II. OPERATION AND DEVELOPMENT OF ATLAS

OVERVIEW

This and the following section report on the operation of the Argonne Tandem Linear Accelerator System (ATLAS) as a national user facility and related accelerator physics R&D projects. ATLAS is used for basic research in nuclear and atomic physics, and occasionally for other areas of research and development, such as material science. Over half of the beam time is allocated to experiments for which the spokesperson is an outside user. Recent ATLAS operating performance and related development projects are described. ATLAS personnel are also involved in developing technology in support of a future advanced facility for beams of short-lived nuclei based on ATLAS. Projects related to the exotic beam facility are also described.

ATLAS operates on a seven-day-per-week schedule. The installation of GAMMASPHERE was completed in December 1997 and the experimental program with GAMMASPHERE began in January 1998. For the 1999 fiscal year, ATLAS provided 6054 hours of beam time for research, surpassing the 6000-hour goal. Beams were provided from twenty-nine different isotopes at intensities up to 250 pnA. Statistics about beam hours and users are given in Table II-1. 74% of all beam time was used by GAMMASPHERE in FY1999. The GAMMASPHERE research program will end in mid-March, 2000 after which ATLAS plans to enter a maintenance period for approximately six weeks.

ATLAS continued to provide a range of radioactive species with intensities generally in the range of 10^5 to 10^6 particles per second. This year 6.4% of all beam-time went to radioactive beams. The fraction of beam time devoted to these low-intensity rare beams decreased this year due to the demands of the GAMMASPHERE research program. Beams of long-lived ($T_{1/2}$ > 2 hours) species produced at other facilities and placed in the ATLAS tandem ion source and beams of short-lived species produced in-flight by inverse-kinematics reactions have been developed at ATLAS. See the Heavy-Ion Research section for a summary of recent physics results from experiments using radioactive beams.

Table II-1. SUMMARY of ATLAS EXPERIMENTS and USER STATISTICS

	FY 1999 (actual)	FY 2000 (extrap.)	FY 2001 (pred.)
Beam Use for Research (hr)			
Nuclear Physics	5586	5000	4600
Atomic Physics	292	250	150
Accelerator R & D	48	100	150
Other	120	110	100
Total	6046	5460	5000
Number of Experiments Receiving Beam	56	50	45
Number of Scientists Participating in Research	251	150	130
Institutions Represented			
Universities (U.S.A.)	23	14	14
DOE National Laboratories	5	5	5
Other	33	20	20
Usage of Beam Time (%)			
In-House Staff	38	35	35
Universities (U.S.A.)	35	38	40
Other DOE National Laboratories	12	12	10
Other Institutions	15	15	15
Total	100%	100%	100%

A. OPERATION OF THE ACCELERATOR

(R.C. Pardo, D. Barnett, B. Batzka, J. Bogaty, B. E. Clifft, S. Daley, A. Deriy, R. Jenkins, A. Krupa, S. McDonald, B. Millar, F. H. Munson, Jr., A. Peevy, D. R. Phillips, D. Quock, A. Ruthenberg, R.H. Scott, J. R. Specht, P. Strickhorn, R. C. Vondrasek, G. P. Zinkann)

a.1. Operations Summary

The operation of ATLAS during FY1999 was dominated by the presence of GAMMASPHERE and the associated fragment mass analyzer (FMA). For FY1999, approximately 74% of all beam time provided by ATLAS went to experiments using GAMMASPHERE. The primary goal of operation was to provide the requested beams with as little unscheduled downtime and as high a reliability as possible. The results for FY1999 are tabulated in Table II-2 and show that ATLAS provided 6046 research hours with beam-on-target or available. This performance was achieved with an operational reliability of 93.2%.

The excellent facility performance was achieved during a period of high personnel turnover. During a significant portion of FY1999, ATLAS operated with only three fully qualified operators and one operations supervisor. Even so, not one shift was left uncovered during that period. The dedication of the operator group to providing coverage for ATLAS deserves our sincere thanks and appreciation.

ATLAS provided a total of 29 different isotopes for research in FY1999. The distribution of species is shown in Figure II-1. The demand for these isotopes was amazingly uniform, with no single species accounting for more than 10.7% of all beam time during the year. Over 37% of all beam time was for isotopes heavier than ^{58}Ni, a return to a more typical distribution for ATLAS from last year's rather light-weight distribution when only 20% of all beam time went to beams heavier than nickel.

