildings neither paving of roads and parking lots nor drainage and landscaping could be afforded.

This does not mean that no changes took place on the site during 1974. The year started with the digging of a 30 ft deep hole for the exterior 10 μA beam dump. A 70-ton cylindrical steel core was lowered into the excavation by Mutual Construction Co., with the help of two giant cranes and installed on a 3 ft thick reinforced concrete slab. The steel core was then encased in 480 tons of heavy concrete, a subsurface drainage system installed and the hole backfilled. Despite great difficulties with cave-ins of the excavation sides due to loose sand conditions and heavy rain, construction of the beam dump was completed by the end of February.

A 30 ft × 40 ft new stores building was erected opposite the workshop building. Prefabricated metal construction on a reinforced concrete base slab was chosen for economy and speed of erection. As the 100 ft shielding beams were completed and installed by CANA Construction Co., the east side of the TRIUMF site was vacated by the contractor and the parking lot could be extended and enlarged to provide sufficient parking for TRIUMF's permanent staff as well as contractors and experimental groups. The temporary southwest parking lot could then be terminated to allow for construction of concrete shielding beams and blocks for the experimental shielding. In preparation for the operational stage the site perimeter fence was relocated to separate the facility from the parking lot, and new heavy steel gates were installed, designed for future remote control.

Inside the TRIUMF main building a mezzanine walkway was constructed in the proton hall as well as the meson hall to provide access for the various power supply units. A number of minor building improvements, such as partition walls for temporary offices on the ground floor of the chemistry annex and for the design office on the second floor, the library in the office building, and the enlargement of the main entrance lobby, were carried out during the year.

Electrical services

The electrical systems operated satisfactorily throughout the year with no serious outages or damage to equipment. To date, our greatest recorded demand has been 5100 kW.

Work continued throughout the year connecting power supplies and their associated magnets along both beam lines in the vault and beam line IV in the proton hall. This work is now ready for testing, and work on beam line I has started.

Mechanical services

All four cooling systems functioned well over the year. A new system has been installed for ISIS and beam line I power supplies, and another is being designed to cool equipment in the meson hall.

As with the electrical systems, the cooling systems have been extended to cool beam line components. Also, the active system in the vault was extended extensively to cool ISIS diffusion and sublimation pumps, RF transmission line and various miscellaneous items.

The cooling to beam line IVa and b has been completed.

A new air compressor was purchased and is yet to be connected up. The main function of this new compressor will be to supply the air pads for moving the large spectrometer in the proton hall.

Handling facilities

The two 50-ton overhead cranes worked almost continuously over the year, and no operational failures occurred. The 7.5-ton circular crane in the vault is causing some problems; however, steps are being taken to remedy them. The purchase of a small tractor and trailer was made to assist in the moving of equipment and material around the site.

EXPERIMENTAL PROGRAMME

In pace with the first commissioning of the machine the preparation for initial experiments proceeded rapidly toward a beginning date early in 1975. The initial experiments at TRIUMF emphasize its uniquely versatile proton beam. Not only does the negative-ion acceleration within the cyclotron make possible simultaneous beams in both the proton hall and the meson hall but each beam will be variable in energy (probably from 200-520 MeV) and have high resolution and 100% macroscopic duty factor.

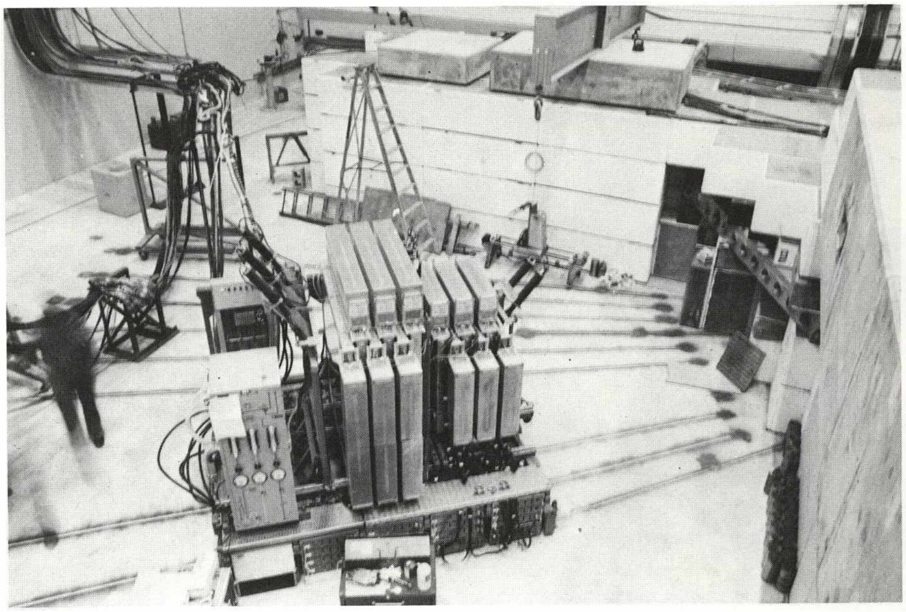
During the tuning-up period when the beam current will at first be low, one will already be able to carry out much nucleon-nucleon work. There are many gaps in the data to be filled. Further, some of these gaps require the use of polarized beams whose intrinsic low beam current makes such experiments especially suitable for the initial year. The polarized ion source at TRIUMF should be in use during 1975. Some of the initial meson experiments, for example the 'stripping' of pions from protons in (p,π) reactions, also take advantage of the variable energy proton beam.

In the following sections progress made with experiments that are being set up in the experimental areas is reported, followed by the latest list of approved experiments.

BASQUE experiments (Proposals 26, 27, 40)

The acronym BASQUE, formed from the initials of the participating institutions (Bedford College, AERE, University of Surrey, Queen Mary College, University of B.C., University of Victoria Experiment), designates the group preparing measurements of free neutron-proton elastic scattering between 200 and 500 MeV. Proposals 26 and 27, relating to measurements of the differential cross-section and polarization, were submitted by staff at UBC and UVic; they were joined, in Proposal 40 (a measurement of both direct and transfer triple scattering parameters), by a consortium of British physicists, sponsored by the Rutherford Laboratory and including staff of Queen Mary College and Bedford College, London; AERE, Harwell; and the University of Surrey. The common aim of these experiments is to determine uniquely the isospin zero part on the nucleon-nucleon scattering amplitude, and its variation with energy in the interesting region near the threshold for pion production.

Neutrons will be produced by the (p,n) reaction in a liquid deuterium target in beam line IVa, and will pass through one of eleven beam ports in a collimator, into the experimental area near the centre of the proton hall. The differential cross-section will be determined by allowing neutrons, produced at 0 deg by the unpolarized proton beam, to strike a thin LH_2 target. Elastically-scattered protons will be detected in a scintillation counter telescope, and their energy determined by a combination of time-of-flight and total energy measurements. For the spin parameter measurements the polarized proton beam will be precessed into the horizontal plane by a spin vector superconducting solenoid, and a polarized neutron beam produced by polarization transfer at a scattering angle near 9 deg. This beam will strike a thick LH_2 target. Both of the



BASQUE polarimeter set up to detect scattered protons emerging from the 24 deg hole of the collimator.

outgoing nucleons will be detected, the neutrons in an array of large plastic scintillators and the protons in a polarimeter consisting of multi-wire proportional chambers and a carbon scatterer.

