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SETBACK TEST USERS MANUAL (U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER'S METHOD)

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September 2011

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Munitions Engineering Technology Center

Picatinny Arsenal, New Jersey

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14. ABSTRACT

The setback test was developed at the U.S. Army Armament Research Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey. This ARDEC setback test method collapses a planer air gap against an explosive sample in a manner to mimic what could happen during launch of a projectile with a base gap. The machine action is essentially one dimensional, where an insulated steel "drift pin" moves towards an explosive sample. The initial space between drip pin and bottom of the explosive constitutes the air gap under test.

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INTRODUCTION

The U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey setback test collapses a planer air gap against an explosive sample in a manner to mimic what could happen during launch of a projectile with a base gap (ref. 1). The machine action is essentially one dimensional, where the insulated steel "drift pin" moves towards an explosive sample. The initial space between drift pin and bottom of the explosive constitutes the air gap under test. These are aligned inside a confinement cylinder, with tolerances selected to produce minimal air leakage. The drift pin is set into rigid body motion to close the gap by impact of an air gun driven hammer. The air gun uses various numbers of shear rods to achieve short release times at the two operating pressures available. Hammer velocity at impact is also controlled by allowing it to accelerate across a precise distance called the "free run." Free run is set by the operator and is determined from the formulas shown in the next section. For one dimensional action to occur precisely, a number of details during setup have to be carefully addressed. Precision during setup minimizes scatter in the results. Comments on where special care is needed are included throughout. The test is amiable to performing a statistical test, as any size gap can easily be set up in real time. It is also sufficiently efficient to operate so shots can be fired with minimal time between them.

PRELIMINARY CALCULATIONS

A trial consists of closing a certain size gap using a predetermined closing velocity. The correlating parameter between velocity and gap size is the acceleration as requested by the customer. Acceleration is kept constant while gap size is varied to generate data to which a statistical model (normal curve) is fit. At the end of a test, the mean and standard deviation should be known to 95% confidence. From this, the one-in-a-million point can be easily calculated.

The statistical test design will supply various gap sizes to be tested. Usually, the next gap size to be tested will be determined by the sum total of all results already in hand. The operator must calculate a free run based on gap size and acceleration. Free run correlates with closing velocity according to known empirical relations. These determine the correct free run to close the gap with the velocity appropriate for the particular gap size/acceleration combination. Formulas for calculating the free run are:

Six shear rods:

$$x(\text{inches}) = \frac{1459.8\,psi}{P_{anticipated}\,psi}\left[(4.3881 \times 10^{-4} * \delta\text{inches} * G) - (1.5935 \times 10^{-2})\right]$$

Four shear rods:

$$x(\text{inches}) = \frac{1075.8\,psi}{P_{anticipated}\,psi}\left[(6.9869 \times 10^{-4} * \delta\text{inches} * G) - 9.6302 \times 10^{-2})\right]$$

where x = free run to be set by operator (plus add 0.040 in. for the drift pin protrusion)
G = desired acceleration (in terms of gravity)
δ = desired gap for this shot.
$P_{anticipated}$ *psi* = expected release pressure for this shear rod

USE THE FORMULA THAT GIVES FREE RUN > ½ IN.
FREE RUN CANNOT EXCEED 0.9085 IN.

Examples:

- A new 0.180-in. diameter by 36-in. long shear rod is prepared according to the procedure in the following section, and the preliminary dummy shot gave a release pressure of 1130 psi. The anticipated six shear rod release pressure is thus 1695 psi. The customer wants setback testing at an acceleration of, say, 17,000 G's. The test design dictates the next shot needs to be at a gap of 0.095 in. The six pin formula determines a free run of 0.597 in. This is a valid setting for the tester and the shot is set up according to the following procedure. The distance between the hammer and confinement cylinder (total standoff) is adjusted to 0.597 in. + 0.040 in. = 0.0637 in. total. The 0.040 in. accounts for the 0.040-in. drift pin protrusion.

- The customer wants setback testing at an acceleration of 15,000 G's and the next gap is 0.075 in. The six pin formula gives 0.412 in. Since this is below ½ in., it isn't recommended. Instead, use the four pin formula to get 0.657 in. and total standoff of 0.697 in. This is a valid setting, so use four pins for this shot.

PROCEDURE FOR FIRING A SHOT

Prepare Shear Rods

A shear rod is selected and cut into sections as described in reference 2. For both four and six pin shots, there needs to be a four pin dummy shot to calibrate the particular shear rod chosen. Thus, a shot is fired using an expendable (likely an empty, used cylinder in reverse orientation) cylinder to stop the hammer. For this shot, the cylinder is pushed up against the face of the hammer, then backed off slightly (about 1 mm). This allows the rods to shear, the hammer to move freely, and the cylinder to stop the hammer. The air gun armor can be omitted during this operation, reducing the effort somewhat. The release pressure is noted and this is taken as the reference value for this particular shear rod. A correction that takes into account that individual shear rods have different release pressure is included in the formulas used to calculate the free run for a particular gap size at given acceleration. Applying this correction is important to reducing scatter in results that occur simply because several different shear rods will be needed during a complete test of a single material. Release pressure should be noted for every shot, and if not characteristic for the shear rod being employed, the shot should be considered invalid because velocity achieved will not be appropriate for that gap at the desired acceleration. This occurs when pressure is off by more than +/- 30 psi from what is expected. Typically, there is no problem staying within this range, but occasional outliers have occurred.