The new ion source, ECR-II, is now fully operational and provided approximately 13% of all beam time during the 1999 calendar year. The associated new bunching system is still undergoing development, especially the traveling-wave chopper. That system is now nearly fully operational and with the ECR-I upgrade project nearing the construction phase, ECR-II will provide a significantly increased portion of all beam time during FY2000.

With two ECR sources in operation it had become imperative that additional effort be directed to the operation of these sources. A second ECR source operator/engineer position has been created and staffed with a person from the operator pool (R. H. Scott). This enhancement to the staffing addresses a crisis situation in which the facility was effectively dependent on a single person for 7-day 24-hour coverage.

The tandem injector continues to be a useful component of the ATLAS facility. The tandem was used for beam delivery 35% of the scheduled time. The tandem has assumed an important role in the ongoing radioactive beam program at ATLAS today. It is used for the acceleration of long-lived isotopes made at other facilities such as ^{18}F, ^{56}Ni, and ^{44}Ti. The development of these beams was described in past annual reports.

A new SNICS negative ion source was purchased in FY1999 so that one source may be dedicated to radioactive beam production. As the ongoing RIB activity has progressed, longer-lived species have become the focus. The problem of maintenance of these, now radioactive, source bodies has become more difficult. Dedicating one source to stable beams will improve the situation. In additional, a new hot lab facility will be constructed in FY2000 for servicing these ion sources. This facility will be constructed in a room adjacent to the tandem vault which previously was used for negative ion source development activities.

The use of the original linac target area, Area II, has increased significantly during the past year as the Canadian Penning Trap Facility gears up for operation. This area had fallen into almost total disuse over the past few years and was bypassed in the various improvements implemented at ATLAS over the past 15 years. This year we started the process of bringing that area up to the standards of the rest of ATLAS including a fully functioning ARIS implementation and computer control of all beamline components. These upgrade activities will be completed in FY2000.

Table II-2. ATLAS Reliability and Hours of Operation

Time Period	Research Beam Hours	Reliability*
FY1999	6046	93.2%
Calendar 1998	6176	92.7

Reliability = 100(Total Research Hours)/(Total Research Hours+Unscheduled Maintenance)

