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# OVERVIEW OF THE ETA/ATA PULSE POWER

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OVERVIEW OF THE ETA/ATA PULSE POWER*

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Introduction

A pulsed electron accelerator has been constructed and is now in operation at the Lawrence Livermore Laboratory[1]. This Experimental Test Accelerator (ETA) a 5 MeV, 10 kA, 50 ns FWHM, five pulse burst at 1 kHz, was designed to be the front end or injector for the Advanced Test Accelerator (ATA). The ATA is presently under construction and will have the following parameters: beam energy - 50 MeV, beam current - 10 kA, pulse length - 70 ns, repetition rate in a ten pulse burst - 1 kHz.

The parameters which make the pulse power components unique for these machines are the high repetition rate in a burst and a high degree of regulation in the system to insure pulse to pulse repeatability. Because of the larger number of components required for the ATA, a much higher degree of reliability will be required. Improvements and modifications continue to be made on the ETA which is serving as a base of development for all ATA pulse power components. Furthermore, all ATA pulse power components will be tested at length in a test stand before beginning mass production to insure proper design to meet voltage, current, rep-rate and life requirements.

Overall System

A block diagram of the overall system is shown in Figure 1. Although many of the major components for the ATA are similar or identical to the ETA's, there are several changes in overall design that are being made and several proposed ones for improved performance.

Charging System

The ETA adapted the existing modulators in a constant current charging mode as the primary regulated power source while the ATA will utilize a much simpler and less expensive capacitor-limited voltage doubler system. The high degree of regulation required for pulse to pulse repeatability will be achieved by one of two ways, depending on the switch chassis system adopted. If the ETA technique of sequential firing of parallel chassis is adopted to achieve high repetition rates, then a crowbar will be used to accurately stop charging when the proper voltage is reached and simultaneously the primary AC power switch is opened. A serial rep-rateable system is also under consideration. If adopted, the regulation will be obtained by the de-queing of a command resonance charging system. In either case the capacitor limited doubler will yield a leading power factor which is beneficial in partially canceling some of the magnet system lagging power factor.

Switch Chassis and Resonant Transformer

The load to the charging system is the 12Ω Blumlein capacitance, about 14 nF. A resonant transformer is still the logical choice for charging the water Blumlein. The ETA utilizes a coupling coefficient of 0.525 thus avoiding a bidirectional switch[2]. All existing systems were capable of handling the extra power required by the less efficient coupling. In the case of the ATA, however, because of the much larger energy involved, it became imperative, that we adopt the more efficient coupling coefficient of K = 0.6 for the resonant transformer. This type of transformer is extensively used for charging capacitive loads and yields optimum conditions for energy transfer from the primary capacitance to the secondary. At the peak of the secondary or Blumlein voltage, the primary voltage and current and secondary current are all zero resulting in almost all the energy being transferred to the Blumlein and then out to the load by the spark gap. In order to carry the reverse current through the switch a thyratron in the reverse direction has been added. This type of a switch will be adopted with either the parallel delivery system or the series rep-rate system. Figure 2 is the schematic for the pulse power conditioning system.

A quick look at SCR technology showed that many advancements have been made in di/dt, but a considerable development program would be necessary before a direct replacement for the thyratron could be made. Schedule, rep-rate and life considerations did not allow us to pursue the usage of a low voltage spark gap as a primary switch.

In comparing the parallel delivery system with the series rep-rate one, there is little doubt that the series one offers less interaction between components, is easier to maintain, and is more flexible. It carries with it a new set of problems such as regulation, frequency response and a large energy storage bank. The parallel one, however, offers the capability of higher repetition rate during a burst since the switch has to handle only one pulse in a burst and recover before the next one fires. This is at the cost of more components.

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## Spark Gap and Blumlein

The Blumlein for the ATA accelerator has been increased in diameter from 15" to 18'. This should yield fewer breakdowns at the 250 kV levels. This design is expected to hold voltage in the full ringing mode at 280 kV without breakdown. Figure 3 shows a typical ringing test at full rep-rate. We are also attempting to equalize the length of the inner and outer lines, but difficuity in air bubble removal from the water dielectric may make this design impraccical. We have further deviated from the ETA design in that we have traded some impedance for length to obtain a 70 ns FWHM. The Blumlein impedance is now 12Ω and the overall result is an increase in the total energy stored.

The spark gap[3] has undergone considerable redesign in order to adapt to the new larger diameter Blumlein. The new design reduces the inductance from the Blumlein to the spark gap electrodes. The electrodes and the spacing remain essentially unchanged. ETA has shown that the coaxial cylindrical geometry allows the trigger electrode to wear uniformly in the axial direction with no change in electrical characteristics resulting in long life. The coaxial geometry further assures high gas velocities to achieve the one kHz burst mode repetition rate.

