Joint Actinide Shock Physics Experimental Research (JASPER) Facility Update

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Abstract:

The JASPER Facility utilizes a Two-Stage Light Gas Gun to conduct equation-of-state (EOS) experiments on plutonium and other special nuclear materials. The overall facility will be discussed with emphasis on the Two-Stage Light Gas Gun characteristics and control interfaces and containment. The containment systems that were developed for this project will be presented.

Introduction:

The Joint Test Organization; Los Alamos National Laboratory, Sandia National Laboratories and Lawrence Livermore National Laboratory identified a need for Equation of State (EOS) to be conducted on Special Nuclear Material (SNM) at pressures achievable with a Two-Stage Light Gas Gun. After several sights were screened to house the Two-Stage Light Gas Gun, the Nevada Test Site was selected for the new facility. Construction began in April 1999, and the first full-up experiment was successfully conducted on March 19, 2001.

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To date the gun (28mm/89mm) has launched projectiles ranging in mass from 14.6 grams to 68 grams and velocities from 2.1 km/sec to 7.6 km/sec. The facility was declared operational this year for actinide targets and has successfully conducted Equation of State experiments on Plutonium targets.

The JASPER Facility will support the following Campaigns:

1. **Campaign 1: Primary Certification** – JASPER data will be an important component of the tools required to certify the performance and safety of any rebuild or aged primary.
2. **Campaign 2: Dynamic Material Properties** – JASPER will provide materials response data used in the development of EOS and strength models for Special Nuclear Material.
3. **Campaign 3: Material Lifetimes** – JASPER will help provide a validated basis for determining when components must be replaced and when new manufacturing facilities are required.

**Two-Stage Light Gas Gun Operational Characteristics and Control Interfaces:**

**Gun Characteristics:**

The JASPER Two-Stage Light Gas Gun, see table #1, consists of a two-piece 89 mm bore Pump Tube that is normally charged to 16 bar (232 psig) Hydrogen gas which is maintained to ± 1 psig of requested fill pressure by the Control System. The Acceleration Reservoir (AR) is a two-piece sleeve design pressed together. It has a 3.9° half angle and is designed to operate with two 5 ksi break diaphragms or one 10 ksi diaphragm with scores on both surfaces. For low velocity shots one 5 ksi break diaphragm can be used with a spacer ring. The launch tube is a single piece barrel; 8.1 meters long with a nominal 28 mm bore.

<table>
<thead>
<tr>
<th>Pump Tube</th>
<th>11.5 meters long</th>
<th>89 mm bore</th>
<th>4.5 kg Piston</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Tube</td>
<td>8.1 meters long</td>
<td>28 mm bore</td>
<td>2.4 – 7.4 km/sec</td>
</tr>
<tr>
<td>Acceleration Reservoir</td>
<td>Sleeved Design</td>
<td>Pressure gauge in petal valve holder</td>
<td>Assembled Hydraulically (1100 bar)</td>
</tr>
</tbody>
</table>

**Table 1: Two-Stage Light Gas Gun Characteristics**
Control System Interfaces:

The Gun operating parameters are under computer control and the gun firing sequence starts with the control system determining the following conditions have been met:

1. Interlocks for the following systems are in the “ready” condition
   a. Breech position
   b. Acceleration Reservoir is locked in proper position
   c. Recoil system is unlocked
   d. Gun Position is correct
   e. Building interlocks are activated

2. Vacuum is 80 millitorr or less (50 millitorr or less is a more realistic number)
   a. Primary Target Chamber (PTC) vacuum is 50 millitorr or less
   b. Secondary Containment Chamber (SCC) vacuum is also less than 50 millitorr and maintained at a vacuum which is slightly greater than the PTC vacuum

3. Three CDU firing sets, one for the propellant charge and two redundantly coupled for the Ultrafast Closure Valve (UCV), gate and debris valves are armed and charged

4. Pump tube pressure is ± 1psig of requested fill pressure and can maintain that pressure

5. Target has been deployed and is docked in aligned position

6. Gate valve is open

7. Debris valve is open

8. Output signal from the continuous x-ray detector is within established limits

9. Output signals from the four Optical Beam Break (OBB) detectors are within established limits

10. Flash x-ray units are charged and both shutters are open

11. Target Diagnostics are ready and reset

12. The Control System panel is green and is ready to be fired

When the Control System has determined all requirements identified above have been met it activates the fire switch. The following sequence; see Figure 2, takes place as the firing pulse is activated.

Containment Timing:

The Timing System in conjunction with the Control System provides the fire pulses for the explosively driven UCV, Gate Valve and Debris Valves. It also precludes any early firing from noise by gating these systems off until it can verify that:

1. The gun has fired

2. The piston is accelerating through the pump tube

As the propellant train is initiated, the Timing System is activated, see Figure 2. There are four piston velocities pins located along the length of the pump tube. Two of these pins provide an enable signal to the Timing System, which opens a window of
opportunity for the Timing System to sense the projectile, measure its velocity and generate the firing pulse to the capacitor discharge units to close the containment valves. After the gun goes through a normal firing cycle, the projectile is detected by a continuous x-ray system as it exits the launch tube. The continuous x-ray has the following functions: First, it provides a trigger through a set time delay to the first flash x-ray which captures the projectile in flight on film. Second it provides the first signal to the Timing System, which is used to determine the actual projectile velocity. The OBB #1, #2, #3 and #4 in that order detect the projectile in flight and provide signals to the Timing System along with the continuous x-ray for real time projectile velocity calculations. OBB #3 also provides a trigger signal to fire a second flash x-ray unit which completes the primary velocity measuring system. The combinations of the continuous x-ray and four OBB detectors signals allow the Timing System to initiate the containment valve closures 37 µsec prior to impact. At the highest velocities this will put the projectile approximately in the middle of the UCV when the high explosives are initiated. This variable distance, constant time trigger enables the UCV to close before debris from the impacted target escapes ensuring PTC containment. If all system failed the a trigger pin on the impacted target will close the explosive containment valves.