During the first half of 1974 the steel and lead collimator, weighing 25 tons, was manufactured, together with the counters and stands for the cross-section measurements. The experimental trailer was placed outside the west wall of the proton hall, a PDP 11 computer from the UBC Physics Department installed, and a data acquisition program for the experiments was written and partially tested. During the summer construction of beam line IVa was started. Also at this time the equipment constructed at the Rutherford Laboratory for Proposal 40 arrived, accompanied by an advance party of British physicists and technical staff. The major items were the superconducting solenoid, the neutron detector array and the proportional chambers. By the end of August some seven UK physicists and students had joined the UBC group, and during the last four months of the year the task of checking and testing the experimental equipment went on in parallel with the construction of line IVa.

By the end of the year one of the neutron spin precession magnets was installed. This magnet is the old UCLA cyclotron magnet, made available through our longstanding good relations with this laboratory. The other magnet was loaned by Rutherford Laboratory, along with another magnet that can be used in the experimental program, thus relieving some of the pinch felt by inadequate funding of the experimental program.

This line was virtually complete by the end of the year, with the major exception of the liquid deuterium target. Though its mechanical components had been assembled and tested at Victoria, the construction of the radiation shield and control system at the main site was delayed, so it was decided that during the initial stages of setting up and calibration a gas target of simple design would be used. Delivery of this is expected in January.

Meanwhile the superconducting solenoid had been installed, cooled with liquid helium and run successfully at a field of 4 T. It showed no sign of 'training' (reversion to normal resistivity under current loading) despite its 5000-mile journey. The proportional chambers also withstood their journey well, only a couple of wires, out of some 2300, needing replacement. By the end of October the scintillation counters and proportional chambers had all been cabled up to the control trailer, powered and tested using sources. By the end of the year a program had been written to test the proportional chambers individually and in detail. Study of their efficiency, and of the track-reconstruction programs, will be one of the first aims of the group when beam becomes available.

Priorities dictated by cyclotron commissioning have had their effects on the BASQUE program. The effect on the liquid deuterium target has already been mentioned; another result is that a polarized proton beam is not expected to be available until mid-1975. Initially, therefore, the unpolarized beam will be allowed to strike the gaseous hydrogen target. The protons scattered elastically near 24 deg (lab) have a high polarization, and the proportional chamber array has been set up at this angle in order to calibrate its analysing power. On replacing the hydrogen gas by deuterium, the group expects to obtain data of high precision on the ratio between the polarizations in H(p,p) and D(p,p) quasi-free scattering, at the same time setting up the neutron detectors using neutrons from the D(p,n) reaction. Thus, by the time the liquid deuterium target and polarized beam are available, the BASQUE team expects to be ready to make the measurements discussed above.

TINA experiments (Proposals 4, 9, 23, 41, 56, 57)

The major event in the year was the arrival of the large NaI crystal in April. The crystal has been nicknamed TINA (TRIUMF iode of natrium) and the group tends to borrow the name as well. The crystal measured 18 in. in diameter by 20 in. long and is viewed by seven RCA 4522 phototubes. In the acceptance test it was found that the uniformity of response to a ^{137}Cs source was typically ±2% along the sides, with the worst scan giving ±4%. As even this is within the specifications, the Harshaw company have certainly produced an excellent crystal. With an 11.68 MeV γ-ray (from the reaction $^{11}B(p,\gamma)^{12}C$) a resolution of 6.7% FWHM was obtained, which is excellent and indicates the original goal of 3% for a 150 MeV γ-ray should be achieved. The rise-time of the pulse is typically 50 nsec which compares favourably with the 100 nsec of the Stanford 16 in. $\phi \times$ 24 in. crystal. With various discriminators, timing resolutions of 3 to 5 nsec have been obtained.

A lightly shielded support has been fabricated and will be used for the initial tests with the proton beam. Plastic scintillators and Cerenkov radiators have also been prepared. Sufficient electronic instrumentation is on hand for the first few months, but significant gaps still exist. The PDP 11/40, belonging to the University of Montreal, will arrive in January and will be used in collaborative experiments.

A counting room has been built in the meson hall and the services are being installed. Cabling will be provided to the stopped π/μ channel area and to the proton area of beam line I. The first tests of TINA will consist of resolution and timing measurements using high-energy protons. Preliminary data may be taken for π^0 production from proton bombardment of carbon and iron. Directly the stopped π/μ channel is ready, time-of-flight and range measurements together with Cerenkov detectors will be used to estimate fluxes of π, μ and e in the channel. Initial experiments will consist of a study of radiative capture of π^- at rest.

Pion production experiments (Proposals 10, 39)

The pion production group has assembled a 50 cm Brown-Buechner spectrograph on beam line I between the T1 and T2 target positions. This spectrograph, provided with a focal plane hodoscope consisting of 24 scintillation counters and at least two transmission scintillation counters, will be used to measure energies of pions between 10 and 140 MeV with an energy resolution of about 2%. The magnetic field of the spectrograph has been measured using the magnet measuring equipment at TRIUMF. The spectrograph can be rotated between angles (positive and negative) of about 30 to 150 deg with respect to the proton beam.

The target chamber, which is mounted in the proton beam, will accommodate either a liquid hydrogen target flask or targets consisting of solid foils.

All equipment (with the exception of the liquid hydrogen target system) required for the initial experimental program is now on site.

Studies with stopped pions and muons (Proposals 18, 51, 19, 42a, 46, 52, 20, 13, 42b)

The mesic X-ray group at University of Victoria has implemented a flexible data acquisition system suitable for the proposed experiments. The hardware for this system has been acquired and tested. Software for event-by-event recording of experiments is under development; this will be needed for the T=1 experiments 13, 37 and 42b. A spectrum-fitting program and a package of utility programs for data analysis have been implemented. Two muonic chemistry experiments are ready to run when a few hundred nanoamperes of beam is available.

Work on the $\mu^- \rightarrow e^+$ search had dealt mainly with multiwire proportional chambers. Construction has begun of chambers 30 cm in diameter and development initiated of two types of readout systems—electromagnetic delay-line and amplifier-per-wire.

A preliminary measurement of the pionic X-rays in ^{3}He has been performed this year at the SREL muon channel. After the experience gained from this run, the group has redesigned the ^{3}He cell of the cryogenic target to eliminate materials that produced unwanted background lines. The superior optics available in the TRIUMF π/μ channel should also reduce backgrounds considerably. This experiment can also be run in $\sim$0.5 μA of proton beam.

During 1974 the counters and electronics for the $\pi \rightarrow e\nu$ experiment were readied. Estimates show that data-taking could begin when the proton current in beam line I reaches a few hundred nanoamperes. To study expected experimental errors the group has performed Monte Carlo calculations for the radiative decay $\pi \rightarrow e\nu\gamma$. They also recomputed the branching ratio for $\pi \rightarrow e\nu$ decay obtained from the 1963 experiment of Di Capua *et al.* (Phys. Rev. 133B, 1333, 1964). Using the current value of the pion lifetime it was found (Bryman and Picciotto, to be published Phys. Rev. D) $[\Gamma(\pi\rightarrow e\nu) + \Gamma(\pi\rightarrow e\nu\gamma)]/\Gamma(\pi\rightarrow e\nu\gamma) = (1.274\pm0.024) \times 10^{-4}$, a change of 2%. The theoretically predicted value 1.33×10^{-4} (Kinoshita, Phys. Rev. Letters 2, 477, 1959) lies within two standard deviations compared to the one-half standard deviation reported previously.

