AN OVERVIEW OF THE ATLAS PULSED-POWER SYSTEMS

W.M. Parsons, E.O. Ballard, G.W. Barr, D. W. Bowman, J.C. Cochrane, H.A. Davis, J.M. Elizondo*, R.F. Gribble, J.R. Griego**, R.D. Hicks, W.B. Hinckley, K.W. Hosack, R.B. Miller, K.E. Nielsen, J.V. Parker, R.L. Rickets, H.R. Salazar**, P.G. Sanchez*, D.W. Scudder, M.C. Thompson, R.J. Trainor, G.A. Valdez, B.N. Vigil, W.J. Waganaar, R.G. Watt, F.J. Wysocki

Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract

Atlas is a facility designed and being constructed at Los Alamos National Laboratory (LANL) to perform high energy-density experiments in support of weapon-physics and basic-research programs. It is designed to be an international user facility, providing experimental opportunities to researchers from national laboratories and academic institutions. For hydrodynamic experiments, it will be capable of achieving pressures exceeding 10 Mbar in a several cm^3 volume.

The 23-MJ capacitor bank will consist of 240-kV Marx modules arranged around a central target chamber. The Marx modules will be discharged through vertical triplate transmission lines to a parallel plate collector inside the target chamber. The capacitor bank is designed to deliver a peak current of 27 to 32 MA with a 4- to 5-μs risetime. Predicted performance with a typical load is presented. Descriptions of the major subsystems are also presented, including data from subsystem performance tests.

I. INTRODUCTION

The Atlas project within the High Energy Density Hydrodynamics Program at Los Alamos is an element of the Department of Energy's Stockpile Stewardship Program. As part of this program, pulsed power machines are used to generate high energy density conditions by discharging multi-megampere currents into a centrally located, cylindrical liner. Near the liner, the current density and associated magnetic fields dramatically increase. The interaction of the current and magnetic field produces Lorentz forces which implode the cylindrical liner. The liner can be used either to compress sample materials to high pressures, or when driven into a central target, to produce extremely high shock pressures for hydrodynamic experiments. Atlas will be capable of driving ~50-g liners into multi-cm^3 targets, producing shock pressures exceeding 10 Mbar.

* Allied Signal Corporation, Albuquerque, NM
** Hytec Corporation, Los Alamos, NM

II. SYSTEM DESIGN

To reach the extreme pressures required for hydrodynamic experiments[1], Atlas must be capable of producing a peak current of 27 to 32 MA. The machine must also be flexible enough to accommodate a wide variety of weapons physics and basic research experiments. Other requirements include (1) maximizing the radial and axial diagnostic access around the target chamber, (2) a machine reliability of 95% or greater, (3) experimental capability of 100 tests/year, and (4) a machine lifetime of 1000 tests at full voltage. Finally, the facility will include areas for eventual support services for users including data analysis and planning and coordination areas.

Atlas is designed as a resistively damped machine to limit capacitor voltage reversal and fault currents. This makes possible the use of medium-energy density capacitors such as those used on Pegasus II[2]. It also reduces the risk of switch damage by preventing excessive ringing of the capacitor charge through the spark gaps.

A simplified schematic of the Atlas discharge circuit is shown in Fig. 1a. In the circuit diagram, C1 represents the equivalent capacitance of the erected Marx modules at 240 kV. The series resistor, R1, provides the required damping. L1 represents the inductance of the erected Marx modules, while L2 is the inductance of the transmission lines and the parallel plate collector. R2 is a shunt-damping resistor to prevent parasitic ringing