**Containment Systems:**

**Primary Target Chamber (PTC):**

The Primary Target Chamber, Figures 3 and 4, has several distinct functions. The PTC holds the Target Assembly and Deployment Mechanism before, during, and after the shot, contains the projectile-to-Target Assembly impact energy and debris, and functions as an interim waste container. Additionally, the PTC allows alignment of the Target Assembly to the gun axis, provides experimental data and control feedthroughs, and interfaces with the JASPER control system. The PTC includes the Ultrafast Closure Valve System (UCVS) and provides the mount for the second pair of Optical Beam Breaks (OBB). The PTC is a one-time use item and is expended with each shot.
The Primary Target Chamber is installed into the Secondary Containment Chamber (SCC) and aligned and locked into place for each experiment. The PTC contains the Actinide target, deployment system and exact constraints assembly for alignment plus target diagnostics to detect the physics data. The PTC volume is evacuated independently of the SCC and is exhausted through dual HEPA filters. The PTC volume is isolated with a gate valve until just prior to gun firing. Experiments are conducted in a vacuum of 50 millitorr or less. The Control System monitors the vacuum levels in both the SCC and PTC and maintains the PTC at a slightly lower vacuum than the SCC to reduce the chance of contamination escaping the PTC.

The target is deployed by opening a pendulum gate valve and driving the target assembly out of the bellows assembly till it docks with the exact constraints system. These systems are aligned to the bore of the launch tube during PTC installation. The Primary Target Chamber is designed to withstand the loading conditions generated during gun firing, projectile/target impact and Ultrafast Closure Valve closure. The projectile is detected and its velocity and position are measured real time during its 0.9 meter free flight. The Ultrafast Closure Valve is explosively closed in less than 100 µsec and is triggered while the projectile is still in free flight. The fast closing portion of the valve provides the initial contamination barrier, preventing prompt target debris from entering the SCC. A slower detonator driven gate valve (approximately 1.5 ms closure time) provides the long-term contamination seal while an additional detonator driven debris valve blocks material following the projectile down the launch tube from reaching the PTC.
Secondary Containment Chamber (SCC):

The Secondary Containment Chamber (See Figure 5), was designed to contain a hydrogen deflagration and provide containment if the Primary Target Chamber (see Figure 3 and 4) fails. The SCC provides a stable platform for the PTC alignment and locking mechanisms.
The gun axis is offset below the centerline of the tank to maximize the working area within the tank. An aluminum floor has been provided to provide a stable surface for personnel. Finally, a blast shield is mounted just off the muzzle of the launch tube to strip gas from the projectile during its 0.9 meter free flight to the target. In addition the blast shield mount provides a base for the final launch tube support and houses Optical Beam Breaks #1 and #2 plus the film holder for the flash x-rays. All valves within the SCC are either pneumatic or explosively driven. The drive gas for the pneumatic valves is Nitrogen generated from a liquid nitrogen farm to reduce the risk of introducing oxygen into the SCC. All lines entering and leaving the SCC are filtered either through dual HEPA filters on the purge and vacuum lines or housekeeping filters on the gas supply lines.

**Diagnostic Capabilities:**

Diagnostics and Timing data recorded on a typical experiment measure or check the following categories of gun and facility conditions. Just prior to the “fire pulse” the Control System checks these areas for proper operation, the Control System, Facility Alarms, Gun Assembly (interlocks), Run Safe (unmanned area), Secondary Containment Chamber (vacuum, integrity and valve position), Pump Tube Pressure (±1psig of set pressure), Gun Diagnostics, Target Diagnostics, Target Docking (alignment), Ultrafast Closure Valve Trigger System, Primary Target Chamber condition (vacuum and valve positions), input optical levels for trigger signals, final instrumentation status and the Firing System are checked and verified. The JASPER Facility has a variety of diagnostic equipment and capabilities. On each experiment the following signals are recorded:

- Breech pressure
- Piston velocity pins 1 – 4
- Projectile base pressure at the burst diaphragm
- Continuous x-ray detection of projectile passage
- Optical Beam Break signals (1 – 4)
- Flash x-rays (two stations Scandiflash 300kev) timing
- PZT output signal indicating the Ultrafast Closure Valve has fired
- Closure indicator signal from the Gate and Debris valves
- Target impact
- Physics data.

**Conclusion:**

The JASPER Facility is fully operational and is conducting Equation of State (EOS) experiments on Actinide targets. All containment systems have been tested and are now in use with the actinide targets. The Timing and Control Systems are operational and have proven reliable.

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