Users groups

The TRIUMF Users Group (an amalgamation in mid-1973 of the former Proton and Meson Users Groups) met on November 29-30. An invitation was extended to the other TRIUMF users groups to form a single body, and by year-end the Neutron Facility Users Group, most of whose members were affiliated with both groups, was combined. It is expected that the Radiobiology and Radiotherapy Users Group will join early in the coming year. Present membership in the two groups is given on pp 72-73.

Apart from providing the usual lively forum for a broad range of technical topics—scheduling, technical support, lab space for experimental teams, beam line development, instrumentation, safety, housing, etc.—the meeting emphasized the need for more frequent opportunities for discussion. It was thus agreed that a Users Group executive committee be elected, including at least one outside user, which by meeting more often than practicable for the group as a whole could ensure that users' interests are represented on a regular basis.

List of approved experiments

Proton Area

[spokesman underlined]

T=0

24 ELASTIC SCATTERING OF POLARIZED PROTONS ON ^{12}C, J.M. Cameron, R.H. McCamis, C.A. Miller, G.A. Moss, J.G. Rogers, G. Roy, D.M. Sheppard, A.W. Stetz (*University of Alberta*), W.T.H. van Oers (*University of Manitoba*)

66 SURVEY OF p-p BREMSSTRAHLUNG FAR OFF THE ENERGY SHELL, J.M. Cameron, J.G. Rogers, A.W. Stetz (*University of Alberta*), J.V. Jovanovich (*University of Manitoba*)

58 POLARIZATION EFFECTS OF THE SPIN-ORBIT COUPLING OF NUCLEAR PROTONS, J.M. Cameron, W.K. Dawson, P. Kitching, W.J. McDonald, C.A. Miller, G.A. Moss, G.C. Neilson, W.C. Olsen, J.G. Rogers, J.T. Sample, D.M. Sheppard, A.W. Stetz (*University of Alberta*)

14 THE INTERACTION OF PROTONS WITH VERY LIGHT NUCLEI IN THE ENERGY RANGE 200-500 MeV, B.S. Bhakar, C. Goulding, B. Murdoch, W.T.H. van Oers (*University of Manitoba*), J.M. Cameron, R.H. McCamis, C.A. Miller, G.A. Moss, J.G. Rogers, G. Roy, A.W. Stetz (*University of Alberta*)

15 NUCLEON QUASI-FREE SCATTERING IN NUCLEI, J.M. Cameron, P. Kitching, W.J. McDonald, G.C. Neilson, W.C. Olsen, J.T. Sample, A.W. Stetz (*University of Alberta*), A. James (*University of Liverpool*)

16 PROTON-DEUTERON QUASI-ELASTIC SCATTERING VIA THE ^{6}Li(p,pd)α REACTION, J.M. Cameron, W.K. Dawson, P. Kitching, W.J. McDonald, C.A. Miller, G.A. Moss, G.C. Neilson, W.C. Olsen, J.G. Rogers, J.T. Sample, D.M. Sheppard, A.W. Stetz (*University of Alberta*)

12 AN EXPERIMENT TO MEASURE THE MASS OF NEW ELEMENTS WITH ISOSPIN T_z=-2 AND T_z=-5/2 USING (p,^{8}He) AND (p,^{9}Li), J.M. Cameron, G.C. Neilson, G.M. Stinson (*University of Alberta*), J.C. Hardy (*Chalk River Nuclear Laboratories*), D.G. Fleming, P.W. Martin (*Univ. of British Columbia*)

26 MEASUREMENT OF THE DIFFERENTIAL CROSS-SECTION FOR FREE NEUTRON-PROTON SCATTERING AND FOR THE REACTION D(n,p)2n, L.P. Robertson (*University of Victoria*), E.G. Auld, D.A. Axen, D.F. Measday, J. Va'vra (*Univ. of British Columbia*)

27 MEASUREMENT OF THE POLARIZATION IN FREE NEUTRON-PROTON SCATTERING, E.G. Auld, D.A. Axen, D.F. Measday, J. Va'vra (*Univ. of British Columbia*), L.P. Robertson (*University of Victoria*), G. Roy (*University of Alberta*)

40 MEASUREMENT OF TRIPLE-SCATTERING PARAMETERS OF THE FREE NEUTRON-PROTON SYSTEM, D.A. Axen, M.K. Craddock, J. Va'vra (*Univ. of British Columbia*), R.C. Brown, D.V. Bugg, J.A. Edgington (*Queen Mary College, London*), N.W. Stewart (*Bedford College, London*), A.C. Clough (*University of Surrey*), I.M. Blair (*AERE, Harwell*)

T=1

28 A PROGRAMME OF DIRECT PICKUP REACTIONS AT INTERMEDIATE ENERGIES, D.G. Fleming (*Univ. of British Columbia*)

59 INVESTIGATION OF THE (p,2p) REACTIONS ON ^{3}He, ^{3}H AND ^{4}He, B.S. Bhakar, C. Goulding, B. Murdoch, W.T.H. van Oers (*University of Manitoba*), J.M. Cameron, P. Kitching, C.A. Miller, G.A. Moss, J.G. Rogers, A.W. Stetz (*University of Alberta*)

Parasite

68 FEASIBILITY STUDY OF USE OF HIGH PURITY GERMANIUM DETECTORS FOR DETECTION OF HIGH ENERGY CHARGE PARTICLES, J.M. Cameron (*University of Alberta*), F.S. Goulding, R.H. Pehl (*Lawrence Berkeley Laboratory*), P.W. Martin, M. Salomon (*Univ. of British Columbia*), D.R. Gill (*TRIUMF*)

3 THE STUDY OF FRAGMENTS EMITTED IN NUCLEAR REACTIONS, J.M. D'Auria, R. Green, R.G. Korteling, B.D. Pate (*Simon Fraser University*)

6 STUDIES OF THE PROTON- AND PION-INDUCED FISSION OF LIGHT TO MEDIUM MASS NUCLIDES, D. Dautet, B.D. Pate (*Simon Fraser University*)

11 A STUDY OF NEW HIGH NEUTRON EXCESS NUCLIDES, J.M. D'Auria, G. Bischoff, H. Dautet, R.G. Korteling, B.D. Pate, W. Wiesehahn (*Simon Fraser University*), G.E. Coote (*INS, Dept. of Science & Industrial Research, New Zealand*)

Meson Area

T=0

9 A STUDY OF THE REACTION OF $\pi^- + p \rightarrow \gamma + n$ AT PION KINETIC ENERGIES FROM 20-200 MeV, M.D. Hasinoff, D.F. Measday, M. Salomon (*Univ. of British Columbia*), J-M Poutissou (*Université de Montréal*)

41 RADIATIVE CAPTURE OF PIONS IN LIGHT NUCLEI, M.K. Craddock, M.D. Hasinoff, M. Salomon (*Univ. of British Columbia*)

52 A MEASUREMENT OF THE $\pi \rightarrow e\nu$ BRANCHING RATIO, G.A. Beer, D.A. Bryman, G.R. Mason, R.M. Pearce, C.E. Picciotto, L.P. Robertson (*University of Victoria*)