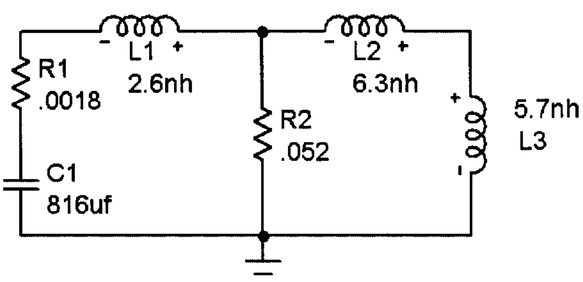

Figure 1a. Simplified Atlas schematic

0-7803-5498-2/99/$10.00©1999 IEEE.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 1999**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **An Overview Of The Atlas Pulsed-Power Systems**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Los Alamos National Laboratory, Los Alamos, NM 87545**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002371. 2013 IEEE Pulsed Power Conference, Digest of Technical Papers 1976-2013, and Abstracts of the 2013 IEEE International Conference on Plasma Science. Held in San Francisco, CA on 16-21 June 2013. U.S. Government or Federal Purpose Rights License.

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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**4**	

between the transmission line capacitance (not shown) and the Marx module inductance. L3 represents the inductance of the power flow channel and the load. A calculated waveform showing the current delivered to a liner is illustrated in Fig. 1b.

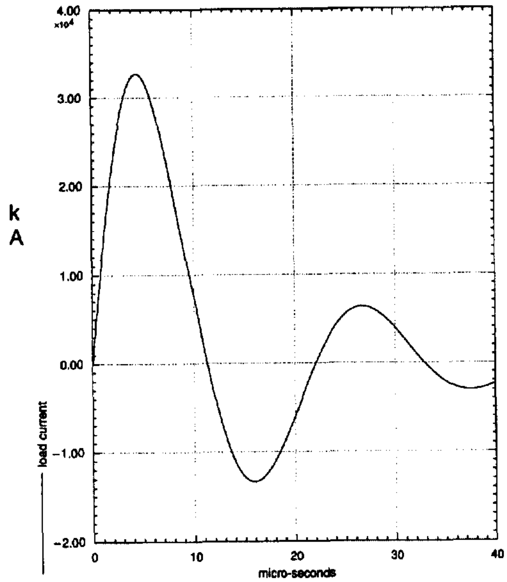

Figure 1b. Calculated current waveform into liner

The 23-MJ Atlas capacitor bank will consist of 96 Marx modules[3] which will be contained in 12 oil tanks arranged in a circular fashion around a centrally-located target area. A total of 24 oil-insulated vertical-triplate transmission lines will carry the Marx module discharge current into a parallel plate collector within the target chamber. Fig. 2 is a CAD rendering of the capacitor bank, transmission lines, and target area.

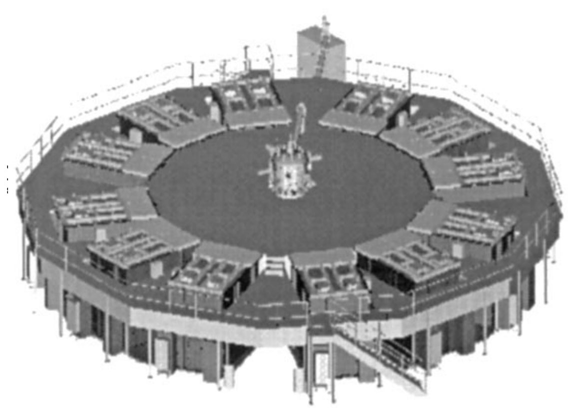

Figure 2. CAD drawing of Atlas Machine

This paper will provide a general description of the major subsystems that comprise Atlas. In particular, these subsystems include the Marx modules, transmission lines and load protection switches, trigger and charging systems, and the controls and data acquisition systems.

A. Marx modules and maintenance units

Each of the 96 Marx modules contains four, 60-kV, 60-kJ capacitors[4]. Two railgap switches[5] are used to "erect" each of the Marx modules into its 240-kV configuration. The two center capacitors in the Marx module are interconnected with a stainless steel resistor to provide damping. Fourteen RG-220 coaxial cables are used to transmit current from the module to an output header. The 240-kV modules are arranged in vertical stacks with two modules in each stack.

Two stacks of Marx modules are physically mounted on a lid to form a "maintenance unit". Each maintenance unit is independently removable from the system and contains its own control and data acquisition module, capacitor charging supply, and railgap trigger system. A picture of the first maintenance unit on an assembly rack is shown in Fig. 3a. Figure 3b is an actual waveform taken at full charge voltage during preliminary testing.

