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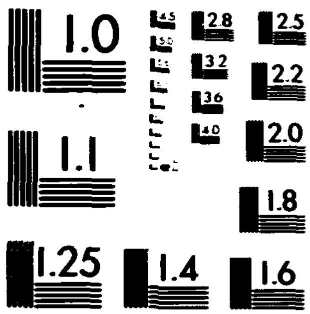
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SHAPED CHARGE JET/PROPELLANT INTERACTIONS IN A VENTED COMPARTMENT

F. T. Brown
W. S. Jackson
R. G. Hippensteel
R. Abrahams
G. Coulter
C. Kingery

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When compartmentalization was first considered for the new main battle tanks (XM1), the Ballistic Research Laboratory ~~(BRL)~~ with support from the XM1 Project Manager's Office, started to collect baseline data on compartmentalization that could be used in the design and implementation of vented ammunition compartments in the XM1 tank. This report describes a series of tests designed to study the environmental conditions present in a vented ammunition compartment when the propellant in a stowed round of ammunition is initiated by a shaped charge jet.

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These tests were conducted with an instrumented ammunition compartment containing a 105mm round of ammunition with live propellant and an inert warhead. Measurements of cartridge case rupture pressures, time histories of compartment pressures and ammunition temperatures, and effects of jet/propellant interactions were made with mechanical crush gauges, piezoelectric transducers, thermocouples, event screens, and witness plates. The propellant was initiated with a precision shaped charge. Data were acquired for a range of jet parameters and path lengths through the propellant.

Some of the conclusions drawn from these tests were that the severity of the environment as measured by cartridge case rupture pressures and compartment pressures increased for either increases in jet residual or increases in the length of the jet's path through the propellant. The temperature profiles for neighboring ammunition were not sensitive to variations in jet strength and propellant paths for this series of tests.

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I. INTRODUCTION

The survivability of armored vehicles depends in part on the reaction of stowed ammunition to attack. This stowed ammunition may be struck by primary penetrators such as shaped charge jets and kinetic energy projectiles, or by spall fragments. Analyses of armored vehicles show that the environment created in a vehicle by the initiation of the propellant charge in only one round of large caliber ammunition has the potential to incapacitate the crew. Initiation of large caliber ammunition in a tank exposes the crew to cartridge case fragments, fire from burning propellants, and toxic gases created by the burning propellants. Besides being lethal to the crew, the initiation of the tank's main gun ammunition could also destroy the tank. One can see that the combustion of this internally stored ammunition, as a result of impact by either primary penetrators or spall, can lead to the catastrophic loss of the armored vehicle.

There are several approaches to reducing the catastrophic loss of a vehicle due to the initiation of stowed ammunition. One of these approaches is the use of massive armor protection for the ammunition to reduce the probability of the ammunition being struck by main penetrators. Shielding could be employed around the ammunition to reduce the probability of initiation by spall; possibly the crew compartment could be lined with a spall suppressive material. The above approaches deal with the prevention of round initiation due to primary penetrators and spall. The weight associated with this sort of vehicle protection would make its application impractical. Another approach is to store the ammunition outside of the crew compartment in a vented ammunition compartment, a concept known as compartmentalization. Compartmentalization is concerned with protecting the crew and the vehicle from attacks on the stowed ammunition by separating the ammunition from the crew compartment and from vulnerable vehicle components. Figure 1 is a drawing of a generic ammunition compartment. The compartment has blast proof doors and external vents on the top and bottom. These vents are covered with vent plates. The blast proof doors separate the crew from the ammunition. When the ammunition is initiated by an attacking round, the vent plates blow off and the flames and toxic gases from the exploding rounds exit the vehicle through the open vents while the crew remains unharmed on the other side of the blast proof doors. Figure 2 shows a generic tank with two possible ammunition compartment locations.

The concept of compartmentalization was considered as early as the late 1940's, but little effort was undertaken until compartmenting techniques were being considered for the main battle tank (MBT 70) about the time that program was canceled. The concept was then applied to the MBT 70 follow-on, the XM803 program. Results from the XM803 tests gave some cause for optimism,* although much baseline data were needed to support the design and evaluation of a feasible implementation of compartmentalization. Early in 1974, the Ballistic Research Laboratory (BRL), with support from the XM1 Project Manager's Office, began to assemble baseline data that could be used for the design and implementation of vented ammunition compartments in the new main battle tank (XM1).

This report describes a series of tests conducted to produce baseline data to aid in the design of ammunition compartments for use in the XM1 tank. These tests were designed to investigate the environmental conditions present in a vented ammunition compartment when a single 105mm round stowed in the compartment is impacted by a shaped charge jet. Parameters of interest in these tests were pressure-time histories in the compartment, rupture pressures of ammunition cartridge cases, ammunition temperatures, residual jet penetration, and jet-tip velocities. Prior to this test series, a mathematical model of a vented ammunition compartment was developed.[1] This compartment model was used as a design tool for parametric studies to show the effects of variations in vent area, cartridge-case rupture pressures, and vent blow-off pressure times on compartment structures. One of the most important parameters in the model is the cartridge-case rupture pressure - all pressures in the compartment are dependent on the magnitude of this rupture pressure. Tests were conducted by the Interior Ballistics Laboratory (now called the Propulsion Division) to determine cartridge-case rupture pressures when rounds were electrically detonated.[2] These cartridge-case pressures were in turn used as input to the ammunition compartment model along with a description of the ammunition compartment that was used to collect baseline data. The output from this program served as a tool in the design of the baseline compartment tests.

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*J. M. Hennessey, "Compartmentalization Work at TACOM," BRL Briefing 29 Jan 1974.

[1] A.J. Budka, and L. Stansbury, Jr., "A Mathematical Model for Design-Evaluation of Vented Ammunition Boxes," Ballistic Research Laboratory Memorandum Report #2590, February 1976. (AD #B009785L)

[2] C.R. Ruth, and J.M. Frankle, "Rupture Pressure for Metal Cartridge Cases," Ballistic Research Laboratory Memorandum Report #2743. April, 1977. (AD #B018599L)

II. TEST COMPARTMENT AND AMMUNITION

The BRL compartment used in this test series is a typical ammunition compartment designed to hold eight 105mm rounds. It has an internal volume of 19,024 cubic inches within walls of 1-inch steel, rolled homogenous armor (RHA); there is a 192-square-inch vent in the top. For this test series, the compartment was laid on its side (Figure 3.) Holes 2 inches in diameter were drilled in the top and bottom of the compartment to provide an entrance and an exit for the shaped charge jet fired through the compartment. The purpose of these holes was to minimize the shock loading (jet impact) on the piezoelectric transducers, mounted on the side of the compartment opposite the open vent and on the door of the compartment, which would be transmitted through the compartment walls. For testing purposes, three rounds were placed in the compartment; one live propellant round was centered in the compartment, and two dummy rounds were placed between the live round and the compartment vent.

The three types of ammunition used were:

Live Propellant Round

APDS M392A2 105mm
Electrical Primer M80A1
Cartridge Case M115B1
Propellant M30 12 lb
Projectile: T382 proof slug 12.9 lb

Dummy Rounds

HEAT M456A1
Inert Warhead
No Propellant
Cartridge Case M148A1B1 steel

HEP-T M393A2
No Propellant
Cartridge Case M148A1B1 steel

The initiating charge used was the BRL 3.2-inch precision-shaped charge, Figure 4.

III. INSTRUMENTATION

Instrumentation for this test series consisted of a combination of piezoelectric transducers, strain gauges on the first couple of tests, mechanical crush gauges, thermocouples, event screens, and witness plates. The piezoelectric transducers were used to measure compartment pressure vs time; the strain gauges to measure ammunition rupture pressure vs time; the mechanical crush gauges to measure peak pressures in the compartment and in the live propellant cartridge case; the thermocouples to record ammunition temperature vs time; the event screens to measure jet-tip velocities; and the witness plates to measure residual penetration. Additional instrumentation provided for high-speed photographs of the events.

Two different types of piezoelectric pressure transducers were used in the compartment during this test series to determine the loading on the side and the end of the vented ammunition compartment. One of these was the Susquehanna Instruments Model ST-4 tourmaline transducer, a nonresonant transducer capable of reproducing the high frequencies of the pressure pulse. However, it is sensitive to the extreme temperatures encountered in these tests and cannot be relied upon to produce valid pressure measurements for more than a short period of time (5 milliseconds, more or less, depending on severity of reaction) after the initial pressure pulse has occurred. Tests indicate that after this time thermal sensitivity causes a severely negative baseline shift in the records, making an accurate assessment of pressure impossible. The Kistler Model 617A transducer was also used to extend the time in which the pressures could be measured. This transducer has a more temperature-stable quartz element which makes it more adaptable to the extreme thermal environment but it becomes excited by sharp pressure pulses with frequencies above approximately 40 KHz. For this reason the signals produced were electrically filtered to reduce recording frequencies above 30 KHz.

A small amount of silicone grease was applied to the sensitive surface of each of the transducers to provide added thermal protection. Sensitivity to acceleration was essentially eliminated by mounting each transducer in a specially designed mechanical shock isolation post. A report of the tests conducted to determine which type of piezoelectric transducers to use and the method of mounting them is contained in Appendix B.

The signals from the transducers were recorded on FM magnetic tape having a frequency response of zero to 80KHz. This capability, when coupled with individual transducer characteristics, produced an overall frequency response of 80KHz for 5 milliseconds with the ST-4 transducer and 30 KHz for more than 30 milliseconds when the Kistler 617A transducer was used.

Each of the piezoelectric pressure transducers was connected by a 3-inch length of low-noise, miniature coaxial cable to an impedance converter which converted the electrical signal produced by the transducer-sensing element to a low impedance signal. This effectively eliminated the introduction of extraneous noise into the 100-foot cables which conducted the signals to the recording room where the remainder of the recording equipment was located.

The signals were amplified and then recorded on a Honeywell Model 7610 magnetic tape recorder with a center frequency of 432 KHz and run at a tape speed of 120 inches per second. A block diagram showing the interconnection of these components of the system is displayed in Figure 5.

The transducers were calibrated periodically by subjecting them to a pressure pulse of known peak value. Based on the electrical response, a sensitivity value in millivolts per psi was obtained for each unit. A calibration voltage determined by multiplying the sensitivity by the predicted peak pressure was momentarily connected to the input amplifier for each channel and was used in the data reduction process as the 100% calibration step upon which the values of the pressure-time history of the blast waves were based.

The output of a time code generator was also recorded on the magnetic tape and provided the time base used in the subsequent treatment of the data.

The tapes containing the analog data were digitized at a 500-KHz sampling rate in preparation for processing on the BRLESC computer. The values for pressure and impulse were then computed and tabulated and an output tape was generated for use by the CALCOMP plotter on which the plots scaled for pressure versus time were produced for inclusion in this report.

Occasionally, the recording of the pressure-versus-time history was interrupted by the mechanical failure of the transducer, or of the signal cables or a connector, causing a noisy segment which was unintelligible. The noisy segments have been deleted from the plots presented and a reason is given for doing so. Concurrent examination of the damaged hardware and the faulty plots usually permitted making a logical diagnosis of the problem.

Internal ferrule gauges were place in the base of the projectile and the nose of the live propellant round stowed in the compartment (Figure 6) to record pressure time histories. Records from these gauges were recorded on analog magnetic tape for further processing. As mentioned previously, Ruth and Frankle successfully used these guages to measure cartridge-case rupture pressures vs time in 105mm rounds that were electrically detonated; however, they did not work well in our tests. We believe that the method of initiating (shaped charge jet) the live propellant round was too violent for this particular type of gauge and the records produced were very noisy. After the first three tests, their use was discontinued.

Mechanical crush gauges were placed in the compartment and in the base and nose of the live propellant round, Figure 6. These gauges were used because they provided an inexpensive way to measure the violence of the interaction of the shaped charge jet and the live propellant. Since they normally are used to measure millisecond events, the gauge readings in terms of pounds per square inch of pressure are not necessarily meaningful; however, the ranking of these readings appears to be useful. A data base of gauge readings for ammunition events is being acquired to determine whether or not differences in readings are significant and useful descriptors for the environment in an ammunition compartment. Mechanical crush gauges were also placed at various locations within the ammunition compartment. Hopefully, some correlation can be made between their measurements and the piezoelectric gauge measurements.

The mechanical crush gauge used was the T-18 gauge which consists of a cylindrical body housing a metal sphere, and a piston and spring combination. One end of the cylindrical body is closed while the other end is partially open, Figure 7. When pressure is applied to the piston through the open end of the cylinder, the piston moves forward and compresses the metal sphere. Pressures are then determined by measuring the compressed sphere with a Pratt and Whitney Super Micrometer. Because of the anticipated higher pressures in the live propellant round, crush gauges with copper spheres were used rather than the aluminum spheres used in the crush gauges placed in the compartment.

Temperature measurements inside the dummy rounds were recorded with thermocouples connected to a Honeywell recorder. Iron-constantan 20-gauge wire was silver-soldered to the interior walls of the inert warheads and cartridge cases. Although 20-gauge wire may seem excessively large for thermocouple work, we decided that this size was needed owing to the violent nature of the environment in the ammunition compartment.

The Honeywell recorder was of the "unbalanced-bridge type" capable of recording eight channels of temperatures, each ranging from 0 to 800°F. The recording paper in this recorder travels at 3 inches per minute. Each of the eight channels is recorded in sequence at the rate of 30 readings per minute. Full deflection of 800°F covers 11 inches on the paper, and increments of 5° can be read directly. Estimates to the nearest degree can easily be made.

Jet-tip velocities were measured with the use of "event screens." These event screens consisted of two sheets of aluminum foil separated by a piece of paper to electrically insulate them. A wire was connected to each sheet of foil, and this pair of wires was connected in series with a 1,500-ohm resistor, a 1-1/2-volt battery and an electronic counter (timer), Figure 8. When the shaped charge jet was fired, the electronic counter was started. When the jet penetrated the event screen, it completed the circuit sending a signal to the electronic counter. This signal stopped the counter. The counter readings, along with the distances between the event screens, were used to determine the jet-tip velocities at various locations along the path through the compartment.

IV. TEST SETUP AND TESTING PROCEDURE

Figure 9 is a diagram of the test setup for this series of tests. The BRL ammunition compartment was placed on a blast table in which a window was cut for the jet to pass through. The top of the blast table was to act as a blast and fragmentation shield in an attempt to minimize vibrational input to the pressure sensors mounted on the walls of the compartment. Four piezoelectric transducers were mounted on the compartment walls, two on the side of the compartment opposite the open vent and two on the loading door. The two gauges on the compartment door were mounted on each side of the base of the live propellant round at positions labeled 2 and 4, and the other two gauges were centered on the side of the compartment at positions labeled 1 and 3 (see Appendix A). The gauges at positons 1 and 2 were Susquehanna Instruments Model ST-4 tourmaline gauges and those at positons 3 and 4 were Kistler Model 617A tourmaline gauges. Thin strips of metal were welded over the transducers on the side of the compartment to protect them from fragments. Mechanical crush gauges were mounted in the side of the compartment opposite the open vent on strips of metal welded in the compartment. The compartment contained three rounds, a 105mm round with live propellant mounted in the center of the compartment and two dummy rounds, a 105mm HEP round and a 105mm HEAT round with inert warheads, mounted between the live round and the open vent. The live round was supported by a steel stand, and the two dummy rounds were clamped in place. The live propellant round was instrumented with mechanical crush gauges and for the first couple of tests with internal ferrule strain gauges. The dummy rounds were instrumented with thermocouples. The mechanical crush gauges and the strain gauges were located in the nose (base of the projectile) (Figure 6), and in the base of the live propellant round. The HEP warhead body contained three thermocouples on its interior walls, one in the nose and two on the sides. The body of the HEAT warhead contained two themocouples, both on the interior walls (Figure 10). One of the empty cartridge cases contained three thermocouples. Steel RHA witness plates were placed under the compartment to measure residual jet penetration. Event screens were placed on top of the jet conditioner, the compartment, the live round, on the bottom of the compartment, and on top of the residual stack of RHA.

A BRL 3.2-inch precision shaped charge jet was fired through a stack of steel RHA, through the entrance hole to the compartment, and into the live propellant round, 12 inches from its base. The jet exited the round, exited the compartment via the jet exit hole in the bottom of the compartment, and penetrated into the residual stack of steel RHA under the compartment. The parameters that were changed in this test series were the amount of jet conditioner used, 4 to 11 inches of steel RHA, and the length of the propellant path through which the jet passed, 1 to 8 inches. Figure 11 shows the different propellant paths used. In an effort to test the effect of a coolant in the compartment, two one-gallon jugs of water were placed in the compartment for several tests.

V. SUMMARY OF TEST RESULTS

Appendix A describes in detail all tests in this series. Included in Appendix A are all presure-time histories, temperature-time histories, and a brief narration on each shot.

Mechanical crush gauge pressures recorded in the live propellant round ranged from 100 psi to 5400 psi in the base of the cartridge case and from 100 psi to 7400 psi in the nose of the cartridge case, the base of the projectile. The pressures in both the nose and the base of the cartridge case increased as the jet residual increased. Figure 12, a bar graph, shows the increase in pressures as the residual of the shaped charge jet increases. The jet propellant path is held constant while the amount of the residual is varied. These pressures also increased as the jet's path through the propellant increased. Figure 13 shows how the cartridge case pressures increase as a function of the jet propellant path. In this figure the amount of jet conditioner is held constant, 8 inches (approximately 4.5-inch residual), while the jet propellant path is varied. As these two figures show, in most cases the pressures are higher in the base of the cartridge case than in the nose, the most notable exception to this being in those tests where there was an 8-inch jet/propellant path. In all tests except those in which there was an 8-inch jet/propellant path, the shaped charge jet impacted the live propellant round 12 inches from the base of the cartridge case. In test shots with the 8-inch propellant path, the jet impacted the cartridge case closer to the neck of the cartridge case. Figure 14 shows the average pressures in the nose and base of the cartridge case for all jet propellant paths.

No results were obtained from the internal ferrule strain gauges mounted in the nose and base of the live propellant cartridge case (Figure 6). As was stated earlier, the records produced by these gauges were extremely noisy and no data could be obtained from them.

In tests conducted prior to this test series to measure the rupture pressures of cartridge cases when the round was ignited by electrical ignition of the primer, the pressures in the base of the round were always higher than those in the neck of the round. Cartridge case pressures for this type of ignition averaged 6200 psi in the base of the round and 3100 psi in the neck of the round. In these tests the method of initiation was always the same and there was little variation in cartridge case pressures. It is interesting to note that in the present test series the base pressures were not always greater than those pressures in the nose of the round. Also of interest is the wide variation in rupture pressures in those tests conducted using the same conditions. This variation in pressure is due to the unpredictable nature of the jet/propellant interaction.

As was the case with the pressures recorded in the live propellant round, the compartment pressures also increased as the jet residual increased. Figure 15, a plot of the pressure ranges recorded on both the side and door of the ammunition compartment, shows that the compartment pressure increased as the jet residual increased. The peak pressures recorded on the door are considerably higher than those recorded on the side of the compartment. Figure 16 shows the average peak pressures recorded as a function of jet residual, for all jet propellant paths tested. Again the compartment pressure increased as the jet residual increased and the peak pressures on the door were higher than those on the side of the compartment. This trend continues in Figure 17, the only difference being that the jet propellant path was held constant, 5 inches, while the jet residual was varied. Figure 18 shows the compartment pressure increasing as a function of the jet propellant path. The amount of jet conditioner was held constant, 8 inches, (approximately a 4.5-inch residual). In most of the cases, the peak pressures recorded on the door of the compartment were higher than those recorded on the side, but for the 8-inch jet propellant path, the pressures on the side were higher. It is interesting to note that in most tests the base pressures were higher in the live propellant round than the nose pressures, with the exception of those shots where an 8-inch jet propellant path was used. Figure 19 shows a comparison between the average peak pressures in the compartment recorded by the piezoelectric gauges and the mechanical crush gauges. Again the jet propellant path was held constant at 5 inches. On the average, there is a fairly good agreement between the piezoelectric transducers and the mechanical crush gauges.

A listing of the peak pressures recorded by the piezoelectric transducers on each channel for each of the tests is given in Table I. Also listed are impulse calculations for each channel for each test. These impulses were calculated by finding the area under the pressure-time curve. Impulses were calculated for intervals up to 5 milliseconds, 10 milliseconds, 15 milliseconds, and 19.5 milliseconds. In some cases calculations were not possible because of noisy records or negative pressures caused by broken signal cables.

Plots of impulse vs time for the compartment walls are shown for all shots with 5-inch, and 8-inch jet propellant paths (Figure 21). The amount of jet conditioner was constant, in inches, in tests plotted on Figure 21.

Peak temperature measurements recorded by thermocouples in the empty cartridge cases stowed in the ammunition compartment ranged from 250°F to 760°F. Maximum temperatures in tests where there was no water in the compartment, tests 1 through 23, ranged from 330°F to 570°F with an average peak temperature of 423°F. In tests where water was used in the compartment, tests 24 through 28, peak temperatures ranged from 250°F to 500°F with an average peak temperature of 328°F. The temperatures recorded during the fifth shot, test 24, were the highest temperatures recorded, 760°F and 610°F. If test 24 could be disregarded, the effect of adding water to the compartment reduced the average peak temperature in the cartridge cases by approximately 100 °. In tests where no water was added to the compartment, the average peak temperature when the jet propellant path was 5 inches was higher than that in tests when the jet propellant path was only 1 inch, 459° as opposed to 388°. No temperature data were acquired from tests where the propellant path was 8 inches; the leads to the thermocouples were always broken.

Maximum temperatures recorded in the inert HEAT warheads ranged from 120° to 165°F with an average reading of 141° as opposed to maximum temperatures in the inert HEP warheads which ranged from 175° to 210°F with an average reading of 191°F. The difference in temperature is due to the difference in the thickness of the warhead case.

Average peak temperatures in the HEAT warheads in tests conducted with 5-inch jet propellant paths (150°F) were higher than those in tests conducted with a 1-inch jet propellant paths (136°F). The opposite was true for the HEP warhead. In the tests with a 5-inch propellant path the average peak temperature was 185°F while the average peak temperature in tests with a 1-inch jet propellant path was 197°F. The inert warheads were not instrumented with thermocouples in the tests which included water in the compartment.

The peak temperatures in both the empty cartridge cases and in the inert warheads in all of the tests occurred within 30 seconds of the time that the shaped charge jet entered the compartment. The cartridge case temperatures fell off rapidly for the first minute or two after the peak temperature had been reached, and gradually thereafter. Temperatures in the inert HEAT and HEP warheads fell off gradually after the peak temperatures were recorded; only a slight decline in tempertures was noted during the 6 minutes that they were monitored.

Figure 22 shows the average peak temperatures recorded in the dummy cartridge cases and the inert HEAT and HEP warheads. Also shown are the average maximum temperatures in the cartridge cases and inert warheads 3 minutes after the jet entered the compartment. These temperatures were recorded in compartments containing no water jugs, and all shots were through 5-inch propellant paths.

A comparison of the peak temperatures recorded in cartridge cases stowed in compartments with and without water jugs is shown in Figure 23. Again these plots are from tests in which the jet propellant path was 5 inches. As in Figure 22 the average peak temperatures were also plotted 3 minutes after the initial event.

A plot of residual penetration of shaped charge jets for all shots, measured in steel RHA witness plates at the bottom of the test fixture, is shown in Figure 24. Note the relatively small differences in residual penetration between those shots where the jet was conditioned with 10 inches of steel RHA and those where 4 inches were used.

The event screens used in these tests to measure jet-tip velocities proved to be unreliable and inconsistent. Only in a few tests were we able to obtain jet-tip velocities from all event screen locations. Those that were obtained are recorded in Table II. The locations of the event screens, labeled A, B, C, D and E, are shown in the figures depicting the test setups in Appendix A. Four counters and five event screens were used. When a jet penetrated event screen A, it started all four electronic timers; each time a jet passed through an event screen one of the timers was stopped, thus giving times elapsed between event screen A and each of the other four screens. The velocities were then computed between event screens A and B, A and C, A and D, and A and E. (Table II)

Table III is a summary of all the test results in this series.

VI. ANALYSIS OF TEST RESULTS

All of the environmental conditions observed in the ammunition compartment in this test series, with the exception of the ammunition temperature/time measurements, are dependent on the magnitude of the jet/propellant interaction. The pressures measured in the compartment are dependent on the rupture pressures of the cartridge case which in turn are dependent on the jet/propellant interaction. The measured residual penetrations of the shaped charge jets are also dependent on this jet/propellant interaction. The magnitude of the jet/propellant interaction is dependent on many parameters, two of which are the shaped charge jet-tip velocities and the length of the jet/propellant path through the impacted round.

Two parameters which have had an effect on the magnitude of rupture pressures in cartridge cases are the shaped charge jet-tip velocities and the length of the jet/propellant path. Jet-tip velocities can be raised or lowered by varying the amount of steel RHA through which the jet passes prior to impacting the target. An unimpeded jet from the 3.2-inch BRL precision shaped charge has a tip velocity of 7.5mm/μsec; whereas, a jet which has passed through a 10-inch jet conditioner of steel RHA has a tip velocity of approximately

4mm/usec.* Other tests conducted at BRL showed that the amount of energy released by the jet/propellant interaction was increased when the jet was more energetic, i.e., when the jet-tip velocity was higher.

The higher tip velocities create a more violent jet/propellant reaction and the magnitude of this reaction is reflected in the rupture pressures recorded in cartridge cases and in the damage to the cartridge cases with live propellant used in this test series. Figure 14 shows that cartridge case pressures increased as the jet-tip velocities increased. The jet-tip velocities varied from approximately 4mm/usec for a jet fired through 10 inches of steel RHA to 5.1mm/usec for a jet fired through only 4 inches. Damage to the cartridge cases with the live propellant correlates with the recorded cartridge case pressures. In shots where 4 inches of jet conditioner were used, high pressures were experienced and the impacted cartridge case fragmented into many pieces. In those shots where 10 inches of jet conditioner were used and lower pressures were experienced, the impacted cartridge cases usually broke into two large pieces.

As the shaped charge jet passed through the propellant bed (live propellant in cartridge case), high pressures induced a violent localized explosion in the jet's path and in a relatively small volume of propellant adjacent to the impacted propellant. Tests are being conducted by J. Majerus of the Warhead Mechanics Division to determine the amount of propellant which participates in this initial detonation. The amount of propellant which participated in the initial explosion was increased by varying the length of the jet/propellant path from 1 inch to 8 inches. While varying the length of the jet/propellant path, the amount of jet conditioner remained constant, 8 inches of steel RHA. Therefore, the jet-tip velocities for these tests should have been fairly consistent. The test results showed that the violence of the jet/propellant interaction was increased as the length of the jet propellant path was increased. This increase in cartridge case pressures was depicted in Figure 13. Figure 25 shows a ruptured cartridge case in which the jet propellant path was approximately 1 inch. Damage to this case was minimal and the pressures recorded in the case were low. Figure 26 shows the remains of a case in which the jet propellant path was approximately 8 inches; damage to this case was more severe and the pressures recorded were considerably higher than those for the former case.

The pressures on the compartment walls are dependent on the rupture pressures of the cartridge case. When the cartridge case ruptures, the expansion of gases sends shock waves out to the compartment walls, and there is a rapid buildup of pressure in the compartment.

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*J. Majerus, "Study of Armor for Vehicle Compartments," DF, Apr 74.

By looking at figures 15 through 17 and the pressure-time traces in Appendix A, it can be seen that the compartment experienced some very high pressures. The fact that the compartment was not damaged in this test series was due, in part, to the large free volume, 17,270 cubic inches, surrounding the impacted round and the 192-square-inch vent located on the side of the compartment. In most tests in this series, the peak pressures were recorded within the first couple of milliseconds after the impacted round ruptured. After this, the pressures fell off rapidly. This phenomenon has also been seen in tests conducted by Battelle Columbus Laboratories; they reported that the initial shock impinging on the walls of the compartment decayed to a relatively small fraction of its initial value in three reverberations across the compartment.[3] It appears that the peak pressures recorded in the compartment are caused entirely by the initial detonation of the impacted round. No pressure buildup is caused by the burning of the remaining propellant owing to the open vent which allows the gases to escape faster than they are generated.

In each test, differences in the pressure/time traces of gauges located adjacent to each other, i.e., the two gauges on the side of the compartment and the two gauges in the door of the compartment, were in part due to the differences in their frequency responses. In addition, because of the nonuniform nature of the shock waves reverberating in the compartment, it is possible that two identical gauges placed side by side would not produce identical pressure/time records since the pressures recorded by each transducer are local pressures. It was also noted that the pressure/time records varied between tests with identical conditions, i.e., amount of jet conditioner, standoff distances, jet propellant path, etc. The reason for this variation is due to the variability of the shaped charge jet and in the way the impacted cartridge case ruptures. Even though the shaped charge jets used are precision laboratory charges, they do not function exactly the same way every time.

The peak pressures measured on the door of the compartment were higher on most tests than those pressures measured on the side, but that was not the case on total measured impulse on the door and side of the compartment. Figure 20 is a plot of total impulse vs time for shots with a 5-inch jet propellant path. As can be seen, the total impulse on the side of the compartment was usually greater than that on the door in those tests where the jet was conditioned with 8 and 10 inches of RHA. Figure 21 is a plot of total impulse vs time for all shots for which the jet was conditioned with 8 inches of RHA. For these shots, the total impulse on the side of the compartment in most

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[3] Bimonthly Technical Progress Report No. 3, "Development of Design Criteria for Ammunition Storage Compartments," January 29, 1975. TACOM Contract No. DARF-07-74-C-0266.

cases was greater than that on the door for all jet/propellant paths tested. Although higher peak pressures were recorded on the compartment door in the majority of the tests, the total measured impulse was higher on the compartment side in most of the test. (Data plotted for 4.5-inch jet residual only.)

Test results showed that the measured residual penetration was less than predicted. Because of the method used to predict residual penetration and the long standoff distances used in these tests, this is not surprising. What is surprising are the relatively small differences in residual penetration between tests using jets with small residuals and those with jets with large residuals (Figure 24). The difference between a shot with 4 inches of jet conditioner and one with 11 inches was only 1/2 inch. This implies that there was a more active jet/propellant interaction when 4 inches of jet conditioner was used. This is indeed what happened. Results of the test where 4 inches of jet conditioner were used show severe damage to the impacted round and very high pressures, both in the ammunition compartment and in the live propellant case. As a jet passes through the propellant bed, the jet is attenuated by its interaction with the propellant. The more energetic the jet, the more violent the jet/propellant interaction, and the greater the jet attenuation. The more the jet is disturbed as it passes through the live propellant cartridge case, the less its residual penetration will be. Therefore, the violence of jet/propellant interaction has a definite effect on the penetration of shaped charge jets.

The severity of the jet/propellant interaction seemed to have no effect on the temperature-time profiles of the instrumented dummy rounds in the compartment. The only parameter that had any effect on these histories was the addition of two plastic 1-gallon jugs filled with water. When the jet entered the compartment and impacted the live propellant round, the jugs were either perforated or melted and the bottom of the compartment was flooded with water. In tests containing water jugs, the bottom of the compartment was usually covered with unburned propellant; in all other tests any propellant remaining in the compartment was burned. On all tests unburned propellant could be found outside the compartment. This propellant was blown through the open vent in the side of the compartment immediately after the live round was impacted by the shaped charge jet. In four of the five tests where water was added to the compartment, the peak temperatures were markedly lower, averaging approximately 100°F less than those recorded in tests containing no water. However, on the fifth test containing water, test 24, the measured peak temperatures were the highest recorded for any test in this series. The reason for this is not known. Baseline hot-plate data obtained by Einstein et al. suggest that even at these reduced temperatures it is probable that had these dummy rounds contained propellant, cookoff would have been almost instantaneous.[4]

[4]S. I. Einstein, J. Misko, and W. L. Taylor, "Thermal Insulation for M119 Propelling Change in 105mm M109A1 Self-Propelled Howitzer (for Cookoff Protection)," Technical Report No. 4251, Picatinny Arsenal, Dover, New Jersey, July 1971, AD 887668L.

According to Howe and Jackson, who conducted tests to determine the cookoff hazard of compartmentalized tank projectiles, the temperatures produced by a single propellant burn in this test series were not sufficient to cause the warheads to cookoff.[5] They concluded from their tests that warhead cookoff in a propellant fire is not a problem.

It should be noted that in all tests in this series the instrumented warheads and cartridges were empty. The measured temperatures probably would have been higher if they had contained explosive and propellant.

The following conclusions can be made:

1. The cartridge case rupture pressures and the compartment pressures increase when the residual of the shaped charge jet or the length of the jet/propellant path is increased.

2. The greater the jet/propellant interaction is, the greater the jet attenuation, thus causing a reduction in the penetration capabilities of the jet after it passes through the propellant bed.

3. The severity of the jet/propellant interaction seems to have no effect on the temperature-time profiles of the neighboring rounds in the compartment.

4. In most tests in this series, the temperatures recorded in the empty cartridge cases were sufficient to cause propellant cookoff had the cases been loaded with propellant.

5. The temperature-time profiles recorded in the inert HEAT and HEP warheads were not sufficient to cause the warheads to cookoff.

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[5] P.M. Howe and W. Jackson, "An Experimental Study of the Cookoff Hazard of Compartmentalized Tank Projectiles," BRL Memorandum Report No. 2666, August 1976. (AD #B014010L)

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4. S. I. Einstein, J. Misko, and W. L. Taylor, "Thermal Insulation for M119 Propelling Change in 105mm M109A1 Self-Propelled Howitzer (for Cookoff Protection)," Technical Report No. 4251, Picatinny Arsenal, Dover, New Jersey, July 1971, AD 887667L.

5. P. M. Howe and W. Jackson, "An Experimental Study of the Cookoff Hazard of Compartmentalized Tank Projectiles," Ballistic Research Laboratory Memorandum Report #26666, August 1976. (AD #B014010L)

TABLE I. SUMMARY OF COMPUTED BLAST PARAMETERS

Shot	Channel	Peak Pressure Psi	Impulse to (Milliseconds) (psi - ms) 5	8	10	15	19.5	
1	1	140.0	174	259	293	335	340	
	2	272.9	-	-	-	-	-	X
	3	178.5	164	234	280	319	366	XX
	4	342.0	218	316	373	420	488	
2	1	154.8	212	305	334	348	-	
	2	112.0	-	-	-	-	-	X
	3	118.0	222	321	377	459	505	XX
	4	140.5	198	267	285	291	-	
3	1	180.7	-	-	-	-	-	X
	2	313.6	268	337	362	404	429	
	3	158.0	-	-	-	-	-	X
	4	308.2	203	252	262	-	-	XX
4	1	175.8	243	315	337	-	-	XX
	2	429.3	302	380	391	375	331	
	3	160.6	297	430	490	570	617	
	4	235.2	223	265	-	-	-	XX
5	1	156.0	-	-	-	-	-	X
	2	363.9	-	-	-	-	-	X
	3	132.0	263	382	427	513	565	
	4	238.0	-	-	-	-	-	XX
6	1	313.8	271	370	412	457	464	
	2	380.0	298	398	437	464	-	XX
	3	124.4	415	457	514	584	604	
	4	401.5	-	-	-	-	-	X
7	1	222.0	309	424	469	518	-	XX
	2	467.0	342	466	517	557	-	XX
	3	315.0	336	491	557	665	699	
	4	546.0	347	459	486	491	-	XX
8	1	130.7	245	353	395	432	-	XX
	2	667.9	274	381	412	-	-	XX
	3	178.9	272	393	447	543	586	
	4	538.0	279	374	391	426	-	XX

X Noisy record
XX Negative pressure

TABLE I. (Continued)

Shot	Channel	Peak Pressure Psi	Impulse to (Milliseconds) (psi - ms) 5	8	10	15	19.5	
9	1	329.4	-	-	-	-	-	X
	2	531.9	482	660	750	868	1006	
	3	162.3	-	-	-	-	-	X
	4	616.0	465	620	693	793	816	
10	1	268.4	322	432	474	504	-	XX
	2	912.2	430	565	609	634	-	XX
	3	213.0	400	574	660	774	829	
	4	502.8	419	594	666	781	823	
11	1	393.8	389	507	543	-	-	XX
	2	935.2	496	667	735	806	-	XX
	3	265.7	463	679	770	906	954	
	4	705.0	486	660	726	838	869	
12	1	323.0	366	485	525	541	-	XX
	2	1034.3	-	-	-	-	-	X
	3	250.0	504	730	843	1042	1154	
	4	653.3	424	531	573	585	-	XX
13	1	150.8	129	169	184	193	-	XX
	2	167.0	180	272	322	397	421	
	3	230.7	159	246	268	305	318	
	4	195.6	132	196	221	229	-	XX
14	1	240.0	262	489	-	-	-	XX
	2	229.0	386	527	520	632	634	
	3	246	340	505	581	685	739	
	4	160	-	-	-	-	-	X
15	1	69	41	47	-	-	-	XX
	2	32	66	92	103	112	-	XX
	3	68	-	-	-	-	-	XX
	4	101	-	-	-	-	-	X
16		NO RECORDS						
17	1	205	290	366	390	841	1195	
	2	228	340	429	438	-	-	XX
	3	338	438	612	725	864	962	
	4	350	-	-	-	-	-	X
18	1	757	931	1469	1795	2292	2478	
	2	1008	1275	1955	2345	2975	3246	
	3	405	928	1482	1820	2389	2691	
	4	1020	1070	1630	1920	2438	2681	

X Noisy record

XX Negative pressure

TABLE I. (Continued)

Shot	Channel	Peak Pressure Psi	Impulse to (Milliseconds) (psi - ms) 5	8	10	15	19.5	
19		NO RECORDS						
20	1	238	467	635	696	708	-	XX
	2	221	585	803	930	1133	1227	
	3	934?	575	828	946	1101	1170	
	4	113	293	414	474	590	659	
21	1	507	-	-	-	-	-	X
	2	544	555	943	1120	-	-	XX
	3	1018?	-	-	-	-	-	X
	4	235	303	430	484	585	607	
22	1	NO RECORD						
	2	582	640	888	975	-	-	XX
	3	755	-	-	-	-	-	X
	4	178	317	443	507	607	644	
23	1	523	-	-	-	-	-	X
	2	410	-	-	-	-	-	X
	3	427	625	945	1115	1367	1474	
	4	210	277	387	437	494	498	
24		NO RECORDS						
25	1	64	42.8	-	-	-	-	XX
	2	55	68	72	-	-	-	XX
	3	144	95	138	151	170	174	
	4	73	28	32	-	-	-	XX
26	1	160	271	347	367	-	-	XX
	2	516	402	505	537	558	-	XX
	3	365	446	644	739	884	950	
	4	530	272	388	440	512	588	
27	1	185	215	-	-	-	-	XX
	2	831	494	610	-	-	-	XX
	3	278	496	696	808	1004	1121	
	4	283	406	662	810	1157	1444	
28	1	257	454	607	676	693	-	XX
	2	738	708	957	1075	1174	-	XX
	3	405	607	1053	1239	1614	1822	
	4	401	-	-	-	-	-	X

X Noisy record
XX Negative pressure

TABLE II. SUMMARY OF TEST RESULTS

Test	Jet Residual	Propellant Path	Peak Pressures (psi)						Peak Temperatures			Residual Penetration
			Ammunition Compartment				Live Round					
			Piezoelectric Gages		Crush Gages		Crush Gages		Cart. Cases	HEAT WH	HEP WH	
			Side	Door	Front	Rear	Nose	Base				
1	2.4"	5"	140 178	273 342	not used		1500	1200	no thermocouples used			3/4"
2	3"	5"	154 118	112 140	490 190	210 150	1000	100	490°F	160°F	190°F	3/8"
3	3"	5"	180 158	313 308	170	160	1200	600	480°F	160°F	190°F	3/4"
4	3"	5"	175 160	429 235	not used		not used		wires cut			1"
5	3"	5"	156 132	364 238	not used		not used		no thermocouples used			3/4"
6	4.5"	5"	313 124	280 401	410 260	190 360	---	600	413°F	148°F	177°F	7/8"
7	4.5"	5"	222 315	467 546	330 700	not	2000	1000	418°F	157°F	175°F	3/8"
8	4.5"	5"	131 179	668 538	230 250	400 500	800	1400	433°F	140°F	203°F	1"
9	6"	5"	329 220	531 616	280 510	215 385	3600	3200	567°F	146°F	180°F	1"
10	6"	5"	268 213	912 502	310 750 1780	--- 210	2300	1777	420°F	138°F	171°F	7/8"
11	6"	5"	394 266	935 705	500 750	300 320	---	---	thermocouple wires burnt & cut			7/8"
12	6"	5"	323 250	1034 653	440 ---	330 710	1900	2600	no thermocouples used			1-3/16"
13	4.5"	1" GS	151 231	167 196	580	390	300	1300	375°F	158°F	210°F	1"
14	4.5"	1"VS	240 246	229 160	530 1090	660 450 1210 400	2100	2400	335°F	121°F	171°F	1-3/8"

GS - Gauge side VS - Vent side

TABLE II. (Continued)

Test	Jet Resid-ual	Propellant Path	Peak Pressures (psi) Ammunition Compartment Piezoelectric Gages Side	Door	Crush Gages Front	Rear	Live Round Crush Gages Nose	Base	Peak Temperatures Cart. Cases	HEAT WH	HEP WH	Residual Penetration
15	4.5"	1" GS	69 68	40 101	310 250	310 380	100	300	502°F	145°F	206°F	1-1/16"
16				JET MISSED	LIVE	PROPELLANT	ROUND					2-1/2"
17	4.5"	1" VS	205 338	228 350	1550 520	1120 1010 620	3000	5400	350°F	131°F	195°F	1/8"
18	8"	5"	757 405	1008 1020	960 2190	400 1240	2900	4100	thermo burnt	couple & cut	wires	1-1/16"
19	8"	5"	blew	fuze	610 620	600 860	2900	6400	thermo	couple	wires	1-1/4"
20	4.5"	8"	238 934	360 113	480 430	430 510	---	3700	415°F	wires	cut	1"
21	4.5"	8"	507 1018	544 235	510 430	500 330	5600	2100	thermo	couple cut	wires	---
22	4.5"	8"	--- 755	582 178	460 830	500 830	1500	4300	no ther	mocoup used	les	5/8"
23	4.5"	8"	523 427	410 210	490 790 1060	450 440	7400	1845	no ther	mocoup used	les	1/4"
24	4.5"	1" GS	no rec	ords	530 460	330 480	400	400	610°F 760°F	no the couple in war	rmo- s used heads	1-5/8"
25	4.5"	1" GS	55 73	64 144	240 490	360 260	200	600	350°F 325°F			1-7/8"
26	4.5"	5"	160 365	516 530	380 310	480 480	900	1500	275°F 310°F			1"
27	4.5"	5"	185 278	831 283	420 450	250 360	900	3800	500°F 350°F			1-1/2"
28	4.5"	5"	257 405	738 401	610 590	870 660	1500	4800	260°F 250°F			1"

GS - Gauge side VS - Vent side

TABLE III. SUMMARY OF JET-TIP VELOCITIES

Test	Predicted Residual at Round	Average Jet Tip Velocity Between Event Screens				Residual Penetration
		A - B	A - C	A - D	A - E	
1	2.4"	---	not used in this test			3/4"
2	3"	---	---	---	---	3/8"
3	3"	---	3.5	3.2	3.2	3/4"
4	3"	---	---	---	---	1"
5	3"	---	3.3	3.1	2.9	3/4"
6	4.5"	---	---	---	---	7/8"
7	4.5"	---	---	---	---	3/8"
8	4.5"	3.75	---	3.4	3.2	1"
9	6"	---	---	---	---	1"
10	6"	---	---	---	---	7/8"
11	6"	4.1	---	3.5	3.2	7/8"
12	6"	---	---	---	---	1-3/16"
13	4.5"	3.8	3.8	---	---	1"
14	4.5"	3.8	3.8	4.0	3.9	1-3/8"
15	4.5"	3.8	3.9	4.0	3.8	1-1/16"
16	4.5"	3.7	---	3.9	3.9	2-1/2"
17	4.5"	3.5	---	---	---	1/8"
18	8"	5.1	---	4.5	4.3	1-1/16"
19	8"	---	---	---	---	1-1/4"
20	4.5"	---	---	---	---	1"
21	4.5"	---	---	---	---	0"
22	4.5"	2.8	3.3	---	3.5	5/8"
23	4.5"	2.7	3.1	3.1	2.9	1/4"
24	4.5"	---	---	---	---	1-5/8"
25	4.5"	---	---	---	---	1-7/8"
26	4.5"	---	---	---	---	1"
27	4.5"	3.8	---	2.7	***	1-1/2"
28	4.5"	4.3	----	3.0	***	1"

ALL VELOCITIES MEASURED IN MILLIMETERS/MICROSECOND

--- THESE EVENT SCREENS FAILED TO FUNCTION PROPERLY

*** ONLY THREE SCREENS USED ON THIS TEST

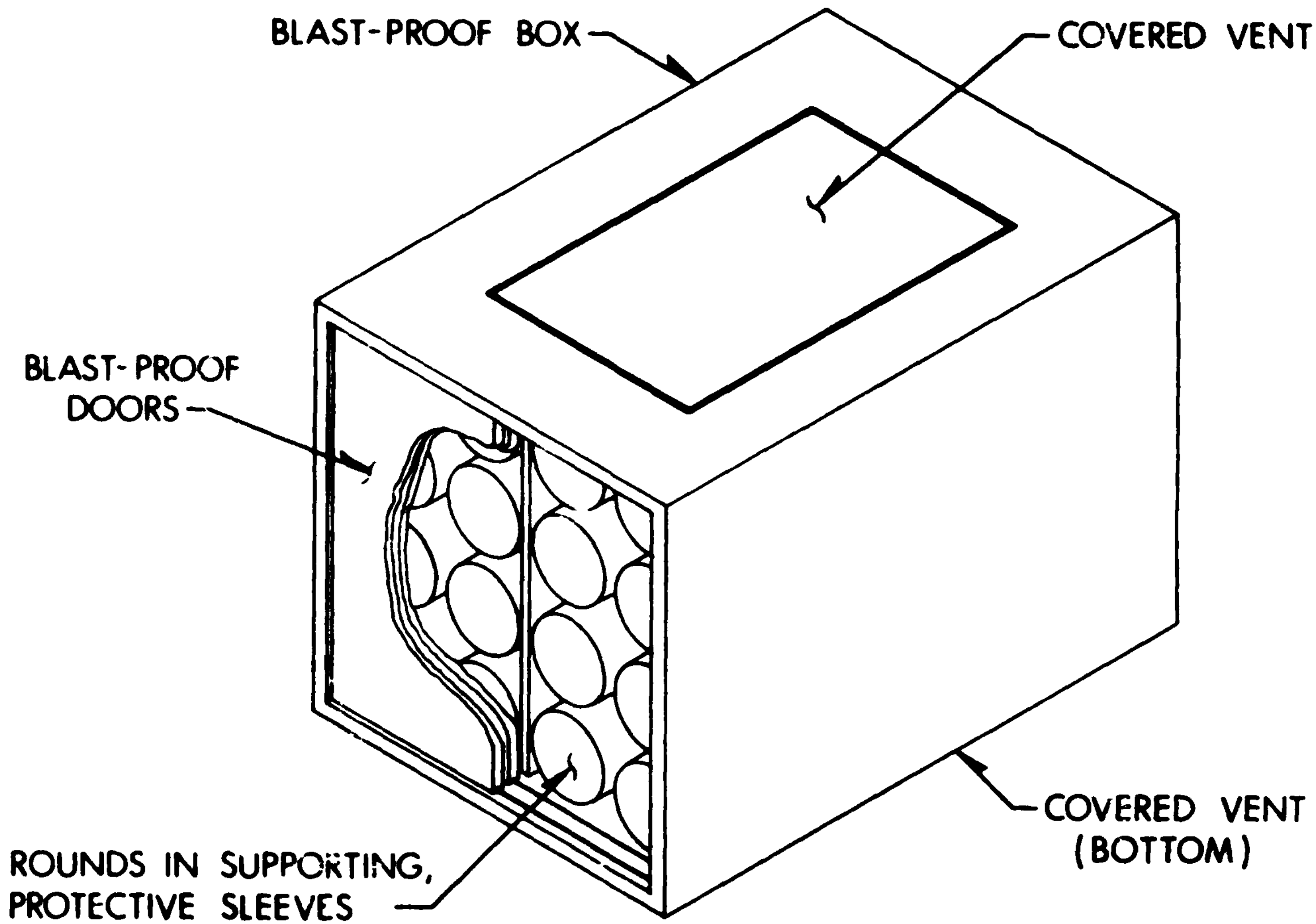


FIGURE 1. Generic Ammunition Compartment

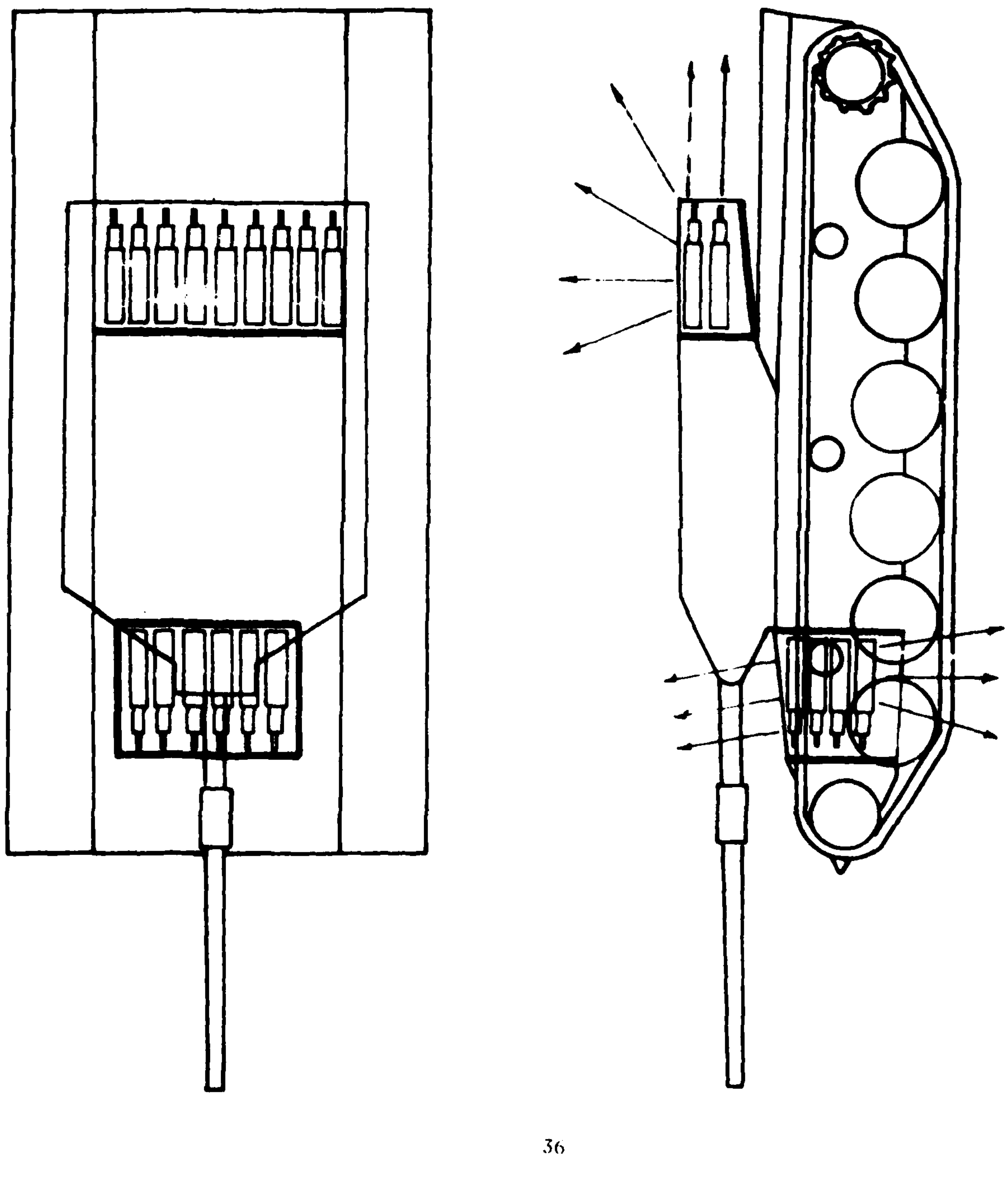


FIGURE 2. Implementation of Vented Ammunition Compartments

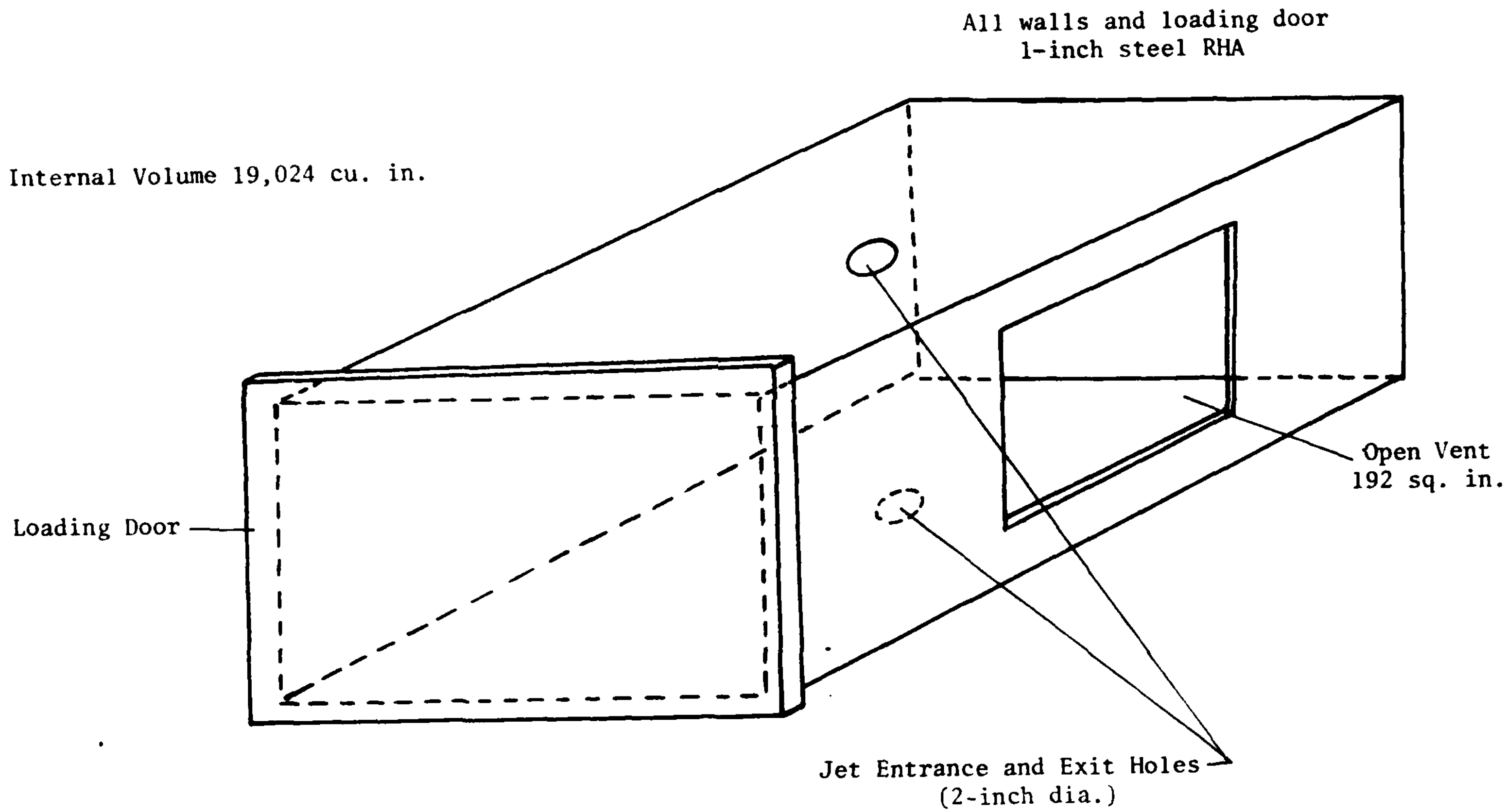


FIGURE 3. Schematic of Test Compartment

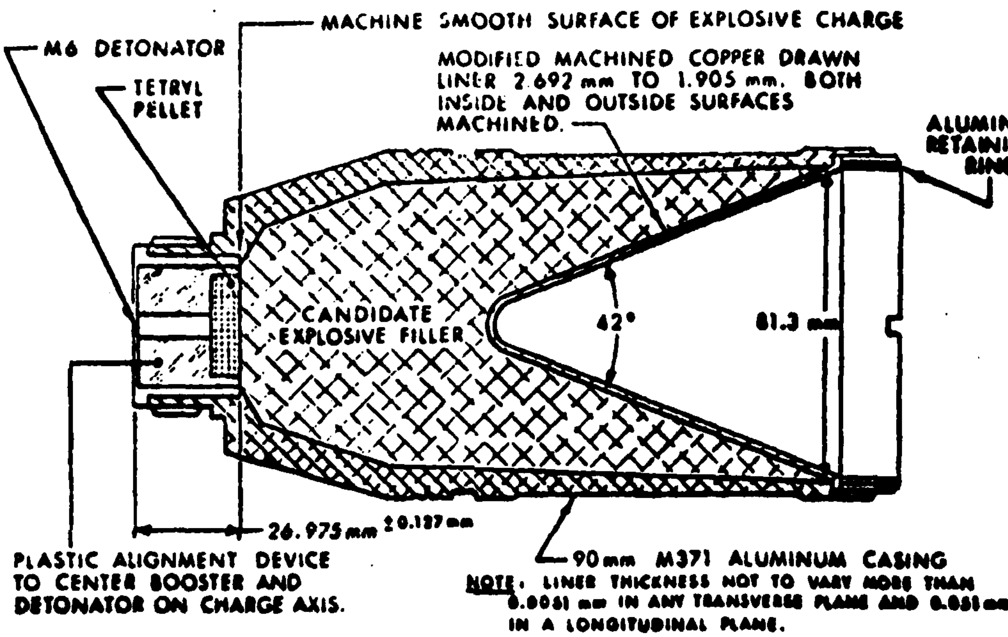


FIGURE 4. Schematic of BRL 3.2-Inch Precision Shaped Charge

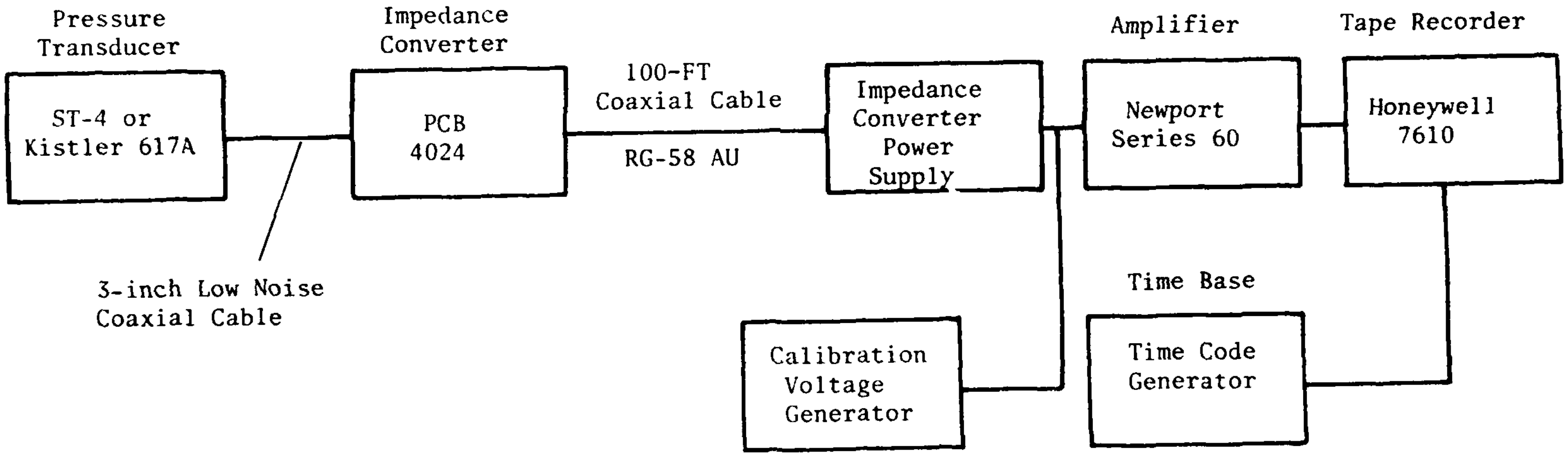


FIGURE 5. Block Diagram of Pressure Instrumentation

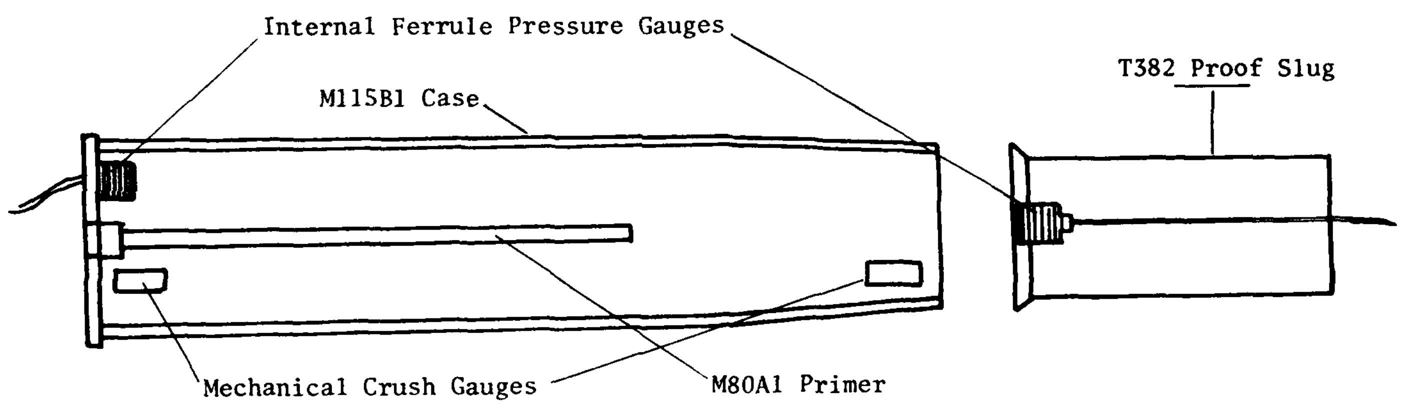
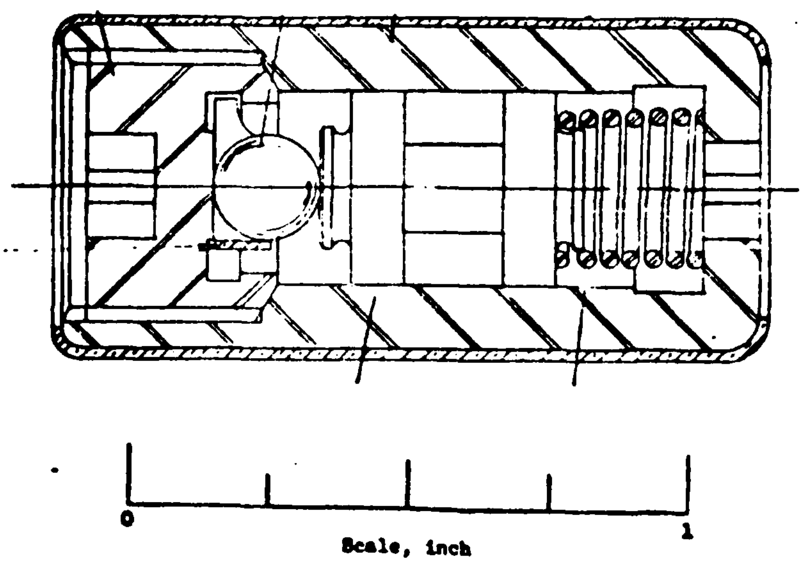


