AN AUTOMATED ADMITTANCE MEASUREMENT AT LAMPF*

by

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ABSTRACT

A computer code was written to automate admittance measurements in the drift tube portion of LAMPF. The procedure was used to identify a misalignment in the first linac tank. This paper discusses the experimental procedure and compares the results with those generated numerically.

I. INTRODUCTION

One of the fundamental properties of a linac employing periodic strong focusing is the admittance or that region in transverse phase space occupied by the initial coordinates of all particles which are accelerated without striking the drift tube walls. The focusing structure is generally designed so that the transverse emittance of the injected beam lies comfortably within the admittance. Errors in quadrupole field or drift tube alignment can severely reduce the admittance, resulting in mediocre transmission. An experimental admittance measurement can be very useful in verifying or diagnosing problems with the transverse performance of a linac.

II. THE MEASUREMENT TECHNIQUE

Until recently, satisfactory current transmission in the LAMPF drift tube linac could only be achieved through certain combinations of exotic horizontal steering. As a result severe oscillations were induced in the beam. This problem could have been the result of any of several possible errors. Because the drift tubes were installed with an accuracy of ± 3 mils using laser techniques, internal misalignment was considered unlikely. The possibility of shorted quadrupole windings, improper quadrupole or steering magnet currents and misalignment between the transport system and the linac were considered and each double-checked.

An automated admittance measuring technique was developed to further study the problem. The technique involves simply probing the initial phase space of the linac with a very small parallel proton beam while measuring transmission. A suitable beam is obtained by reducing the ion source current to minimize space charge effects and inserting jaws to form an axial pin hole. To verify the size divergence and position of this reduced beam an emittance measurement is made near the entrance to the linac. Typical beam dimensions for the experiment are 1 mm by 1 mrad in both transverse planes. Larger or more divergent beams reduce the resolution of the admittance measurement.

Two steering magnets shown in Fig. 1 are used to scan the pin-hole beam across the linac's input phase space. The first magnet (SM1), because of its long lever arm, is primarily responsible for the transverse displacement while the second magnet (SM2), capable of a stronger field, is responsible for the angular divergence. A FORTRAN program was written for the LAMPF - SEL - 840 control computer to automatically vary the two magnets in a uniform way,

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measure the accelerated current, and plot the results on a storage scope while at the same time storing the raw data on disk for later analysis.

The results of the admittance measurement of the first tank of the LAMPF drift tube linac are presented in Figs. 2 and 3. The axes are scaled in units of steering magnet current, the horizontal axis corresponding to the first magnet and the vertical axis corresponding to the second. To map this area onto true phase space requires a simple transformation. The numbers plotted on one graph reflect the relative amount of current transmitted for the corresponding steering magnet combination.

III. INTERPRETATION OF THE MEASUREMENTS

The vertical admittance appeared to be very good; large, reasonably well centered and symmetrical. However, the horizontal admittance was so bad that the magnets were incapable of scanning its full area. The measurement confirmed previous experience which indicated that the best transmission could be achieved with strong right steering using magnet SM2.

The same effect was observed when the admittance of tank one was measured during its initial operation. The procedure used involved manually varying magnet power supplies and recording current signals. Since one measurement required several hours to make, the horizontal problem was not pursued, and because of the lack of data. The early horizontal admittance reported in 1971 was misunderstood and believed to be in error.[1] The automated technique has allowed a more detailed study to be made.

As a result of these measurements it was determined that a recheck of the drift tube alignment in tank one was required. A small probe about 1-in. long was machined to fit snugly in the bore of the drift tubes. A 6-V lamp was installed inside the probe which emitted light through a 30-mil pin-hole centered in the upstream end of the probe. As this "tail light" probe was pulled from drift tube to drift tube, an alignment scope, bucked in on the linac axis, was focused on the pin hole to measure the displacement of each drift tube. Whereas each drift tube had originally been aligned with an accuracy of ± 3 mils, drift tubes number 7 and 9 were found to be displaced by ten times that tolerance to the south. Drift tubes 26 and 28 were each displaced by 20 mils while other drift tubes were found to have smaller random misalignments.

The theoretical admittance of the LAMPF linac is routinely calculated using PARMILA program. A large area in the initial x - x' or y - y' phase space is uniformly populated with 500 test particles while there corresponding longitudinal coordinates are set to the synchronous values. As particles are transformed through the linac, particles whose radial position exceeds the radius of the drift tube bore are eliminated from the calculation. At the conclusion of a run the initial coordinates of those surviving particles are plotted. It is useful however for investigating the effects of misalignments, to determine the admittance of sections of the linac separately, and then transform each of these areas backward to the linac entrance. The common intersection of each of these areas is then the admittance of the total system.

