

OPERATING EXPERIENCE WITH THE R.P.I. LINAC

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ABSTRACT

The R.P.I. Linac, one of the most powerful electron accelerators in the world, has been in operation for several months. It has been operated at 130 megawatts peak power and at average beam power of 50 kilowatts for sustained runs. Evidence of pulse shortening has been observed only at currents of 0.8 ampere for pulse widths of 4.6 microseconds. A detailed discussion of performance is presented as well as current improvements.

INTRODUCTION

During the last year three high-powered L band linacs were installed: General Atomic (3 sections), Yale University (5 sections) and Rensselaer Polytechnic Institute (9 sections). One more is under construction for the National Bureau of Standards.¹

Considering the interest that is current in this type of accelerator, the operating experience of the R.P.I. Linac is summarized.

The R.P.I. Linac and facilities have been described elsewhere² and will

not be described in detail here. The design parameters are summarized in Table I, with photographs of the accelerator presented in Figs. 1, 2, 3, and 4. In the following it is seen that the accelerator met or exceeded the design parameters of Table I.

1. All of these accelerators were designed and constructed to the customer's specifications by the Applied Radiation Corporation, Walnut Creek, California.
2. E.R. Gaerttner, et.al., "Rensselaer Polytechnic Institute Linac Facility", Proceedings of the Neutron Physics Symposium, May, 1961; Academic Press, 1962.

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Table I—Design Specifications of R.P.I. Linac

1. Rated electron energy*	35 Mev
2. Rated average electron power*	48 kw
3. Pulse duration†	0.1, 0.3, 1.0, 2.0, 4.5 μ sec.
4. Repetition rates	7.5, 15, 30, 60, 120, 180, 240, 300, 360, 420, 480, 540, 600, 660, 720, single shot and externally triggered
5. Beam size	2 cm.
6. Angular divergence	1 milliradian
7. Number of sections	9
8. Length of sections	3 feet
9. Accelerating mode	Traveling wave, TM_{01}
10. Guide loading	$\gamma/4$
11. Attenuation constant	0.12 nepers/ft.
12. Shunt impedance	12.0×10^6 ohms/ft.
13. Filling Time	1.24 microseconds
14. Microwave frequency	L band, 1300 mc/sec.
15. Rating of klystrons amplifiers	10 megawatts peak 15 kilowatts average

* See text for measured values

† Refer to text for present range of pulse widths

Preliminary MSS rec'd by PGNS 7/2/62, final MSS rec'd 8/15/62

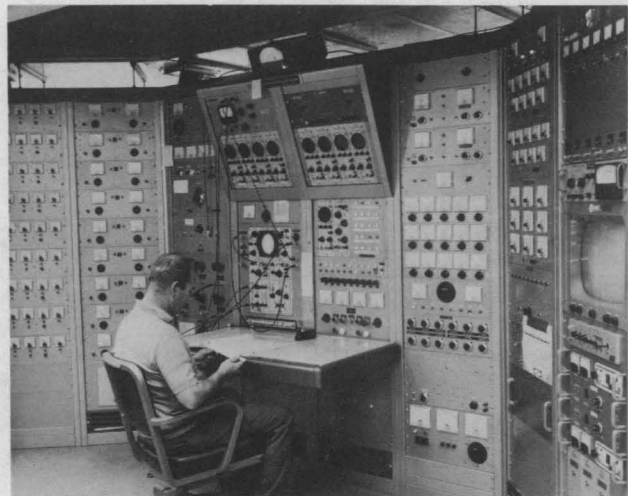


Fig. 1—The console of the R.P.I. Linac.

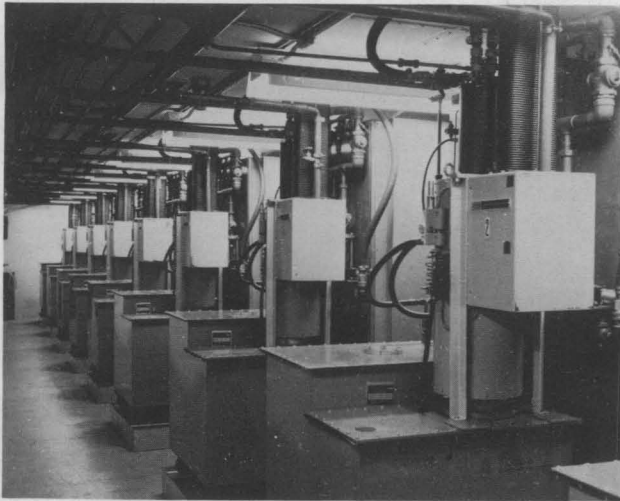


Fig. 2—The row of klystrons in the modulator room.

