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OPERATED AS A JOINT VENTURE

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UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

OCTOBER 2005

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

ACCELERATOR TECHNOLOGY DIVISION

INTRODUCTION

The Accelerator Technology Division is responsible for most of the engineering, design and fabrication at TRIUMF. Other responsibilities include planning for projects and shutdowns, electronics development and services, the Building department, the Design Office and Machine Shop. The site beam dynamics effort is also now coordinated through the division. This year, as for the past number of years, much of the available effort went into supporting the ISAC-II project. In the Requests for Engineering Assistance (REA) that were submitted during the year, there were 40 ISAC related jobs and 34 non-ISAC in mechanical engineering and design. In electronics development there were 29 REAs and in electronics services there were 16 REAs.

On external projects, the Beam Dynamics group continued their work on the design of FFAG accelerators with special effort on the specification of an electron model.

Magnet work included the supervision of contracts for the superconducting solenoids being fabricated by Accel Instruments, the S-bend dipoles for the ISAC-II transfer line, and the large coils for the Q_{weak} experiment at Jefferson Lab. The Kicker group started on the design of a kicker for the Brookhaven AGS upgrade project and also made improvements and repairs to the MuLan kicker developed for an experiment at PSI.

Among the achievements in the engineering and design groups, and for many other groups at TRIUMF, was the first ISAC-II cryomodule assembly and tests and the successful commissioning of the 500 W refrigeration system by Linde Kryotechnik. Support was also given to TITAN, TIGRESS and external projects, KOPIO at Brookhaven and K2K, T2K at J-PARC in Japan. The Design Office has decided to adopt SolidWorks 3D modelling software as the site standard.

The Planning group looked after the scheduling and coordinating of the many ISAC projects, the planning of the cyclotron shutdowns and the priority scheduling in the Machine Shop. The Machine Shop purchased a second CNC vertical machining centre to increase the efficiency and capability in meeting the demanding requirements for fabrication.

The Building department was involved in several structural projects for ISAC, including the installation of the large helium tank for the ISAC-II refrigeration system and the TITAN platform. The usual building and site maintenance and repair jobs were supervised, and some architectural designs for a new lobby and cafeteria were proposed.

In the Electronics Services group, hardware support was given to a large number of experimental groups, the MuLan kicker repairs and vault cabling replacement. The computer network for TRIUMF House was commissioned and requests for PC support at TRIUMF continue to increase. An interesting motor control project was the LaserBall manipulator system developed for the K2K collaboration.

The Electronics Development group continued to provide all of the hardware installation, maintenance and upgrades for the ISAC control system. The controls interface for the helium refrigeration system was commissioned and there were new developments in the control systems for vacuum and in other areas. Several new types of modules were designed and built for experiments and for ongoing developments on ISAC. Assistance was given to the PET group in upgrading the pneumatic delivery system between TRIUMF and the UBC Hospital.

Once again it was a busy year for the division which resulted in several notable achievements.

BEAM DYNAMICS

Muon and Electron Acceleration in FFAGs

The collaboration with BNL and FNAL on the design of FFAG accelerators for a future neutrino factory has widened in scope, to include an electron demonstration model, and in composition, with the participation of Daresbury, UK as a probable host for the model. Two types of investigations have been completed: parameter optimizations of general applicability, and design work specific to the electron model.

For the US Neutrino Factory, FFAGs are the preferred acceleration model to high energy due to their significantly reduced cost and larger acceptance, implying a factor of 4 reduction in transverse cooling and total elimination of longitudinal cooling relative to recirculating linear accelerators. These are not MURA-style scaling FFAGs, but a new breed of accelerator, using strictly linear elements, with characteristics well matched to the rapid acceleration of beams with large 6D emittances. Physically, they will bear a strong resemblance to electron storage rings, but will be operable over a tremendous momentum range.

Magnet Lattices

The thin element models of F0D0, doublet and triplet based lattices were developed further to cover unequal integrated quadrupole strengths. These models indicate that when the horizontal focusing strength is greater than the vertical, as occurs when the tunes are split, the path-length variation is reduced by $\simeq$20% with a corresponding increase in the number of turns. The scope of the thick element models was widened to include cells with two sector bends, one of them reverse bending to reduce the aperture requirements, and by the addition of doublet cells to the stable of F0D0 and triplet types. These analytic models, which are more accurate for large momentum offset than the optics program MAD, neglect terms of second order in displacement divided by bending radius ($\Delta x/\rho$). Computations with the differential algebra program COSY show the errors to be 5% or more for rings with fewer than 30 cells, but negligible for the $\simeq$100 cell muon rings. The models form the basis for scripts that automatically optimize lattice parameters to minimize time-of-flight variation, subject to constraints on betatron tunes and peak pole-tip fields, etc.

Acceleration

The longitudinal dynamics has two key parameters: voltage and radio frequency (V, f). The serpentine channel responsible for acceleration may pinch closed for small variations in V or f, and the muon machine will operate close to these conditions. The parameter choice depends upon a compromise between acceleration range, dwell time and decay losses, acceleration efficiency, emittance growth and matching conditions for the phase-space ellipse. Based on analytic expressions for all these quantities, a lower-emittance working point has been found which reduces the ellipse distortion due to stalling at the fixed-points.

Electron Model

The linear-field FFAG lattices demonstrate compaction of a very large range of momenta into remarkably narrow apertures. The FFAG operates at fixed magnetic field, and with a range of momenta many times larger than a synchrotron. This has two consequences: (i) *asynchronous acceleration* within a rotation manifold outside the rf bucket; and (ii) *multi-resonance crossing*: the combination of a $\pm 50\%$ $\delta p/p$ momentum span and uncorrected, natural chromaticity leads to the beam crossing many betatron resonances including integer and $\frac{1}{2}$-integer. Both features rely on untested beam dynamics and it is proposed to investigate in detail the complex parameter dependencies, of the non-scaling FFAG, in a few MeV electron model at a tiny fraction of the cost of the multi-GeV muon machines. Initial plans, led by BNL, focused on a near-table-top device with 25 cells, or less, and 3 GHz rf cavities. TRIUMF expertise has successfully reshaped this model into one that better emulates the resonance-crossing behaviour of the full-sized rings. The present model has lower frequency, 1.3 GHz rf, more cells, 42, and operates over a greater number of turns – proportional to the square of cells. At fixed length, the magnets become a smaller number of rf wavelengths long, leading to a smaller phase slip, and yet more turns. The 42 cell design entails a three-fold symmetry to cancel 1/3-integer structure resonances. Since the summer, the Daresbury Laboratory has identified itself as a probable host and, along with UK and EU collaborators, has begun overtures to potential funding agencies for construction of the electron model downstream of their ERLP, a ring-like energy recovery linac prototype.

EURISOL Beta Beam

The Beta Beam Study is part of the EU-funded EURISOL initiative which will develop a proposal for a new European ISOL-based radioactive ion beams facility. Beta Beam is a novel concept for a neutrino factory which utilizes radioactive light ions produced by the ISOL front end. These ions are collected, accelerated to highly relativistic energies in order to extend their lifetime, and then injected into a racetrack-shaped storage ring (the "decay ring") where copious neutrinos will be produced from the ions via the radioactive beta decay process. The EURISOL Beta Beam Study will formally commence in January, 2005 and will run for four years.

TRIUMF was invited to participate in Beta Beam in the area of multiparticle simulations of the operation of the decay ring, using our tracking and simulation code ACCSIM and other available tools such as GEANT4 and/or MARS. ACCSIM's space charge capabilities will also be of use in studying beam-intensity limitations in the ion acceleration stages of the Beta Beam facility.

Some preparatory work was done in order to assess the needs and objectives of the simulation program and to specify some needed extensions to ACCSIM for handling radioactive ions, decay products, and ion interactions in matter.

A survey was also conducted of other computational tools which would complement ACCSIM. It was noted that there is current interest from several fields in extending the physics reach of particle simulation codes to include ions, and that advanced models of ion physics processes are being pursued by groups involved with GEANT4, MARS, and Tech-X corporation. Of particular note is the Quark Gluon String Model (QGSM) being developed for GEANT4, which extends into the comparatively high energy regime of the decay ring.

