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**Alpha Fuels Environmental
Test Facility Impact Gun**

Charles G. Anderson

December 14, 1978

Monsanto

MOUND FACILITY

Miamisburg, Ohio 45342

operated by

MONSANTO RESEARCH CORPORATION

a subsidiary of Monsanto Company

for the

U. S. DEPARTMENT OF ENERGY

Contract No. EY-76-C-04-0053

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Abstract

The Alpha Fuels Environmental Test Facility (AFETF) impact gun is a unique tool for impact testing $^{238}\text{PuO}_2$ -fueled heat sources of up to 178-mm diameter at velocities to 300 m/s. An environmentally-sealed vacuum chamber at the muzzle of the gun allows preheating of the projectile to 1,000°C. Immediately prior to impact, the heat source projectile is completely sealed in a vacuum-tight catching container to prevent escape of its radioactive contents should rupture occur. The impact velocity delivered by this gas-powered gun can be regulated to within ± 2 percent.

Introduction

Radioisotope heat sources are multilayered containers filled with a radioactive fuel that produces heat as it decays. All such heat sources must be qualification tested to assure safe, leak-free performance over their expected lifetime. Heat sources used in space must meet especially stringent standards that require safe containment of fuel after high-velocity (100-150 m/s) impact.

The AFETF Impact Gun was developed in support of the Milliwatt Generator Program to safely perform impact tests on $^{238}\text{PuO}_2$ -fueled heat sources in a facility designed to contain a heat source if it ruptures upon impact.

To minimize the risk of contaminating the facility, simulant fuels are used in otherwise prime heat source components impacted in excess of the velocity required to qualify the heat source for its intended use. If the design is satisfactory, then sources containing radioisotopic fuel are impacted at the qualifying velocity.

Gun design

The AFETF Impact Gun is an original test system designed with these requirements in mind:

1. System containment of radioactive fuel in the event a fueled heat source ruptures.
2. Velocities to 300 m/s with ± 5 percent predictability and accuracy.
3. Heat source pre-impact heating to 1000°C.
4. Accommodation of any heat source configuration within the limits of the barrel size (<178 mm).
5. Heat source impact at any desired angular orientation.
6. Minimum per shot cost.
7. Uncomplicated design.

These design requirements resulted in a vertically-mounted gun with all parts--except the catch tube insert--reusable for economy of operation. The heat source, brought to temperatures of up to 1,000°C by a clamshell heater, rides a sabot which plugs into the vacuum-boxed catch tube assembly (Figures 1 and 2) sealing it immediately before impact. Redundant light traps measure the projectile velocity, satisfying the design requirement for accuracy.

FIGURE 1 - Drawing of AFETF impact gun showing principal parts.

FIGURE 2 - Catch tube assembly (top; as shown in Figure 1, No. 4) and aluminum sabot (projectile) which carries heat source to impact plate.

The heat source, sabot, and catch tube are loaded and unloaded through the vacuum box at the muzzle end of the gun. The entire vacuum box system is backed up with a facility HEPA filter which is further backed up by a building HEPA filter system to prevent radioactive release from the controlled environment.

Gun description

Figure 1 shows the gun installed vertically with the breech at the bottom and the muzzle at the top. The clamshell heater is located above the barrel muzzle, and the catch tube is just above the heater. The catch tube is connected to the impact damper which in turn is mounted to the large reaction mass and the hydraulic vertical positioning system. The vacuum box, pass box, and fumehood locations are shown dotted in. Figures 3 and 4 are photographs of the actual hardware.

The staging fixture, mounted on top of the sabot, is used to hold the heat source in the desired orientation for impact. A nest in the upper portion of the staging fixture sleeve holds the heat source in a manner that allows the heat source to continue its flight to the impact plate without rubbing the nest and changing its orientation. The sleeve containing the nest is made of graphite, as is the intermediate piece bolted to the bottom portion of the staging fixture. A synthetic mica insulator is used to connect the graphite assembly to the aluminum sabot. The nest varies with the type of heat source tested and its desired orientation.