## Accelerator Cell and Transmission Lines

The accelerator consists of a 2.5 MeV electron gun and 190 accelerator induction units. Each accelerator unit generates 250 kV. The energy at each gap is achieved the same way as in the ETA;[4] the induction electric field is generated by a changing magnetic flux in the ferrite materials. The ATA cavities have been tested and have shown that they can support the 70 ns FWHM required. The ferrite cores were carefully selected so that they would automatically be reset to reverse saturation by the Blumlein charging current. One major difference between the ETA and ATA accelerator cell is the added ferrite pieces on the feed points and back plane of the cell to suppress the beam breakup mode frequencies.[5] (Figure 4) This has eliminated the need for pulsed magnetic fields to insure beam stability. The magnet power supplies require a stability of 0.02% to insure a stable beam.

## Trigger System

Even with the voltage limitations imposed by the cables, the jitter on the ETA was quite acceptable. On the ATA, however, we will use higher voltage cables which will allow us to increase the trigger voltage level by 50% and easily insure the low jitter. A similar fan-out system as the ETA will be used until sufficient outputs are available to trigger the whole accelerator (Figure 5). The timing of the accelerator gap voltages relative to each other is adjusted by cable lengths. The same switch-chassis, resonant transformer and spark gap as the rest of the system will be used except for the Blumlein which will store less energy.


1. The Experimental Test Accelerator (ETA), by R.E. Hester, et al, IEEE Transactions on Nuclear Science, Volume NS26, No. 3, June 1979
2. Off-Resonance Transformer Charging For 250 kV Water Blumlein by E. Cook, L. Reginato, Thirteenth Pulse Power Symposium, Buffalo, New York 1978
3. High Repetition Rate Burst-Mode Spark Gap, by A. Faltens et al Thirteenth Pulse Power Symposium, Buffalo, New York 1978
4. Pulsed Ferrite Core Tests For 50 ns Linear Induction Accelerator, by L. Reginato, E. Cook, W. Dexter, J. Schmidt at The International Magnetics Conference, Florence, Italy May 9-12, 1978
5. Reduction of The Beam Breakup Mode Q Values In The ETA/ATA Accelerating Cell by Daniel Birx, UCID #18630.

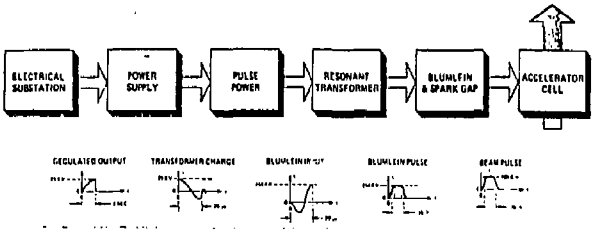


FIGURE 1. POWER CONDITIONING DIAGRAM

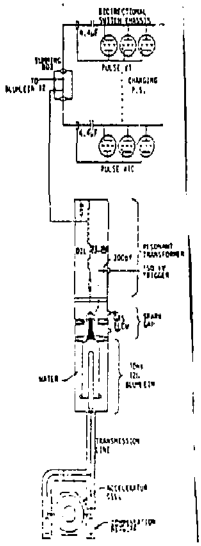


FIGURE 2. PULSE POWER CONDITIONING COMPONENTS

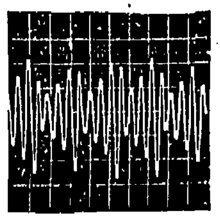

FIGURE 3. BLUMLEIN RINGING TESTS
100 kV/cm - SPARK GAP OVERPRESSURIZED

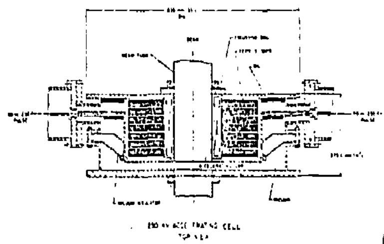

FIGURE 4. ACCELERATOR CELL

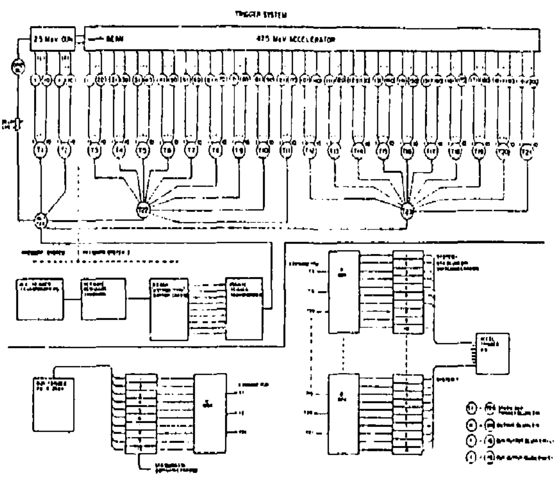


FIGURE 5. SPARK GAP TRIGGER SYSTEM