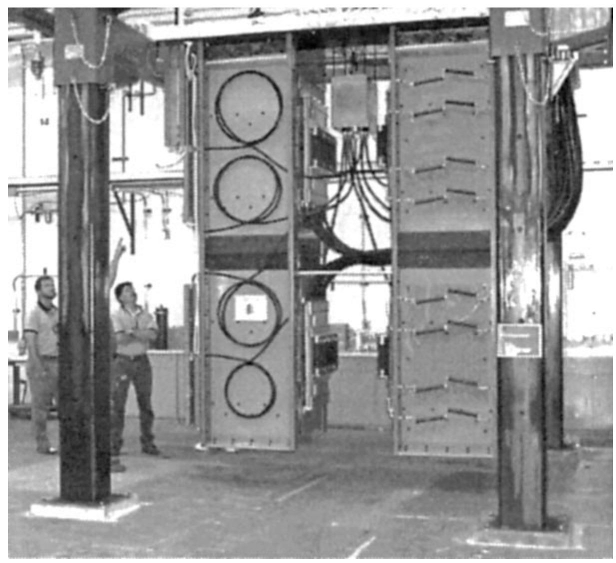

Figure 3a. Maintenance unit assembly

There will be two maintenance units in a single oil tank. We anticipate that periodic maintenance of the railgaps will require that one or more maintenance units will be removed from the system on a monthly basis. Ready spares will be available to replace them. The modularity of the maintenance units will help achieve the maximum anticipated operation of 2 experiments per week while still insuring the overall system reliability requirements.

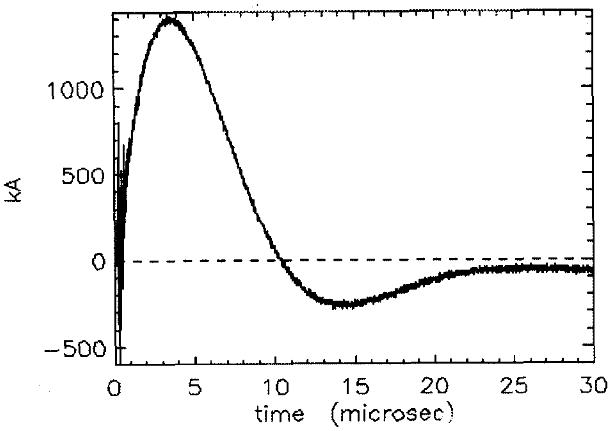

Figure 3b. Current waveform at 240 kV

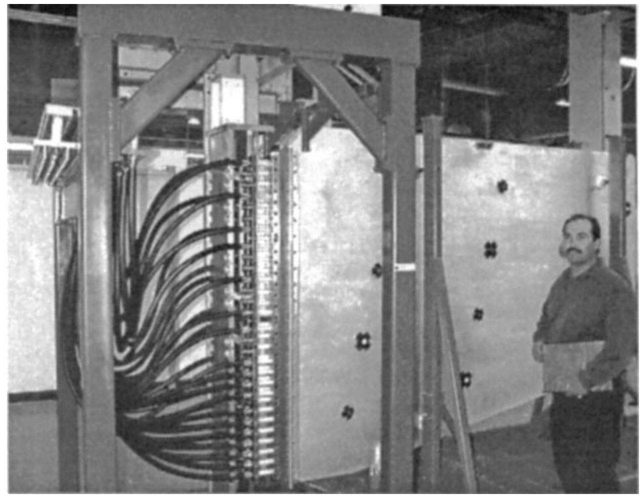

Figure 4. Load protection switch connected to transmission line section

B. Transmission line and load protection switch

Each maintenance unit will be connected to the target area by an oil-insulated, vertical triplate system. These transmission lines must carry 1.3 MA under a normal discharge, withstand a discharge voltage of 220 kV, and introduce minimum inductance to the system.