FIGURE 6. Gauge Locations in Live Propellant Round



Model No. - T18
Piston area - 1/10 inch^2
Sphere diameter - 3/16 inch
Sphere material - Copper
Pressure Range - 2000-19000 PSI (14-131 MPa)

FIGURE 7. Cross Section of a Mechanical Crush Gauge

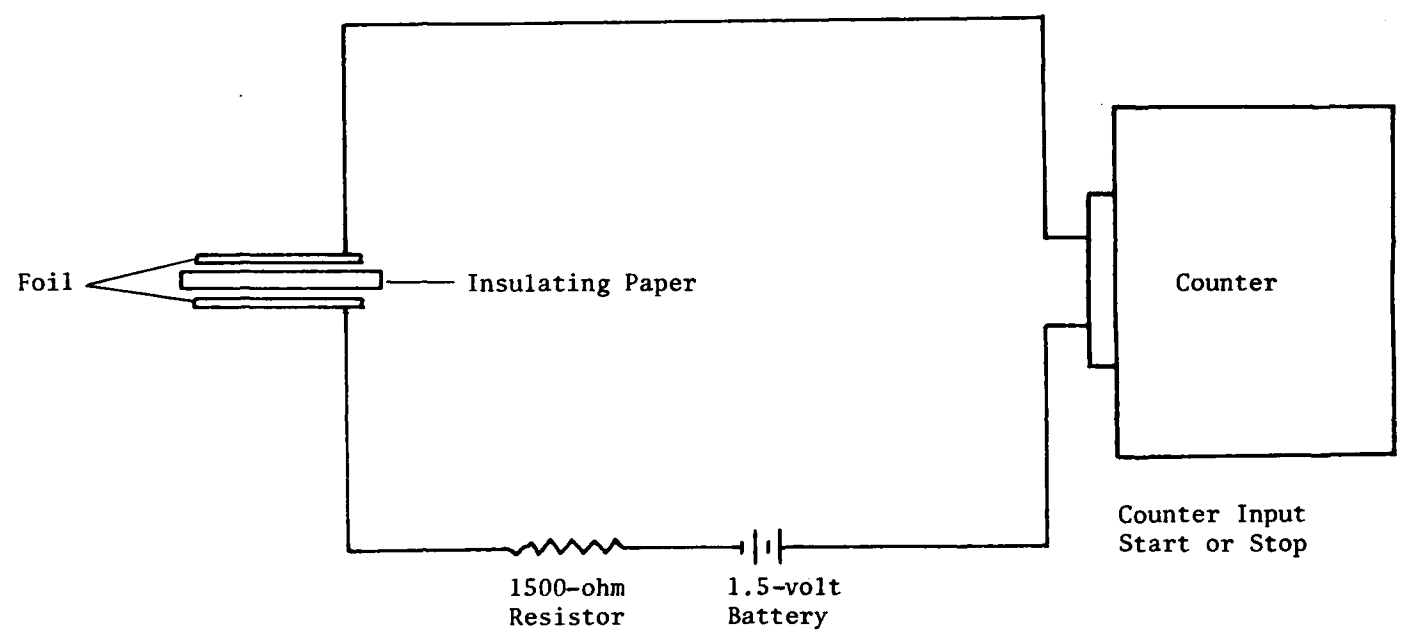


FIGURE 8. Wiring Diagram for Velocity Screens

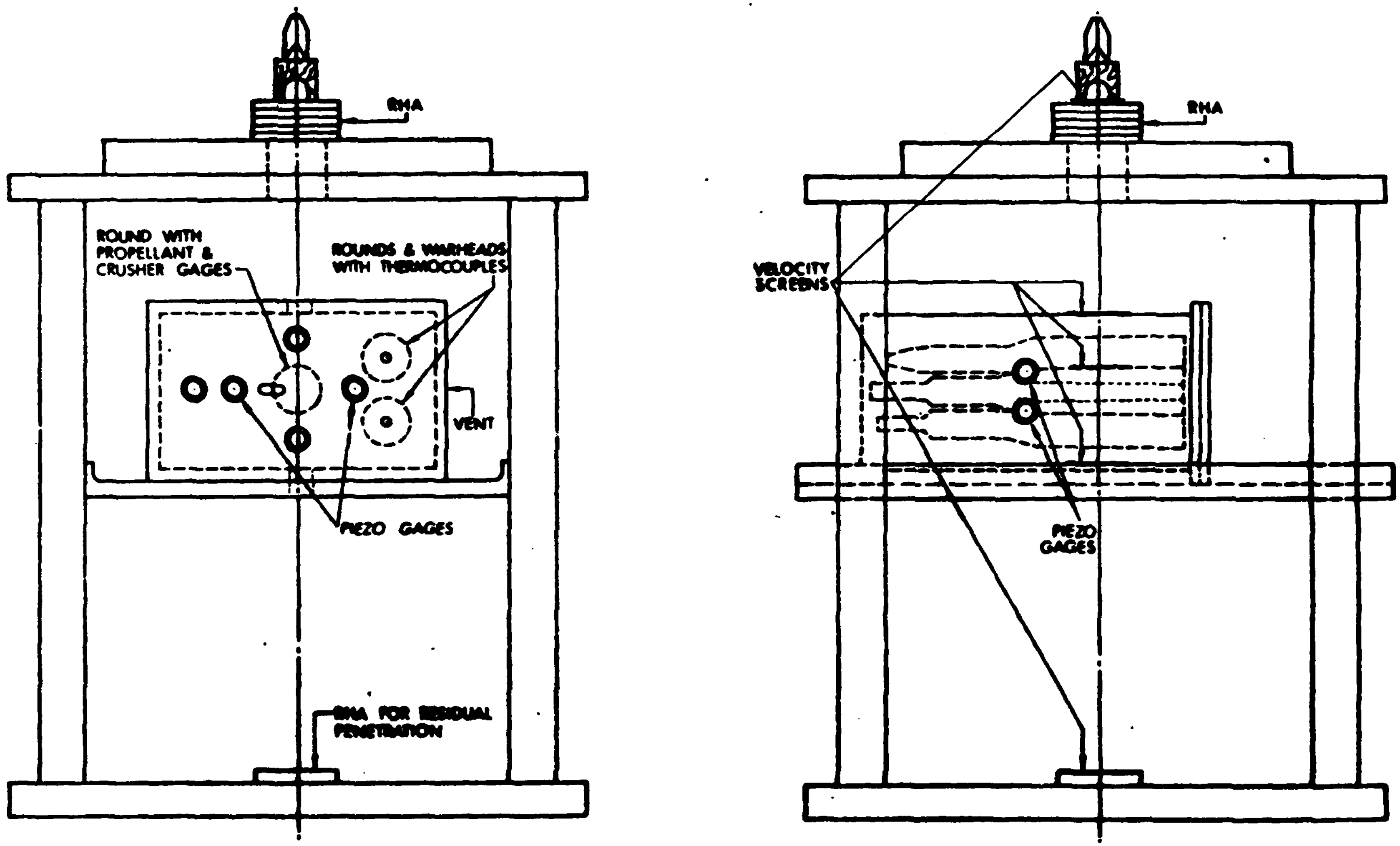


FIGURE 9. Jet/Propellant Interaction Test Setup

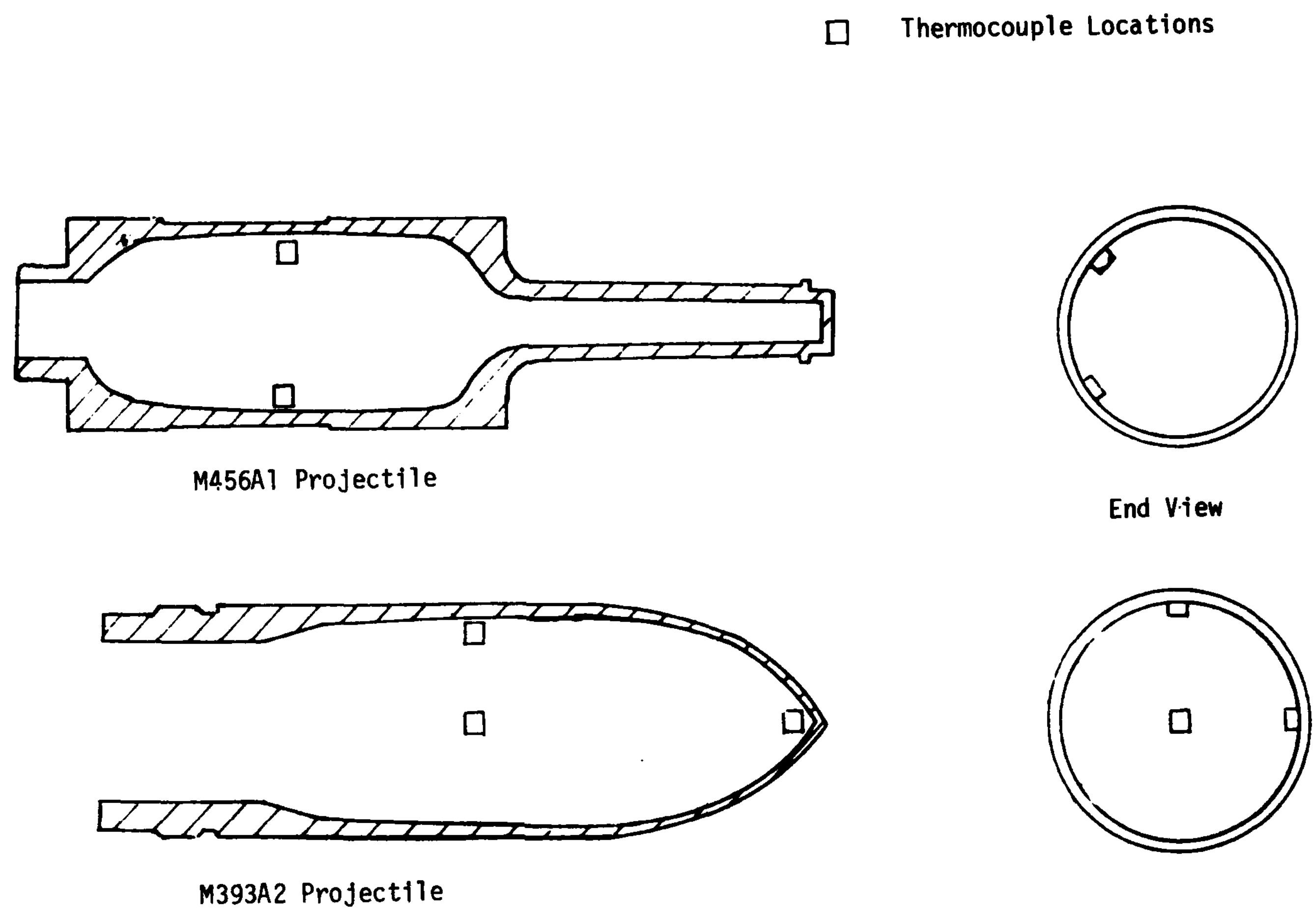
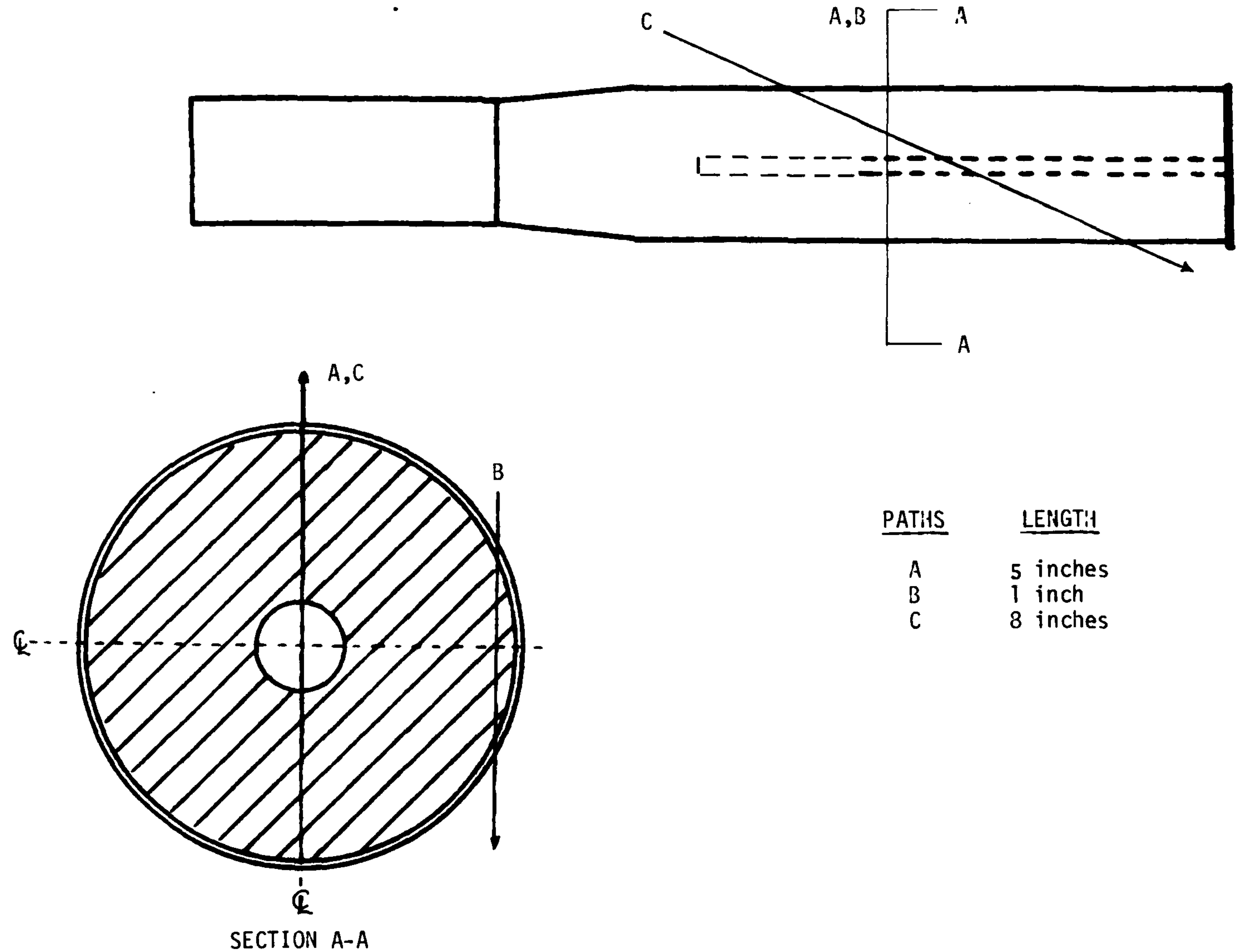


FIGURE 10. Thermocouple Locations in Inert Rounds



PATHS	LENGTH
A	5 inches
B	1 inch
C	8 inches

FIGURE 11. Jet/Propellant Paths Through the Live Rounds

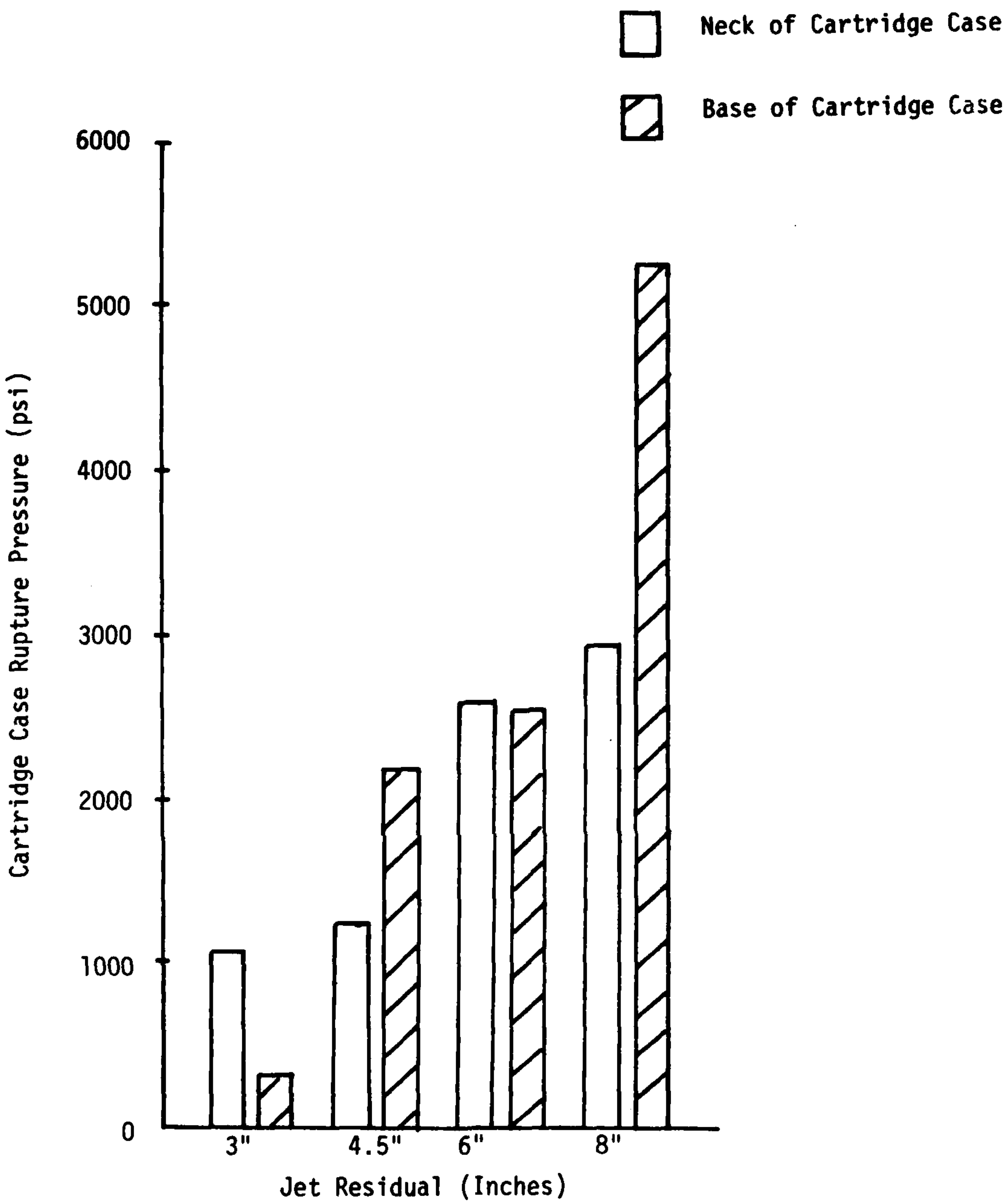


Figure 12. Average Peak Pressures in the Cartridge Cases as a Function of Jet Residual - Constant 5-Inch Jet/Propellant Path.

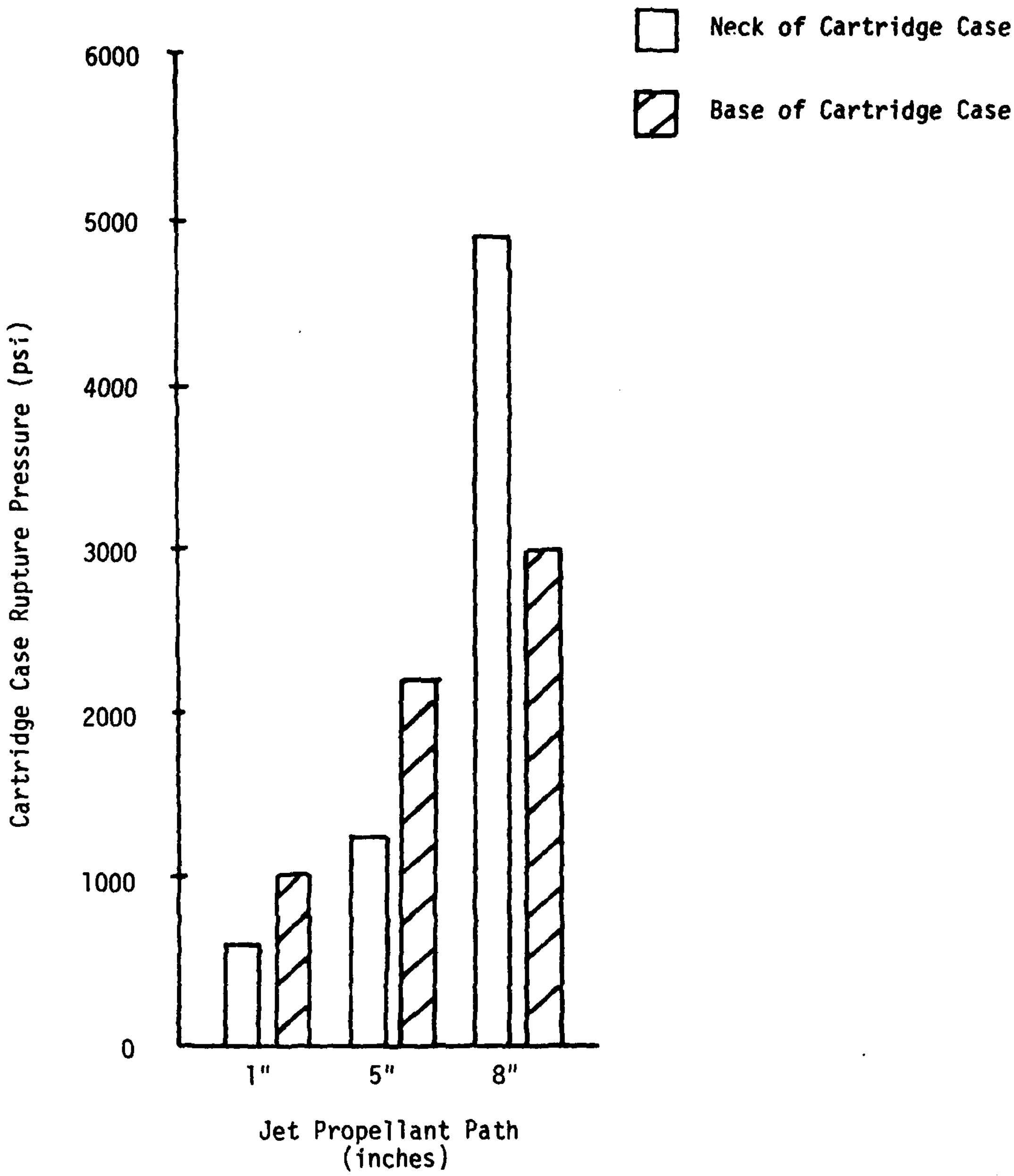


Figure 13. Average Peak Pressures in the Cartridge Cases as a Function of Jet/Propellant Path - Constant 4.5-Inch Jet Residual.

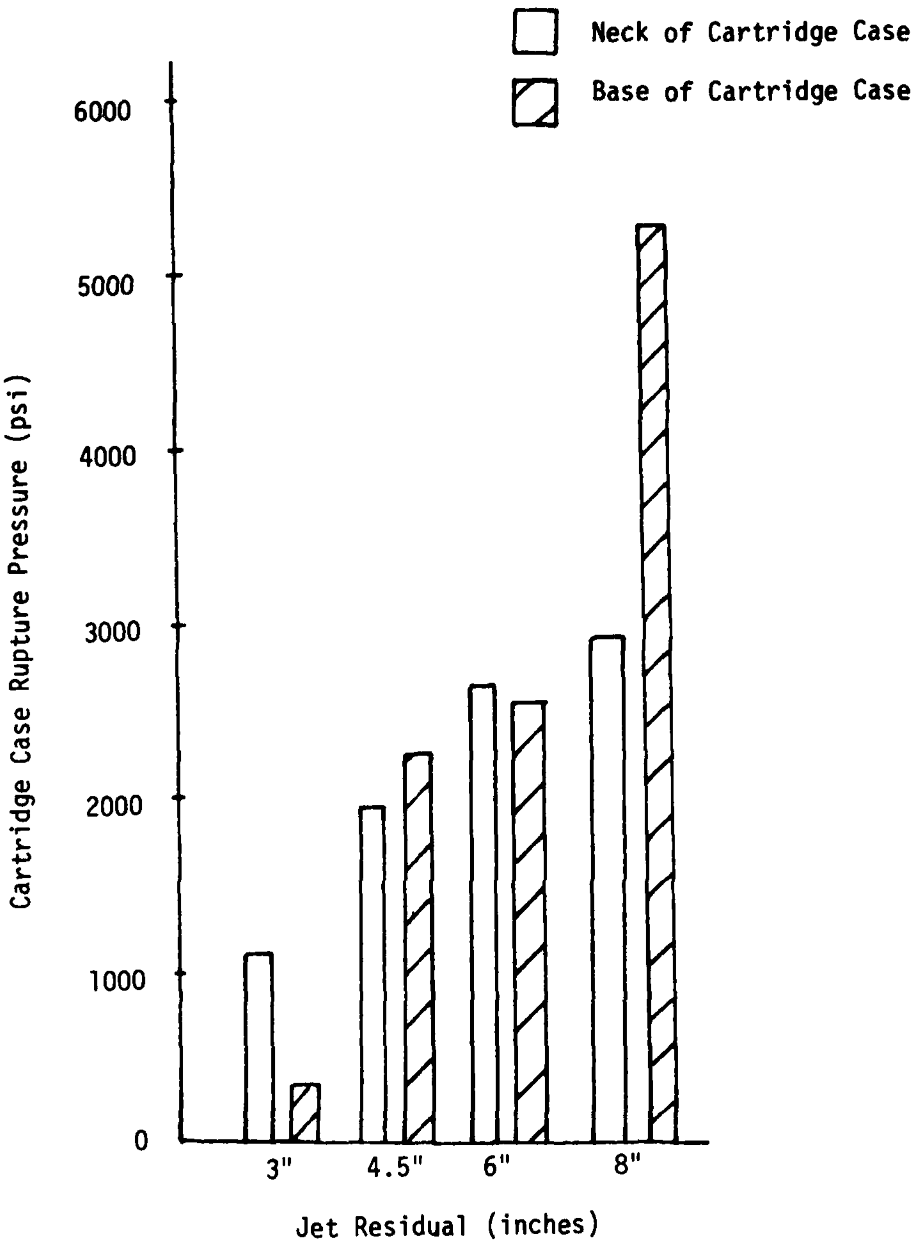


Figure 14. Cartridge Case Rupture Pressures - All Jet/Propellant Paths.

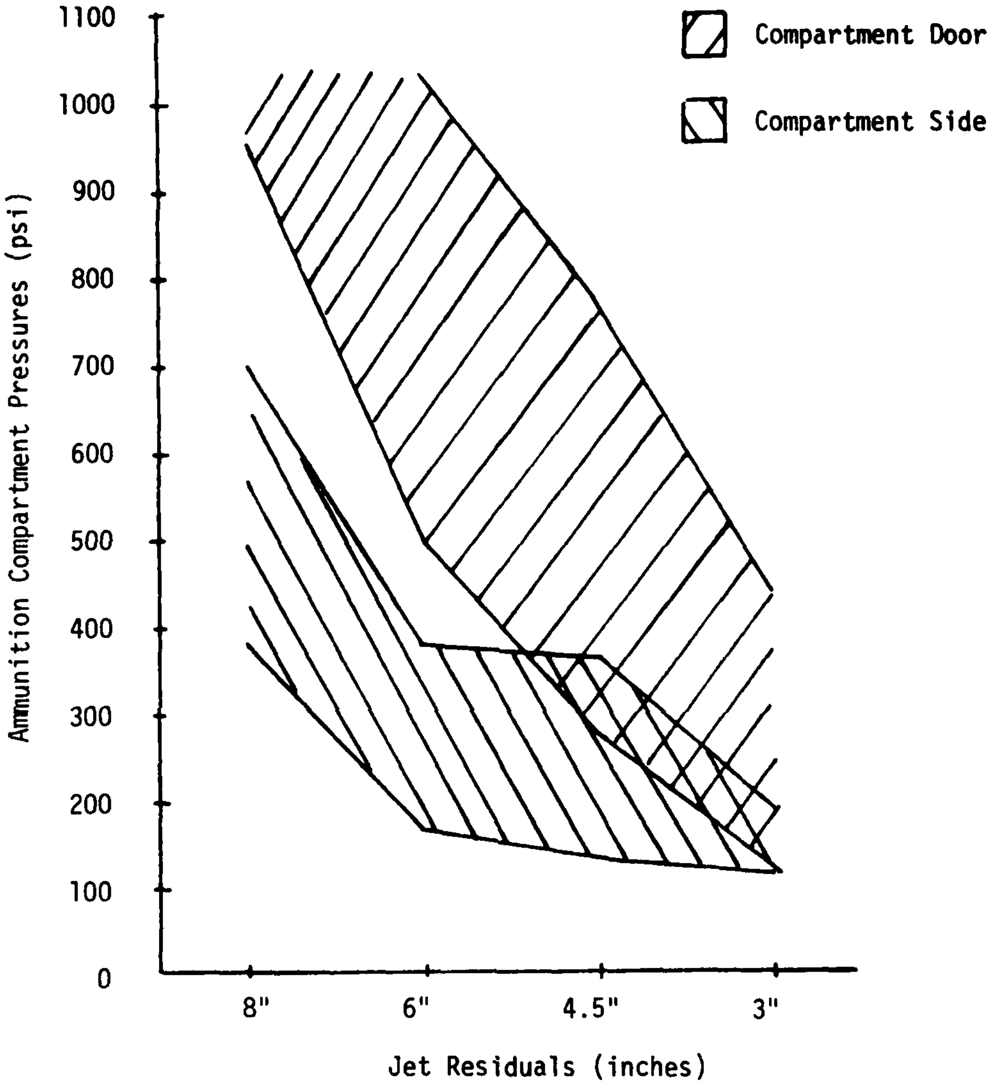


Figure 15. Peak Pressure Ranges as Measured in the Ammunition Compartment by Piezoelectric Transducers as a Function of Shaped Charge Jet Residual - Constant 5-Inch Jet/Propellant Path.

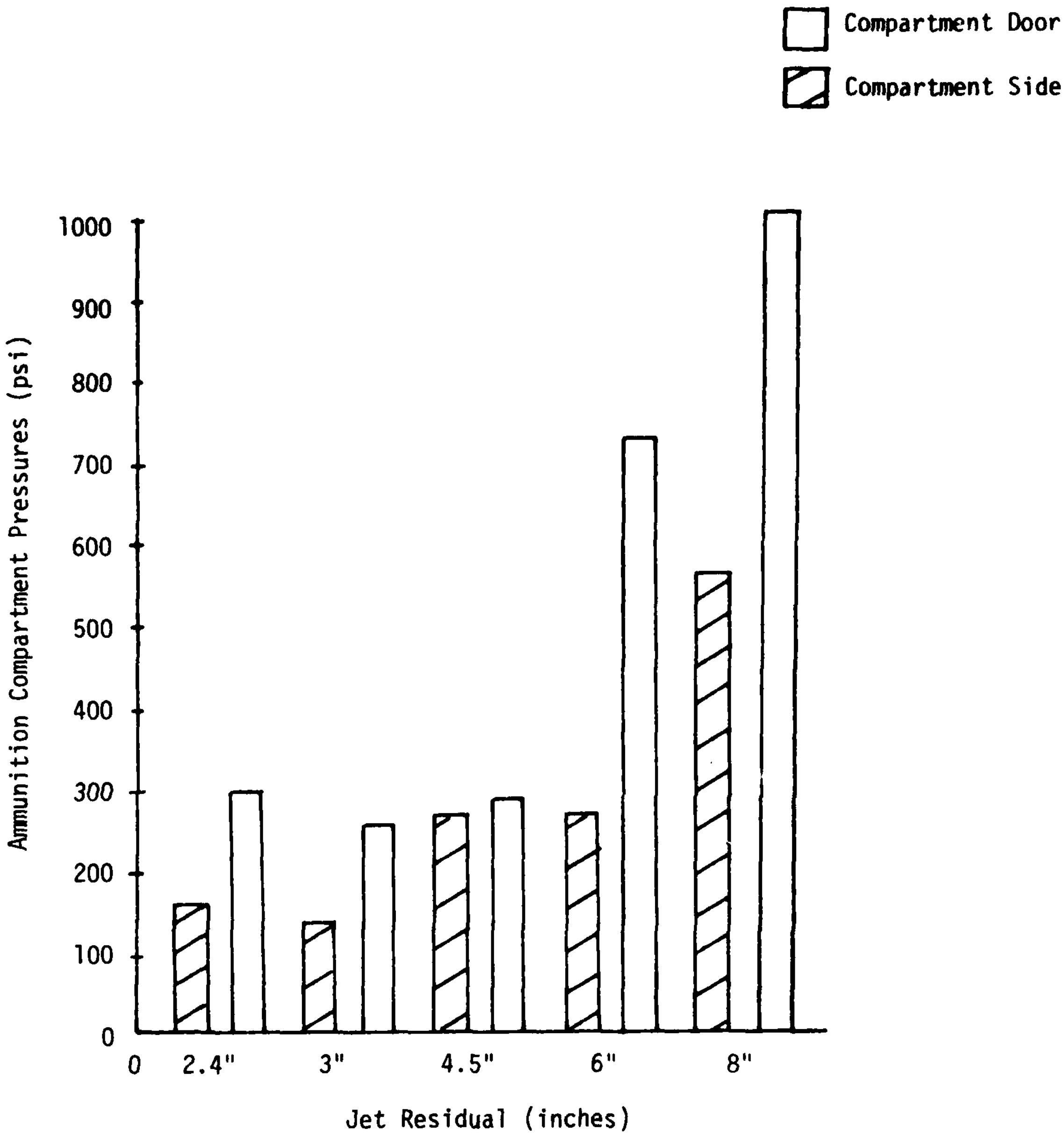


Figure 16. Average Peak Compartment Pressures as a Function of Shaped Charge Jet Residual - All Jet/Propellant Paths.

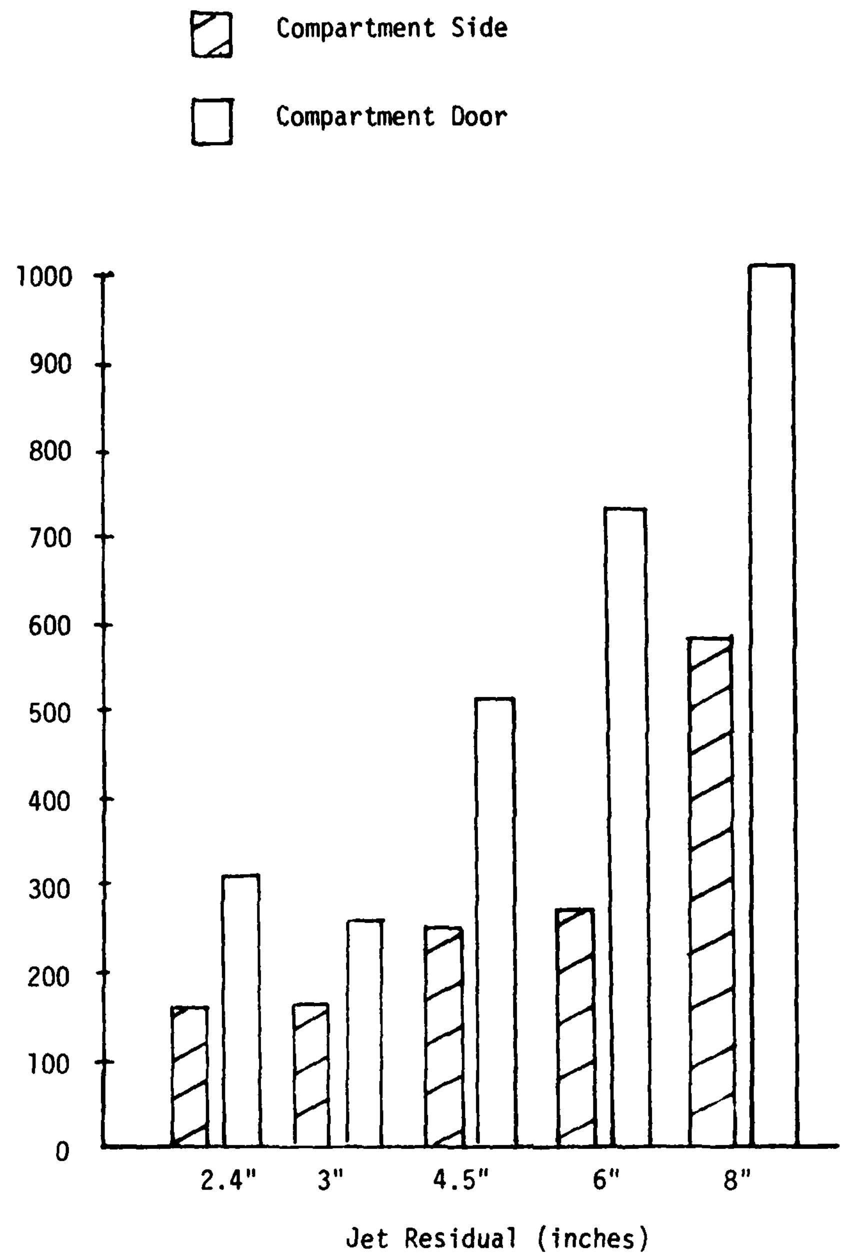


Figure 17. Average Peak Ammunition Compartment Pressures as a Function of Shaped Charge Jet Residual - Constant 5-Inch Jet/Propellant Path.

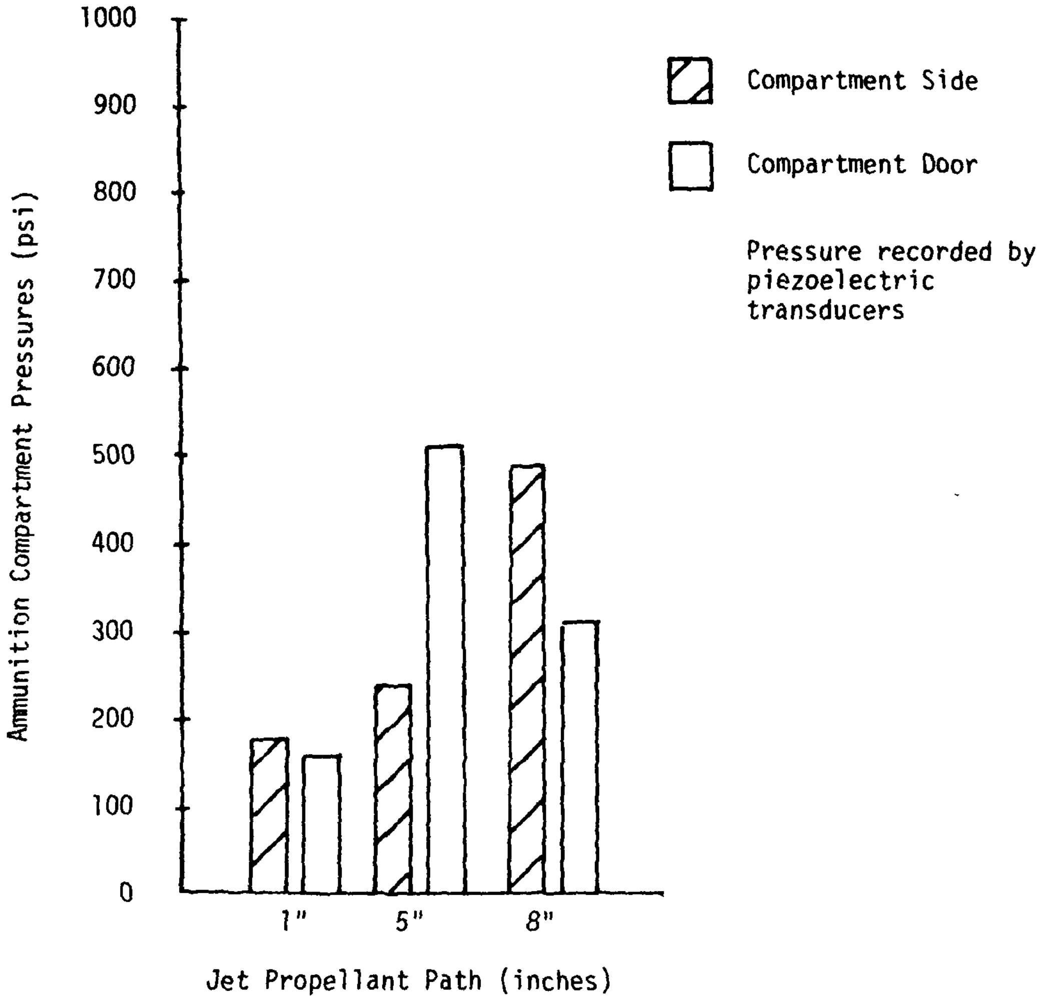


Figure 18. Average Peak Ammunition Compartment Pressures as a Function of Jet/Propellant Path - Constant 4.5-Inch Jet Residual.

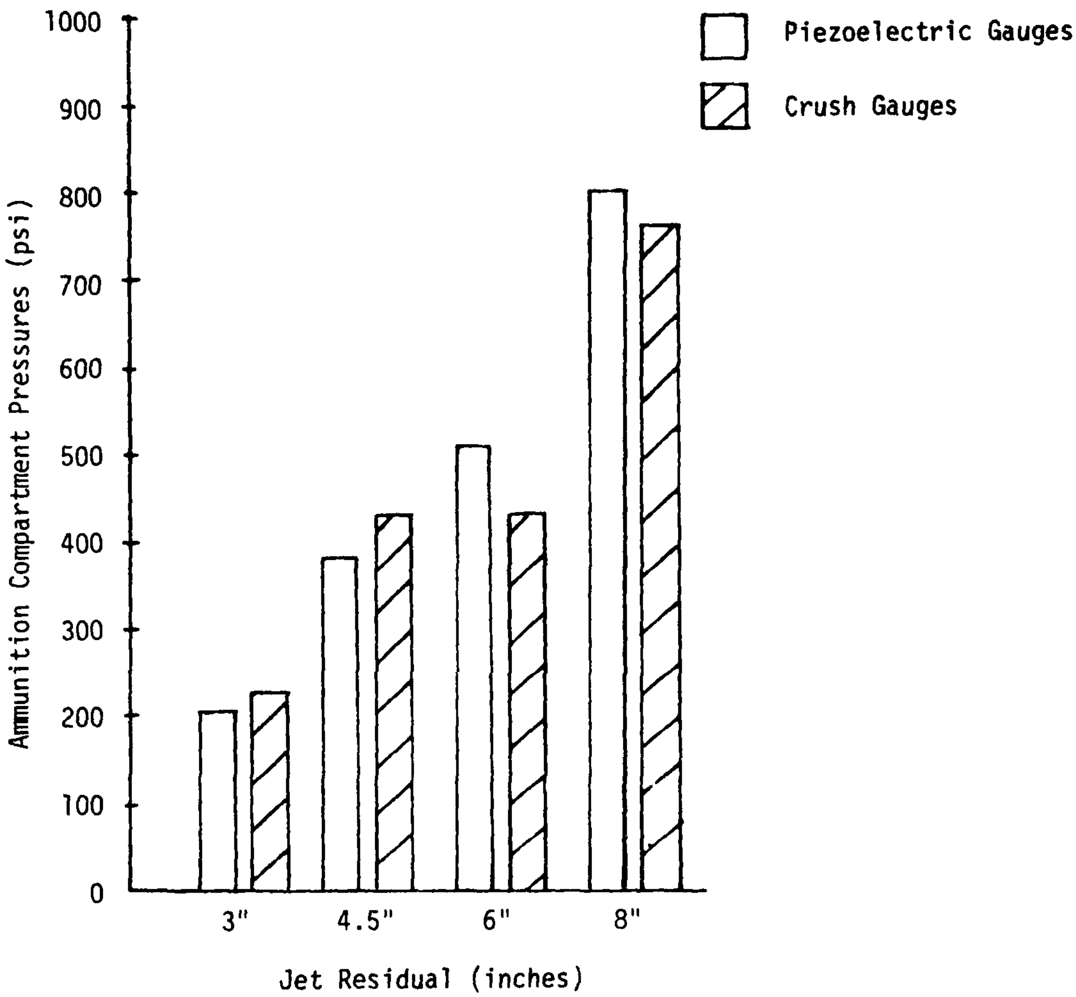


Figure 19. Average Peak Ammunition Compartment Pressures as a Function of Shaped Charge Jet Residual. Constant 5-Inch Jet/Propellant Path. A Comparison of Pressures as Recorded by Piezoelectric Transducers and Mechanical Crush Gauges.

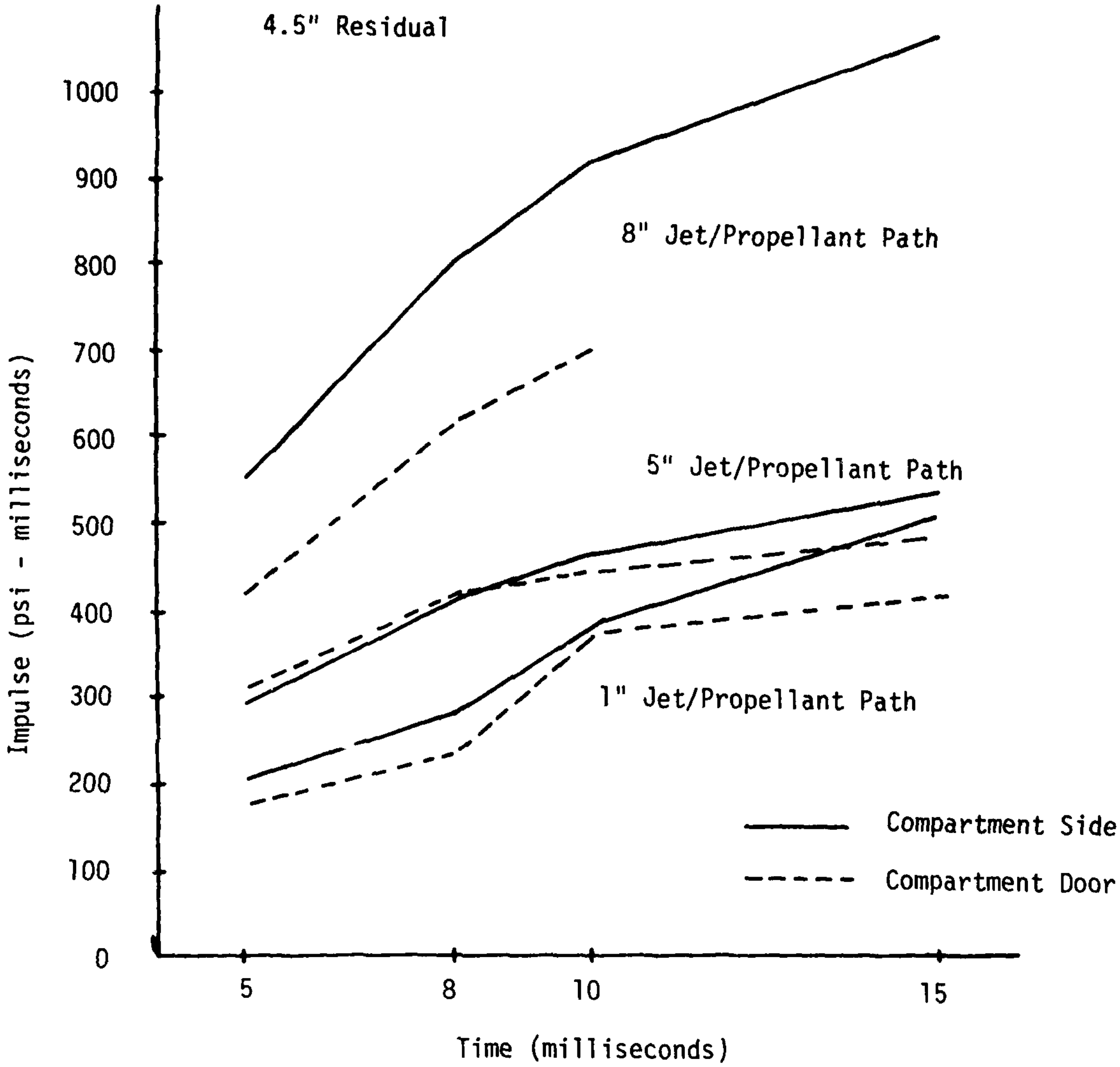


Figure 20. Impulse Loading on Compartment Walls - Constant Jet Residual

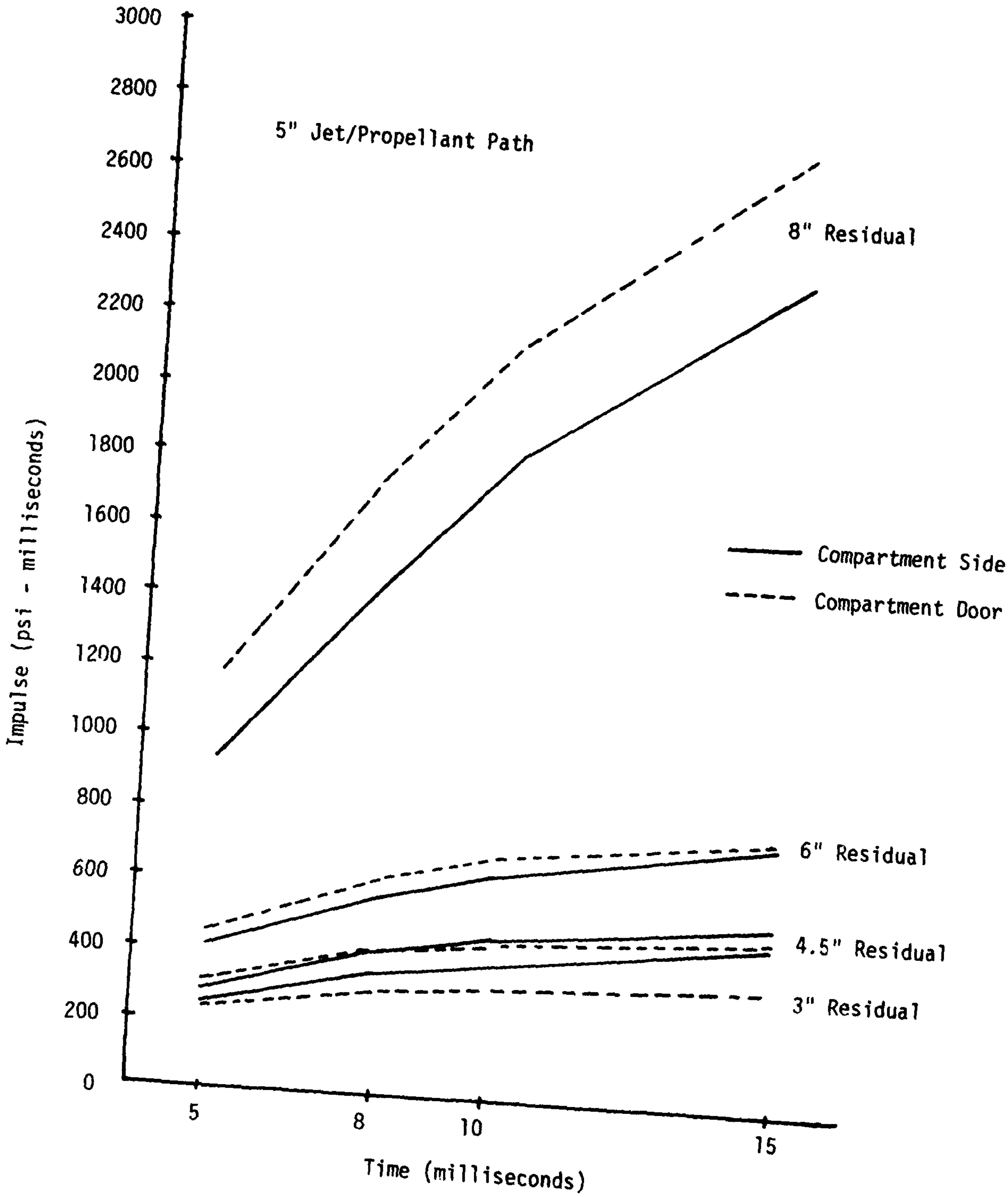


Figure 21. Impulse Loading on Compartment Walls - Constant Jet/Propellant Path.

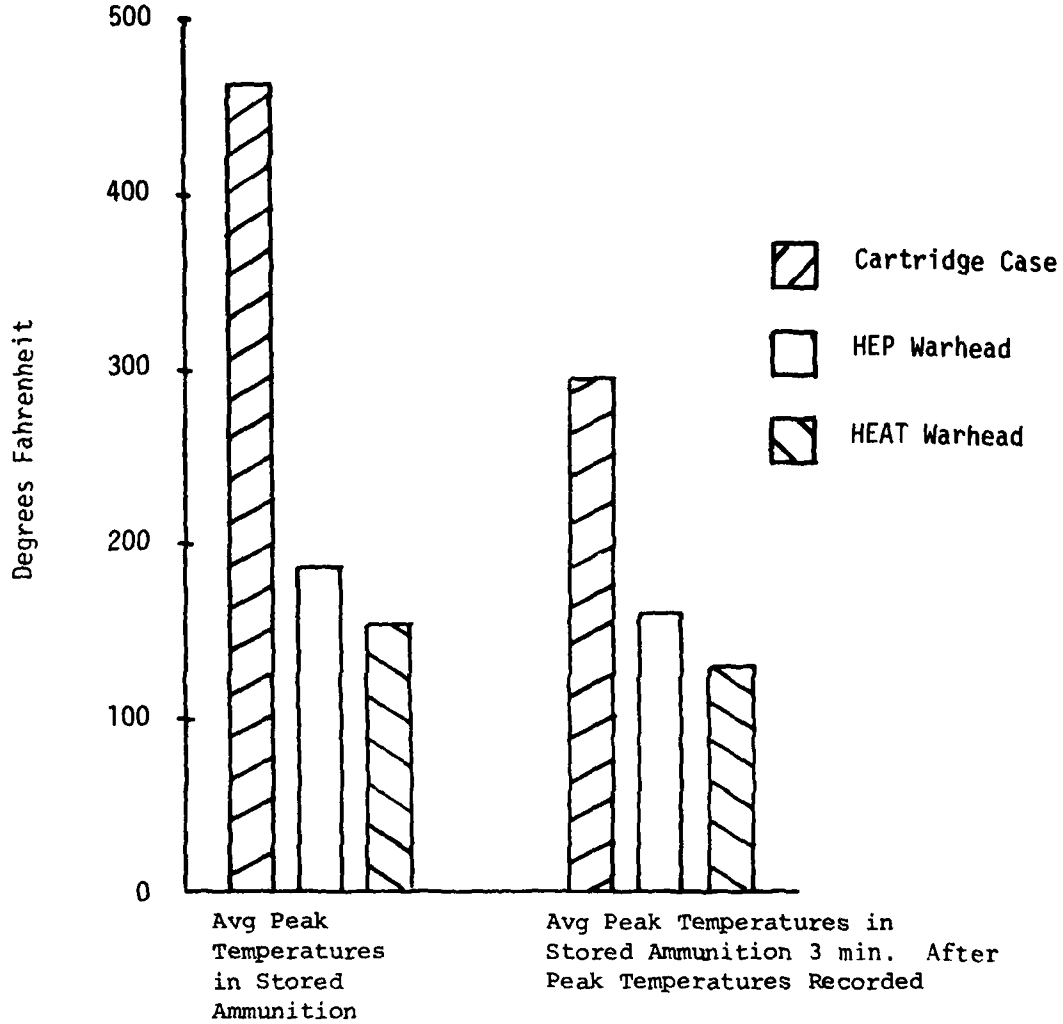


Figure 22. Change in Temperature Measurements Over a 3-Minute Period.

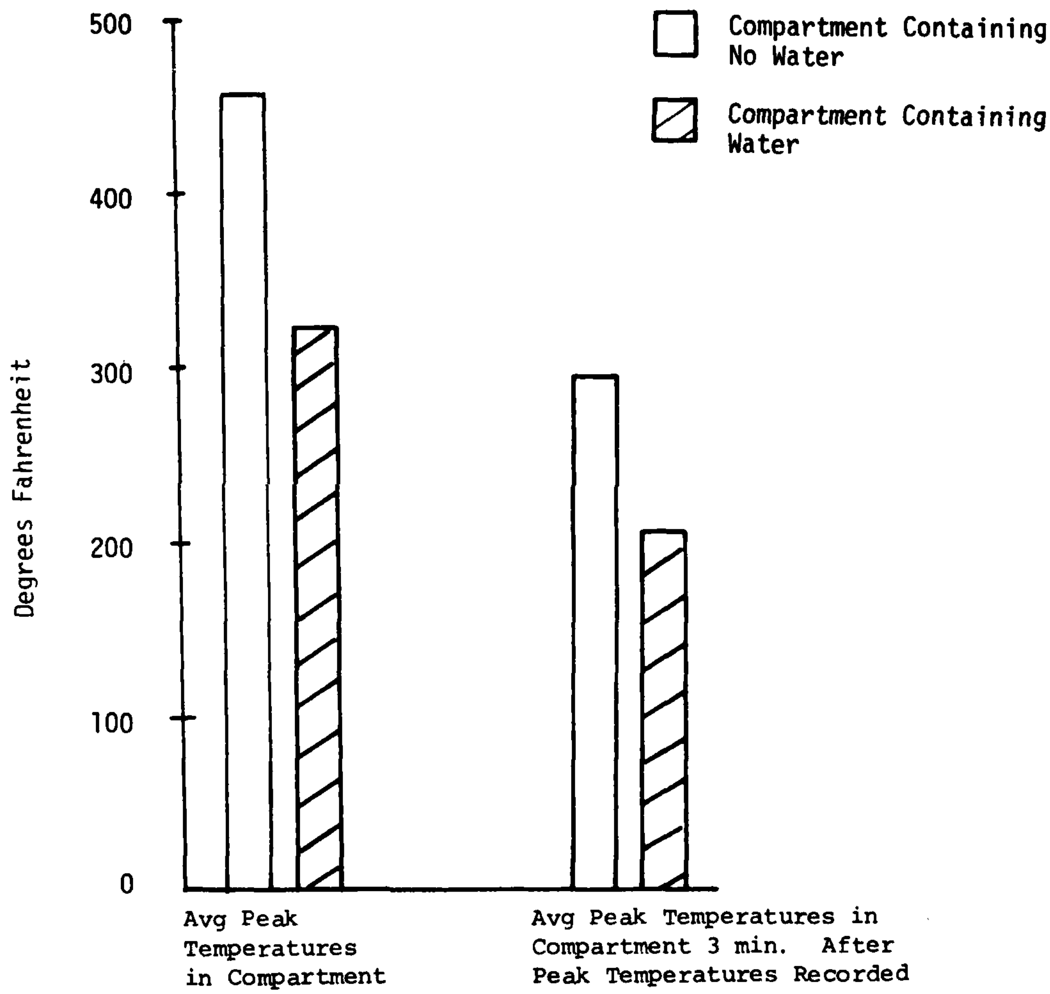


Figure 23. Comparison Between Peak Temperatures - Water vs No Water.