Disregarding any misalignment, the theoretical horizontal admittance of the first nine cells of tank one is plotted in Fig. 4 as is the admittance of cells 9 - 31 which has been transformed backward to the linac entrance. The intersection of the two ellipses represents the horizontal admittance of tank one taken at the rf surface. A similar calculation with the inclusion of the measured misalignments is presented in Fig. 5. Notice that the admittance through cell 9 which includes two grossly misaligned drift tubes is a little different from the perfect case. The admittance of the latter portion of the linac which has been transformed backward through the quadrupole fields of the misaligned drift tubes is severely displaced. The area of the resulting intersection is reduced by about a factor of two and the center of the linac's admittance is displaced by about 25 mrad in angle which corroborates the experimental admittance measurements.

Drift tubes 7, 9, 26 and 28 were subsequently realigned using the "tail light" probe as the alignment target. Figures 6 and 7 show the results of the post-alignment admittance measurements. The raw data in these plots has been transformed to the more familiar x - x' and y - y' phase space at the rf surface of tank one. Figures 8 and 9 show the corresponding theoretical admittance including the final alignment data.

The theoretical plots represent the admittance corresponding only to the synchronous particles. The experimental plots represent all accelerated particles, effectively reducing the relative transmission near the perimeter. In addition the emittance of the beam used to probe the admittance is finite causing a smearing at the edge.

Taking these two points into consideration the comparison between measured and theoretical admittance is very good. The correspondence is clear in the vertical plane but a little more difficult to interpret in the horizontal case. Unfortunately the second steering magnet (SM2) was not capable of a field strong enough to scan the entire admittance. However, the most important features are the fact that it is large in area, well centered and symmetrical. The automated admittance technique is so easy to use that it will be used to check other portions of the linac as well as certain sections of the transport lines.

REFERENCE

1. D. A. Swenson, B. C. Goplen, M. A. Paciotti, and J. E. Stovall, "Beam Measurements on the First Tank of LAMPF," Proc. 1971 Particle Accelerator Conf., NS-18, 3, p. 309 (June 1971).

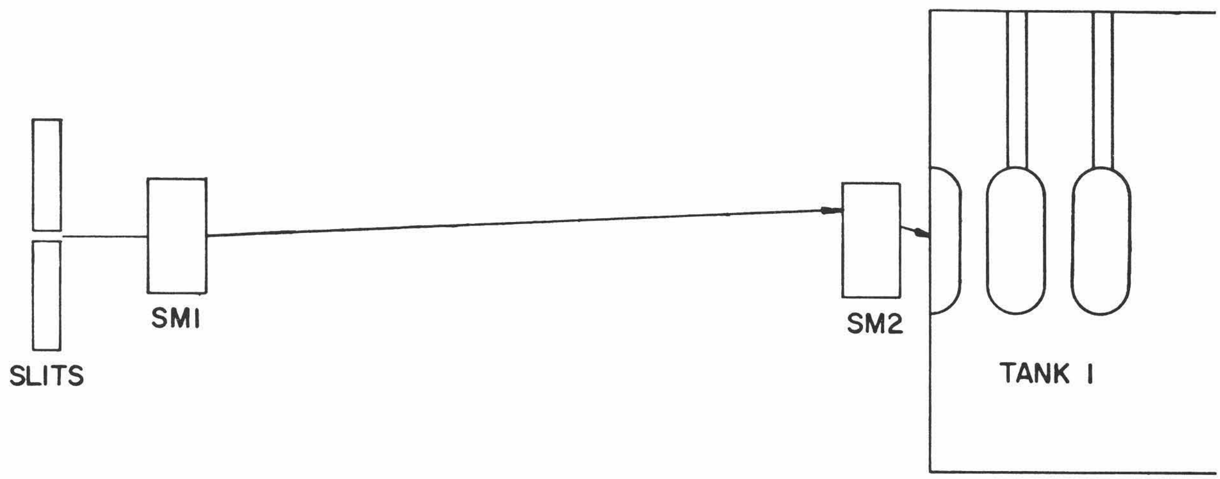

Fig. 1. Magnet arrangement for admittance measurement.