23b INVESTIGATION OF THE DECAY MODE $\pi^+ \rightarrow e^+ + \nu_e + \gamma$, P. Depommier, J.P. Martin, J-M Poutissou (*Université de Montréal*)

4 A STUDY OF THE REACTION $p + p \rightarrow p + p + \pi^0$ NEAR THRESHOLD, D.F. Measday (*Univ. of British Columbia*

18 INFLUENCE OF CHEMICAL ENVIRONMENT ON ATOMIC MUON CAPTURE RATES, G.A. Beer, T.W. Dingle, D.E. Lobb, G.R. Mason, R.M. Pearce (*University of Victoria*), D.G. Fleming (*Univ. of British Columbia*), W.C. Sperry (*Central Washington State College*)

51 SEARCH FOR TRANSFER OF μ^- FROM LITHIUM LATTICE TO HEAVY IMPURITIES, G.A. Beer, D.A. Bryman, A.D. Kirk, G.R. Mason, A. Olin, R.M. Pearce (*University of Victoria*), K.R. Kendall (*B.C. Cancer Institute*)

19 NUCLEAR DECAYS FOLLOWING MUON CAPTURE, G.A. Beer, G.R. Mason, R.M. Pearce, C.E. Picciotto, C.S. Wu (*University of Victoria*), D.G. Fleming (*Univ. of British Columbia*), W.C. Sperry (*Central Washington State College*), in collaboration with G.A. Bartholomew, E.D. Earle, F.C. Khanna (*Chalk River Nuclear Laboratories*)

42a π^- - ^{3}He: STRONG INTERACTION SHIFT, M. Krell (*Université de Sherbrooke* G.A. Beer, D.A. Bryman, S.K. Kim, G.R. Mason, A. Olin, R.M. Pearce, C.E. Picciotto, L.P. Robertson, J.S. Vincent, C.S. Wu (*University of Victoria*)

46 HYPERFINE SPLITTING IN POLARIZED MUONIC ^{209}Bi ATOMS, G.T. Ewan, B.C. Robertson (*Queens University*), G.A. Beer, G.R. Mason, A. Olin, R.M. Pearce (*University of Victoria*), K. Nagamine, T. Yamazaki (*University of Tokyo*), D.G. Fleming (*Univ. of British Columbia*)

10 POSITIVE PION PRODUCTION IN PROTON-PROTON AND PROTON-NUCLEUS REACTION, D.A. Axen, R.R. Johnson, G. Jones, M. Salomon, J.B. Warren (*Univ. of British Columbia*), L.P. Robertson (*University of Victoria*), P. Kitching, W.C. Olsen (*University of Alberta*)

39 S-WAVE PION-NUCLEAR INTERACTIONS, D.A. Axen, G. Jones (*Univ. of British Columbia*)

53 EMISSION OF HEAVY FRAGMENTS IN PION ABSORPTION, G. Jones, K.C. Mann, P.W. Martin, M. Salomon, E.W. Vogt (*Univ. of British Columbia*), J.M. Cameron (*University of Alberta*), H.S. Caplan (*Univ. of Saskatchewan*), L.W. Swenson (*Oregon State University*)

1 LOW ENERGY PI NUCLEAR SCATTERING, E.G. Auld, D.A. Axen, R.R. Johnson, G. Jones (*Univ. of British Columbia*)

30 SCATTERING OF PIONS FROM ISOTOPES OF HYDROGEN AND HELIUM, B.S. Bhakar, N. Davidson, W. Falk, W.T.H. van Oers (*University of Manitoba*)

29 A STUDY OF THE REACTIONS $\pi \pm p \rightarrow \pi \pm p$ AT PION KINETIC ENERGIES FROM 10-90 MeV, D.A. Axen, R.R. Johnson (*Univ. of British Columbia*), E.W. Blackmore (*TRIUMF*)

35 A STUDY OF POSITIVE MUON DEPOLARISATION PHENOMENA IN CHEMICAL SYSTEMS, K.M. Crowe (*University of California*), D.G. Fleming, D.C. Walker (*Univ. of British Columbia*), R.M. Pearce (*University of Victoria*), J.H. Brewer (*TRIUMF*)

60 STUDY OF MUONIUM FORMATION IN MgO AND RELATED INSULATORS AND ITS DIFFUSION INTO A VACUUM, D.G. Fleming, G. Jones, J.B. Warren (*Univ. of British Columbia*)

37 SEARCH FOR REACTION $\mu^- + Cu \rightarrow e^+ + Co$, G.A. Beer, D.A. Bryman, L.P. Robertson (*University of Victoria*), M. Blecher, K. Gotow (*Virginia Polytechnic Institute & State University*)

T=1

56 A STUDY OF THE DECAY OF THE MUON ('TINA'), D. Berghofer, M. Hasinoff, R.N. MacDonald, D.F. Measday, M. Salomon, J.E. Spuller (*Univ. of British Columbia*), P. Depommier, J-M Poutissou (*Université de Montréal*)

23a SEARCH FOR THE DECAY MODE $\pi^0 \rightarrow 3\gamma$, P. Depommier, J.P. Martin, J-M Poutissou (*Université de Montréal*)

57 SEARCH FOR THE $\mu^+ \rightarrow e^+ + \gamma$ DECAY MODE, P. Depommier, J.P. Martin, J-M Poutissou (*Université de Montréal*)

20 ISOTOPE EFFECT IN μ CAPTURE, G.A. Beer, G.R. Mason, R.M. Pearce, C.E. Picciotto, C.S. Wu (*University of Victoria*), D.G. Fleming (*Univ. of British Columbia*), W.C. Sperry (*Central Washington State College*)

13 MEASUREMENT OF THE ELECTROMAGNETIC SIZE OF THE NUCLEUS WITH MUONIC X-RAYS, PARTICULARLY THE 2s-2p TRANSITION, G.A. Beer, G.R. Mason, R.M. Pearce, C.E. Picciotto, C.S. Wu (*University of Victoria*), D.G. Fleming (*Univ. of British Columbia*), W.C. Sperry (*Central Washington State College*)

42b π^- - ^{3}He: NEUTRON-NEUTRON SCATTERING LENGTH, M. Krell (*Université de Sherbrooke*), G.A. Beer, D.A. Bryman, G.R. Mason, R.M. Pearce, C.E. Picciotto, L.P. Robertson, J.S. Vincent, C.S. Wu (*Univ. of Victoria*)

67 TWO NUCLEON EMISSION FOLLOWING REACTIONS INDUCED BY STOPPED PIONS, J.M. Cameron, W.J. McDonald, G.C. Neilson (*University of Alberta*), P.W. Martin (*Univ. of British Columbia*), G.A. Beer, G.R. Mason, A. Olin (*University of Victoria*)

47 PHOTON ASYMMETRY IN RADIATIVE MUON CAPTURE, M. Hasinoff (*Univ. of British Columbia*)

Parasite

49 A COMPARATIVE STUDY OF THE RADIATION EFFECTS OF PIONS AND ELECTRONS, D.C. Walker (*Univ. of British Columbia*)

54 $\pi^\pm$ REACTION CROSS-SECTION MEASUREMENTS ON ISOTOPES OF CALCIUM, K.L. Erdman, R.R. Johnson (*Univ. of British Columbia*), J.L. Beveridge (*TRIUMF*)