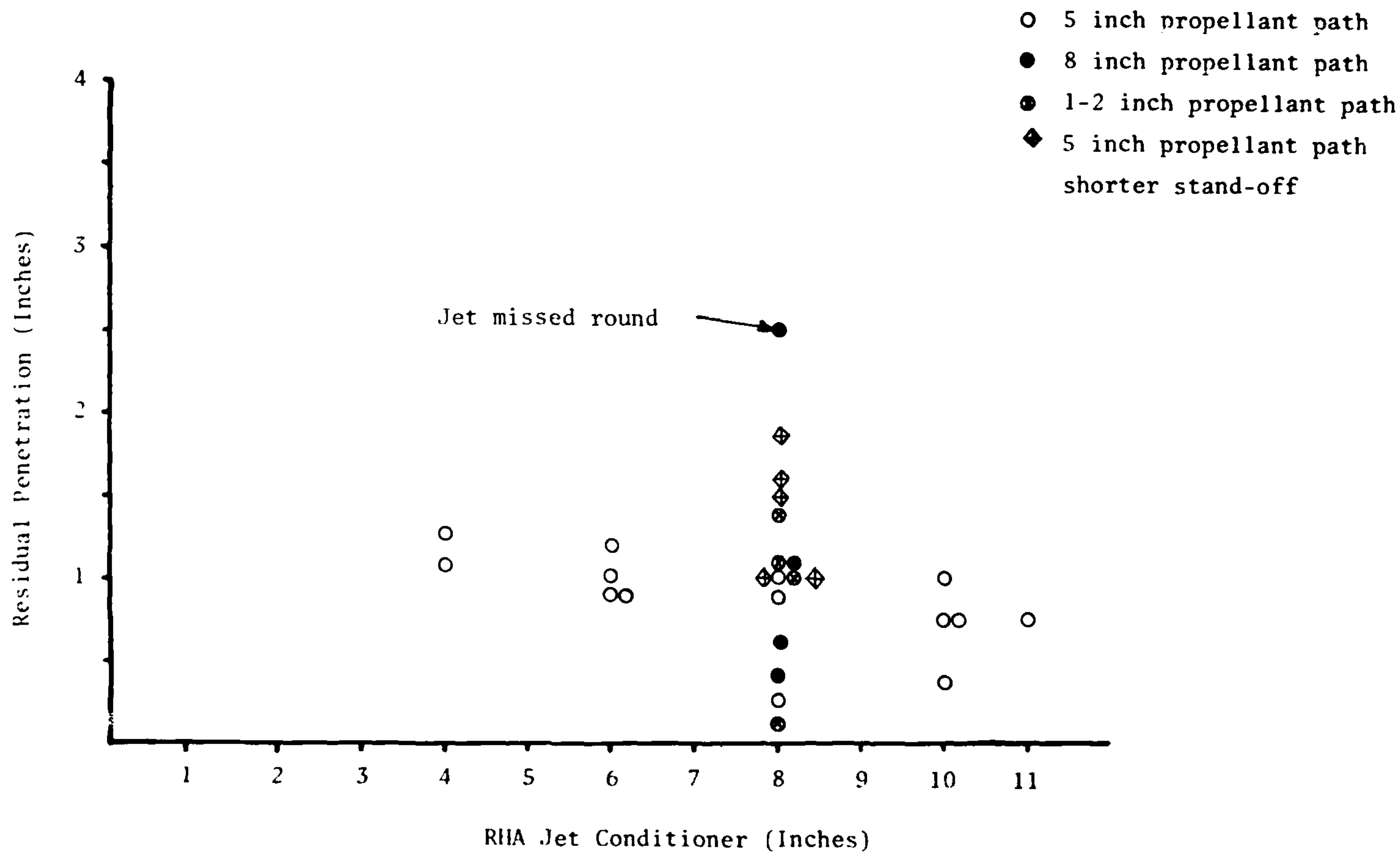


Figure 24 Measured Residual Jet Penetration

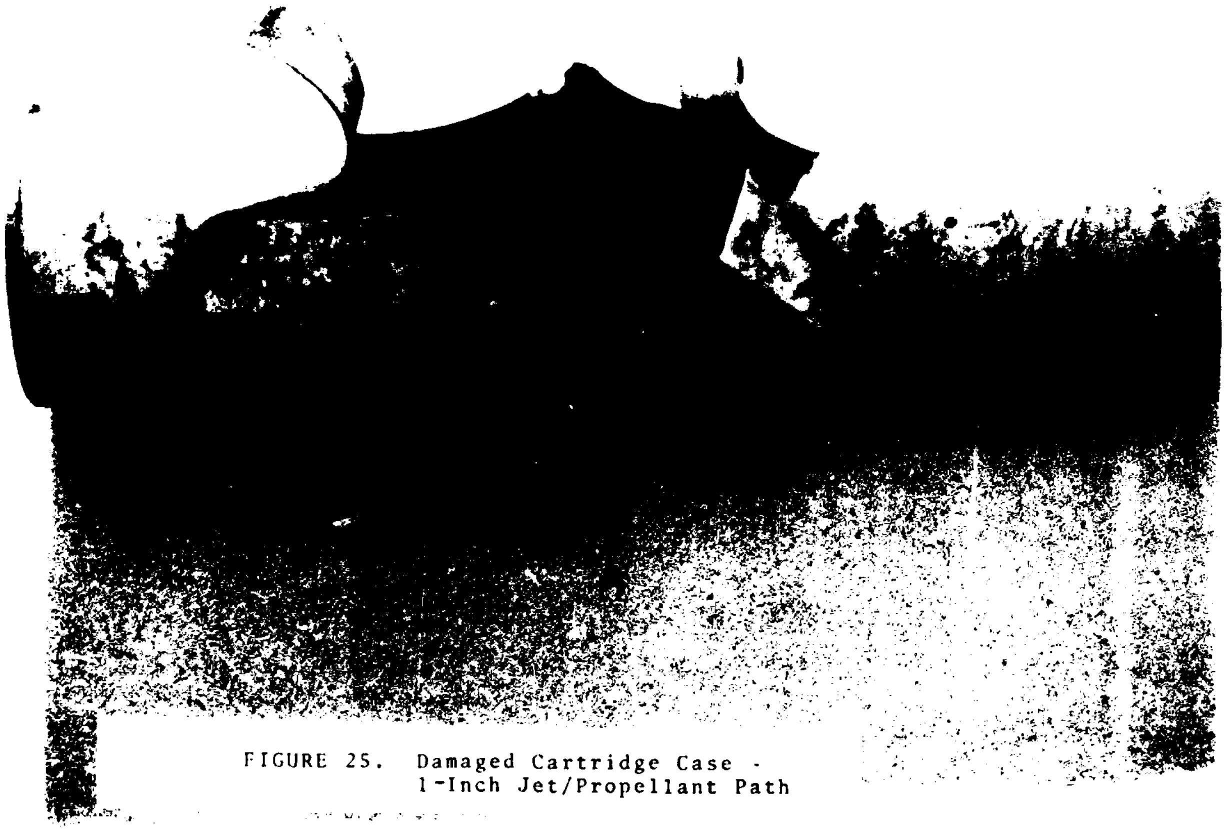


FIGURE 25. Damaged Cartridge Case -
1-Inch Jet/Propellant Path

FIGURE 26. Damaged Cartridge Case - 8-Inch Jet/Propellant Path

APPENDIX A

ROUND-TO-ROUND DESCRIPTION OF PROPELLANT TESTS

I. BRL PROPELLANT TEST NO. 1

Date: 21 June 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 2.4-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The desired environmental conditions were recorded with a combination of piezoelectric transducers and mechanical crush gauges.

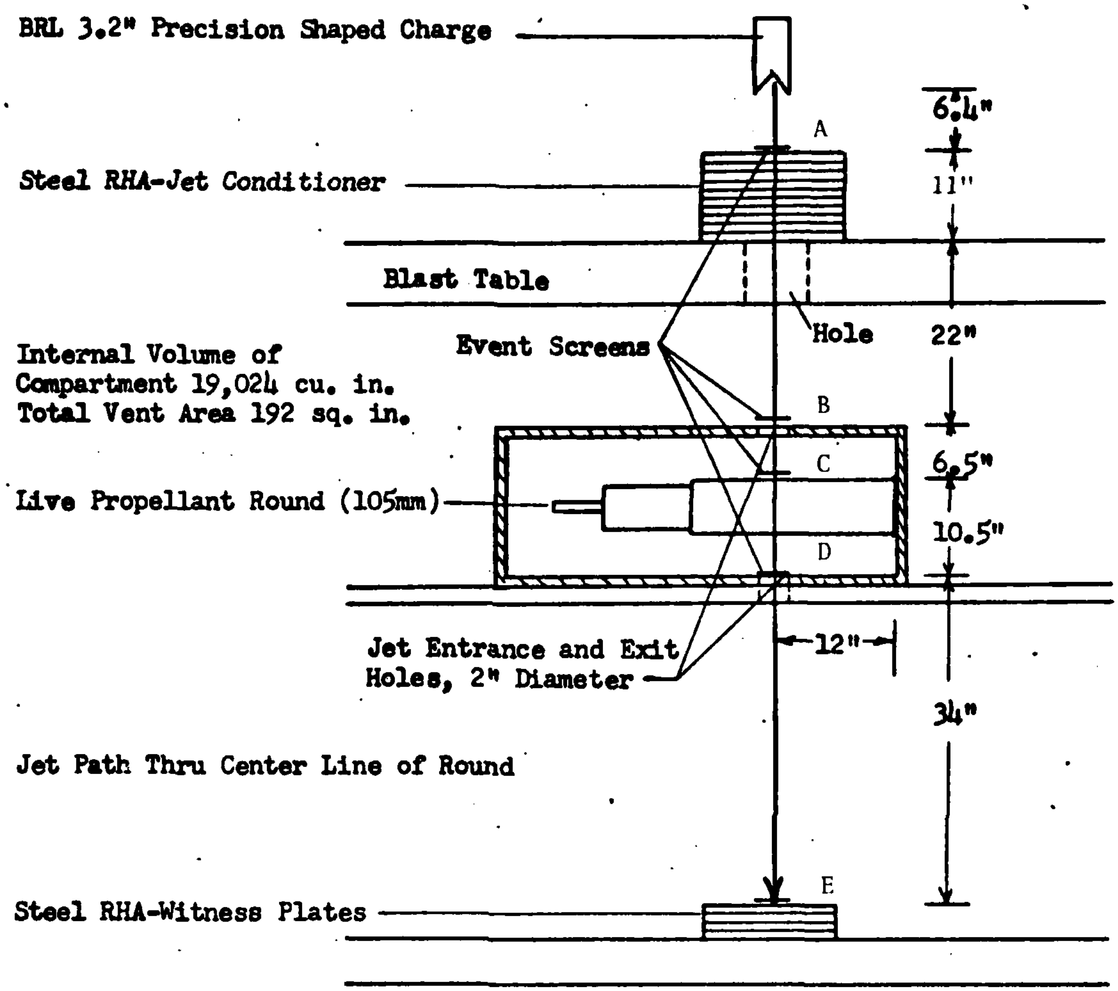
Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 3/4 inch into the residual stack of steel RHA.

The cartridge case of the live propellant round was torn apart in the area of jet impact, and the remaining portion of the case was split open; the warhead separated from the cartridge case; and the primer was in two pieces. The cartridge case of the dummy round in the lower corner of the compartment was squashed, but not broken open. There was no damage to the dummy HEAT round nor was there any damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 140 psi and 178 psi and on the loading door, 273 psi and 342 psi. All of these peak pressures were recorded during the first 100 microseconds of the event, their duration being only a matter of several microseconds.

Mechanical crush gauges placed in the live propellant case recorded pressures of 1500 psi in the nose and 1200 psi in the base. No valid data was acquired from the internal ferrule gauges placed in the nose and base of the live propellant cartridge case.



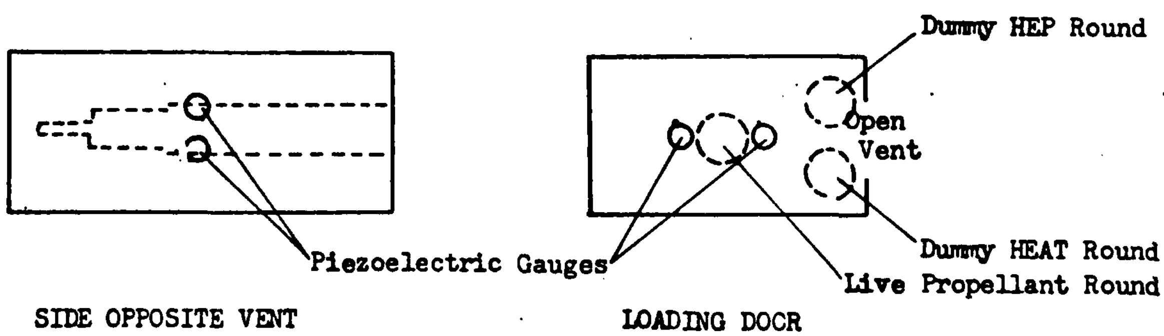


Figure A-1 Test Setup for Propellant Test No. 1

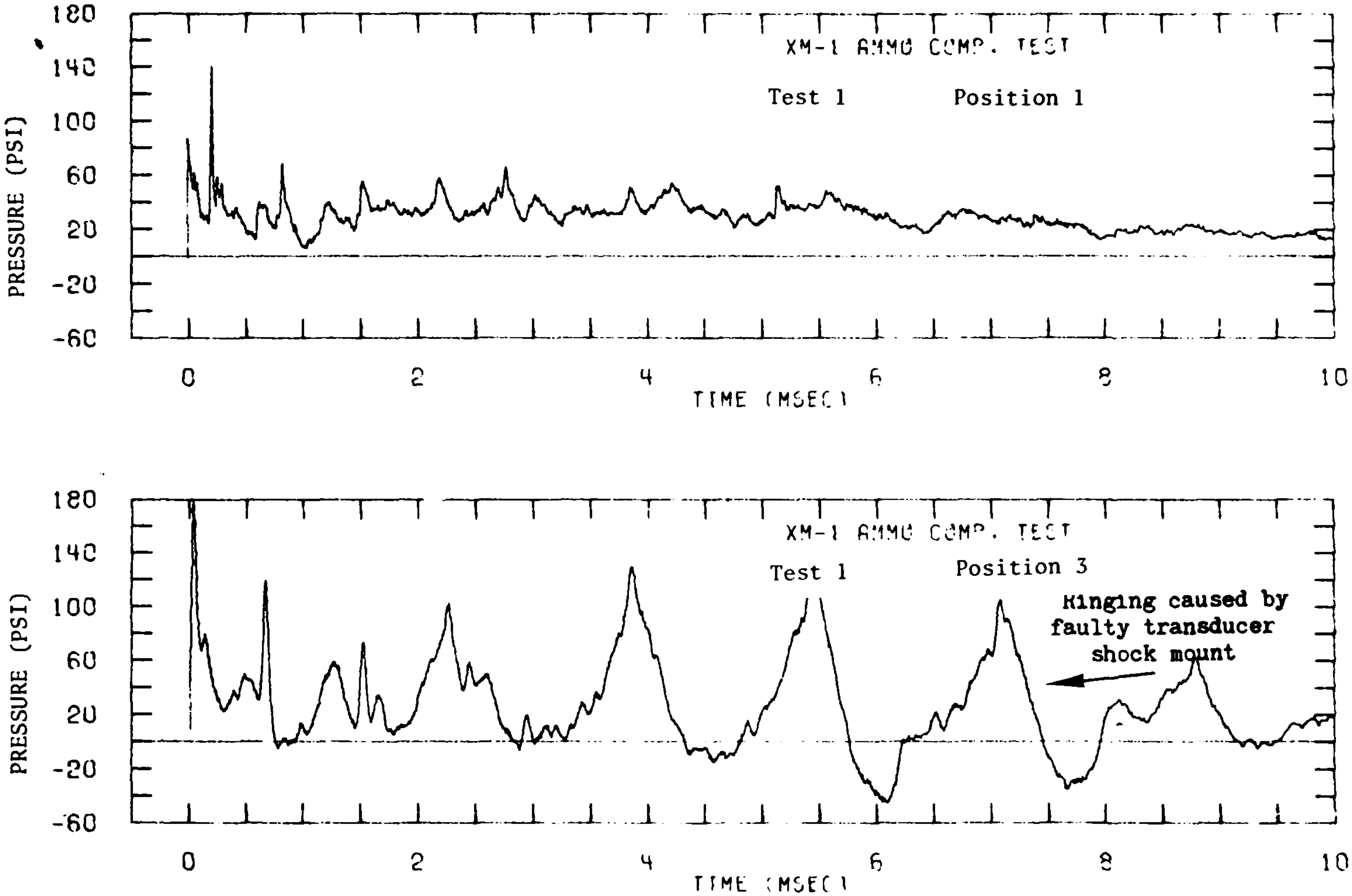


Figure A-2 Pressure Time Histories on Compartment Wall - Test No. 1

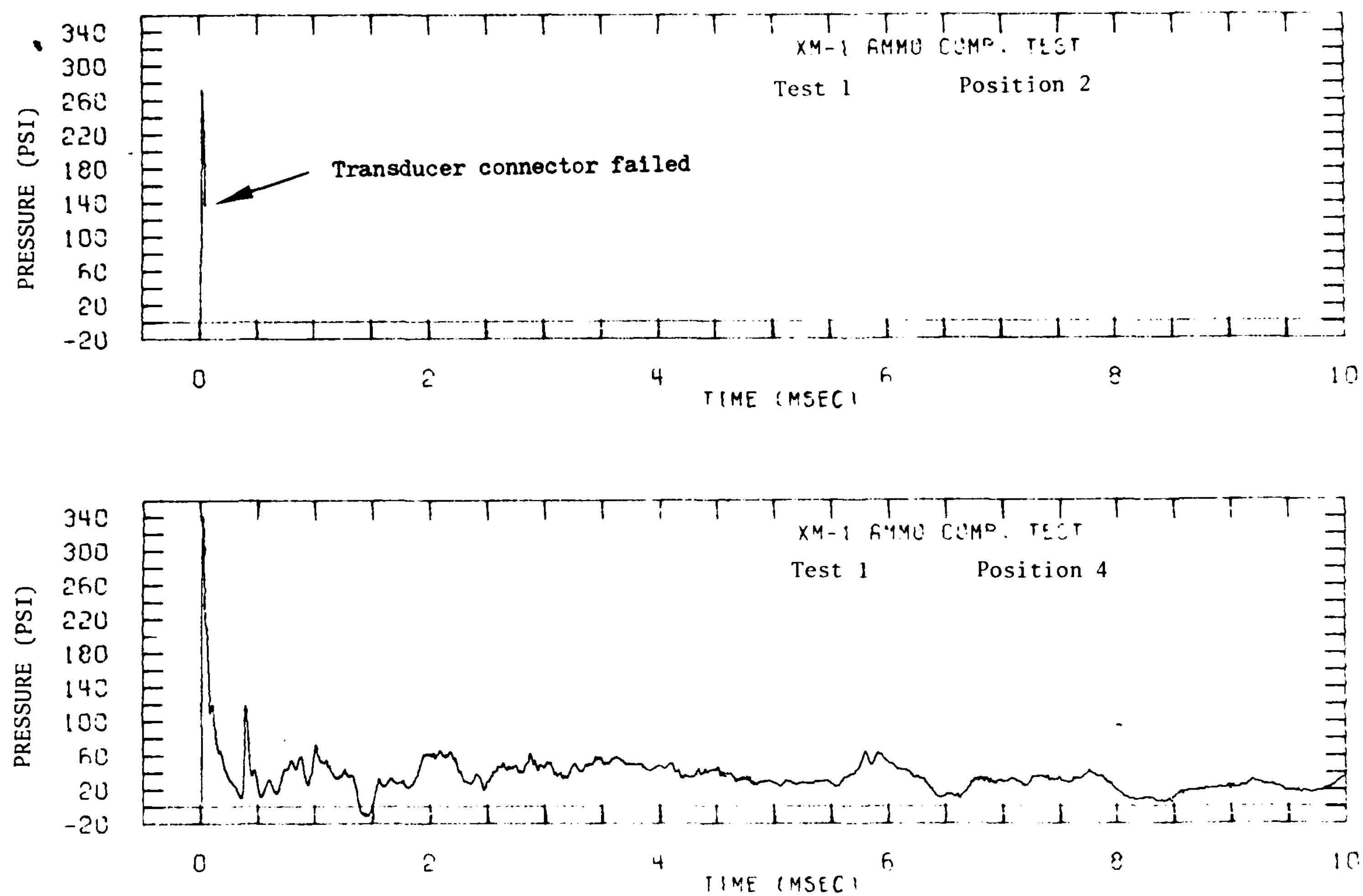


Figure A-3 Pressure Time Histories on Loading Door - Test No. 1

II. BRL PROPELLANT TEST NO. 2

Date: 27 June 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 3-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through the center line of a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 3/8 inch into the residual stack of steel RHA.

The cartridge case of the live propellant round was torn apart in the area of jet impact and the remaining portion of the case was split open. The projectile separated from the case, and the primer was in two pieces. There was no damage to dummy rounds nor was there any damage to the compartment.

The piezoelectric transducers recorded peak pressures of 154 psi and 118 psi on the side of the compartment, and 112 psi and 140 psi on the door. Mechanical crush gauges in the front of the compartment recorded peak pressures of 490 psi and 190 psi, and in the rear 210 psi and 150 psi.

Crush gauges in the live round recorded pressures of 1000 psi in the nose and 100 psi in the base. The internal ferrule transducers in the live propellant cartridge case failed to provide any valid data. A maximum temperature of 490°F was recorded in the HEAT round cartridge case. Maximum temperature in the HEAT and HEP warheads were 160° and 190°F respectively.

The event screens failed to function properly.

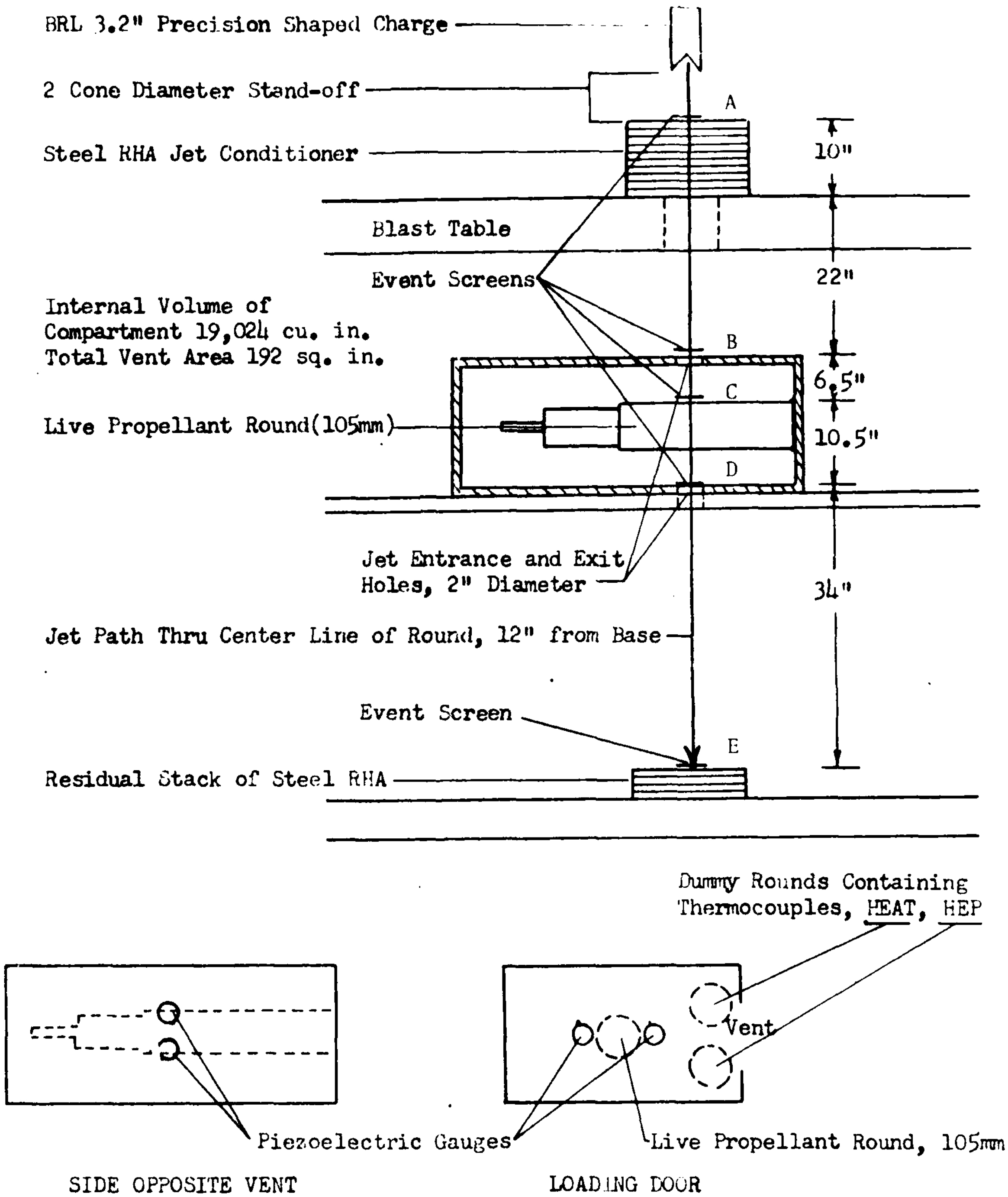
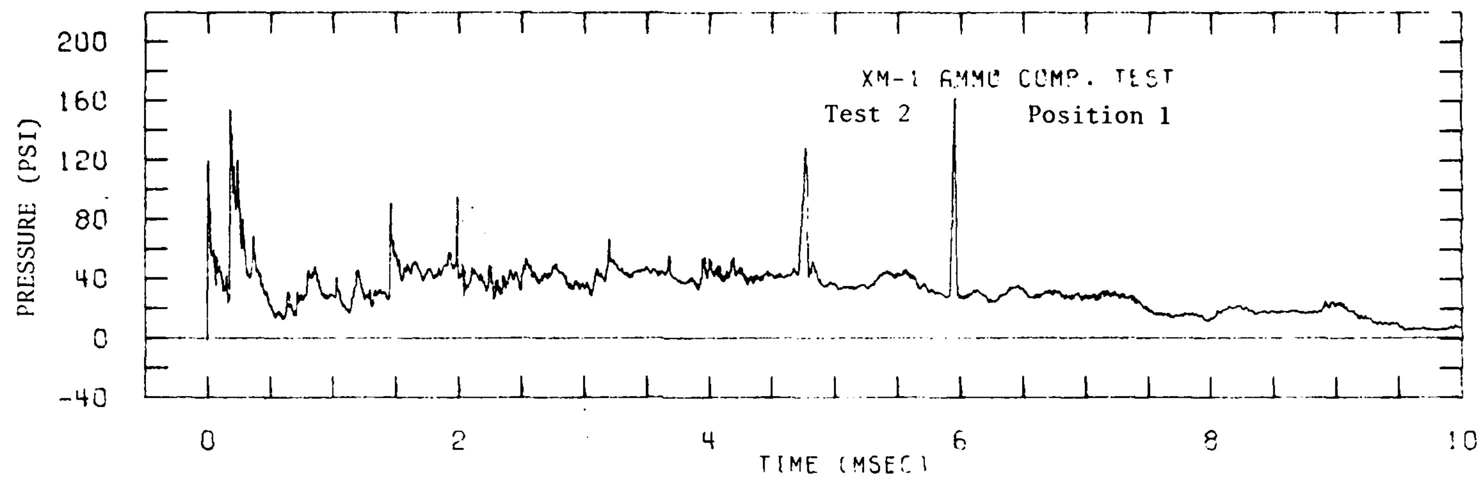


Figure A-4 Test Setup for Propellant Test No. 2



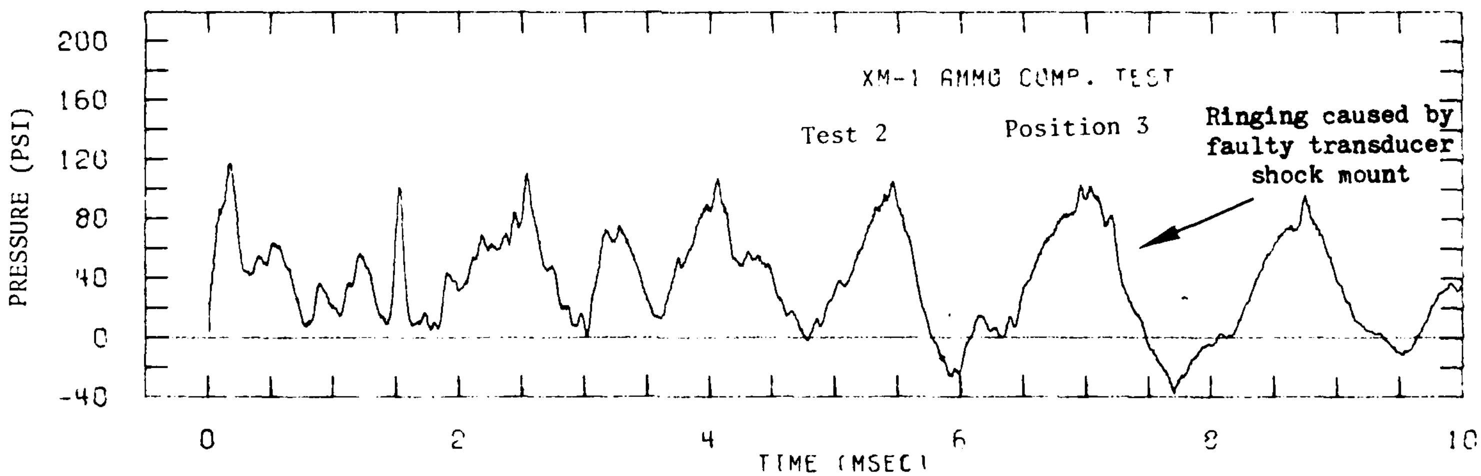


Figure A-5 Pressure Time Histories on Compartment Wall - Test No. 2

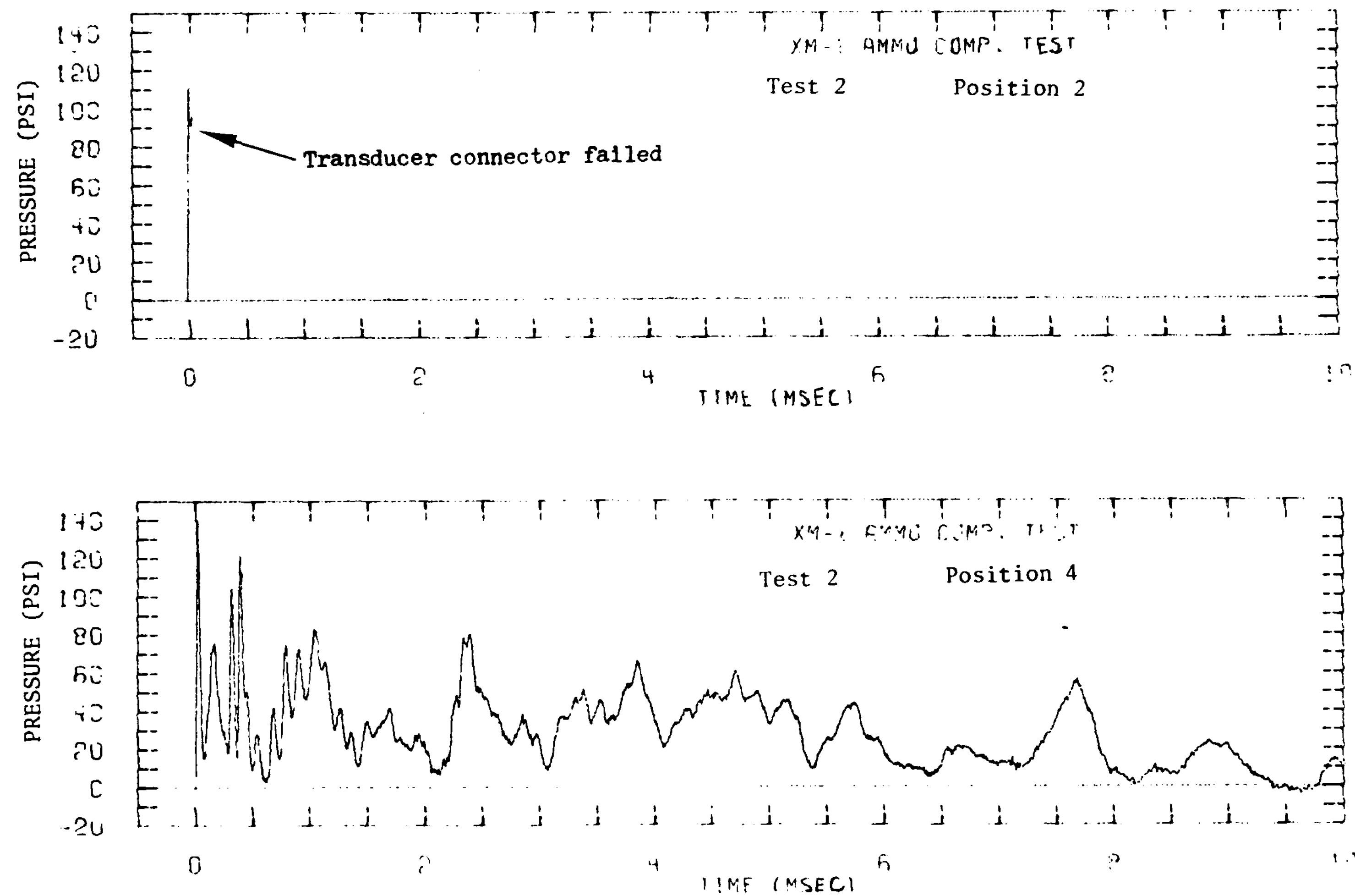


Figure A-6 Pressure Time Histories on Loading Door - Test No. 2

CARTRIDGE CASE TEMPERATURES

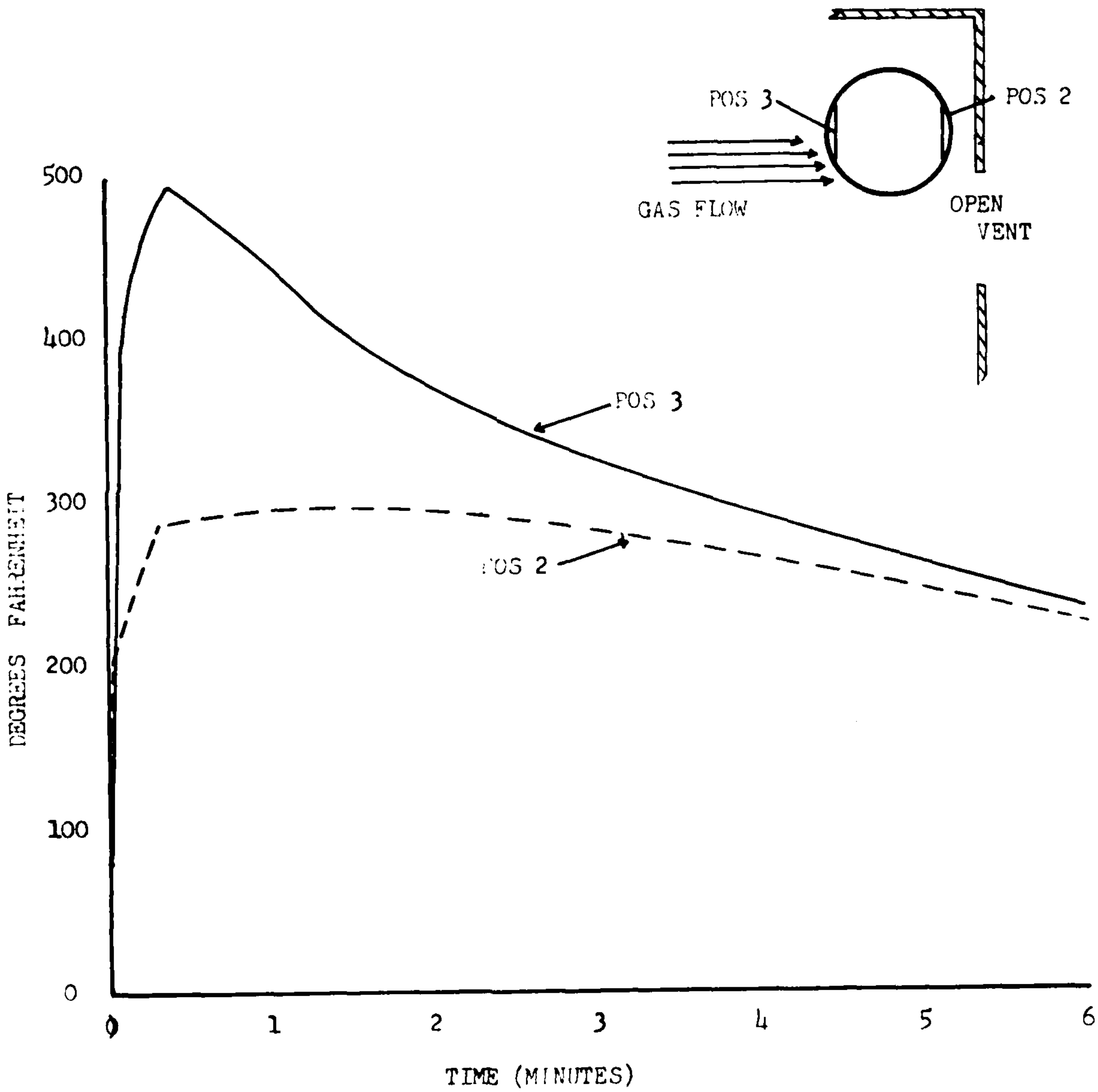


Figure A-7 Cartridge Case Temperature Time Histories - Test No. 2

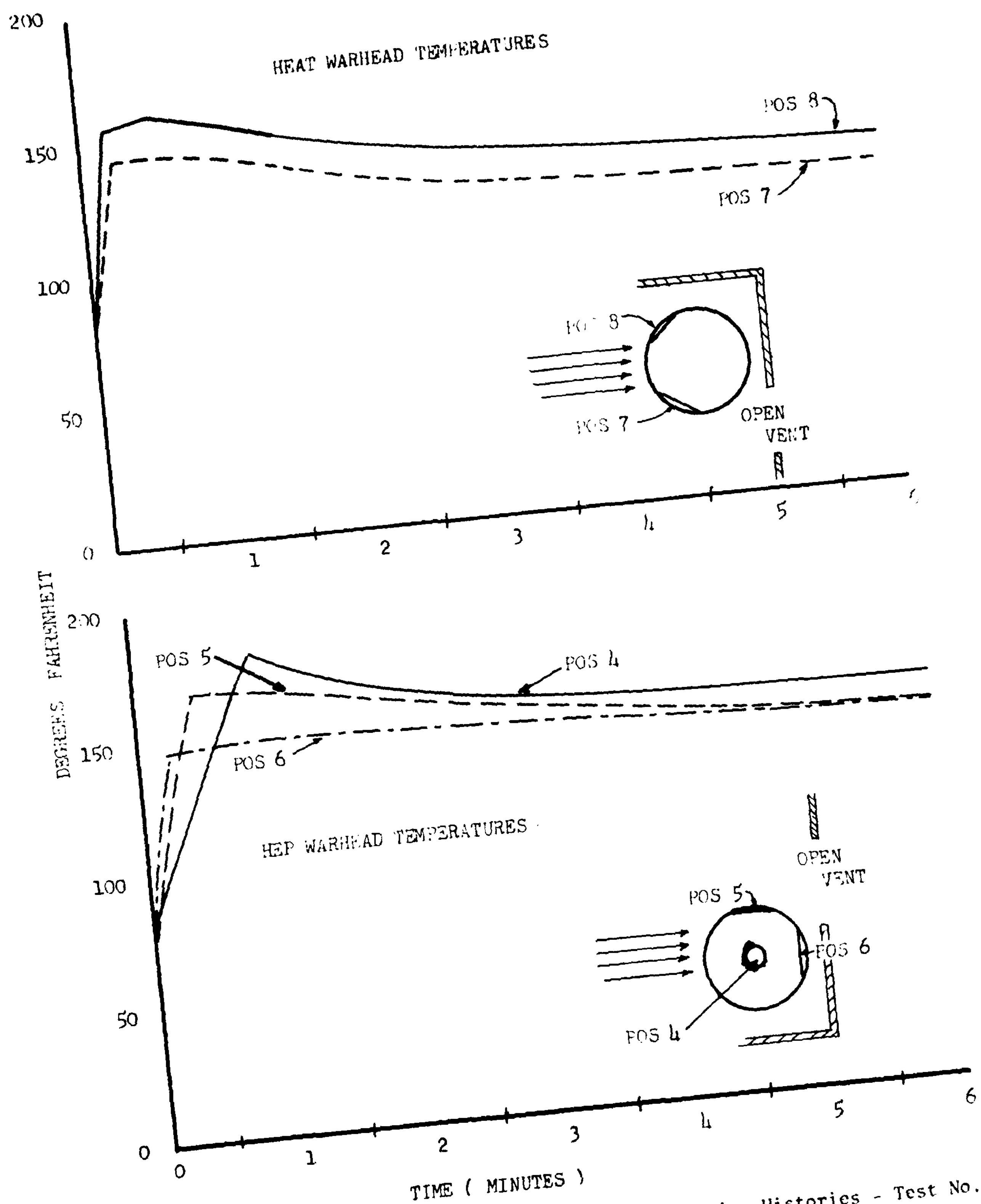


Figure A-8 HEP and HEAT Warhead Temperature Time Histories - Test No. 2

III. BRL PROPELLANT TEST NO. 3

Date: 3 July 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 3-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 3/4 inch into the residual stack of RHA.

The projectile of the live propellant round was seperated from its cartridge case. The cartridge case was torn apart in the area of jet impact, and the remaining portion of the case was split open. The primer was in two pieces. There was no damage to the dummy rounds nor was there any damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 180 psi and 158 psi. These pressures occurred during the first 100 microseconds of the event. The peak pressures recorded on the door were 313 psi and 308 psi. These pressures were recorded during the first 20 microseconds of the event. All of the peak pressures recorded were in the form of sharp spikes, their duration being only a matter of several microseconds. The mechanical crush gauge in the front of the compartment recorded 170 psi, and the gauge in the rear recorded 160 psi.

Mechanical crush gauges placed in the live propellant cartridge case recorded pressures of 1200 psi in the nose and 600 psi in the base. No valid data were acquired from the internal ferrule gauges placed in the nose and base of the live propellant cartridge case. The records produced by these transducers were extremely noisy. Maximum temperature readings were 480°F in the cartridge case of one of the dummy rounds, 160°F inside the dummy HEAT warhead, and 190°F inside the dummy HEP warhead.

The average jet-tip velocity as measured by the velocity screens between points A and C was 3.5mm/μsec; between A and D, 3.2mm/μsec; and between A and E, 3.2mm/μsec.

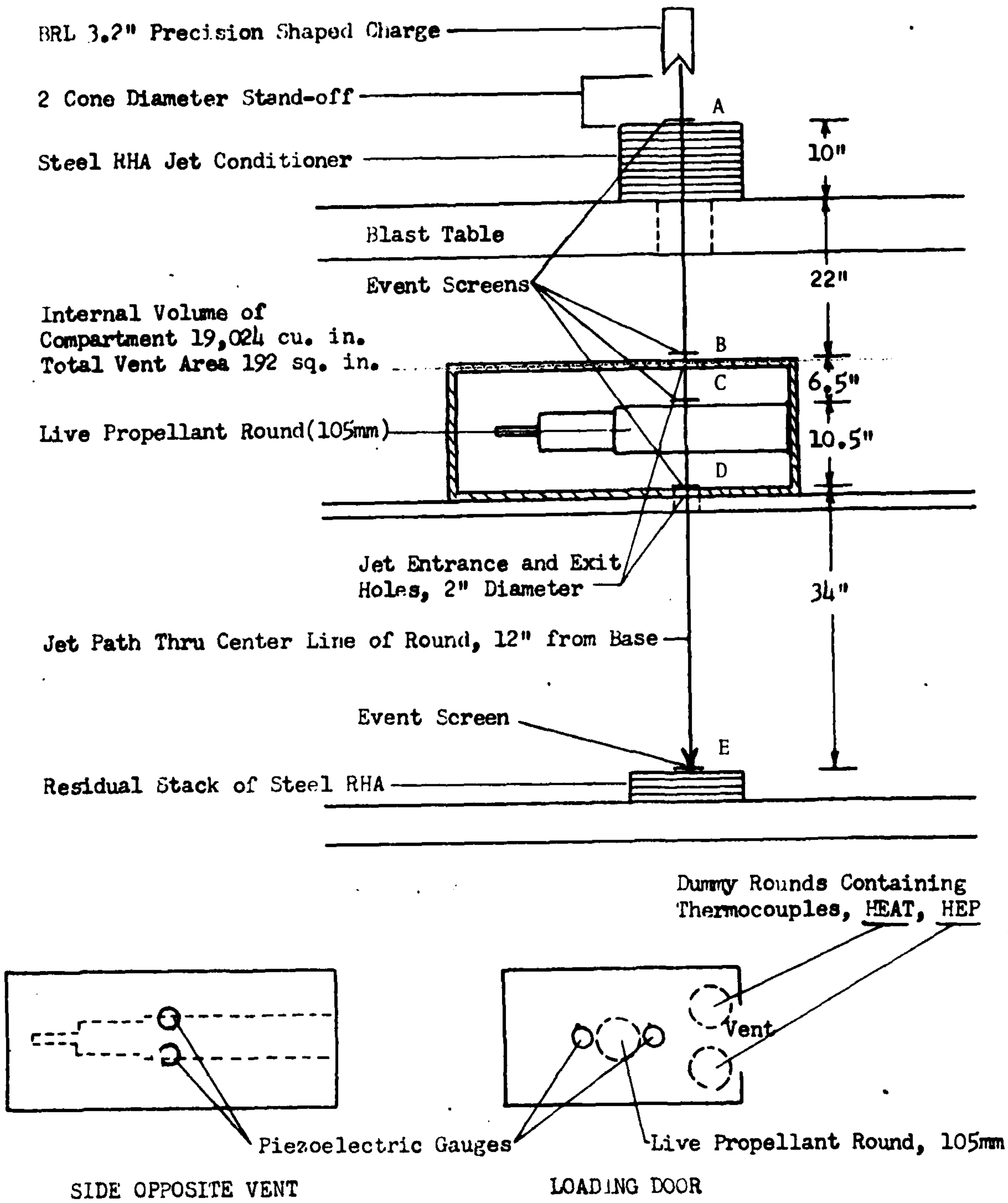


Figure A-9 Test Setup for Propellant Test No. 3

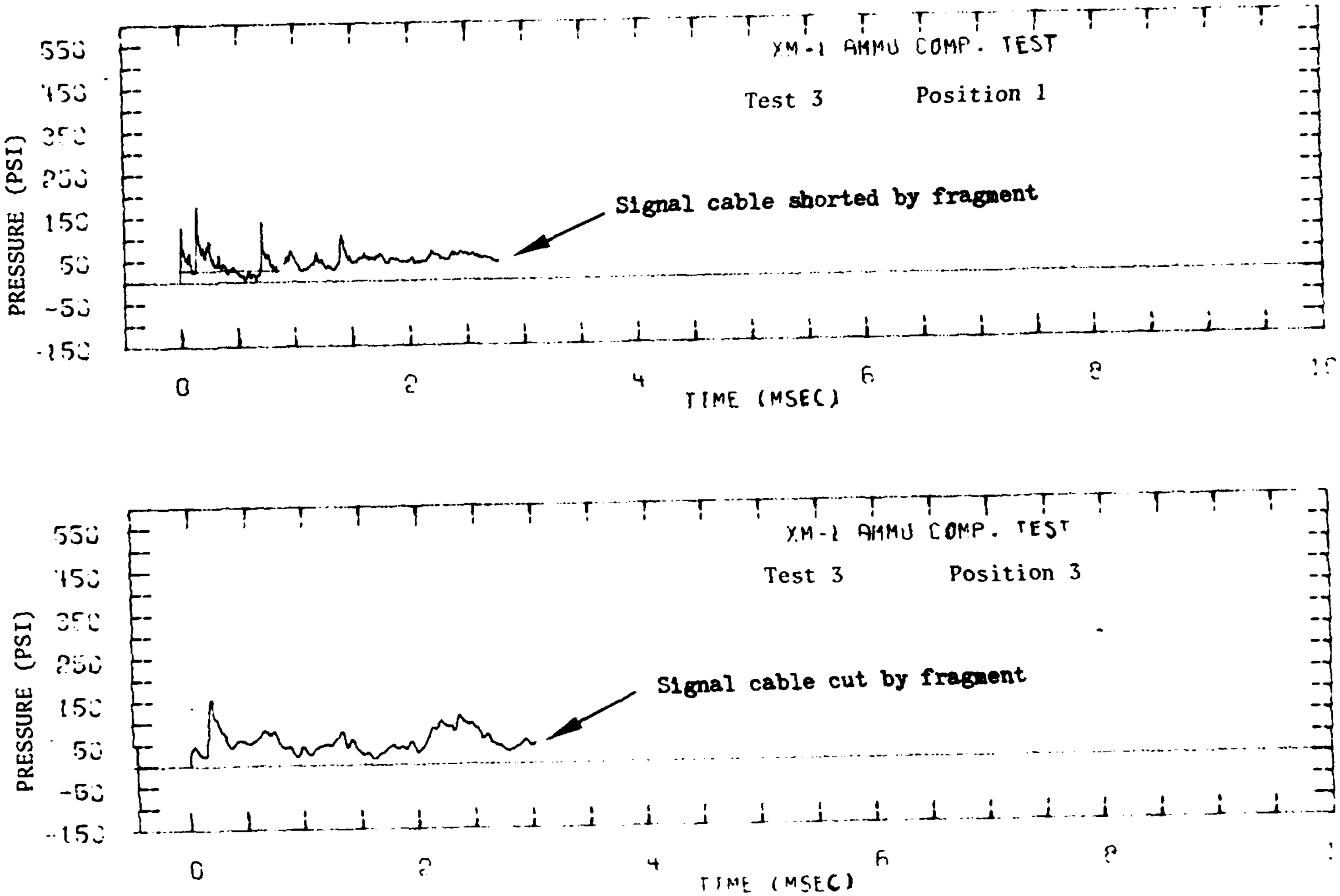


Figure A-10 Pressure Time Histories on Compartment Wall - Test No. 3

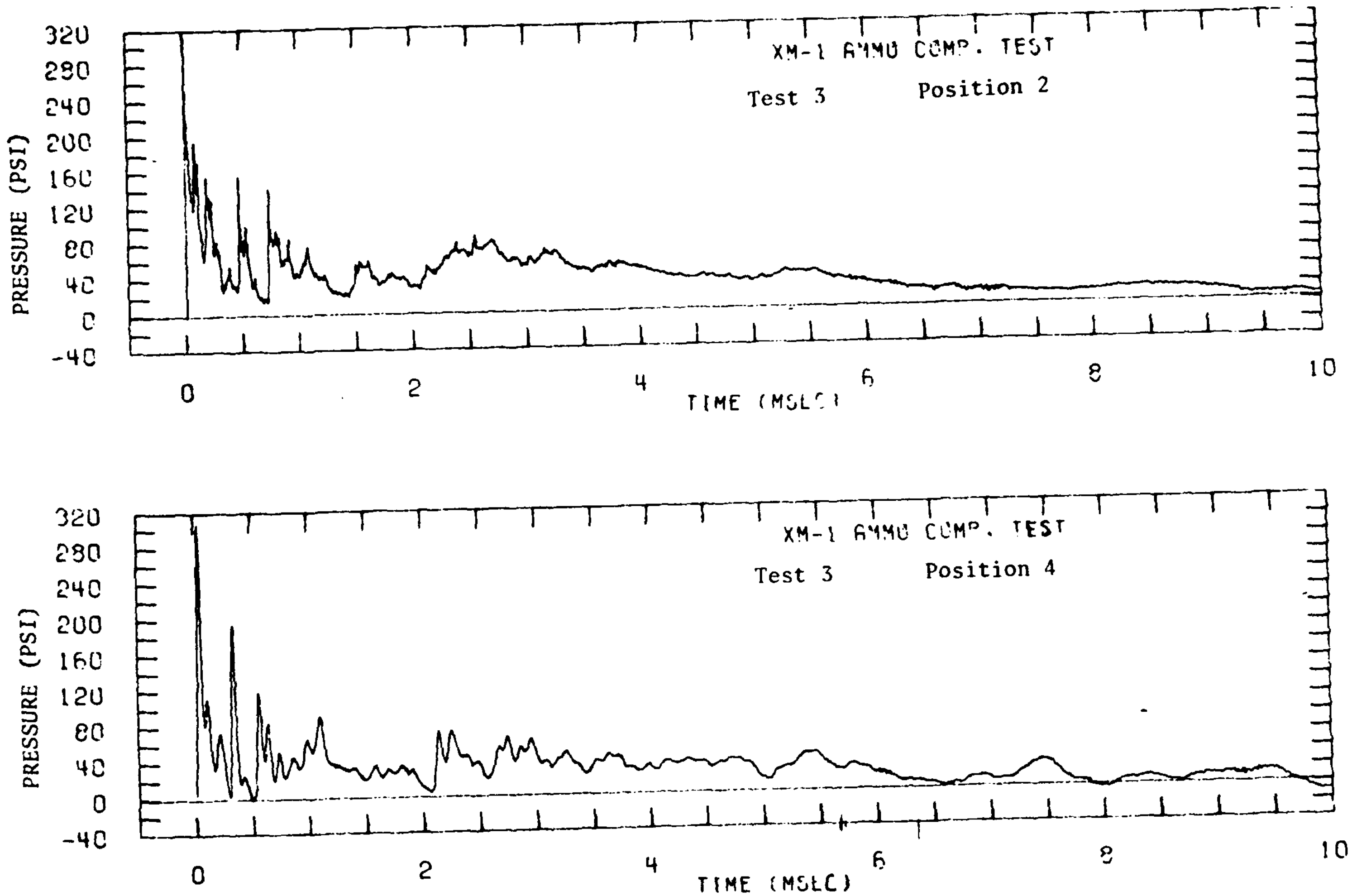


Figure A-11 Pressure Time Histories on Loading Door - Test No. 3

CARTRIDGE CASE TEMPERATURES

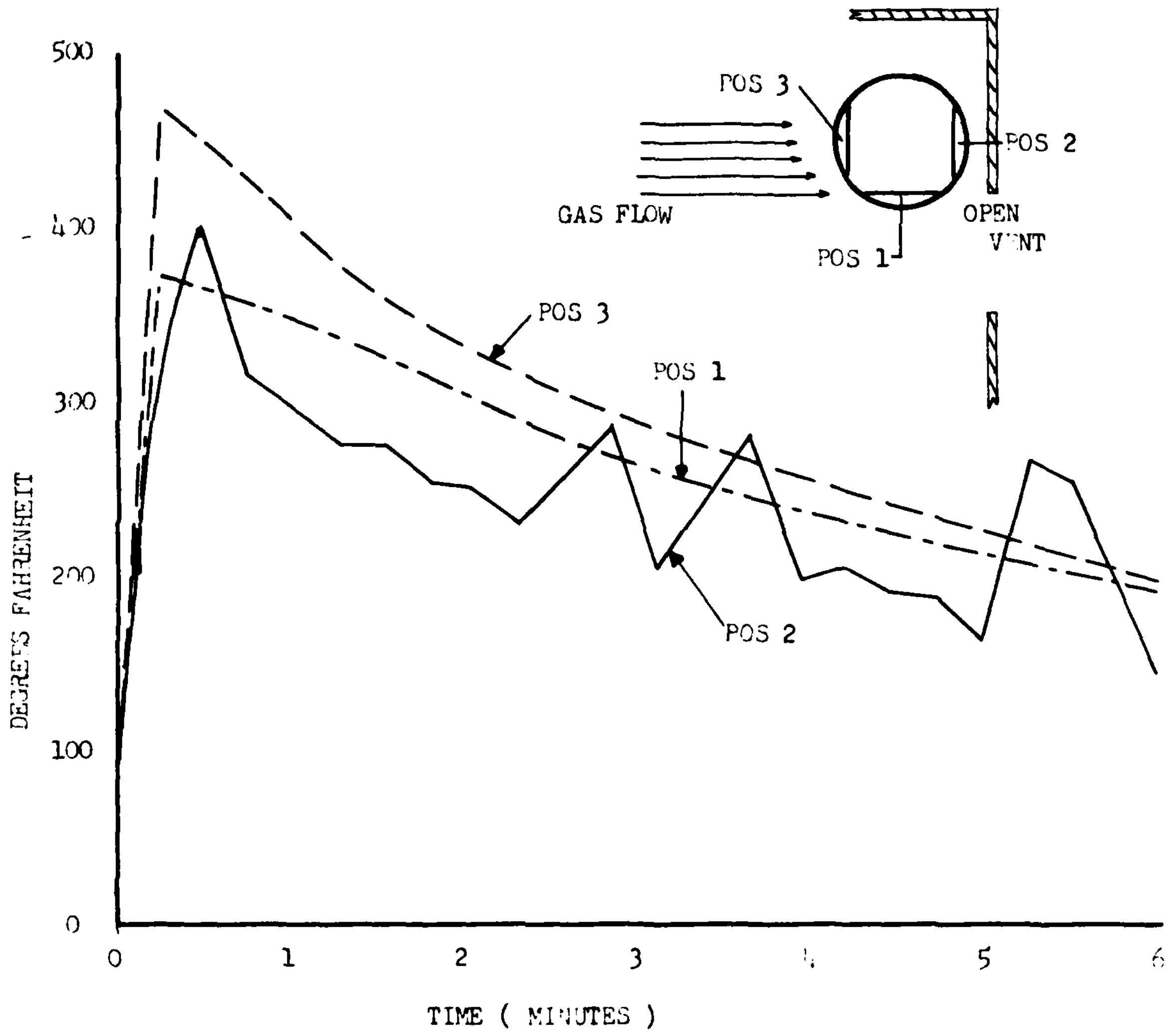


Figure A-12 Cartridge Case Temperature Time Histories - Test No. 3

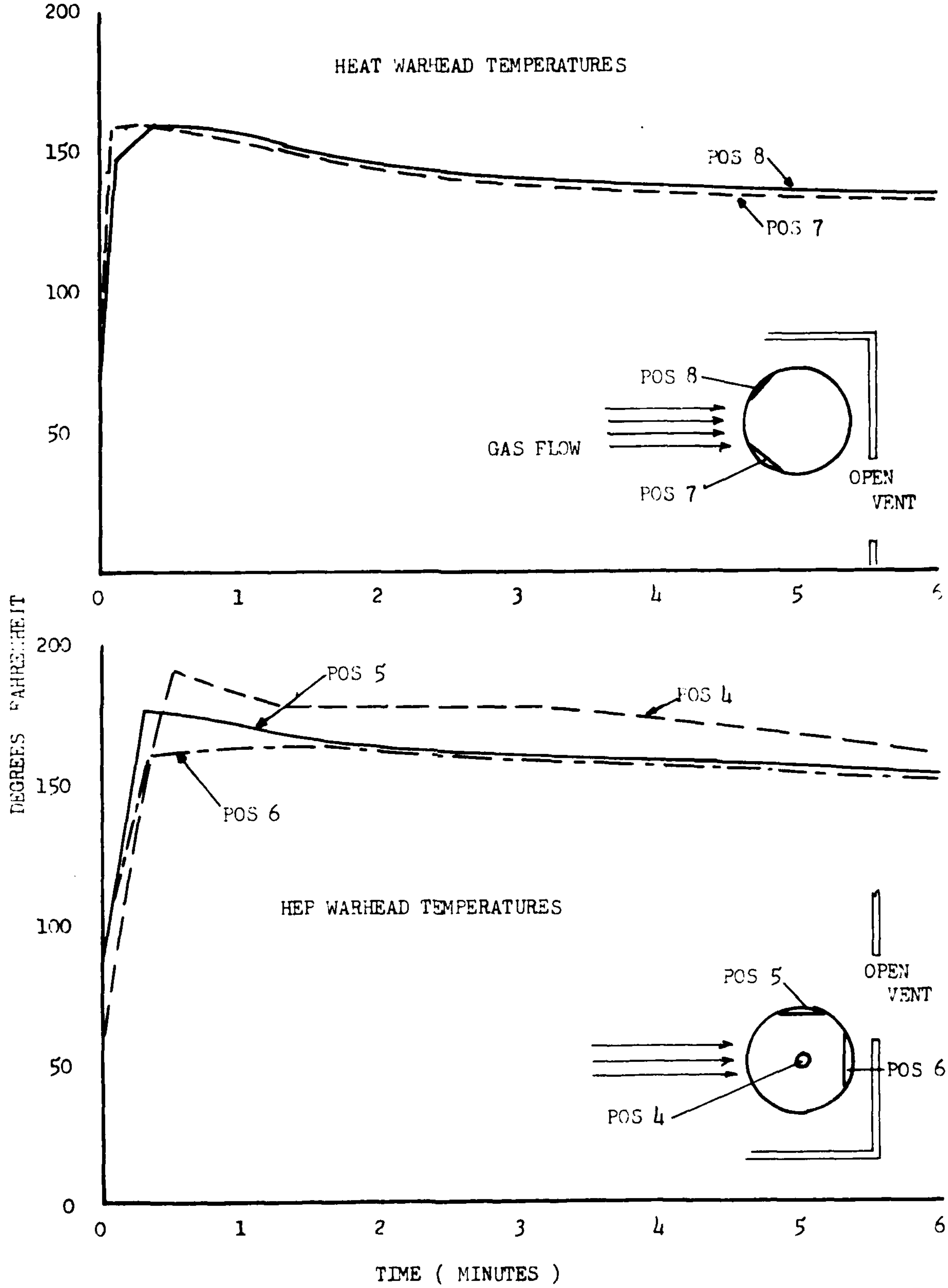


Figure A-13 HEP and HEAT Warhead Temperature Time Histories - Test No. 3

IV. BRL PROPELLANT TEST NO. 4

Date: 12 July 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 3-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) grazing the primer; it then exited the compartment and penetrated 1 inch into the residual stack of RHA.

The projectile of the live propellant round was separated from its cartridge case. The cartridge case was torn apart in the area of the jet impact, and the remaining portion of the case was split open. The primer was bent. The cartridge case in the upper corner of the compartment was perforated by fragments from the impacted live propellant round. The cartridge case of the other dummy round was squashed. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 175 psi and 160 psi; those recorded on the door were 429 psi and 235 psi.

Temperatures were not recorded, and jet velocities were not measured. The thermocouples wires were cut by fragments and the event screens failed to function properly.