Prepare the Air Gun

Decide what velocity range is needed for the upcoming shot and select four or six shear rods previously prepared and calibrated as described. As described in the reference 2, the air gun should be used with free runs between ½ in. and 0.9085 in. Free runs less than ½ in. are restricted because small free runs are under the influence of the breaking process in the shear rods and beyond that, some peculiarity exists in the bore. Both these factors act to reduce reproducibility for free runs < ½ in. Free runs greater than 0.9085 in. allow the front guide ring to scrape over the shear rod holes potentially damaging the ring. Calibrations were based on data for free run >1/2 in. where shot-to-shot variations were around +/-2%.

Pin the Piston in its Initial Position

Push in hammer fully rearward, keeping alignment of the marks on piston face and on barrel. There is only one azmuthal orientation that allows the intended fit between holes in the piston face and in the gun barrel. Insert shear rods from outside through aligned shear rod holes or, if a subsequent shot on the same shear rods, simply lower them in their respective holes. Allow tips of rods to extend so ~1/8 in. to 3/16 in. is visible near the hammer. Do not insert the rods any deeper otherwise it will be difficult to extract the broken off "nubs" after a shot, and a single shear rod will not last for as many shots. Rubber bands stretched between pairs of the external ends of the shear rods are used to keep the rods in position through friction in their holes. Shear rods are a loose fit, so must be restrained from sliding. This fit is dictated by a compromise between close tolerances to attempt to get the rods to fail in shear only, and loose tolerances so the broken nubs, which have a burr afterwards, will still slide through and not jam (fig. 1). Note: shear rods are to be installed in a symmetrical pattern to reduce any "cocking" forces on the internal guide rings.

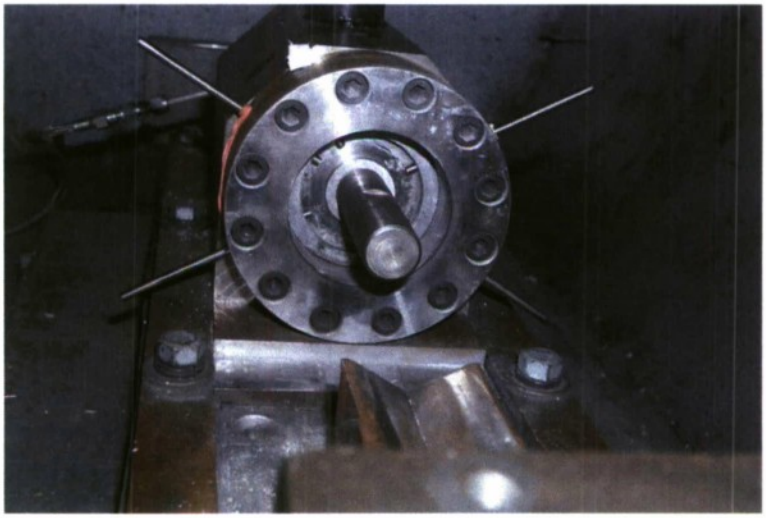


Figure 1
Air gun ready for four pin shot

Prepare the Hammer

Remove the hammer and insert a new impact washer (washers are not reusable), then tighten hammer just enough that the washer and hammer come up snug against the air gun piston face. This causes the hammer to line up with the axis of the machine. Excess tension in the mounting stud is not necessary and too much tightening can compromise the shear rods by distorting them after they are in place. A loose fitting thread for the hammer mounting stud is beneficial. It will still go into tension as needed, but will resist being jammed as the hammer mounting system goes into compression at the hit. A hammer, used for about 30 shots where some of the responses were strong, showed a 0.001 in. deep dent had formed. It was easily ground flat again. It is good practice to flatten the hammer face occasionally and check it if an especially strong explosive reaction occurs. This will be indicated by mushrooming of the drift pin as it is thrown back against the hammer.

Align the V-block Support

Place a cylinder with drift pin inserted so only a few millimeters protrude on the v-block support and slide forward enough that the drift pin and hammer come into contact. Check that this contact is flat, using a suitable light source from the opposite side. Any light between the two parts means misalignment and needs to be corrected by shimming the v-block. Misalignment of 0.001 in. or so is easily detectable with this procedure. The contact should be observed from two perpendicular directions. When the v-block is aligned, remove and set aside this cylinder with drift pin. The v-block is often knocked out of alignment during a shot, so needs to be checked for each shot.