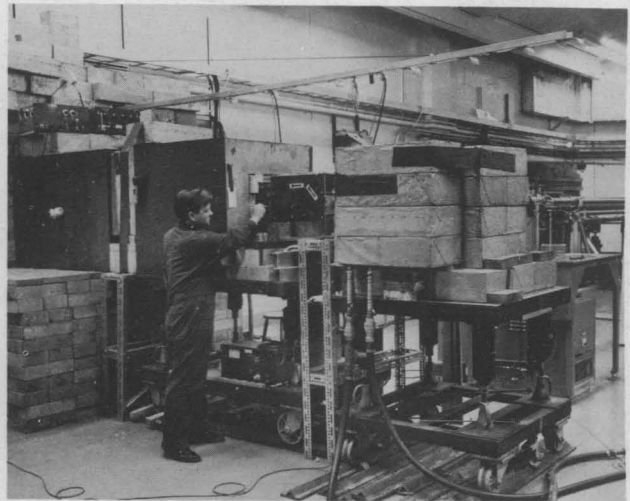


Fig. 4—The experimental area.

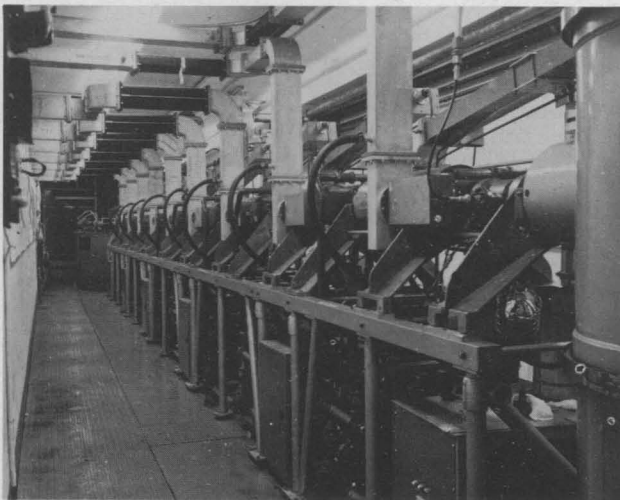


Fig. 3—The accelerator proper.

The operating experience to date has been in demonstration tests prior to delivery to Troy, in acceptance tests at R.P.I. and in running experience since acceptance. All operation which will be described was performed at about 45 MW of input r.f. power. It should be borne in mind that the L-3250 klystrons are capable of operation such that the r.f. input to this accelerator can be greater than 100 MW.

Subsequent to January 1, 1962, all tests have been performed at the No. 1 experimental station (Fig. 4 and ref. 2) which is about 30 feet from the accel-

erator. The fractional loss of beam to this station is estimated to be about 10 per cent.

PERFORMANCE

The highest peak current to date was 2 amps at the No. 1 experimental station. This was done with a pre-baked injector gun operated at 160 kv injection voltage. Undoubtedly the current was higher at the end of the accelerator proper. Earlier tests performed at the end of the accelerator but with a gun inferior to this one showed peak current in excess of 1.1 amps for all pulse lengths less than 4.6 microseconds. A peak current of 0.82 amps was the largest observed using 4.6 microsecond pulses. There is a very strong indication that pulse shortening begins to set in for higher currents in guides using the $\lambda/4$ loading. (The National Bureau of Standards machine has been designed to use the $\lambda/3$ mode³ which should avoid this current limitation.)

The highest peak power of 130 Mw was also observed at the No. 1 experimental station. This was 2 amps at 66 Mev on a pulse width of 0.1 microsecond. The fact that the peak beam power can exceed the peak r.f. input power is a manifestation of significant utilization of stored energy as expected in L band accelerators.

The 4.6 microsecond beam pulse shows no such effect and gives a peak energy conversion efficiency of about 73%. This

is probably not the optimum because the accelerator was tuned to produce the maximum peak current and not peak efficiency.

The demonstrations of high power capability were performed with the Faraday cup at the end of the accelerator but the beam was going through the standard output window and several inches of air before stopping in the cup. Under these conditions, the accelerator was operated at 50 kw of average power for a total of 18 hours distributed over 2 days. During this 18 hours the accelerator was off a total of 45 minutes of which a major fraction was intentional shutdown. Runs of 3 or 4 hours with no interruptions at all were attained. These tests were performed at about 50 Mev with an average output beam current of 1 ma at a repetition rate of 300 pps.

In all measurements it was found that the pulse-to-pulse jitter was too small to be observed directly on the oscilloscope but was estimated to be less than 2%.

3. J.C. Nygard and R.F. Post, "Recent Advances in High Power Electron Accelerators for Physics Research," Nuc. Instr. and Methods, Vol. II (1961).