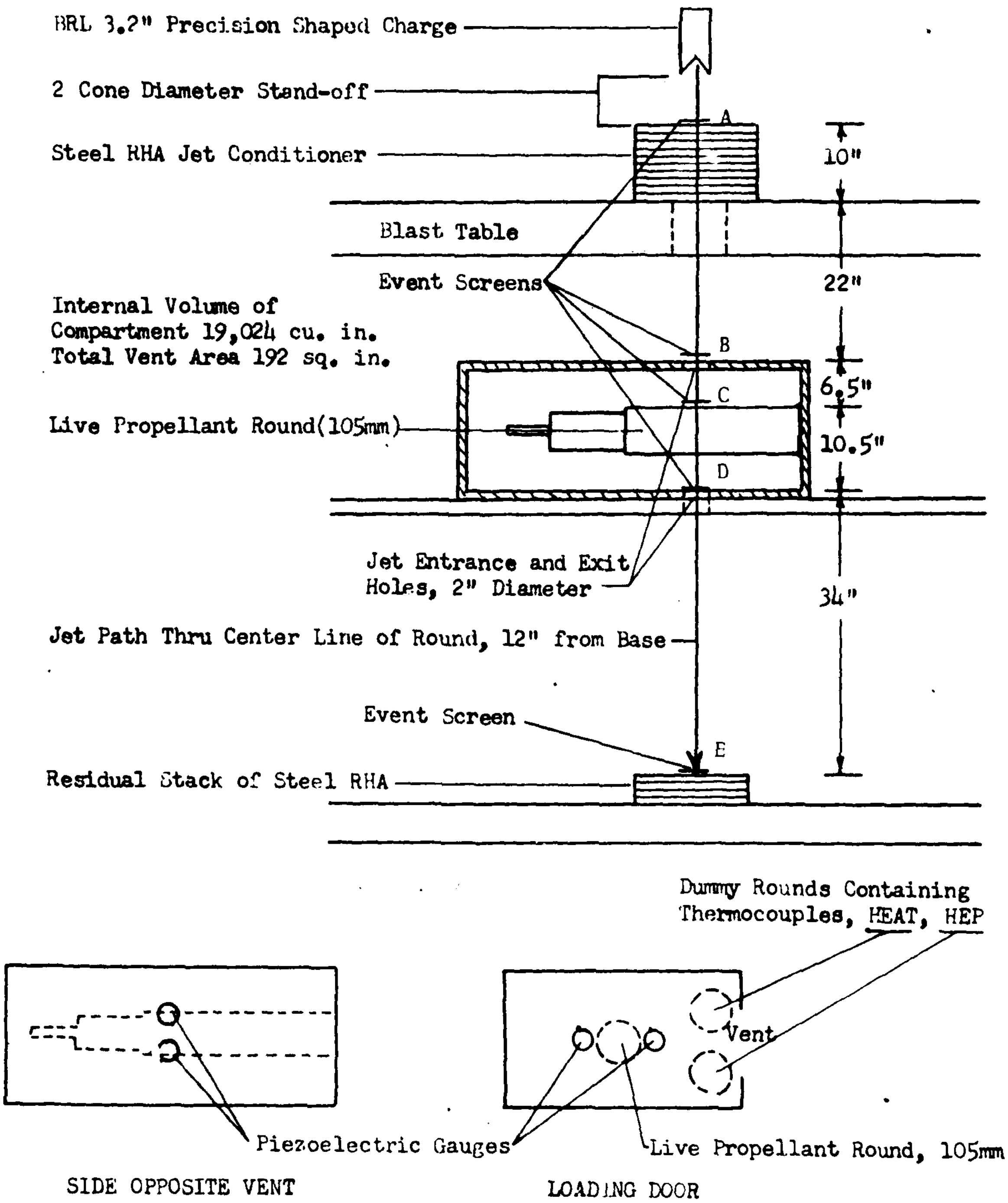


Figure A-14 Test Setup for Propellant Test No. 4

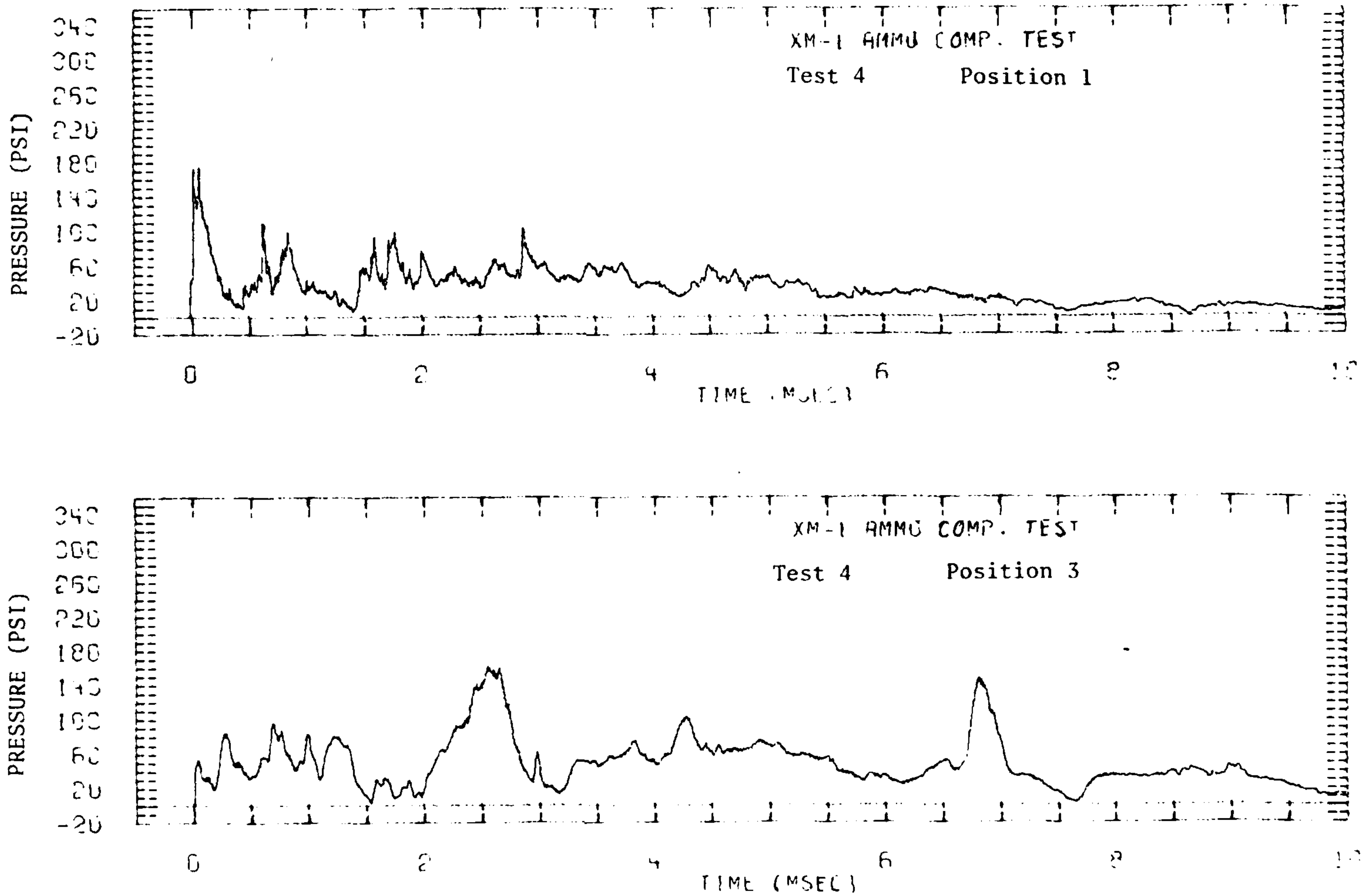


Figure A-15 Pressure Time Histories on Compartment Wall - Test No. 4

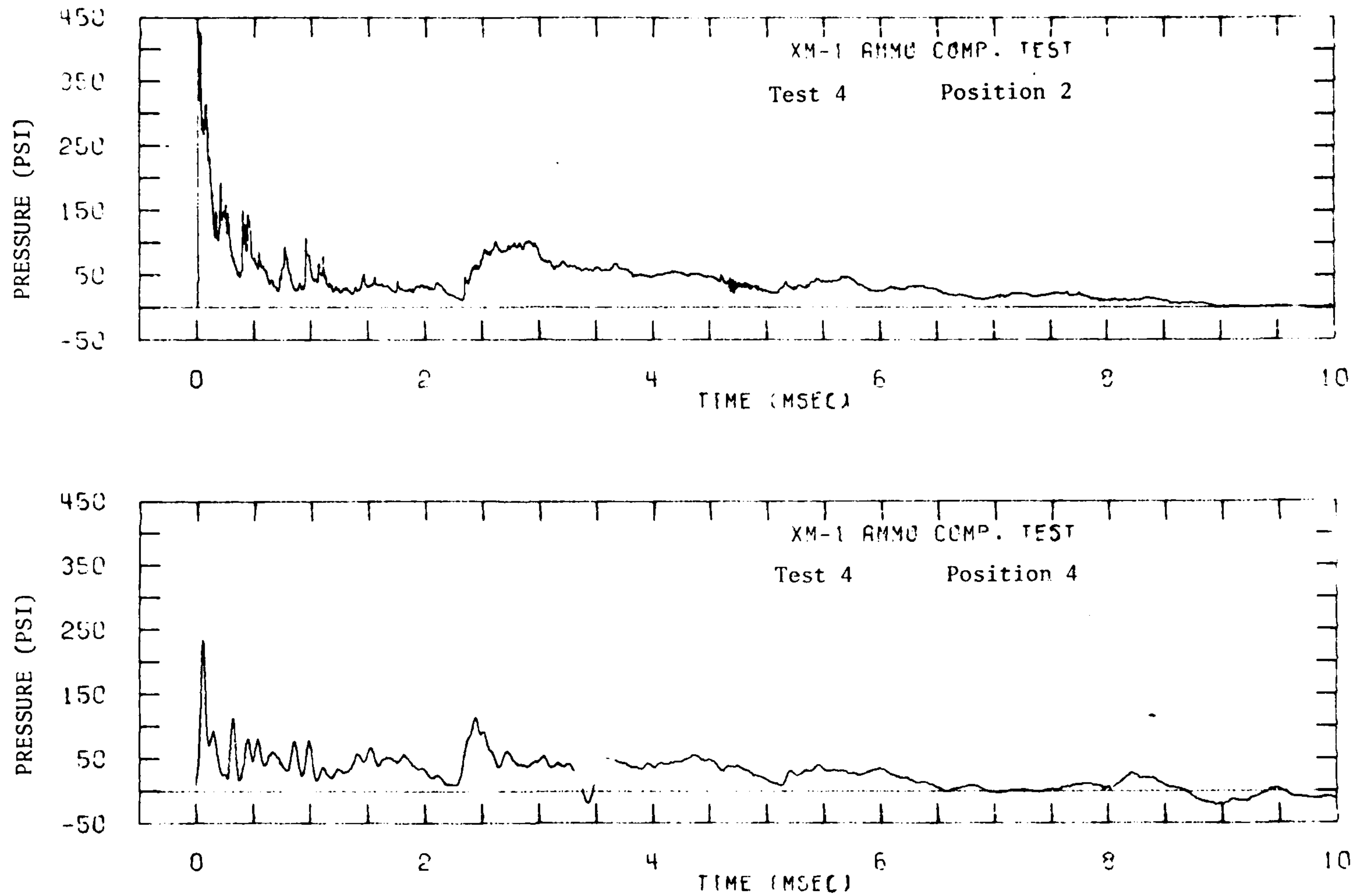


Figure A-16 Pressure Time Histories on Loading Door - Test No. 4

V. BRL PROPELLANT TEST NO. 5

Date: 18 July 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 3-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) grazing the primer; it then exited the compartment and penetrated 3/4 inch into the residual stack of RHA.

The projectile of the live propellant round was separated from its cartridge case. The cartridge case was torn apart in the area of jet impact, and the remaining portion of the case was split open. The primer was bent. There was no damage to the dummy rounds or the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 156 psi and 132 psi. These pressures occurred during the first few milliseconds of the event. The peak pressures recorded on the door were 364 psi and 238 psi.

The live round was not instrumented for this test nor were thermocouples mounted in the dummy rounds.

The average jet-tip velocity as measured by the velocity screens between points A and C was 3.3mm/μsec; between A and D, 3.1mm/μsec; and between A and E, 2.9mm/μsec.

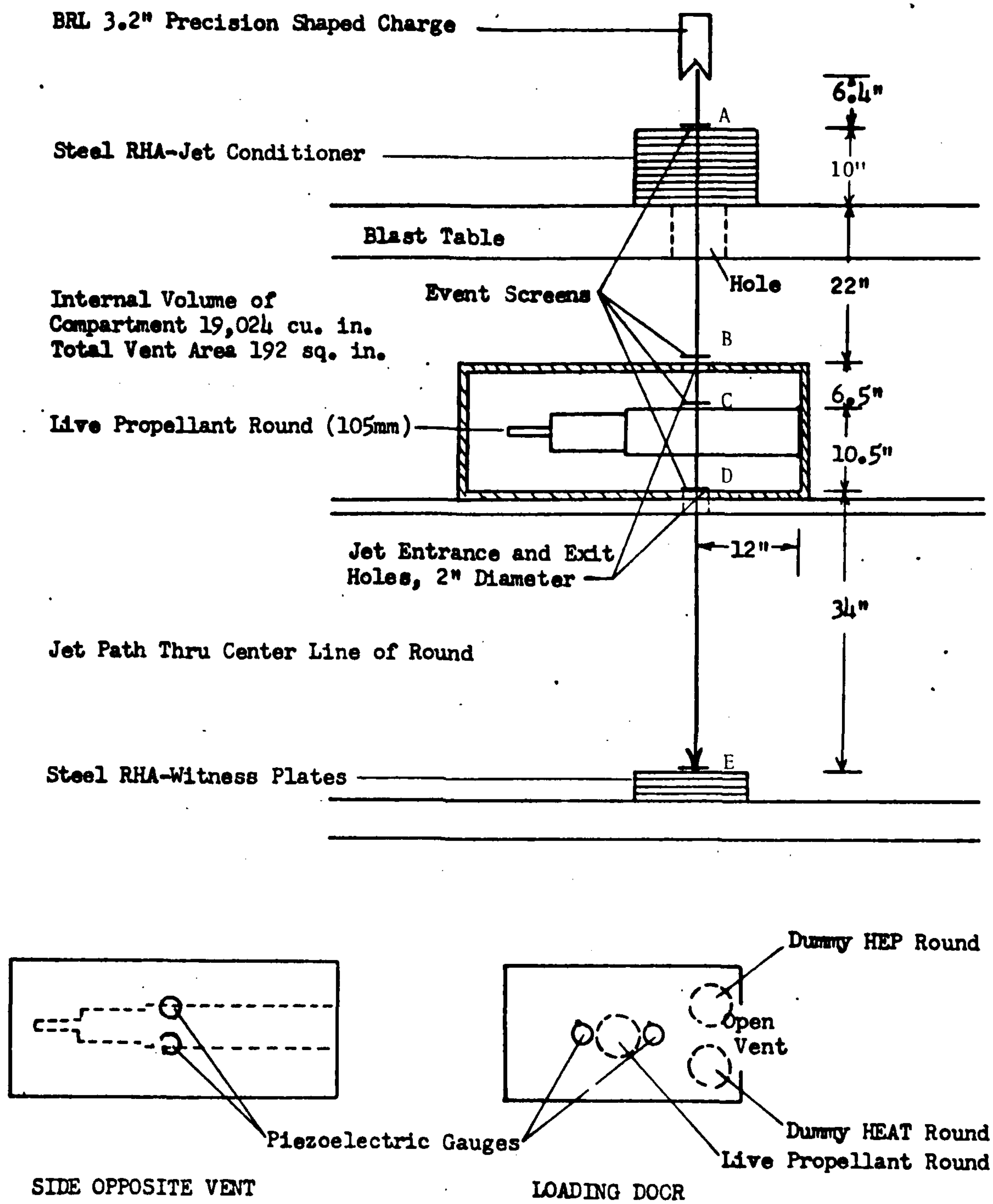


Figure A-17 Test Setup for Propellant Test No. 5

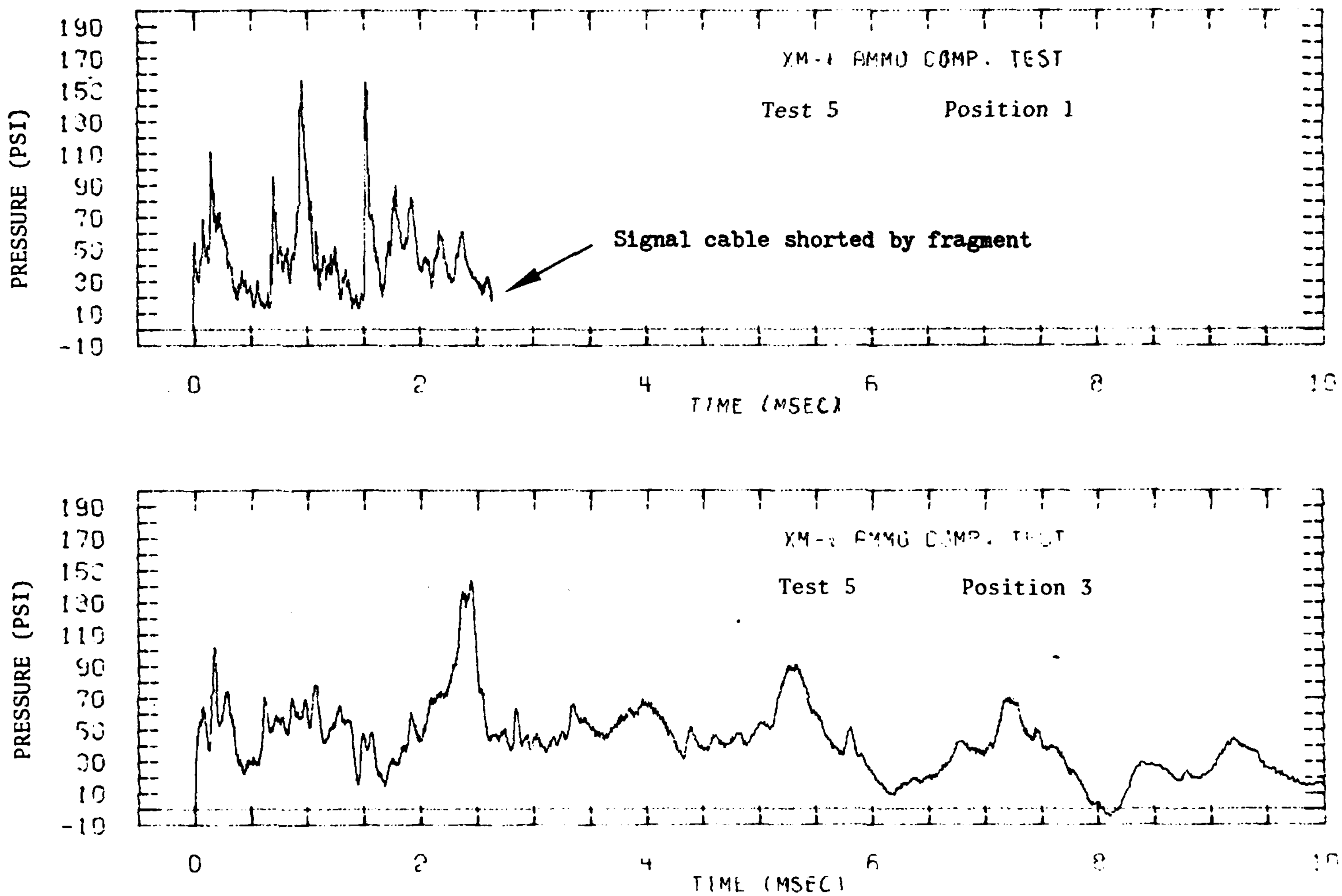


Figure A-18 Pressure Time Histories on Compartment Wall - Test No. 5

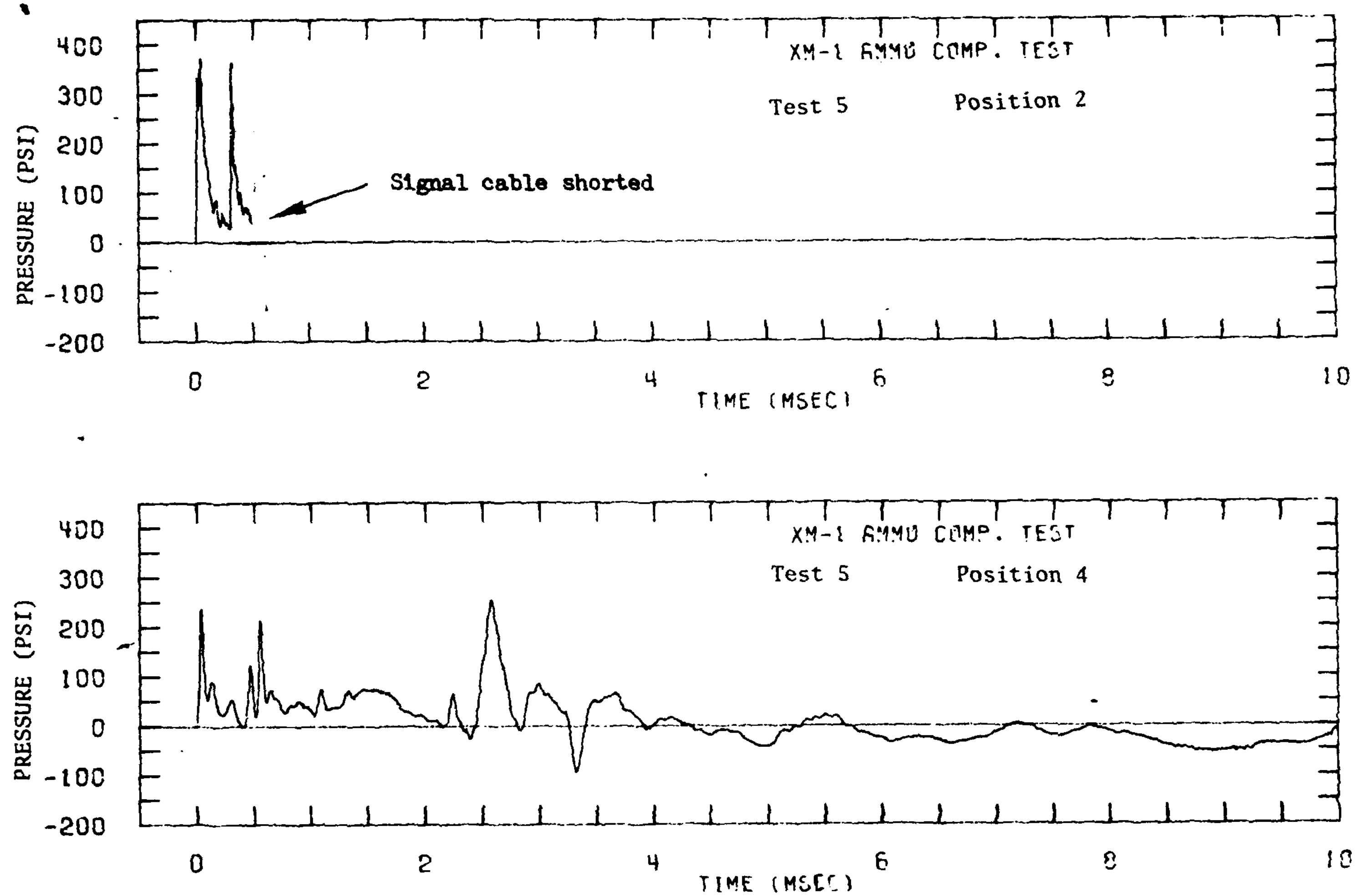


Figure A-19 Pressure Time Histories on Loading Door - Test No. 5

VI. BRL PROPELLANT TEST NO. 6

Date: 30 July 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 7/8 inch into the residual stack of RHA.

The projectile from the live round separated from its cartridge case. The cartridge case was torn in half in the area of the jet impact; both sections were split open. The primer was in two pieces. The cartridge cases of the dummy rounds containing the thermocouples were dented, but not perforated. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 313 psi and 124 psi; those on the door recorded peak pressures of 280 psi and 401 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 410 psi and 260 psi, and crush gauges located in the rear of the compartment, 190 psi and 360 psi.

The mechanical crush gauge in the nose of the live propellant cartridge case was damaged. The gauge in the base recorded 600 psi. A maximum temperature of 413°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 148° and 177°F, respectively.

The average jet-tip velocity as measured by the velocity screens between points A and B was 3.7mm/μsec; between A and D, 3.2mm/μsec; and between A and E, 3.0mm/μsec.

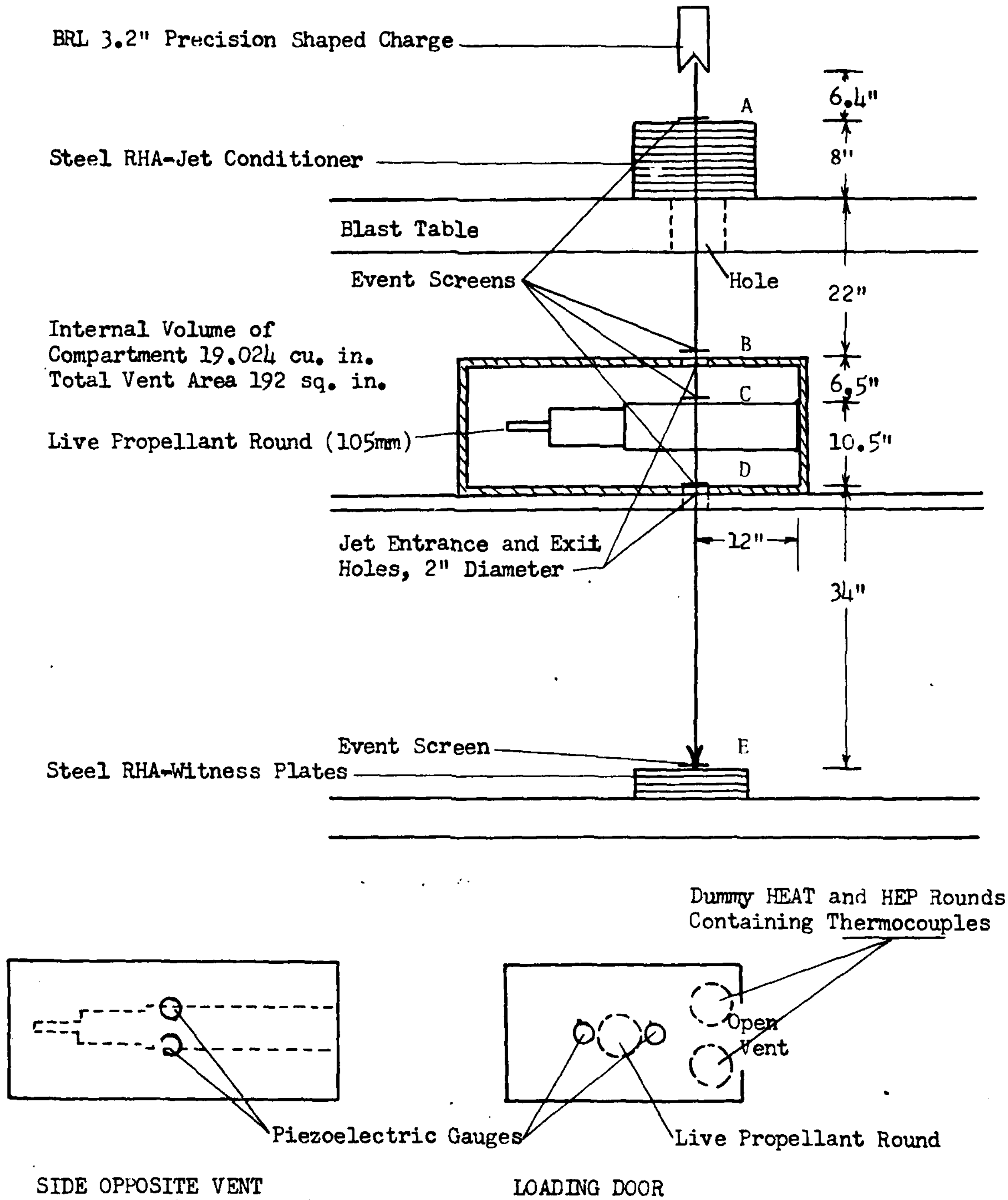


Figure A-20 Test Setup for Propellant Test No. 6

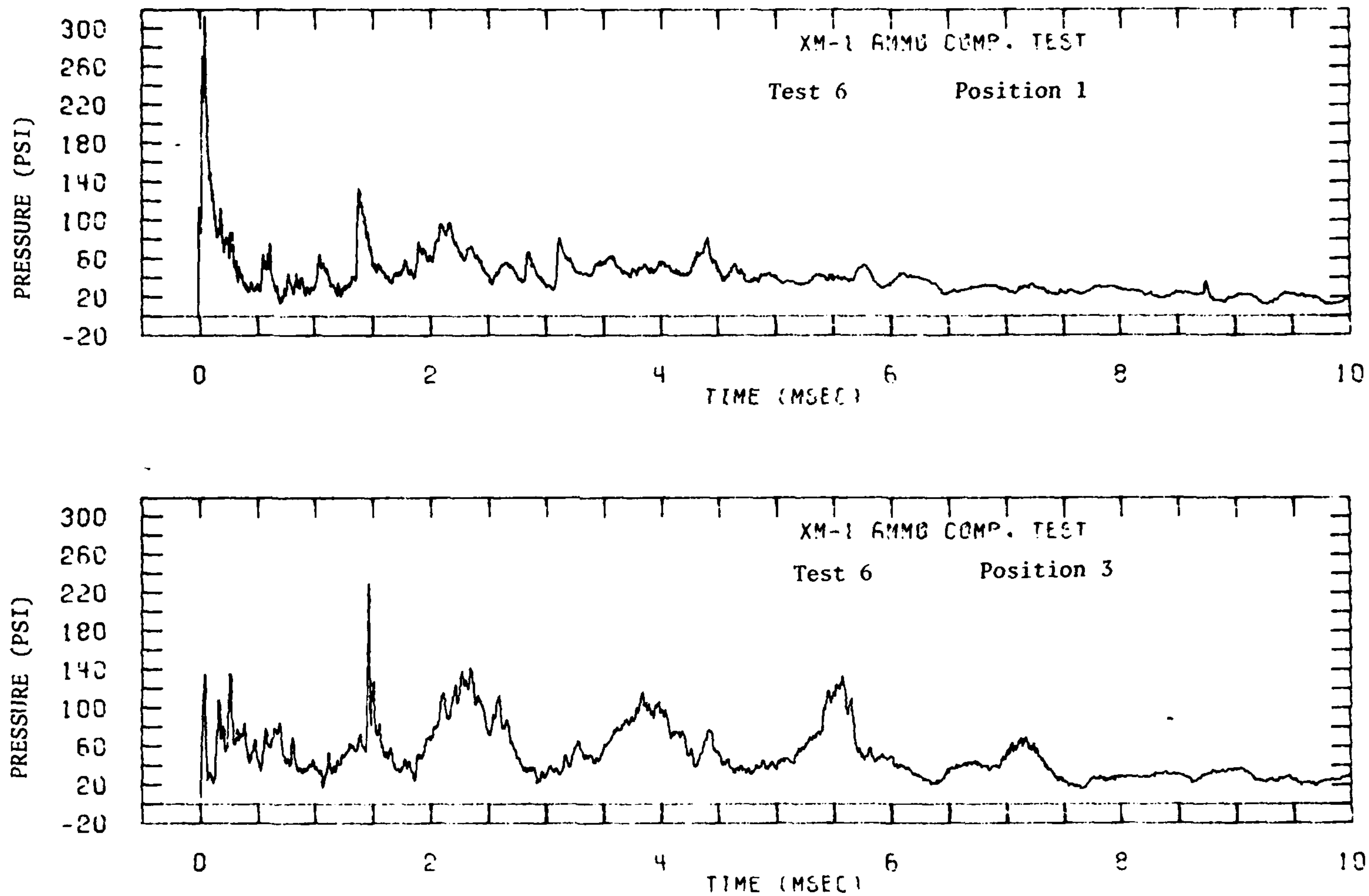


Figure A-21 Pressure Time Histories on Compartment Wall - Test No. 6

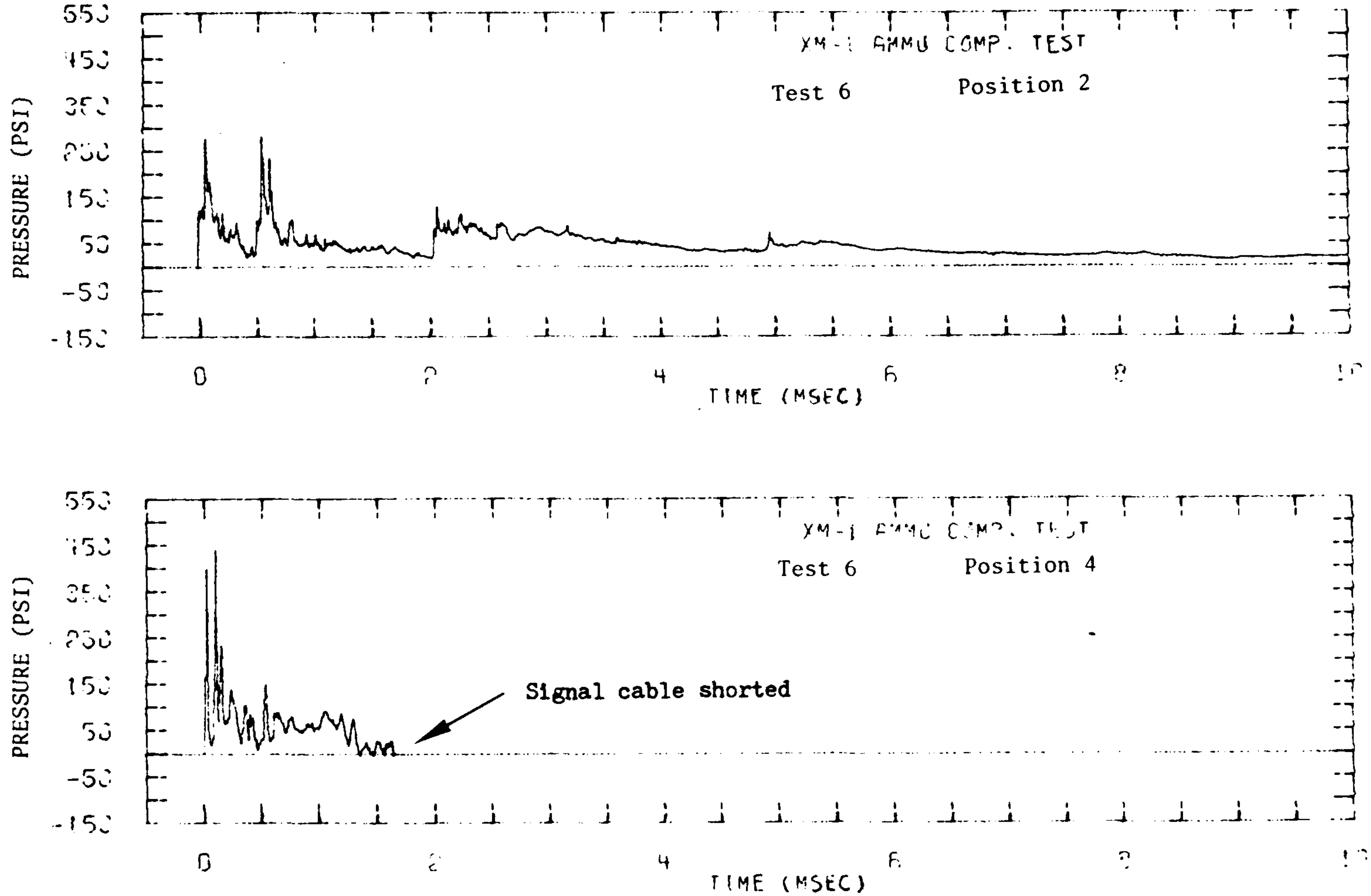


Figure A-22 Pressure Time Histories on Loading Door - Test No. 6

CARTRIDGE CASE TEMPERATURES

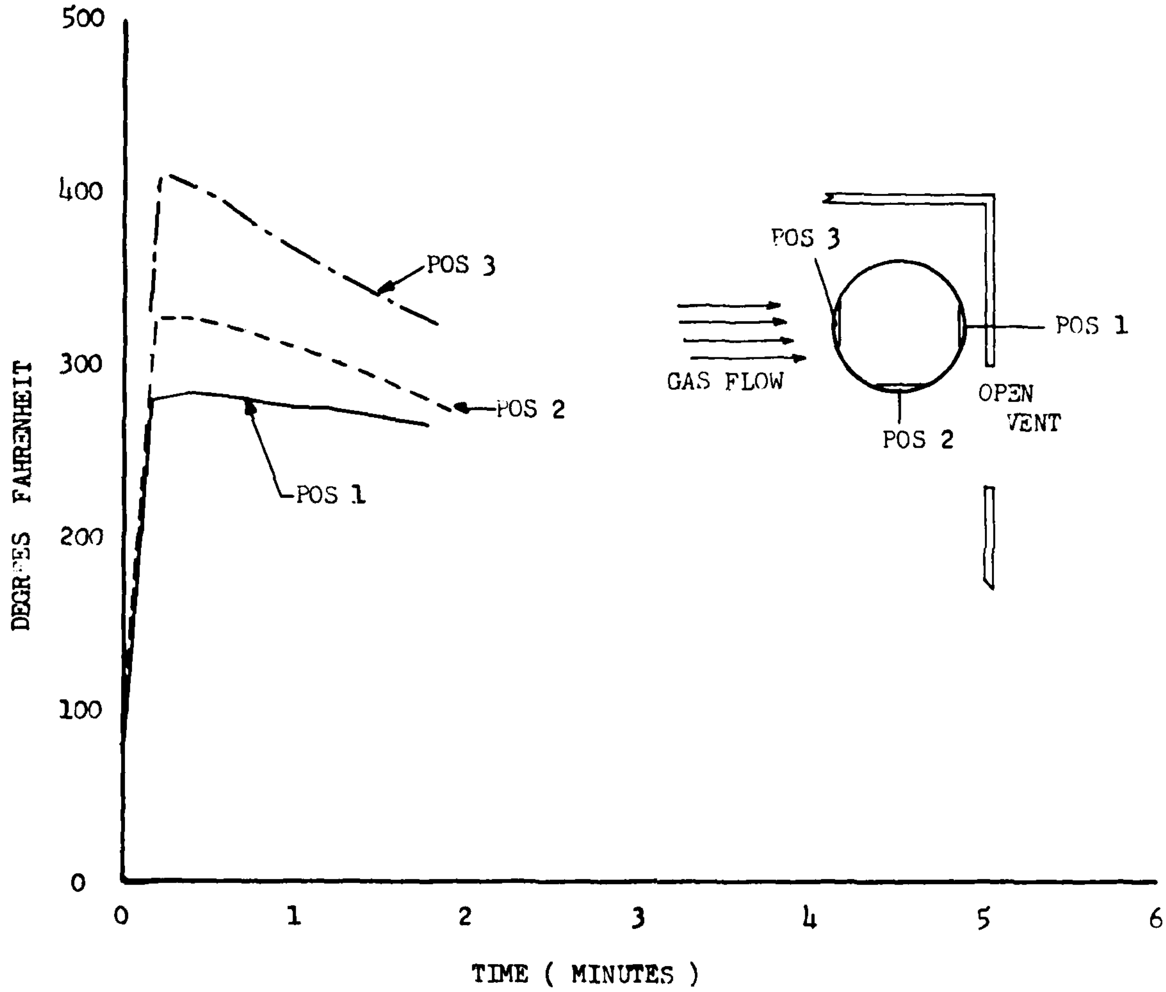


Figure A-23 Cartridge Case Temperature Time Histories - Test No. 6

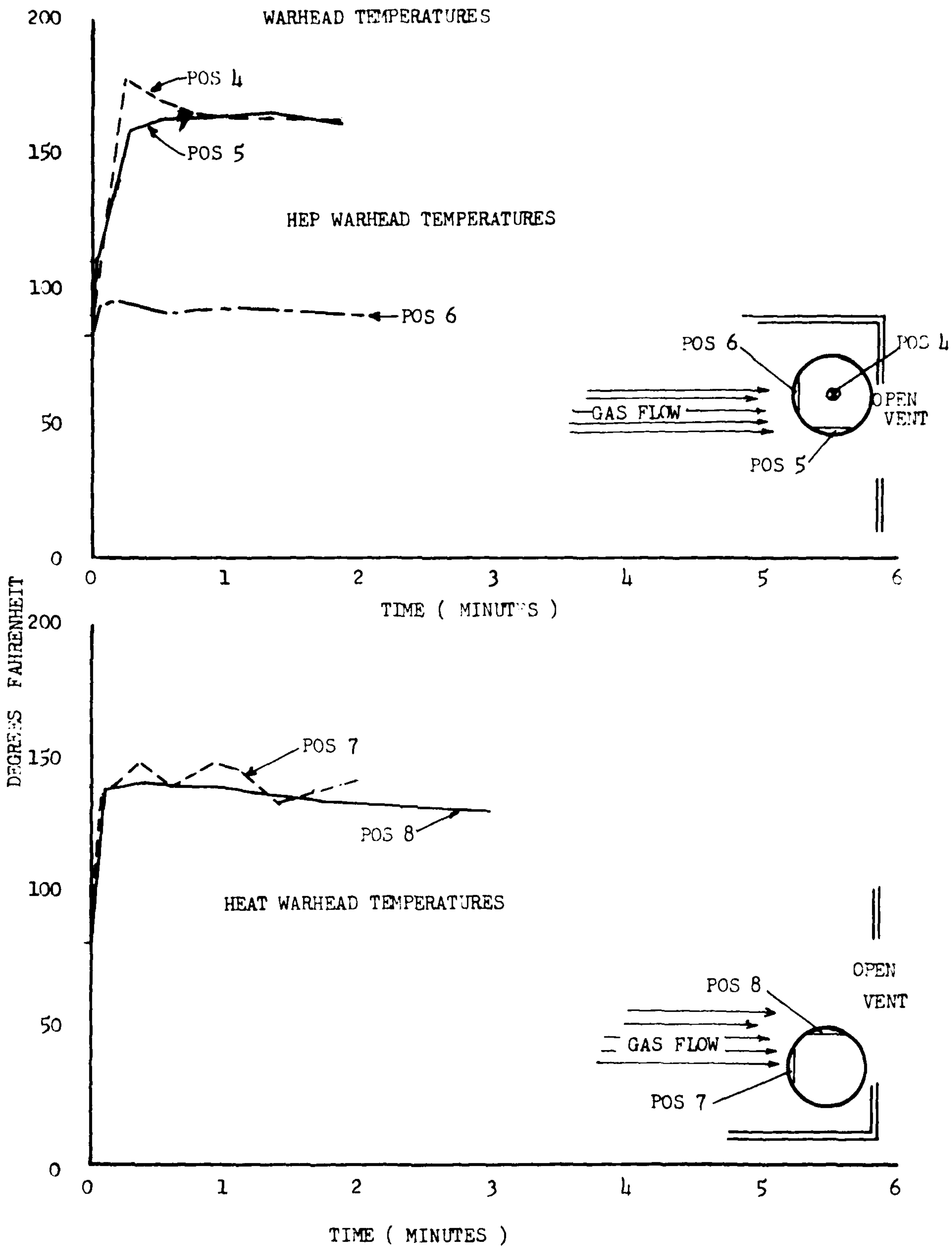


Figure A-24 HEP and HEAT Warhead Temperature Time Histories - Test No. 6

VII. BRL PROPELLANT TEST NO. 7

Date: 31 July 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

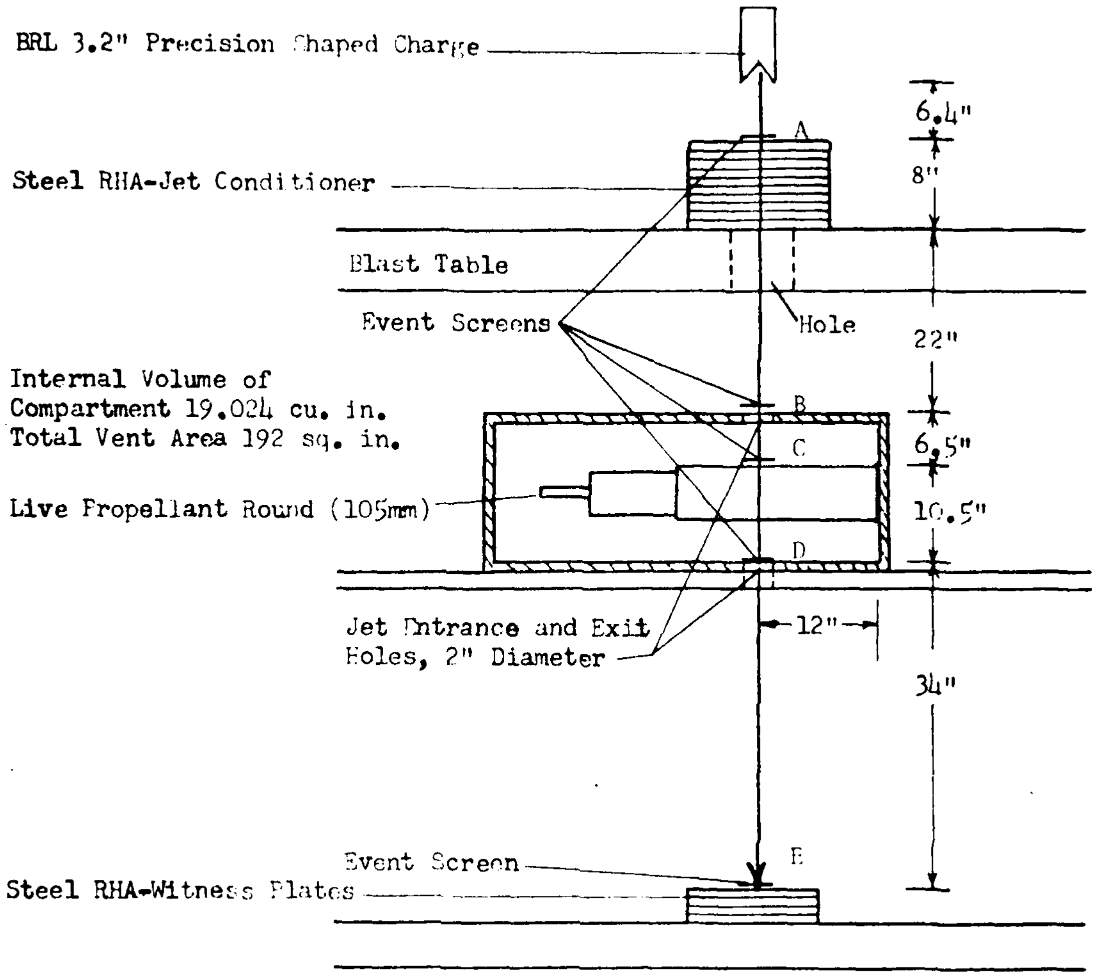
The shaped charge jet nicked the compartment as it entered and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 3/8 inch into the residual stack of RHA.

The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was in two pieces. The cartridge cases of the dummy rounds containing the thermocouples were dented and split. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 222 psi and 315 psi; those on the door recorded peak pressures of 467 psi and 546 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 330 psi and 700 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 2000 psi in the nose and 1000 psi in the base. A maximum temperature of 418°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 157° and 175°F, respectively.

The event screens failed to function properly so there are no recorded jet-tip velocities.



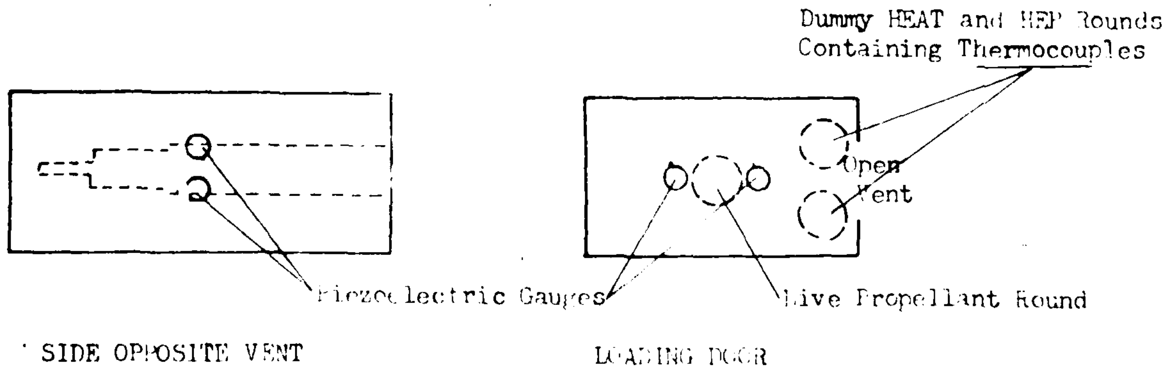
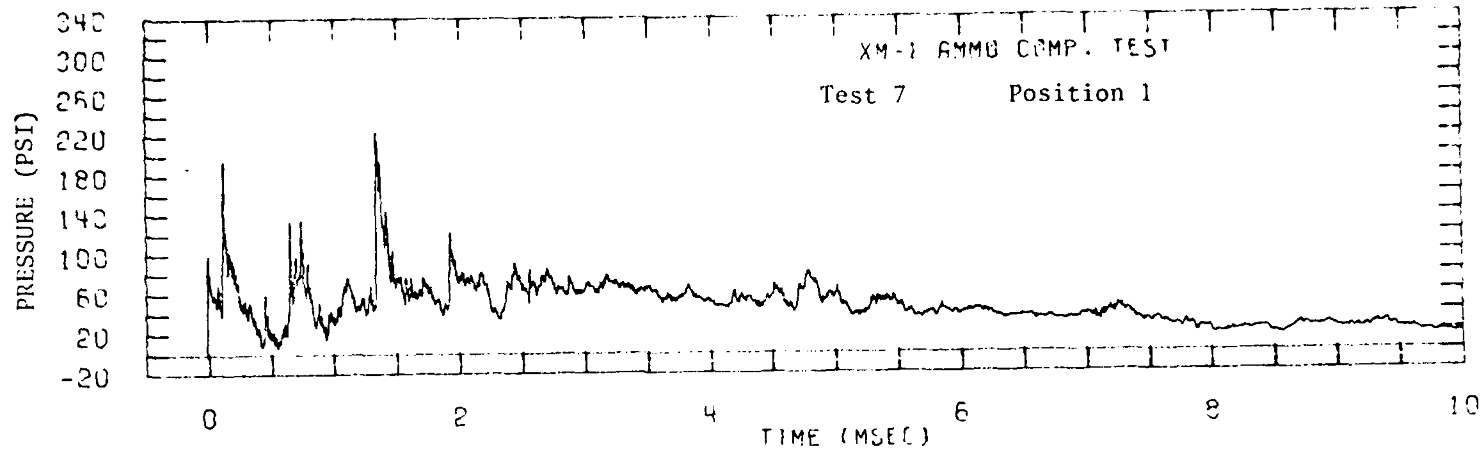


Figure A-25 Test Setup for Propellant Test No. 7



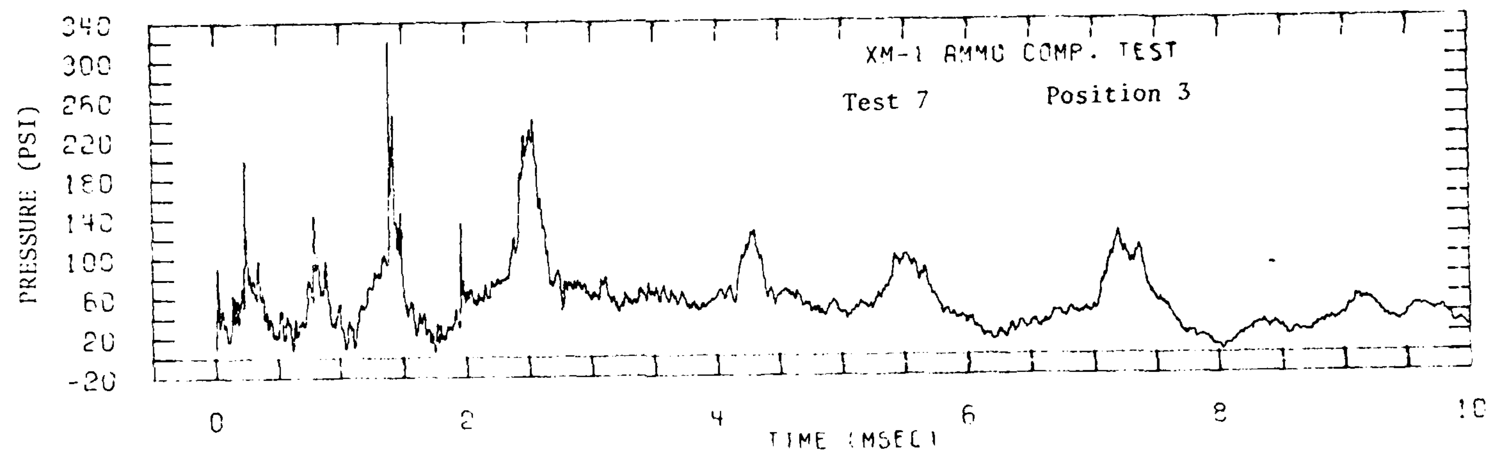


Figure A-26 Pressure Time Histories on Compartment Wall - Test No. 7

AD-A081 778 ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND ABERD--ETC F/G 19/1
SHAPED CHARGE JET/PROPELLANT INTERACTIONS IN A VENTED COMPARTME--ETC(U)
DEC 79 F T BROWN, W S JACKSON

UNCLASSIFIED ARBRL-MR-02977 SBIE-AD-E430 379 NL

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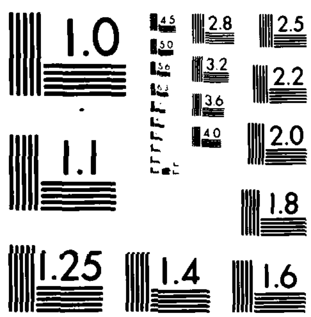


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

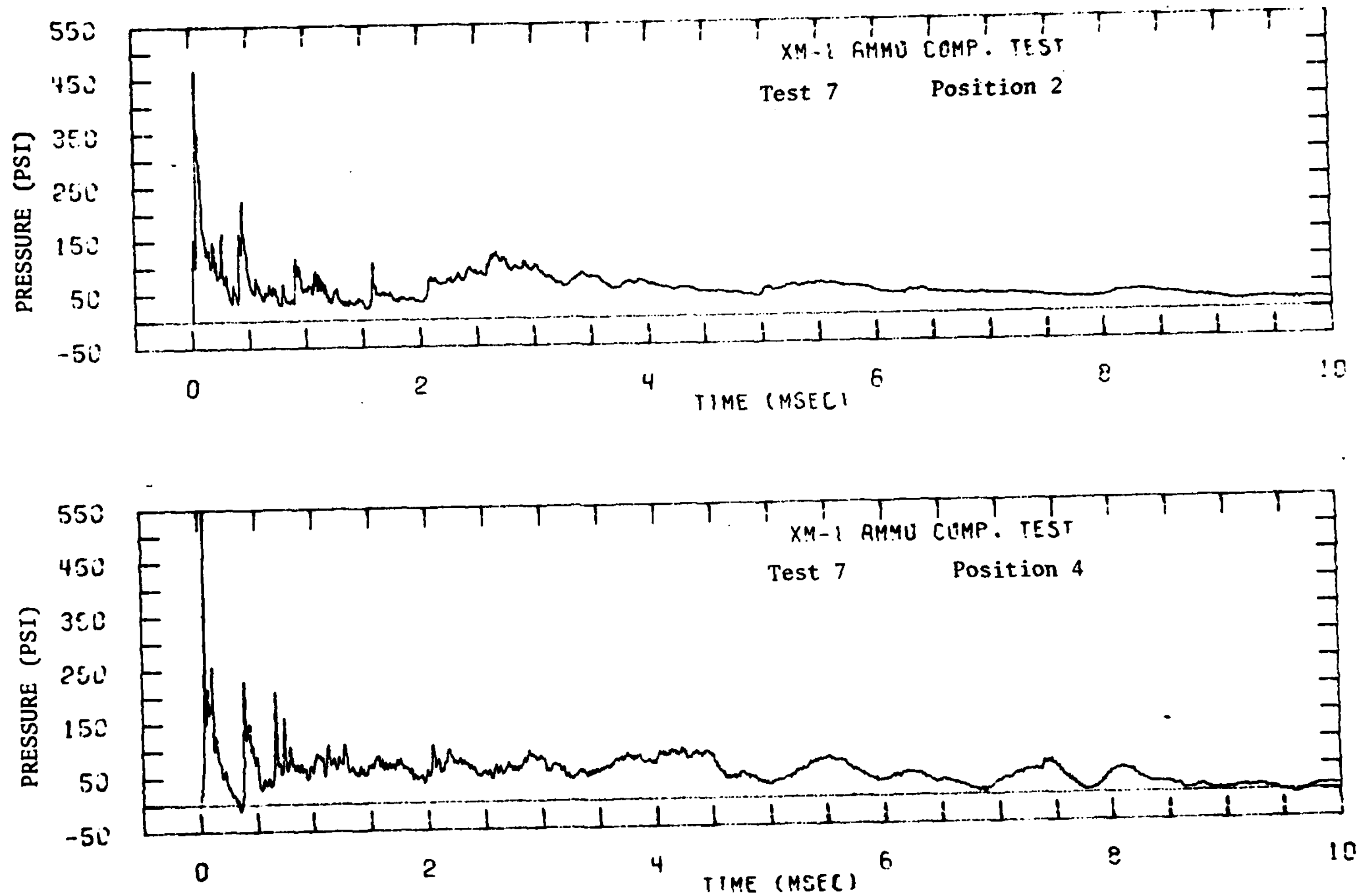


Figure A-27 Pressure Time Histories on Loading Door - Test No. 7

CARTRIDGE CASE TEMPERATURES

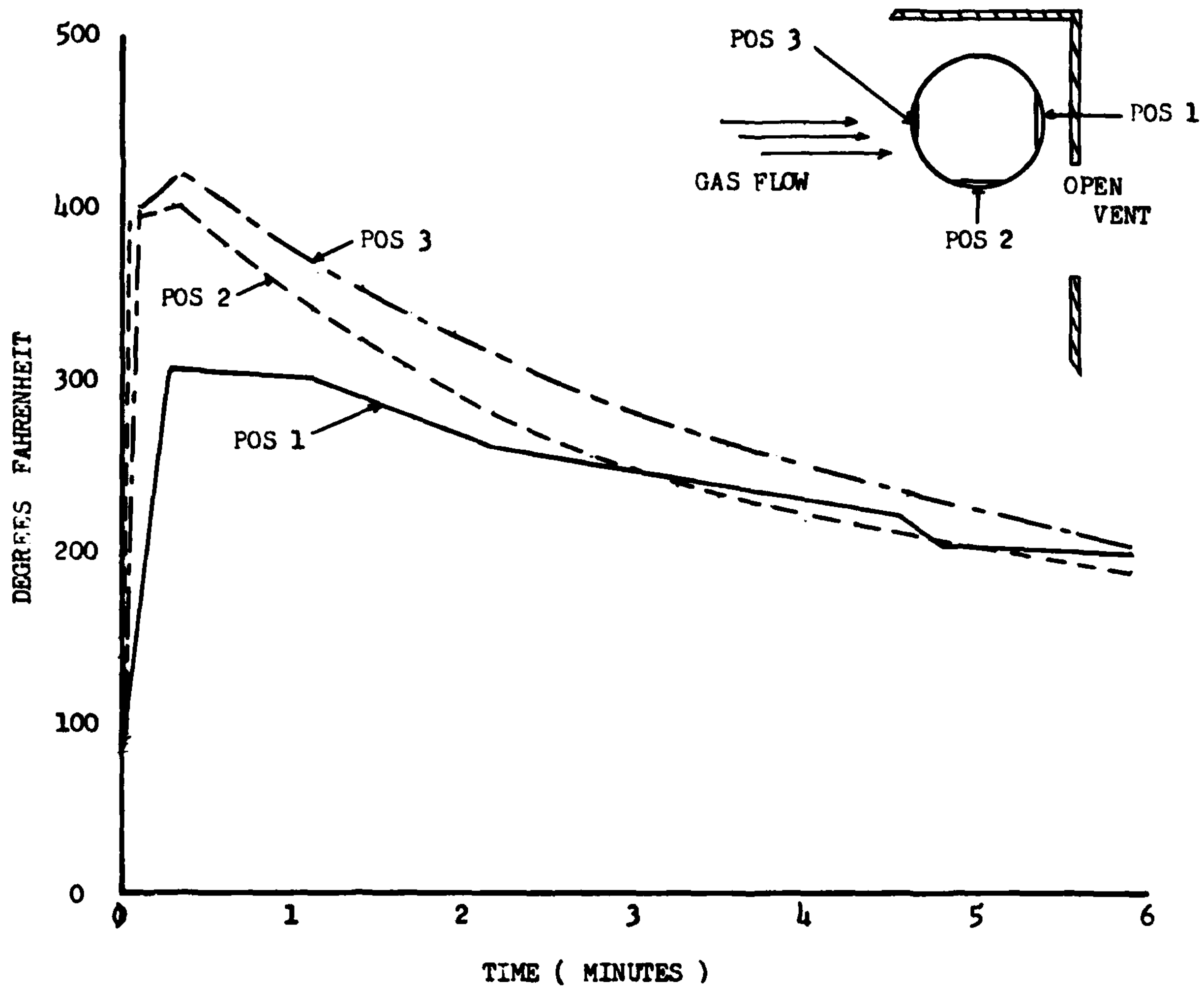


Figure A-28 Cartridge Case Temperature Time Histories - Test No. 7

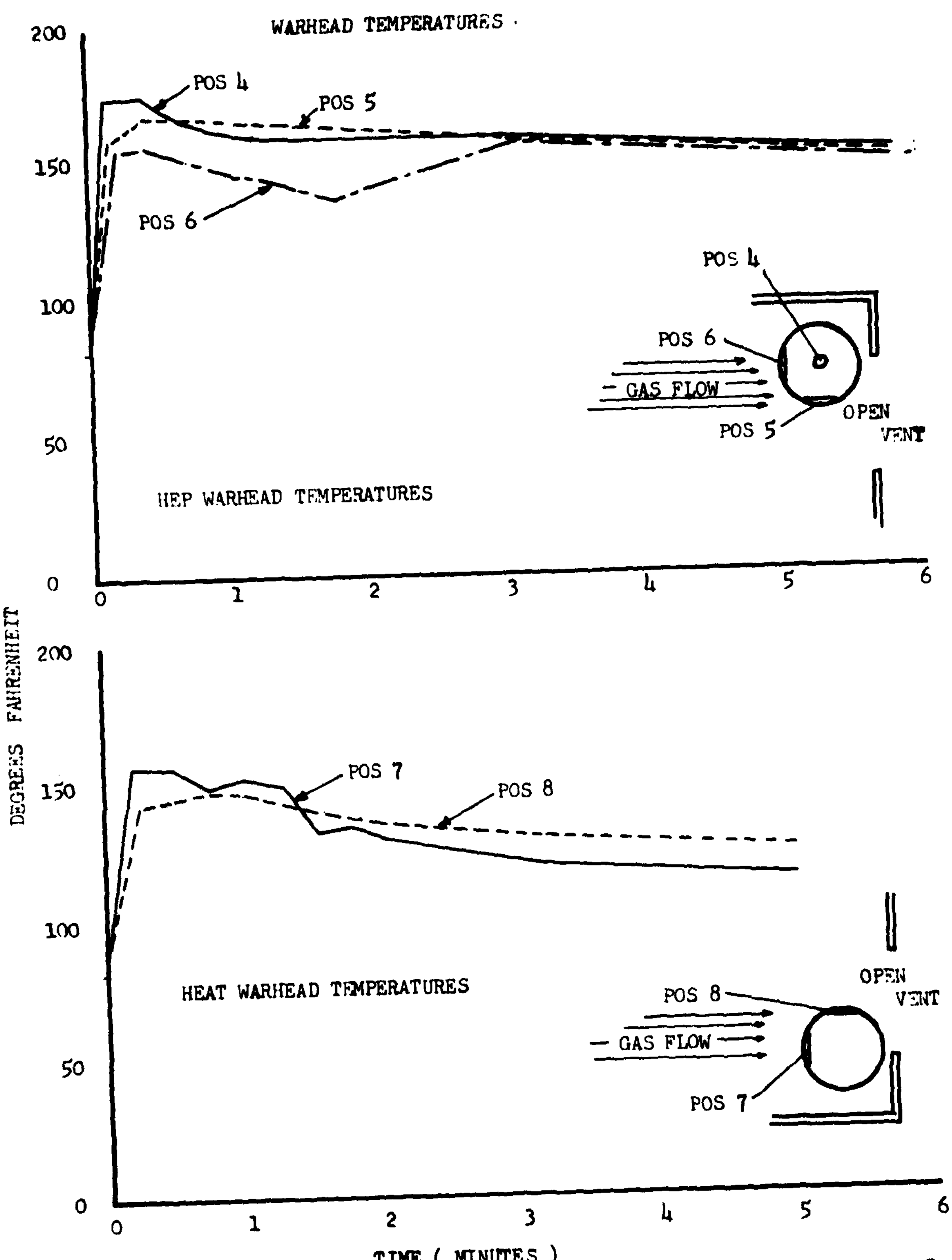


Figure A-29 HEP and HEAT Warhead Temperature Time Histories - Test No. 7

VIII. BRL PROPELLANT TEST NO. 8

Date: 2 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 1 inch into the residual stack of RHA.