Replace the Air Gun Armor

There are four steel parts to support and brace the bottom of the armor against the back of the receiver, and a bolt-in-tube arrangement that goes over the top of the barrel housing to hold the top. After making sure the armor is seated properly, especially the plate over the back of the barrel housing, tighten the bolt-in-tube assembly to a tight fit. Armor protects the air gun and prevents the piston from launching in the event the explosive destroys the confinement cylinder during reaction. The piston is heavy and there is a lot of gas pressure behind it. More damage is possible from an errant piston than from the explosive itself.

Check that the Wood Backstop is in Place

Insure that a wood "cushion" is in place in the holder on the blast tank door (fig. 2). The explosive sample can get high velocities exiting from the confinement. In fact, a sample has penetrated about ½ in. into the wood and stuck in place. Wood reduces the shock associated with such an event and is easily replaceable as needed.

Figure 2
Wood backstop in place

Prepare the Sample

Ensure the explosive sample meets dimensions. It is important that the end of the sample that is to become one side of the gap have accurate diameter for the first inch. If the other end is slightly undersize by less than 0.003 in., the sample will still be acceptable. A fixture consisting of steel confinement cylinder and drift pin is selected. Clean out the confinement cylinder bore using an acetone wetted gun patch; a convenient plastic "ramrod" is available to push the patch through. Generally, a few passes will be needed until a last patch finally comes out clean. As a last check on how the pieces fit, the operator will make sure the drift pin can slide freely through the cylinder bore and yet will hold a vacuum against its weight when the opening at one end is plugged with a finger. Tolerance is less than 0.001 in., so vacuum should last (pin doesn't fall out other side) for several minutes in this test. The gap end of the drift pin is covered with double sided tape of thickness 0.007 in., and by this means a 0.001 in. thick piece of Teflon™ is affixed to the pin face (fig. 3). Thus, the tape and Teflon™ together are 0.008 in. thick. After application, the edge is trimmed flush to the edge of the drift pin with a blade. This Teflon™ performs the role of insulating the end of the pin and its Poisson effect under pressure contributes to reducing air leakage from the gap. Glue a copper "dummy liner" disc onto the back of the explosive sample. This act is a historical relic from the warhead program that financed building of the tester. However, the database only has tests where the dummy liner was included, so it is retained to be consistent with the data base.

Figure 3
Insulation on end of drift pin

A tare measurement of the length of the particular drift pin with insulation and an explosive sample is obtained with the setup fixture using a half-cylinder specially cut for the purpose (fig. 4). Note this length and retract the micrometer sufficiently to replace the half cylinder with actual cylinder.

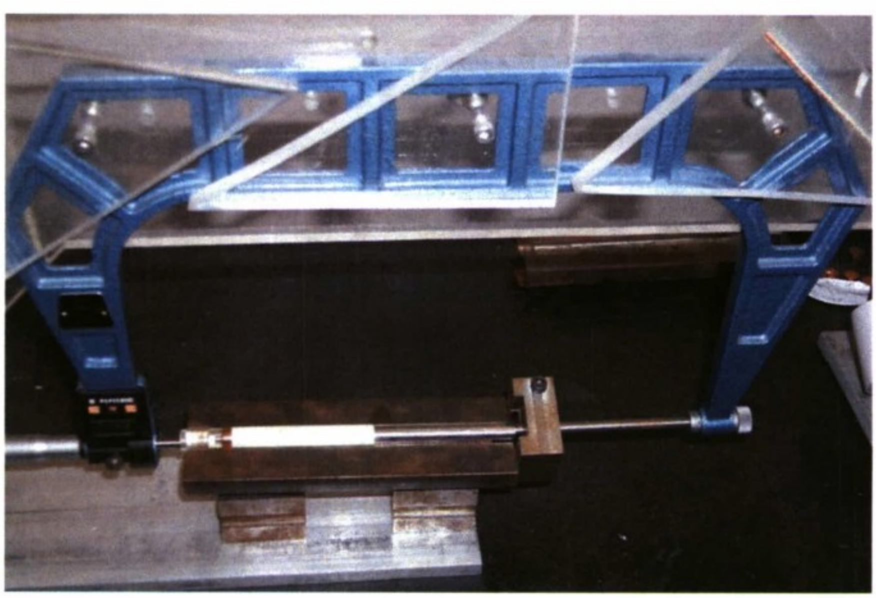


Figure 4
Setup fixture with explosive in position to make tare reading

At this point, the drift pin is painted with grease (Dow Corning Compound 111, valve lubricant and sealant), but the leading edge of the grease is kept about ¼-in. back from the insulated end. It is inserted partially into a cylinder and the cylinder placed in the setup fixture with the protruding pin towards the fixed end. Pushing the cylinder until it hits its stop, inserts the pin further into the cylinder until it protrudes precisely 1 mm. The explosive sample is similarly painted with grease (fig. 5) and initially partially inserted into the open end of the cylinder. Make sure the end inserted has no chips or visible defects around the edge.

