Atlas Acceptance Test[1]

J. C. Cochrane, Jr, J.V. Parker, W. B. Hinckley, K.W. Hosack, D. Mills, W.M. Parsons, D.W. Scudder, J. Stokes, L. Tabaka, M.C. Thompson, F. J. Wysocki
Los Alamos National Laboratory, Los Alamos, NM, USA
T.N. Campbell, D.L. Lancaster, C.Y.Tom,Jr
Bechtel-NV; Bechtel Las Vegas NV, USA

Abstract

The acceptance test program for Atlas, a 23 MJ pulsed power facility for use in the Los Alamos High Energy Density Hydrodynamics program, has been completed. Completion of this program officially releases Atlas from the construction phase and readies it for experiments. Details of the acceptance test program results and of machine capabilities for experiments will be presented.

I. Introduction

Atlas is a pulsed power facility designed and built at Los Alamos National Laboratory for use in hydrodynamic studies for both weapons physics issues and basic research.[2] With a delivered current to an imploding load of over 30MA, pressures of 5-15Mbar can be achieved depending on the final implosion radius of the load. Velocities greater than 10mm/μs with liners having masses of 40g or greater and centimeter dimensions are achievable. Atlas uses high energy density capacitors and resistive damping to control voltage reversal on the capacitors. Gas filled 'rail gap' multi-channel spark gap switches are used and triggered by a high voltage charged cable trigger system. These designs allow the Atlas pulsed power system to be capable of firing every 15 minutes, the limiting factor being the heating of the series resistors. This capability has been demonstrated. The shot rate on Atlas will be determined by the experimental turn-around time. Considerable damage inside of a 1meter diameter is expected. A simple circuit diagram for Atlas is given in figure 1. The facility was completed ahead of schedule (December 2000) and under budget. Present plans are to dismantle Atlas and move it to the Nevada Test Site where it will be re-assembled. Until a new building can be constructed to house the facility, an experimental program will be conducted at Los Alamos. The first experiments are scheduled in July of this year when Atlas is expected be given permission to begin operation as an experimental facility.

II. ACCEPTANCE PLAN

The DOE requires execution of an approved acceptance plan before a major construction project such as Atlas can be declared complete. Atlas is constructed with a 'maintenance unit' (MU) as its basic minimum unit. This unit consists of 4 Atlas Marx units in parallel, mounted on a common lid. Each MU has its own tri-plate transmission line connecting it to the central radial disk line at the center of the machine. There are 24 MU's in Atlas in 12 oil tanks. During assembly, each of the MU's was tested at full rated voltage and current (240kV, 1.3MA), with a tri-plate line connected to a resistive, inductive dummy load. It was then placed in an oil

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14. ABSTRACT
The acceptance test program for Atlas, a 23 MJ pulsed power facility for use in the Los Alamos High Energy Density Hydrodynamics program, has been completed. Completion of this program officially releases Arias from the construction phase and readies it for experiments. Details of the acceptance test program results and of machine capabilities for experiments will be presented.

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tank in the Atlas machine. The machine acceptance plan was to certify the operation of Atlas by firing each tank separately, then 4 tanks simultaneously, then 8 tanks simultaneously, and then the full machine discharge of 12 tanks. All of these tests were performed at an erected voltage of 160kV, 180kv, and 192kV, except for the full system shot which was fired at 160kv, 172kv, and 180kV. The logic of firing 'tanks in quadrants' of Atlas is that the operating voltage of the machine is only a factor of two at most. If experiments are designed which require less current than with the full machine at 1/2 of its voltage, using tanks in machine quadrants can still supply the needed current and maintain current symmetry at the load. The load for all of these acceptance tests was an inductor mounted at the periphery of the inner radial disk line. The power flow channel was specifically not part of the construction project, so the acceptance test load was a large diameter (~80cm) single turn toroid. The Atlas design current was 27-32MA with the full machine, so the acceptance test target current was 27MA into the dummy load. The dummy load had an inductance of 9nH with a possible configuration of 6nH that was not used. In addition to output current magnitude, trigger simultaneity, power supply charging rates, and all control and data acquisition functions had to be satisfactory. The reason that the machine acceptance tests were not conducted at 240kV is that the damping resistance of the machine is designed so Atlas can deliver >30MA into a 16nH inductance using the dL/dt of a fast liner to aid in preventing excessive voltage reversal on the capacitors. A slow liner or dummy load requires less voltage for a given current but doesn't damp the voltage swing on the capacitors. 180kV was sufficient to exceed the 27MA level into 18nH and keep the voltage swing less than 276kV. Without the damping of a fast liner, 192kV into 16nH (I=30MA) is the maximum voltage to not exceed 276kV swing on the capacitors. The capacitors should tolerate a 300 kV voltage swing without significant lifetime degradation.