ORGANIZATION

Board of Management

The Board of Management of TRIUMF manages the business of the project and has equal representation from each of the four universities. It reports to the Board of Governors of the University of British Columbia which has legal and financial responsibility for TRIUMF. At the end of 1974 the Board comprised:

University of Alberta	President H.E. Gunning Dean Kenneth B. Newbound Dr. J.T. Sample
Simon Fraser University	Dean S. Aronoff Mr. G. Suart Dr. B.G. Wilson
University of Victoria	Dr. J.M. Dewey Dr. H.W. Dosso Dr. S.A. Jennings
University of British Columbia	Dr. R.R. Haering Dr. E.W. Vogt (Chairman) Dean G.M. Volkoff (Secretary)

Ex-officio Dr. J.R. Richardson, Director, TRIUMF

In December Professor W.M. Armstrong, Chairman of the Board since its formation in May 1968, stepped down, and his place as member for the University of British Columbia was assumed by Professor Vogt. The Board unanimously elected Professor Vogt to serve as Chairman. Earlier in the year University of Alberta's former President Max Wyman and Dr. H. Schiff served on the Board in places now occupied by President Gunning and Dr. Sample. The Board met twice in 1974.

Operating Committee

The Operating Committee of TRIUMF is responsible for the operation of the project. It reports to the Board of Management through its chairman, Dr. J.R. Richardson. It has four voting members, one from each of the four universities. The members of the committee (alternate members in parentheses) at the end of 1974 were:

Dr. J.R. Richardson	Director	(Chairman)
Dr. R.M. Pearce	Associate Director	(Secretary)
Mr. J.J. Burgerjon	Chief Engineer	
Dr. W.K. Dawson	University of Alberta	(Dr. W.C. Olsen)
Dr. B.D. Pate	Simon Fraser University	(Dr. R.G. Korteling)
Dr. L.P. Robertson	University of Victoria	(Dr. G.R. Mason)
Dr. J.B. Warren	University of B.C.	(Dr. D.F. Measday)

In July J.T. Sample returned to University of Alberta after serving as Associate Director during a sabbatical year at main site and was succeeded by R.M. Pearce, on leave from University of Victoria for the 1974/75 academic year. Also in mid-year G.C. Neilson stepped down as University of Alberta member, and K.L. Erdman who represented the University of British Columbia left for a sabbatical year at CERN. The Committee met seven times.

TRIUMF Safety Executive Committee

Dr. R.M. Pearce (Chairman)
Dr. E.W. Blackmore
Mr. J.J. Burgerjon
Mr. J.W. Carey
Mr. A.J. Otter
Dr. B.D. Pate
Mr. I.M. Thorson
Dr. J.R. Richardson
Mr. M. Zach
Dr. G.D. Wait (Secretary)

Dr. M.W. Greene, B.C. Dept. of Health Services and Hospital Insurance
Dr. L. Katz, University of Saskatchewan
Mr. W. Rachuk, Radiation Protection & Pollution Control Officer, UBC
Dr. L. Skarsgard, B.C. Cancer Institute

Mr. S.C. Frazer of the Workers Compensation Board attends meetings as an observer.

Experiments Evaluation Committee

Dr. E.W. Vogt (Chairman)	University of British Columbia
Dr. E.M. Henley	University of Washington
Dr. E.P. Hincks	Carleton University
Dr. R.G. Korteling	Simon Fraser University
Dr. W.J. McDonald	University of Alberta
Dr. B. Margolis	McGill University
Dr. D.F. Measday	University of British Columbia
Dr. H. Primakoff	University of Pennsylvania
Dr. J.R. Richardson	TRIUMF
Dr. L.P. Robertson	University of Victoria
Dr. L. Skarsgard	B.C. Cancer Institute
Prof. Sir Denys Wilkinson	Oxford University
Mr. J.E.D. Pearson (Secretary)	University of British Columbia

At its July meeting, J.T. Sample, Chairman since the EEC was established in 1970, turned over his responsibilities to the newly-appointed Chairman, E.W. Vogt. Three members completed their three-year term in 1974—A.S. Arrott, A.E. Litherland and J.E. Rothberg—and the committee was joined by B. Margolis, H. Primakoff and D. Wilkinson.

Biomedical Experiments Evaluation Committee

Dr. L. Skarsgard (Chairman)	B.C. Cancer Institute
Dean S. Aronoff	Simon Fraser University
Dr. M.J. Ashwood-Smith	University of Victoria
Dr. J.M.W. Gibson	B.C. Cancer Institute
Dr. H.C. Johns	Ontario Cancer Institute
Dr. R.R. Johnson	University of British Columbia
Dr. T.R. Overton	University of Alberta
Dr. J.T. Sample	University of Alberta
Dr. D.C. Walker	University of British Columbia
Dr. G.F. Whitmore	University of Toronto

FINANCIAL STATEMENT

A. Statement of revenue and expenditures, April 1, 1973-March 31, 1974:

Revenue

Atomic Energy Control Board contribution		$4,650,000
University contributions		
University of Alberta	$250,000	
Simon Fraser University	160,000	
University of Victoria	136,363	
University of British Columbia	715,000	1,261,363
B.C. Cancer Institute reimbursement		36,630
Interest and cash receipts		22,938
Total		5,970,931
Subtract: Balance carried forward from previous year		(1,669,871)
		$4,301,060

Expenditures

Salaries	$2,355,178
Engineering & consultants	69,410
Travel	78,948
Telephone, telex and broadband	23,701
Electricity	175,485
Construction	364,869
Capital equipment	2,128,699
Operating	577,453
Total	5,773,743
Subtract: Overexpended funds at March 31, 1974	(1,472,683)
	$4,301,060

B. Expenditures by major and minor codes, 6-month period April 1, 1974- to September 30, 1974:

Major code breakdown:

Administration (basic facility)	$ 27,246
Cost centres	37,450
Cyclotron	599,469
Experimental facilities	1,206,794
Experimental programme	409,790
Medical facility	104,560
Initial operations	56,611
Payroll (basic facilities)	986,525
Technical services	156,945
	$3,585,390

Minor code breakdown:

Salaries and benefits	$1,368,281
Capital	1,997,992
Operating	219,117
	$3,585,390

CONFERENCES AND PUBLICATIONS

Conference presentations:

G. Dutto, The present status of TRIUMF, Symposium on Nuclear Physics Applied to Cyclotrons and Tandems, Louvain-la-Neuve, May

J.J. Burgerjon, TRIUMF progress report, 14th Annual Meeting and International Conference on Nuclear Reactors, Canadian Nuclear Association, Montreal, June

L.P. Robertson, π production measurements with 600 MeV protons, Joint Congress of Canadian Association of Physicists and Canadian Astronomical Society, St. John's, June

J.H. Brewer, μ^+SR spectroscopy: the positive muon as a magnetic probe in solids, Conference on Hyperfine Interactions Studied in Nuclear Reactions and Decay, Uppsala, June (to be published, Physica Scripta)

J.R. Richardson, Strengths of meson factories in few-particle physics, Meeting on Few-Body Problems in Nuclear and Particle Physics, Quebec, August (to be published, Les Presses de l'Université Laval)

J.M. Cameron, Experimental facilities for few nucleon studies at TRIUMF, *ibid.*

E.B. Cairns and W.K. Dawson, A modular (amplifier per wire) wire chamber and readout system, 21st Nuclear Science Symposium, 14th Scintillation and Semiconductor Counter Symposium and 6th Nuclear Power Systems Symposium, Washington, December (to be published, IEEE Trans. Nucl. Sci.)

