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ATLAS FACILITY FABRICATION and ASSEMBLY*

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Abstract

Atlas is a pulsed-power facility recently completed at Los Alamos National Laboratory to drive hydrodynamic experiments. This new generation pulsed-power machine consists of a radial array of 24, 240-kV Marx modules and transmission lines supplying current to the load region at the machine center. The transmission lines, powered by the Marx modules, consist of cable headers, load protection switches and tri-plates interfacing to the center transition section through detachable current joints. A conical power-flow-channel attaches to the transition section providing an elevated interface to attach the experimental loads for diagnostic access. Fabrication and assembly of all components for the Atlas machine was completed in August 2000. The machine has also progressed through a test phase where the Marx module/transmission line units were fired, individually, into a test load. Progression continued with eight and sixteen lines being fired. Subsequently, an overall machine test was conducted where all 24 transmission lines were fired simultaneously, delivering 28.6 MA into the test load. The machine assembly went smoothly with very few problem areas developing during all phases of installation of the structure, oil tanks, transmission lines and center transition section. The target chamber and vacuum system have also been installed. All components are performing as designed at the voltage and current levels expected at this point in the diagnostic testing. The machine was designed, fabricated, assembled and tested within the original budget and on schedule and is meeting the specified performance goals.

I. ATLAS MACHINE CONFIGURATION

The Atlas machine configuration is shown in Fig. 1. The 23 MJ capacitor bank is housed in 12 separate, oil-filled Marx tanks surrounding the target chamber. Each tank contains two, independently removable maintenance units composed of four parallel connected Marx modules. The Marx modules have four capacitors charged at up to ± 60 kV and two rail-gap switches. When the switches are triggered, the Marx modules erect at up to 240 kV. The output of each maintenance unit is connected to a fast-acting mechanical load protection switch (LPS) that shorts out the load to prevent it from being damaged in case of a pre-fire. A set of 24, tapered, vertically oriented, oil insulated, tri-plate transmission lines carry the current from the 24 maintenance units to a transition section at a radius of 48.85-in. (1.24 m). The transition section couples the current to a solid-dielectric insulated radial and conical transmission line that delivers current to the load. The load is housed in a 72-in.(1.83 m) diameter, stainless steel vacuum chamber that also provides debris containment. There is also an internal debris shield to protect the vacuum vessel wall.

Figure 1 Atlas personnel platform and target chamber

II. ATLAS MACHINE OPERATION

The output of each Marx maintenance unit is connected to a low inductance, oil-insulated, cable header (CH) by fifty-six, 50 Ohm cables. The CH provides a means to quickly disconnect the maintenance unit from the rest of the system for servicing. Each CH is connected by a second set of fifty-six, 50 Ohm cables to the input of the load protection switch (LPS). The LPS shorts the output of the maintenance unit through a low inductance path during capacitor charging. In case of a pre-fire, only about 35 kA flows through the load and permanent damage to the load does not occur, thus preventing costly load replacement. Once the capacitors are charged, the LPS opens the short circuit path in 0.25-s. This reduces the time the load is vulnerable to a pre-fire from several seconds to a fraction of a second, which is sufficient to meet the 95% shot reliability requirement.

As seen in Fig. 2, the output of each LPS is connected to an oil insulated, tri-plate transmission line. The plate-to-plate gap is nominally 0.811-in. (2.06 cm) and the lines taper from a height of 68-in.(1.75 m) at the switch end to 12.5-in.(0.32 m) at the output end. The tri-plate aluminum conductors are held together by 20 nylon insulating spacers which maintain the gap between the conductors. The tri-plate assemblies are inserted as a unit into radial, oil-filled, steel tanks. The negative, high-voltage, center conductor is 1-in. (2.54 cm) thick and the outer ground conductors are 0.625-in. (1.59 cm) thick.

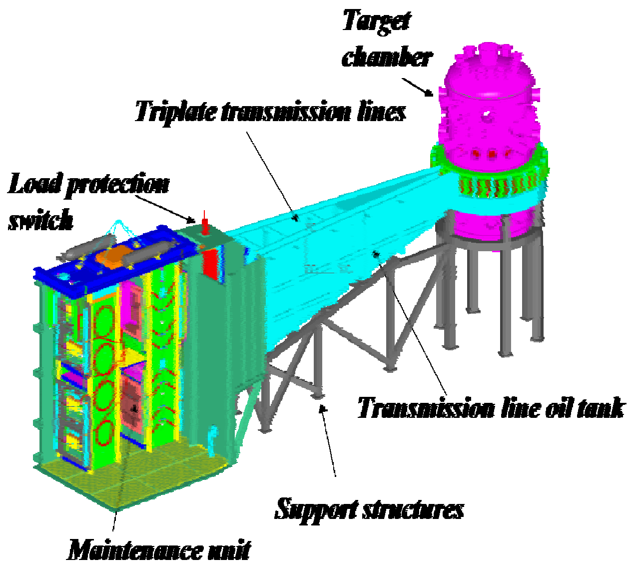

Figure 2 Transmission line configuration

The 24, tri-plate transmission lines connect to a transition section at a radius of 48.85-in. (1.24 m). The transition-section couples the 24 transmission lines to a single, solid dielectric insulated inner transition that interfaces to the load. The center high-voltage conductor is supported so that it transmits impulse loads from the current pulse to the support structure. It also provides seals between the target chamber vacuum and surrounding air and oil. The high-voltage conductor sits on insulating disk segments, which isolate it from the base-plate and allows the base-plate and vacuum chamber to be grounded.