A comprehensive simulation of the decay ring, capable of supporting the needs of the ring design and operational phases, represents a considerable challenge and will require advancements in both the particle tracking and physics aspects of existing codes. For the near future, we expect that ACCSIM, which will provide the large-scale particle tracking and particle loss information for the beta beam rings, will be used in concert with codes such as GEANT4 and MARS which will act as post-processors to give a detailed account of the ion interactions in matter and resulting secondary particles.

MAGNETS

The ISAC-II superconducting linac uses superconducting solenoid magnets to focus the ion beam. Accel Instruments (Germany) tested and delivered 5 solenoids for the medium-beta section (see Fig. 238). The specification calls for these magnets to operate at 9 T. All of these magnets operated at over 10 T before quenching. Since the solenoids operate next to the superconducting rf cavities, the specification limits the fringe and residual fields in the cavity area. When operating at 9 T, the field at the cavity is less than 0.1 T. After operating at 9 T and degaussing, the residual field is less than 1 mT. The linac designers had hoped that the residual field would be less than 0.1 mT. This can be achieved, but only by warming the magnet above the transition temperature to release the flux trapped in the coil winding. Based on the success of the medium-beta solenoids, three solenoids for the high-beta linac were ordered.

A concept design of a new septum magnet for the M11 beam line was written [TRI-DN-04-12]. This design lowers the magnet's resistance and power by about 6%.

Fig. 238. ISAC-II SC solenoid in test at Accel Instruments (photo courtesy of Accel).

The high field ISAC HEBT (S-bend) transfer line dipoles that were designed last year, were manufactured by Alpha Magnetics (California) and Sunrise Engineering (Delta, BC). These magnets were field mapped and met the design specifications. At year-end, one magnet was installed and the others were ready to be installed.

To assist the Canadian contingent to the Q_{weak} experiment at the Jefferson Lab, TRIUMF ordered nine coils for the QTOR spectrometer magnet from Sigmaphi (France). The copper conductor was delivered to France by Jefferson Lab. At year-end, Sigmaphi was developing a technique to splice the large cross section conductor. These coils are expected to be delivered in July, 2005.

Magnet Measurements

Magnets surveyed this year include twenty-three ISAC-II L2 experimental hall quadrupoles, a UCLA dipole (Clyde), five ISAC-II L5 experimental hall quadrupoles, four S-bend double steering magnets, four S-bend dipole magnets, a HiTime superconducting solenoid for M15 (measured from 2 T to 7 T with test shimming), a Belle superconducting solenoid at 6.2 T field, and finally a repeat mapping of the HiTime superconducting solenoid twisted on physical axis at 7 T field.

Experiment 614 – TWIST

TOSCA 3D simulations have previously been carried out for the TWIST magnet. These simulations provide important information because the measurements provide only one component (Bz) of the field at a limited number of space points. By contrast a good TOSCA computer model can provide the three-field components at any point. A detailed comparison was made between field maps taken for the TWIST solenoid, at a field of approximately 2 T, and the TOSCA predictions. The maximum discrepancy between the predicted and measured Bz field is 8 mT: this reduced to 3 mT when a simplified representation of the iron of two upstream quadrupoles and a dipole was included. The TOSCA model also confirms that the solenoid results in an offset-field being added to the pole tip field of the Q7 quadrupole; means of shielding the Q7 quadrupole, from the solenoid generated field, are currently being investigated.

KICKERS

AGS collaboration

The present AGS injection kickers at the A5 location were designed for 1.5 GeV proton injection (see Fig. 239). Recent high intensity runs have pushed the

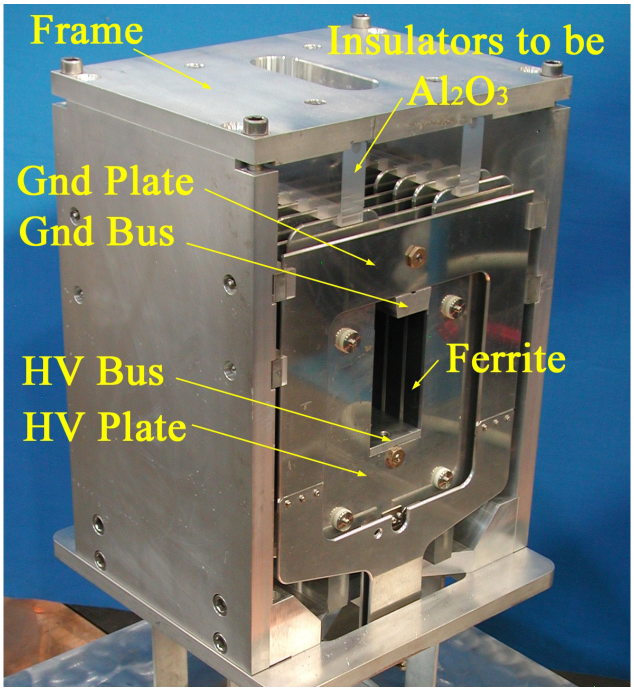

Fig. 239. Photo of KAON kicker assembly that is similar to proposed AGS kicker.

transfer kinetic energy to 1.94 GeV, but with an imperfect matching in transverse phase space. Space charge forces result in both fast and slow beam size growth and beam loss as the size exceeds the AGS aperture. A proposed increase in the AGS injection energy to 2 GeV with adequate kick strength would greatly reduce the beam losses making it possible to increase the intensity from 70 TP (70 $\times$ 10^{12} protons/s) to 100 TP. However, the integral of flux density over the length of the present AGS A5 injection kickers is insufficient for injection at 2 GeV. R&D studies are being undertaken by TRIUMF, in collaboration with BNL, to design two new kicker magnets for the AGS A10 location to provide an additional kick of 1.5 mrad to 2 GeV protons. The kick strength rise and fall time specifications are 100 ns, 3% to 97%; the design goal is to achieve a field uniformity of $\pm$1% over 85% of the cross sectional area of the aperture. TRIUMF has proposed a design for a 12.5 W transmission line kicker magnet powered by a matched 12.5 W pulse forming line.

To achieve low ripple and minimize field rise/fall time the impedance of the kicker magnet must be close to 12.5 W. Hence detailed electromagnetic simulations of the proposed A10 kicker magnets have been used during the design stage:

- 3D modelling to accurately predict capacitance of capacitance plates (including edge effects);
- 2D modelling of electric and magnetic field in the aperture to optimize the aperture geometry to achieve a kick uniformity of $\pm$1% over 85% of the aperture without unduly increasing cell inductance. Ferrite and ground conductor have been shaped to achieve this;
- A modified equivalent circuit of the kicker magnet has been developed. The revised model has been shown to give almost identical predictions to the previous model but negative mutual coupling between cells is represented in a more intuitive manner, simplifying the derivation of values for the model;
- Incorporation of a model of beam bunches into PSpice equivalent circuit, for the 3 different operating modes, to allow a better optimization of the kicker system.

Two co-op students worked on this project at TRIUMF during 2004.

NLC collaboration

The collaboration with SLAC, to analyze the failure mechanism of the IGBTS under fault conditions in the prototype NLC modulator, was successful. A paper was co-authored with SLAC and presented at the 2004 Power Modulator Conference. A more complete version of the paper has been accepted for publication in a special issue of the IEEE Transactions on Plasma Science.

PSI MuLan collaboration

An international collaboration plans to measure the lifetime of the muon to a precision of 1 ppm. The MuLan experiment will take place at PSI in northern Switzerland. The central idea employed in MuLan invokes an artificial time structure on an otherwise dc beam. The MuLan method requires a fast beam line kicker, which can turn the beam on and off at a repetition rate of up to 40 kHz: the TRIUMF Kicker group designed and built the kicker. The kicker runs with a standard “on-off time cycle”, or in a “muon on request” mode. The MuLan kicker consists of 2 pairs of deflector plates mechanically in series, driven by 4 FET modulators. Each pair of plates is 0.75 m long. One plate of each pair is driven by a +12.5 kV FET based modulator and the other plate is driven by a –12.5 kV modulator. The potential difference between a pair of deflector plates is variable up to 25 kV. Each modulator consists of two stacks of FETs operating in push pull mode.