Journal publications:

R.D. Fyvie and D.E. Lobb, An analysis of short rotating coil measurements in the fringe field of a quadrupole magnet, Nucl. Instr. & Meth. 114, 609 (1974)

H. Blok, F. Hanappe, F.M. Kiely, B.D. Pate and J. Péter, Further measurement of the track lengths of heavy ions in mica, Nucl. Instr. & Meth. 119, 307 (1974)

J.H. Brewer *et al.*, Muonium chemistry in liquids - evidence for transient radical formation, Phys. Rev. 9A, 495 (1974)

Reports:

TRI-74-1	M. McMillan and R.H. Landau, A calculation of the single scattering contribution to the differential cross-section for the elastic scattering of 25-100 MeV positive pions by deuterium
TRI-74-2	M. Salomon, Low energy (0-250 MeV) pion-nucleon phase-shift fits

STAFF

BREAKDOWN OF TRIUMF STAFF TOTAL AS OF DECEMBER 31, 1974

	Main site	UBC	UVic	SFU	UAlta	Total
Scientists	21	4	4[1]	4[1]	2[1]	35
Faculty full-time main site 1973/74[2]	(2)	(1)	(1)			
Faculty part-time		11	4	4	11	30
Engineers	14				1[1]	15
Operators	12					12
Programmers	3			2		5
Graduate students		12	7	5	2	26
Technicians	58	4	6		4[1]	72
Designer-draftsmen	8		1			9
Workshop staff	14		1		1	16
Plant	8					8
Administration	4					4
Office staff:						
Secretarial & clerical	10	1	1	0.6	1	13.6
Library/Information Office	2					2
Stores	4					4
	158[1]	32	24	15.6	22	251.6

[1]Main site total includes one additional scientist from University of Victoria, one from Simon Fraser University, and four from University of Alberta who are based at main site. Also working full-time at main site from University of Alberta: one additional engineer and two technicians.

[2]Faculty members spending the 1974/75 academic year at main site have been included in appropriate category; during such leave faculty members are paid by TRIUMF rather than the respective university.

TRIUMF Vancouver (listed in order of joining the project)

Name	Position	Area	% TRIUMF Payroll	Staff Changes During 1974 From	Until
J.R. Richardson	Director				
J.J. Burgerjon	Chief Engineer				
G.H. Mackenzie	Research Associate	Beam Dynamics			
L. Root	Research Associate	Beam Dynamics			
R.H.M. Gummer	Research Associate	RF			
A.J. Otter	Magnet Engineer	Beam Lines			
M. Zach	Research Engineer	RF/Magnet/Operations			
R. Poirier	Research Engineer	RF			
E.W. Blackmore	Research Associate	Probes/Operations			
J.W. Carey	Plant Engineer				
O.K. Fredriksson	Cyclotron Engineer				
D.R. Heywood	Research Associate	Controls			
G. Dutto	Research Associate	Beam Dynamics/ISIS			
R.G. Bendall	Critical Path Co-ordinator				
C. Kost	Computer Analyst	Beam Dynamics	100		
J.V. Cresswell	Research Engineer	Electronics			
P. Bosman	Research Engineer	ISIS			
D.C. Healey	Research Associate	Vacuum			
F. Choutka	Structural & Architectural Designer				
I.R. Heath	Mechanical Engineer	Cyclotron General			Jan 11
K. Balik	Mechanical Engineer	Beam Lines			May 24
V.J. Verma	Electrical Engineer	Beam Lines/Cabling			
R. Gibb	Research Associate	Magnet			Apr 30
R. Marek	Research Engineer	Magnet & Power Supplies			
J.H. Brewer	Research Associate	MSR Facility			
R. Riches	Research Associate	ISIS			
D. Ericson	Commissioning Engineer	Beam Lines			Mar 20
C.W. Bordeaux	Business Manager				
R. Washburn	Critical Path Co-ordinator				Apr 30
R. Wimblett	on leave from RL		0		Aug 8
W. Cameron	Mechanical Engineer	Probes/Remote Handling			
L. Moritz	Research Associate	Safety			
G. Best	Research Associate	Magnet			Jul 12
D. Pearce	Research Associate	Alignment			
P. Schmor	Research Associate	Beam Dynamics			
J. Beveridge	Research Associate	ISIS			
D.R. Gill	Research Associate	Safety		Oct 1	
J. Yandon	Shift Supervisor Operations				
K. Lukas	Shift Supervisor Operations				
G. Roy	Operators				
N. England					
J. McIlroy	Shift Supervisor Operations				
S. Langton			100		
F. Bach					
J. Kaminski				Jan 8	
M. McDonald	Operators			Apr 16	
G. Wight				May 1	
A. Hurst				Sep 9	
B. Stanton				Sep 20	
L. Udy		Vacuum			
N. Rehlinger		Magnet			Feb 28
K. Poon		Magnet			Feb 8
J. Fawley	Technicians	RF			
B. Ozzard		Controls			
M. Hone		ISIS			Jan 11
H.H. Simmonds		RF			

TRIUMF Vancouver (cont'd)

			% TRIUMF Payroll	Staff Changes During 1974 From	Until
D. Evans		Magnet			
G. Walsh		Vacuum			May 31
B. Evans		Controls			Nov 15
L. Voboril		Magnet/Alignment			
B. Trevitt		ISIS			
A.M. Teteris		Safety			
F. Humphrey		Electronics			
P.C. Taylor		Probes			
K.R. Arbuthnot		ISIS			
D.W. Thompson		RF			May 31
U. Arthur		Electronics			Aug 31
Y. Langley		Electronics			
S. Turke		Probes			
J. Lenz		ISIS/Safety			
L. Humphreys		RF/Beam Lines			
W. Noelte		RF/Beam Lines			
B.E. Evans		ISIS			
B. Salama		ISIS			Jul 31
A.O. Lacusta		Controls			
R. Hilton		Magnet/Beam Lines			
W. Wu		ISIS			
L. Chua		Electronics			
R. Corman		Controls/ISIS			
C. Lawrence		ISIS			Apr 5
L. Lambkins		Electronics			Mar 29
G. Takacs		ISIS			
T. Moskven		Safety			
R. Hansen		Electronics			
E. Klassen		Controls			
P. Guerin	Technicians	Magnet	100		
D. Johnson		Magnet/Remote Handling			
L.T. Wong		ISIS			
W. Rawnsley		ISIS			Jun 21
J. Case		Vacuum			
C. Yee		Electronics			
C. Walters		Magnet/RF			Oct 18
M. Stenning		RF			May 31
J. Stewart		Probes			
D. Shorter		Electronics			
E. Hinves		Electronics			Jun 21
N. Shiboaka		Electronics			
S. Greene		Vacuum			Aug 31
M. Smyth		Probes			
C. Fairey		Vacuum/Beam Lines			
R. Skegg		Electronics			
C. Lay		Magnet/RF			Aug 13
D. Smith		Electronics			
C. LaForge		ISIS			
L. King		Safety			
P. Tautz		Controls			
R. Chowdhry		Civil			May 5
G. Cox		Electronics/Cabling			Sep 30
J. Gehlen		Electronics			
H. Shum		ISIS		Jan 9	
R. Palmer		Night Watchman		May 6	
P. Bennett		Beam Dynamics		May 13	
M. Lewis		Electronics		Jul 16	
J. Hu		RF		Aug 1	
J. Lau		Electronics		Aug 1	
S. Storgeoff		Night Watchman		Aug 1	
R. Callon		Beam Dynamics		Aug 5	

