OPERATION OF THE FIRST TANK OF LAMPF*

Donald A. Swenson
University of California
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87544

ABSTRACT

The first tank of the Los Alamos Meson Physics Facility (LAMPF) is a 5 MeV drift-tube linac. It came into operation, along with its .75 MeV Cockroft-Walton injector, on June 10, 1970. A general description of the operation since that time will be given.

A brief account of the operation of the first tank of the Los Alamos Medium Energy Physics Facility (LAMPF) is presented here. The first tank of LAMPF is 11 ft long, contains 31 drift-tubes, and accelerates the .75 MeV injected beam of protons to an energy of 5.39 MeV. The completed tank is shown in Fig. 1. The low energy transport system leading to the first tank is shown in Fig. 2.

Beam was accelerated to 5 MeV for the first time on June 10th of this year (1970). Only a few days prior to that, the first beam had been extracted from the ion source, and accelerated to 0.75 MeV. On the evening of June 10th the beam was transported to the entrance of the linac, and within minutes, the beam was observed at the other end of the linac. A quick experiment with the rf field level established that the beam was indeed accelerated beam.

The first exciting moments were some 15 weeks ago. Since then a considerable effort has been made to run the accelerator as much as possible, and to learn as much about the beam as possible. We still have a way to go before we can be satisfied with our ability to run this portion of LAMPF as an accelerator. Our schedule will allow us to continue working with the 5 MeV beam until mid-January, when we must cease these activities to complete the installation of the drift-tube linac.

A review of our log book reveals that we have had 5 MeV beam on 17 occasions, for a total of 44 hrs. On another 21 occasions we measured properties of the 75 MeV beam for a total of 96 hrs.

One unusual problem that we noticed just before our initial operation, was revealed by the fact that excitation of the quadrupole magnets caused the rf field levels to fluctuate from pulse to pulse. The fluctuation set in and died away with a 5 - 10 second time constant. This sort of ruled out an electron phenomena. Examination of the outputs of the quad magnet power supplies revealed a large (±20%) 14 Hz oscillation on the output of one supply. The oscillation frequencies of the drift-

---

*Work performed under the auspices of the U. S. Atomic Energy Commission.

tubes in the tank had been calculated to range from 9 to 16 Hz. We were driving one or more drift-tubes into longitudinal oscillations large enough to effect the resonant frequency and cause the pulse to pulse fluctuations in the cavity field. This problem was cured by adjusting the stability of the SCR supply so as to eliminate the oscillation.

The tank is evacuated by a 2400 ℓ/sec ion pump. On initial pumpdown a pressure of 10^{-8} Torr was reached, and after some rf operation, the pressure was in the 10^{-9} Torr range. A short while later three new factors evolved:

1. the inter-tank spacer was installed,
2. the 5 MeV beam pipe was valved in, and
3. a tuning slug developed a leak which allowed a small amount of oil to enter the tank.

Subsequently, the lowest pressure achieved until last week was 7×10^{-8} Torr. The base pressure was gradually rising. Sudden pressure bursts with gradual pump-down were noted. Operating pressure with rf was 1×10^{-6} Torr with fluctuations as high as 7×10^{-6} Torr. Also, a dark residue appeared on the copper surfaces in the lower half of the tank. The same residue was found on the ceramic monitor loop thimbles. Analysis indicated the main elements were carbon and sulphur, which pointed to oil contamination. The pressure continued to rise until the best pressure we could get was 4×10^{-6} Torr with rises well into the 10^{-5} Torr range.

Toward the end of July the decision was made to remove the downstream head and inter-tank spacer in an attempt to locate the problem. A water to vacuum leak was found in the inter-tank spacer. This appears to have been the main problem. The ion pump was exchanged for a new one, and the black deposit was removed from the cavity wall.

Following this repair, the base pressures were better for a month; somewhere around 1×10^{-7} Torr. Then for one week the base pressure was found to be in the 10^{-6} Torr range, and on the weekend, the pressure was found to be in the 10^{-5} Torr range. Extensive testing finally revealed another water to vacuum leak in the inter-tank spacer. We operated last week by pulling a rough vacuum on that water circuit, and the base pressure is now 10^{-8} Torr.

