

AIR GUN TEST FACILITY

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ABSTRACT

This paper describes a facility that is potentially useful in providing data for models to predict the effects of nuclear explosions on cities. IIT Research Institute has a large air gun facility capable of launching heavy items of a wide variety of geometries to velocities ranging from about 80 fps to 1100 fps. The facility and its capabilities are described, and "city model" problem areas capable of investigation using the air gun are presented.

INTRODUCTION

A unique, large air gun facility exists at IITRI which is capable of launching virtually any shaped object weighing hundreds of pounds. This facility can be used to study what happens to building debris or building contents after a nuclear explosion. Specifically, testing can answer the questions that currently require assumptions in the analytical models.

1. How do different types of debris break-up on impact with the ground?
2. How much bouncing occurs after the debris initially impacts the ground?
3. What do debris piles really look like? What is their bulk density, for example?
4. If a section of wall or a furniture item is burning while it is being lofted, is it extinguished or is the burning accelerated?

The large air gun (Figure 1) has over one million foot pounds of energy available. Thus, we have launched 500 lb objects to 500 fps and 50 lb objects to 1100 fps. Currently two gun tube sizes are available, 8 in. and 12 in. diameter. (The gun was designed to accommodate up to a 24 in. diameter barrel.) We have launched 1 ft long cylinders and 20 ft long telephone poles; we have launched I-Beams (the I-Beam was outside the gun tube), concrete rubble, and other shapes. We see no problem with launching a full size couch or arm chair (burning or not burning during launch), wall section, etc. by using the same methods that were used to launch I-Beams.

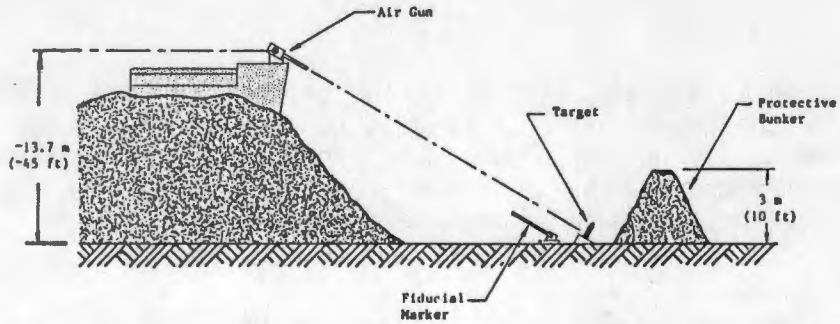


Figure 1. Typical range set up for 12 inch diameter air gun test

A second smaller air gun (4-in. diameter tube) can be fired in tandem with the larger gun. Firing the two guns with any time separation desired can answer such questions as effects of burning debris impacting non-burning debris and vice versa.

VELOCITY RANGE

Figure 2 shows empirically derived velocity curves for several projectile weights as functions of gun chamber pressure. A least squares curve fit of experimental data was used as the basis for these curves:

$$v = 280p^{0.449} M^{-0.495} \quad (1)$$

where p is the chamber pressure (psig) and M is the projectile mass (lb).

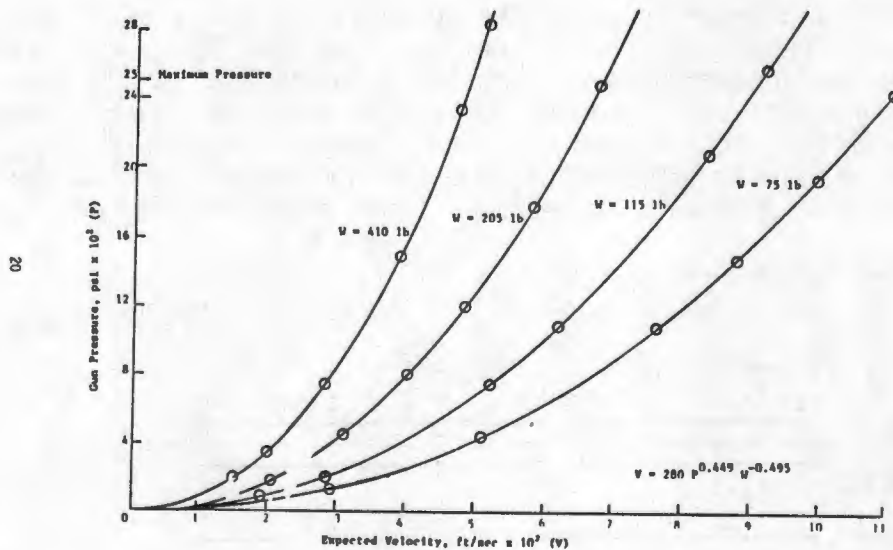


Figure 2. Air Gun Capability

This relation is for tests in which the projectile is positioned almost at the back end of the gun barrel, causing it to receive nearly the full chamber pressure initially during a shot. In order to see what other options are available to modify the pushing action of the gun, an analytic expression for projectile velocity has also been derived:

$$v = f \sqrt{2 g_c \left(\frac{P_1 V_1 + P_2 V_2}{M} \right) \ln \left(1 + \frac{X A}{V_1 + V_2} \right) + 2 X \left(g \sin \theta - \mu g \cos \theta - \frac{g_c P_2 A}{M} \right)} \quad (2)$$

where g_c is the dimensional constant, P_1 is the chamber pressure, P_2 is the ambient pressure, V_1 is the chamber volume, V_2 is the initially ambient volume of gas behind the projectile, M is the projectile mass, X is the projectile position in the gun barrel relative to its initial position, A is the gun barrel cross-sectional area, g is the gravitational acceleration, θ is the gun tilt angle relative to the horizontal, μ is the projectile-barrel friction factor, and f is a correction factor to account for non-ideal effects (on the order of 0.8 to 0.9). This equation shows us that although P_1 and M are the dominant parameters defining the projectile velocity v , the final velocity and rate of acceleration can also be influenced by the ambient volume behind the projectile (V_2), the barrel length (X), the barrel cross-section (A), and the tilt angle (θ). The barrel length and cross-section are somewhat fixed by the apparatus available, but the initial ambient volume (V_2) behind the projectile can be altered more easily. By cutting a large hole in the rear obturator in the pusher tube (see Figure 3), the internal volume of the pusher tube can be added to V_2 . This makes it possible to achieve lower projectile velocities as well as provide a "softer" push to the projectile. It is estimated that a 400 pound projectile (e.g., 200 pound furniture item plus 200 pound pusher assembly) could be given velocities between about 83 and 500 fps. A 200 pound projectile (e.g., 100 pounds for the item plus 100 pounds for the pusher assembly) could be given velocities between about 117 and 680 fps. It should be noted that the pusher tube in Figure 3 is inserted into the gun barrel. It can be made to separate from the launched item (e.g., I-beam) after the launch.

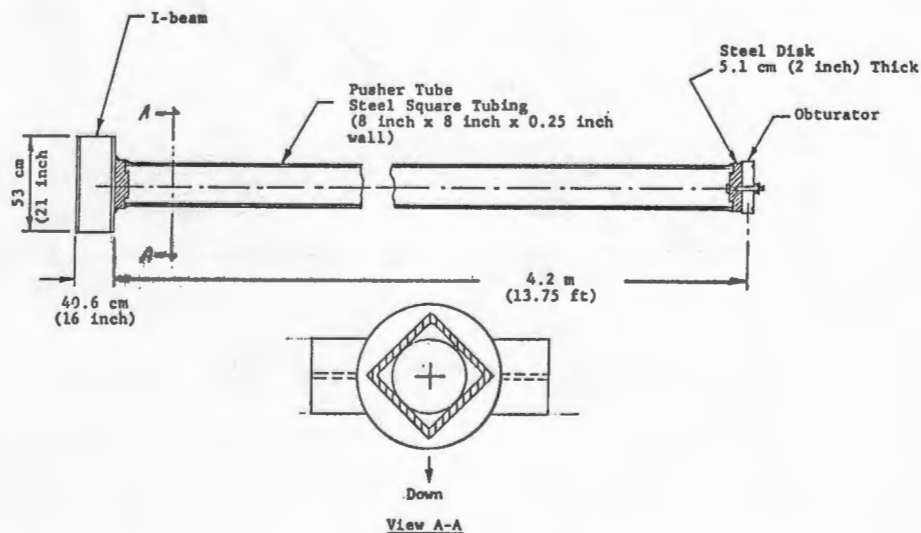


Figure 3. I-beam Projectile with Pusher Tube for 12 inch Diameter Air Gun

ACCELERATION OF ITEM

Using Equation 2, the acceleration of the projectile during its launch can be estimated. A typical acceleration curve is shown in Figure 4 (400 pound projectile with an initial chamber pressure of 500 psig). The actual acceleration duration will be longer than the estimated value due to the effects of mechanical part movements and flow through orifices such as a hole in the rear opturator on the pusher tube. However, it is expected that the actual acceleration duration is within 0.2 or 0.3 seconds. Although this is a short time period, the push is extremely gentle compared to conventional guns. For example, thin-walled liquid filled FAE* cannisters have been accelerated to high velocities using the air gun with no damage to the cannisters.