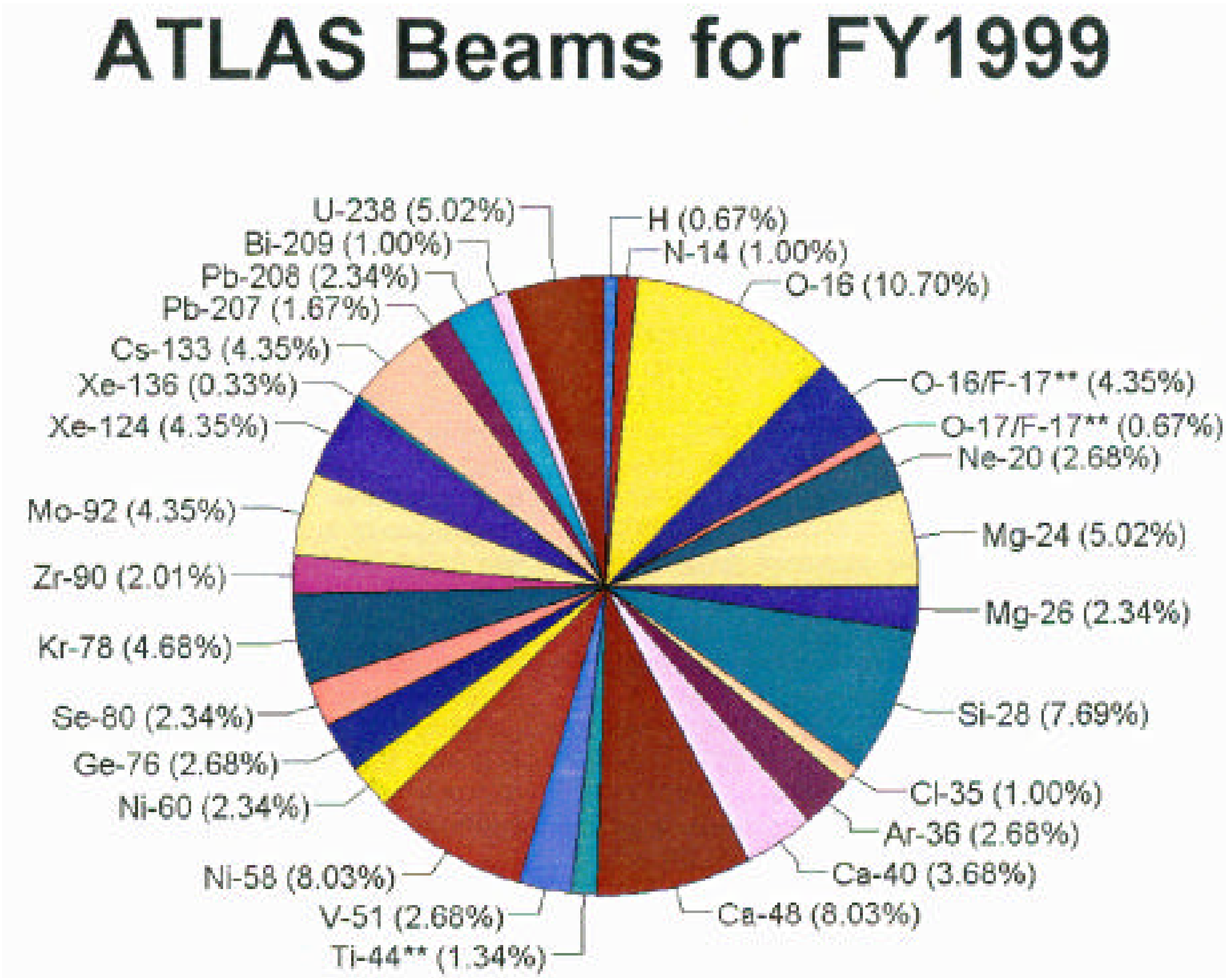

Figure II-1. Distribution of beam time, by isotope, provided by ATLAS in FY1999. A total of 29 different isotopes were provided to the research program. Radioactive beams of ^{17}F and ^{44}Ti comprised 6.4% of all beam time in FY1999.

B. DEVELOPMENTS RELATED TO ATLAS

b.1. Status of the 14-GHz ECR Ion Source (ECR-2) (R. Vondrasek and R. H. Scott)

ECR-2 has continued to be used for the injection of beams into the PII linac. Due to its higher beam output it has been used for most of the runs using gas as a feed material. Solid material development has continued with an emphasis on the sputtering technique (employed at ECR-1) as well as the introduction of magnetic materials (Fe, Ni, Co). The high temperature oven has been used to produce beams of ^{76}Ge, ^{84}Sr, ^{152}Sm, and ^{208}Pb.

The sputtering technique has been used at ECR-1 very successfully for the past several years. A solid piece of sample material is introduced into the plasma chamber and a negative voltage is applied to it. The plasma ions accelerate towards the sample and sputter material from its surface. This technique was utilized with many materials (iron, nickel, molybdenum, lead, and uranium) with great success. We are developing this technique at ECR-2 as well. We have made good progress except with magnetic materials. Due to the close proximity of the sample to the edge of the plasma chamber slot, as well as the presence of the high magnetic field from the hexapole, material sputtered from the sample creates a short between the sample and the chamber. Further work in this area is required. In the interim we are delivering these beams (iron and nickel) out of the high temperature oven.

We used the sputtering technique at ECR-2 to produce stable beams of ^{208}Pb and ^{238}U. The uranium was produced using a sample of depleted uranium metal, which was biased to 3.0 kV. The lead was produced using a natural metal sample with a bias voltage of 1.1 kV. A lead beam was produced using the oven under the same source conditions and the results confirm that the oven technique produces a higher peak charge state than the sputtering technique. However, both techniques are capable of producing >1 puA of lead. Results are summarized in Table II-3.

Table II-3. Performance of ECR-2 for Heavy Metal Beams

Q	**^{238}U Sputtering**	**^{208}Pb Sputtering**	**^{208}Pb Oven**
23		27.5	14.5
25	11.8	31.0	21.5
27	8.2		
28	6.5	12.5	24.0
32			8.8

All intensities are in euA as measured on the source platform.