Another area of major concern is the ceramic dome used around the rf drive loop. The first dome developed a pinhole leak after about 30 hrs of operation. This dome was only 97% alumina, compared to the 99.5% alumina in our remaining domes. The second dome lasted until a few weeks ago (230 hrs of operation) when it failed in the same way. The third dome lasted only 20 min, at which time it imploded, sending large chunks of ceramic into the tank, causing several gashes on the adjacent drift-tubes. Although frightening to contemplate, the resulting damage was minor. Gashes were smoothed up, ceramic was swept out and a fourth dome installed.

The cause of the failure of the third dome is not known. A heavy black deposit was found at the lowest point inside the dome, which suggests that a foreign object, such as a piece of spring ring, had fallen into the dome, and had given rise to uneven heating of the dome, causing the dome to fracture.

Whereas a series of minor problems have severely limited our effort to operate this portion of LAMPF as an accelerator, I believe our hardware is sound. The various components of the cavity and drift-tube systems have demonstrated their ability to survive the 6% rf duty, which is 20 times the nominal duty of the NAL linac, and 60 times the nominal duty of the BNL linac. The drift tube alignment procedure proved convenient to use and the support hardware proved capable of outstanding rigidity. Servo control of the cooling system has proved satisfactory for controlling the resonant frequency of the tank.

After our initial operation, a quadrupole doublet and a 180° double focusing spectrometer were installed at the 5 MeV end of the linac. This region is shown in Fig. 3. The quadrupole doublet is a prototype of those to be used in the side-coupled portion of LAMPF, and the spectrometer has been around the Laboratory since 1954.

Because of the short length of our linac, it is often true that between ¼ and ½ of the beam emerging from the linac is low energy beam. The spectrometer is used to determine the magnitude of the accelerated current. Toward the end of June, the ratio of the accelerated current to the injected current reached ~ 25%, which is the expected value for no buncher and a stable phase angle of -26°.

Only preliminary work has been done to determine the design excitation of the cavity fields. Threshold excitation was found to require about 256 kW, some 12% more than predicted on the basis of calculated losses and 85% theoretical Q. This result is in agreement with the measured Q of 50,000 for the tank. This would imply that design excitation would require 316 kW. For most of our operation to date we have used a net input power of 340 kW, which implies that our fields are 3.7% above design value.

Momentum spectra of the accelerated beam have been measured for all excitations from threshold to approximately 10% above design fields. As yet, the spectra do not compare well with the calculated spectra. Work will continue in this area.

In mid-July we installed the gear for measuring the emittance of the beam going into the linac. The region immediately in front of the linac is shown in Fig. 4. The emittance apparatus consists of four jaws mounted on separate linear actuators, and two collector strip assemblies mounted on separate actuators. Two jaws set to form a slit; and one collector assembly is used for the emittance measurement in each plane of the transverse phase space. The linear actuators are controlled and the data is collected by a small digital computer (NOVA). The data is displayed on a storage oscilloscope in a format similar to that developed at NAL. An example of this display is shown in Fig. 5.

At present we have similar sets of hardware installed at two additional locations; one set in line with the ion source and accelerating column, and one set at the 5 MeV end of the linac. We have made hundreds of emittance measurements at these three locations, and have learned some things about the transverse phase space of the beam.

One cavity of our two-cavity buncher system is installed and was used for the first time during the week of September 21st. The cavity that is installed is ~ 1.5 m from the linac and operates as a standard single cavity buncher. The cavity yet to be installed has the role of a pre-buncher and is located 5 - 6 m from the linac. Both cavities will operate at 201.25 MHz. The double-cavity single-frequency buncher system provides an extra degree of freedom in the adjustment of the longitudinal phase space, and allows quite compact bunches of particles to be achieved if desired. In our initial operation of the single buncher, increases in the accelerated current by a factor of 2 were achieved.

For the purpose of beam measurements we normally operate with the rf at its nominal 6% duty, and with the beam gate at a much reduced duty. The nominal 6% rf duty is achieved with a 500 μsec pulse at a rate of 120 Hz. The beam gate that we normally use is a 100 μsec pulse at 15 Hz. As for beam current, we normally inject 20 mA of protons into the linac and accelerate ~ 4 - 5 mA without the buncher, and 8 - 10 mA with the buncher.