TRIUMF Vancouver (cont'd)

Name	Position		% TRIUMF Payroll	During 1975 From	During 1975 Until
A. Bishop	Technicians	Vacuum	100	Aug 23	
J. Tipton	Technicians	Magnet	100	Oct 16	
R. Ginn	Technicians	Magnet	100	Oct 21	
R. Moore	Technicians	Cabling	100	Oct 28	
O. Thorkelson	Technicians	RF	100	Nov 1	
P. Harmer	Technicians	Vacuum	100	Nov 28	
P. van Rook	Design Office Supervisor		100		
H. Hansen	Designer-draftsmen		100		
A.T. Bowyer	Designer-draftsmen		100		
J. Hallow	Designer-draftsmen		100		
H. Sprenger	Designer-draftsmen		100		
G.C. Bryson	Designer-draftsmen		100		May 10
H. van Weerden	Designer-draftsmen		100		
E. Markewitz	Designer-draftsmen		100		Nov 26
B. Scheuring	Designer-draftsmen		100		Oct 25
B. Bruggen-Cate	Designer-draftsmen		100		Nov 30
H. Mertes	Designer-draftsmen		100		
H. Westra	Designer-draftsmen		100		Jan 15
D. Mattingley	Designer-draftsmen		100		Apr 30
C. Mark	Designer-draftsmen		100		
A. Mandelman	Designer-draftsmen		100		Jan 18
W. McCain	Designer-draftsmen		100		Mar 31
R. Brewer	Machine Shop Supervisor		100		
S. Olsen	Machinists		100		
W. Frey	Machinists		100		
R.C. Stevens	Machinists		100		Apr 30
W. Koch	Machinists		100		
L. Crozier	Welder		100		
P. Gormley	Machinists		100		
L.M. Nazar	Machinists		100		
P. Sterritt	Machinists		100		
W. Carr	Machinists		100		
G. Fletcher	Woodworker		100		
J. Neuberg	Machinists		100		Mar 8
W. Nagel	Machinists		100		Sep 18
V. Duggal	Machinists		100		
R. Roper	Late Shift Supervisor		100		
P. Inderbitzen	Machinists		100	Nov 4	
F. Bousek	Machinists		100	Nov 12	
G.J. Ratzburg	Electrician		100		
W.P. Healy	Maintenance Technicians		100		Mar 31
S.J. Smith	Maintenance Technicians		100		
S.P. Lee	Maintenance Technicians		100		
P. Ram	Maintenance Technicians		100		
L. Clement	Crane Operator		100		
A. Salter	Maintenance Technicians		100	May 1	
H. Dougan	Maintenance Technicians		100	May 6	
W. Thaller	Maintenance Technicians		100	Jul 1	
D. Marquardt	Programmers		100		
W. Fung	Programmers		100		
P. Brown	Programmers		100		
H. Houtman	Programmers		100		Apr 26
M. Merchant	Programmers		100		Apr 30
W. Dawes	Stores Supervisor		100	Jul 22	
P. Sparkes	Buyer		100		
C. Bruce	Receiver/Storekeeper		100		
D. Sawyer	Storekeeper/Receiver		100		

			% TRIUMF Payroll	Staff Changes During 1974 From	Until
TRIUMF Vancouver (cont'd)					
A. Strathdee	Asst. Information Officer		100		
N. Palmer	Secretary to Director		100		
M. Williams	Secretary		100		
P. Moase	Purchasing Assistant		100		
M. Tainsh	Secretary		100		
V. Hannah	Clerk		100		
V. Turner	Accounting Assistant		100		
S. Crerar	Receptionist		100		Apr 19
M. Stancer	Inventory Control Clerk		100		
I. Duelli	Clerk		100	Jan 21	
H. Fernandes	Clerk		100	Apr 22	
D. Staples	Secretary		100	Jun 13	
D. Osaduik	Receptionist		100	Aug 15	
UBC					
Faculty					
E.G. Auld	Assoc. Professor	on sabbatical	0	Jul 1	
D.A. Axen	Assoc. Professor	Vacuum	0		
M.K. Craddock	Assoc. Professor	Beam Dynamics	0		
K.L. Erdman	Professor	on sabbatical	0	Jul 1	
D.G. Fleming	Asst. Professor	MSR Facility	0		
M. Hasinoff	Asst. Professor	Experimental Programme	0		
R.R. Johnson	Assoc. Professor	Controls	0		
G. Jones	Professor	on sabbatical at TRIUMF	60	Jul 1	
D.F. Measday	Assoc. Professor	Experimental Programme	0		
E.W. Vogt	Professor		0		
J.B. Warren	Professor		0		
B.L. White	Professor	ISIS	0		
Graduate Students					
D. Berghofer		Experimental Programme	0		
K. Brackhaus		RF	0		Jul 31
M. Currie-Johnson		Experimental Programme	100		
A. Duncan		Experimental Programme	0		
L. Felawka		Experimental Programme	100		
D.M. Garner		Experimental Programme	100		
C. Lee		Experimental Programme	50		
R. MacDonald		Experimental Programme	100		
G. Marshall		Experimental Programme	0		
P. Olenik		Experimental Programme	100		
D. Ottewell		Experimental Programme	100		
J.E. Spuller		Experimental Programme	0		
T. Suzuki		Experimental Programme	30		
TRIUMF UBC					
S. Jaccard	Visiting Fellow	Experimental Programme	30		
T. Masterson	Research Associate	Experimental Programme	90		
A. Morgan	Technician	Experimental Programme	100		
K. Nagamine	Visiting Fellow	Experimental Programme	0		
J-M Poutissou	Visiting Fellow	Experimental Programme	0		
L. Ratcliffe	Secretary	Experimental Programme	100		
M. Salomon	Research Associate	Experimental Programme	100		
R.C. Stevens	Technician	Experimental Programme	100		
A.K. Stevenson	Technician	Experimental Programme	100		
J. Va'vra	PDF	Experimental Programme	100		
P. Walden	Research Associate	Experimental Programme	90		
S. Wood	Technician	Experimental Programme	100		
T. Yamazaki	Visiting Fellow	Experimental Programme	30		