An issue reported in the 1998 status report was the electrical noise generated by the ALPHA power supplies used to power the source solenoid coils. An interim fix was implemented using spare power supplies as well as heavy filtering of the power line on the deck. We replaced the power supplies with Lambda EMI high frequency switching power supplies. These power supplies do not produce the line noise present from the SCR-based supplies and all systems on the deck are now fully functional.

b.2. **Upgrade of ATLAS ECR-1 Ion Source** (D. P. Moehs, R. H. Scott, R. Vondrasek, and R. C. Pardo)

Renovation of the ATLAS 10 GHz ECR-1 ion source, which began operation in 1987, is in the construction and testing phase. The original ion source has served ATLAS well, but a major redesign of the magnetic confinement fields and plasma chamber should significantly improve performance. The primary goal for the upgrade is to improve the average charge state distribution produced by the source, shifting the average charge state up by approximately 10%. A secondary goal is to increase the total useful extracted beam current by up to a factor of two.

To accomplish these goals, while maintaining a source design that continues to emphasize the importance of solid feed materials, the old two-stage source is being converted to a single-stage design similar to ECR-2. The new source will utilize an electron donor disk and high gradient magnetic field design that preserves radial access for solid material feeds and pumping of the plasma chamber. A rail-mounting system for the injection coil provides flexibility and easy access to the plasma chamber. The overall magnetic field profile should allow for the possibility of a second ECR zone at a frequency of 14 GHz (see Fig. II-2).

An open hexapole configuration with radial ports 2.8-cm long and 1.7-cm wide through the plasma chamber allows access to the plasma chamber for solid feed materials. Pumping of the chamber will be provided through all six of the radial ports as well as through the extraction tank. Measurements of the magnetic field strength near the surface of the plasma chamber are in good agreement with computer calculations. At the chamber wall, 4 cm in radius, the field strength is nearly 9.3 kG along the magnet poles and 5.7 kG along the pole gaps. Eight solenoid coil pancakes from the existing ECR are being reused to produce the axial mirror in conjunction with a 2-inch-thick iron yoke. These coils can carry a current of up to 500 A and computer models predict a minimum B field of 3 kG with injection and extraction mirror ratios of 4.4 and 2.9, respectively. The parameters are summarized in Table II-4. The rebuilt source is expected to begin operation in the summer of 2000.