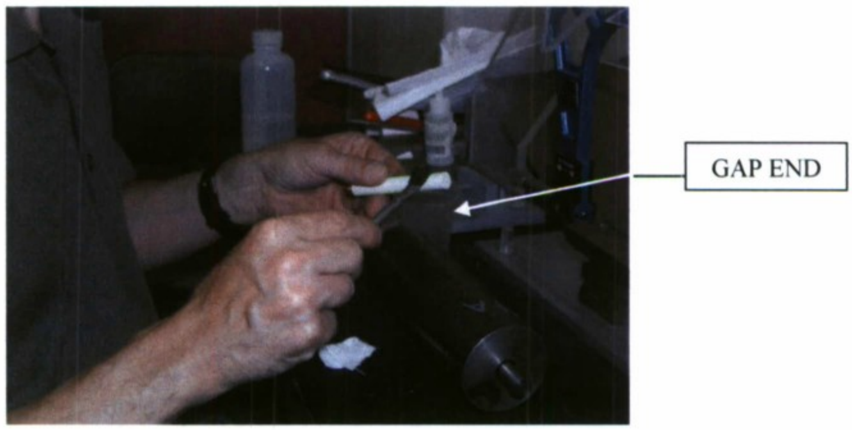


Figure 5
Applying grease to explosive sample

The fixture micrometer is then used to insert the explosive until precisely the chosen gap exists between the drift pin insulation and the explosive sample (fig. 6). You cannot backup, so this operation requires attention. Pulling the explosive back, even a small amount, risks getting grease in the gap and that will compromise the test. Allow the assembly to set for sufficient time that there can be no rebound from trapped air pressure, typically 15 min. Then retract the micrometer plunger and the specimen is ready for test. Be aware that sudden, large changes in room pressure or temperature can upset the gap dimension at this point, so avoid opening or closing the blast doors too rapidly.

Figure 6
Setting the gap

Load the Tester

Carefully place the loaded cylinder and pin on the v-block support so the hammer will strike the protruding drift pin. The intended free run for the shot, plus 0.040 in. to account for the protrusion of the drift pin, is set up as a "standoff" gage. The threaded rear stop is turned until the proper free run exists between the hammer and the drift pin (fig. 7). The threaded rear stop is locked by screwing the locking nut against the support.

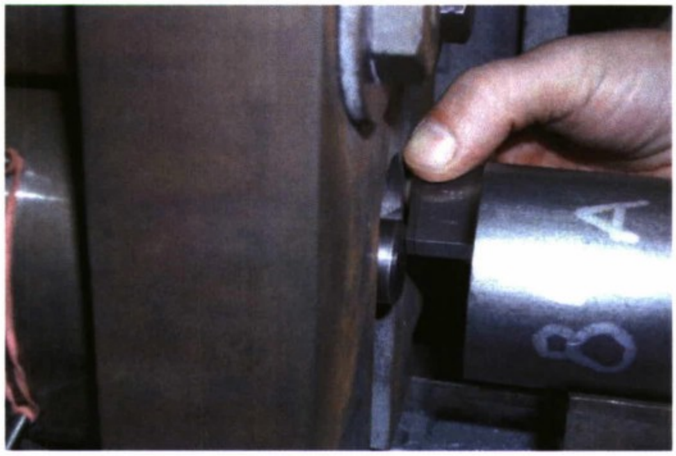


Figure 7
Setting the standoff

Gently insert the pull-out sled into the containment tank until it contacts the metal blocks set up against the back side of the tank. Wedge in place. When the shear pins break, there is considerable force that can move a loose sled quicker than the hammer can get to the drift pin. This can cause the sample to move before being hit, contributing unnecessary scatter in the results. If the sled is tight against the rear metal blocks, such motion is minimized. Close and secure the door (fig. 8). Remove the safety interlock plug from its storage position on the interlock board and then plug into the armed connections on the board. Exit the test bay and seal the door. This completes the last electrical connection. Tester can now fire.

Figure 8
Closing the tank/ready for a shot

Hearing protection is required in the Standard Operating Procedure (SOP), so don proper hearing protection. A nonconductive rubber floor mat is provided for the operator to stand on in order to prevent potential problems when energizing the safety interlock system. The building floor is conductive. Check that there is a sufficient nitrogen supply remaining to complete the shot. Tare the digital pressure gage. Arm the interlock by applying power to the unit and then holding the safe/arm switch in the armed position. With the other hand, slowly open the valve supplying nitrogen pressure to the air gun (fig. 9). Gas can be supplied at a goodly rate, but as pressure nears the release value, throttle gas supply so remaining pressure rise occurs gently. This helps with accuracy on the pressure gage reading, and prevents any differences in pressure between the gage and the reservoir in the air gun due to high flow speed through the small diameter tubing leading into the reservoir.

Figure 9
Firing the setback test

The sound of the air gun release is unmistakable. Immediately stop the flow of gas to the air gun (close the valve you are using to control the flow to the reservoir). Open the purge valve (slowly) to depressurize the system. Note the peak pressure reading that was trapped on the pressure gage; it must be within +/- 30 psi of the expected value for the shot to be considered valid.

