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OPERATING EXPERIENCE WITH THE 50 MeV 10 kA POWER CONDITIONING SYSTEM

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"OPERATING EXPERIENCE WITH THE 50 MeV 10kA ATA POWER CONDITIONING SYSTEM" *

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Introduction

The Advanced Test Accelerator (ATA) has been operational for over one year and has achieved full parameters in the power conditioning system. The pulsed power system has been previously described[1,2] however, during the past year of operation a considerable amount of statistical data has been accumulated on the 211 gas blown spark gaps that perform the main switching function in the ATA.

These spark gaps were designed for 250kV, 40kA and 70ns pulse. The parameter that made this spark gap somewhat unique was the requirement that it be able to provide a burst of ten pulses at one kilohertz with an average repetition rate of 5Hz.

Data Recording Technique

Fig. 1 shows a block diagram of the on-line diagnostic system for gathering data on the jitter of the 211 spark gaps. It consists of an LSI 11/23 microprocessor running RSC11-M, and eleven CAMAC crates arranged as shown in Figure 1 on two serial fiber optic branch highways. Timing information is obtained by measuring the time of arrival of the accelerating voltage on each cell. The method used is to start a time to digital converter CAMAC module (TDC) with a signal referred to as t0. Cell voltage monitors are used to stop the counters on the TDC's. All TDC's are started by the same signal minimizing error due to different start signals. The standard deviation of the times for each cell is then reported as the jitter on each cell. Also, by knowing the lengths of all the cables, the time it takes the spark gap to close, and the absolute time of arrival of the cell voltage can be determined to ± 0 .5nsec.

The Gas Blown Spark Gap

Although the pulsed power system has been reported at previous conferences, for continuity purposes it will be briefly described here. Basically a 2.5 μF capacitor is switched into the primary of the 0.6 coupled transformer which rings in the double resonance mode and also steps up the voltage from 22kV to 250kV (Fig. 2). The transformer output charges the Blumlein through the anode of the spark gap. An important characteristic of the double resonance transformer is that the primary voltage, primary and secondary currents are zero at the peak of the secondary voltage or spark gap fire time (Fig.3). Most of the energy is therefore transferred to the Blumlein and the load leaving little residual energy behind to be dissipated in the L/R of the transformer or spark gap. This is an important point in achieving fast spark gap recovery for 1 KHz burst operation.

The spark gap geometry is basically the same as that of the ETA (Fig. 4). Since the ATA Blumlein is larger in diameter, careful consideration was given to keeping inductance to a minimum in the transition section. Improvements were made in the water to gas and the gas to oil interfaces. The anode consists of a solid rod of stainless steel 1.5 inches OD; the trigger electrode is 0.030 thick annular ring of inconel 1 inch long welded to the support structure so that it can be easily replaced; the cathode or ground return is a solid stainless steel annular ring 3 inches ID. Since the trigger electrode undergoes most of the wear, it is designed as a thin tube so that it can erode in the axial direction with no changes in the electrical characteristics over the life of the electrode. The trigger electrode is normally biased at the mid potential of the charging pulse (+125kV) and a negative going pulse of 150kV initiates field emission or gap closure. The 150kV trigger pulse is capacitively coupled to the electrode through a 50 ohm resistor; this voltage begins to double until the gap breaks down.

Spark Gap Characteristics

During the planning stages of the ATA pulse power system it was decided to keep the brute force approach for achieving 1 KHz burst. That is, use a combination of high pressure and high flowrate mixture of 7% SF_6 and 93% Nitrogen. This spark gap had proven itself in the ETA and since greater than one kilohertz repetition rate was not a requirement, magnetic pulse compression was briefly considered and not pursued. To achieve the repetition rate by this method we have made a considerable investment in high pressure pipes and blowers. For the complete operation of the ATA's 211 spark gaps, eight 400 hp blowers provide an airflow of 250 CFM at a maximum pressure of 150 PSIG. The high pressure gas flows from the inlet air plenum at the top, splits to both sides of the trigger electrode and returns through the outlet air plenum (Fig. 4). The flow rate at the throat of the spark gap is 5cm/ms. This high flow rate sweeps away the debris from the previous breakdown into the field free region allowing voltage recovery before the application of the next pulse 1 ms later.

Test Results

It had been projected from prototype test results that about 4×10^6 shots could be accumulated before the trigger electrode would have to be changed. Operation of the ATA over the past year not only confirms that number but it appears that the actual life will exceed 5×10^6 pulses. About 2×10^6 shots have been accumulated in the injector, 1.5×10^6 in the first 10 MeV and 1.0×10^6 in the remainder of the accelerator. Typically the spark gap is operated at about 75% of the self breakdown voltage. By operating in this range, the prefires are virtually eliminated and the jitter is kept within $\pm$ 2ns. Fig. 5 shows both the anode closure time and jitter as a function of the trigger pulse level and charging voltage. The operating range is

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fairly broad and one can make minor changes in timing by adjusting the trigger level. Needless to say, the overall machine timing is set by cable lengths so that the cell voltages are synchronized to the arrival of the beam pulse head. Fig. 6 shows the maximum repetition rate as a function of pressure and voltage. As expected the repetition rate decreases almost linearly with voltage and increases not quite as a linear function of pressure at constant flowrate.