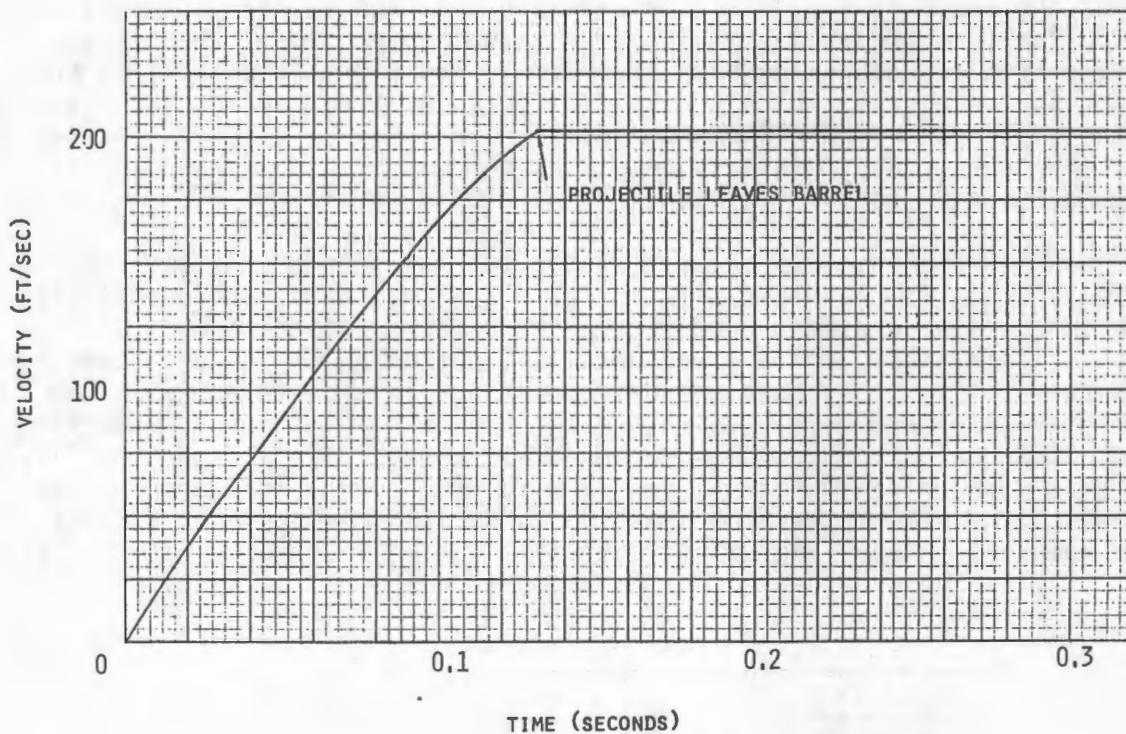


Figure 4. Typical Calculated Air Gun Acceleration Curve
400 lb. Projectile, Initial Pressure 500 PSI

* Fuel-air Explosion Weapon System

NUCLEAR EXPLOSION MODELING NEEDS

The large air gun is seen to address two categories of problems useful in city fire modeling. First, to determine how furniture or structural items break up, bounce, and form debris piles, the absolute velocity of the item relative to the ground must be produced. It should also be noted, for this category of problems it is clear that the gun would have to be taken off of its 45 foot bunker and put at ground level in order to obtain the proper interaction with the ground surface.

The second category of problems is concerned with extinction or enhancement of fires in items by the relative velocity between the item and the wind following the shock front. The high pressure and high velocities immediately following the shock front may in itself extinguish the fire. The air gun facility cannot reproduce the high pressures. Therefore, the facility can only address those cases where the initial pulse will not extinguish the fire. Then, the subsequent wind effects on the fire can be realistically investigated using the air gun. In this case, the gun can be used either in its current position on top of its bunker or at ground level.

Figure 5 shows absolute velocities for several furniture items and the relative velocity for a sofa estimated for a 1 MT weapon at the 5 psig peak overpressure distance from ground zero. These represent the low end of velocities of interest, since structures will not break up at much lower peak overpressures. Figure 6 shows the extreme change in wind velocity as one moves closer to ground zero. Therefore, much higher absolute and relative velocities can be expected in the region of interest. The air gun facility can be used to accelerate heavy items (200 to 400 pounds, including pusher arrangements) to velocities from about 83 to 680 feet per second, a range of extreme interest in modeling debris activity from nuclear explosions in cities. The facility can be a valuable tool to support such modeling activities.