Always follow the SOP. Sometimes a “GO” is obvious from the sound; sometimes not. A 1-hr wait is called out for a no-go. For a GO, allow time for the venting system to remove fumes from the tank (at least 10 min). Then, open the outside bay doors first. Some fumes often get in the room, and these can be kept out of the interior of the building by letting them escape to the outside. Open the tank door slowly as debris may fall out. Remains of the hardware and test explosive are then cleaned out and the device is made ready for the next trial.

LIMITATIONS OF THE TESTER

The testing machine has a maximum safe value of free run at 0.9805 in. This takes into account the depth of dent that forms in the confinement cylinder (maximum is 0.091 in. deep) and the 0.040-in. initial protrusion. Limiting to this free run keeps the guide on the piston from scraping across the shear rod holes, which could damage the guide. Thus, maximum hammer velocity (using six shear rods) is 20.246 ms. After accounting for the transfer from hammer to drift pin, this sets a maximum velocity possible for closing the base gap of 32.4 ms. Eight shear rods are possible, but several trials indicated only a modest increase in velocity was achieved. Not enough to be worth the considerable effort to place the other two shear rods and the loss of shots from each nitrogen bottle since higher pressure is required to activate the air gun. No calibration with eight shear rods has been performed.

The test actually gives pairs of points; velocity and associated gap size. Pairs of points are interpreted in terms of acceleration through the simple formula [close enough to results from full computer simulations of gap collapse (ref. 2)]

$$U^2 = 2(\text{acceleration})(\text{gap})$$

Thus, acceleration is the correlation parameter, and both velocity and gap size are varied together to keep the parameter constant during a test. This strategy is changed when the formula would indicate a velocity larger than 32.4 ms was needed. When velocity is maxed out, a maximum gap size is calculated commensurate with this velocity and the desired acceleration (fig. 10). Five trials at this condition with no reaction indicate the mean is at a larger unknown gap size. Basically, it is beyond the capability of the apparatus. Using a larger acceleration in the formula only produces a smaller gap at the same maximum velocity and thus a less severe test stimulus, adding no new information. Just increasing the gap size while holding velocity maxed out, gives a result that really relates to a lower acceleration. Even if a big gap gives reaction, it has to be interpreted as something that happens at low acceleration. Results have always supported the concept that increasing acceleration (i.e., increasing the velocity) reduces the gap size. So a big gap obtained in this way is a lot larger than the value at the desired higher acceleration. Since the relation between gap size and various accelerations is not known a priori, a big gap cannot be related back to the initially desired acceleration. It may set an upper limit, but is of little practical use and has never been pursued.

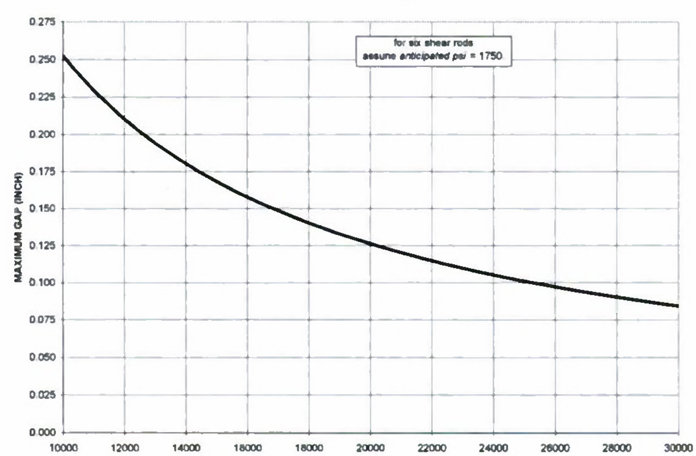


Figure 10
Maximum gap versus acceleration

The test relies on the equivalence between a gap closing at constant velocity and one closing because the drift pin is accelerating smoothly towards the explosive. That is how the apparatus avoids having to precisely generate various high accelerations on demand, a difficult task. This equivalence was established during initial computer modeling in support of designing the test, showing the important part of the resulting gap pressure pulse is the same for either event. But, closing the gap by instantaneously applying a velocity to the drift pin with hammer impact actually sets up reverberating shock waves in the gap. These reverberate hundreds of times as the gap closes. Smoothly accelerating the drift pin does not produce such waves; instead the gap sees basically an isentropic compression. This difference causes error if the drift pin velocity is large enough. But estimates of the error using an ideal gas law for the air indicate drift velocity would need to be around 60 ms before the difference exceeds 0.5%. At 100 ms, the difference between reverberating shocks and isentropic compression is near 1%. At 30,000G's, a drift velocity of 61.1 ms would be needed for a 0.250-in. gap and 86.4 ms for a 0.500-in. gap. A hammer driven machine can satisfactorily cover the range of gaps and accelerations usually found in artillery.