Last Friday, September 25th, we pulled out the stops a bit and accelerated a 8 mA proton beam at the 6% duty of the rf pulse. The beam with its 2.5 kW of average power was dumped onto a water-cooled gold plated copper jaw for about one minute before the beam bored a hole into the water circuit. The forward and reflected powers, the cavity fields and the injected and accelerated beam currents looked quite normal during this brief moment of full duty operation. At this level we were producing 60 mrad/h of γ radiation and 80 mrem/h of neutrons at a point 20 ft upstream from target and through one ft of concrete shielding.

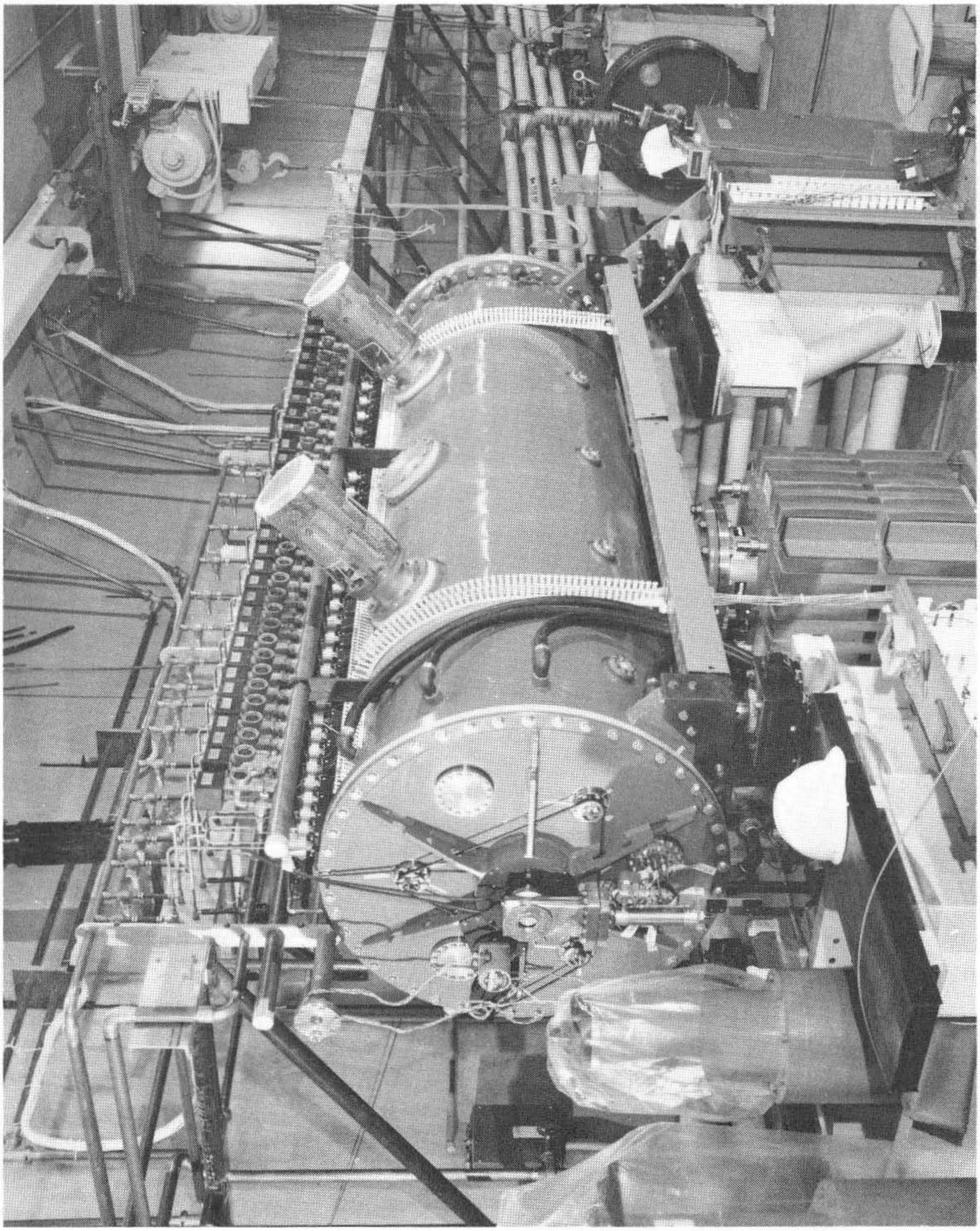

Fig. 1. First tank of LAMPF.