The kicker was successfully commissioned at PSI in July, 2003. However, as a result of the very fast switching times of the MOSFETs (<2 ns compared with approximately 30 ns in the previous generation of the FET cards), and the external interconnections required for the 4 kicker racks, significant rf noise was generated. In addition the specifications for the flatness of the voltage pulse were modified, now calling for a pulse flatness of 1 V in 12500 V, compared to the achieved 22.5 V in 12500 V. The kicker was returned to TRIUMF in January, 2004, and extensive changes were made which were based on detailed PSpice modelling of the system. The rf was reduced by a factor of approximately 5000. The flat top droop, for a 20 ms pulse duration, was reduced from 0.18% (22.5 V) to less than 0.001% (100 mV). In addition the pulse overshoot, at the front and back edges of the pulse, which occurs for ∼70 ns duration, was reduced from 10% to 2%. The kicker was successfully recommissioned at PSI during October. However, some of the MOSFETs were destroyed during physics runs in December. The cause of the failures is not completely understood but is believed to be due to several reasons including a short circuit on the output of a kicker and damaged fibre optic cables. The MOSFET cards have been returned to TRIUMF: a gate-resistor is being incorporated on the PCB to make the MOSFETs less susceptible to failure resulting from timing mismatch (e.g. due to minor damage to the fibre optic cables). In addition the timing of all the cards is being measured and adjusted, where necessary.

One co-op student worked on this project at TRIUMF during 2004.

A very similar kicker is required at TRIUMF as part of the Five-Year Plan. The co-op student also investigated using magnetic coupling to trigger the MOSFETS, rather than using fibre optics.

Research into a thyratron replacement

Starting in September, with the return of a previous co-op student, now a graduate student at UBC, the Kicker group commenced a research project into replacing high-power thyratrons with IGBT modules for kicker systems. The collaboration with SLAC, into the cause of IGBT failures in the SLAC klystron modulator, resulted in a good understanding of some of the problems associated with using IGBTs in pulsed power applications.

After an initial period researching manufacturers and devices, attention has been turned towards Westcode branded IGBT modules from the UK. These modules differ from the previously analyzed (EUPEC) modules, in that they are encapsulated in a disc-like "hockey puck" package with the top and bottom of the package being the emitter and collector respectively (Fig. 240 – right). The EUPEC modules are encased in a more conventional "brick-type" package with the collector and emitter contacts being bolt-on terminals on the top of the device (Fig. 240 – left).

If the hockey puck device fails it does so to a short circuit, allowing a series stack with redundancy to continue to operate, whereas because of internal bond wires in the brick package, a brick package can fail to open circuit. The fact that the hockey puck package does not fail to an open circuit is a significant advantage over the brick package as it provides improved reliability in a series stack.

Fig. 240. Comparison of IGBT module packaging (EUPEC module on left, Westcode module on right).

In the Westcode IGBT module, each current "path" through the individual IGBT die is the same length and has the same fundamental geometry. In addition the gate-trace is almost completely orthogonal to the main current flow, making it less susceptible to magnetic coupling to the main current paths than was evidenced in the EUPEC IGBT module.

However, while the physical geometry of each path in the Westcode IGBT is identical, mutual coupling to return path(s) is not. During a high rate of change of current, as a result of differences in mutual coupling to the return paths, current crowds to the outermost IGBT die. The current imbalance could potentially be of sufficient magnitude to destroy the IGBT, or at least raise its switching impedance to a degree that would make it unusable for the intended application. Additionally, unlike the EUPEC modules, the placement of the return current paths is very important in this case because of the effect of the return path on the current distribution within the IGBT module.

Using techniques developed while analyzing the EUPEC module, an investigation has commenced into the current sharing between the IGBT die during fast switching. This analysis is being undertaken using several electromagnetic analysis codes, including: FastHenry, Vector Field's Opera2D and Opera3D, and Integrated Engineering Software's Oersted. The results from these simulations are cross-checked with each other, and then fed into the PSpice circuit simulator as linear resistor and coupled-inductor parameters.

The initial results from these simulations show that current sharing might, in fact, be a significant issue with the Westcode IGBT module, and the determining factor appears to be the conductivity of the actual silicon IGBT die. As this parameter varies considerably during the switching process, and is dependent upon the gate-emitter voltage, it is planned to include a nonlinear model of IGBT die in the PSpice simulation. In addition it is planned to carry out measurements, during fast switching, on a representative IGBT module. These experiments are set to commence shortly with the assistance of an IGBT expert, Dr. Patrick Palmer, of the Department of Electrical Engineering at UBC.

TITAN

The TITAN radio frequency quadrupole (RFQ) beam cooler is a device that is employed to cool and collect ions with short half-lives created by ISAC. An rf square wave driver performs 2 dimensional focusing of the ion beam within the RFQ, along a plane normal to the beam's intended trajectory, in an effort to confine ion motion along a stable path; hence the ions can be trapped and collected for extraction. The rf square wave driver, which is based on the MuLan kicker design, employs two stacks of MOSFETs, operating in push-pull, to generate high voltage rectangular waveforms at a prescribed frequency and duty cycle. Currently a 500 V, 2 MHz drive system is in operation, however, the system configuration allows for operation with higher voltage and a repetition rate from 300 kHz up to 3 MHz, continuous.

The Kicker group has provided significant design support for the TITAN RFQ driver, providing advice and carrying out simulations. Simulations include analyses of the capacitance of the RFQ using Coulomb, 3D modelling software from Integrated Engineering Software (Canada), and modelling of the equivalent circuit using PSpice.

MECHANICAL ENGINEERING

Mechanical engineering and design work is initiated by the submission of a Request for Engineering Assistance (REA) form. These are assessed weekly and assigned according to the size, complexity and schedule of the work. Larger tasks requiring engineering input often require a team approach guided by a project engineer. The KOPIO project and the ISAC-II linac project fall into this category.

During 2004 there were 40 ISAC REAs and 34 non-ISAC REAs submitted (this differentiation has been dropped for 2005). There are also lengthy projects that are carried forward from the previous year. As well there is participation of engineering personnel in engineering analyses, FEA, on-site safety issues, design reviews, etc.

ISAC-I

Target module 4, which was scheduled for completion in 2004 to be used for target and ion source development, was rescheduled to coincide with the Febiad ion source development program which will occur in 2005. Work on the module was interrupted as a result of this schedule change and also due to the redeployment of manpower to support the cyclotron shutdown. Work will recommence in the spring of 2005.

ISAC-II

TRIUMF is currently constructing a 43 MV superconducting heavy ion linear accelerator (linac) to accelerate radioactive ion beams from the current ISAC-I level of 1.5 MeV/u to 6.5 MeV/u. The initial stage, phase 1, currently under way, involves the manufacture, assembly and installation of 5 medium-beta cryomodules and phase 1 of the liquid helium refrigeration system necessary to support their operation (500 W at 4.5 K). This phase is scheduled for completion by the end of 2005 and will add 18 MV of accelerating voltage for initial experiments. Phase 2 will add 3 high-beta cryomodules, an extension to the helium distribution system, and doubling of the refrigeration capacity.

Cryomodules

A medium-beta cryomodule consists of 4 two-gap, bulk niobium, quarter wave rf cavities and one superconducting solenoid magnet housed in a vacuum tank and supported from the tank lids. A helium reservoir provides a total inventory of 190 l of liquid helium at 4.5 K under constant replenishment from the refrigeration system during normal operation. The vacuum tank is lined with μ-metal to protect the cryo elements from the earth's magnetic field. There is also a separate box and lid inside, cooled with liquid nitrogen which acts as a thermal shield surrounding the cryo elements. The engineering challenge in the design of a cryogenic accelerator module such as this is the internal support and alignment of the cryo elements. The cryo elements must be as thermally isolated as possible and supported in such a way as to allow for thermal contraction without inducing stored energy in the support structure such that alignment repeatability of $\pm 200\,\mu$m can be achieved over repeated cooldown cycles.