The test is not intended to crush cavities. The equivalence alluded to previously will not work if something in the gap besides air "pushes back" on the advancing drift pin. An annular column of explosive, as exists when cylindrical cavities in the explosive are envisioned, will exert such a force opposing the drift pin. The pin may still crush the cavity, but probably not in a realistic manner. The test was intended for the case where the explosive is temporarily supported until acceleration has built up, then, the support instantaneously gives way. The worse case is when this happens just as maximum acceleration is obtained, as assumed for the test.

DATA REPORTED FROM A TEST

Most tests were performed using a Langlie procedure, modified by the "what if" analysis of a statistician in real time. The goal always is to find the mean gap and standard deviation to 95% confidence level with the minimum number of trials. Any test designed to accomplish this can be used. Probably the Neyer program would be a good choice to guide the test if available. A good estimate of the standard deviation is important, because it will be used to find the one-in-a-million point gap size. Depending on the standard deviation, very small gaps may be indicated at such a low probability. The mean value gaps have generally been fairly large. The mean and standard deviation of a well known reference material (likely TNT or Comp B) should be reported along with data on a new material.

Tested explosives have given a wide range of violence when they ignite. None have detonated. LX-14 is the only explosive that consistently split open the steel confinement, but without detonating. The problem is with explosives where the ignition is feeble and doesn't have time to propagate in the short duration available in the tester. Defining a "go" response becomes more difficult. Many such explosives produce enough gas to eject the remaining explosive sample strongly from the confinement. These are "go's" because they have a probability of more extensive reaction if the explosive is in a pressure tight vessel like a projectile. Some formulations have only produced surface discoloration of the explosive at the gap. There is no evidence of gas generation, and changes are mainly heating effects on the binder. For example, melted wax showed up on the gap surface of Comp A-3 after a shot, and there was only insignificant evidence of any RDX crystals actually reacting. This is a "no-go." A more complex case is where the binder itself is an explosive, like a formulation that was tested based on DNAN as binder. Discoloration was not accompanied by any sign of gas generation. These were "no-go's." Subsequent experiments compressing this material in closed containers and keeping them under pressure ~10 ms or so, verified that discoloration without any sign indicative of eventual burning or gas generation does occur for this material. Of course, at higher stimuli, this material did burn, although slowly and incompletely after a delay.

Clearly, there will be cases where judgment is required on whether ignition occurred or not. These guidelines are intended to help with those judgments.

CALIBRATION

Calibration has been done with a 100 kHz laser interferometer. The unit employed was designated "LXS-range" from "LMI Sensors95," and claimed accuracy of 0.23 mm. It could measure 45 mm of travel, more than enough for the 25.4 mm stroke of the air gun. Mounting hardware is available so the unit sets in the proper relation to measure the motion of the hammer towards it. After installation, various distances between hammer and interferometer are manually set and the output voltage obtained. When plotted, this constitutes the voltage versus distance for the unit. It should resemble the plot in the instruction book for the interferometer. But, use the actual measured numbers. Obviously, during a shot, the hammer must be stopped before hitting the laser unit. Our procedure is to use the armor shield to stop the hammer and piston. Care must be exercised to prevent piston damage from occurring in this process.

First, examine the 3/8-in. stud attaching the hammer and its crush washer to the face of the piston. The problem is that a loose hammer can fly off from the stud when the piston is stopped and impact the interferometer. Threads must be in very good condition. No root cracks or worn threads. Hammer must be tight, but do not put the stud into excessive tension. Use moderate torque when tightening. The sudden stopping puts the stud into tension, so you don't want excessive tension initially. Looseness creates an impact situation, then, can strip threads. When properly tightened, no problem occurs (fig. 11).

Figure 11
Six shear rods installed, hammer tightened

The air gun piston must be protected. To this end, circular discs of ¼-in. natural latex rubber are punched so they are an exact fit to the bore of the air gun (fig. 12).

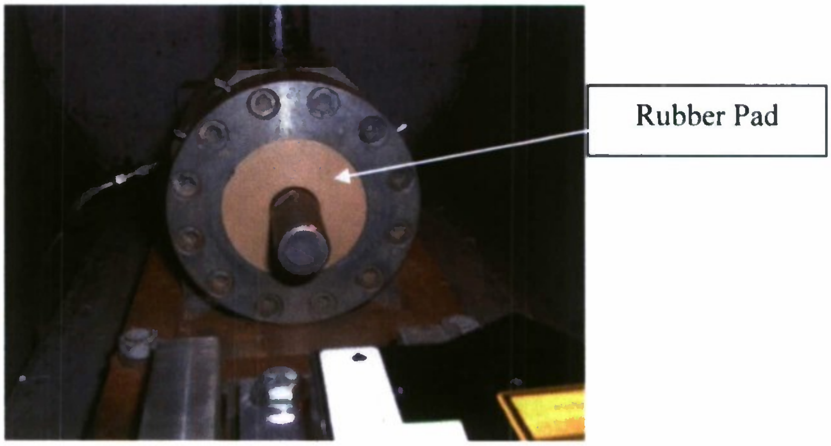


Figure 12
Add rubber pad

A central hole is cutout to let it slip over the hammer. Unfortunately, this means the last ¼-in. of hammer stroke is influenced by compressing the rubber. So the data must be interpreted accordingly. Basically, a curve is generated for the first ¾-in. of travel and extrapolated to 1 in. An aluminum 0.10 in. or so thick crush plate is placed in front of the air gun as in figure 13.

