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Gas Gun Capstone Project

A multi-organization team across Los Alamos National Laboratory's (LANL) Associated Level Directorate for Weapons Engineering (ALDW) sponsored the Gas Gun Capstone project at Montana State University (MSU). All MSU Mechanical Engineering (ME) and Mechanical Engineering Technology (MET) students are required to complete a two-semester Capstone project. During the first semester the students design their project, which they will then build the following semester. LANL provided the barrel, catch tank and some diagnostic equipment; all other components were manufactured or procured by the students.

The goal of the project was to design and build a single stage gas gun for determining the dynamic strength of materials using Taylor anvil experiments. The design focused on a new breech mechanism to achieve the benefits of a dual diaphragm and wrap-around breach to attain a wider range of projectile velocities with a simple change of a breach insert.

The Gas Gun project consisted of two teams of four students each. The two teams included the Structural Team (ST) and the Gas, Vacuum, and Instrumentation Team (GVI). The ST Team was responsible for designing and building the structural elements of the system, including the high pressure breech, a trigger cylinder that unblocks ports for firing when axially actuated, and a sabot that held the Taylor cylinder. Additionally, there was an anvil plate that served as the target for the Taylor cylinder, and a mobile support system. The GVI Team was tasked with the gas supply delivery system, vacuum system, and all instrumentation for data recording and processing. The two teams worked together to design an experimental test plan, which was successfully executed to demonstrate functionality of the Taylor anvil gas gun capability illustrated in Figure 1.

Figure 1. Fully assembled gas gun.

In the design illustrated in Figure 2, a trigger cylinder seals the breech ports allowing the pressure tank to be primed to a specified pressure. The projectile sits in the barrel in front of the trigger cylinder. A vacuum is pulled inside the barrel in front of the projectile to reduce drag. This vacuum applies a force on the projectile down the barrel, which is counteracted by another vacuum being pulled through the trigger cylinder that keeps the projectile in place until firing. One of the benefits of this configuration is that the breech pressure does not act on the sabot before firing, allowing it to remain lighter and be fired at higher velocities, like a double diagram breech functions. This setup should allow for a high rate of fire of around one shot every hour. Using a sabot provides flexibility around projectile shapes and sizes (e.g., plates, cylinders, and spheres).

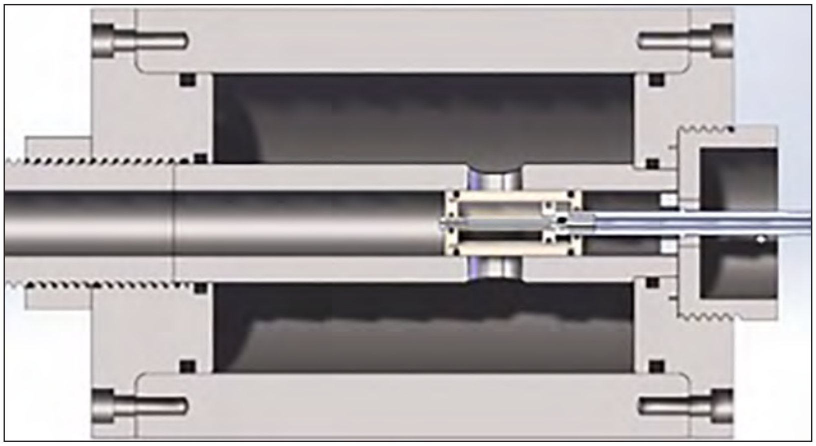

Figure 2. Cross section view of the wrap around breech and trigger cylinder. The breech can be used in a wraparound or double diaphragm configuration by a simple change of breech insert. In traditional designs, two separate breech assemblies are required and must be swapped to transition between low and high velocities.

To fire the gun, gas is released through a firing cylinder into and through the trigger cylinder. This firing gas simultaneously acts on both the projectile and trigger cylinder pushing the projectile forward and the trigger cylinder backwards to open the breech ports and allow the highly pressurized gas to flood the barrel and accelerate the projectile down the barrel. The mass of the projectile and trigger cylinder were designed to be similar so that the gun firing would be repeatable and fast acting. The highly precise gun firing is essential for timing diagnostics to the impact at the end of the barrel.

The Gas Gun Capstone project at MSU met all the desired specifications. The new breech design combined some of the benefits from both the wrap around and double diaphragm mechanisms. It was designed to operate for 10,000 cycles at a maximum breech pressure of 5,000 psi, utilizing a 10-foot barrel with 1.50 inch bore diameter. All the components were mounted on a large rigid I-beam, which was mounted on rollers allowing it to be easily moved in a lab environment. Operation manuals and procedural safety checklists were also developed for the gun's use.

Figure 3. Sabot and aluminum Taylor cylinders in unfired and fired configurations, at higher velocities from left to right.

The pressure vessel was hydrostatically tested to 5,300 psi for safety verification. The gas gun was then fired successfully three times in May 2024 to perform Taylor anvil experiments (Figure 3). A projectile velocity up to 350 m/s (~Mach 1) was recorded so far. All components were designed for a breech pressure of 5,000 psi, which is expected to produce a projectile velocity of approximately 1.2 km/s.

The LANL team is sponsoring follow-on Capstone projects (Fall 2025 semester) around this gas gun to further improve its performance and capabilities. The projects will focus on improving the trigger cylinder, catch tank, control system, and a few smaller elements to make the system more useful for routine dynamic materials research.

Group picture following the first successful shot of the Gas Gun Capstone Project at MSU. LANL scientists Cindy Bolme, Kyle Ramos, and Bryan Zuanetti are pictured with the team. Nichole Matuszynski (i.e., pictured second from the right) was hired as a Research and Development Technologist in LANL's Shock and Detonation Physics (M-9) to continue her work with gas guns and dynamic materials' response research.

The MSU students exceeded all the LANL sponsors' expectations in their execution of this Capstone project. The Structural and GVI Teams demonstrated excellent proficiency in manufacturing components with tight tolerances, assembling electrical and vacuum/pressure systems, and integrating diagnostics. The Teams' planning and coordination were evident as they adhered to budget, created risk registries, purchased hundreds of components, worked with external hydrostatic testing shops and pressure system vendors, and ensured that every component arrived on time for assembly and testing. Overall, the project was a significant achievement and a testament to the importance of engineering Capstone projects to develop both new technical capabilities as well as the associated future work force.

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