The first cryomodule constructed (designated SCB3) was completed in April, 2004. Thermal testing commenced shortly thereafter in the test area of the SCRF clean room. Thermal migrations of the cryo elements were measured by means of a wire position monitor (WPM) installed in the cryomodule on each of the cryo elements at the beam port level. This allows thermal migrations to be continuously monitored during cooldown and warm-up. This information is backed up by optical targets installed in the beam ports of the end rf cavities. The cooldown cycles were conducted down to liquid nitrogen levels where 85% of the contraction occurs. Three cooldown/warm-up cycles were performed and the repeatability was $80\,\mu$m vertically and $120\,\mu$m horizontally which is well within the specified limit. Subsequent to these tests there were 2 cooldowns to liquid helium temperature in order to establish the "cold offset" (contraction compensation). The cryo elements were adjusted by use of the adjustable support posts such that the beam ports were concentric to the tank beam ports.

The cold-offset was measured as 3.8 mm for the rf cavities and 5 mm for the solenoid. Subsequent to these tests the cryomodule was prepared for rf testing by removal of the WPM and installation of rf ancillaries and the rf tuner. A more detailed report on all of the tests performed on SCB3 appear in the ISAC section of this Annual Report.

SCB3 served as the prototype for the remaining medium-beta cryomodules. There were a number of problems that were dealt with such as the cryo element mounting beam suspension system which was simplified over the original design; the nitrogen thermal shield had a number of fit problems and the μ-metal panels were difficult to install. These and more were changed for the manufacture and assembly of the next two units SCB1 and SCB2. A second new and improved assembly frame was also manufactured such that one was available for both the initial experimental hall assembly stage and for the class 3 clean room final assembly. The initial assembly of SCB1 began in December, 2004 with cold tests scheduled for April, 2005.

Refrigeration system

Due to budget constraints the phase 1 refrigeration system was broken down into subsystems which were all managed by TRIUMF personnel. The subsystems were as follows:

1. Refrigeration system major components, i.e. compressors, cold box, gas management system, oil removal system, and control system.
2. Warm piping subsystem – all the stainless steel pipe work necessary to connect all the refrigeration components.
3. Buffer storage tank – for the storage of gaseous helium.
4. LHe dewar – for the storage of liquid helium produced by the cold box and to be distributed by the CPS/s.
5. Cold piping subsystem (CPS/s) – to transport LHe from the dewar to the cryomodules and clean room test area.

Item 1 – a contract was signed in November, 2003 with Linde Kryotechnik AG of Switzerland to provide a 500 W class helium refrigerator. The components were delivered to TRIUMF starting in early 2004 with the final component, the model TCF50 cold box, being delivered in July (see Fig. 241). Included in this contract

Fig. 241. Cold box arriving at TRIUMF from Linde Kryotechnik.

were process and instrumentation diagrams specifying line sizes and valves. The contract included commissioning the system in April, 2005.

Item 2 – Linde Kryotechnik provided process and instrumentation diagrams as part of the contract. TRIUMF used these to create 2 and 3 dimensional drawings of the warm piping subsystem and the installation within the building in order to create a specification and tender package and engage a contractor. Lockerbie and Hole was the contractor selected and they began work in September.

Item 3 – A custom made, single, vertical storage tank of 90000 USG proved to be far too expensive and it was suggested that 3 smaller 30000 USG horizontal tanks of the propane storage type would work well. These could be stacked on a special frame. Phase 1 would only require one tank initially. Gary L. Nadon Enterprises was engaged to locate one, and a new tank was found at a price within budget. A pad was poured east of the experimental hall and the tank was installed in the fall.

Item 4 – This was supplied from the Chalk River inventory of equipment that TRIUMF acquired. It is an older 1000 l dewar by Cryofab. It was inspected and found to be adequate for the job. It will be installed in early 2005.

Item 5 – This is the most complex task for TRIUMF to manage. It is a specialized technology with only a few manufacturers in the world to deal with. The TRIUMF distribution team visited several laboratories and met with many groups in order to learn as much as possible about the technology. This resulted in a set of drawings depicting what was deemed to be the best solution from the point of view of distribution and thermal losses as well as cost. A specification was drawn up and submitted for tender in December.

SCRF cavity tuner system

Considerable progress was made this year on the development and integration of the SCRF cavity tuner system for the prototype cryomodule SCB3 of the ISAC-II superconducting linac. We successfully completed the assembly and debugging of the electronic wiring/cabling, inside and out, of the prototype servo amp cabinet in the ISAC-II clean room. Stable, low noise, closed loop motor control was achieved for all tuners installed onto the completed 4 cavity cryomodule.

As well, extensive servo control and communication systems integration was performed successfully. Extensive safety interlock software and control subroutines were written for integrating functional control of the tuner motors from the rf supervisory control system. All interlocks and control functions were tested and found to perform as required. This performance was maintained throughout the alpha beam acceleration tests where the tuner position control specifications well exceeded the required specifications.

Engineering – Other

FEA analysis

The TRIUMF 54 ton spreader beam is used for moving the long shielding blocks by crane. Extensive theoretical and FEA calculations were done to determine the safety factors involved after non-destructive testing revealed cracks in the welds in sensitive areas of the spreader beam. An approach was developed for the maintenance of similar spreader beams at TRIUMF, and a company found to independently proof test and certify the beam. All lifting beams at TRIUMF are now being maintained and certified in this manner.

The design of a very high pressure, cryogenic temperature, high performance compound hydrostatic pressure cell was studied for producing very high pressures in target materials. This job is for the μSR group and the final products will be used in local experiments and for export to other laboratories.

The usual salvo of analysis was performed on freshly designed mechanical structures for determination of design integrity, safety factors and approval for fabrication.

KOPIO

Scintillator extrusion Work continued to improve the external profile and shape of the holes in the KOPIO scintillator extrusion. It was nearly perfected to achieve the desired tolerances on size, flatness and straightness for the 1 cm $\times$ 7.2 cm cross section. The process was refined and made fully automatic to run the extruder without operator intervention to fill the die and produce consistent profile. This profile was acceptable enough to go into production.

Then the KOPIO collaboration decided to make the scintillator thinner to 8 mm. A new die was designed and manufactured for this new thickness. Modifications were made on this die and the profile produced is fairly close to the final size. The next run is planned after die and spider plates are polished and electroless nickel plated. We expect to have a mini production run to produce enough scintillator for one module in the spring of 2005.

These 7.2 cm wide extruded scintillator planks will be machined to have tongue on one side and groove on the other side. A gluing jig has been designed to glue 35 of these planks to make 8 ft $\times$ 8 ft sheets for the KOPIO preradiator. This jig is designed to give flat sheets with equi-spaced holes from plank to plank with no glue protruding out of the surface of the sheet. This jig is out for manufacture and has a tolerance of 200 μm over the entire front surface area of 236 cm $\times$ 236 cm.

Preradiator fibreglass panels Preradiator wire chambers required fibreglass sheets varying in thickness from 0.011 in. to 0.25 in. 8 ft $\times$ 8 ft size with 1 oz copper on one or both sides of some of these panels. These sheets are required to have quasi-isotropic mechanical properties. The commercially available standard size is 4 ft $\times$ 8 ft. After a worldwide search, a company (Profile Composites) has been located in Sydney, BC that is willing to try to make these sheets. They have successfully produced 4 ft $\times$ 4 ft sheets meeting our tolerances, with their existing tooling with minimal cost to us. We have obtained quotes from this company to produce sheets for prototype. A visit is planned to look at the facilities and products of this company. So far it looks promising.