The projectile from the live propellant round was separated from its cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was in two pieces. The cartridge cases of the dummy rounds containing the thermocouples were dented, but not perforated. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 131 psi and 179 psi and those on the door 668 psi and 538 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 230 psi and 250 psi, and crush gauges located in the rear, 400 psi and 500 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 800 psi in the nose and 1400 psi in the base. A maximum temperature of 433°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 140° and 203°F, repectively.

The average jet-tip velocity as measured with the velocity screens between points A and B was 3.75mm/μsec; between A and D, 3.4mm/μsec; and between A and E, 3.2mm/μsec.

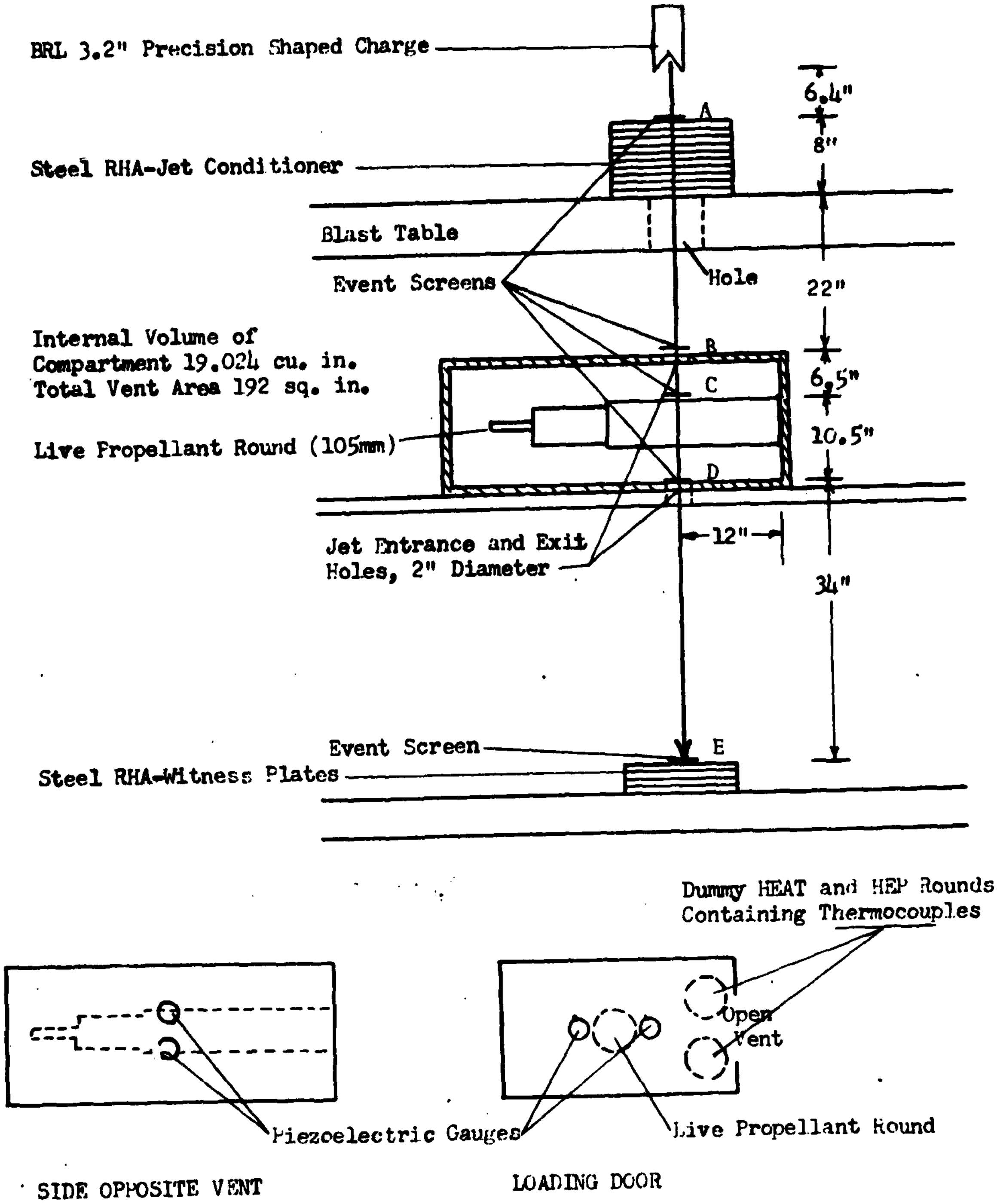
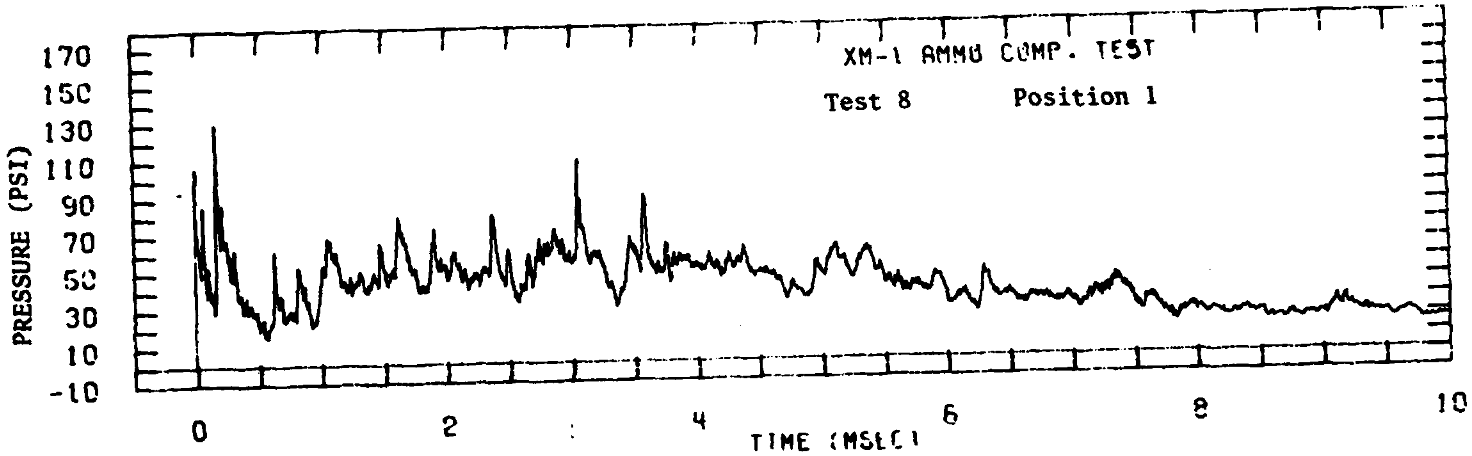


Figure A-30 Test Setup for Propellant Test No. 8



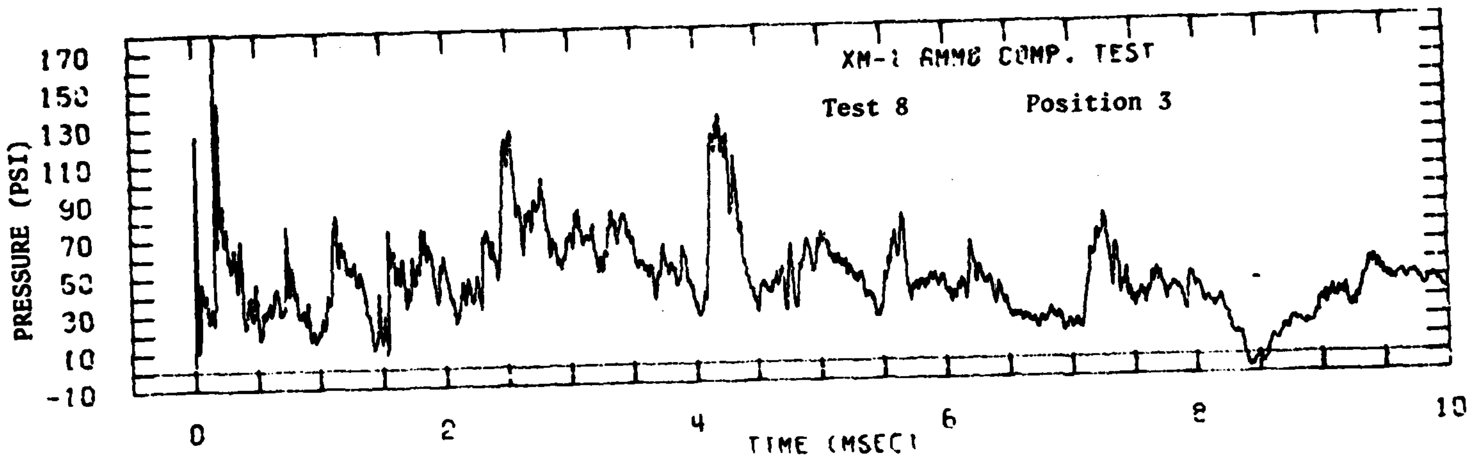


Figure A-31 Pressure Time Histories on Compartment Wall - Test No. 8

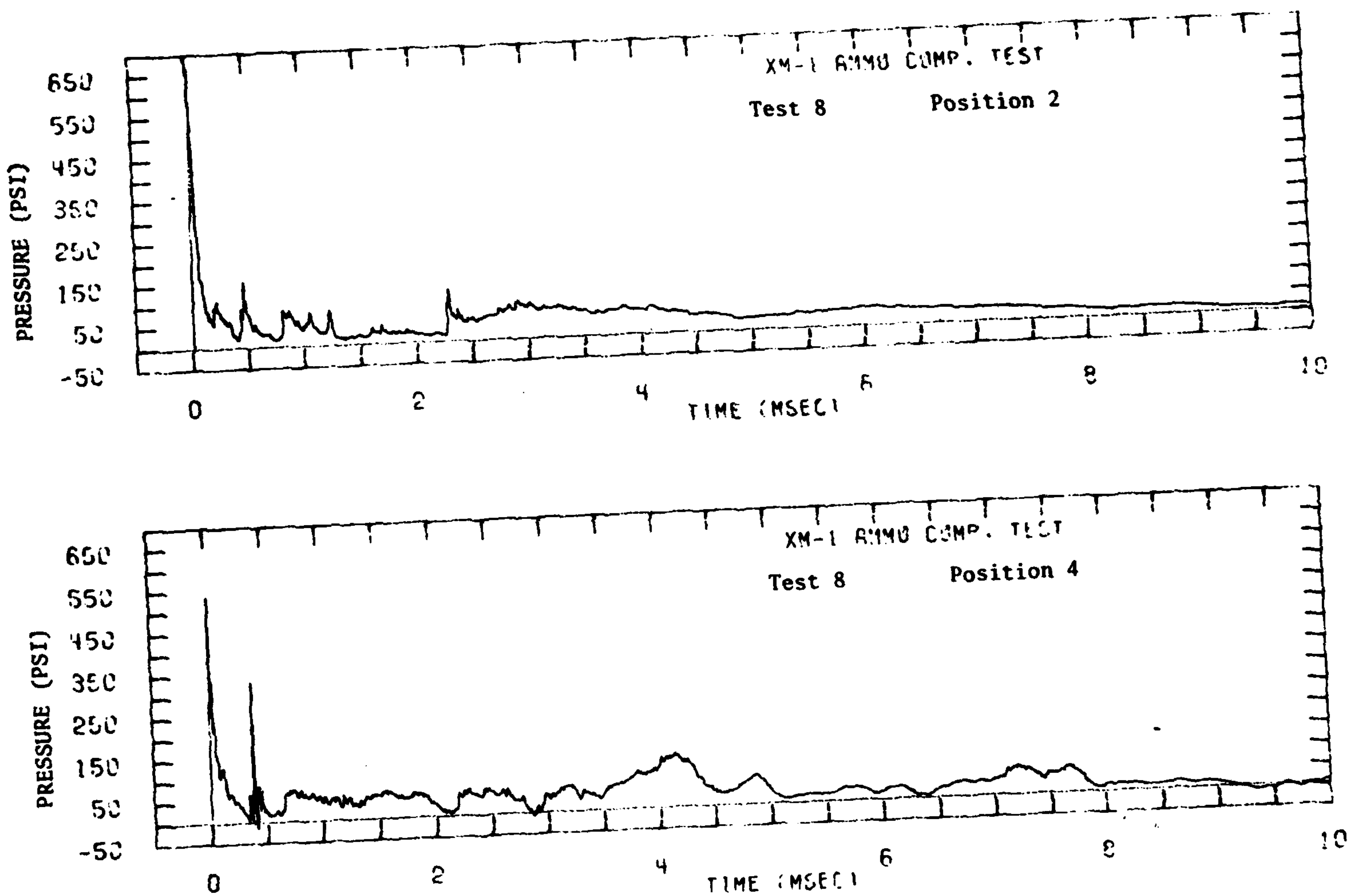


Figure A-32 Pressure Time Histories on Loading Door - Test No. 8

CARTRIDGE CASE TEMPERATURES

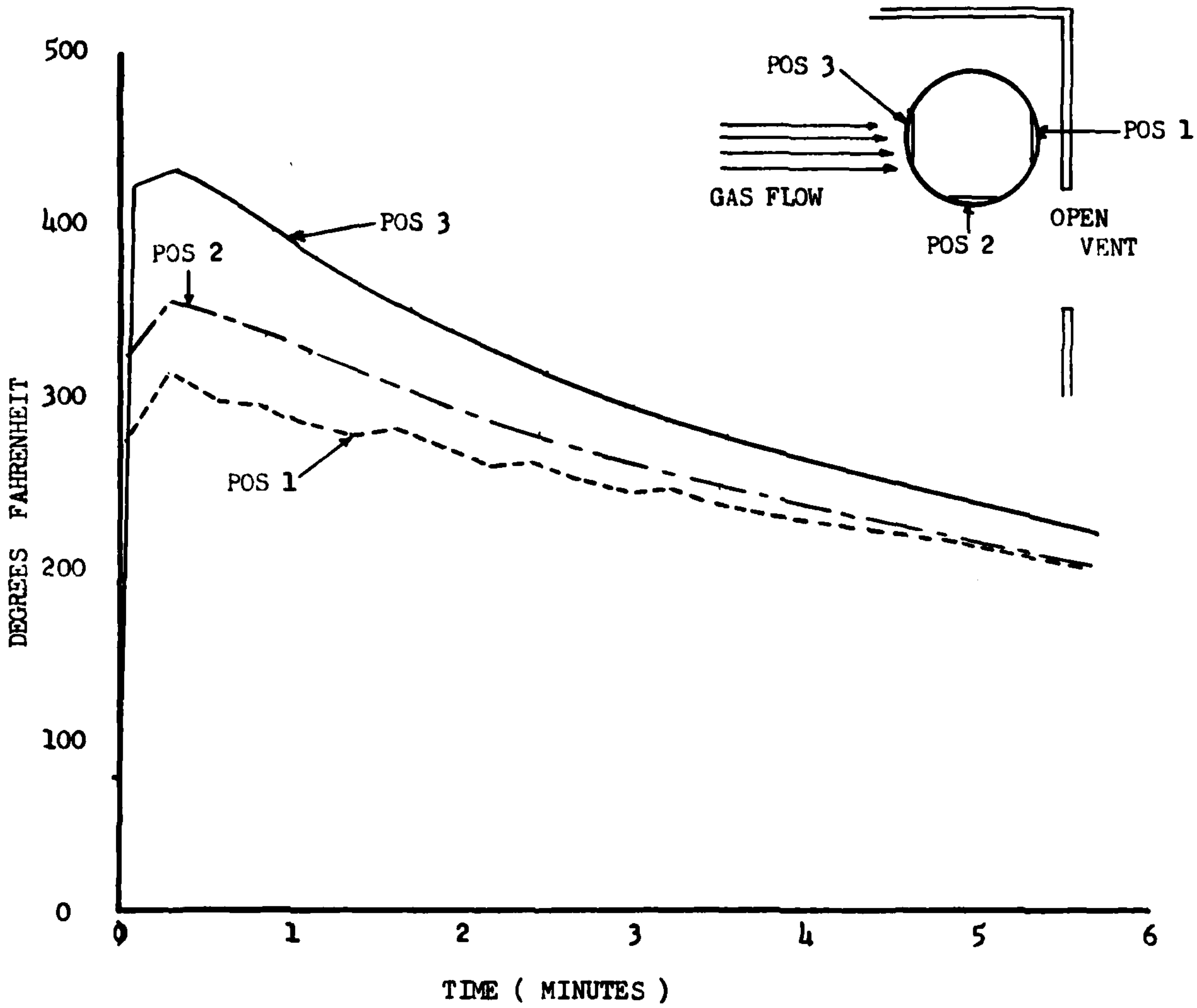


Figure A-33 Cartridge Case Temperature Time Histories - Test No. 8

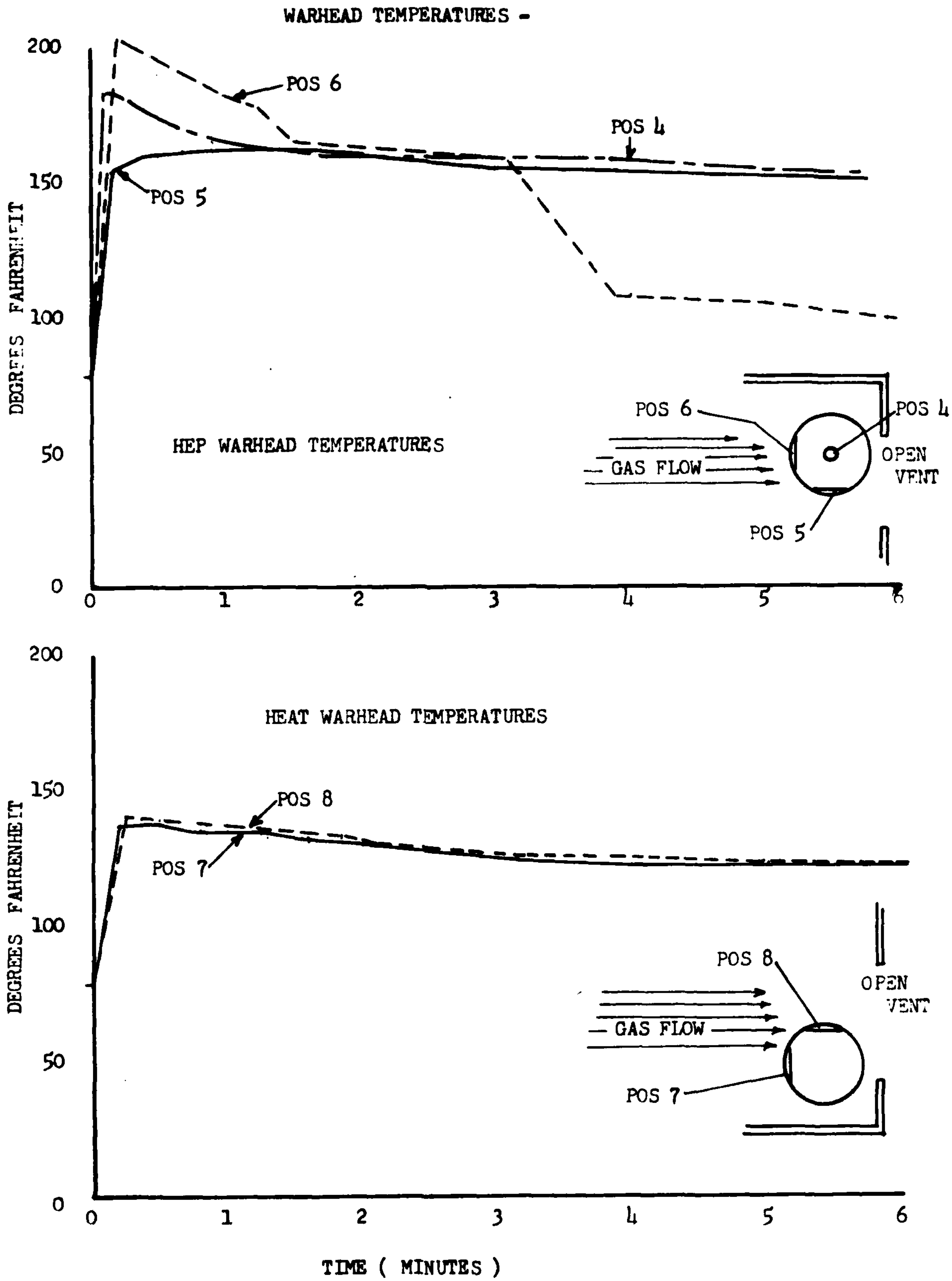


Figure A-34 HEP and HEAT Warhead Temperature Time Histories - Test No. 8

IX. BRL PROPELLANT TEST NO. 9

Date: 6 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 6-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

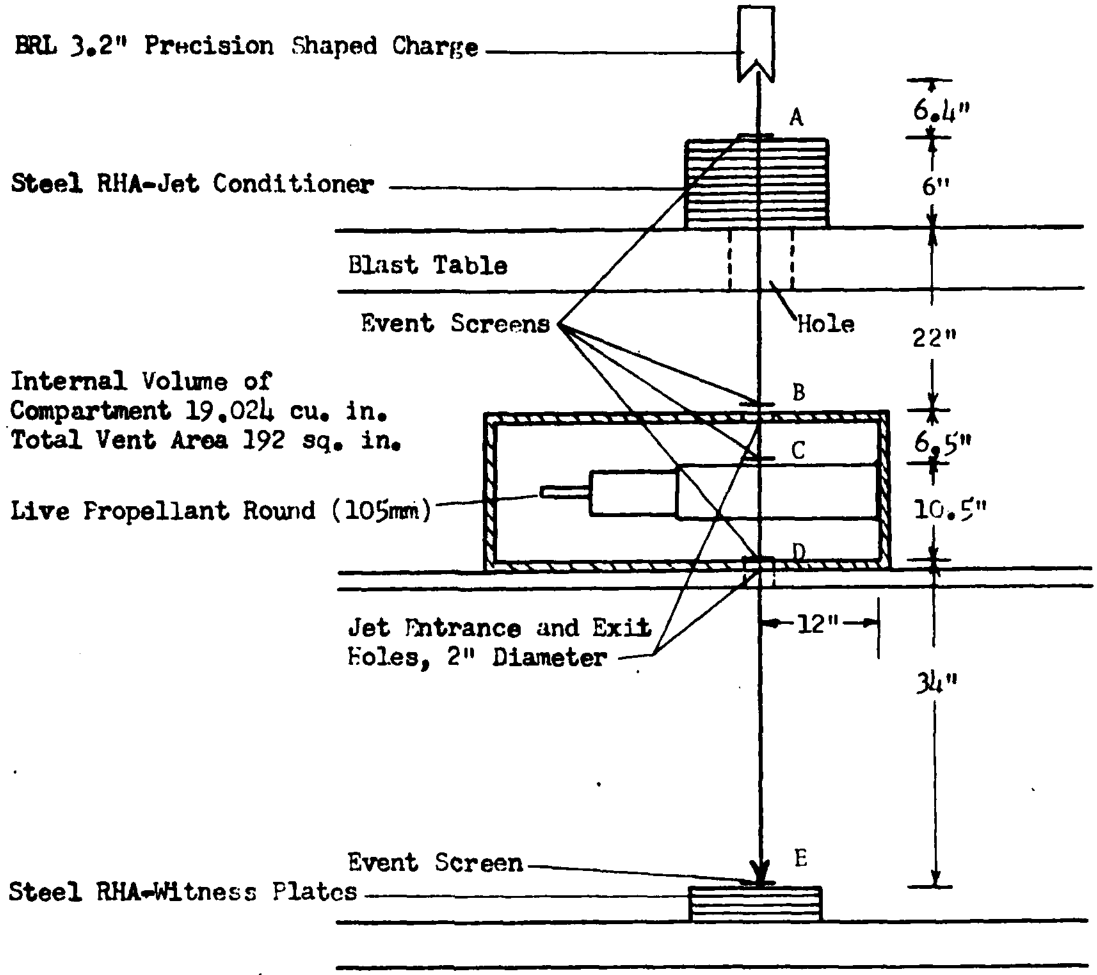
The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) missing the primer; it then exited the compartment and penetrated 1 inch into the residual stack of RHA.

The projectile was separated from the live propellant cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was bent and split open. The cartridge cases containing the thermocouples were dented, but not perforated. There was no damage to the compartment.

The piezoelectric transducers mounted on the side of the compartment recorded peak pressures of 329 psi and 220 psi; and those on the door, 531 psi and 616 psi. The mechanical crush gauges located in the front of the compartment recorded pressures of 280 psi and 510 psi, and crush gauges located in the rear, 215 psi and 385 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 3600 psi in the nose and 3200 psi in the base. A maximum temperature of 567°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 146° and 180°F, respectively.

The event screens failed to function properly.



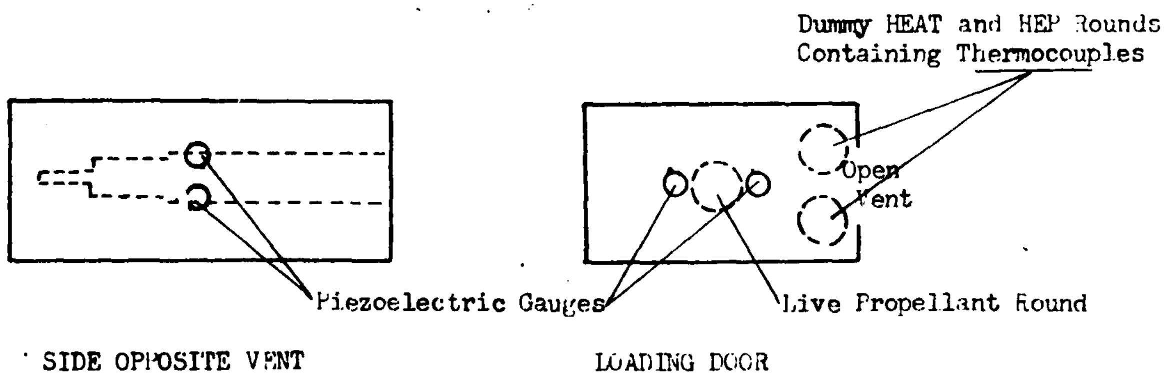


Figure A-35 Test Setup for Propellant Test No. 9

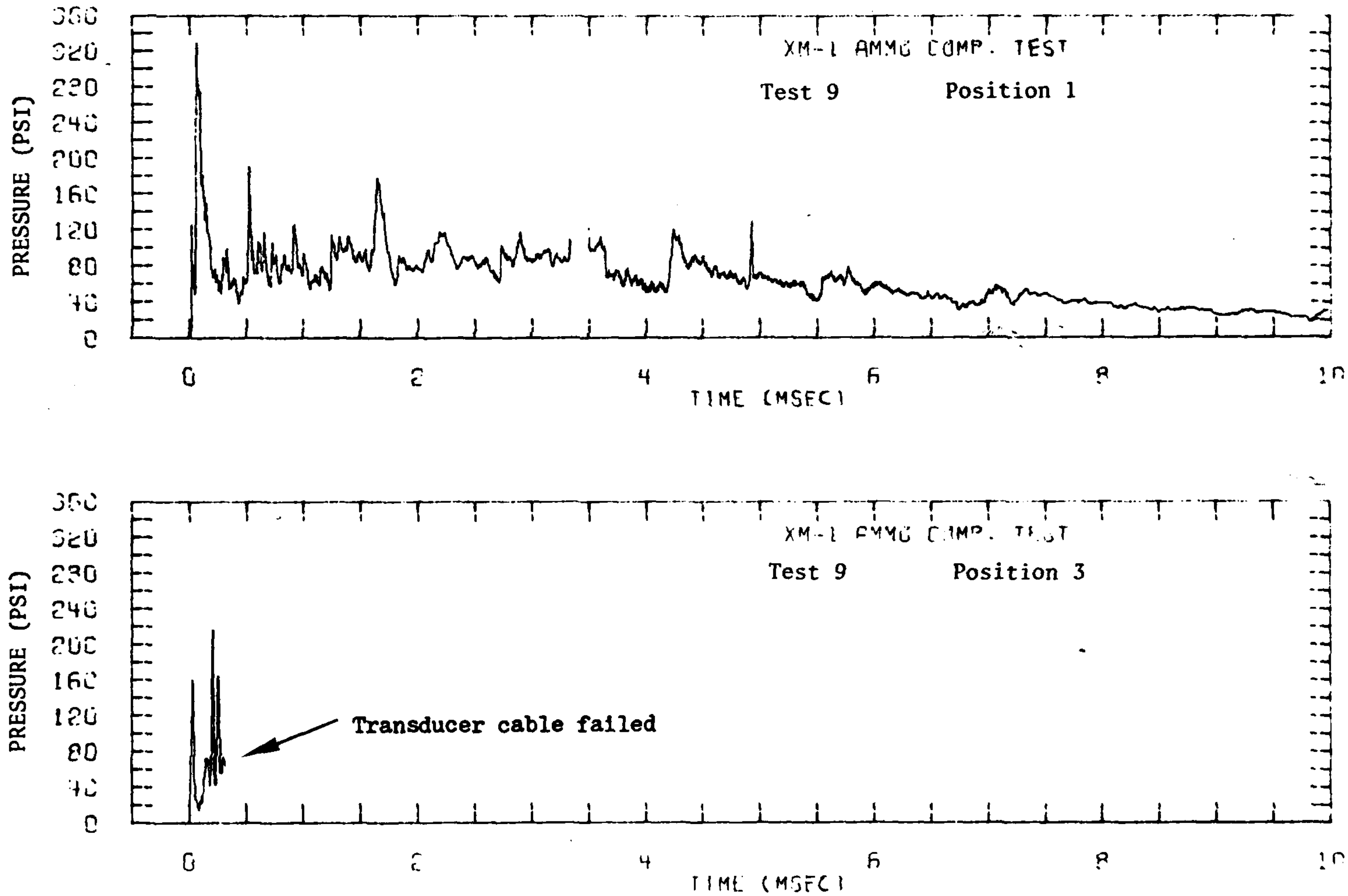


Figure A-36 Pressure Time Histories on Compartment Wall - Test No. 9

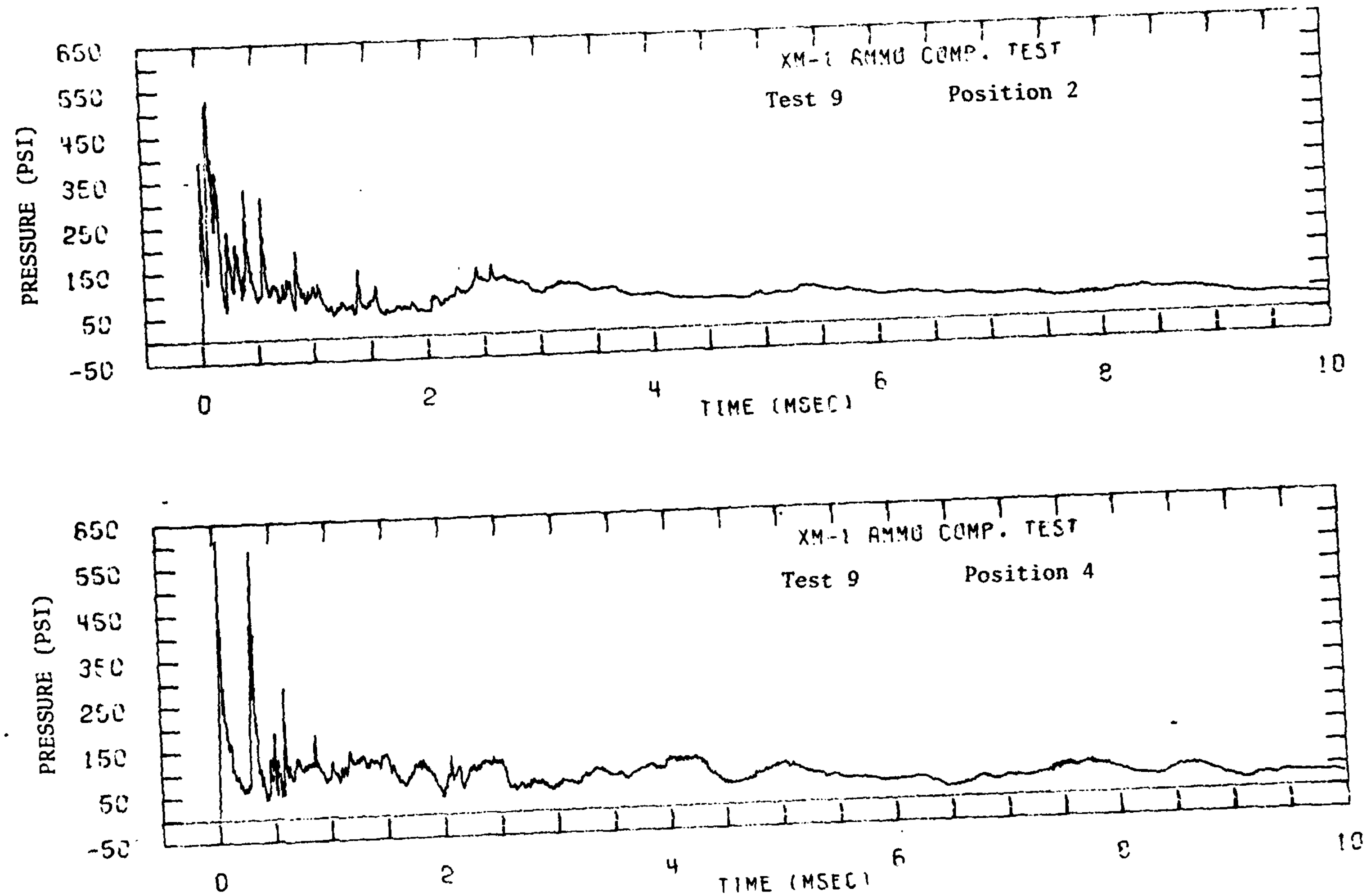


Figure A-37 Pressure Time Histories on Loading Door - Test No. 9

CARTRIDGE CASE TEMPERATURES -

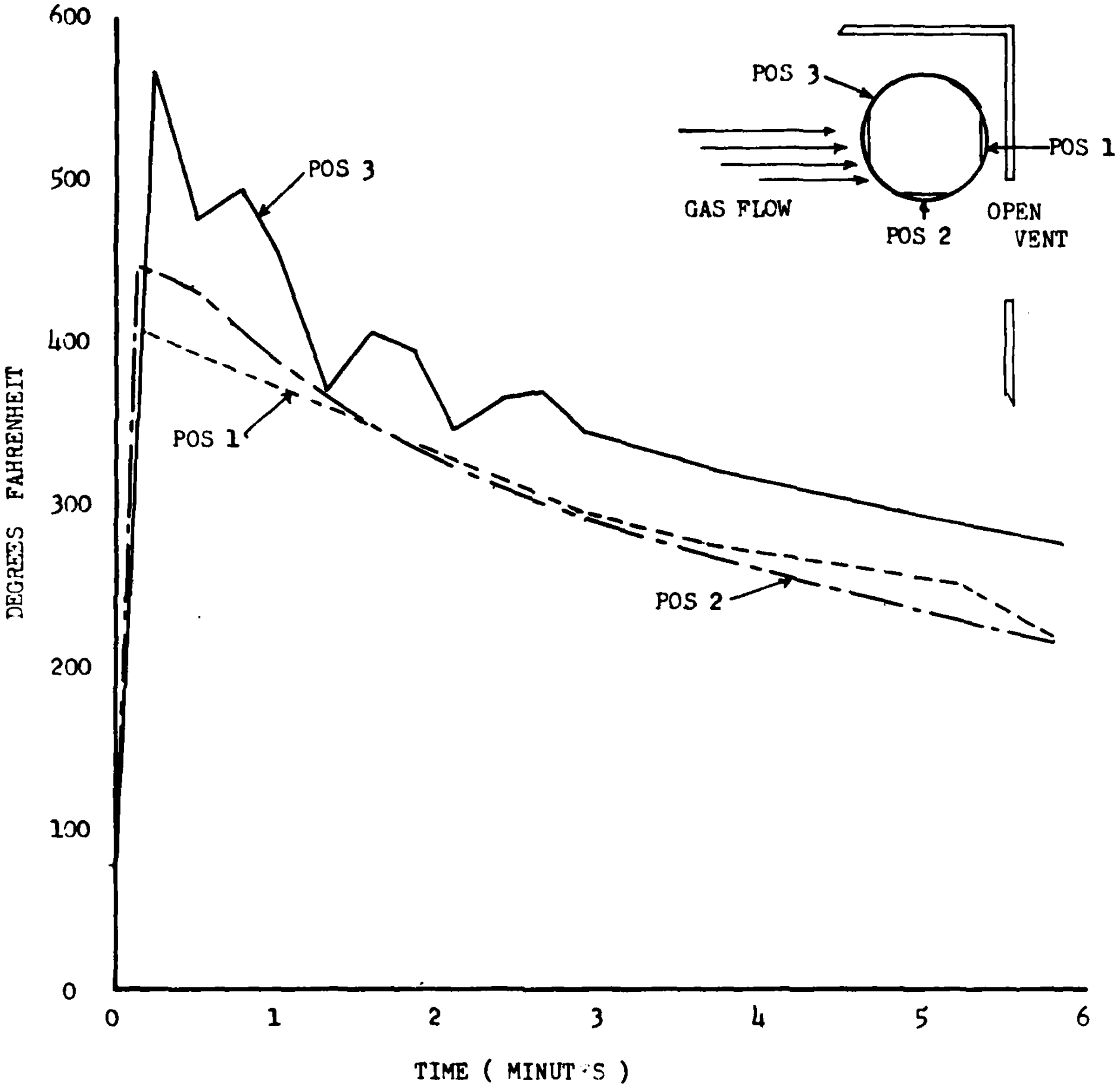
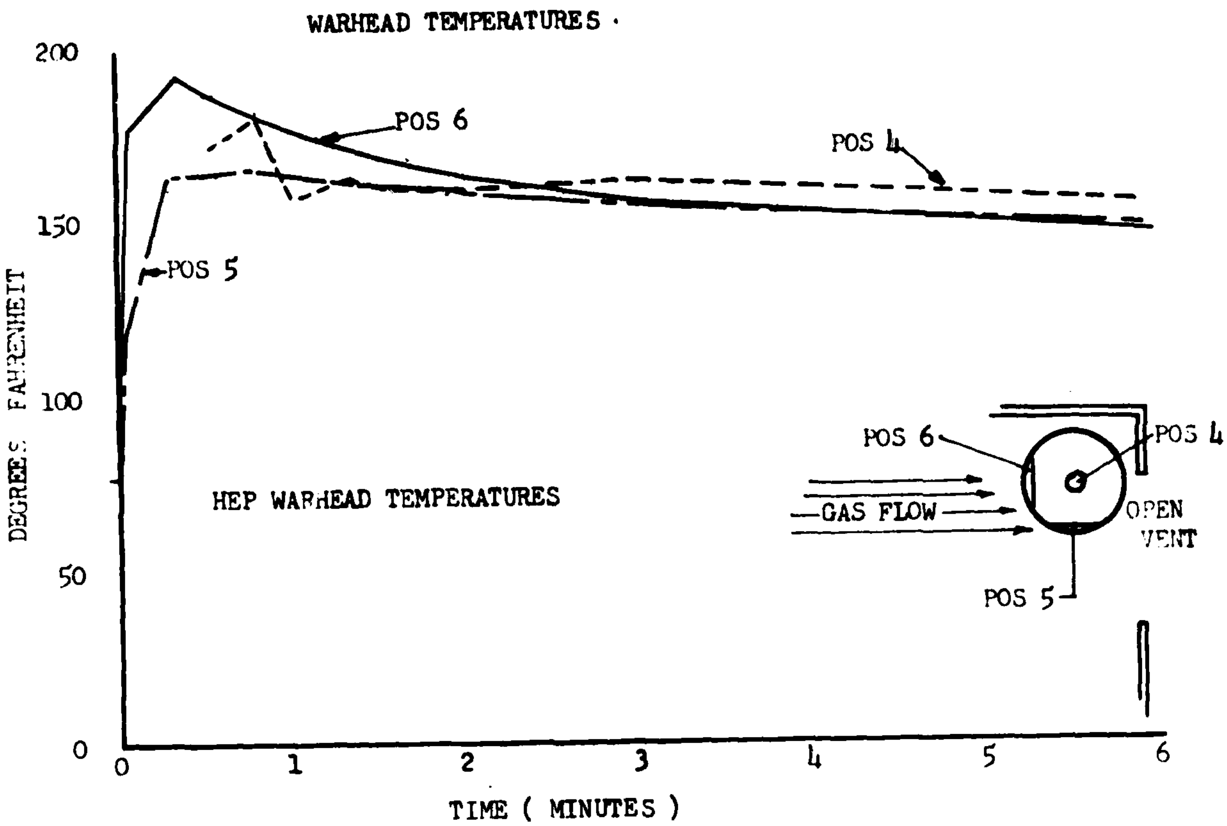


Figure A-38 Cartridge Case Temperature Time Histories - Test No. 9



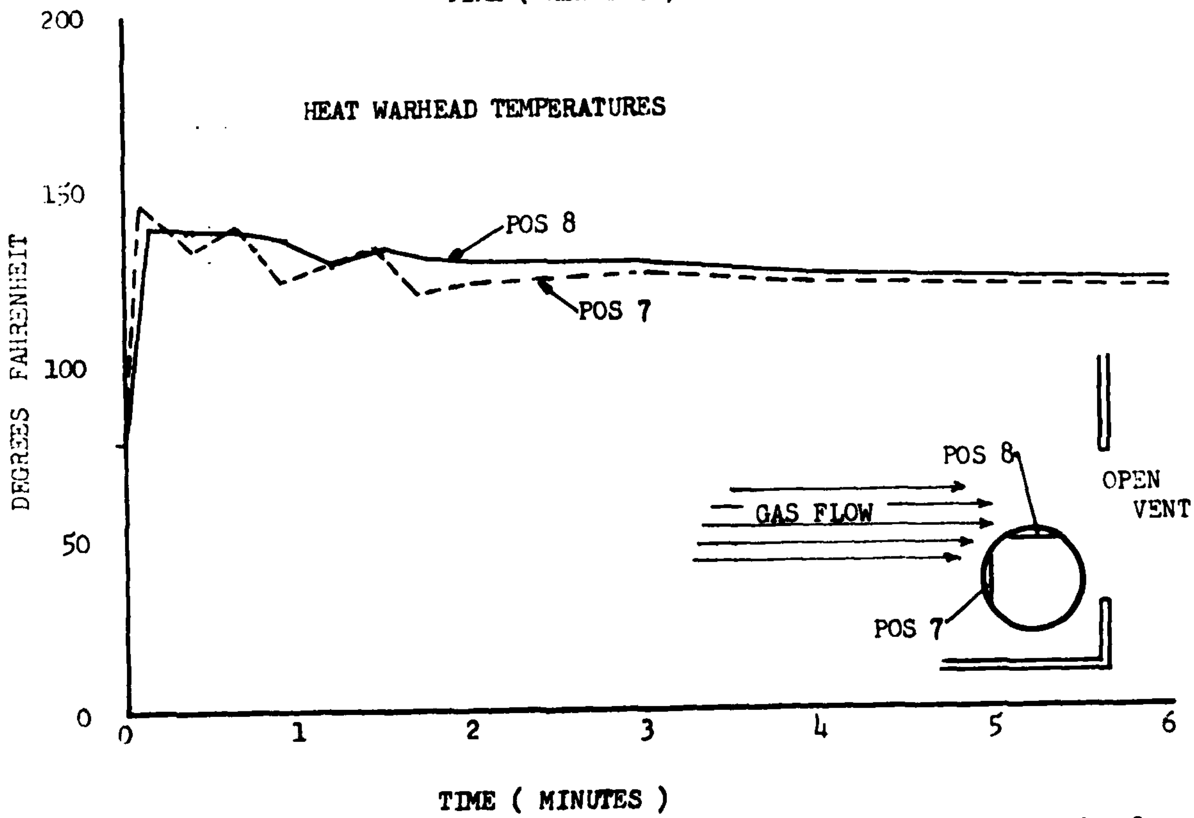


Figure A-39 HEP and HEAT Warhead Temperature Time Histories - Test No. 9

X. BRL PROPELLANT TEST NO. 10

Date: 8 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 6-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

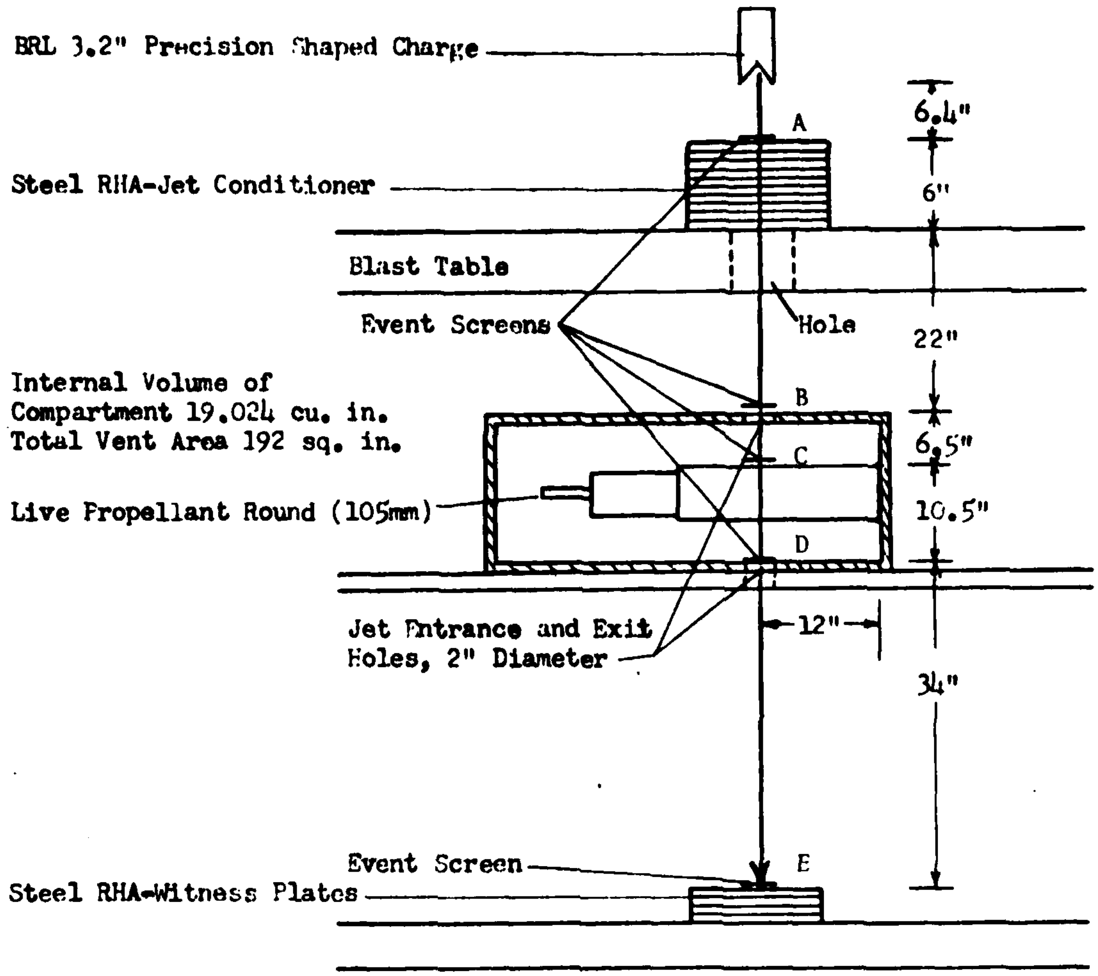
The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) missing the primer; it then exited the compartment and penetrated 7/8 inch into the residual stack of RHA.

The projectile was separated from the live propellant cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. A portion of the cartridge case was jammed in the jet exit hole in the bottom of the compartment. The primer was bent and split open. The cartridge cases containing the thermocouples were dented, but not perforated. There was no damage to the compartment.

The piezoelectric transducers mounted on the side of the compartment recorded peak pressures of 268 psi and 213 psi; those on the door, 912 psi and 502 p i. The mechanical crush gauges located in the front of the compartment recorded pressures of 310 psi, 750 psi, and 1780 psi. The crush gauge at the rear recorded a pressure of 210 psi.

Mechanical crush gauges in the live propellant cartridge case recorded pressures of 2300 psi in the nose and 1777 psi in the base. A maximum temperature of 420°F was recorded in the HEP round cartridge case. Maximum temperatures recorded in the inert HEAT and HEP warheads were 138° and 171°F, respectively.

The event screens failed to function.



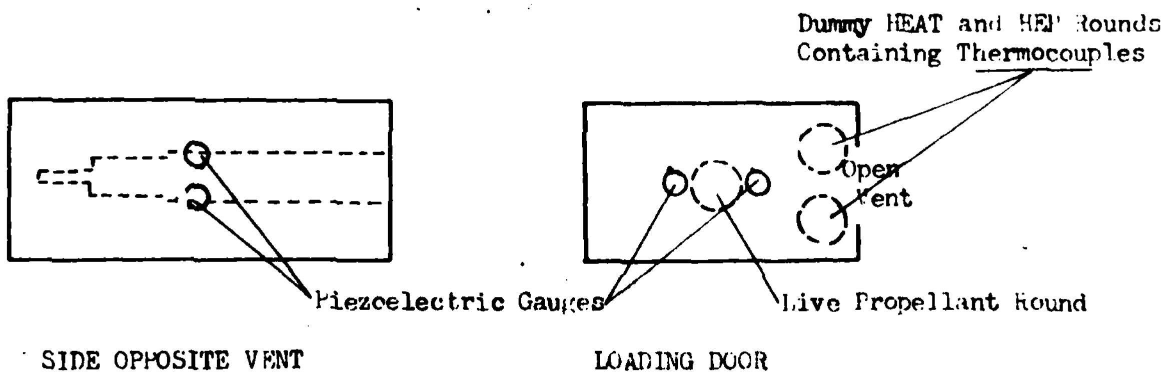


Figure A-40 Test Setup for Propellant Test No. 10

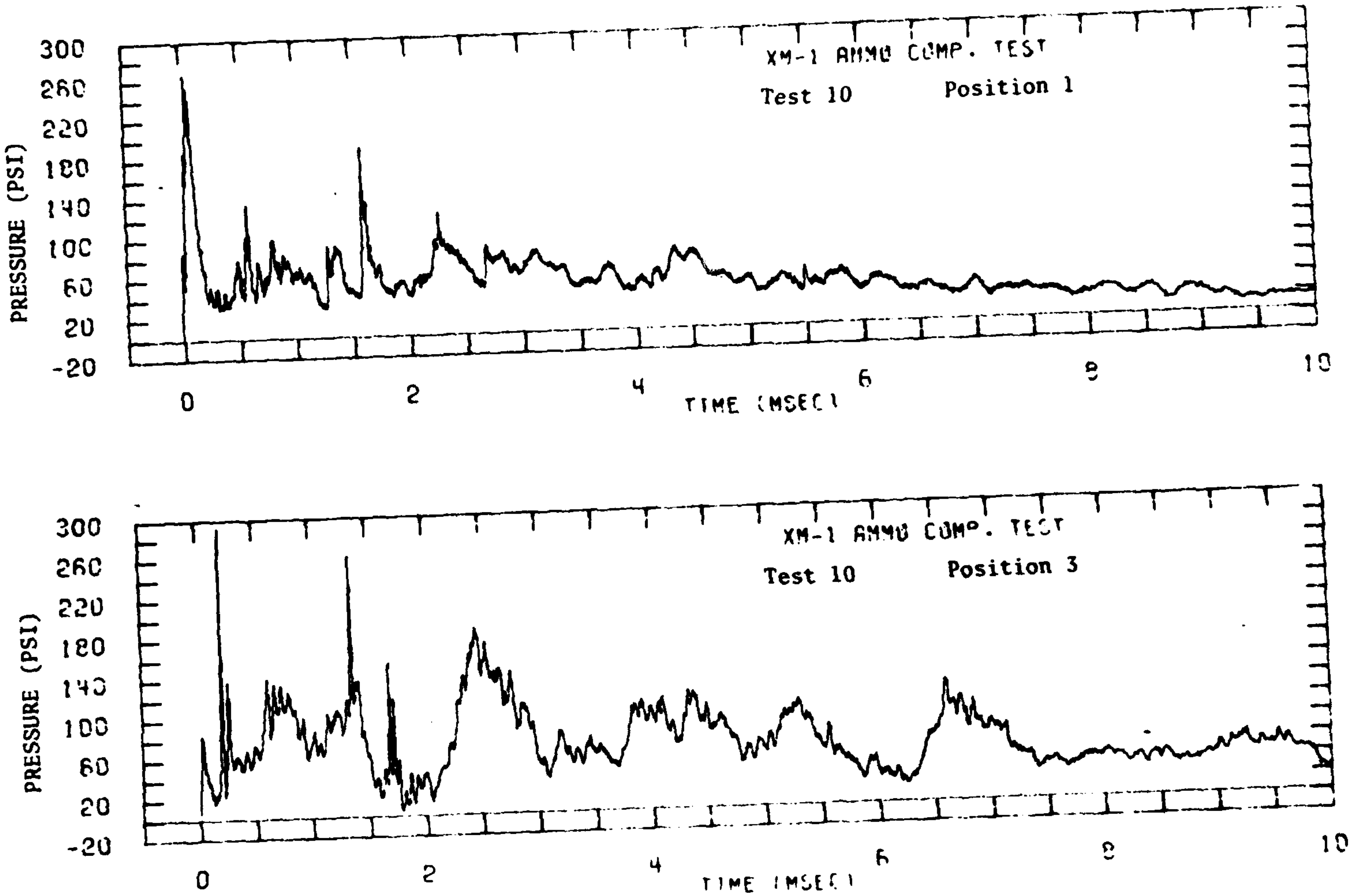


Figure A-41 Pressure Time Histories on Compartment Wall - Test No. 10

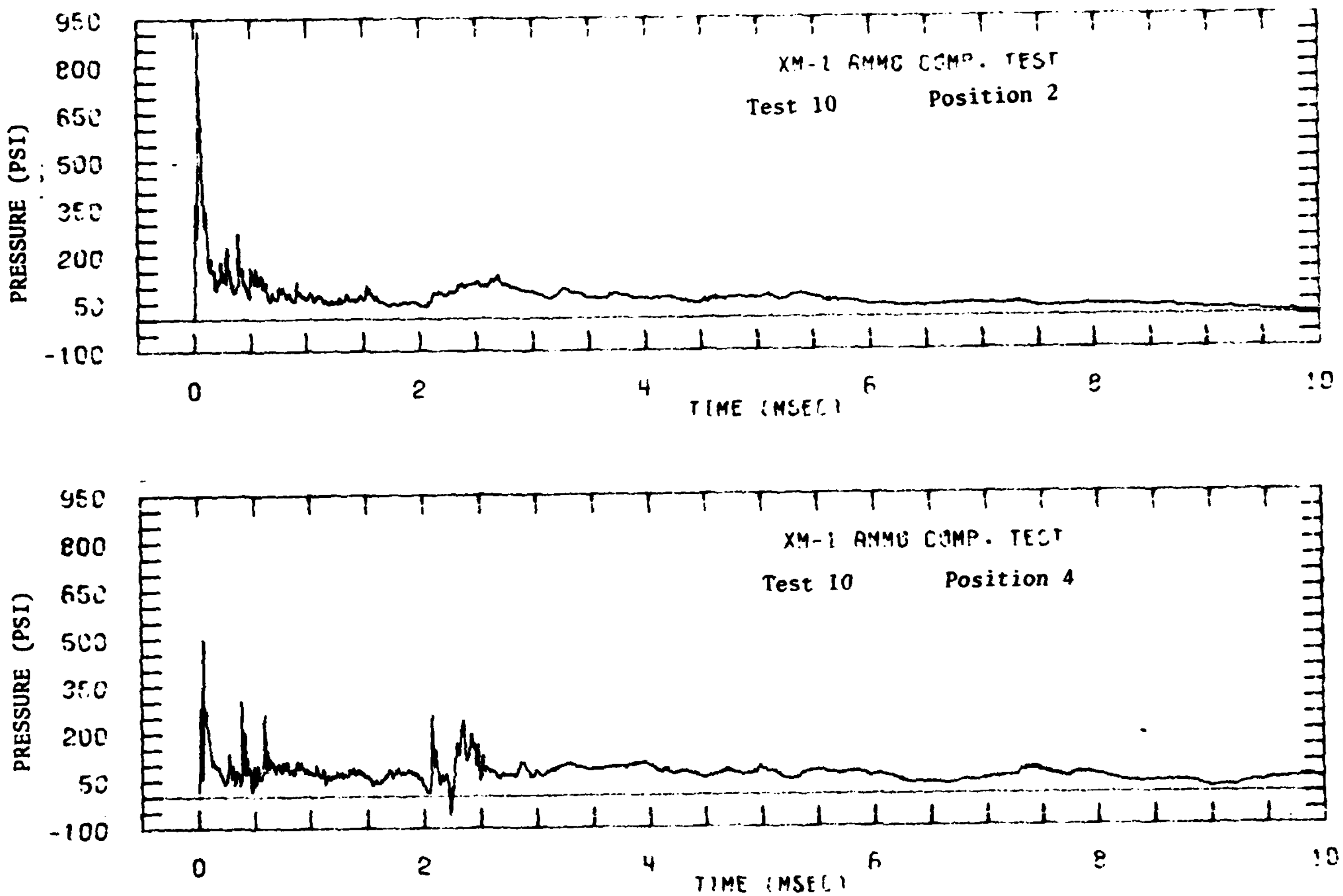


Figure A-42 Pressure Time Histories on Loading Door - Test No. 10

CARTRIDGE CASE TEMPERATURES

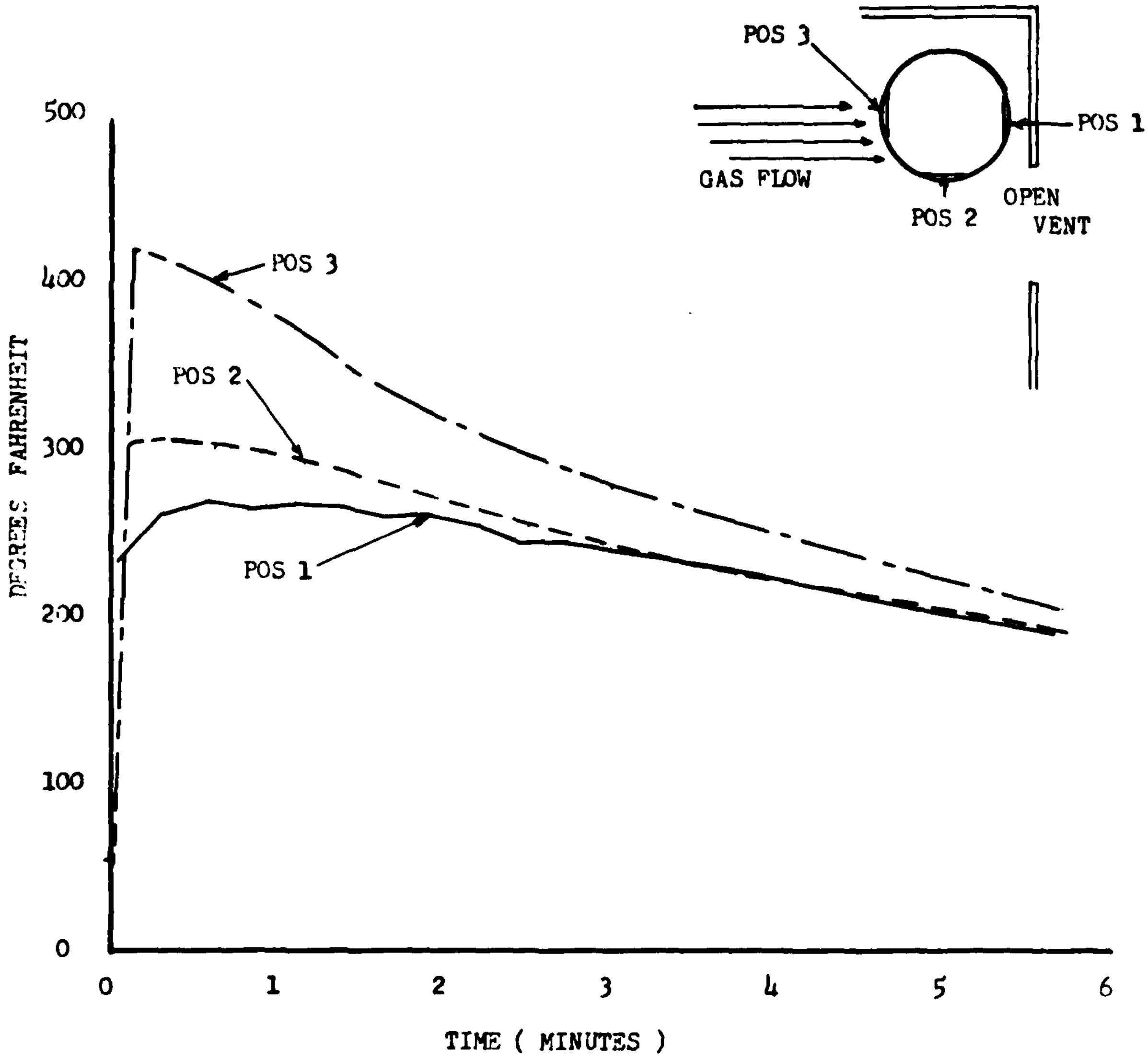


Figure A-43 Cartridge Case Temperature Time Histories - Test No. 10

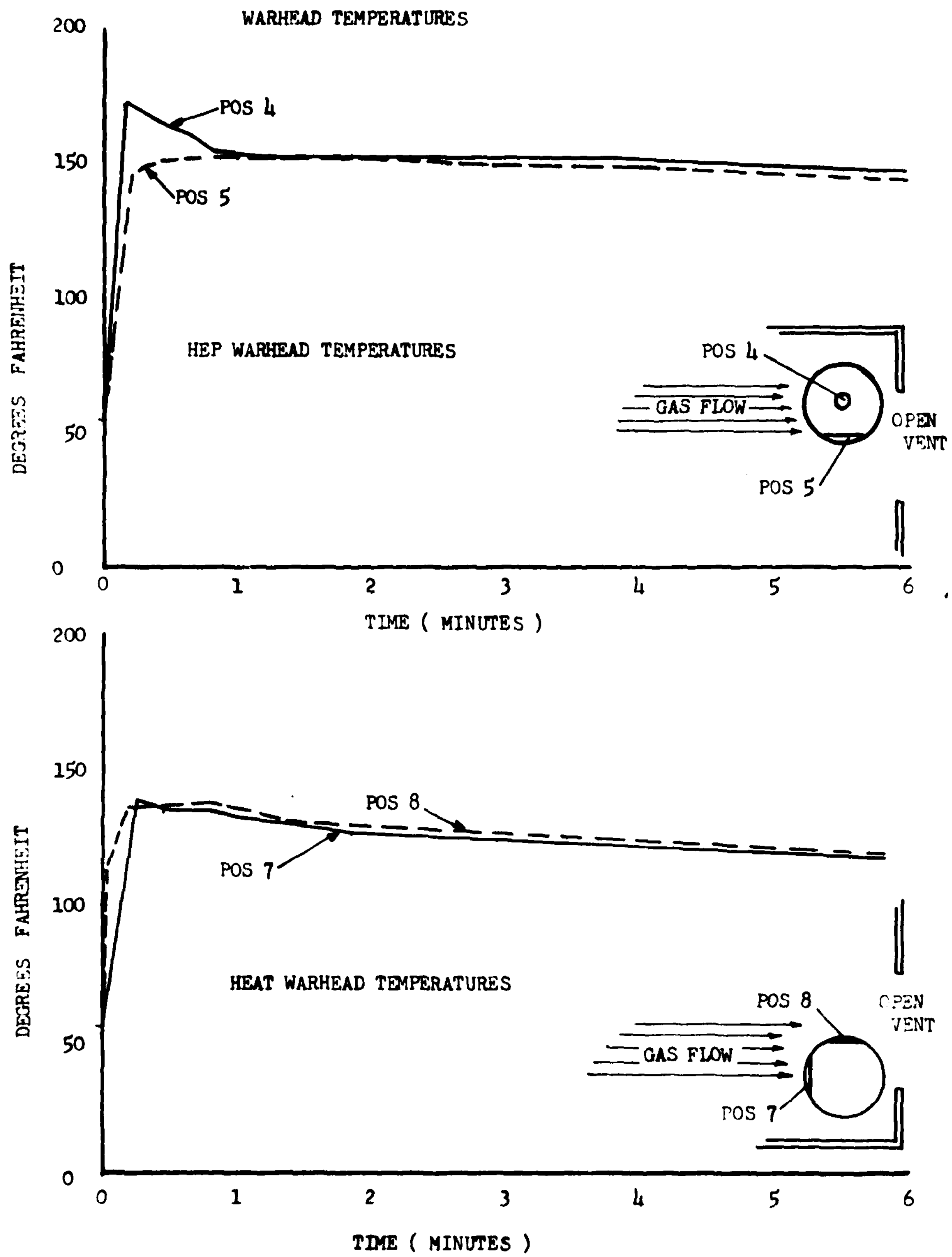


Figure A-44 HEP and HEAT Warhead Temperature Time Histories - Test No. 10

XI. BRL PROPELLANT TEST NO. 11

Date: 20 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 6-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) missing the primer; it then exited the compartment and penetrated 7/8 inch into the residual stack of RHA.