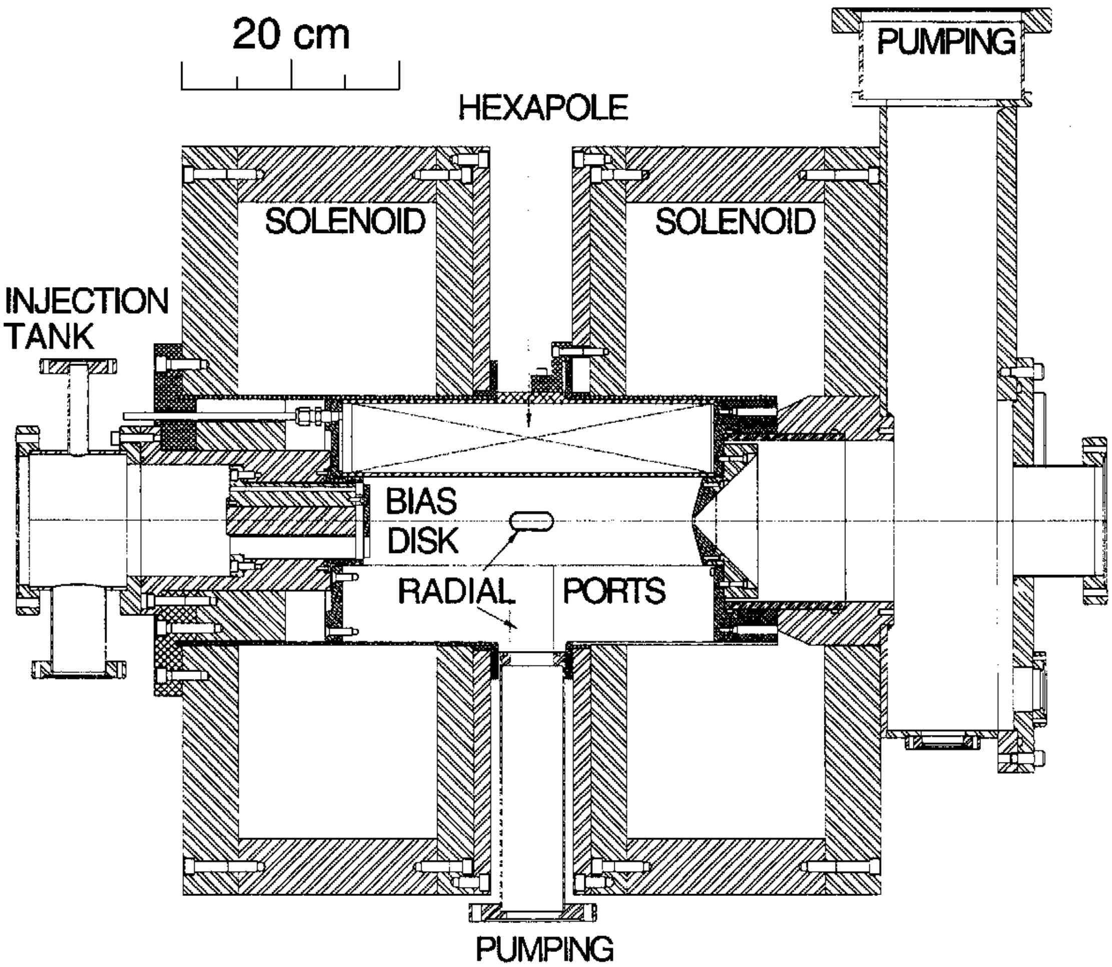

Figure II-2. Schematic of the upgraded ECR-1 10-GHz ECRIS with the injection tank on the left. Pumping of the plasma chamber will be provided through two of the radial ports and through the extraction region.

Table II-4. Summary of the upgraded ECR-1 parameters.

Microwave Frequency	10 GHz 14 GHz possible		
Aluminum plasma chamber		Hexapole	
Inner Diameter	8.0 cm	Length	33.0 cm
Radial ports	2.8 cm by 1.7 cm	Easy axis angle (radial ref.)	38.0°
Water channel cross section	0.38 cm^2	B_r Pole tip field, r = 4 cm	≈ 9.3 kG
		B_Φ Gap field, r = 4 cm	≈ 5.6 kG
Solenoid coils		Cooling water	
Current range for 10 GHz	350 – 500 A	Input temperature	≈ 11° C
Minimum Field (500 A)	3.0 kG	Head pressure	80 psi
Injection side MR	4.4 kG	Max. expected $\Delta T_{hexapole}$ For a 2 kW input	< 10° C at 1.0 gpm per channel
Extraction side MR	2.9 kG	Max. expected ΔT_{coils} For a current of 500 A	< 30° C at 4.0 gpm per coil

b.3. **Vibration Damper** (A. Facco*, G. P. Zinkann, and K. W. Shepard)

Phase stability of low-velocity superconducting accelerating structures is limited by ambient acoustic noise that excites mechanical vibrations in the cavities. In the PII section of the accelerator, these effects are most troublesome in the heavily loaded very low beta (.008 and .016) four-gap quarter wave resonators. A vibration damper has been designed and installed in a β = 0.016 (I2) resonator to reduce such phase noise. Figure II-3 illustrates the components of the Vibration Damper. The mechanical damper consists of a stainless steel holding tube and a sliding load. The load sits on the holding tube terminating disk and it is free to slide over it while being maintained in a coaxial position with the inner conductor by three centering rods. Every vibration of the inner conductor makes the load slide, producing mechanical power dissipation and reducing the mechanical Q.

*INFN- Laboratori Nazionali di Legnaro,via Romea 4, I-35020 Legnaro (Padova) Italy