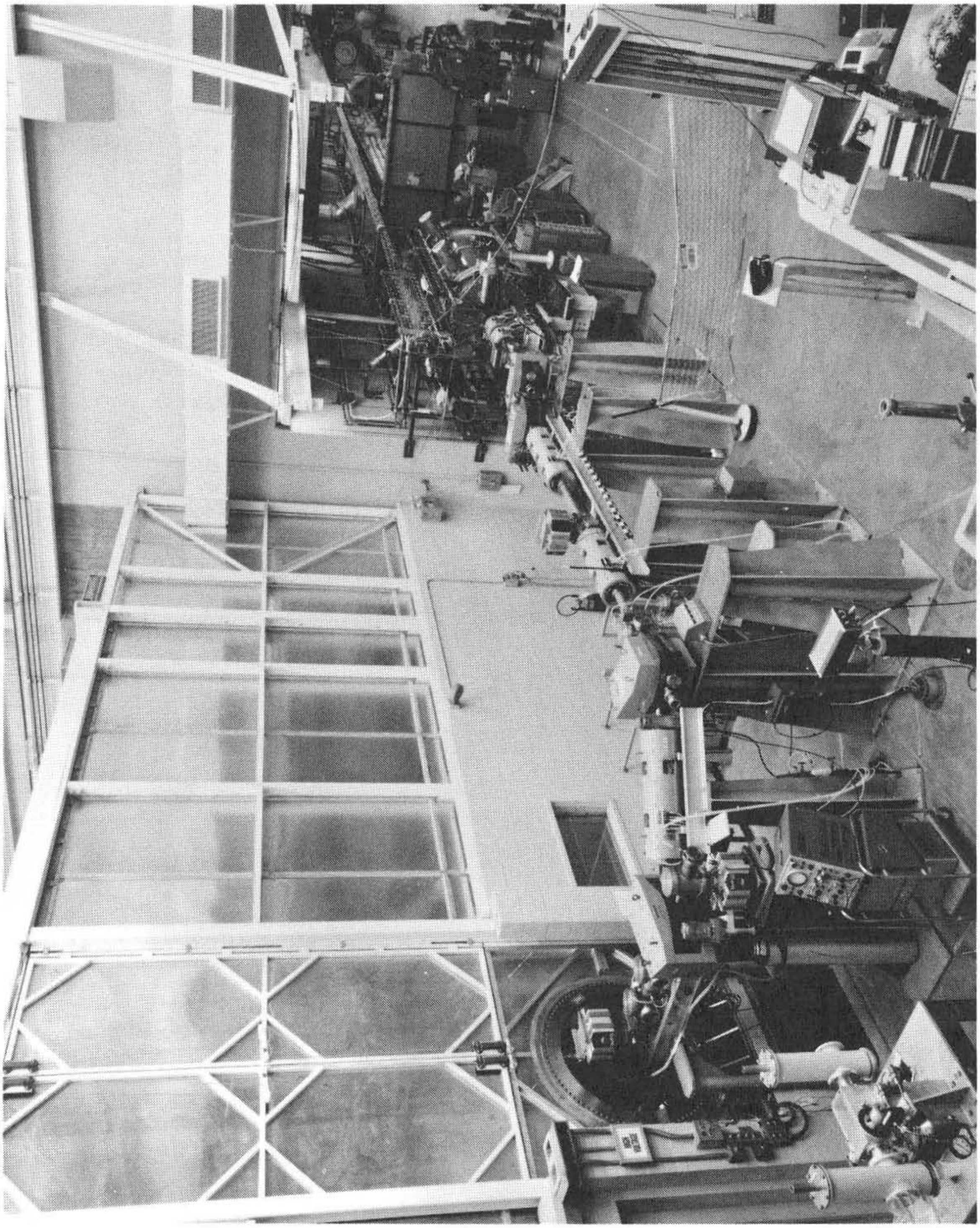

Fig. 2. Low-energy beam-transport system.