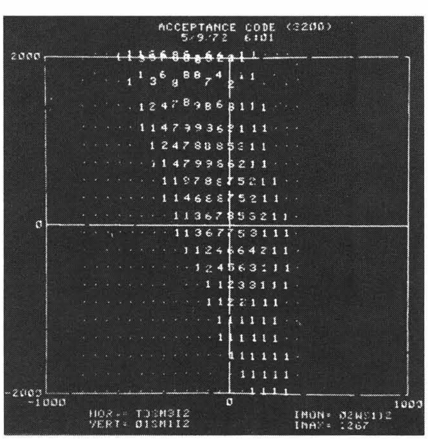

Fig. 2. Horizontal admittance raw data.

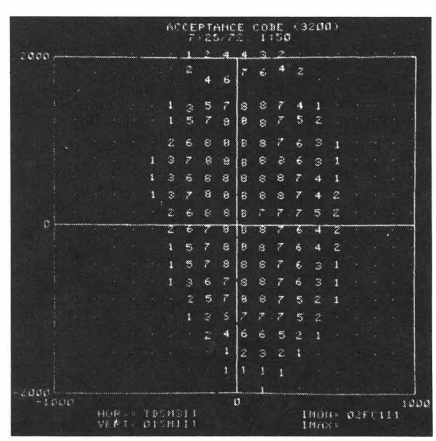

Fig. 3. Vertical admittance raw data.

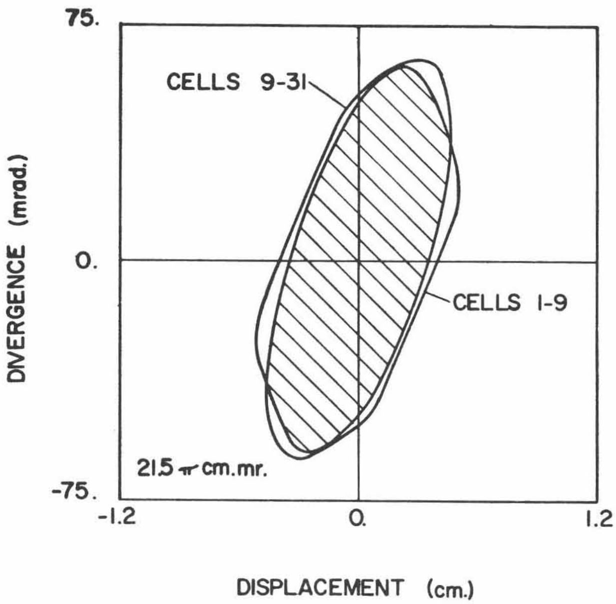

Fig. 4. Horizontal admittance assuming perfect alignment.

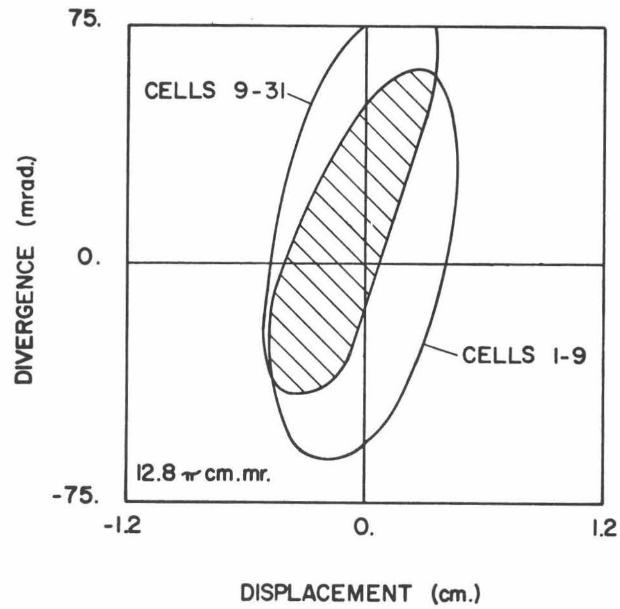

Fig. 5. Horizontal admittance including measured misalignments.

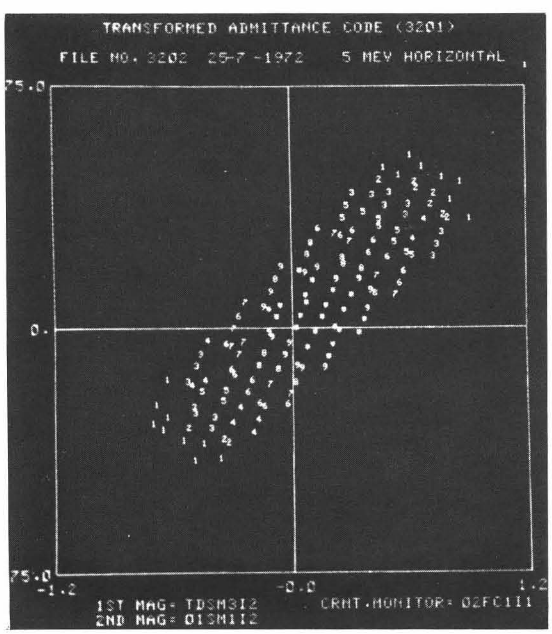

Fig. 6. Horizontal admittance measured after realignment.