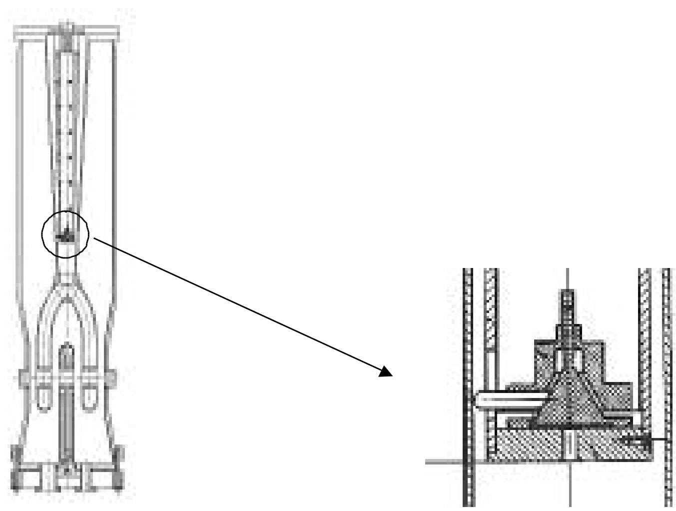

Figure II-3. Components of the Vibration Damper

An I2 class resonator with the largest amount of mechanical vibration was chosen to test the damper design. Calculations were done to compute the mass needed to dampen the I2-type resonator. The damper was constructed in November 1998 and installed in December during a scheduled maintenance period. Room temperature testing and optimization could not be done given the short duration of the downtime available. The results of the damper are given in Table II-5

Table II-5. Table of Vibration Damper Results

	R112		R113 (control cavity)
	Noise Frequency (Hz)	Vibration Decay Time (s)	Noise Frequency (Hz)
Without damper	~375	28	~125
With damper in R112	~40– 80	0.5	

The success of the Vibration Damper enables the reduction of the tuning window on the fast tuner. This has several benefits.

1. The reactive power that the PIN diodes are required to switch is lower.
2. The output power required of the drive amplifier is lower.
3. The energy spread of the beam is smaller due to less phase wobble from the fast tuner.

Plans to install another Vibration Damper in the other $\beta = 0.008$ resonator are underway.

b.4. Status of the Transmission-Line Chopper for ATLAS (R.C. Pardo, J.M. Bogaty, B.E. Clifft)

A ten-segment transmission-line chopper (Fig. II-4) whose job is to remove unbunched tails from a partially bunched heavy-ion beam in order to avoid undue emittance growth in the linac and eliminate undesirable satellite beam bunches has been installed on the PII low-energy beamline. This chopper is designed to work with a new PII bunching system geometry that requires a bunch width of approximately 16-17 ns at the chopper location.

When poorly bunched beams traverse the traditional sine-wave chopper, unacceptable transverse emittance growth and unnecessary beam loss result. Significant reduction in the emittance growth and beam losses compared to a sine-wave chopper was reported last year. The chopper was rebuilt with a new water-cooled semi-rigid delay line to allow CW operation at 12 MHz. A new driver and power supply was constructed and operated off-line at 6 MHz, but 12 MHz operation has continued to elude us. New driver circuitry is being designed and initial testing is planned for the spring of 2000.

b.5. ATLAS Control System (F. H. Munson, D. Quock, J. Figueroa, B. Chapin)

A number of new features and improvements were made during this reporting period. The more significant changes involved ion source control and monitoring, data acquisition, and record keeping.

The original ECR ion source was incorporated into the main control system. Ion sources at ATLAS make use of two levels of high voltage. In the past, insulated rods were required to control devices at one of these levels on the ECR sources. Hardware and appropriate software have been added to allow the use of fiber optic cable to control and monitor the entire ion source from any one of the control consoles. Faraday cup currents originating on the high-voltage platform can now be read using a new process that makes use of a graphical analog meter.

The control system's data-acquisition software comprises in-house written processes, and Vista Inc.'s Vsystem graphical interface. Therefore, it is integrated seamlessly into the overall system. Improvements were made to the method of setting cursors about peaks in graphical energy and timing plots. In addition, a new data-acquisition diagnostic region was added providing a more flexible user interface for modifying constants.

Record keeping is an important function of the control system. One feature of this effort is the ability to store and retrieve complete accelerator tune configurations. Previously only three possible charge-state stripping -foil configurations were allowed. Recently a fourth was added at the exit of ATLAS.

b.6. ATLAS Cryogenic System (J. R. Specht, B. Millar, and S. W. MacDonald)

Improving operational reliability and safety has been the goal for cryogenic enhancements this year. Condensation and ice were a problem with the lines and heaters venting cold nitrogen from the various cryostat shields etc. We rebuilt all the cold gas heaters to move the ac power leads to the warm end of the heater. In addition the on-off type temperature controllers were replaced with proportional ones with SCR outputs. This should eliminate controller failures due to output relay problems.

Vacuum insulated hoses were installed on one cryostat to eliminate the condensation problem with the interconnecting hose. This test went very well and as a result during the next few years all the lines will be replaced on the remaining six cryostats.

We designed, built, and operated an automatic LHe fill system for a superconducting magnet used in radioactive beam experiments. This system increased beam time while eliminating worker exposure to radiation.