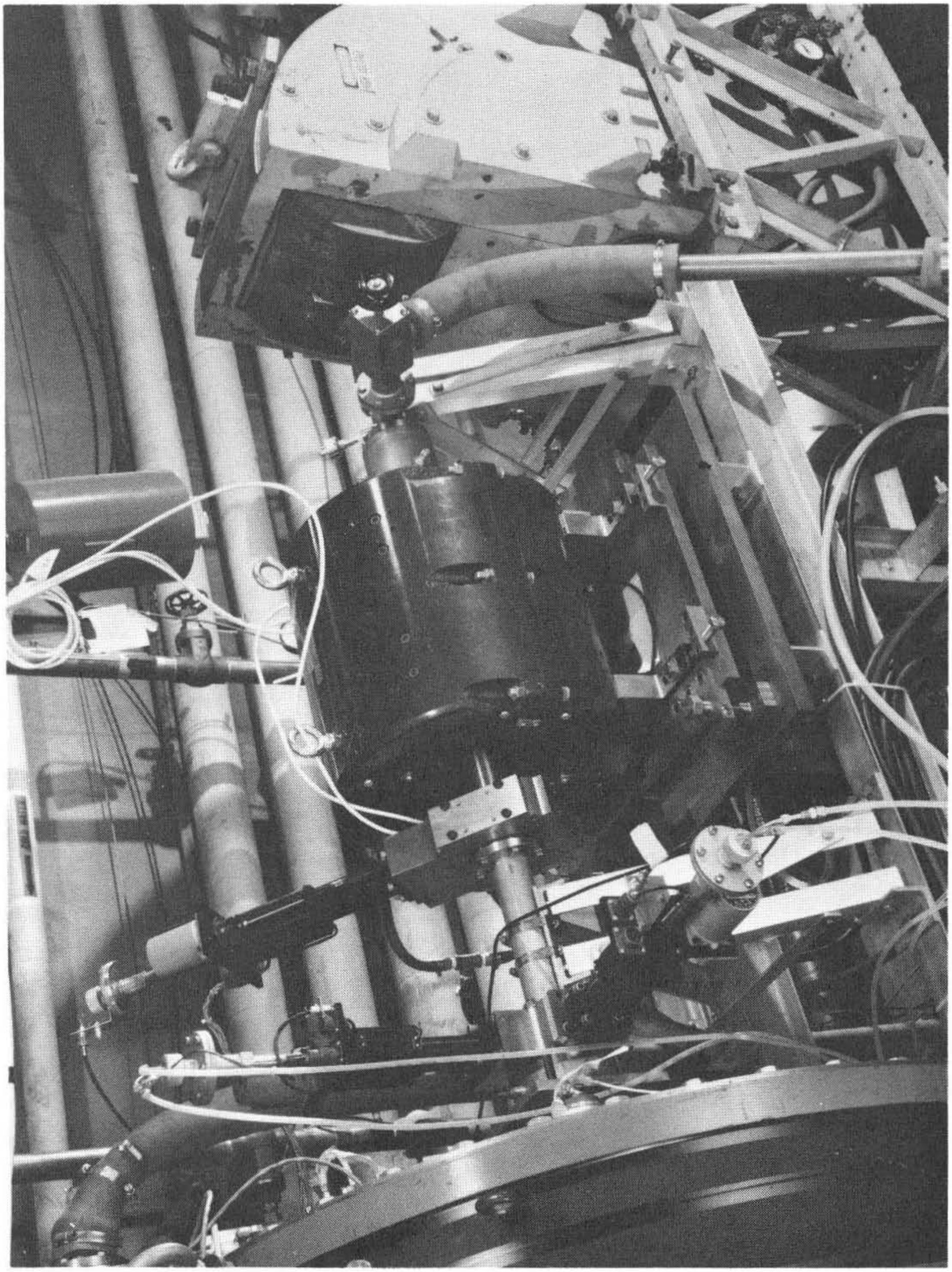

Fig. 3. Beam pipe and spectrometer at end of Linac.