Structural The above-mentioned preradiator wire chambers are pressurized with chamber gases. It was desired to optimize the thickness of the lid and the base made of the above-mentioned fibreglass sheets, and also to optimize the location and number of fasteners holding the lid and the base together, to minimize bulging of these thin sheets. A finite element program

ANSYS was used to analyze and optimize these parameters. Based on this study, a thickness of 0.055 in. was chosen for both the base and the lid.

Figure 242 shows a plot of displacements in the lid of the KOPIO preradiator wire chamber under chamber gas pressure.

Cathode strips KOPIO needs a flexible circuit of polyamide base Nova clad material as cathode plane for the wire chambers of the KOPIO preradiator. A company (Sheldahl) has been selected which could make rolls of as much as 12 in. wide kapton based material with 1/2 oz glueless copper deposit. This company has promised an accuracy of 0.001 in. between the traces of copper strips. A minimum quantity for testing has been ordered.

Q_{weak}

Contract management services are being provided to supply coil carrier and coil carrier stiffener plates for the QTOR spectrometer for the Q_{weak} experiment at Jefferson Lab. Four 5 in. × 81 in. × 206 in. plates and sixteen 1.25 in. × 36 in. × 152 in. aluminum plates are needed. Aluminum supply has been very tight in 2004 and mills were not accepting orders until late into the fall at which time they would assess their positions and may or may not take orders. Suppliers have been found who, because of their quota allocations with the aluminum producing mills, were able to place orders of aluminum plates in these circumstances for timely delivery to the project.

Budgetary quotes have been obtained from several machining centres to machine these plates to final shapes.

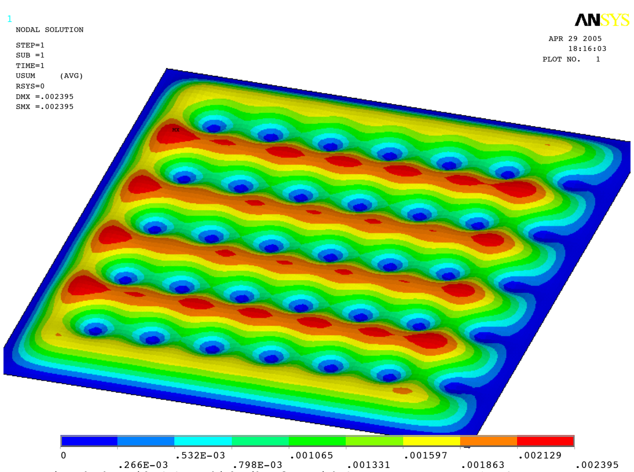

Fig. 242. Plot of displacements in the lid of the KOPIO preradiator wire chamber.

Engineering – Victoria

ISAC target development

High temperature vacuum chamber The design and construction of a high temperature vacuum chamber is complete, which includes a double-walled tubular graphite filament and an effusion cell capable of reaching 2300°C. The crucible, made from tantalum, was used for a series of tests with samples such as lithium, sodium, potassium, rubidium, cesium, boron, aluminum, gallium, tin, lead, arsenic, antimony, bismuth, and indium, to determine the out-gassing properties of materials at high temperatures for future consideration in target development.

From the data that were collected and analysed at the University of Victoria through the summer, modifications are under way to include a 45° filament ribbon. This will increase the opportunity to observe diffusion characteristics as the atomic beam from the crucible interacts with the 45° filament and is directed into the RGA through a cross beam ionizer. The design of this vacuum chamber has also been used for other experiments at TRIUMF, and a patent application is under way for its design.

ISAC Febiad ion source An improved filament design for the ISAC Febiad ion source was required to replace the traditional wound wire filament, which began sagging and causing electrical shorts. With the success of the tubular filament in the high temperature vacuum system, a similar concept was considered to replace the existing filament.

A single-walled tubular design was created by replacing the graphite from the high temperature vacuum system with welded tantalum foil, as the higher vapour pressure of graphite prevented its use for this application. Initial testing at TRIUMF has shown that this design is more stable, demonstrating a resistance to sagging while being subjected to high temperature, around 2200°C, from power supply heating.

A double-walled tubular filament has also been created, and testing for this design will begin in 2005. Using a double-walled system increases the length of the filament, allowing twice the thickness of tantalum foil to be used without an increase in current, which doubles the expected lifespan of the filament. Further analysis and design for both the single-walled and double-walled concepts will continue in 2005, which should provide a more reliable filament for the ISAC Febiad ion source.

Time projection chamber (TPC)

A TPC is the leading candidate for the central tracking system of an experiment at the international linear collider. The physics goals for the project require an exceptionally precise tracker, and the University of

Victoria Engineering group has been involved in the proof of principle demonstrations with a prototype detector. The prototype was modified to accept UV laser beams and a complex laser delivery system (LDS) was constructed for the TPC test to be performed in a 5 T SC magnet at the DESY Laboratory. The system was capable of delivering one or two beams at various locations within the TPC chamber under remote control. The mechanical design for the LDS was completed in the summer, and was operated with the TPC prototype at DESY in early fall. The tests were very successful and results are explained in the Science Division section of this Annual Report. The experience gained from the TPC studies for the linear collider has opened the door for the Engineering group to be involved in leading the construction of the TPC modules for the T2K experiment in 2005.

K2K calibration manipulator arm

A device was needed to extend the calibration capabilities for the K2K neutrino detector at KEK, Japan, to provide off axis calibration beyond the current system, which consists of hanging a wire dropped through a tube into the water filled detector. The Engineering group prepared an initial concept for a multi degree of freedom manipulator arm, which could be positioned with locking segments into the detector and used remotely for precise calibration of the photomultiplier tubes (PMT).

After successful presentation of the PMT calibration proposal while visiting the facilities at KEK, the conceptual design was approved and final dimensions were confirmed. Drag force analyses were performed to determine safe working speeds, applied torques on the joints and motor specifications for the manipulator, as it will be submerged in water during use. The formal design of the K2K calibration manipulator arm was designed and is being manufactured with plans for assembly and testing at TRIUMF prior to operation at KEK in 2005.

ISAC charge state booster (CSB) insulator

A strength analysis for the ISAC CSB insulator that failed in operation was required so recommendations could be made for an improved design with appropriate materials. Forces acting on the insulator were determined from the magnetic field acting on the steel pole of the CSB; however, it appears that improper sizing and possible material flaws of the supplied insulator were to blame for the failure. The improved design has successfully replaced the original insulator after minor modifications were made.

Safety

Technical support was provided to better understand the certification requirements for radioactive material packaging as part of TRIUMF's waste removal system in conjunction with TRIUMF's quality assurance program. After determining the annual leak testing and servicing procedures required for continued use of the packaging, along with the appropriate codes for the transportation of radioactive materials, this information was given to Safety personnel to develop appropriate flow charts.

Remote handling

An engineering load review was needed for the cyclotron elevating system hoist frame used by Remote Handling. This hoist is used during shutdown periods for removal of the cyclotron elevation system bearings and their components. While initial calculations suggested that continued use of the system was safe, the use of the system could be simplified if several modifications were considered. The re-design of this system will continue in 2005.