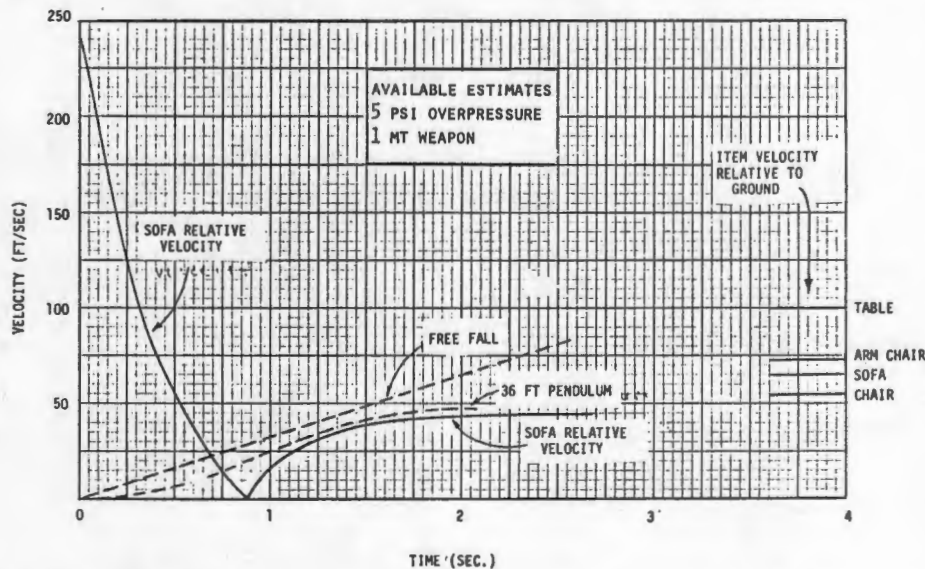


Figure 5. Relevant Velocity Profiles for 1 MT Weapon at 5 psi overpressure

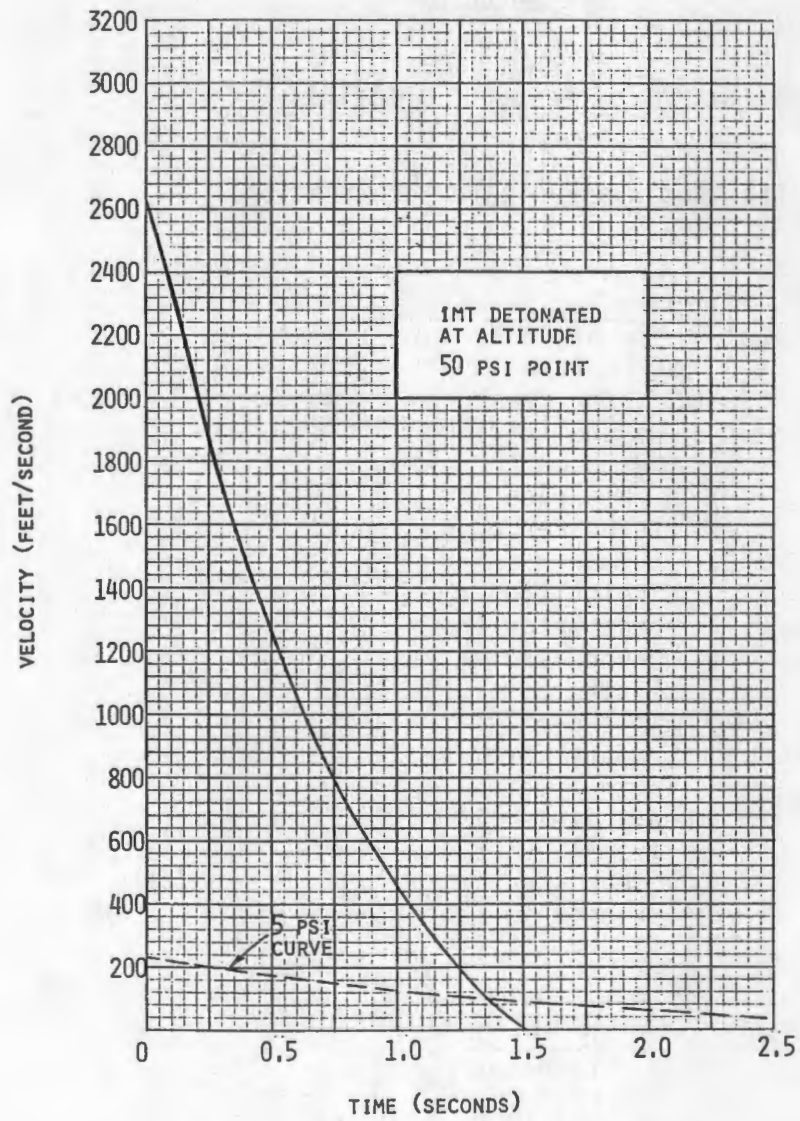


Figure 6. Comparison of Wind Following Blast from 1 MT Weapon at 5 and 50 psi Peak Overpressure Locations