FIGURE 3 - Impact gun as installed in the Alpha Fuels Environmental Testing Facility. The building is designed to contain any radioactive material that may be released during heat source testing.

The sabot, the projectile or working piston in the system, rests in the extreme upper section of the muzzle with the heat source staging fixture and capsule mounted on top of it. After the capsule has been heated to the desired temperature, the clamshell heater opens

FIGURE 4 - Projectile velocity vs. N; Pressure required = N x Wt. of projectile in pounds.

and the catch tube is rapidly lowered to mate with the barrel.

The breech assembly is at the extreme lower end of the barrel. The breech reservoir is loaded with one cubic foot of the working gas contained by a large, sliding valve at the pressure required for the intended velocity. The operating sequence is as follows:

1. Heat the heat source and open clamshell heater.
2. Pull firing pins supporting sabot after lowering catch tube.
3. Sabot drops in vacuum through barrel, bumping the breech valve servo and breech valve, opening them in sequence.

When the breech valve opens, gas is ported between the sabot and the breech

valve and pushes the sabot to its intended velocity. The movement of the breech valve is dampened with fluid in the lower part of the breech. The gas pressure required to obtain a given velocity is shown in Figure 4.

The large tubular steel catch tube holds the aluminum insert, steel stripper plate, and hardened steel impact plate. The insert is sealed to the catch tube with "O" rings, as is the impact plate. The stripper plate allows the heat source to proceed to the impact plate but allows little of the staging fixture to pass through. When the sabot impacts the catch tube insert, it forms a vacuum-tight container before the heat source can strike the impact plate.

The major portion of the moving sabot's energy is taken up by impact momentum exchange with the catch tube and movable portion of the dampening assembly. The work required to stop the sabot is ultimately passed on to the large reaction mass and its supporting columns and pistons (see Figure 1), but the forces are relatively low because of the longer reaction time.

The supporting columns can absorb all of the load without a dampening system for a few such impacts for safety reasons. Repeated use in such a mode could, however, cause column failure.

After the system is set up and the heat source heated to the desired temperature, the operator fires the gun by simply pushing the firing switch on the remote operating console. Before the pins that

hold the sabot in position are pulled, however, a safety circuit tests the system to ensure faultless performance.

Two separate light traps at the muzzle end of the barrel indicate the velocity in m/s on two separate displays. A velocity calibrator test box simulates sabot velocity to calibrate this system to $\pm 2\%$ accuracy.

The fume hood allows access to the vacuum box by way of the pass box, should the vacuum box ever become radioactively contaminated. The vacuum box, Figures 1 and 5, can provide an inert atmosphere when required, as well as a vacuum for gun firing. A vacuum in the gun barrel allows the sabot to drop freely. A vacuum in the vacuum box enhances the heating of the heat source.

Test results and capabilities

Figure 6 shows a Milliwatt Generator heat source before impact. This capsule, containing simulant fuel, was impacted side-on at 169.7 m/s and a temperature of 450°C. A series of seven photographs (Figure 7, a thru g) show the results of this impact which did not compromise the heat source.

The AFETF Impact Gun Facility can accommodate heat sources of up to 178 mm diameter, heat them to a maximum of 1000°C, and impact them at a maximum velocity of 300 m/s at any desired angular orientation. The facility has been used successfully to perform qualification testing for the MWG Heat Source Program.

FIGURE 5 - Vacuum box line (Figure 1, No. 8) which sits atop impact gun. Vacuum facilitates heat source heating and free-fall drop to breech.

FIGURE 6 - Milli watt generator heat source (MT-16F) before impact.

a) Top view

b) Side view

FIGURE 7 - Heat source after impact at 169.7 m/s, preheated to 450°C.

c. Impacted surface view.

d. View of cut through impacted surface.

FIGURE 7 - Continued

e. View normal to the cut.

f. Photomicrograph of dome end of impacted heat source.

g. Photomicrograph of weld end of impacted heat source.

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