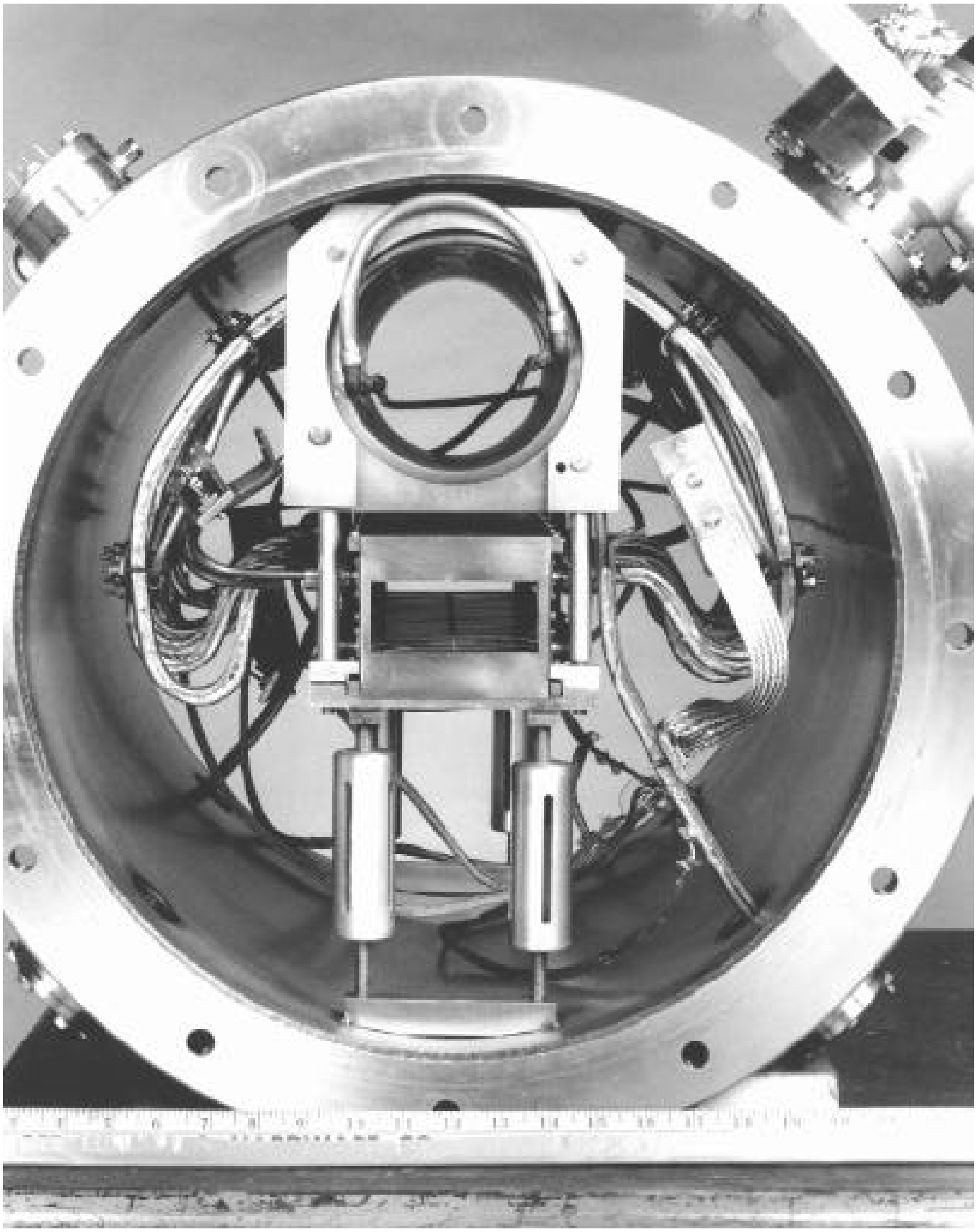

Figure II- 4. Photograph of the assembled transmission-line chopper in its vacuum housing. Shown is a portion of the semi-rigid delay-lines connecting the sequential electrodes visible in the rectangular beam aperture.