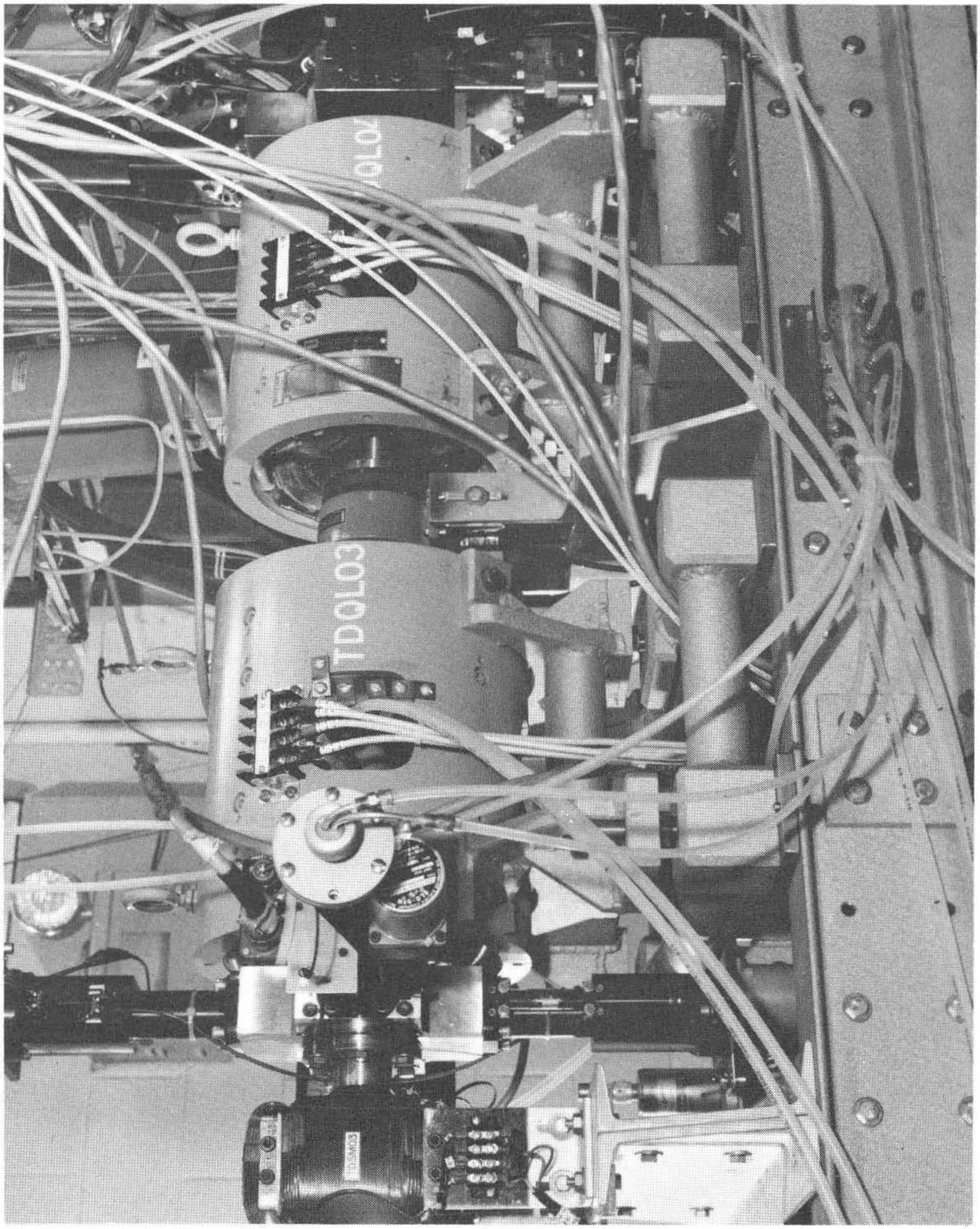

Fig. 4. Emittance-measuring apparatus at entrance to Linac.