The projectile was separated from the live propellant cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was bent and split open, but still in one piece. There was extensive damage to the cartridge cases containing the thermocouples. The top thermocouple case was cut to the center by a fragment and the thermocouple wires inside were cut and burned. The bottom thermocouple case was badly dented and had two holes in it where a fragment had entered one side of the case and exited the other side. There was no damage to the compartment.

The piezoelectric transducers mounted on the side of the compartment recorded peak pressures of 394 psi and 266 psi; those on the door, 935 psi and 705 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 500 psi and 750 psi, and crush gauges in the rear, 300 psi and 320 psi.

Crush gauges were not placed in the live propellant cartridge case for this test. No temperature records were obtained because the thermocouple wires were burned and cut.

The average jet-tip velocity as measured by the velocity screens between points A and B, was 4.1mm/μsec; between A and D, 3.5mm/μsec; and between A and E, 3.2mm/μsec. The event screen labeled C on top of the live propellant round failed to function properly.

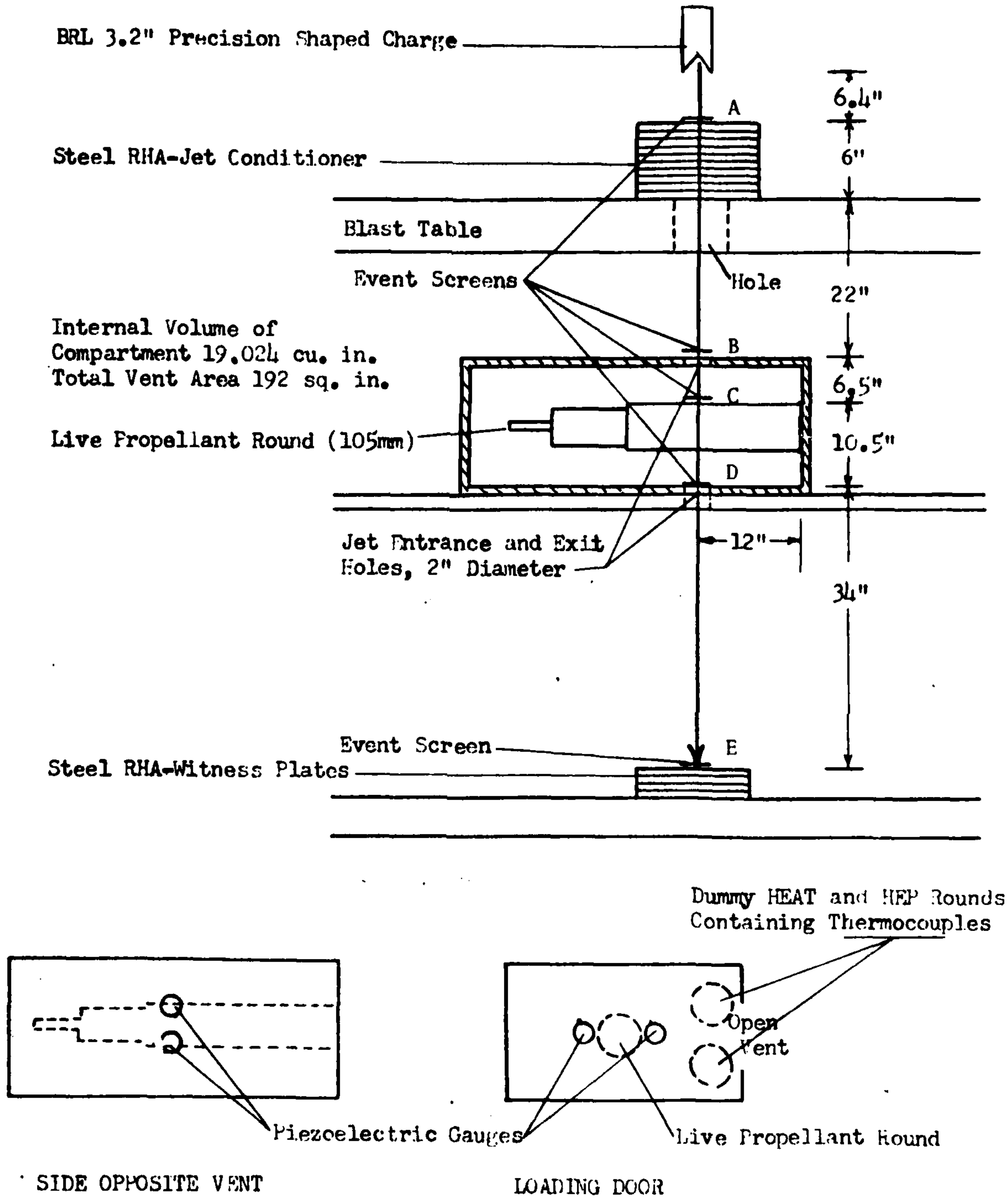


Figure A-45 Test Setup for Propellant Test No. 11

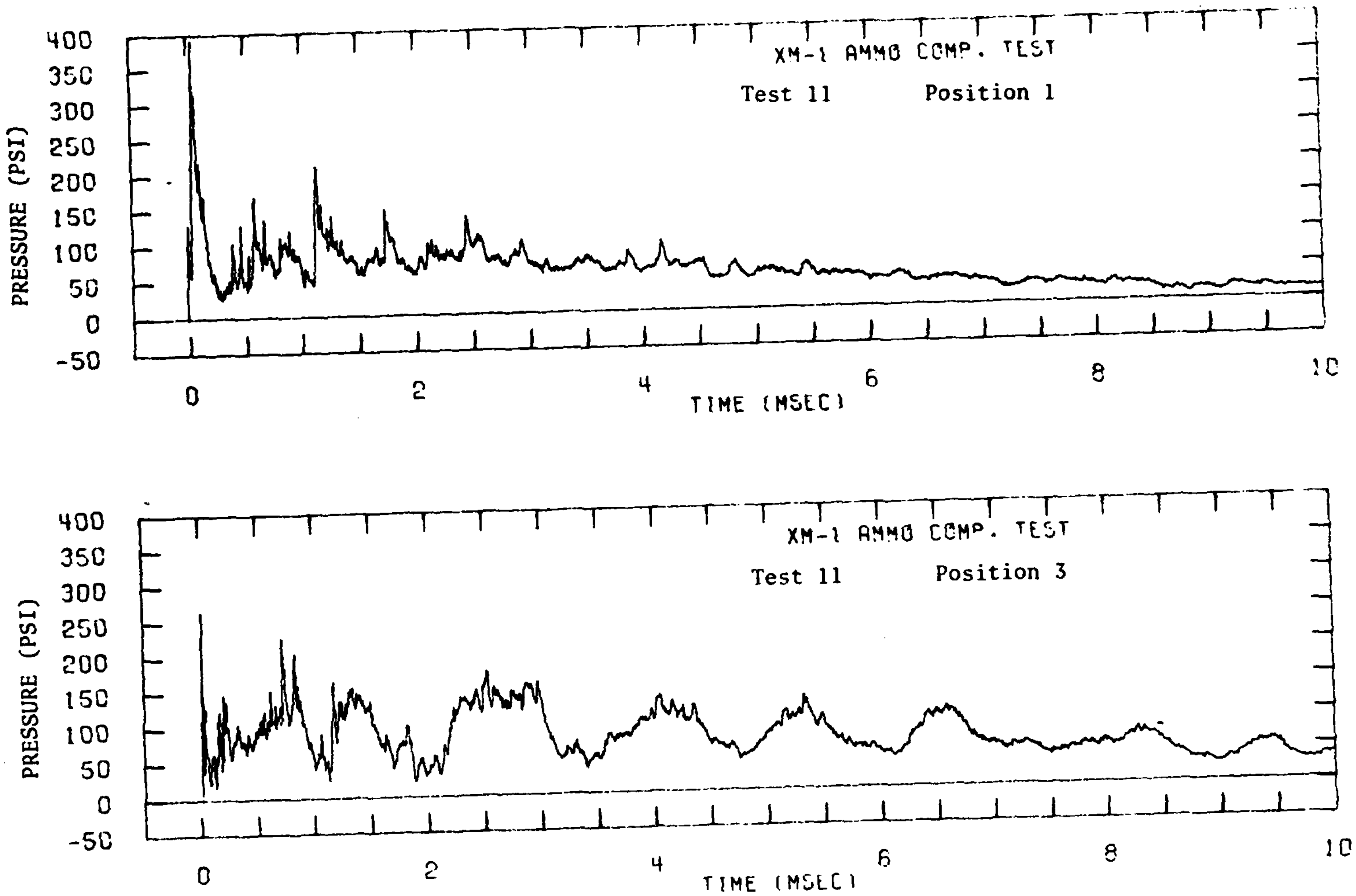


Figure A-46 Pressure Time Histories on Compartment Wall - Test No. 11

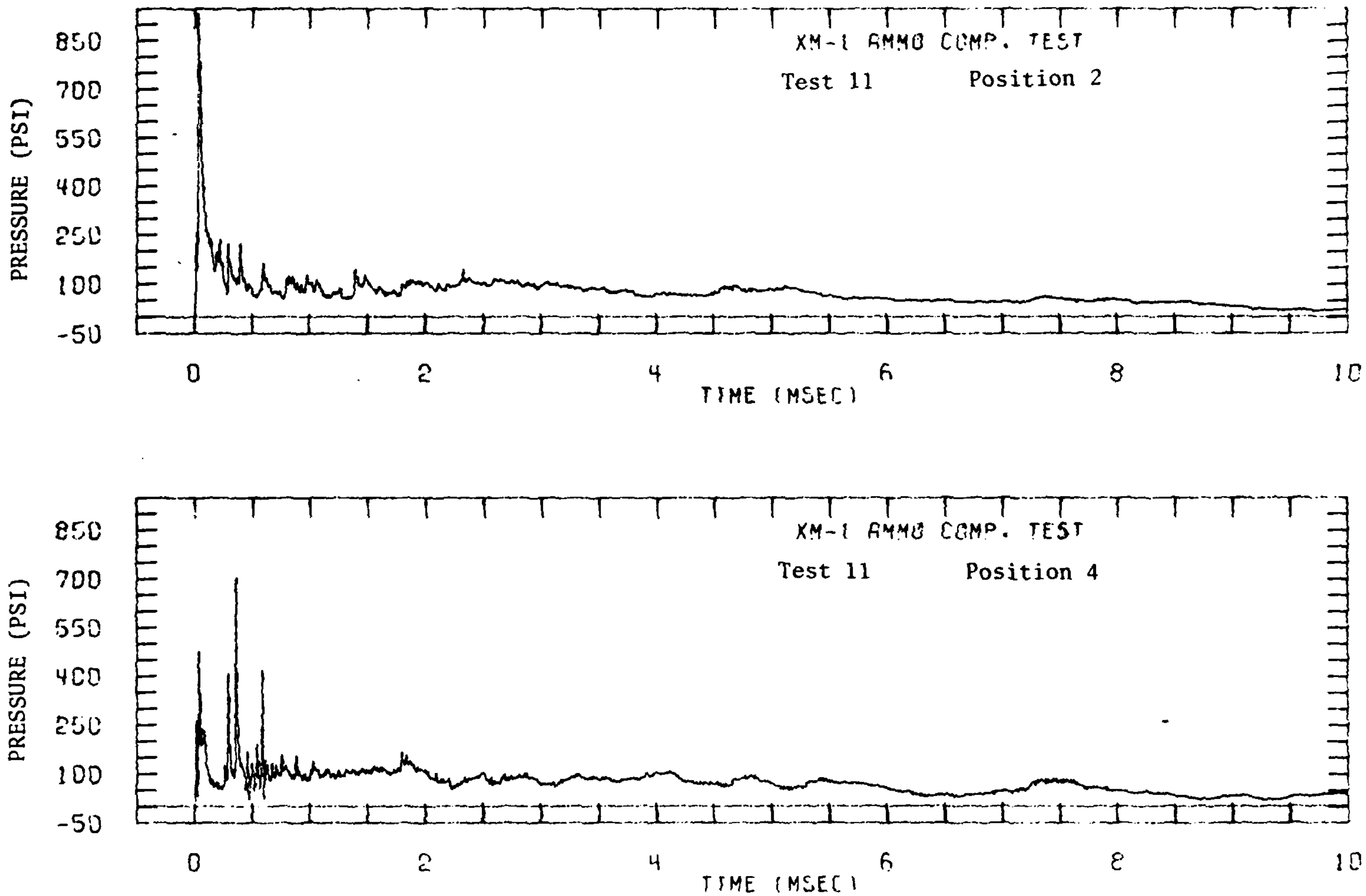


Figure A-47 Pressure Time Histories on Loading Door - Test No. 11

XII. BRL PROPELLANT TEST NO. 12

Date: 26 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 6-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded a combination of piezoelectric transducers, mechanical crush gauges, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 1-3/16 inches into the residual stack of RHA.

The projectile from the live propellant round was separated from its cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was in two pieces. The cartridge cases of the dummy rounds containing the thermocouples were dented and split. There was no damage to the compartment.

The piezoelectric transducers mounted on the side of the compartment recorded peak pressures of 323 psi and 250 psi; those on the door, 1034 psi and 653 psi. The mechanical crush gauge located in the front of the compartment recorded a pressure of 440 psi, and crush gauges located in the rear, 33 psi and 710 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 1900 psi in the nose and 2600 psi in the base.

Temperatures were not recorded, and the event screens failed to function properly.

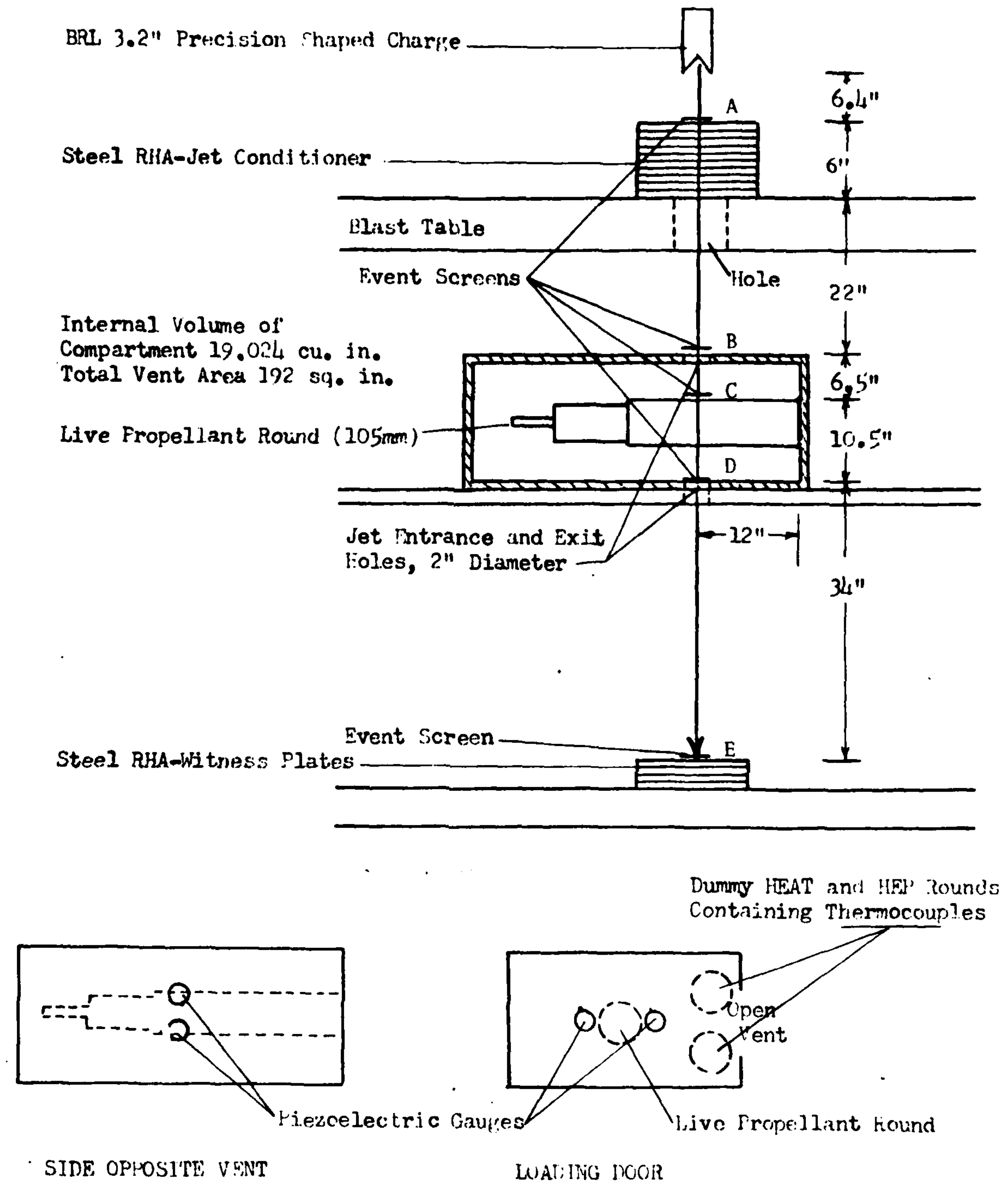


Figure A-48 Test Setup for Propellant Test No. 12

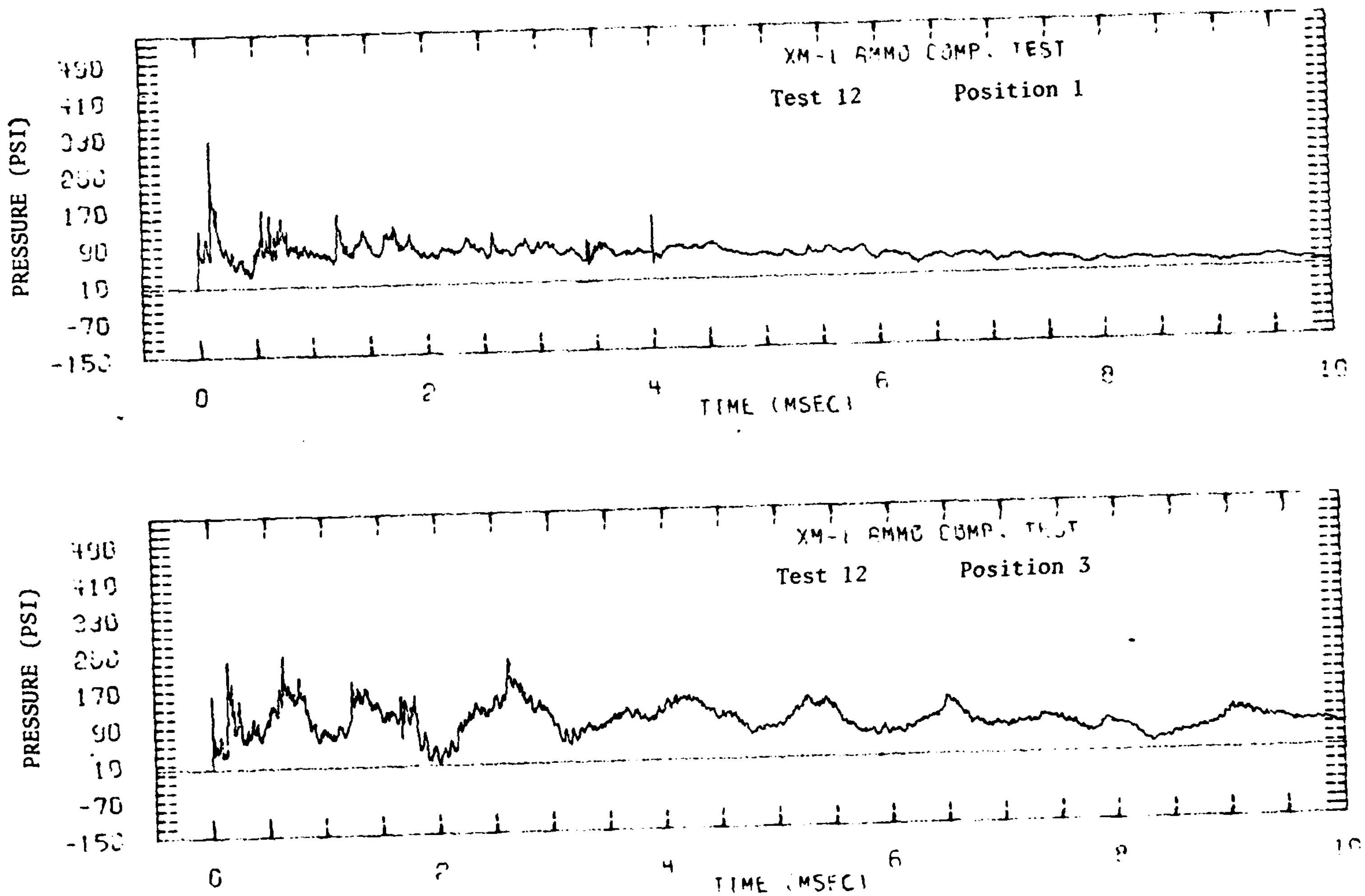


Figure A-49 Pressure Time Histories on Compartment Wall - Test No. 12

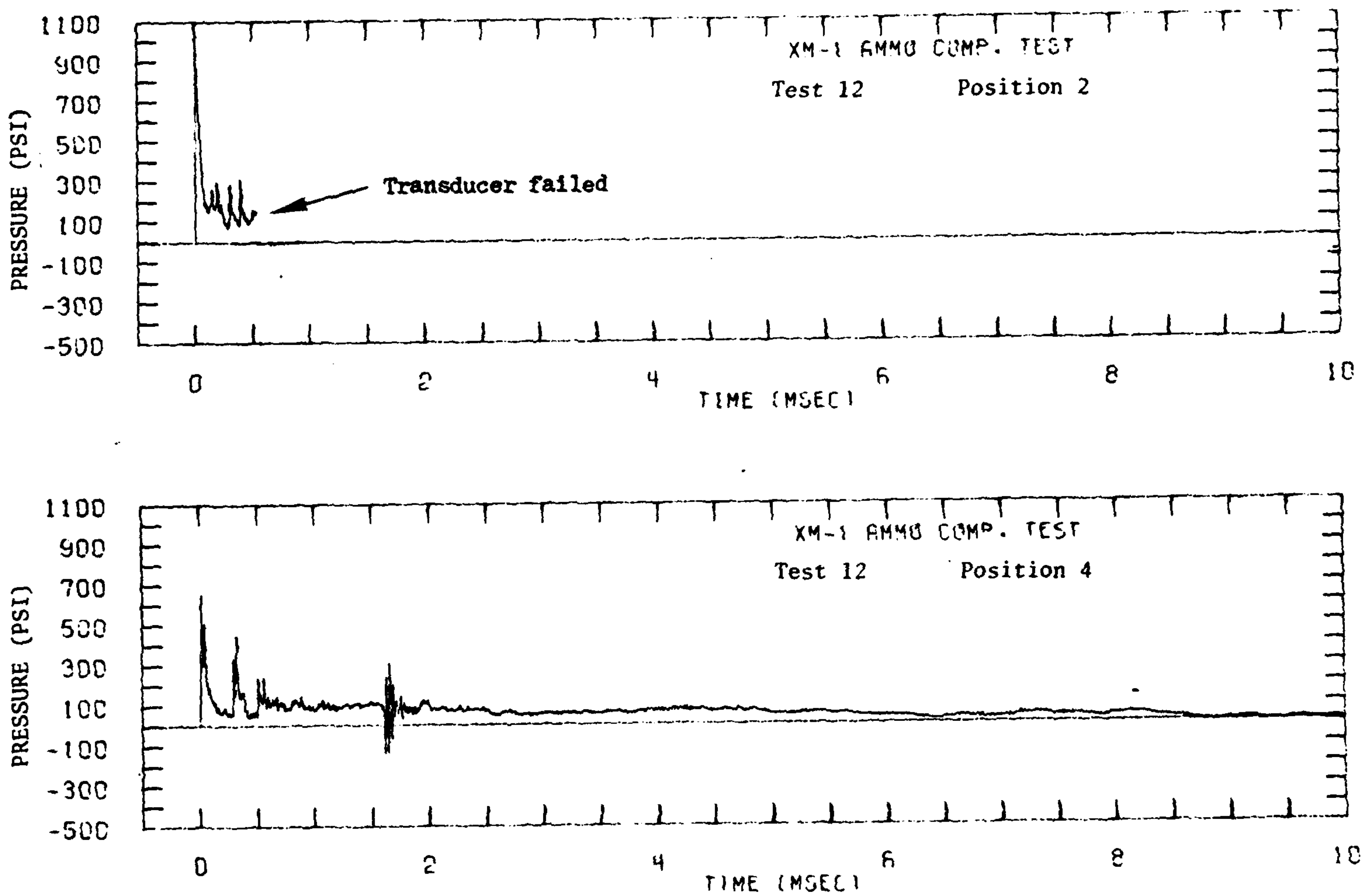


Figure A-50 Pressure Time Histories on Loading Door - Test No. 12

XIII. BRL PROPELLANT TEST NO. 13

Date : 28 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1-to-2-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet so that it grazed the cartridge case of the single, live propellant round stowed in the compartment. The desired environmental conditions were recorded with a combination of piezoelectric gauges, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, grazed the live propellant round on the gauge side of the compartment, exited, and penetrated 1 inch into the steel RHA witness plates.

The projectile from the live propellant round separated from its cartridge case. The cartridge case was torn apart in the area of jet impact; the rest of the case remained intact. There was no damage to the dummy rounds containing the thermocouples nor was there any damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 151 psi and 231 psi; these mounted on the door, 167 psi and 196 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 580 psi, and crush gauges located in the rear, 390 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 300 psi in the nose and 1300 psi in the base. A maximum temperature of 375°F was recoded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 158° and 210°F, respectively.

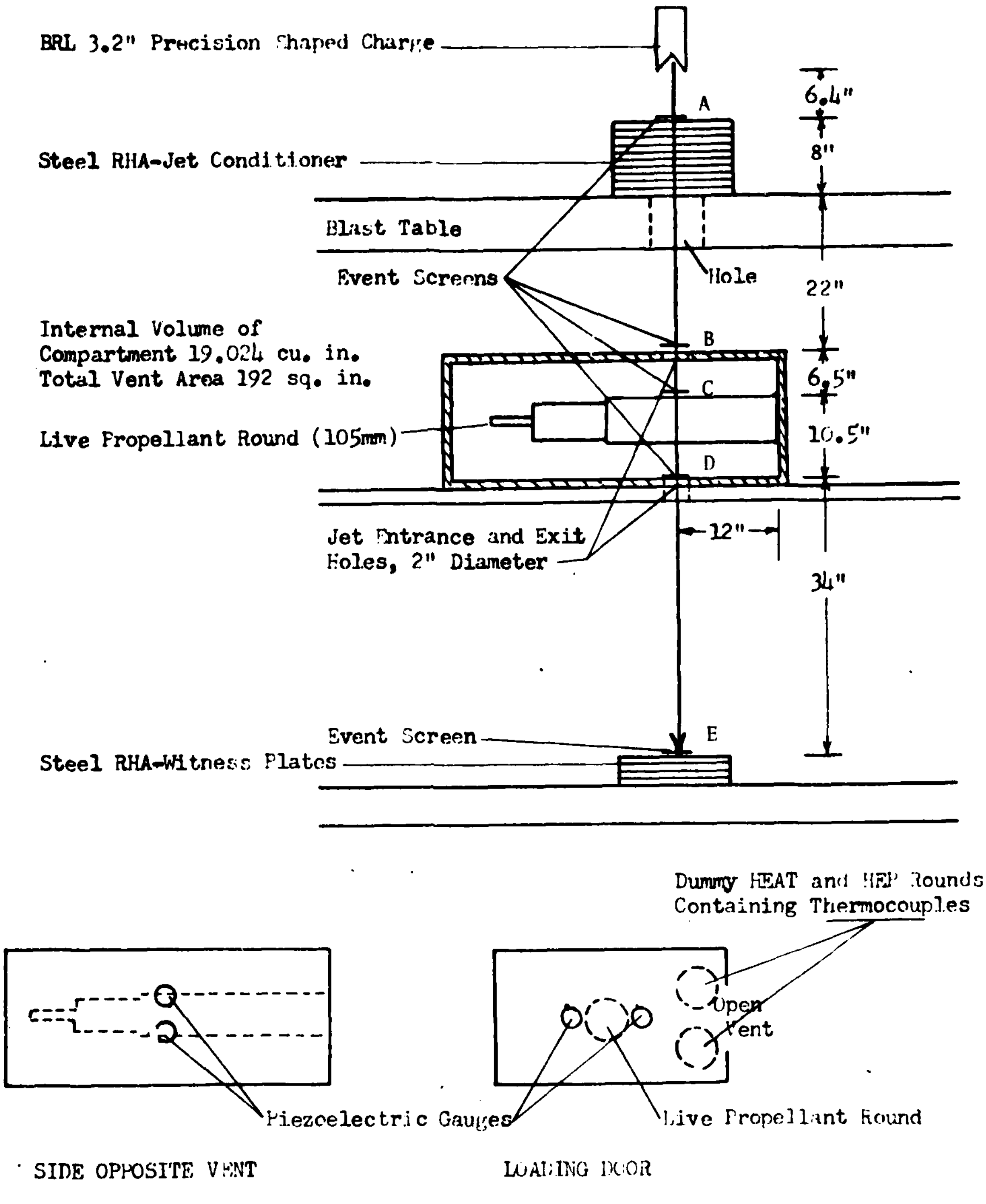


Figure A-51 Test Setup for Propellant Test No. 13

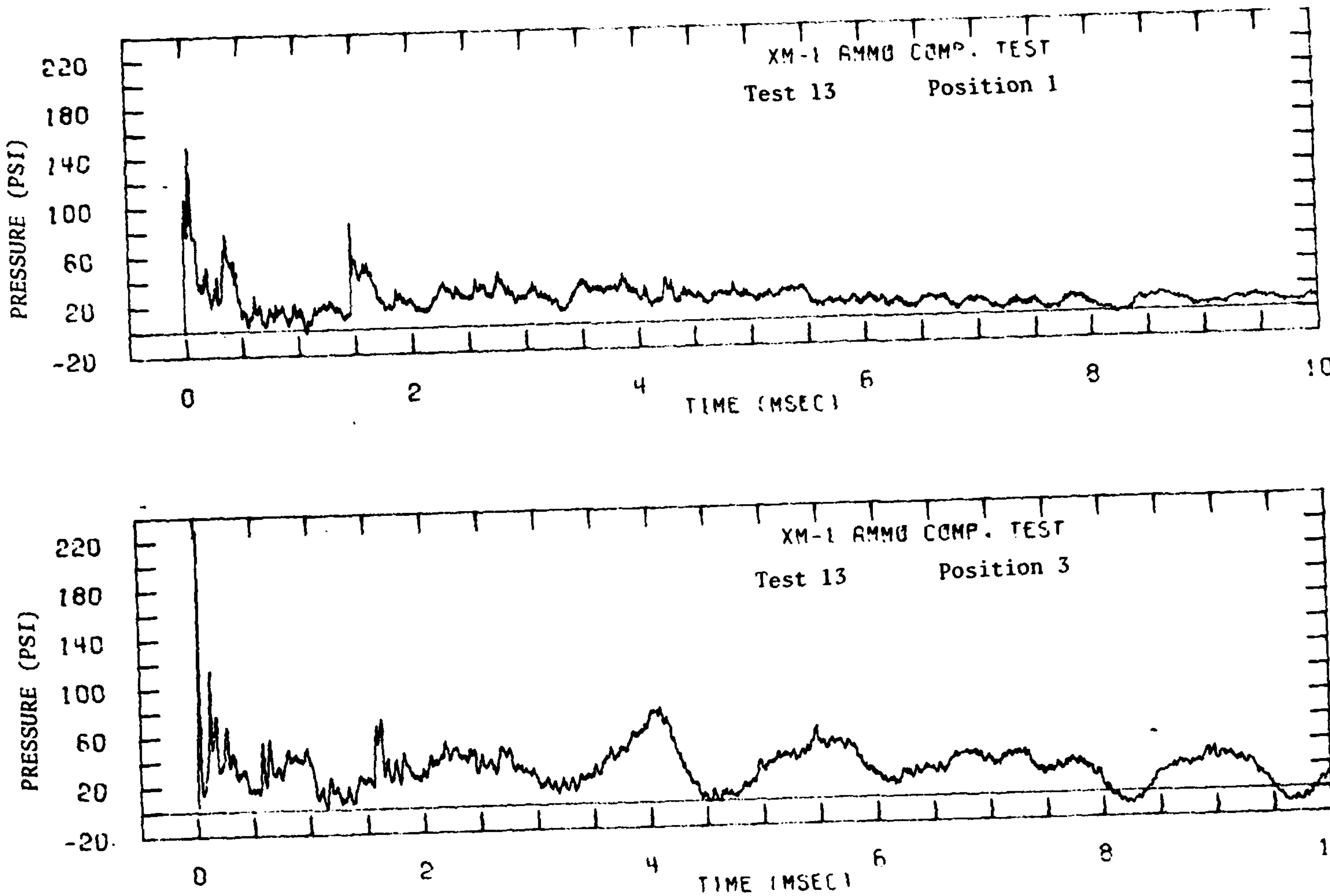


Figure A-52 Pressure Time Histories on Compartment Wall - Test No. 13

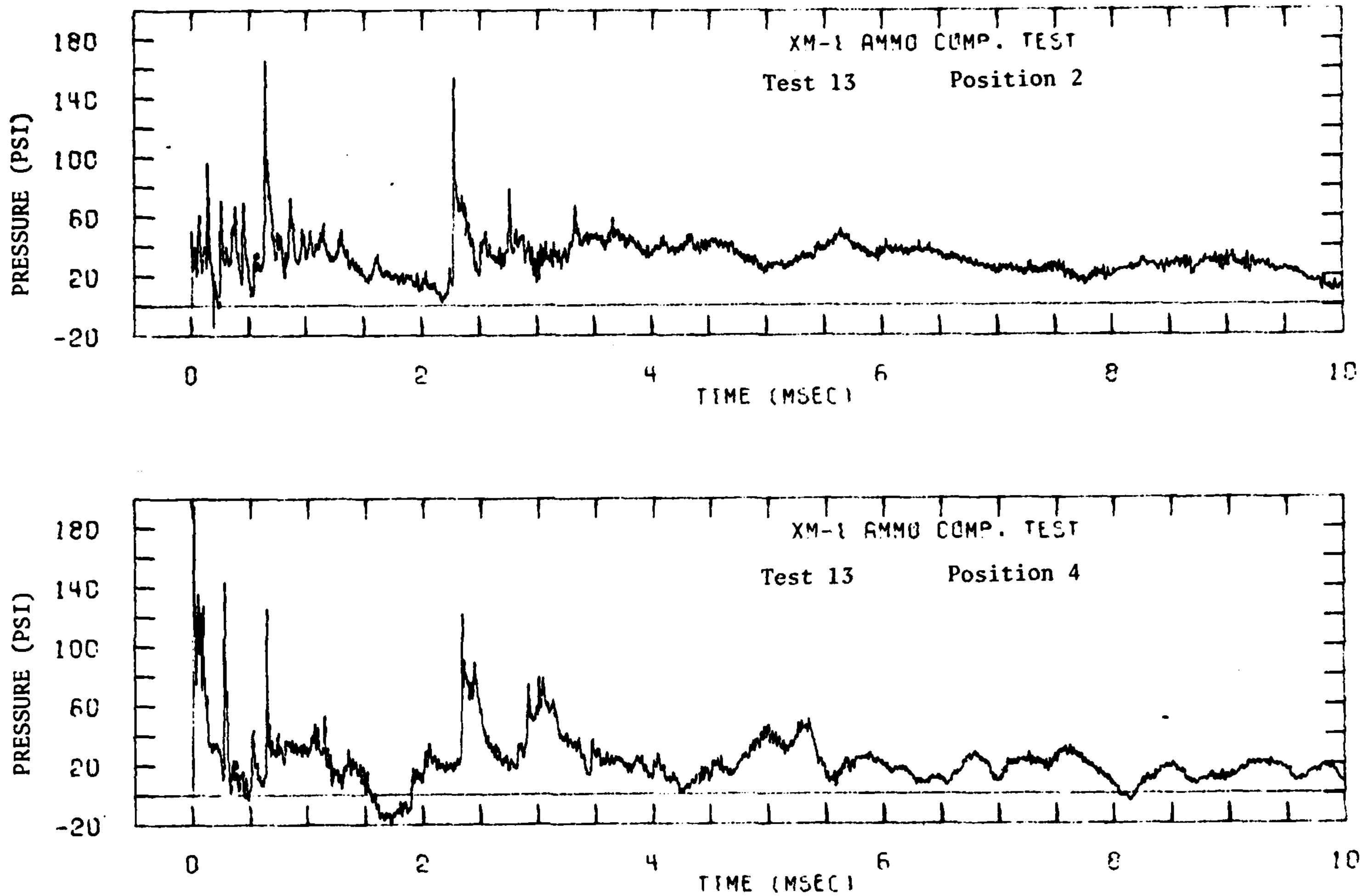


Figure A-53 Pressure Time Histories on Loading Door - Test No. 13

CARTRIDGE CASE TEMPERATURES

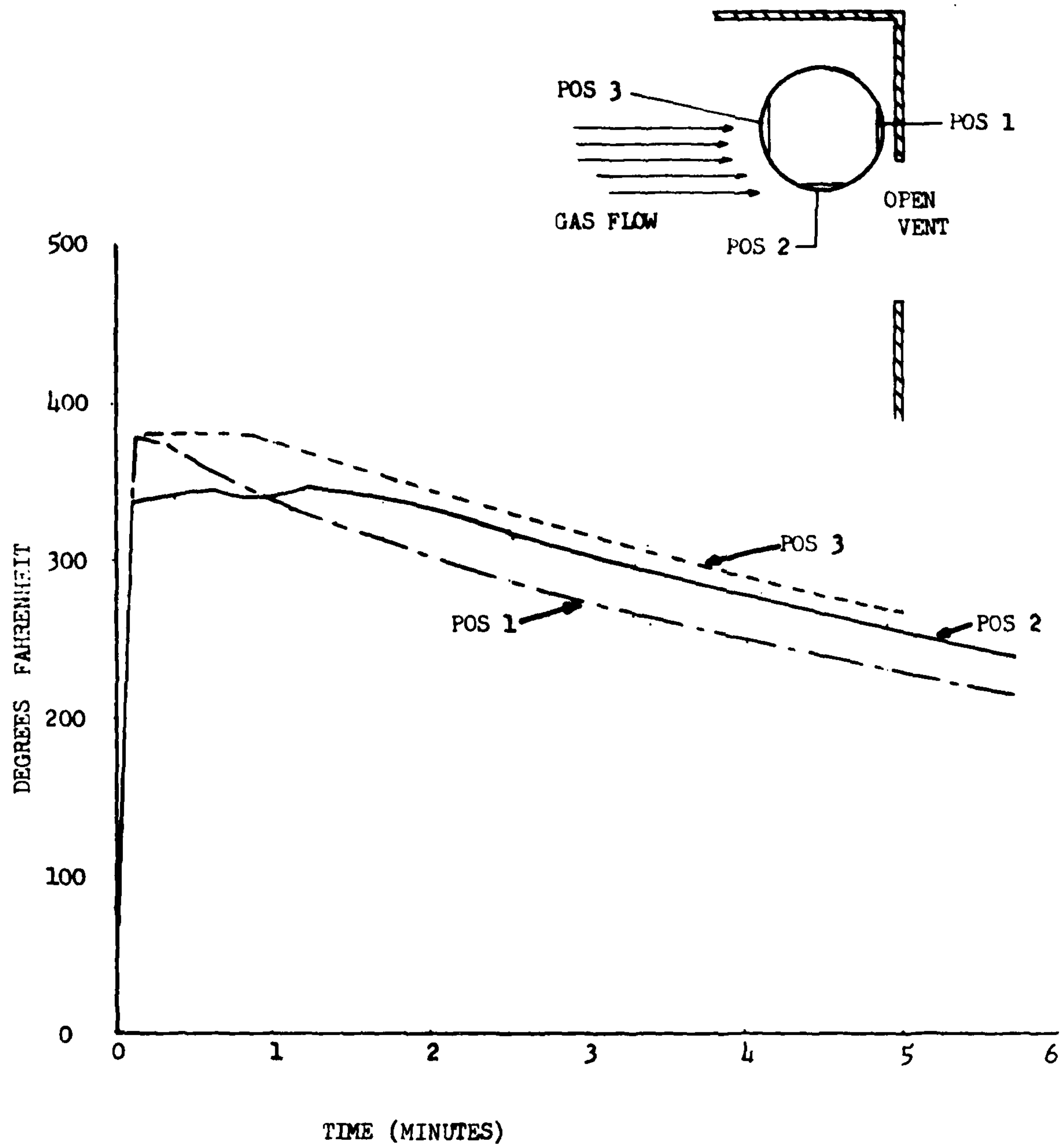


Figure A-54 Cartridge Case Temperature Time Histories - Test No. 13

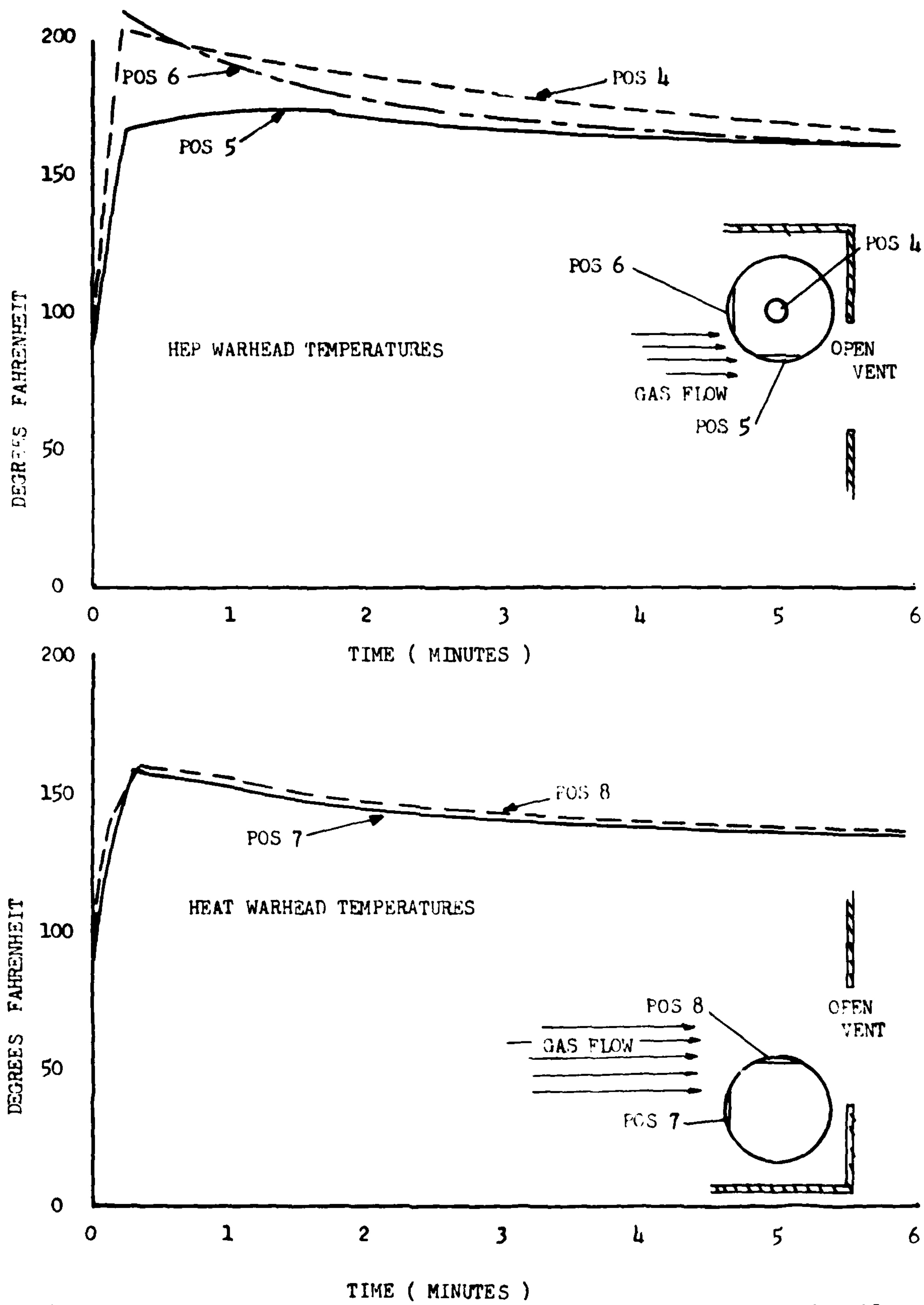


Figure A-55 HEP and HEAT Warhead Temperature Time Histories - Test No. 13

XIV. BRL PROPELLANT TEST NO. 14

Date: 29 August 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1- to 2-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet so that it grazed the cartridge case of the single, live propellant round stowed in the compartment. The desired environmental conditions were recorded with a combination of piezoelectric gauges, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, grazed the live propellant round on the vent side of the compartment, exited, and penetrated 1-3/8 inches into the steel RHA witness plates.

The projectile from the live propellant round separated from its cartridge case. The cartridge case was torn apart in the area of jet impact; the rest of the case remained intact. There was no damage to the dummy rounds containing the thermocouples, nor was there any damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 240 psi and 246 psi; those mounted on the door, 229 psi and 160 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 530 psi and 1090 psi, and crush gauges located in the rear, 1220 psi, 400 psi, 660 psi, and 450 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 2100 psi in the nose and 2400 psi in the base. A maximum temperture of 335°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 121° and 171°F, respectively.

The average jet-tip velocity as measured by the velocity screens between points A and B was 3.8mm/μsec; between A and C, 3.8mm/μsec; between A and D, 4mm/μsec; and between A and E, 3.9mm/μsec.

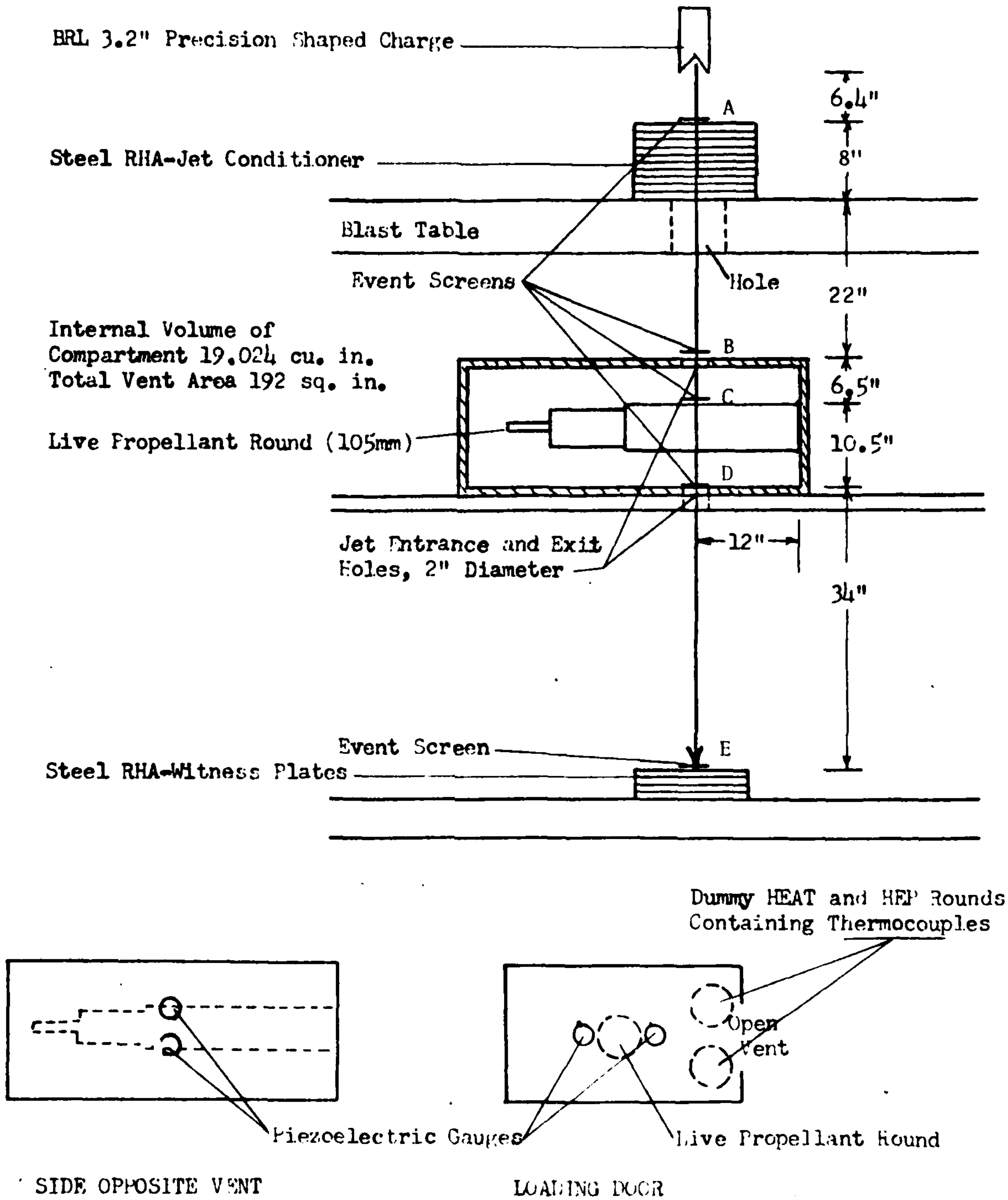


Figure A-56 Test Setup for Propellant Test No. 14

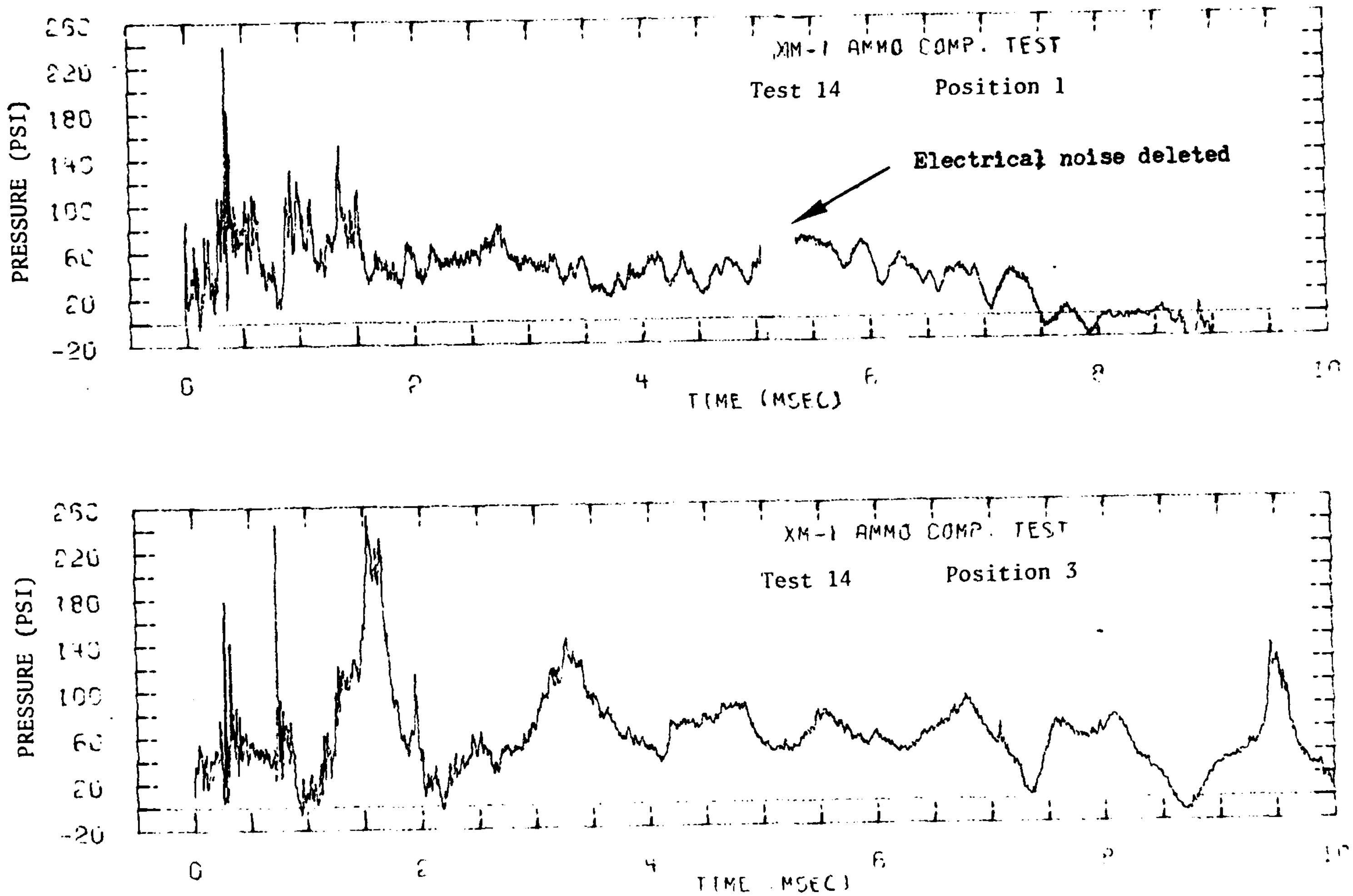


Figure A-57 Pressure Time Histories on Compartment Wall - Test No. 14

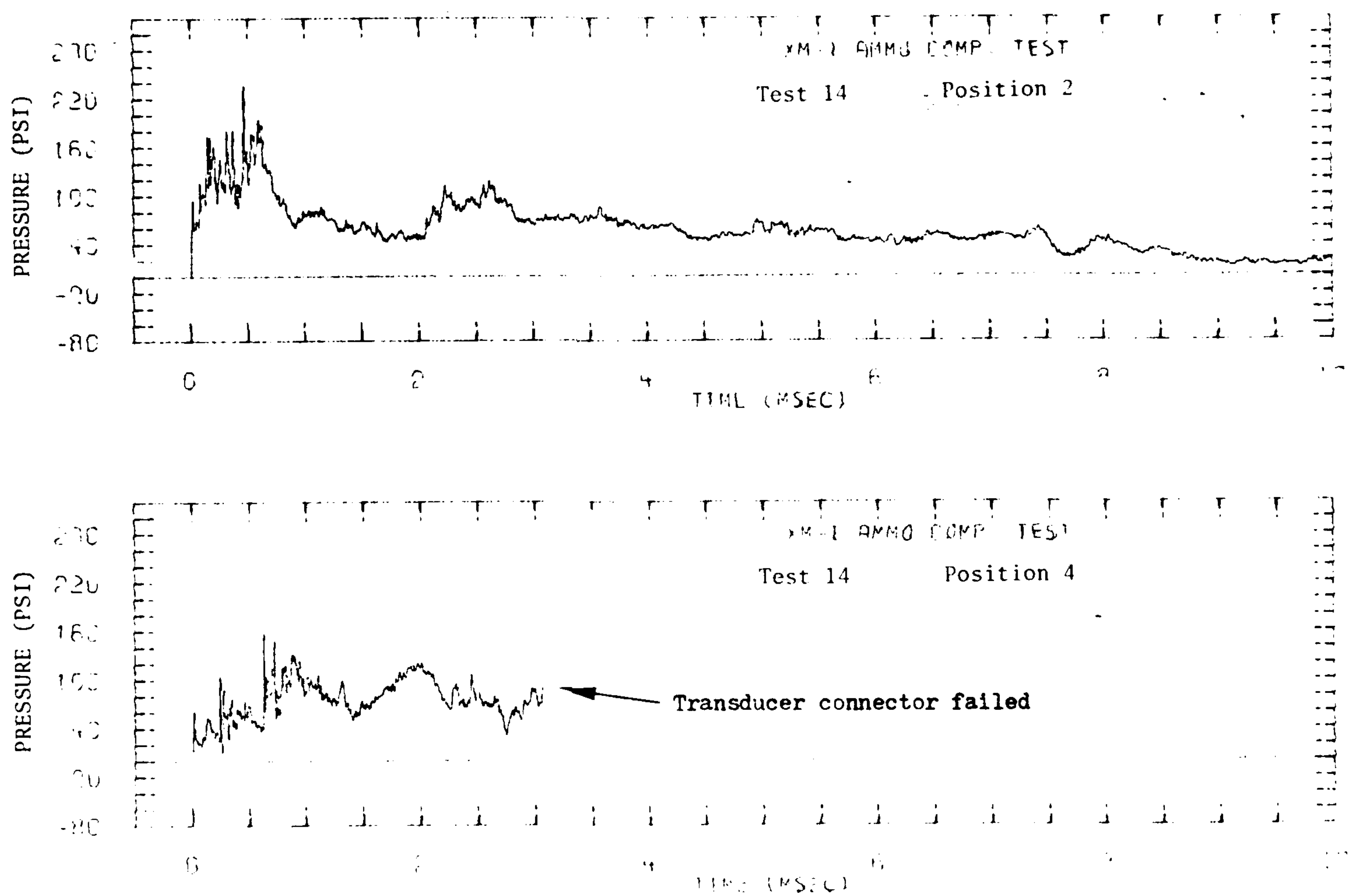


Figure A-58 Pressure Time Histories on Loading Door - Test No. 14

CARTRIDGE CASE TEMPERATURES

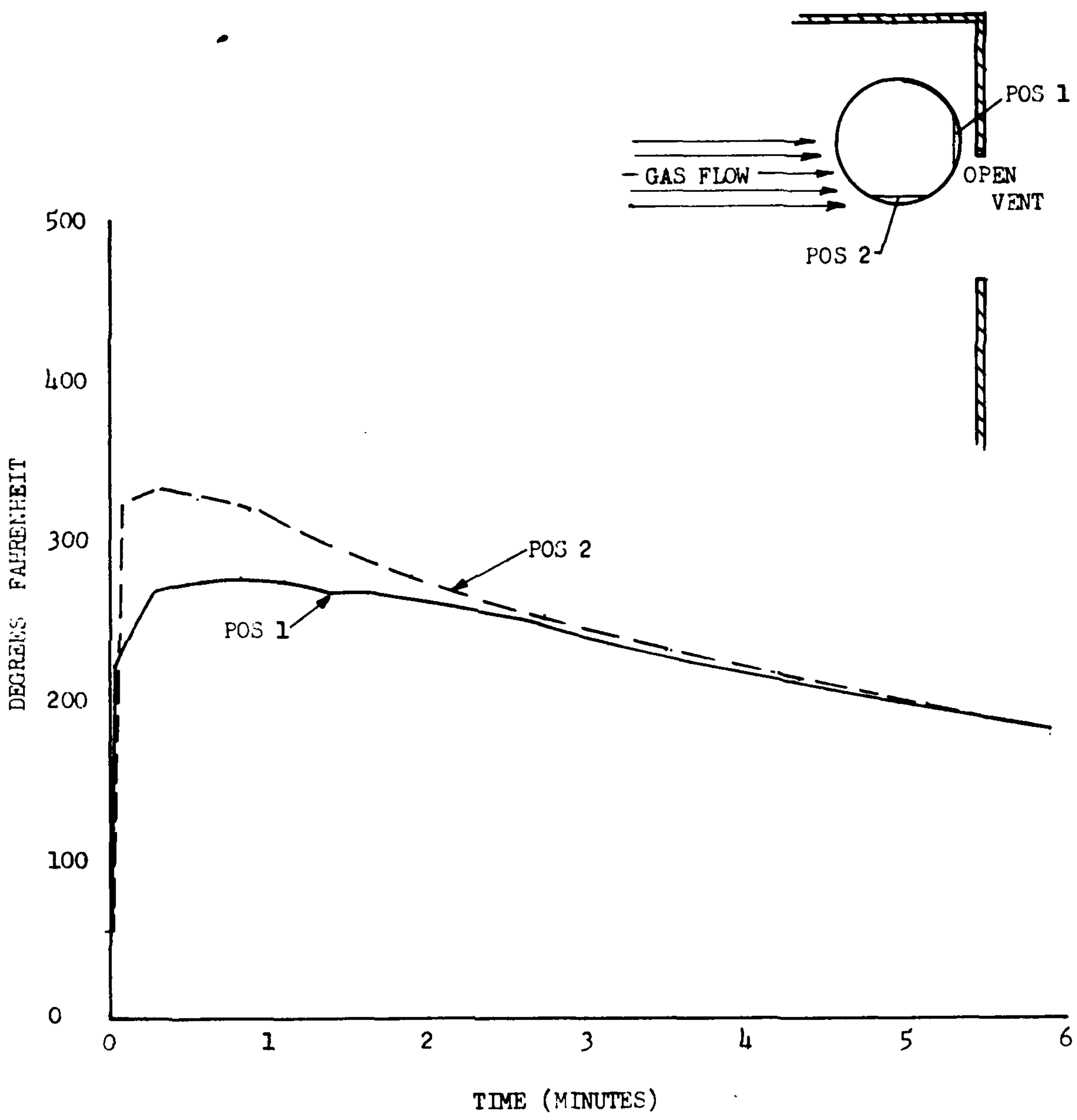


Figure A-59 Cartridge Case Temperature Time Histories - Test No. 14

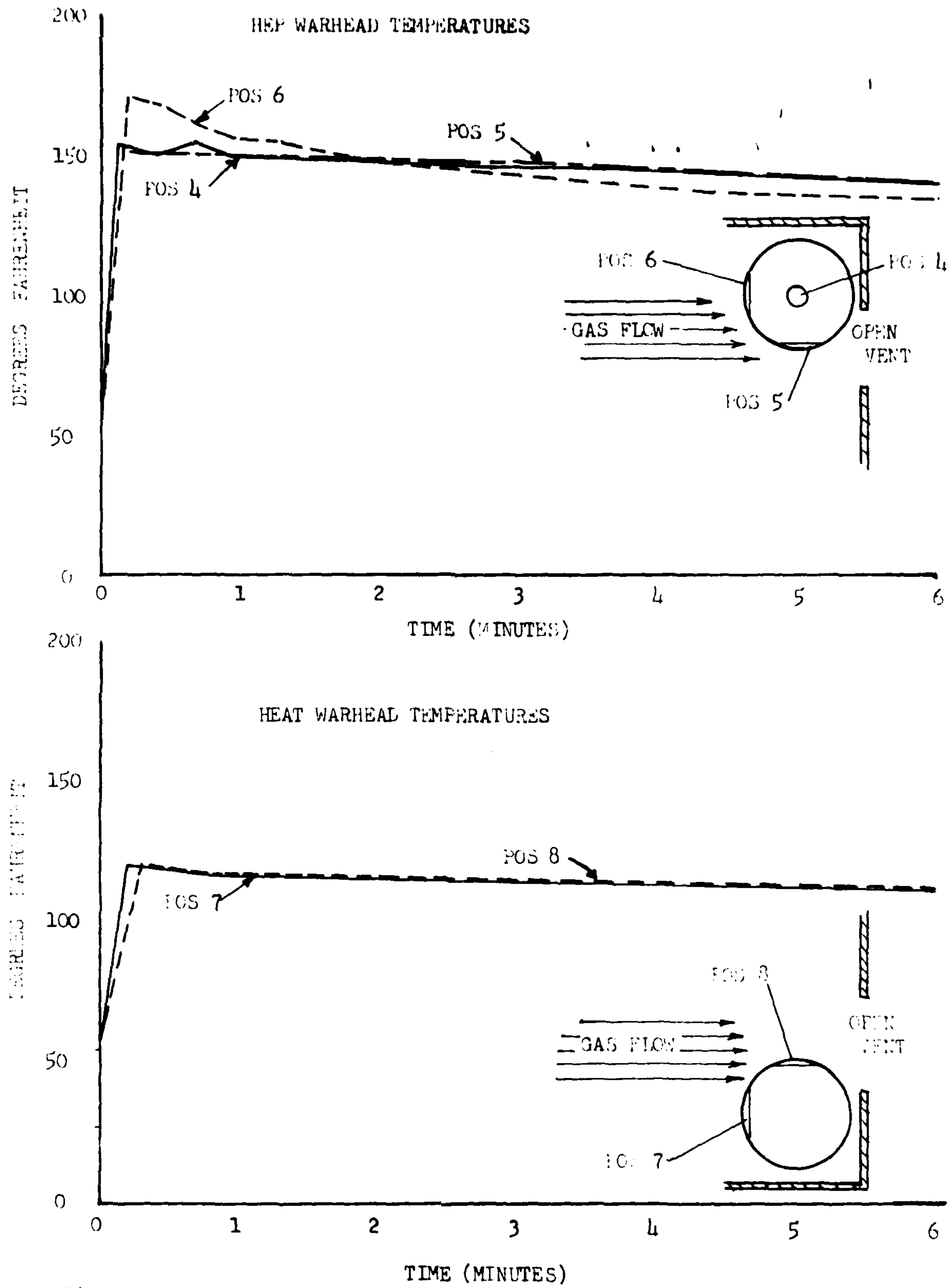


Figure A-60 HEP and HEAT Warhead Temperature Time Histories - Test No. 14

XV. BRL PROPELLANT TEST NO. 15

Date: 5 September 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1-to 2-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet so that it grazed the cartridge case of the single, live propellant round stowed in the compartment. The desired environmental conditions were recorded with a combination of piezoelectric gauges, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, grazed the live propellant round on the gauge side of the compartment, exited, and penetrated 1-1/16 inches into the steel RHA witness plates.