			% TRIUMF Payroll	Staff Changes During 1974 From	Until
TRIUMF Victoria					
T.A. Hodges	Research Associate	Targets	100		
P.A. Reeve	Research Associate	Beam Optics	100		
J.S. Vincent	Research Fellow	Med/Fast π Channel	100		
D.A. Bryman	Research Fellow	Sec Beam Monitors	88		
A. Olin	Research Fellow	Mesic X-rays	100		
L.M. Williams	Programmer				Mar 31
D.F. Smith	Research Assistant	Targets			Jan 24
J.G. Gibson	Research Assistant	Targets			
R.R. Langstaff					
N.O. Williams					Apr 15
O.E. White	Designer-draftsmen				Oct 31
D.K. Garthwaite					Jan 31
P.G. Verstraaten	Machinist				
J.T. Nelson			100		
D.A. Beale					May 31
T.R. Gathright					
E. Garsonin	Technicians				Mar 31
J.D. Ridley				Jan 28	
H. Hodapp				May 1	
P. Scrimger				Nov 1	
J. Hunt	Secretary				
UVic					
Faculty					
R.M. Pearce	Professor	on leave to TRIUMF	58	Jul 1	
L.P. Robertson	Professor	on leave to TRIUMF	58		Jun 30
G.R. Mason	Assoc. Professor	Secondary Beams	0		
D.E. Lobb	Assoc. Professor	sabbatical at RHEL	0		Jun 30
G.A. Beer	Asst. Professor	Experimental Area	0		
Graduate Students					
P.W. James		π Production Experiment	30		
S.K. Kim		Mesic X-rays	50		
C.D. Ko			50	May 1	
E.L. Mathie			100	Jun 1	
R.P. Fryer		Experimental Programme	100	Sep 1	
J. Reyes			100	Sep 1	
D. Lim			20	Sep 1	
TRIUMF Burnaby					
I.M. Thorson	Research Associate	Shielding & Activation			
G.D. Wait	Research Associate	Safety			
W.J. Wiesehahn	Research Associate	Chem & Exp Facility			
R. Green	Research Scientist	Nucl Eqpt Development			
D. McMillan	Research Associate	Safety	100		May 31
F.M. Kiely	Research Scientist	Chem & Exp Facility			Sep 30
J. Grabowski	Research Scientist	Fission		Jul 1	
M. Kurn	Programmer				
W. Bishop	Programmer				
S. Heap	Secretary		66		
SFU					
Faculty					
B.D. Pate	Professor	Chem & Exp Facility	0		
A.S. Arrott	Professor	Neutron Target	0		
R.G. Korteling	Assoc. Professor	Nucl Eqpt Development	0		
J.M. D'Auria	Assoc. Professor	Chem & Exp Facility	0		

SFU (cont'd)			% TRIUMF Payroll	Staff Changes During 1974 From	Until
Graduate Students					
H. Dautet		Experimental Programme	0		
D. Dautet		Experimental Programme	0		
G. Bischoff		Experimental Programme	0		
H. Blok		Experimental Programme	0		
A. Seamster		Experimental Programme	0	Sep 1	
TRIUMF Edmonton					
R. Adolph	Technician		100	Jun 1	
R. Churchman	Technician		100	Jun 1	
H. Coombes	Technician		100	Sep 1	
H.W. Fearing	Visiting Scientist		100	Jul 1	
D.P. Gurd	Asst. Res. Professor	Controls	100		
A. Lank	Machinist	Wire Chambers/P-Area	100		
T. Lesoway	Technician	Wire Chambers	100		
J.A. Lidbury	Design Engineer	Spectrometer	100		
A. Miller	Research Associate		100	Mar 1	
E. Pearce	Technician		100		Oct 31
M. Proverb	Secretary		100		
J.G. Rogers	Research Associate		100		
J.R. Schaapman	Technician		100		Oct 31
A.W. Stetz	Research Associate		100		
G.M. Stinson	Asst. Res. Professor	Spectrometer/P-Area	100		
A.N. Thorn	Design Engineer		100	Mar 1	
UAlberta					
Faculty and Research Staff					
G.C. Neilson	Professor	on sabbatical to TRIUMF	20		Jul 1
W.K. Dawson	Professor	Controls and P-Area	0		
J.T. Sample	Professor	on sabbatical to TRIUMF	20		Jul 1
W.C. Olsen	Professor	P-Area	0		
G. Roy	Assoc. Professor	on leave at TRIUMF	100		Jul 1
W.J. McDonald	Assoc. Professor	P-Area	0		
G.A. Moss	Assoc. Professor	P-Area	0		
D.M. Sheppard	Assoc. Professor	P-Area	0		
J.M. Cameron	Assoc. Professor	on leave at TRIUMF	100		Jul 1
P. Kitching	Assoc. Professor	P-Area	0		
E.B. Cairns	Professional Officer	P-Area/Eqpt Development	0		
J.B. Elliott	Professional Officer	P-Area/Eqpt Development	0		
H.S. Sherif	Asst. Professor	P-Area	0		
Graduate Students					
K. Chudleigh					
R.H. McCamis					

Appendix C

USERS GROUPS

TRIUMF Users Group

University of Alberta:

W.J. McDonald, Chairman 1974

E.B. Cairns
J.M. Cameron
W.K. Dawson
J.B. Elliott
G.R. Freeman
H.E. Gunning
P. Kitching
R.H. McCamis
C.A. Miller
G.A. Moss
G.C. Neilson
A.A. Noujaim
W.C. Olsen
T.R. Overton
J.G. Rogers
G. Roy
J.T. Sample
D.M. Sheppard
H. Sherif
A.W. Stetz
G.M. Stinson

University of Victoria:

G.A. Beer
D.A. Bryman
G. Bushnell
T.W. Dingle
T.A. Hodges
A.D. Kirk
D.E. Lobb
G.R. Mason
A. Olin
C.E. Picciotto
R.M. Pearce
P.A. Reeve
L.P. Robertson
J.S. Vincent
C.S. Wu

Simon Fraser University:

A.S. Arrott
J.M. D'Auria
G.E. Coote
J. Grabowski
R. Green
C.H.J. Jones
R.G. Korteling
B.D. Pate
I.M. Thorson
W.J. Wiesehahn

University of British Columbia:

D.G. Fleming, Chairman 1975

E.G. Auld
D.A. Axen
D.S. Beder
M.K. Craddock
K.L. Erdman
R.R. Haering
L.G. Harrison
M.D. Hasinoff
R.R. Johnson
G. Jones
K.C. Mann
P.W. Martin
T. Masterson
C.A. McDowell
J.M. McMillan
D.F. Measday
M. Salomon
E.B. Tregunna
J. Trotter
J. Va'vra
E.W. Vogt
P. Walden
D.C. Walker
I.H. Warren
J.B. Warren
W. Westlund
B.L. White

TRIUMF Vancouver:

J. Beveridge
E.W. Blackmore
J.H. Brewer
D.P. Gurd
G.H. Mackenzie
J.R. Richardson

Visiting experimentalists:

J.A. Edgington, R. Brown, C. Oram, K. Shakarchi, *Queen Mary College, University of London*
N.M. Stewart, G. Ludgate, *Bedford College, University of London*
A.S. Clough, *University of Surrey*
S. Jaccard, *Université de Neuchâtel*
G. Waters, *Rutherford Laboratory*
J-M Poutissou, *Université de Montréal*
T. Yamazaki, K. Nagamine, R.Hayano, N.Nishida, *University of Tokyo*

Other institutions:

E.P. Hincks, R.L. Clarke, *Carleton University*
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