The 10-90% rise-time (Fig. 7) of the spark gap is 18ns which indicates an internal inductance of 48nH. The flat top in voltage at the accelerator cell is about 50ns. Fig. 7 shows a ten pulse burst at one kilohertz; note also pulse width of the cell voltage decreasing due to ferrite saturation as the 250kV is exceeded.

Conclusion

The existing ATA gas blown spark gap has met or exceeded all parameters for which it was intended. Jitter and wear have exceeded expectation set by the prototype unit. The 211 spark gaps have proven to be extremely reliable in the over two million shots of operation. Although all of the operation has been at one to two hertz average, burst rate tests on the actual system show that one kilohertz operation will be achievable when the physics experiments demand it. With the magnetic pulse compression at hand, higher repetition rate upgrades would utilize that technology and not gas blown spark gaps.

REFERENCES

1. Faltens, A., et al, "High Repetition Rate Burst-Mode Spark Gap.

2. Reginato, L., et al, "The Advanced Test Accelerator (ATA) a 50 MeV, 10 kA Induction Linac.

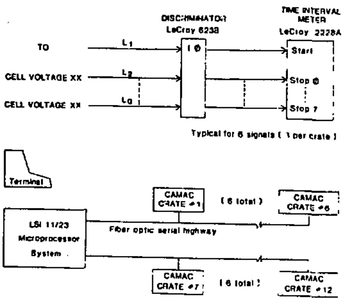
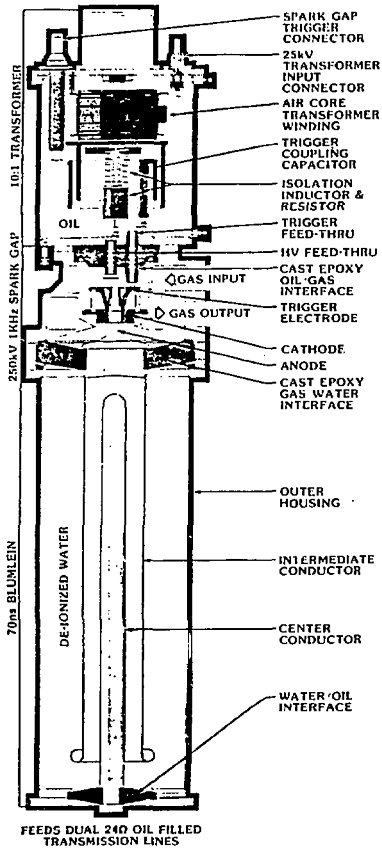
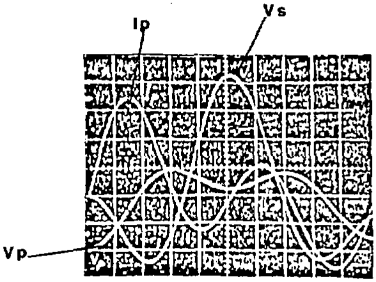


Figure 1
CAMAC DATA ACQUISITION SYSTEM



ATA PULSE POWER UNIT ASSEMBLY

Fig. 2



IDEAL CASE K = 0.6

Cp = 2.03 μF

Cs = 14.4 ηF

Ip = 7.0 A

νs = 2 15 V

Eff = 82%

Fig. 3

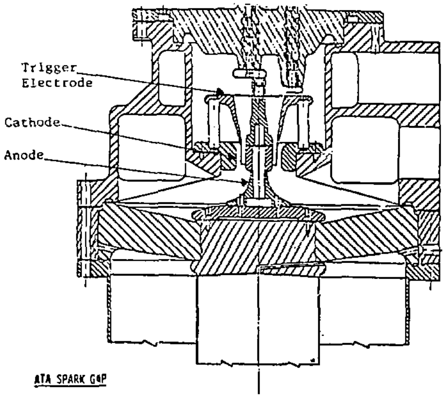


Fig. 4

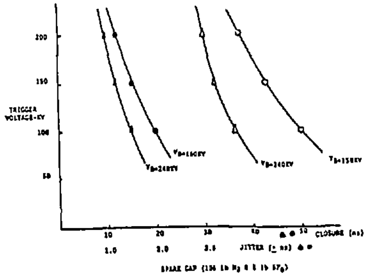


Fig. 5

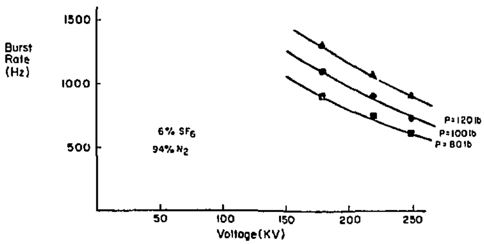


Fig. 6

BLUMLEIN CHARGING **CELL VOLTAGE**

5uS/CM 125KV/CM 20NS/CM 133KV/CM

Ten Pulse Burst

Fig. 7