The projectile from the live propellant round did not separate from its cartridge case. The cartridge case was torn apart in the area of jet impact; the rest of the case remained intact. There was no damage to the dummy rounds containing the thermocouples, nor was there any damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 69 psi and 68 psi; those mounted on the door, 40 psi and 101 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 310 psi and 250 psi, and crush gauges located in the rear, 310 psi and 380 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 100 psi in the nose and 300 psi in the base. A maximum temperature of 502°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 145° and 206°F, respectively.

The average jet-tip velocity as measured by the velocity screens between points A and B was 3.8mm/μsec; between A and C, 319mm/μsec; between A and D, 4mm/μsec; and between A and E, 3.8mm/μsec.

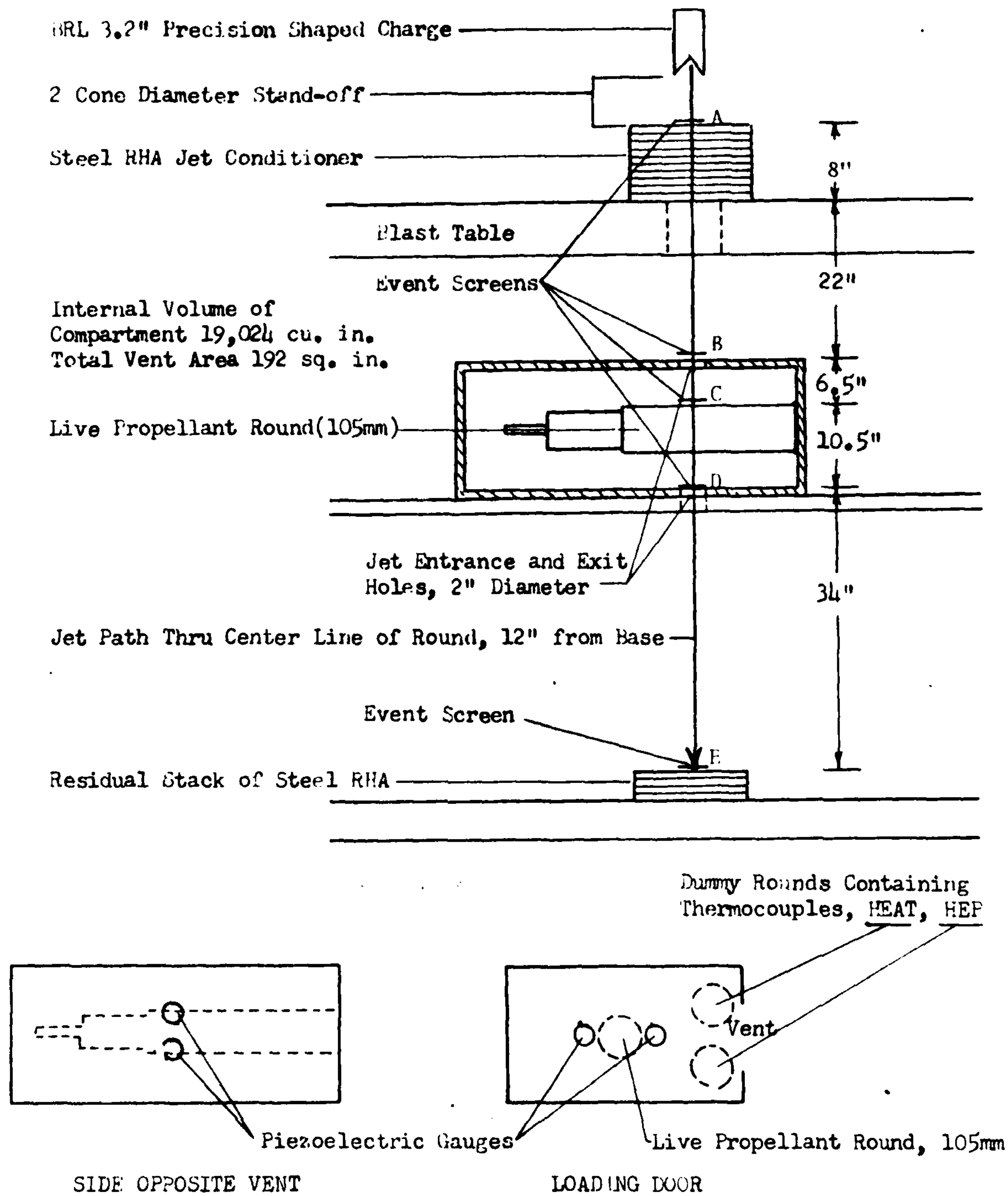


Figure A-61 Test Setup for Propellant Test No. 15

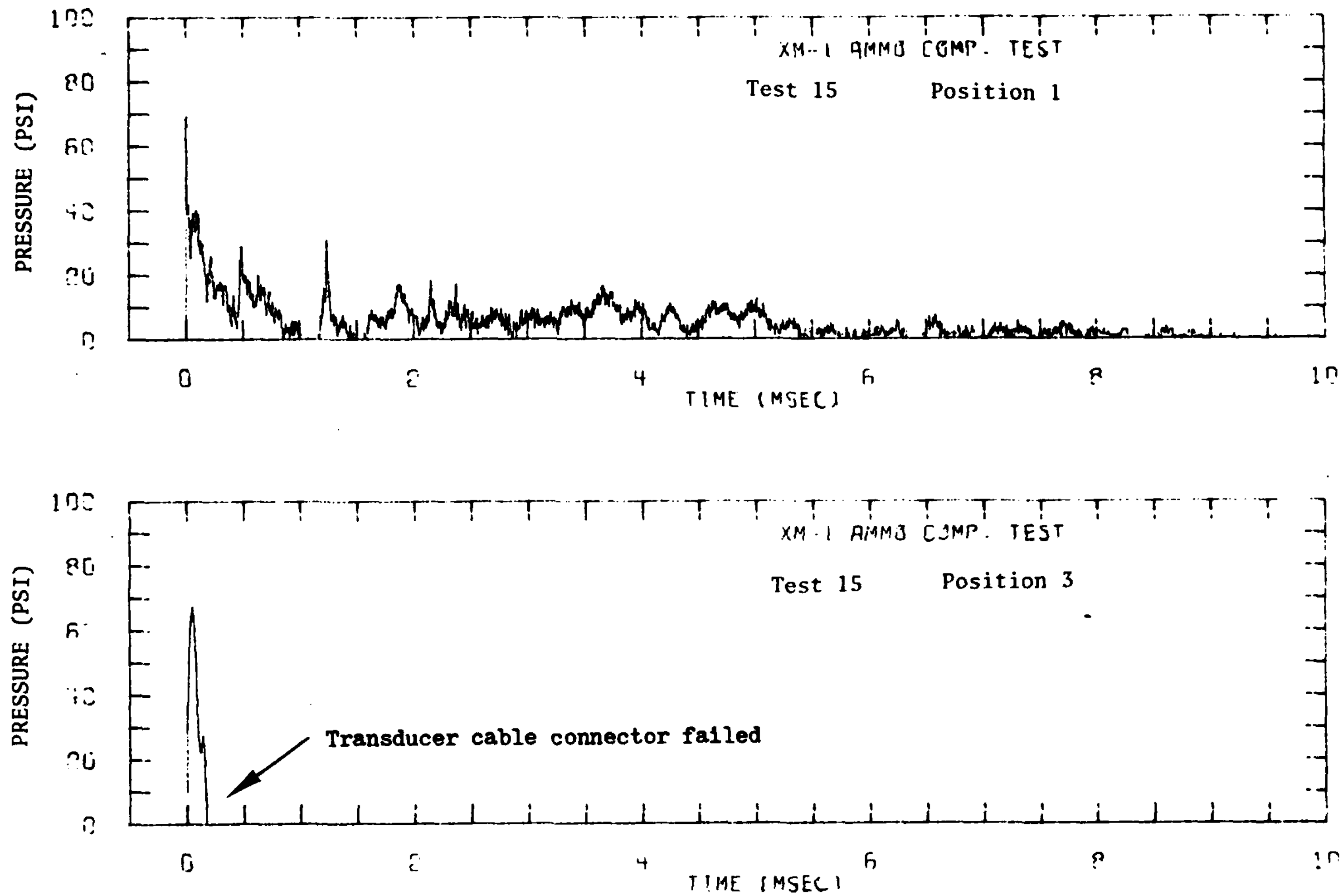
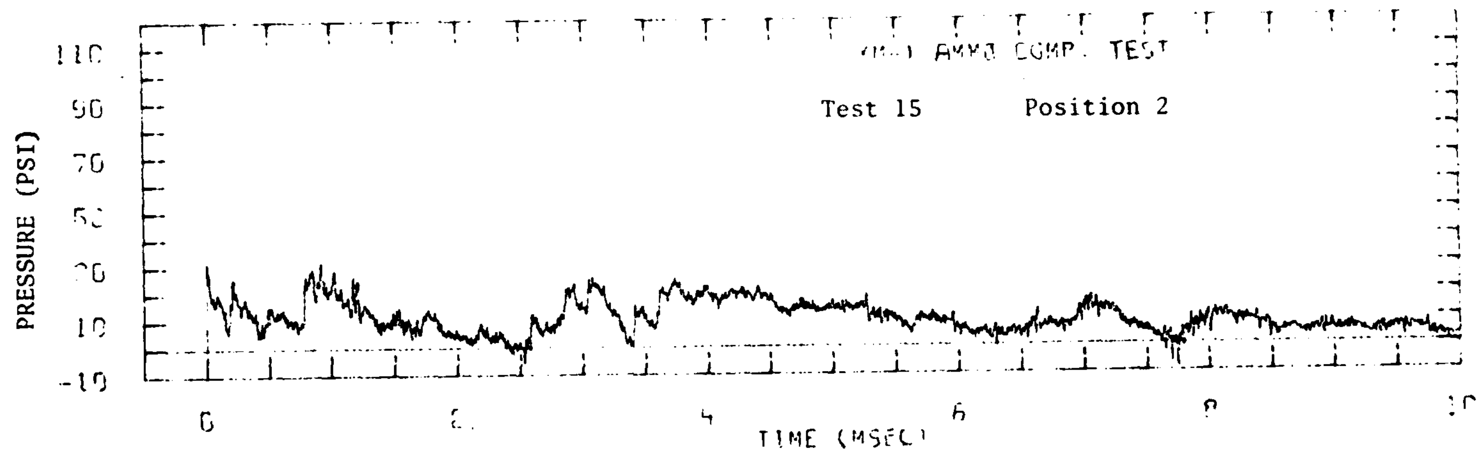


Figure A-62 Pressure Time Histories on Compartment Wall - Test No. 15



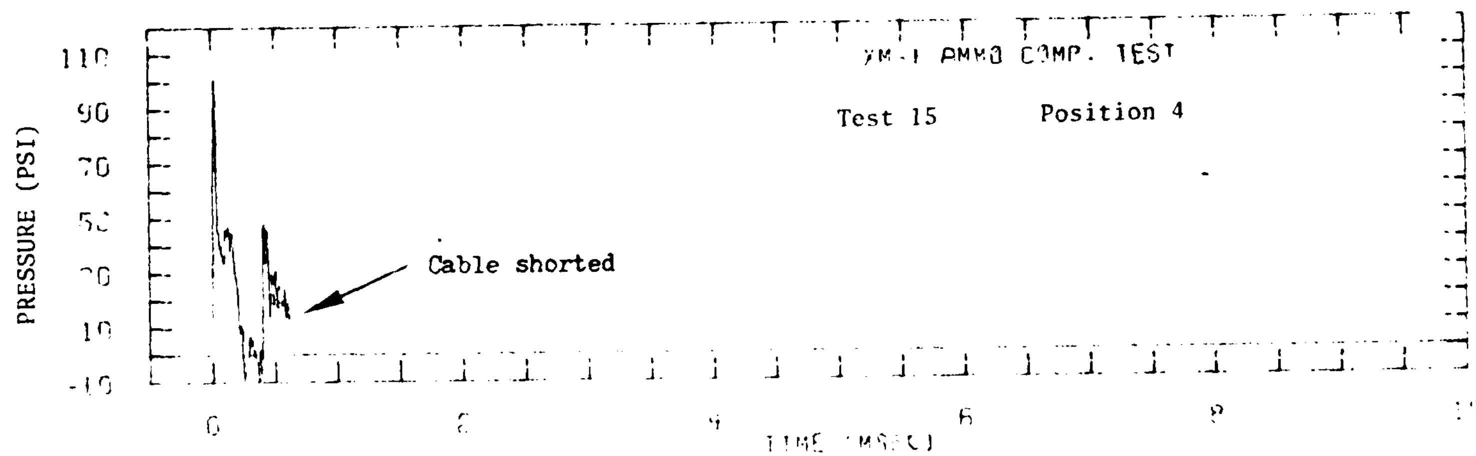


Figure A-63 Pressure Time Histories on Loading Door - Test No. 15

CARTRIDGE CASE TEMPERATURES

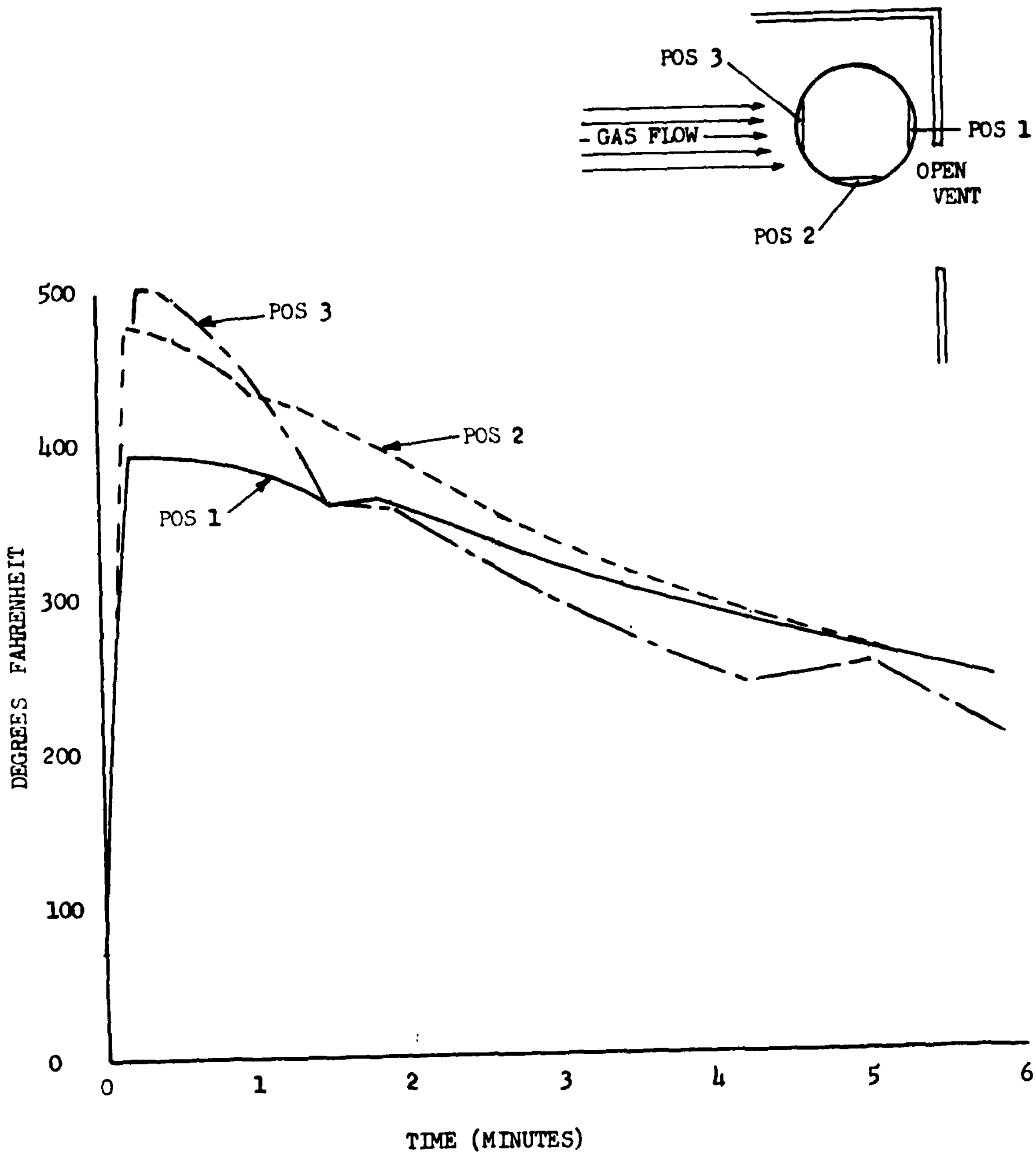
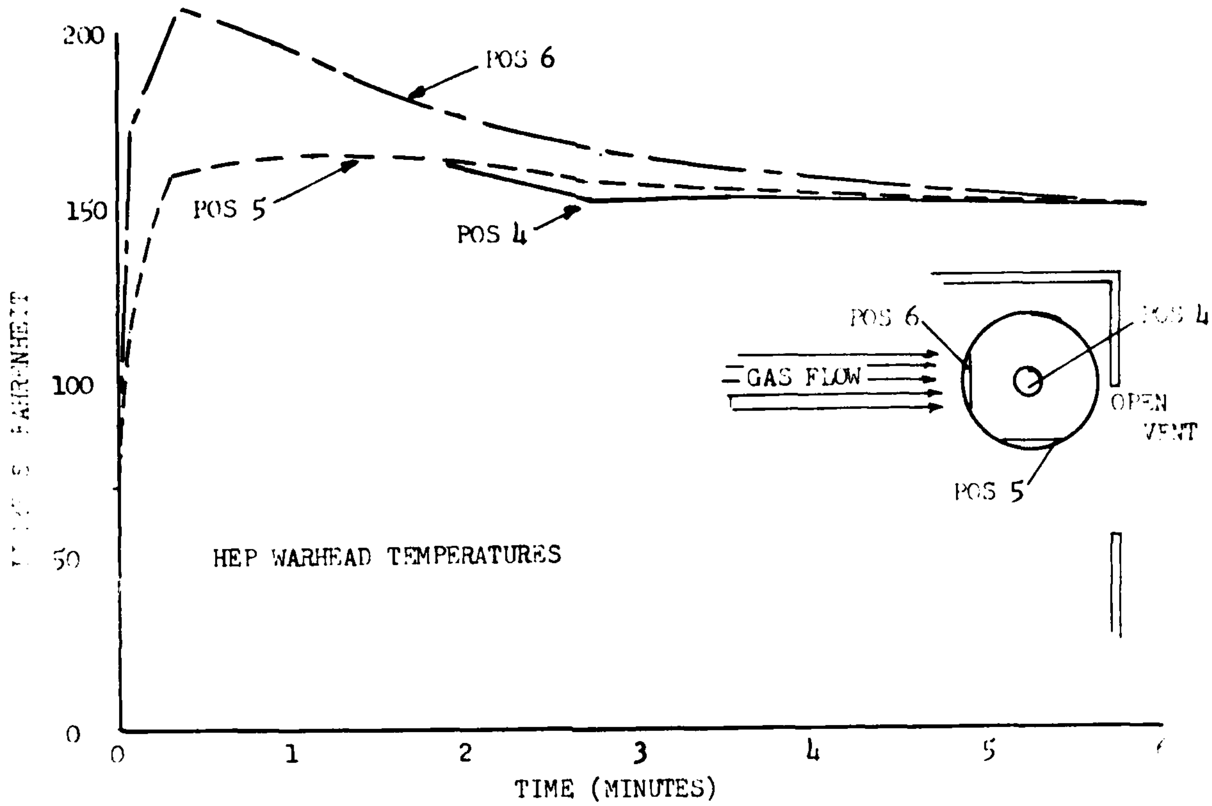


Figure A-64 Cartridge Case Temperature Time Histories - Test No. 15



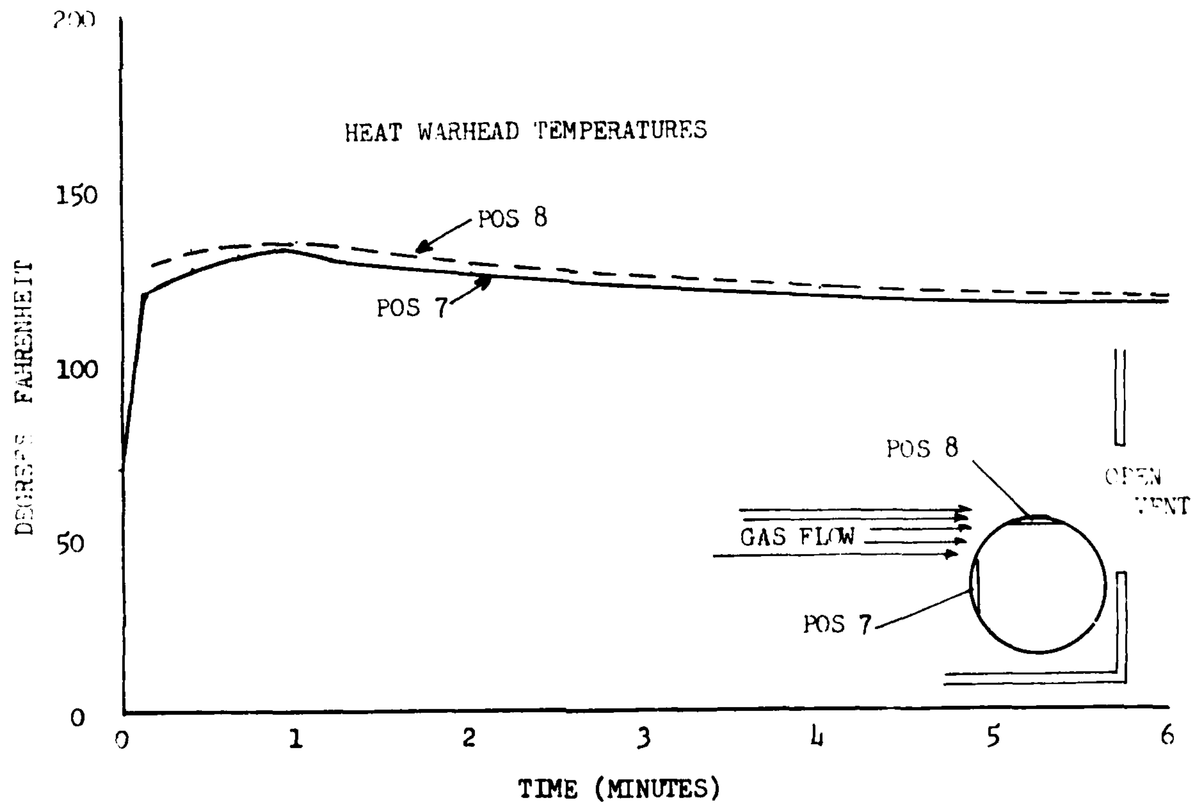


Figure A-65 HEP and HEAT Warhead Temperature Time Histories - Test No. 15

XVI. BRL PROPELLANT TEST NO. 16

Date: 9 September 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1-to 2-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet so that it grazed the cartridge case of the single, live propellant round stowed in the compartment. The desired environmental conditions were recorded with a combination of piezoelectric gauges, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, missed the round, exited, and penetrated 2-1/2 inches into the steel RHA witness plates.

There was no damage to the compartment or the dummy rounds containing the thermocouples. The live propellant cartridge case had two small dents in it.

No pressure-time histories or temperature-time histories were obtained.

The average jet-tip velocity as measured by the velocity screens between points A and B was 3.7mm/μsec; between A and D, 3.9mm/μsec; and between A and E, 3.9mm/μsec.

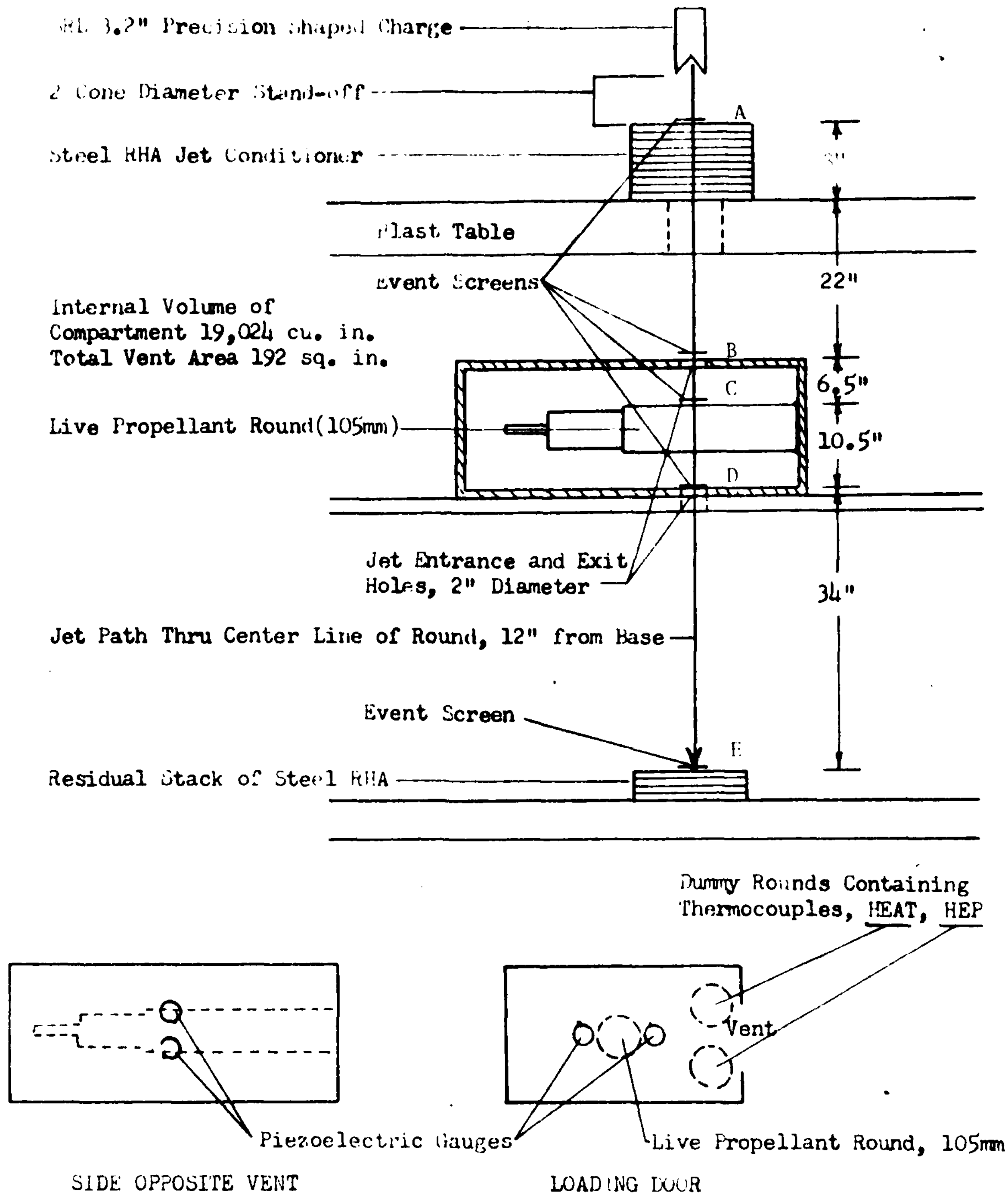


Figure A-66 Test Setup for Propellant Test No. 16

XVII. BRL PROPELLANT TEST NO. 17

Date: 11 September 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1-to 2-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet so that it grazed the cartridge case of the single, live propellant round stowed in the compartment. The desired environmental conditions were recorded with a combination of piezoelectric gauges, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and grazed the live propellant round on the vent side of the compartment; it then exited and penetrated 1/8 inch into the steel RHA witness plates.

The projectile from the live propellant round separated from its cartridge case which was torn apart in the area of jet impact; the rest of the case remained intact. There was no damage to the dummy rounds containing the thermocouples nor was there any damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 205 psi and 328 psi; those mounted on the door, 228 psi and 350 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 1550 psi and 520 psi and crush gauges located in the rear, 620 psi, 1010 psi, and 1120 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 3000 psi in the nose and 5400 psi in the base. A maximum temperature of 350°F was recorded in the cartridge case of the HEP round. Maximum temperatures recorded in the inert HEAT and HEP warheads were 131°F and 195°F, respectively.

The jet-tip velocity between points A and B was 3.5mm/μsec. The remaining event screens failed to fuction properly.

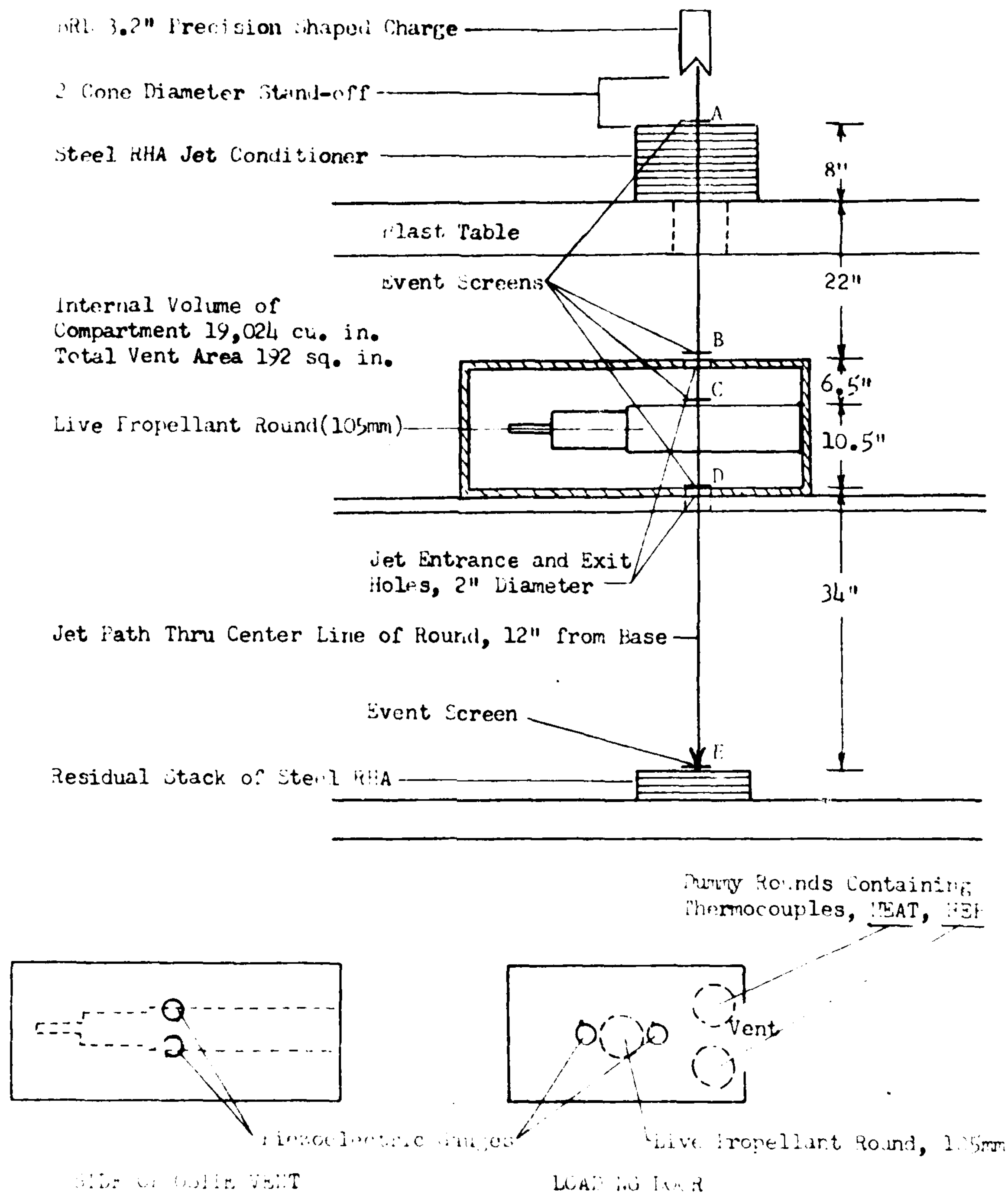
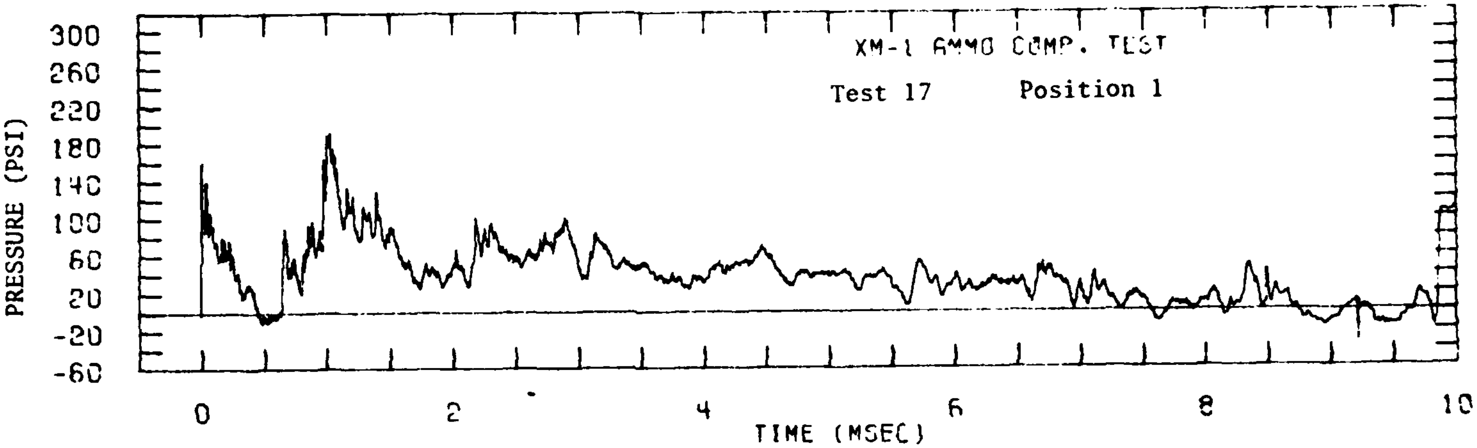


Figure A-67 Test Setup for Propellant Test No. 17



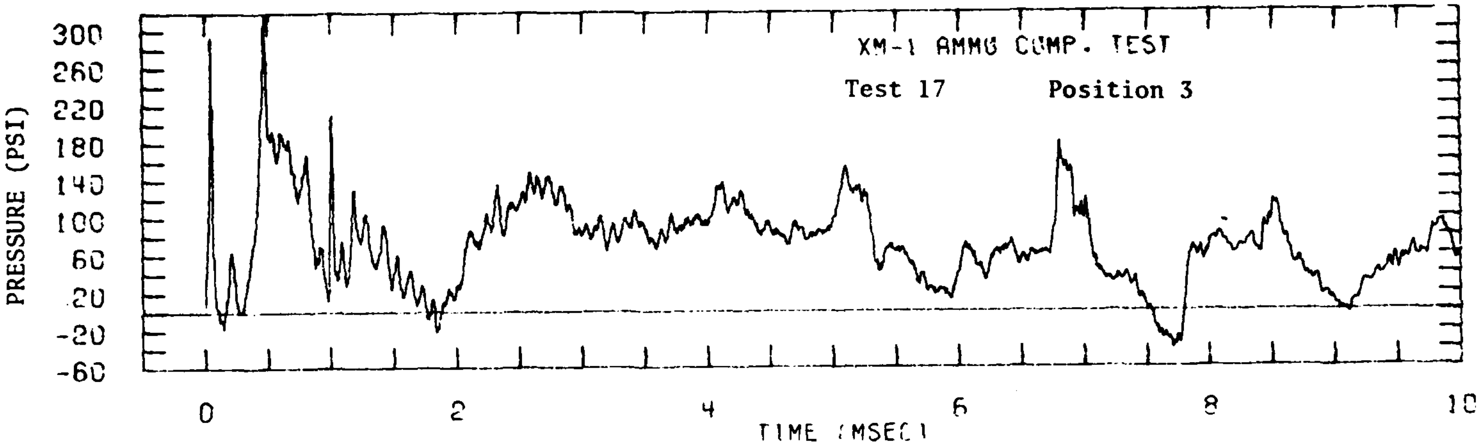


Figure A-68 Pressure Time Histories on Compartment Wall - Test No. 17

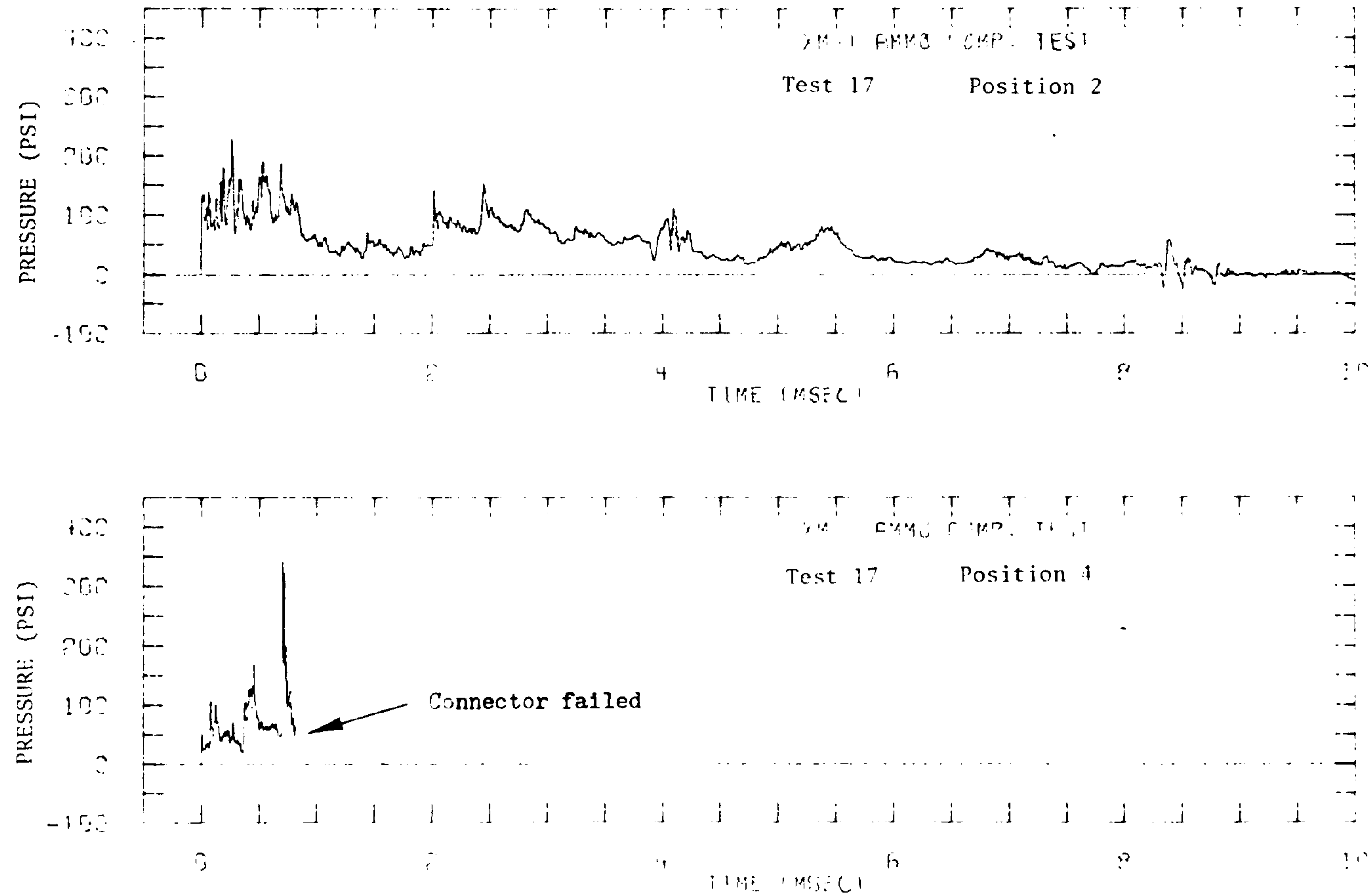


Figure A-69 Pressure Time Histories on Loading Door - Test No. 17

CARTRIDGE CASE TEMPERATURES

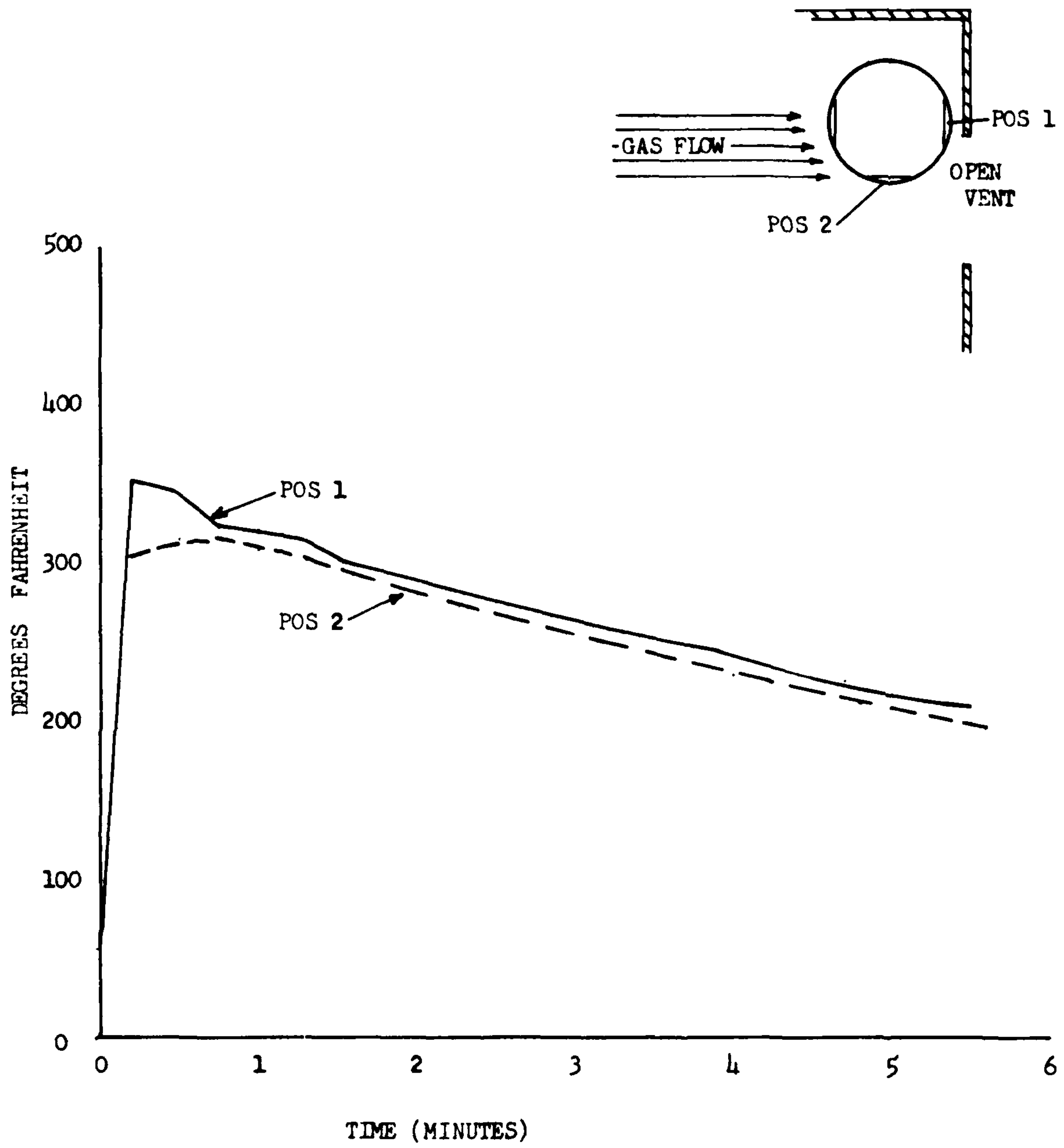


Figure A-70 Cartridge Case Temperature Time Histories - Test No. 17

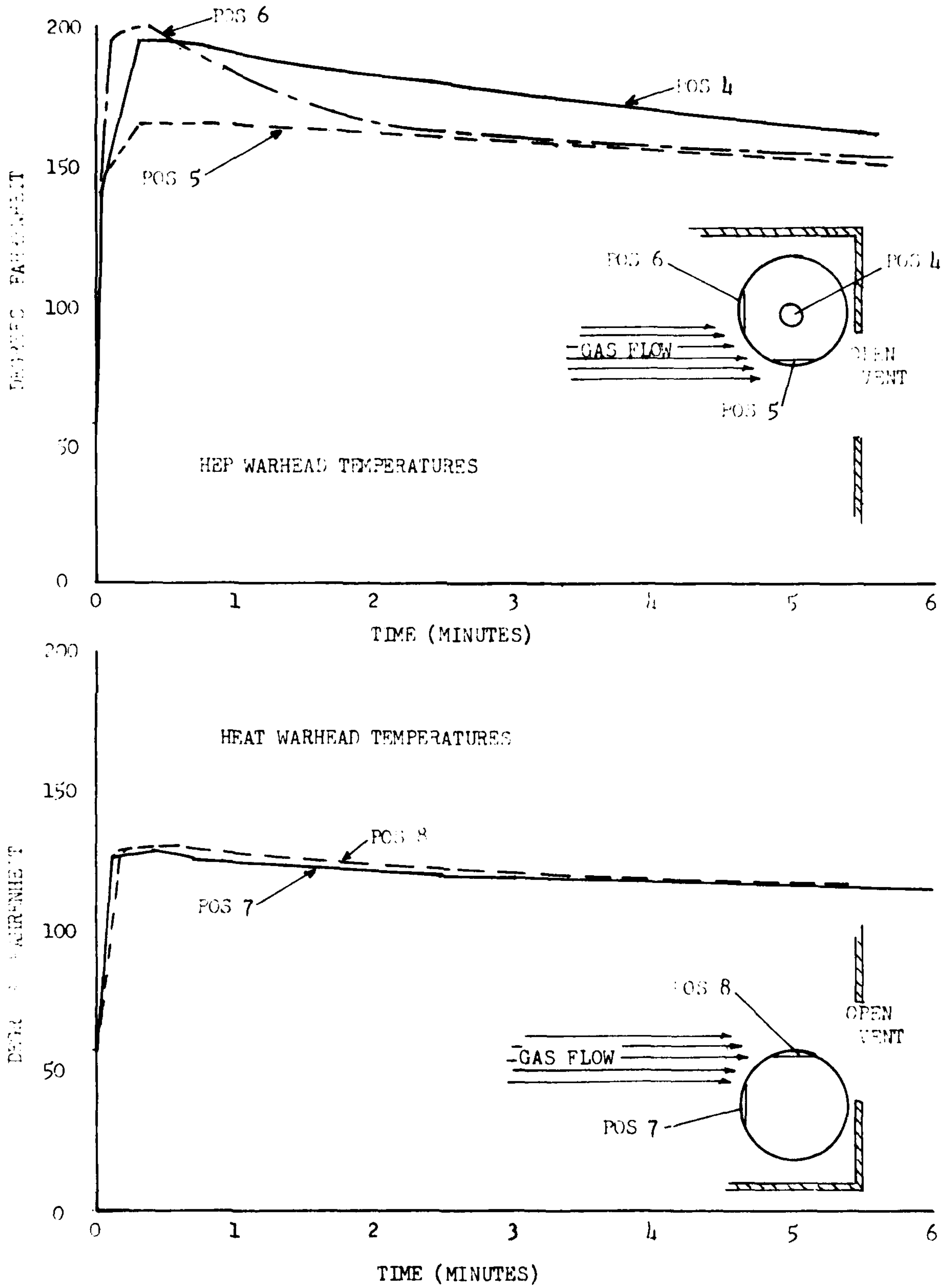


Figure A-71 HEP and HEAT Warhead Temperature Time Histories - Test No. 17

XVIII. BRL PROPELLANT TEST NO. 18

Date: 16 September 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with an 8-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

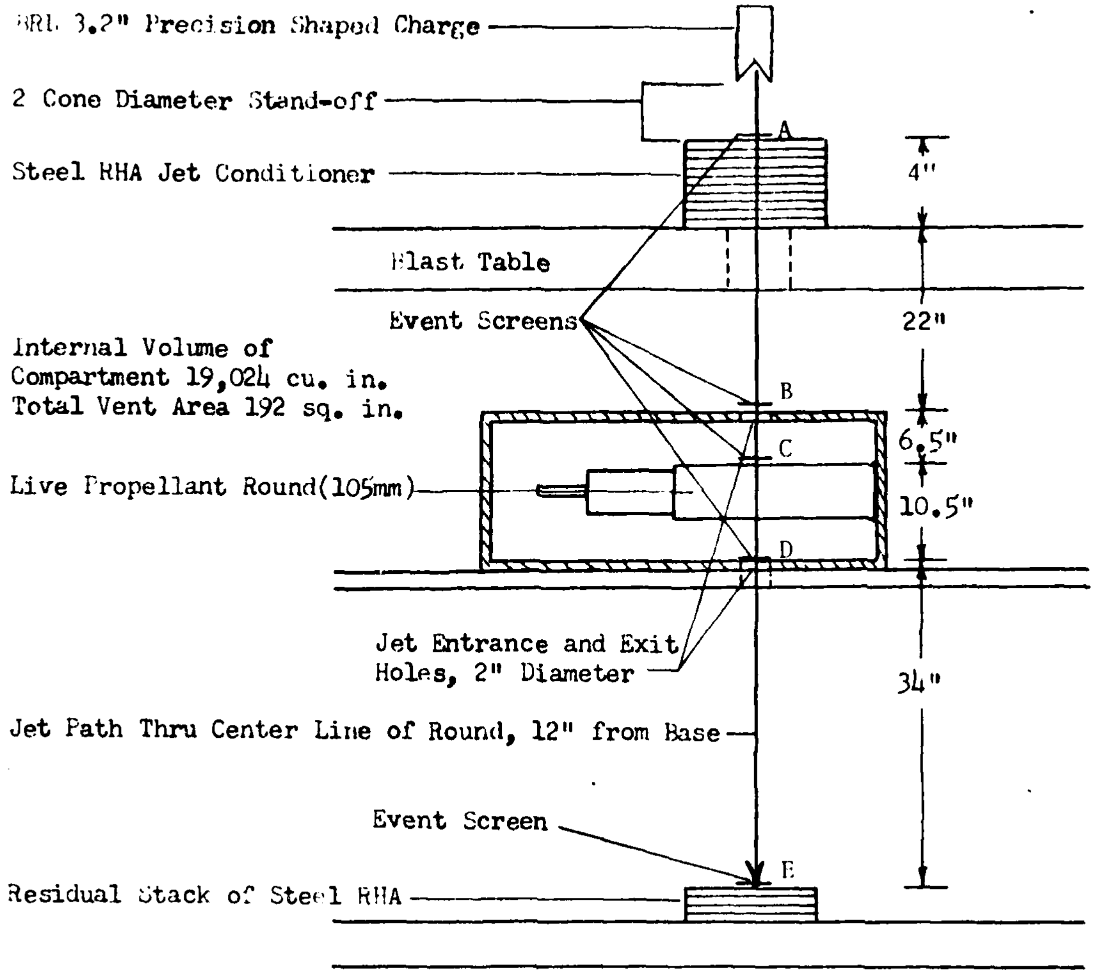
The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited the compartment and penetrated 1-1/16 inches into the residual stack of RHA.

The live propellant cartridge case impacted by the shaped charge jet broke up into many small pieces. This reaction broke the fixture holding the thermocouple cases. The HEP projectile was separated from its cartridge case and the end of the case was sticking through the open vent. The cartridge case of the dummy HEAT round in the lower corner of the compartment was perforated and badly dented. There was no damage to the main structure of the compartment.

The piezoelectric transducers mounted on the side of the compartment recorded peak pressures of 757 psi and 405 psi. Peak pressures recorded on the door were 1008 psi and 1020 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 960 psi and 2190 psi; those located in the rear, 400 psi and 1240 psi.

Mechanical crush gauges located in the live propellant cartridge case recorded pressures of 4100 psi in the base and 2900 psi in the nose. No temperature records were obtained; the violence of the event broke and burned the thermocouple wires.

The jet-tip velocity between points A and B was 5.1mm/μsec; between A and D, 4.5mm/μsec; and between A and E, 4.3mm/μsec. The event screen on top of the live propellant round failed to function properly.