III.ACCEPTANCE TEST RESULTS

Current and voltage measurements were made at the entrance of the transmission line using both the raw and integrated signal from Rogowski belts. Near the exit of the lines, voltage was measured via B-dot and E-dot probes. Current in the dummy load was measured using Faraday rotation. Circuit parameters were calculated three ways; a single loop approximation based on knowing only C, a double loop Spice calculation using constant parameters, and a full circuit Scat calculation using calculated values of L, and a temperature and switch-current based resistance model. For the single loop approximation, the current is given by eq. (1) below.

$$I = (V/\omega L)e^{-\alpha t}\sin(\omega t) \qquad \text{eq. (1)}$$

(where $\alpha = R/2L$ and $\omega = \sqrt{((1/LC) - \alpha^2)}$)

At the time to current maximum (tmax),

$$\alpha = \omega \cot(\omega(t\max)) \qquad \text{eq. (2)}$$

Here, ω is obtained from the time of the first half cycle in these highly damped discharges. Then if C is known, L and R follow. In Atlas, shunt resistors to dampen cable oscillations provide another path to ground in parallel with the load. Their effect is included in α with small error. This method gives an equivalent R and L that may be used in place of the Atlas resistance model and

calculated inductance. The model R(total) for the full machine of 96 Marx modules is the sum of

R(switch) = eq.(3)

$$(1/96)*(5.9/(\int I(switch)^{0.667}dt+100))$$

and the stainless steel series resistors

R(T)= eq. (4)

$$0.00156(1+.001(\Delta T))$$

Using a constant R gives results to within 2% of amplitude and time. Table 1 gives the inferred constant circuit values consistent with the Atlas full machine acceptance tests. Using the equations above with a fixed resistance to infer Atlas L and R will give a slightly lower than average R and higher L. In Table 1, the 18.4nH and 1.8mΩ are the parameters that give the best constant parameter fit using the 2 loop simple Spice model. The single loop approximation gives R as 1.7mΩ and L as 19nH. Using the Atlas resistance model gives a resistance that falls from ~2.2mΩ to 1.75mΩ in 10μs with a limiting value of 1.73mΩat 20μs. With this resistance profile, the inductance to match the experimental shape is 18.11nH. The calculated value using previous Marx test results and Flux 3D is 18.15nH. The important note is the inductive division before and after the shunt resistor (2.6nH before, and 7.8nH plus the power flow channel (pfc) and load inductance, respectively, for experiments). Figure 2 shows a circuit simulation using Scat with the full resistance model, 18.1nH. and 816μF. The simulation is accurate to within 0.5% of the current waveform shape during the first cycle. While the combination of R, L, and C to produce a given shape are not unique, both the inductance calculations and cold series resistance measurements would have to be incorrect in inverse proportion if C were changed The current amplitude for the full machine 45 kV shot was 28.5MA using Faraday rotation, and 27.5 MA using data from three scaled Rogowski's. The simulation overlay is to the scaled Rogowski belts. For reference, at 45 kV, the 8 tank shot gave 21MA and the 4 tank shot gave 11 MA. This implies a useful current range of ~8-30MA using tanks in each quadrant along with all 12 tanks.