A transmission line consists of three parallel plates. The center conductor will carry current to the load while the outside plates act as the return. The plates are approximately 2-m tall at the maintenance unit end and have a constant spacing of 2 cm over their entire length. At the target chamber end, the transmission lines narrow to approximately 0.3-m tall and transition to a horizontal, parallel plate collector. Two sets of transmission lines will be housed in a single oil containment tank connected to each of the 12 maintenance-unit tanks.

Each transmission line will have a load-protection switch located near its connection to a maintenance unit. During charging, these switches will remain closed. When the bank reaches full charge, they will open in approximately 250 ms. The bank will then be immediately triggered. The load protection switches provides three functions. First, they protect the load assembly from current in the case of a Marx module prefire. Second, they allow the flexibility to discharge the modules, individually or collectively, without subjecting the load region to significant voltage or current. This technique could be used to condition components and test for faults without affecting the center of the machine. Third, they provide an additional safety system to protect personnel from any residual voltage on the capacitors when they are working in the center of the machine. A picture of the first load protection switch connected to a one-half-length section of transmission line is shown in Fig. 4.

C. Trigger and charging systems

The modular nature of the Atlas pulsed power system is enhanced by the fact that each maintenance unit has a dedicated trigger unit and charging supply. The high-voltage trigger submaster is attached to the underside of the maintenance unit lid, while the master trigger generator is located on the outside wall of the oil tank and serves both submasters in a tank. The charging supplies are also outside the oil tank, but located on the floor in 19-inch racks.

The trigger system chosen for use in Atlas is a Maxwell Technologies Model 12600. It provides a 100-kV pulse to each railgap with a dV/dt greater than 10 kV/ns. Jitter has been measured to less than 10 ns and prefire/nofire rate was specified to be less than 1 in 500. Each of the two submasters has 8 output cables connecting to the 8 railgaps in the maintenance unit (all the railgaps are actively triggered). The master trigger generators are controlled by a maintenance unit control system located on the maintenance unit lid, but will be triggered using direct fiber-optic connections to the control room. There are a total of 12 master trigger generators and 24 submaster trigger generators in the Atlas system.

The charging system chosen for use in Atlas is an array of 96 Maxwell Technologies Model CCS12065 supplies. Each maintenance unit will have 4 supplies – two positive polarity and two negative polarity. The same-polarity supplies are parallel connected and then the opposite-polarity pairs are connected in series. Like the trigger systems, the supplies are controlled by the maintenance unit control system. Each supply is rated for 12.5 kJ/s with a maximum output voltage of 65 kV. This arrangement will permit charging of the capacitor bank to full voltage in ~25 seconds.

D. Controls and data acquisition systems

Attached to each of the 24 maintenance units will be a dedicated control[6] and monitoring station. This station will control the charging, dump, and isolation switches, and will monitor voltage, current, gas pressure in the railgaps, and the railgap triggering timing. During the charge cycle, the station will control the power supplies while monitoring the charge current and voltages to detect fault conditions. If a fault is detected, each control station will have the ability to shut down its power supply and notify the rest of the system to initiate a shutdown-on-fault sequence.

The master data acquisition system will acquire the data from the machine diagnostics, as well as coordinating with user-provided diagnostic systems and storing and disseminating data. The master diagnostic system will also provide a reasonable degree of flexibility for experimenters to record their data the way they want, while at the same time enforcing a uniform and efficient approach to making the experimental data available to users.

In addition to data recording equipment, the data acquisition system will consist of several workstations to interface with the recording equipment, appropriate fiber-optic network connections between the workstations and the recording equipment, and a powerful database server running a high-end database management system to store the data.

III. SUMMARY

In summary, Atlas has been designed to support the hydrodynamic mission of DOE's Stockpile Stewardship Program. The machine itself is a 23-MJ capacitor bank designed to drive imploding liners with 27 to 32 MA of current at a peak voltage of 240 kV. The design is modular to allow off-line maintenance and easy upgrades. Components and major subsystem performance has been verified and construction is underway. Operation is scheduled to begin in early 2001.

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