C. RESONATOR DEVELOPMENT AND CONSTRUCTION FOR THE NEW DELHI LINAC

c.1. Resonator Construction Project (K. W. Shepard, P. Potukuchi*, S. Ghosh*, and M. Kedzie)

Construction of the first twelve niobium quarter-wave cavities has been completed. Shipment of the cavities to New Delhi awaits removal of the Nuclear Science Centre from the proscribed entity list by the U. S. DOE Office of Non-Proliferation. The completion of twelve cavities within the budget and schedule allotted for ten cavities was made possible by the increase in productivity in the electron-beam welding process that was achieved during this project in collaboration with the e-beam welding vendor, Sciaky, Inc.

c.2. Slow-tuner Development (M. P. Kelly, P. Potukuchi*, S. Ghosh*, K. W. Shepard, M. Kedzie, and B. E. Clifft)

Tests of a niobium-bellows slow tuner fully assembled with a production version of the New Delhi 97-MHz quarter-wave cavity were completed. Accelerating gradients as high as 5 MV/m can be stably maintained with no measurable performance decrease due to rf-loss-induced heating of the bellows assembly as was observed in an earlier design. Figure II-5 shows the niobium-bellows tuner and the flange for attaching to the quarter-wave resonator. Internally, a newly re-designed Belleville washer assembly provides an additional restoring force which increases the range of motion to 2 millimeters for applied (He) gas pressures of 0 - 1 atmosphere. The corresponding tuning range was measured to be 45 kHz at 4.2 K.

* Nuclear Science Centre, New Delhi, India

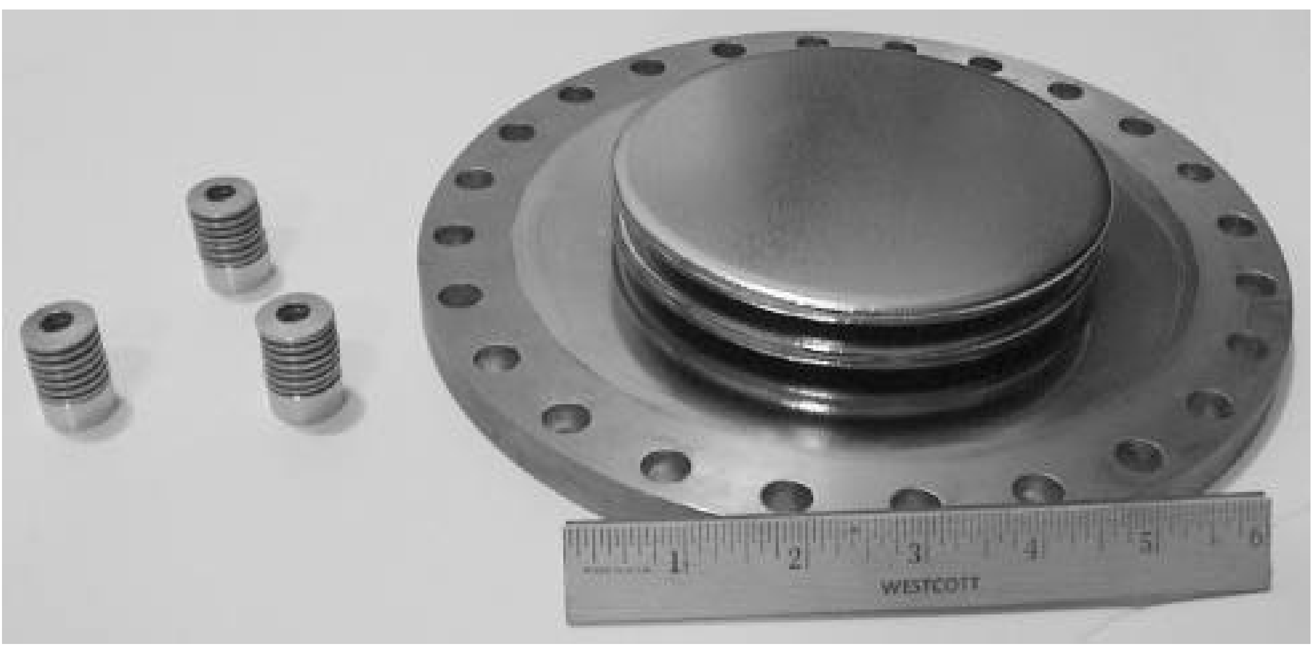

Figure II-5. The niobium-bellows tuner assembly together with three Belleville washer stacks used to provide an additional restoring force.