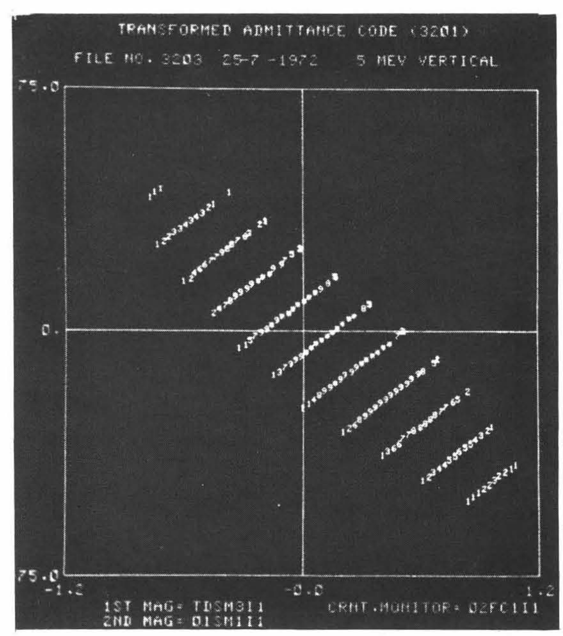

Fig. 7. Vertical admittance measured after realignment.

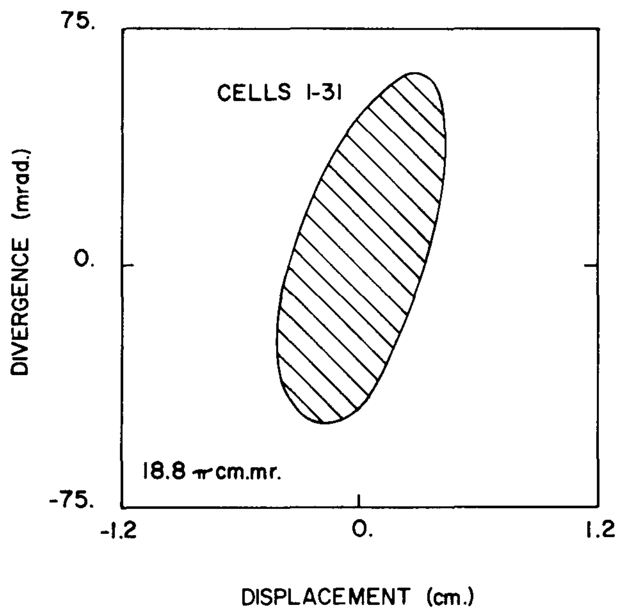

Fig. 8. Theoretical horizontal admittance.

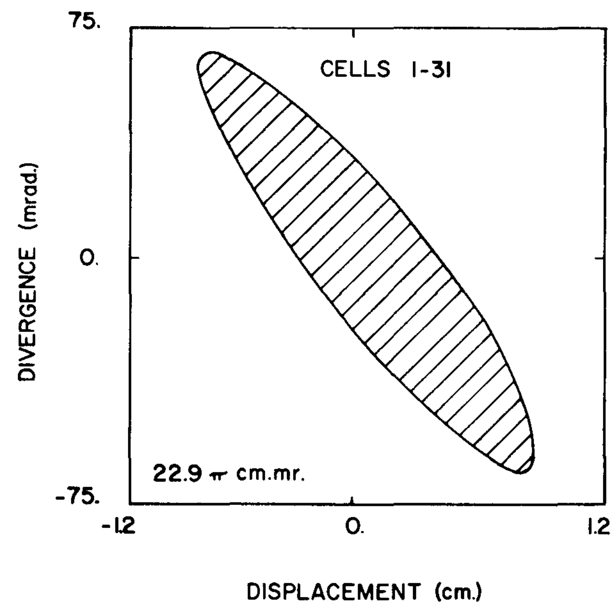

Fig. 9. Theoretical vertical admittance.