Engineering – Carleton

Enriched Xenon Observatory (EXO)

Engineering at Carleton University assumed the lead engineering role in the development and design of the EXO 200 kg prototype. With the copper cryostat already designed, the next major components to be designed were the lead shielding and an overhead crane, that resides in the clean room with the experiment, used to assemble the shielding (see Fig. 243). As the experiment is to be set up and tested first at Stanford University, then moved to an underground location at

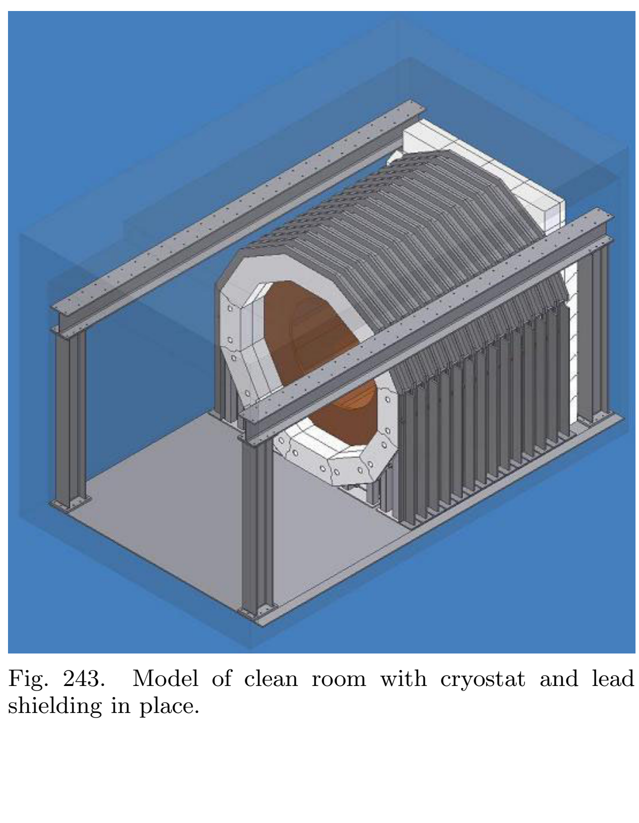

Fig. 243. Model of clean room with cryostat and lead shielding in place.

the Waste Isolation Pilot Plant (WIPP) in New Mexico, the lead shielding is designed in blocks that can easily be assembled, disassembled and reassembled in the two locations. It is necessary to disassemble the lead for moving because the total mass of lead is approximately 54 tonnes and the handling equipment at WIPP has a maximum load rating of 30 tonnes.

The experiment occupies 6 portable clean room modules that need to be lowered into the mine and transported approximately 640 m underground to the experiment location. Engineering is under way to be able to move these modules, the heaviest being 27 tonnes, in the confined tunnels of the mine.

PLANNING

This year the Planning group was involved in planning, scheduling, coordinating and expediting several sub-projects for ISAC-II (medium-beta cavities, wire position monitor, cryogenics system, high-beta cavities, charge state booster (CSB), HEBT transfer, H-HEBT, ECR); planning and coordinating activities for two shutdowns (December 22, 2003–April 15, 2004 and September 13–October 6); ISAC experimental facilities (TIGRESS, TITAN); and M20Q1,2 refurbishing. The Planning group was also extensively involved in preparing manpower and cash flow estimates for the Five-Year Plan (2005–2010), as well as setting up a new job recording system for the Machine Shop, and setting priorities in the Machine Shop to meet various milestones for ISAC, Cyclotron and Science division projects.

Technical details and progress on PERTed activities for ISAC are described elsewhere in this report.

Shutdown Activities

There were two shutdowns during the year: the winter shutdown (December 22, 2003–March 17, 2004 for ISAC beam production, and beam to proton therapy and PIF, and to April 14, for BL1A), and a fall mini shutdown (September 13–October 6).

Winter shutdown

BL1A activities started early with the removal of 60–70 shielding blocks from the meson hall on December 29–30, to get a headstart for shutdown work.

Major jobs completed by the Remote Handling, Beam Lines, Vacuum and Diagnostics groups in the meson hall included: repairing several BL1A vacuum leaks in the T2 area, 1AQ14, M8 blank-off flange, M20Q1 and M20B2 O-ring, removal and replacement of several crumbling blocks near 1AM10 and T2 water package, and installation of new custom designed shielding blocks (as needed), repairs of M20Q1 water leaks, M20 separator window valve, M13 beam blocker work, T1 and T2 target, and water packages MRO. Very good vacuum was achieved in the T2 area after repairing these vacuum leaks. While the area was accessible, a remote video survey was taken of the M20 front-end area to prepare for a future installation of radiation hard components. To help reduce the dose to technical experts, several volunteers were used to help with the replacement of up to 6 crumbling blocks. Due to several additional MRO jobs and high dose levels, the removal of the M11 septum and the repairs of a small vacuum leak in M15 were postponed to the January, 2005, shutdown.

In the vault, the cyclotron lid was not raised until January 19 in order to do the elevating jacks maintenance (station #8 and some calibrations). After that the lid was up until February 23 to complete the maintenance jobs for probes (2C extraction foils, LE inspection, replace NW periscope prism), engineering physics (MRO on Q3 correction plate, replacement of radiation damaged cabling for some upper correction plates as a quick repair with a plan to do a more thorough job in the next shutdown). The RF group completed several jobs that included: periscope survey, GAT position measurement, HAT adjustment for resonator #10, thermocouple replacement, chore pads replacement in UQ3 and UQ4, and resonator water leak test. The removal and reinstallation of the STF target was also completed to correct the misalignment and repair the limit switch. This job became more complex and took longer than scheduled due to a persistent leak (at the seal between the STF target housing and the water column above it) that was finally repaired by using a different style clamp and mocking up the repairs in the hot cell.

Vault work on the jacks (station #11, check all jack counters) continued with the lid down while the cyclotron was baking, pumping and leak checking. The main magnet was energized on March 4, followed by injection and cyclotron tuning and a beam in 2A with TM1 at ITW on March 17. BL1A beam production started on April 14, due to the heavy workload planned in the meson hall.

Beam line 2C contributed up to 50 mSV to the total dose of 190 mSV for the whole shutdown distributed over 105 workers.

Fall mini shutdown

1A shutdown was from September 13 to October 6; 2A shutdown was from September 22 to October 4.

It was decided to shut beam off to 1A a week early in order to repair 1AV8 and to allow the triplet to cool down for 2 weeks before doing repairs to it. The major jobs completed in the meson hall included: repair 1AVA8 leak, 1AQ15 water flush and flow test, 1AQ14 vacuum leak, T1 and T2 water package MRO, replace

HV cables to beam spill monitor #56, as well as many MRO jobs.

In the vault, the beam was off September 22, and turned back on September 28. During that time the major jobs completed were: 2C4 monitor wiring and check wire scanner alignment, replace WCP flow meter, check phase probe wiring, C/P cabling, as well as MRO jobs by RF, Vacuum and Plant groups.

DESIGN OFFICE

ISAC received the majority of billable hours again this year (55% or approximately 8540 hours). ISAC-II used 5160 hours for the design of the S-bend to ISAC-II, the SCB3 prototype and SCB2 production medium-beta cryomodule, and LN2 shield; GHe (from storage to compressor and refrigerator), LHe (from refrigerator to cryomodule) and LN2 distribution subsystems; TIGRESS prototype, EMMA proposal, charge state booster (CSB) development and ISAC-II experimental beam lines.

ISAC development and MRO used the rest, with target and target module improvements, laser spectroscopy (source and port shielding), OLIS upgrades, LEBT extension to GP3, CSB development, TITAN (RFQ off-line test and platform for installation in experimental hall), LTNO Faraday cup and beam transport upgrades, conceptual design for β-NQR and on HEBT, improvements to rf tuners, DRAGON and TUDA.

TRIUMF's main program, MRO and upgrades, continued with beam line upgrades on 1A, M9, M11, M13, and M20. Cyclotron upgrades were made to: rf power switching devices, PA tube filament and hairpin inductor, development of new HE and LE probes. Proposals were made for future upgrades to the 2C solid target facility. (Total main program = 26% or approximately 4110 hours.)

External projects continued with CERN 66 kV power supplies as-built documentation, xenon detector for LADD, KOPIO detector prototype, and AGS Brookhaven upgrade and kicker design (external projects = 17% or approximately 2670 hours).

Photographic and visual art services provide support for seminars, conferences, and publications, such as the Annual Financial and Administrative Report, the Five-Year Plan brochure and material for TRIUMF's corporate presentation and Outreach Program. A large part of our miscellaneous hours go to visual art services and, this year, included training hours for our SolidWorks users and a new junior/intermediate designer.