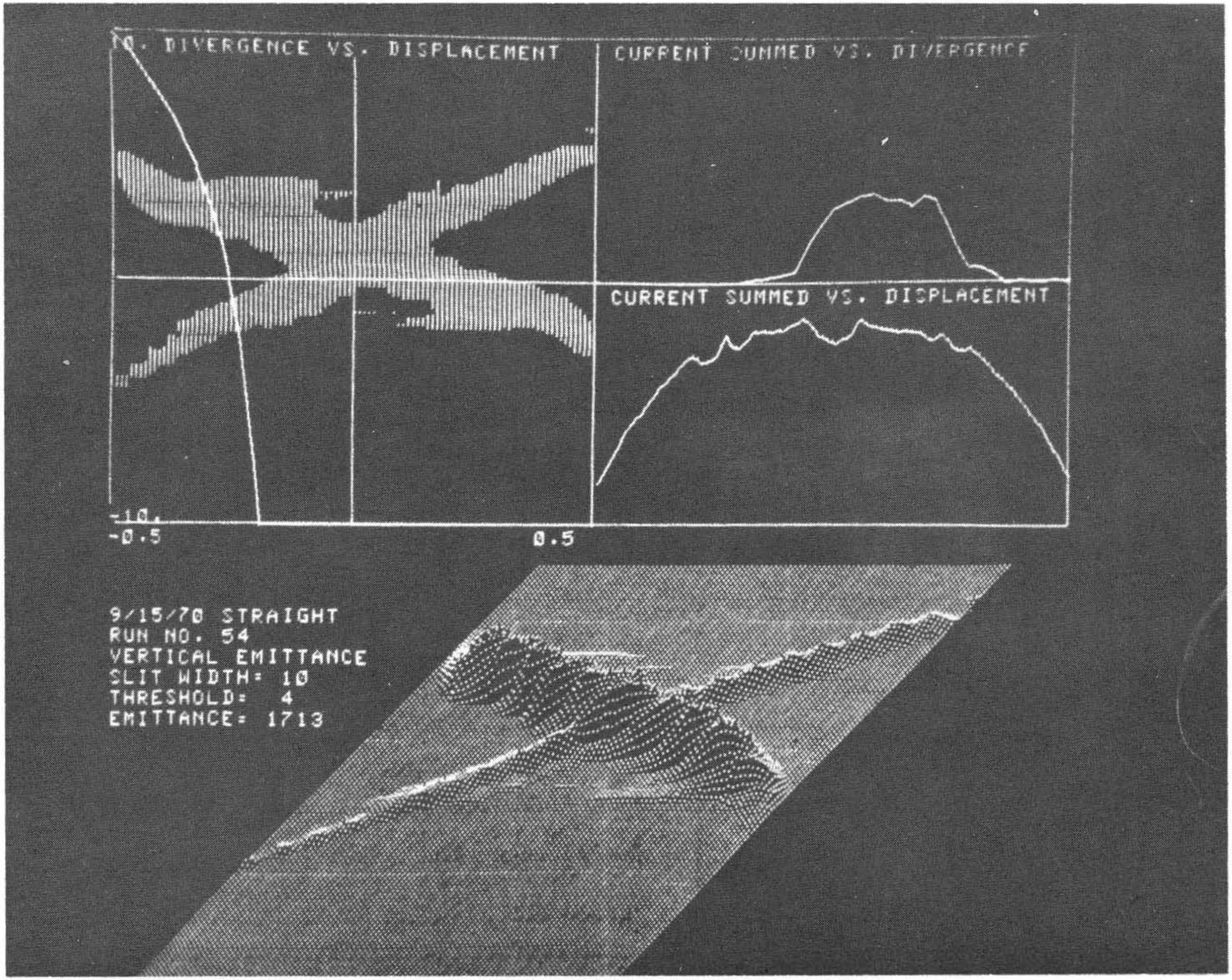

Fig. 5. y-y' emittance plot showing proton and H_2^+ beams.

DISCUSSION

R. H. Miller (SLAC): Was the ceramic dome coated? Klystron windows have oxide coatings to reduce secondary emission.

D. A. Swenson (LASL): The third dome, which imploded, was coated, as is the fourth, which is now installed.

R. H. Miller: Was the rf on at the time of the dome failure?

D. A. Swenson: Yes. I might add that there was a very black smudge at the lowest point inside the dome. The smudge was analyzed and copper was found. The most likely explanation is that a foreign object, possibly a piece of spring ring, was present which set up arcing conditions causing the dome to heat locally and fracture.