The center high-voltage conductor of the tri-plate line connects to radial vanes on the high-voltage transition conductor through a current joint. The outer ground conductors of the tri-plate are also connected to the ground transition conductor through a similar current joint, which allows the tri-plate to be engaged or disengaged from the transition section.

III. ATLAS FABRICATION and ASSEMBLY

A. *Transmission Line Components*

The Atlas transmission line starts with a cable header that provides a mechanism for disconnecting the Marx maintenance unit from the transmission line. This allows the Marx to be removed for maintenance without disruption to the remainder of the transmission line. Half of the cable header remains in place along with the 56 cables connecting it to the LPS. The other half remains connected with 56 cables to the Marx. The LPS attaches directly to the tri-plate with a bolted current joint that has a nominal current density of approximately 5 kA/cm. The cable header and load protection switch are suspended from a lid that rests on the top surface of the Marx tank. Fig. 3 shows the lid/CH/LPS assembly.

Figure 3 Cable header and load protection switch assembly

Fig. 4 shows a tri-plate with its 20 stand-off insulators used to establish the proper plate separation and support the center high-voltage conductor. The tri-plate is approx. 20 feet (6 m) long with a tri-angular shape that allows interfacing with the transition section.

The tri-plates were machined from large plates using a CNC bridge mill programmed to machine the outer periphery and bore the holes individually in each plate. Prototype tri-plates were match drilled to achieve precise alignment of the holes. Individual boring was thought to be too imprecise to assure the alignment of holes in three plates that are mounted together with tight fitting insulators. However, when the first production set was CNC machined it was found that tight enough tolerances could be maintained so that the plates could be assembled.

Current joints connect the tri-plate to the transition and provide the capability to disconnect the tri-plate from the transition, for tri-plate maintenance, without disturbing the transition assembly. The current joint uses a high-pressure interface obtained by using an eccentric rod that presses the interfaces together when turned into position at assembly. Top and bottom clamp bars, with copper wire interfaces, also provide additional current transfer capability to prevent burning in high current density regions.

Figure 4 Tri-plate installation

Fig. 5 shows how the current joint slides together joining the tri-plate and transition components. The top and bottom clamp bars are then installed to complete the current joint assembly.

Figure 5 Current joint assembly

B. Transition Components

The central region of Atlas comprises two major assemblies, a mechanical assembly and a high current convolute. There are two principal components of the mechanical assembly. The base-plate is a 3.25-in. thick, annular stainless steel plate that provides the structural support for the machine central region. The base-plate is rigidly supported from the floor through four steel columns. Mounted on the outer edge of the base-plate is the tri-plate tank attachment ring. This is a large, machined, stainless steel casting that provides the center structural hub and oil containment for the machine central region. This ring can be partially seen in Fig. 6 as vertical walls interfacing to the flanges of the tri-plate oil tanks.

The high current convolute also consists of two principal components. The high-voltage conductor is a large aluminum hub with 24 radial vanes. Fig. 6 shows the HV conductor during installation. The HV conductor has a large central hole, as does the base-plate, to provide diagnostic access to the bottom of the load. The HV conductor is supported by the base-plate through 2.5-in. thick polyurethane insulating blocks. These blocks are sized to support both the static weight and the large impulse load applied to the HV conductor during a discharge.

Figure 6 Transition high-voltage conductor installation

The ground conductor of the convolute is a second annular aluminum ring which is slotted in 24 locations to fit over the vanes of the HV conductor with a spacing of 0.689-in. (1.75 cm). This oil-filled gap provides adequate insulation for the expected 140 kV potential while minimizing the system inductance. Fig. 7 shows the ground conductor during installation.

Figure 7 Transition ground conductor installation

The electrical conductors were made from large aluminum forgings, that were rough machined and ultrasonically inspected for material defects. The forgings were then machined into the configurations shown, with extremely tight tolerances held on many of the features. These components were very difficult to machine and required vibratory stress relief and fixturing to stabilize the material during the final machining process.

The oil-to-vacuum interface between the HV conductor and the base-plate utilizes a machined, cast polyurethane insulator that seals in the insulating oil surrounding the HV conductor and is shown in Fig. 8.

Figure 8 Bottom insulator installation

The transition section is the last part of Atlas that is oil insulated. Current is carried from the transition section by conductors that are insulated with 0.25-in. (6.3 mm) of cast polyurethane dielectric from 31.5-in. (0.8 m) radius inward to 17-in. (0.43 m). These conductors, called the inner transition section, contain a 45 deg. conical region which elevates the load region for better diagnostic access, and a flat disk region which brings the current inward towards the load. The Atlas machine, as constructed, ends at two current joints at approx. 17-in. radius. Inside this radius, the hardware is generally expended on each test and is the responsibility of the experimental program. The general design of the inner transition section, however, presumes that solid dielectric insulation will continue to the load.

C. Target Chamber Components

The Atlas target chamber consists of upper and lower, stainless steel, vacuum vessels shown in Fig. 9 and 10, respectively. The upper vessel seals on the transition ground conductor and is removable for experimental access to the inner transition and load regions. The lower vessel is bolted to the bottom of the base-plate and has a 36-in. diameter personnel access hatch, which is opened and closed by a motor driven actuator. Both vessels have internal debris shielding to prevent damage to the vessel interior walls.

Figure 9 Atlas upper vacuum vessel

Figure 10 Atlas lower vacuum vessel

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