Following the policy statement of December, 2003, "CAD Strategy at TRIUMF", SolidWorks 3D modelling software has been adopted as the platform of choice for all TRIUMF users. We will extend this to support a network of designers through the next Five-Year Plan. The close relationship between software for engineering analysis (COSMOS) and CNC machining (MasterCam) is proving to be both powerful and efficient. Network 2D CAD is available through PC Support and currently provides access for 75 part-time users on a 9-seat network. This represents a considerable savings on the maintenance required by the (previously) 55 single seat users.

MACHINE SHOP

Over the past year the Machine Shop has gone through a restructuring process that entailed implementing the following procedures:

1. Initiating a system of setting priorities by collaborating with TRIUMF's project coordinator.
2. Restructuring the shifts in order to maximize efficiency.
3. Purchase of a second CNC vertical machining centre. Both machines have already had a major impact on the quality, quantity and versatility of work produced in the shop.
4. Recruitment of four highly skilled technicians, three of whom are are experienced programmer/machinists using software such as MasterCam and SolidWorks.
5. Linking up to the Design Office database to expedite the transfer of solid/Autocad files to the HAAS machining centres and to facilitate the speedy procurement of quotes by e-mailing drawings to companies we consider awarding contracts to.

Major projects worked on included the TIGRESS prototype, TITAN RFQ, and cryomodules 1 and 2. The Machine Shop kept pace despite a heavy workload and the continual shortage of manpower due to retirements and lag time, as a result of the recruitment process.

The Machine Shop continues to support local industries by sub-contracting out work that is beyond the capacity of the shop or large volume components that are extremely time sensitive in nature. Speciality companies which provide anodizing, electro-polishing and copper plating among others are also supported.

Table LI demonstrates utilization of the Machine Shop by TRIUMF divisions and other user groups.

The goal for the coming Five-Year Plan is to continually upgrade and modernize the Machine Shop by replacing old and obsolete machinery that is not cost effective to maintain. As designs are becoming more complex it is becoming increasingly difficult to machine these components on manual machines, consequently CNC machining is the only option (see Fig. 244).

Table LI. Machine Shop utilization.

ISAC development	4.48%
Science	22.14%
ISAC operations	7.27%
Nordion	5.78%
ISAC-II	41.94%
Cyclotron operations	7.59%
Cyclotron refurbishing	5.48%
CERN	0.16%
Affiliated institutions	2.42%
NSERC	1.80%
Miscellaneous (CFI)	0.16%
Site infrastructure	0.38%
Accelerator Technology and Administration	0.19%
AGSUPER and Royalty	0.18%

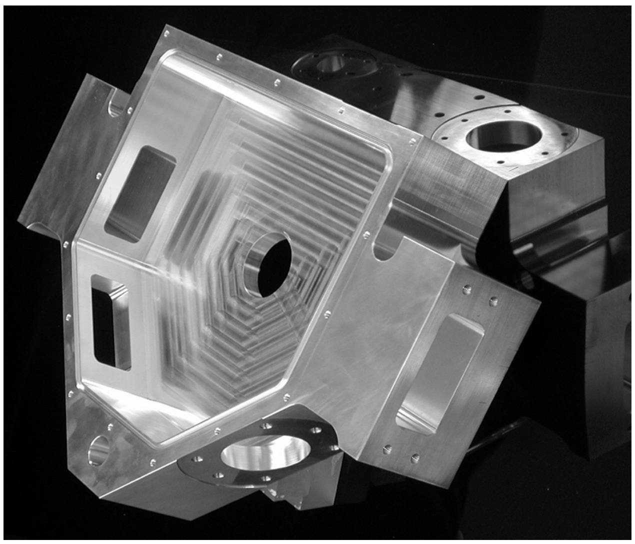

Fig. 244. Part made from a solid block of aluminum using the CNC machine.

BUILDING PROGRAM

Design and management of minor construction projects

The department was involved in a number of small construction projects around the site such as the He compressor room roof reinforcement, CRM water pipes trench, and the He tank slab (see Fig. 245).

Structural design and engineering review

Structural design was done for a variety of structures including the TITAN installation platform and the He tank slab. Engineering review was performed for various small structures like cranes, trench bridges, etc.

Construction review

Besides the reviews of minor construction projects managed by the department, construction reviews of the free standing crane in the ISAC-II building and the clean room bridge crane were also done.

Fig. 245. He tank for the ISAC-II refrigeration system.

Architectural design

The Building department worked on the architectural re-design of the lobby and cafeteria areas in the main office building. Architectural re-design was also done for the mailroom in the main office building.

Management of maintenance and repair work

During the course of the year, approximately \$100 K was spent on maintenance and repair work at various TRIUMF buildings and around the site. This included the annual maintenance and repair contract, interior and exterior painting, upgrading the parking lot and repairing some of the access roads.

Management of landscaping work

The Building department continued with the management of the landscaped areas on the site. Most of this work is done through an annual landscape maintenance contract.

Drawing library maintenance and services

The department continued with organizing and updating the site and buildings drawing library, and provided services of creating new and issuing existing drawings to many “in-house” clients.

ELECTRONICS SERVICES

Overview

In 2004, the Electronics Services group continued the tradition of offering services to a large percentage of the site. This year was no exception from commissioning a computer network at the new TRIUMF House, down to repairing cables in the bowels of the cyclotron vault. Twelve members of this group handled a great variety of services including: consulting, design, assembly, repair, manufacturing, testing, programming and debugging. This department also handled approximately 12 tons of electronics goods for recycling.

Electronics Repair Shop

Significant effort was put into implementing the directives of the new recycling program (necessitated by the large volume of dated equipment deemed to be obsolete) wherein otherwise unavailable parts are salvaged for re-use, before the equipment is sent out for environmentally sound disposal. Also, numerous repairs were performed on the readout displays, motor controllers, and servo controllers for the Machine Shop lathe and milling machines. Otherwise, most of the maintenance activity involved the repair and calibration of a total of 193 various electronic devices, including: 26 monitors and terminals (comprising 15 colour units and 11 monochrome units), 50 power supplies (of which 8 were NIM types, 13 were CAMAC types, 11 were high-voltage types, and the remaining 18 were miscellaneous types), 74 nucleonics modules (including 62 NIM devices and 12 CAMAC devices), 11 test and measurement instruments, and 32 miscellaneous devices of an electronic nature (vacuum pump controllers, etc.).

PC Support/Desktop Services

The Desktop Services department continues to provide a strong support service for the TRIUMF community. Typical responsibilities include support for Windows operating systems and common Windows applications as well as recommending and maintaining PC, notebook, and server hardware. Other provided services include file serving, scheduled backup services, virus control, stocking spare parts, as well as assisting with network, e-mail, and printer connection issues.

The PC backup service has been upgraded from a tape based system to disk based utilizing a new server with RAID protection and new backup software. This has improved the capacity, speed, and reliability of the backup service. Several Dell servers and Windows 2003 server licenses were purchased to create a Windows server environment that will replace our Novell services and allow the Windows services provided by TRIUMF computing services to be amalgamated with our services.

The increasing threat of spyware and malware has caused us to review many products to help protect our Windows systems. This is a quickly evolving problem requiring immediate attention yet no single product is available to adequately protect us. Solutions will be available soon but in the meantime we are spending many hours cleaning up infected systems.

PC hardware specifications remained relatively static this year as there was not much new product being introduced. This has led to many nearly identical PCs being ordered this year. The Intel motherboards being used in most configurations are very stable hence leading to fewer service calls for our department. We continue to see higher than expected hard disk failures, however, the problem is not confined to a single manufacturer. We are now recommending disks with a five-year warranty in the hope that reliability is improved. It appears that the LCD monitor has achieved a price point where it has replaced the CRT monitor. Over 90% of new monitor orders are for LCDs.

Help desk activities have increased in comparison to 2003. PC hardware related tasks have grown by 20% to 369 tasks. Software related jobs increased by 57% to 514 tasks, and network related activities decreased by 23% to 107 tasks. The number of people accessing this department's servers has increased by 32% to 162. The PC backup service is utilized by 60 PCs which is up from 51 PCs last year. The backup size is now at 194 Gbytes for the PCs and 99 Gbytes for the servers. The networked AutoCAD 2000 pool consisting of nine licenses has 76 registered users.