IV SUMMARY

Atlas has successfully met its design goals in delivering current to the outer radius of the power flow channel. The acceptance tests have shown the entire pulsed power system and computer control and data acquisition system to be ready for experiments. Atlas has the flexibility to fire one, two, or all three tanks in each quadrant for a range of total delivered current of approximately 8-32MA. The Atlas pulsed power system is capable of firing a shot every 15 minutes. The actual shot rate will be determined by clean up time and the time required to assemble and align the load and diagnostics for a shot.

The acceptance tests have also given experimental data to support the calculated machine parameters to within 0.5%. Atlas is ready to begin experiments as soon as it receives approval to become an operational facility. The experimental life at Los Alamos is estimated to be one to one and one half years before disassembly begins in order to prepare for shipment to Bechtel Nevada at NTS.

component	Value for Accept..test	exp.
MU	2.6 nH	2.6nh
Series + switch resistance	R(I,T) or (1.8mΩ)	
Shunt resistor	50mΩ	50mΩ
cables	1.17 nH	1.17nH
Header + LPS	.53nH	.53nH
Transmission lines + transition region	4.85 nH	
Oil-plastic interface	(included)	(.52 nH)
Disk line	NA	(.76 nH)
Pfc 'cone'	NA	(3.7 nH)
Load Acceptance test load	NA 9 nH	(>1nH) NA
Total series L ,C, R	18.15 nH (18.4nH) 816μF816μF (1.8mΩ)or	(14.13+ L(load)) R(I,T)

Table 1. Atlas circuit values from acceptance tests. The "exp." values are the inductances of planned experimental hard ware.

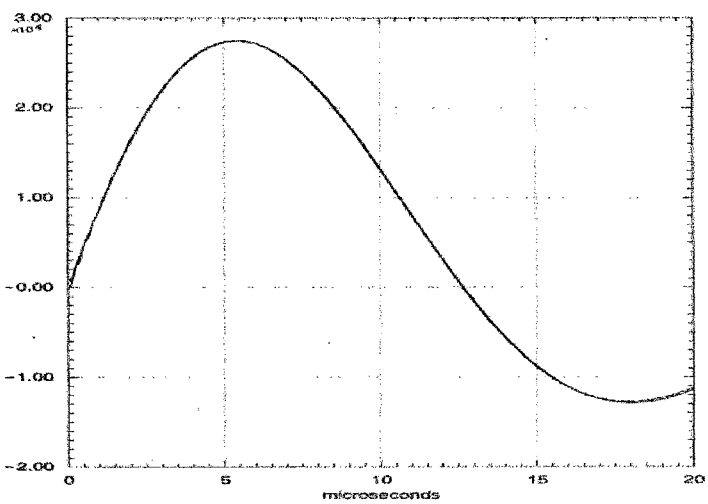

Fig.2 Current (kA) vs. time (μs) overlay of Scat simulation and Rogowski data for 45kV full machine acceptance test

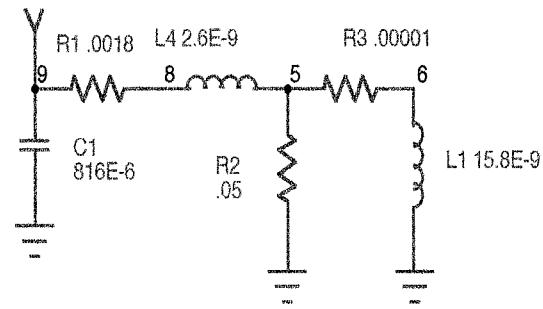

Fig. 1 Simplified constant parameter Atlas circuit for values used in full machine acceptance test

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[2] W.M. Parsons et.al.,"An Overview of the Atlas Pulsed Power Systems" in *Proc.12th IEEE int. Pulsed Power Conf.*, June, 1999, p. 976