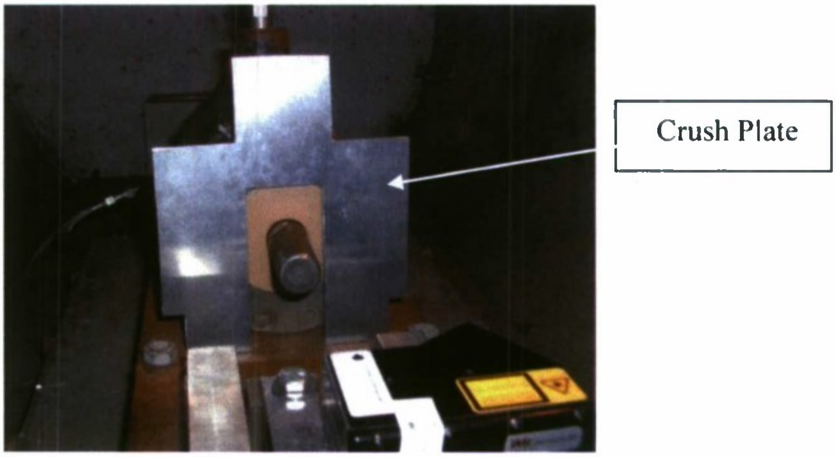


Figure 13
Add crush plate

This is the final cushion between the air gun piston and the armor stopping plate. The aluminum will be destroyed each shot as considerable cratering will occur. Use a fresh one for each shot. Lastly the armor is put in place. It sets on a plate that just slides under the bore with the step towards the front. Armour plate sets on the step. Then the heavy steel support bars are placed before tightening the bolts over the air gun. Figure 14 shows the five pieces of the support system in place. Push right longitudinal bar against the laser mount. Then the two spacer pieces align the other bar symmetrically with respect to the hammer.

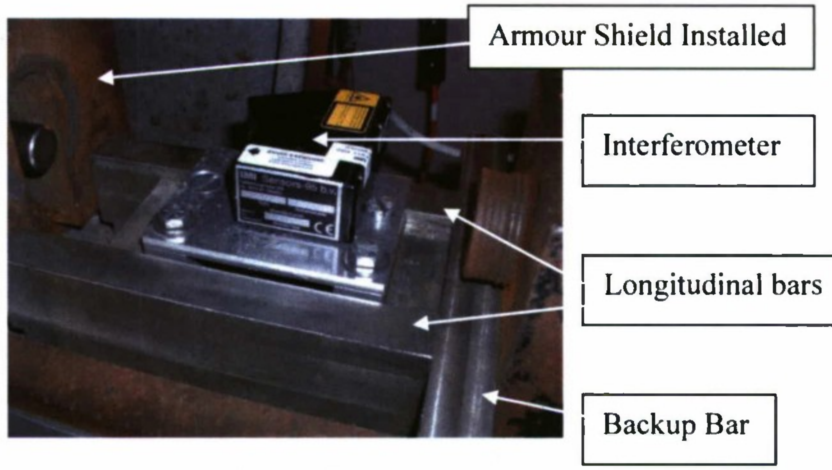


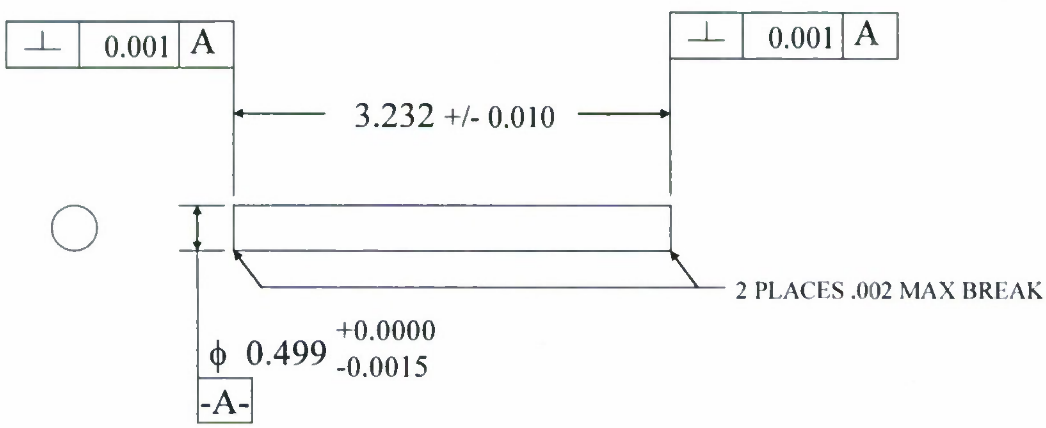
Figure 14
Ready for firing

At this point, tighten the bolts over the air gun. These bolts pass through compression tubes (heavy wall pipes) of the proper length. It is good practice to lift these tubes as high as possible against the interior bolts before tightening. This will reduce the stress they see when stopping the hammer. Make sure these tubes tighten against the armor and don't have some of the aluminum crush plates caught in the gap.