Experimental and Target Technical Support

Much of the year was spent on rework and repair of the MuLan Kicker project. Another major project involved work on the ISAC cryomodule tuner system and packaging a prototype system. For the 8π group, an equipment protection and fire alarm system was proposed, designed and installed. Ongoing background tasks included items such as target maintenance and repairs.

High Level Software Support

The past year included several projects for a variety of groups at TRIUMF.

The principal project was the control system for the LaserBall manipulator system for the K2K collaboration. This system used four motors, solid state inclinometers, MIDAS and MatLab to operate the arm. Preliminary design of an automated wire plane measurement system was started for the detector facility. This is a motorized camera system that will measure wire positions on drift chamber frames. A solid state bridging firewall was implemented to protect the BL2A and BL2C extraction probe computers from uncontrolled access over the network. This also resolved problems with an excessively noisy network affecting the computer's operation. A rewrite of the magnet survey system was started to replace the software running on a DECStation 5000 and the ULTRIX operating system. The Java acquisition system (JACQ) was used for this. Support for the Data Acquisition group included work on TIGRESS, Expt. 920 and LTNO. This included data acquisition equipment, software development, and hardware repair. The ISAC-II superconducting cavity washer was completed, allowing automated washing of the cavities before installation into the accelerator.

Technical Support

Major work for Technical Support included the design and installation of a prototype servo system and supporting electronics for the ISAC-II cryomodule tuners. Another main project involved the design, construction and installation of a PLC-based control system for the TWIST experiment TEC chamber. Support was provided for the re-cabling of the cyclotron main tank periscope systems. Printed circuit boards were designed to support LTNO as well as some mechanical design, and assembly and wiring for a gas control system for TIGRESS. There were approximately 30 small jobs, which included items such as helping the RF group debugging software and improving documentation for an rf multiplexer switch.

Site Communications

Site Communications worked closely with the Central Computing department to plan and prepare for installation of redundant fibre optics cable links on the site. A related job was the transfer of existing copper cabling to the new rack in the MOB. Communications was also involved in planning, coordinating, and preparation, with a pressing deadline, to reach an agreement to dig a trench from the MOB to the proton hall extension and install various conduits and pipes. A direct savings of $10,000 was realized by TRIUMF. With only a few hours notice, the group coordinated with fibre installers to determine the routing requirements at TRIUMF House, as well as patching the copper network in time for the opening day. In order to preserve data and save space, help was given in archiving some 270 floppy disks and transferring them to CD media.

Electronics Shop

Work for CERN was a major component for our group. The Electronics Shop spent a lot of hours every month in 2004 producing and modifying boards and making up fibre optic cables for CERN. Controls required modifications to 20 units of our power and diagnostic 0918 modules. We replaced two large sets of correction plate cables that had suffered radiation damage over the last 30 years. For the KOPIO project we assembled delay boxes. Other best sellers during the year were visual scalers and flowswitches. Making cables for all projects on site is a priority of the Electronics Shop. Groups like DRAGON, TUDA, TITAN, LADD, TIGRESS and all others require lemo cables, ribbon cables, high voltage, delay cables and other one-off specials on a regular basis.

ELECTRONICS DEVELOPMENT

The majority of the group's work this year was again in support of the ISAC control system. Several specialized hardware modules were constructed for ISAC and further development continued on the data acquisition board (DAB) for CERN. Two members of the group visited the Canadian Light Source (CLS) to discuss controls for the helium refrigeration system for ISAC-II. Two members attended a one-week course on new PLC programming tools. The group received 29 requests for engineering assistance (REA) and 23 engineering change requests (ECR).

ISAC Support

The group continued to provide all the hardware installation, maintenance and upgrade support for the ISAC control system.

For TITAN, an existing 6-channel 500 V VME module design was modified to provide 6 channels at 2 kV. The group also assisted in the manufacture of FET modules used for the TITAN RFQ. A module was designed and installed to handle the gas and vacuum on the HV platform.

Assistance was provided for the installation of the Linde Kryotechnik helium refrigeration control system.

With the experience gained from the rf amplifier monitoring system, it was decided to move towards a more distributed vacuum control system with the installation of the S-bend beam line. Higher density convectron gauge readout modules were redesigned as single channel versions to allow for installation at the device, which eliminates the need for extra cabling.

Modifications were undertaken in the ICB target conditioning station to accommodate the testing and development of a Febiad ion source.

The CAN-bus controllers' installation and cabling for the 85-magnetic element HEBT, MEBT, and DTL power supplies were reconfigured to allow for better maintenance and individual controller reset.

Three beam current integrator modules were installed for 8π.

A hall probe readout module was modified to allow faster magnet scanning and installed in the CSB test stand.

CERN

The DAB-64x design in VME-64 form-factor was finalized and manufactured. Five prototypes were assembled, two of which were sent to CERN for beam loss monitor mezzanine development. Firmware development is ongoing.

The group assisted in the production of 30 DAB-III modules for CERN.

Engineering Support

The group provided engineering support as members of technical committees, design review panels and the QA task force. The group also provides electronics engineering assistance to other groups at TRIUMF. These included the Central Controls group, the Safety group, and the RF Controls group.

This year a new version of the PET rabbit pneumatic transmission controller was implemented. Eleven new transmitters were designed, built and installed in the manholes along Wesbrook Mall between TRIUMF and the UBC Hospital. The new transmitters provide both the hospital and PET staff with information about the location of the rabbit during the trip from TRIUMF to the hospital. The controller for the send station was replaced with a PLC based system.

Layout, assembly, and wiring of a methyl iodide chemistry control box were also started for the PET group.

A photo detector and amplifier/shaping module has been designed for evaluation as a gamma detector for PET. A frequency to voltage stage will be added if the detector is suitable for the application.

Experimental Support

The DRAGON 300 kV power supply stack was rebuilt with a redesigned capacitor board after the stack failed in operation.

More functionality was added to the VME based Gate Logic board as requested by the μSR group.

Work continued on the design of pre-amplifier electronics for a silicon E-deltaE detector for the DRAGON beam line.

PSpice simulations were performed to evaluate and improve the pick-up circuit and rf transmission system of the LTNO detector.

A 200/400/800 MHz summation amplifier capable of the faster rise times achievable with the new detectors was constructed.

Secondary Channel Support

A plug-in ADC module was designed and retrofitted into the M13 secondary channel motor controller. This module provided a more accurate position readback and hence a more accurate positioning of the M13 slits and jaws.

New Hardware Designs

Several new modules were designed and built:

- The VME high voltage module was redesigned to accommodate ELCO HV plug-in modules, as the Spellman modules have been discontinued.
- The VME QSX module was reworked to include a DAC and an upgraded FPGA.
- A CAN-bus to GPIB and serial converter module was developed to provide greater flexibility in interfacing to more exotic devices, such as laser controllers.
- In order to generate the necessary frequencies required for the TITAN RFQ, a version of the previously built VME POL SYNTH module was built with modified firmware.
- Optical isolation was added to the remote integrator module.
- The pulse controller module, originally developed for the PSI kicker, was modified for use with the TITAN RFQ.
- An Altera Cyclone board was designed and built for KOPIO development. Additional support was provided for developing applications with the NIOS-II embedded processor.
- A pre-amplifier and VME digitizing/signal processing module was built for use in the Q_{weak} experiment at Jefferson Lab.
- A 4-channel modulated frequency synthesizer has been designed as a VME module for β-NMR.

Infrastructure

The group's Web-based REA tracking system was expanded. Search and browse capabilities were increased. NCR tracking was included and automatic communication with the ISAC NCR system was implemented.

The group's computer network was expanded to include the controls working area next to the ISAC control room and the controls development room in the ISAC-II building.

The use of the Mentor Graphics Expedition software package for schematic design and PCB layout was abandoned after a time-consuming trial period because the package proved to be non-stable. The newest versions of the Protel tools have addressed most of the group's concerns, which had earlier prompted the switch to Mentor Graphics.