Recently an injector modification has been installed with the result that the pulse widths which can be selected by operating a switch on the console are: 0.0086, 0.027, 0.1, 0.3, 1.0, 2.5, and 4.5 μ sec. The rise time observed on the 0.0086 μ sec. pulse is 0.0036 μ sec. At the time of measurement the injector gun was being held to 80 kv at which voltage it is difficult to exceed 0.8 amp even on the short pulse.

The energy spread of the beam is usually less than 10%; the best observed to date was 5%. It is well known that this energy spread depends very strongly on the tuning of the machine, but without a way of directly monitoring the spectrum, the tuning is rather haphazard. A magnetic analyzer that has a large number of Faraday cups would be extremely useful.

The beam spot size was measured in 2 different ways, in both cases after the beam had penetrated the output window. The more dramatic was to burn a hole in a lead brick while monitoring the average current, with the intention of stopping when the current drops to 10% of its initial value. However,

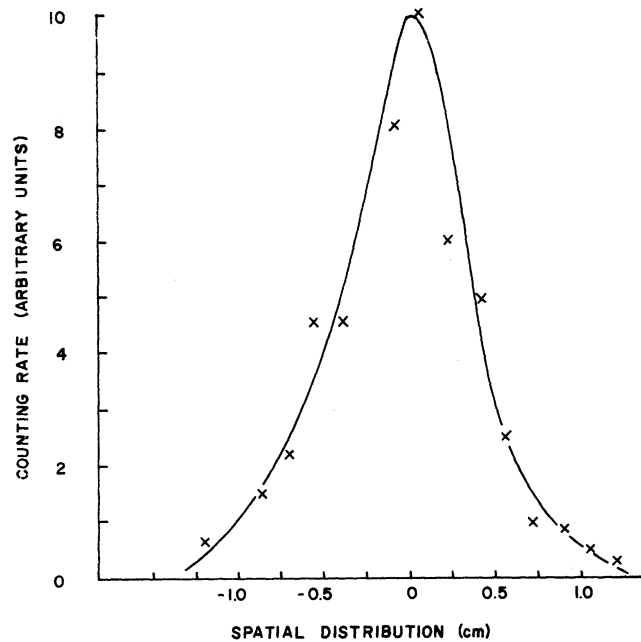


Fig. 5—Beam spatial profile.

various stray currents made this indecisive. The final method used was to irradiate a glass plate backed by a 5 mil. brass foil sandwich; a 1.5 mm wide strip of the brass was cut through the center of the beam spot as indicated on the glass plate. This strip was cut into squares 1.5 mm sq. which were counted separately for radioactivity. This distribution is shown in Fig. 5 and indicated a width, between 10% amplitude values, of 1.7 cm.

GENERAL COMMENTS

During the first quarter of this year, the initial period of full scale operation, 270 beam hours were available for research. The highest total for any one week was 62 hours, with the most direct limitation being the number of people available for operation and of course the down time for experimental changes.

The vacuum stands have been modified so that in the event of failure of any type, as indicated by the fore-vacuum, the stand will close down; i.e., a vacuum solenoid valve isolates the fore-pump and the oil diffusion pump, the diffusion pump heaters are turned off and the quick-cooling loop on the base of the pump is turned on. The vacuum stand remains in this condition until it is reset manually.

Injector guns in the past have been rather delicate and required long and painstaking bake-out and activation upon installation. Recently ARCO has developed a matrix or donor cathode that will withstand exposure to air after activation. The first such gun had been in use a few days prior to installation on our machine and pumped down in a few hours. The second such gun has been held as a spare for about 3 months and was found to be very gassy requiring about 2 days to pump down even though it had been packed in argon. It is therefore planned to mount spare guns on an ion-pump stand to keep them clean until they are needed.

APPLICATIONS

One of the chief virtues of a high-powered electron linac is the wide scope of the research program which can be built around it, using the high flux electrons, neutrons, and gamma rays which it can provide. At Rensselaer the experiments at present fall mainly in the areas of reactor physics and neutron cross section studies. The plans for

these activities have been described elsewhere.^{2,4} Additional studies pro-

4. E.R. Gaerttner, J.B. Sampson, and M.L. Yeater, "Proposal for a Reactor Development Program for the KAPL Technical Department Using a Linear Accelerator as a Pulsed Neutron Source," KAPL Technical Report, (Feb. 16, 1956)

posed by staff of the Department of Nuclear Engineering and Science include radiation damage in solids and isotopic-analysis. Other groups are considering additional research programs in nuclear physics and in areas of biology, chemistry, and metallurgy related to the atomic energy and space nuclear programs.

ACKNOWLEDGMENT

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