Nominally 10 shots are usually fired. Try to get as many as possible from the same shear rod so release pressure stays consistent at least over a few shots. Data was recorded at 100 kHz. It only takes 2.6 ms for the hammer to finish its stroke, so high frequency data acquisition is indicated. Raw data is noisy, the interferometer manufacturer claims that is endemic for instruments capable of such high speed measurements. Significant averaging was done to get the derivative (velocity) from basic position data. Attempts at Fourier transform filtering failed; there was no dominant frequency to the noise. The procedure used was to employ a large number of points to either side of the current point to determine a linear regression line for that point, and take the slope of this line as the derivative at that point. A check was to integrate the derivative as determined and see if the resulting position curve is a good fit to the original. The most satisfactory fit to the velocity versus piston position data was a linear regression to the data plotted as velocity squared verses piston position (stroke). The goal is to have velocity versus stroke curves fall within +/- 2% of the average; otherwise the correlation to acceleration will have errors over +/- 5%. More details are in reference 1.

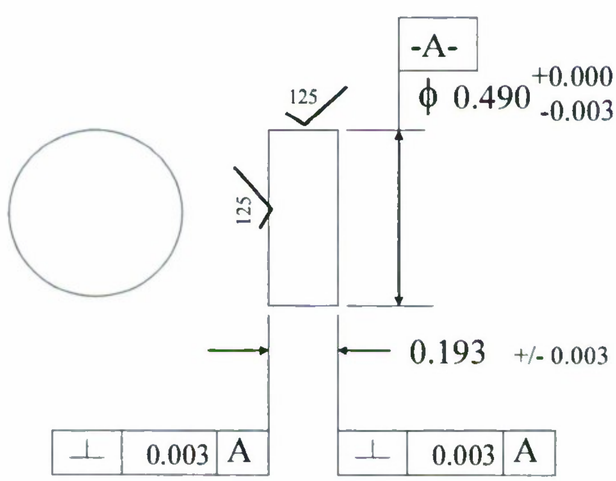
DRAWINGS

The sample must meet drawing 1. This insures the face of the gap is parallel to the drift pin and air leakage along the sample is minimal. The length was designed according to the original warhead effort that funded development of the tester. It has been kept constant and a database has accumulated for this length. Length of sample can affect the results. Likewise, a copper disk (drawing 2) has traditionally been attached to the sample opposite the gap end, originally to mimic the geometry of the original warhead.



Drawing 1
Explosive sample

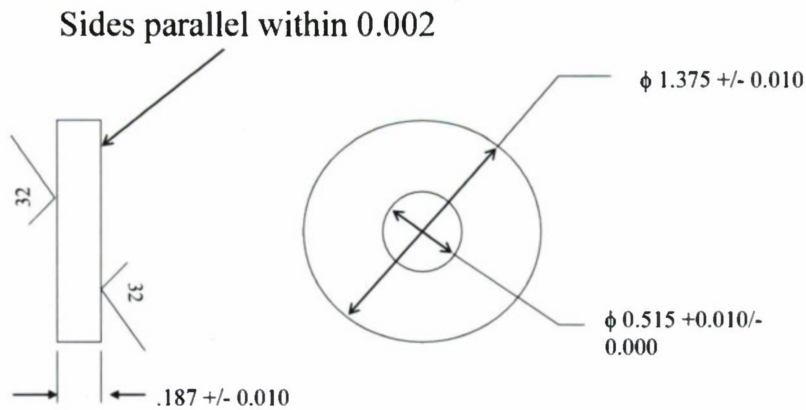
NOTE: Material : copper bar



Drawing 2
Dummy liner

The sacrificial washer is specified in drawing 3. Sides need to be parallel as alignment of the hammer depends on being tightened up against this washer. Washers cannot be hardened steel as their role is to absorb impact deformation and protect the face of the air gun piston. They must be the softest element in the hammer attachment setup.

Material: 12L14 steel at 92
Rockwell B or equivalent.



Drawing 3
Sacrificial crush washer

REFERENCES

1. Fishburn, Barry, “Design Modification and Calibration of the Picatinny Activator for Setback Safety Testing of SADARM,” Technical Report ARAED-TR-92001, U.S. Army Armament Research, Development and Engineering Center, Picatinny Arsenal, New Jersey, May 1992.

2. Fishburn, B. and Redner, P., “Calibration of the ARDEC Setback Testing Maching for 17,000 G’s,” Technical Report ARWEC-TR-00010, U.S. Army Armament Research, Development and Engineering Center, Picatinny Arsenal, New Jersey, Jan 2001.

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