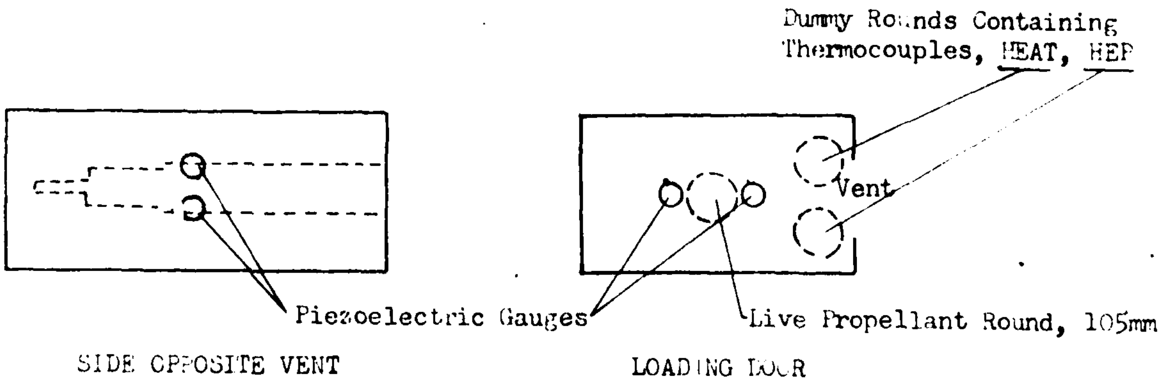


Figure A-72 Test Setup for Propellant Test No. 18

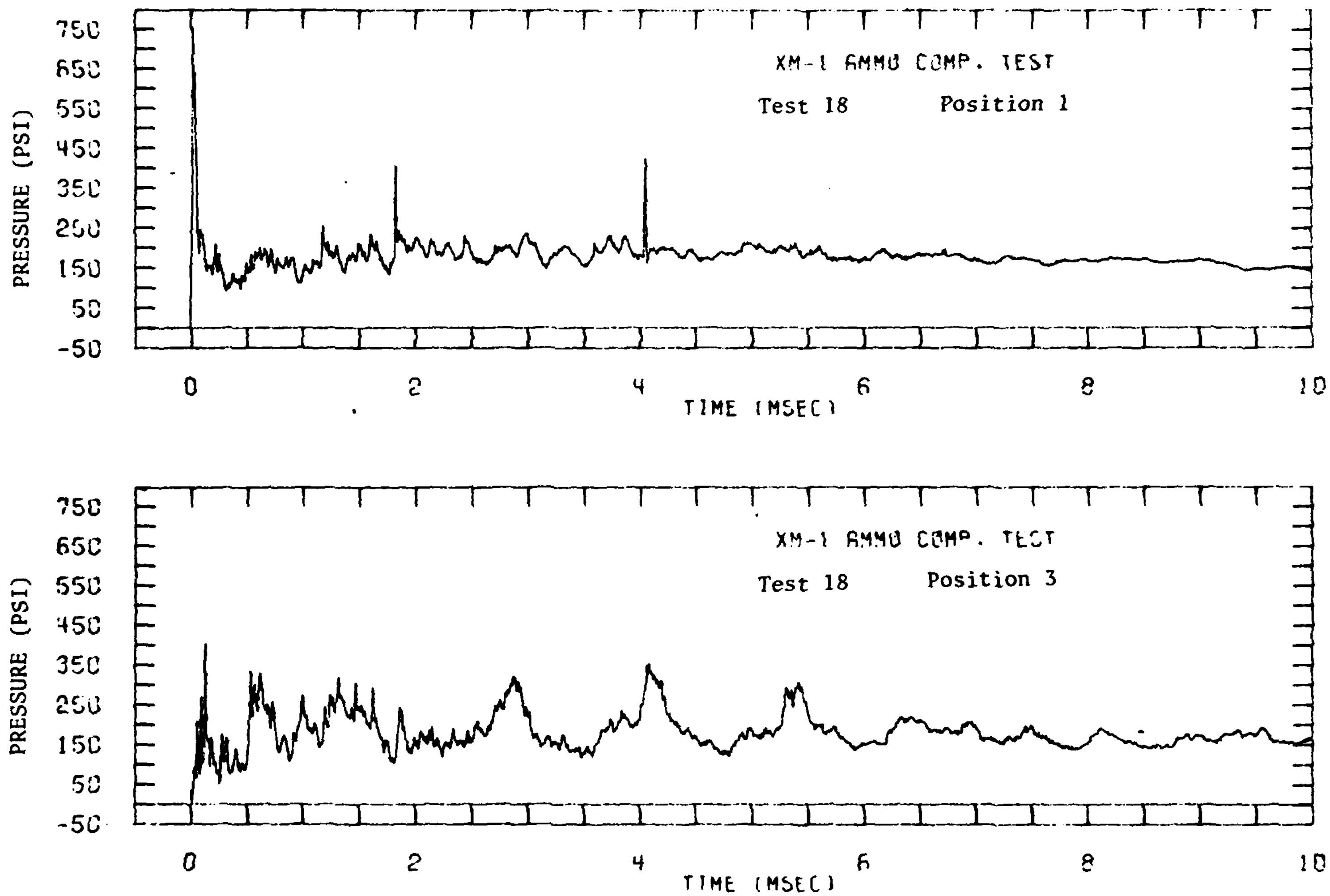


Figure A-73 Pressure Time Histories on Compartment Wall - Test No. 18

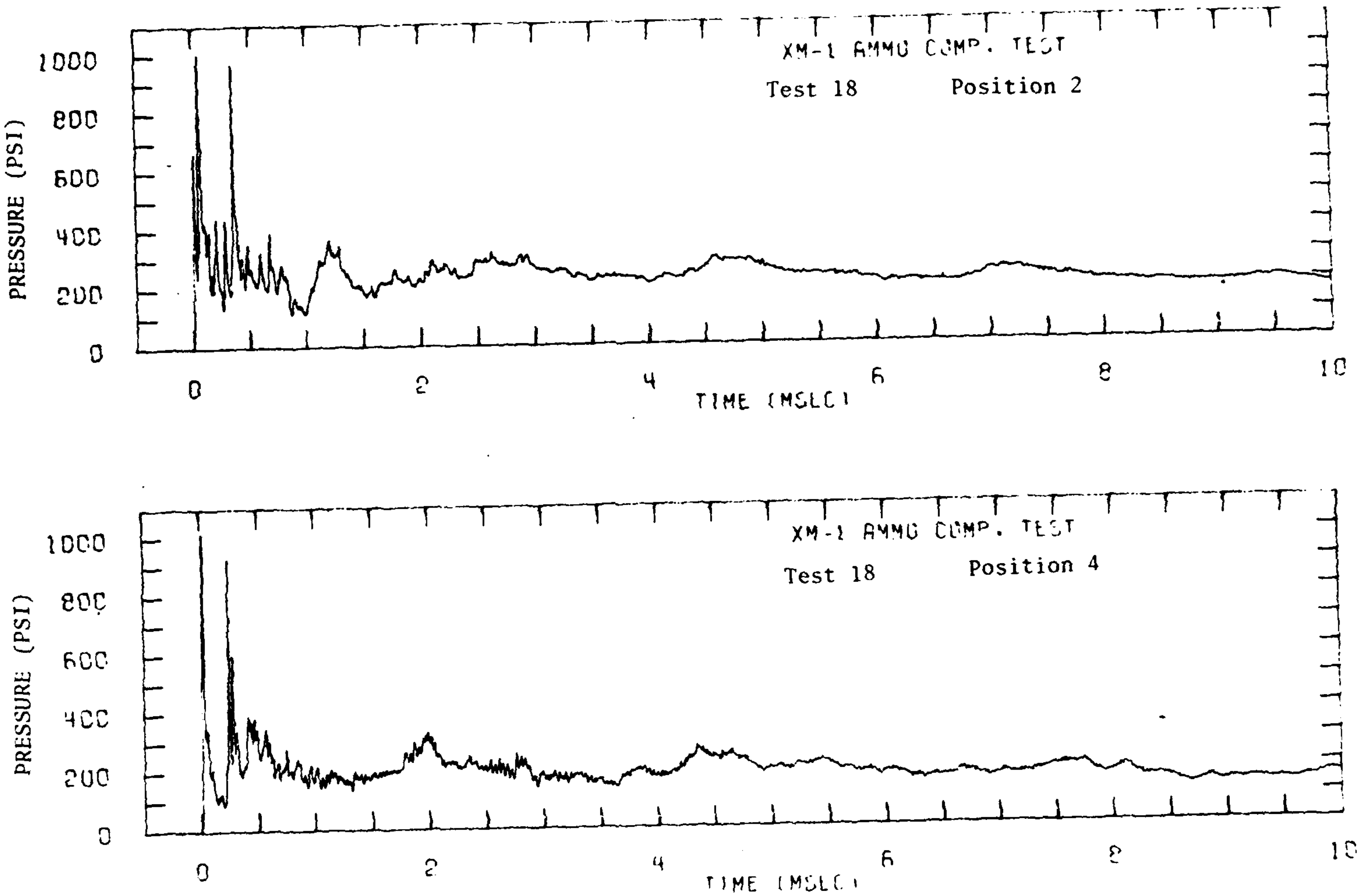


Figure A-74 Pressure Time Histories on Loading Door - Test No. 18

XIX. BRL PROPELLANT TEST NO. 19

Date: 18 September 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with an 8-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant 105mm round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then exited and penetrated 1-1/4 inches into the residual stack of RHA.

The live propellant round impacted by the shaped charge jet broke up into many small pieces. The dummy rounds were blown out of their rack; they were perforated and badly dented. The compartment was displaced 10 inches but it was not damaged.

No pressure-time records were obtained because the recorders failed to function. Mechanical crush gauges located in the front of the compartment recorded pressures of 610 psi and 620 psi; those located in the rear, 600 psi and 860 psi.

Crush gauges located in the live propellant cartridge case recorded pressures of 2900 psi in the nose and 6400 psi in the base. No thermocouples were used.

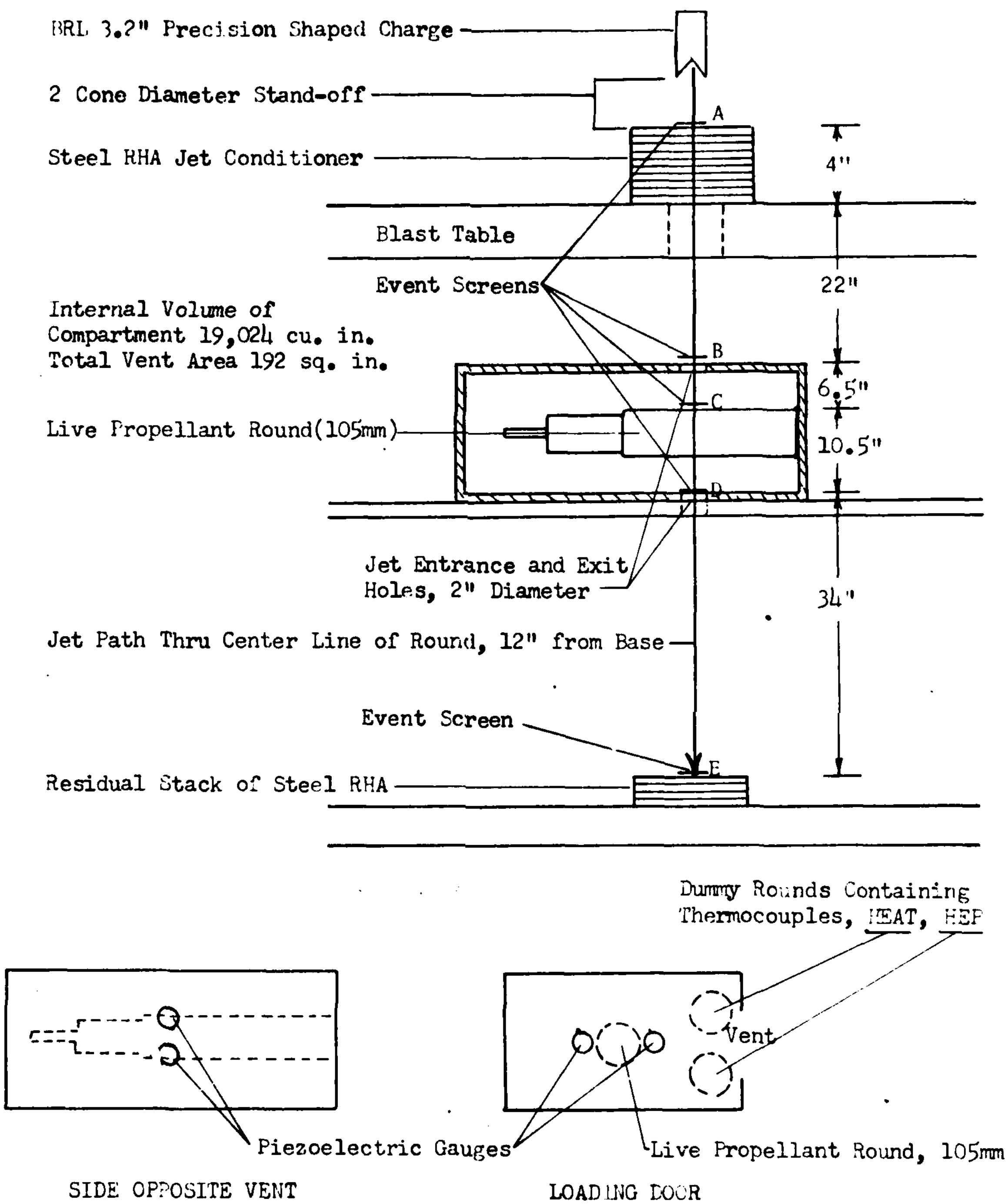


Figure A-75 Test Setup for Propellant Test No. 19

XX. BRL PROPELLANT TEST NO. 20

Date: 30 September 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired at an angle through the center line (8-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, passed through the center line of a live propellant 105mm round stowed in the compartment, struck the primer, and exited.

The live propellant case impacted by the shaped charge jet broke up into several large pieces. The primer was in two pieces. The top thermocouple case was badly dented, while the bottom thermocouple case was dented and broken open. One of the fragment shields protecting the piezoelectric transducers on the side of the compartment was bent. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 238 psi and 934 psi; those on the door, 360 psi and 113 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 480 psi and 430 psi and crush gauges located in the rear, 430 psi and 510 psi.

The mechanical crush gauge in the nose of the live propellant cartridge case was damaged, and the gauge in the base recorded a pressure of 3700 psi. No thermocouples were placed in the inert warheads for this test, but thermocouples were placed in the dummy cartridge cases. The maximum temperature recorded in the dummy cartridge cases was 415°F.

The event screens failed to function properly; therefore, there are no jet-tip velocity measurements The jet penetrated 1 inch into the steel RHA witness plates underneath the compartment.

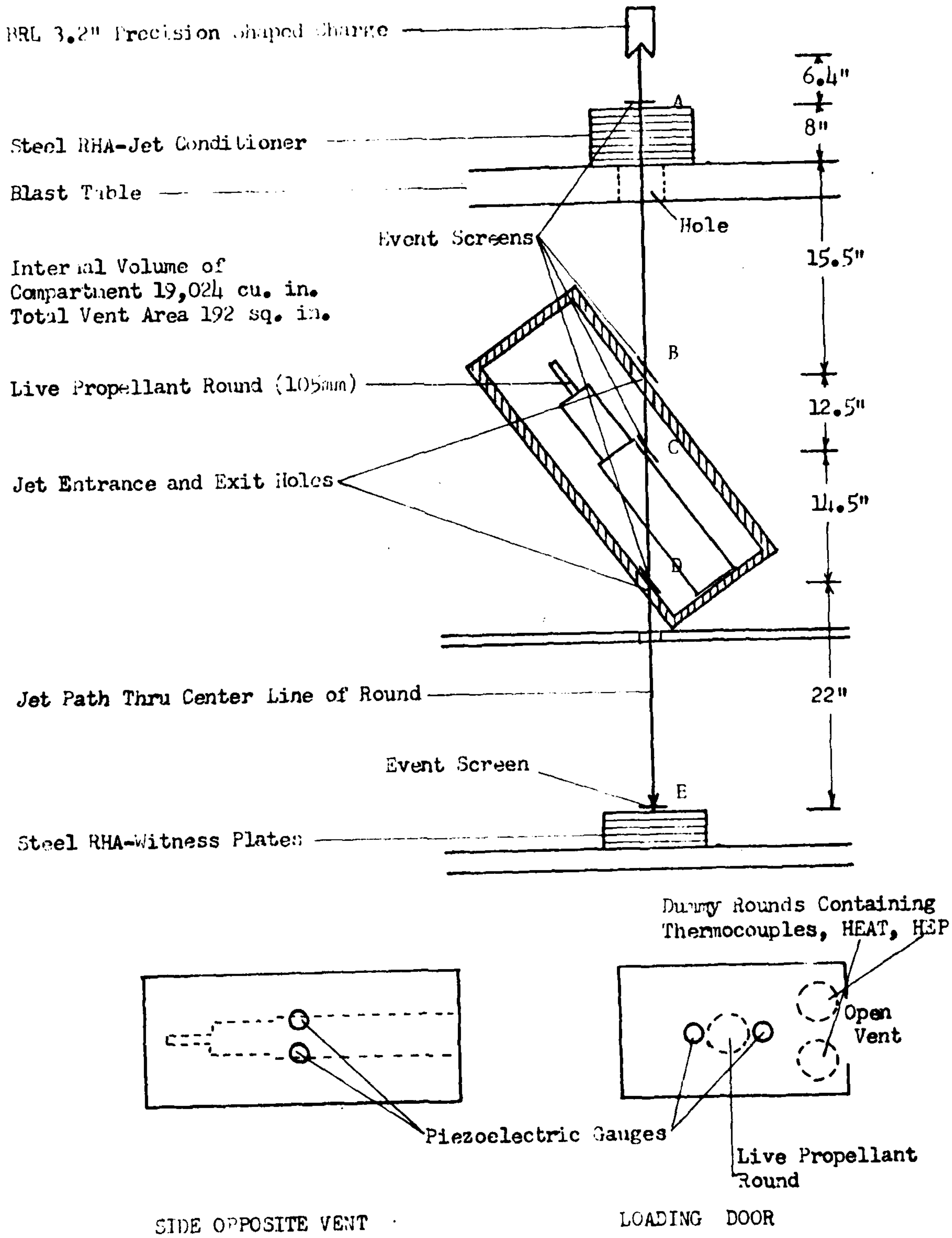


Figure A-76 Test Setup for Propellant Test No. 20

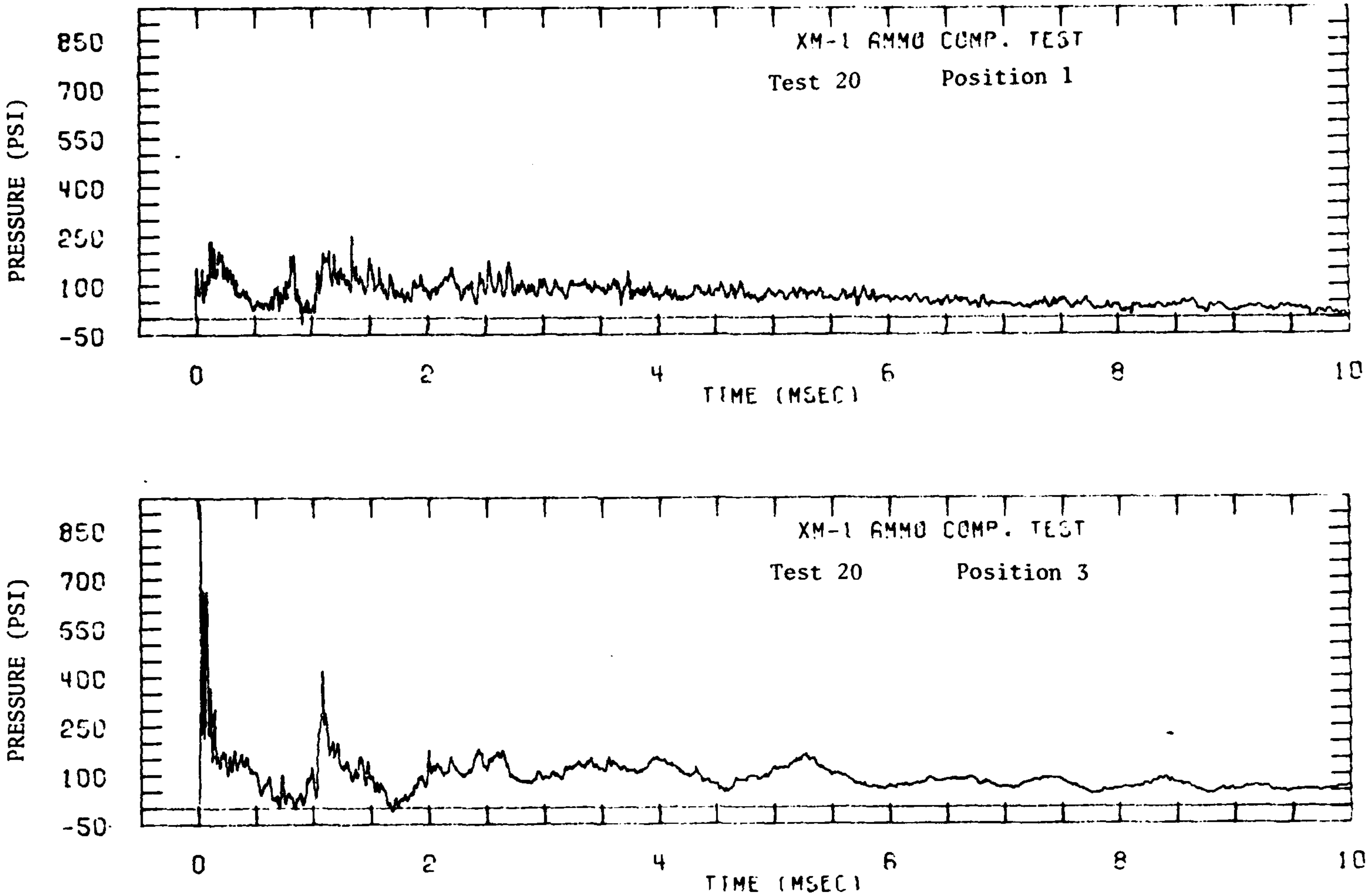


Figure A-77 Pressure Time Histories on Compartment Wall - Test No. 20

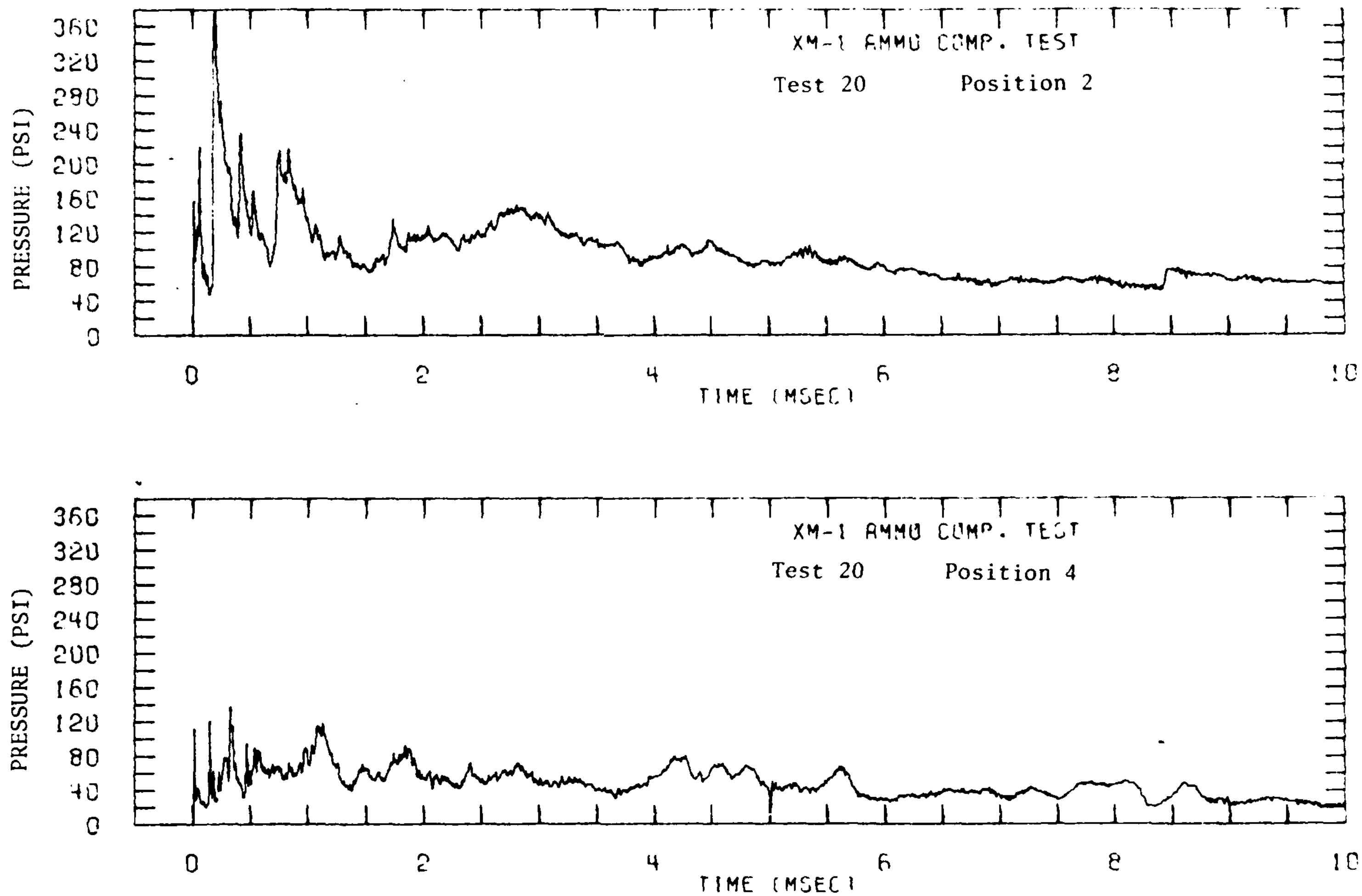


Figure A-78 Pressure Time Histories on Loading Door - Test No. 20

CARTRIDGE CASE TEMPERATURES

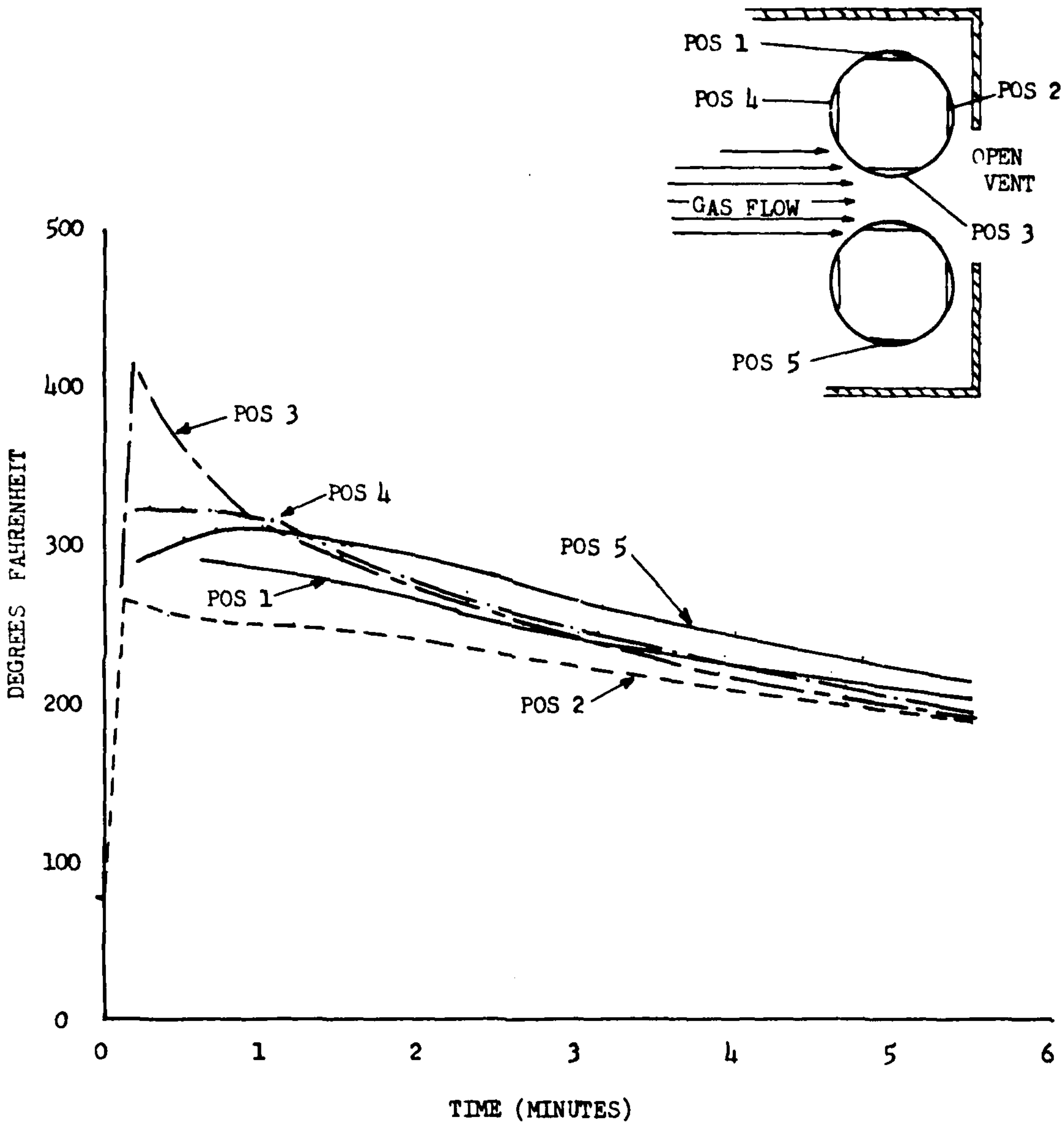


Figure A-79 Cartridge Case Temperature Time Histories - Test No. 20

XXI. BRL PROPELLANT TEST NO. 21

Date: 2 October 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired at an angle through the center line (8-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, passed through the center line of a live propellant 105mm round stowed in the compartment, struck the primer, and exited.

The live propellant case impacted by the shaped charge jet broke up into several large pieces. The primer, was in two pieces. The top thermocouple case was badly dented, while the bottom thermocouple case was dented and broken open. One of the fragment shields protecting the piezoelectric transducers on the side of the compartment was bent. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 507 psi and 1018 psi; those on the door, 544 psi and 235 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 510 psi and 430 psi and crush gauges located in the rear, 500 psi and 330 psi.

The mechanical crush gauge in the live propellant cartridge case recorded pressures of 5600 psi in the nose and 2100 psi in the case. No temperature records were obtained from this test; the thermocouple wires were cut and burned.

The event screens failed to function and there was no sign of jet penetration on the steel RHA witness plates underneath the compartment.

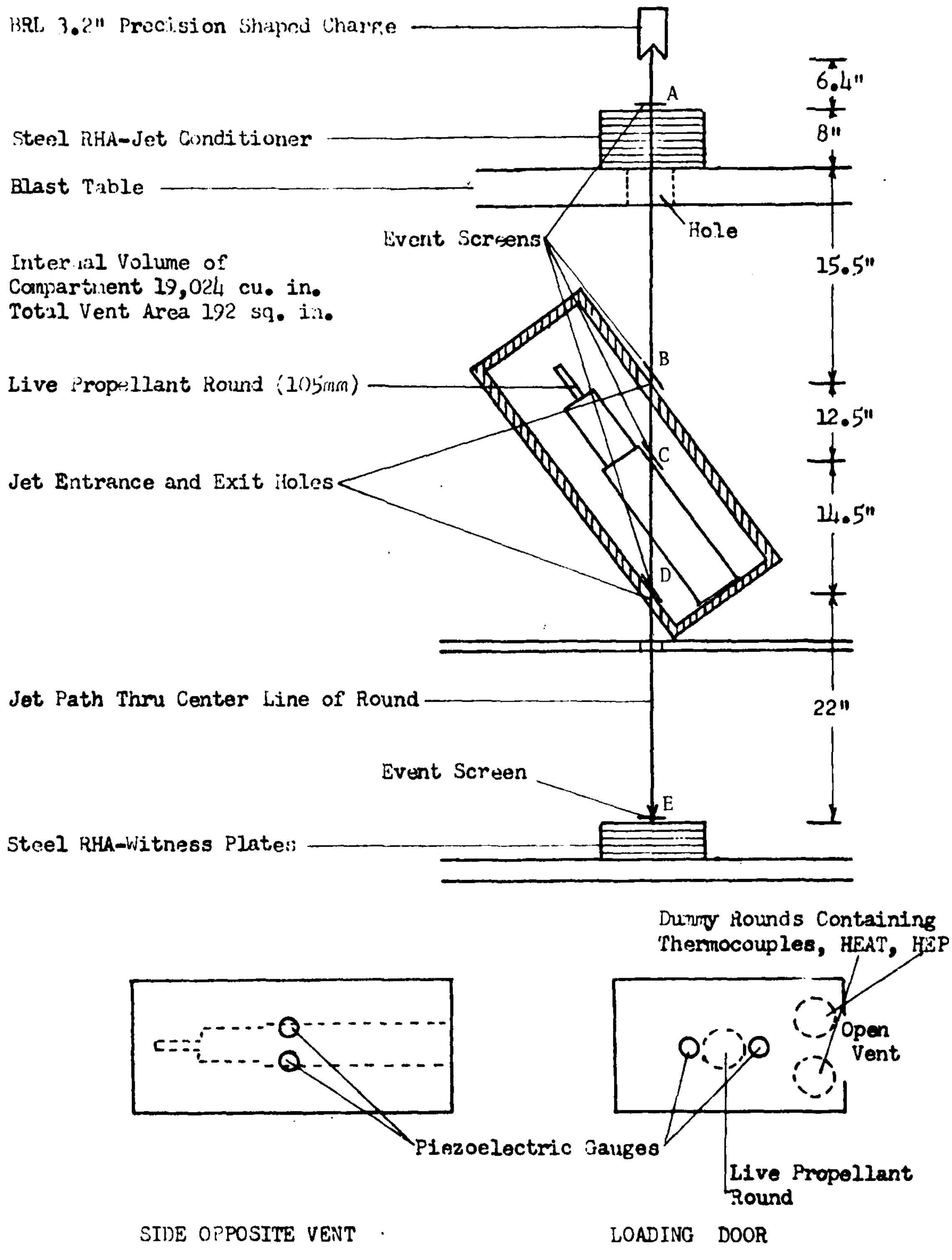


Figure A-80 Test Setup for Propellant Test No. 21

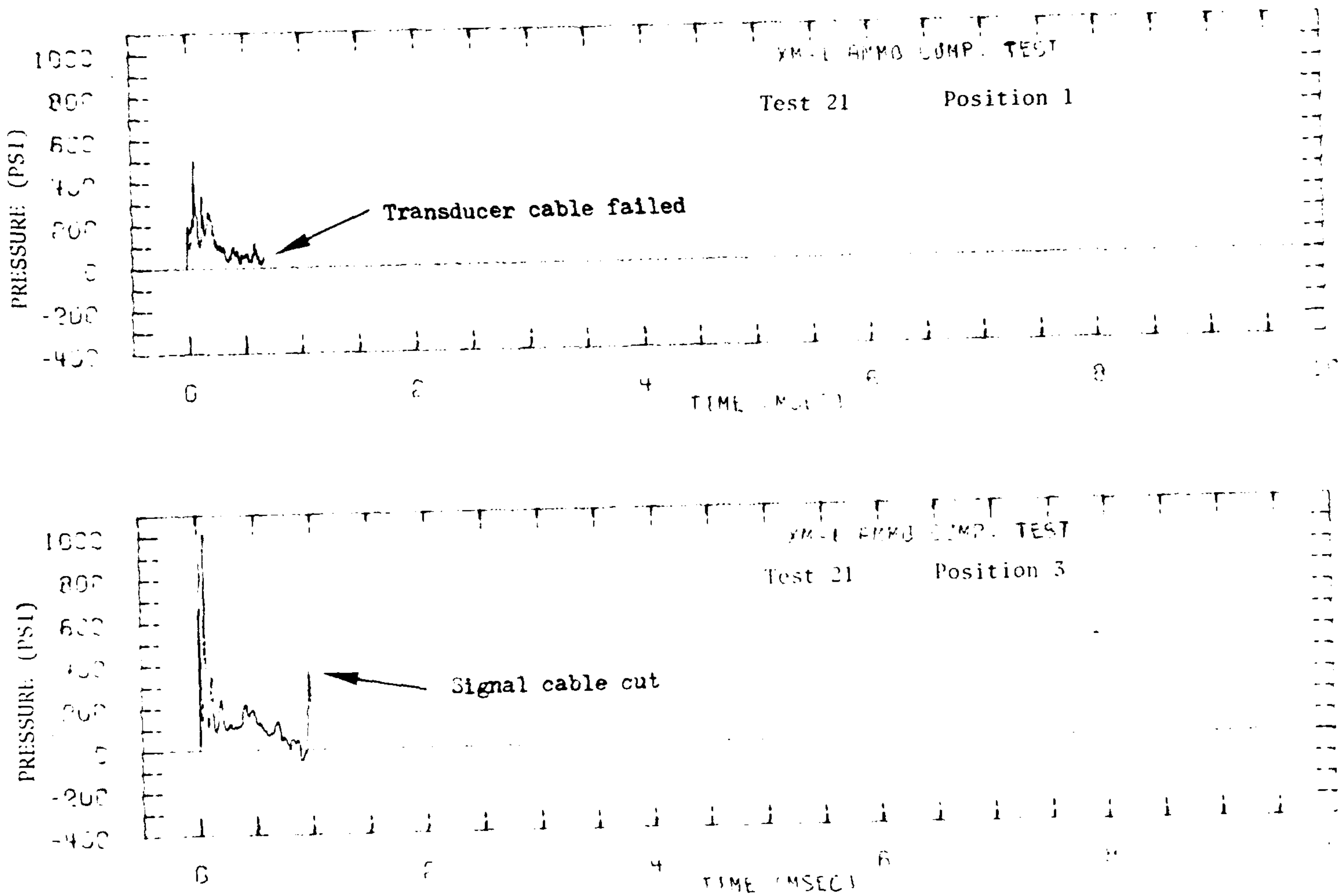


Figure A-81 Pressure Time Histories on Compartment Wall - Test No. 21

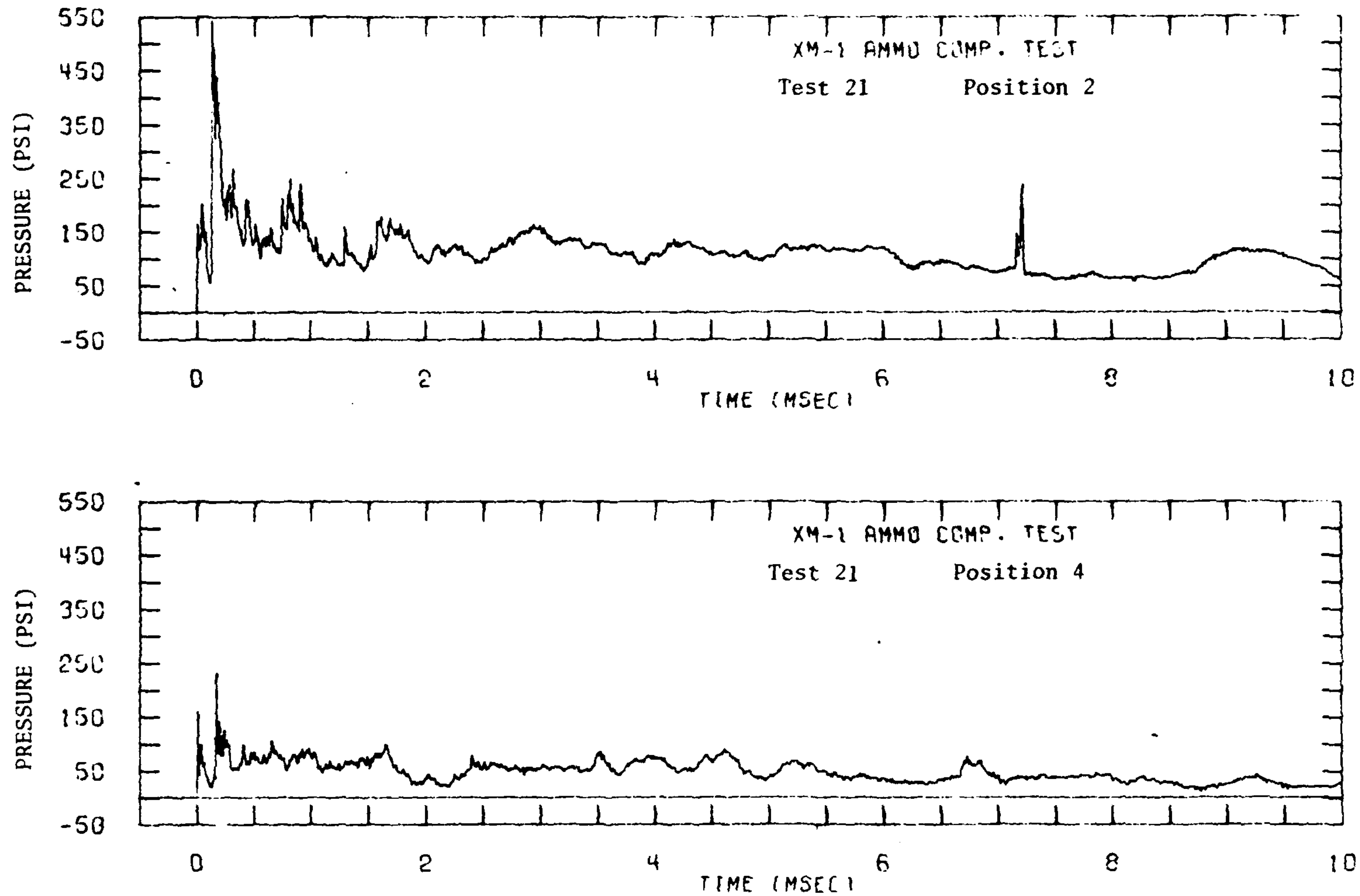


Figure A-82 Pressure Time Histories on Loading Door - Test No. 21

XXII. BRL PROPELLANT TEST NO. 22

Date: 15 October 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired at an angle through the center line (8-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, and event screens.

Results

The shaped charge jet entered the compartment, passed through the center line of a live propellant 105mm round stowed in the compartment, struck the primer, and exited.

The live propellant case impacted by the shaped charge jet broke up into several large pieces. The dummy HEP round in the upper corner of the compartment was nearly split in two and was blown out of the compartment. The dummy HEAT round in the lower corner of the compartment was squashed. Two of the three bolts holding the dummy rounds in position broke, and one of the two bolts, holding the fragment shield on the side of the compartment in place was sheared off. There was no damage to the main structure of the compartment.

One of the piezoelectric transducers on the side of the compartment recorded a peak pressure of 755 psi; those on the door, 582 psi and 178 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 460 psi and 830 psi and crush gauges located in the rear, 500 psi and 830 psi.

The mechanical crush gauge in the live propellant cartridge case recorded pressures of 1500 psi in the nose and 4500 psi in the base. No thermocouples were used.

The jet-tip velocity between points A and B was 2.8mm/μsec; between A and C, 3.3mm/μsec; and between A and E, 3.5mm/μsec. The event screen in the bottom of the compartment did not function properly.

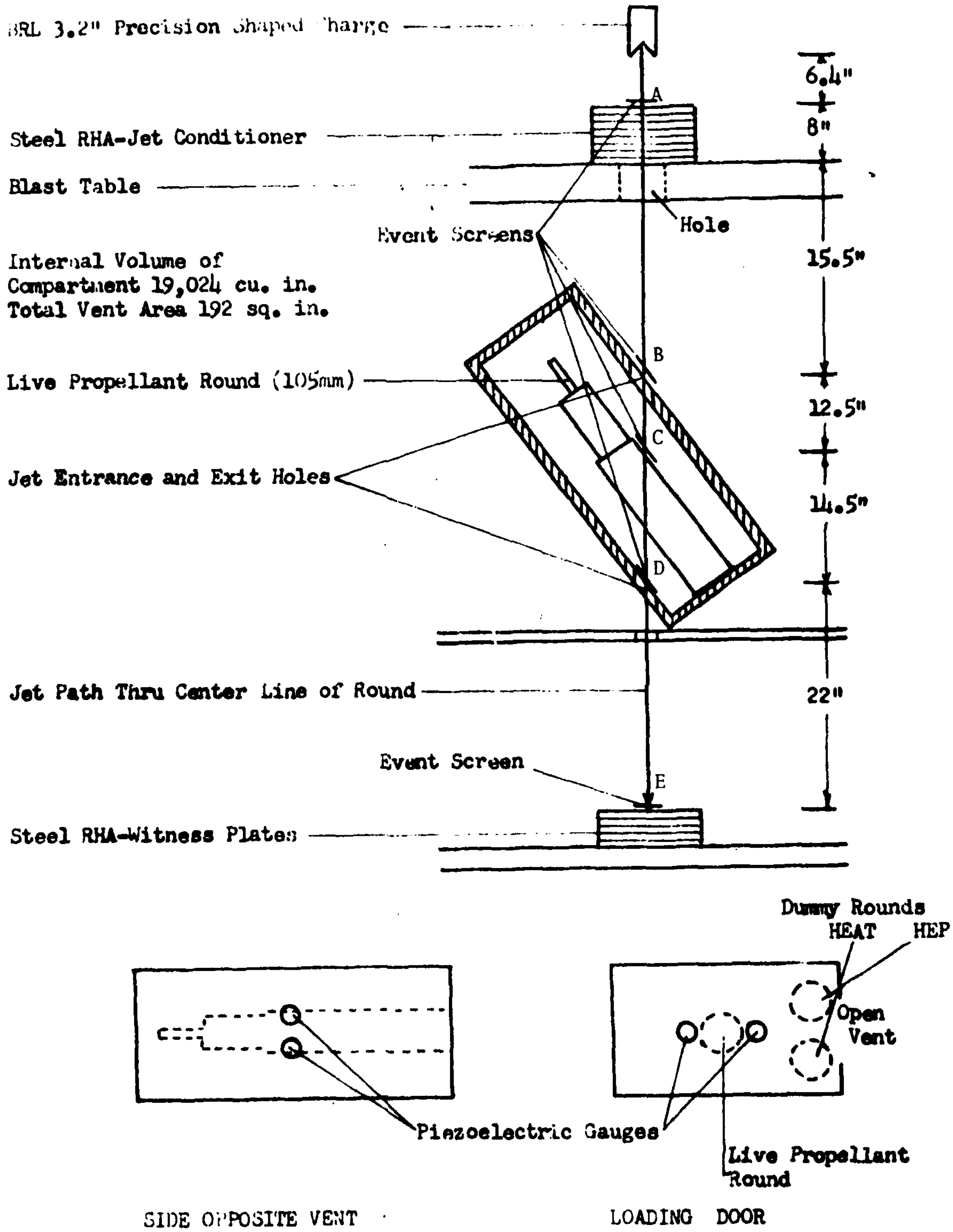
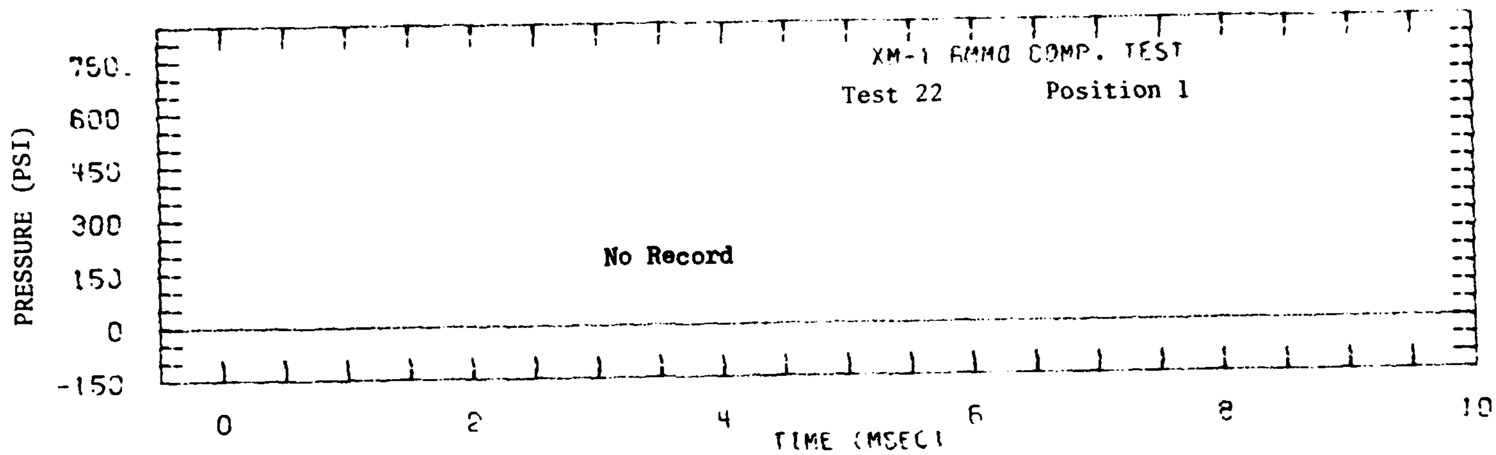


Figure A-83 Test Setup for Propellant Test No. 22



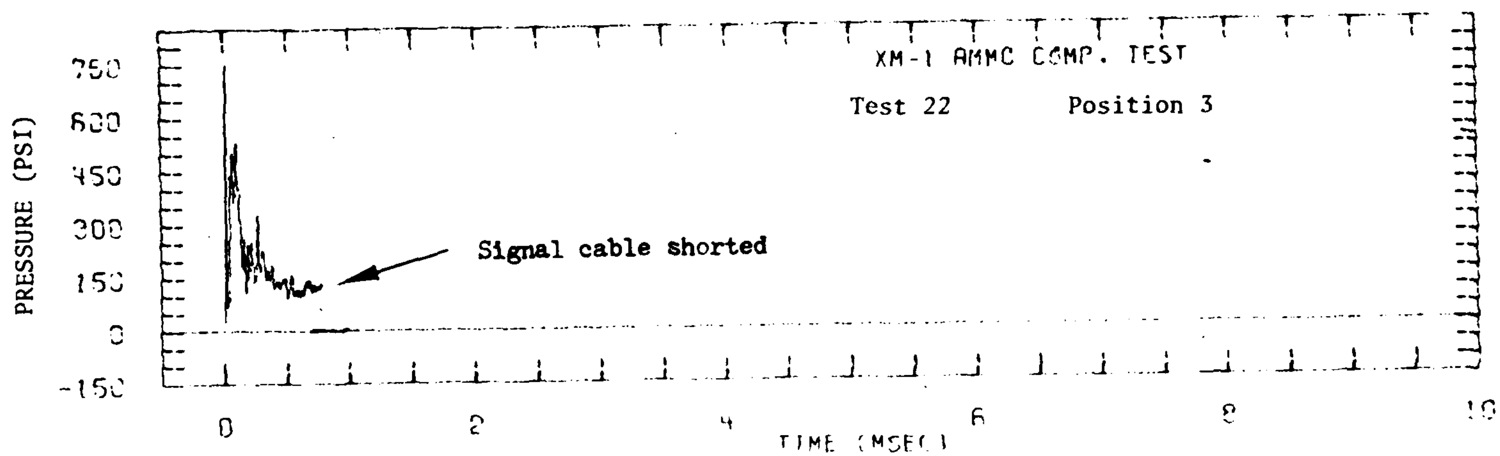


Figure A-84 Pressure Time Histories on Compartment Wall - Test No. 22

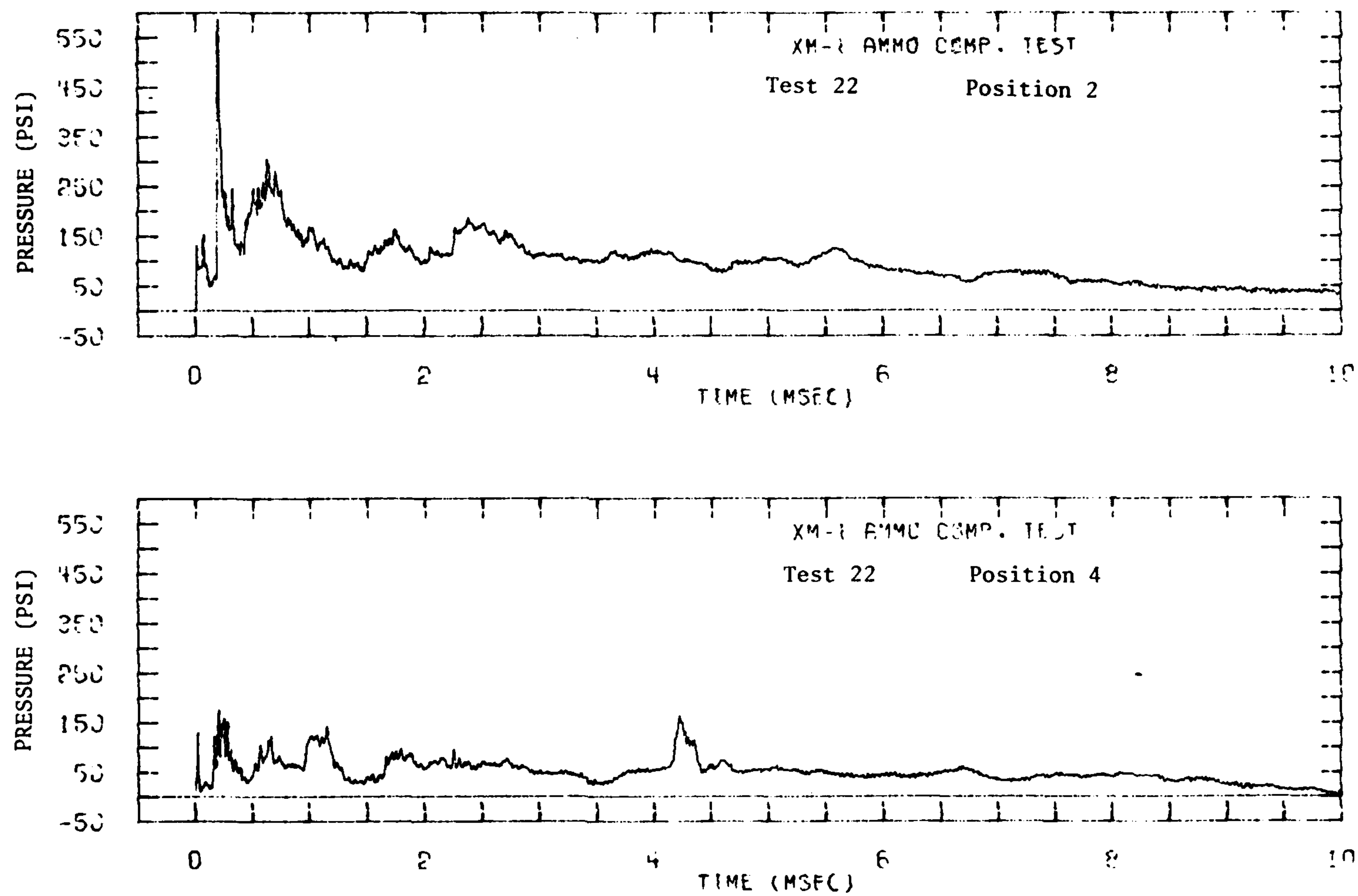


Figure A-85 Pressure Time Histories on Loading Door - Test No. 22

XXIII. BRL PROPELLANT TEST NO. 23

Date: 18 October 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired at an angle through the center line (8-inch propellant path) of a single, live propellant round stowed in the compartment.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, and event screens.

Results

The shaped charge jet entered the compartment, passed through the center line of a live propellant 105mm round stowed in the compartment, missed the primer, and exited.

The live propellant case impacted by the shaped charge jet broke up into several large pieces. The dummy HEP round in the upper corner of the compartment and the dummy HEAT round stored in the lower corner of the compartment were badly dented. One of the fragment shields protecting the piezoelectric transducers on the side of the compartment was bent. There was no damage to the compartment.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 523 psi and 427 psi; those on the door, 410 psi and 210 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 490 psi, 1060 psi, and 790 psi, and crush gauges located in the rear, 450 psi and 440 psi.

The mechanical crush gauge in the live propellant cartridge case recorded pressures of 7400 psi in the nose and 1845 psi in the base. No thermocouples were used.

The average jet-tip velocity between points A and B was 2.7mm/μsec; between A and C, 3.1mm/μsec; between A and D, 3.1mm/μsec; and between A and E, 2.9mm/μsec.

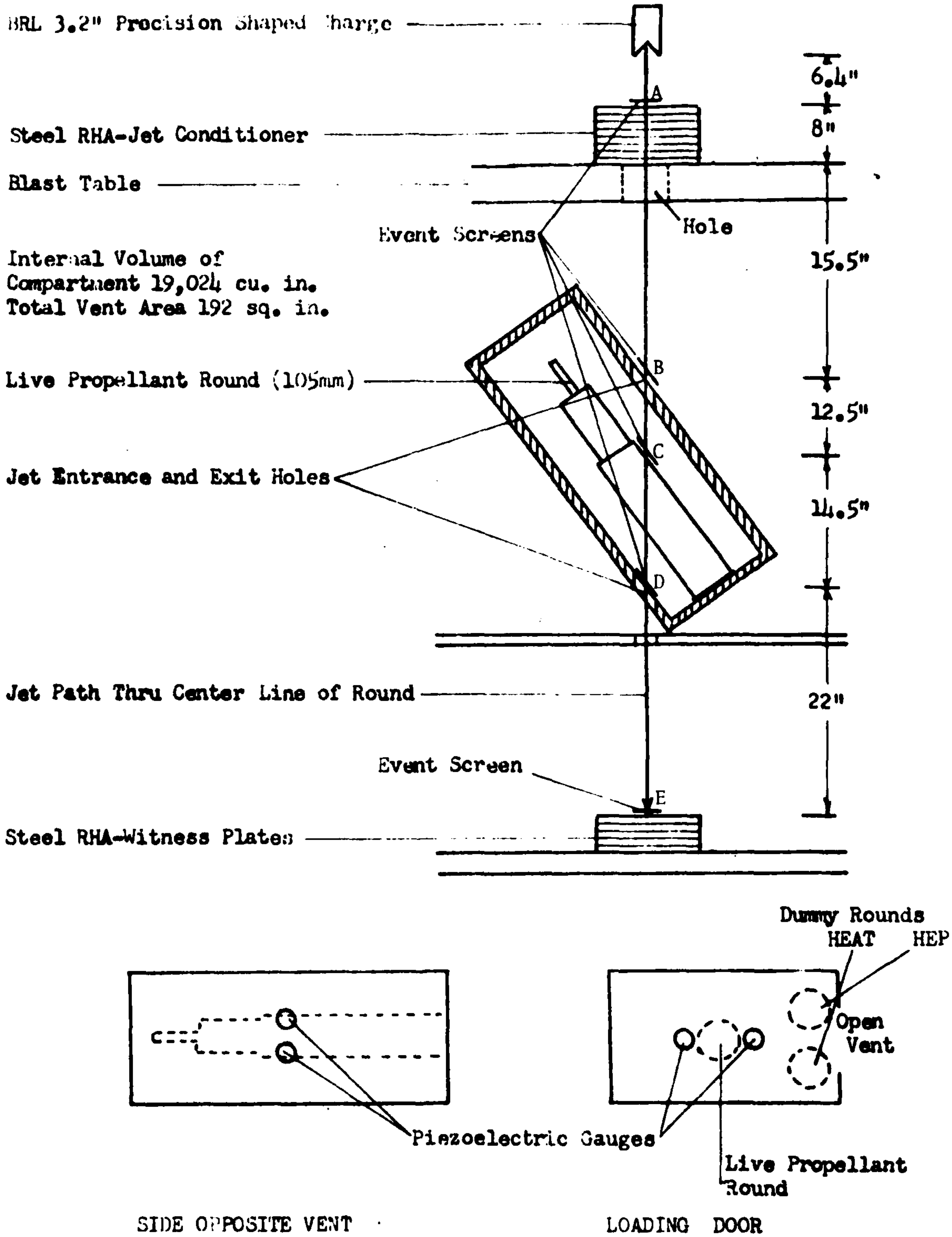


Figure A-86 Test Setup for Propellant Test No. 23

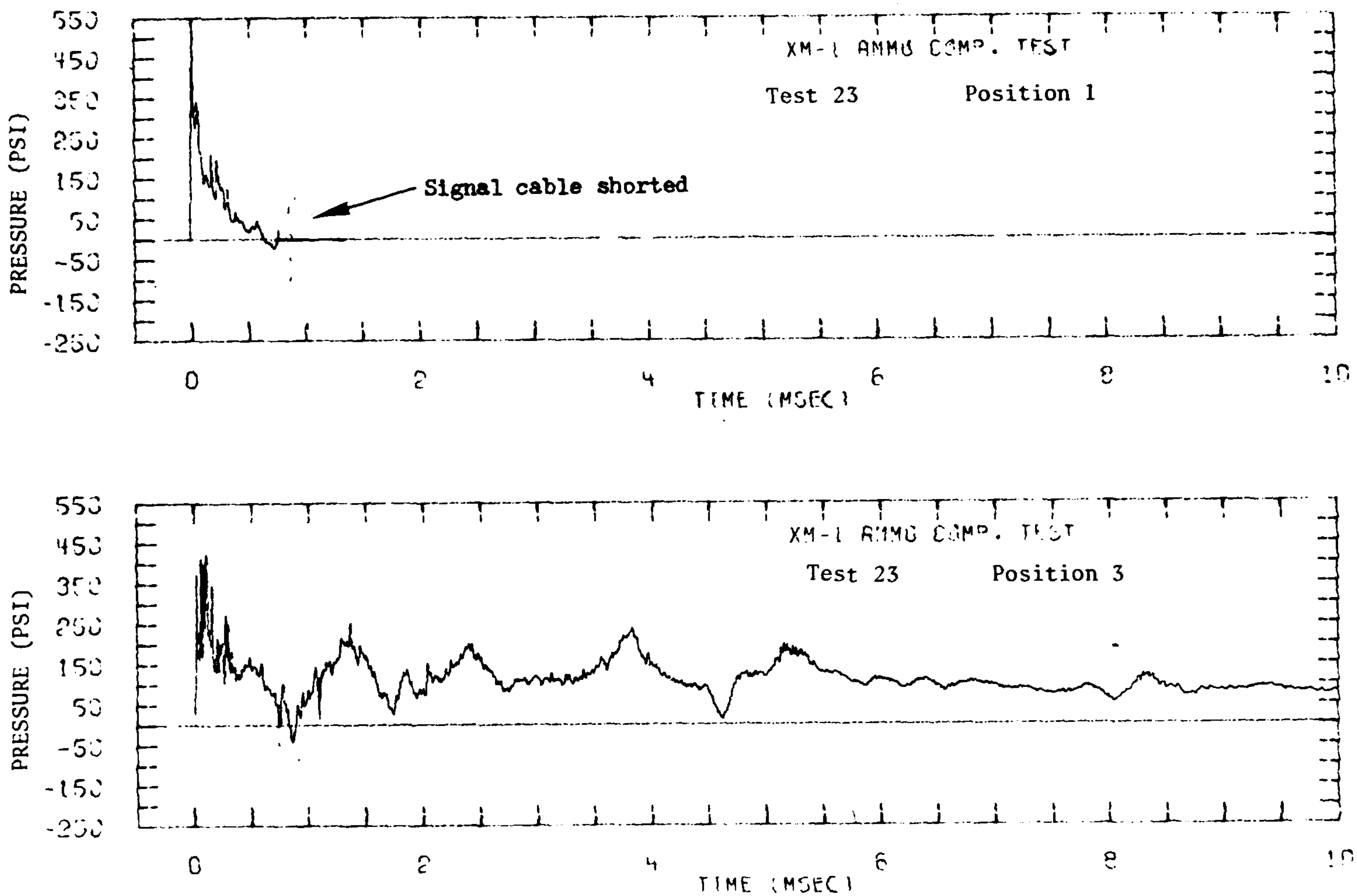


Figure A-87 Pressure Time Histories on Compartment Wall - Test No. 23

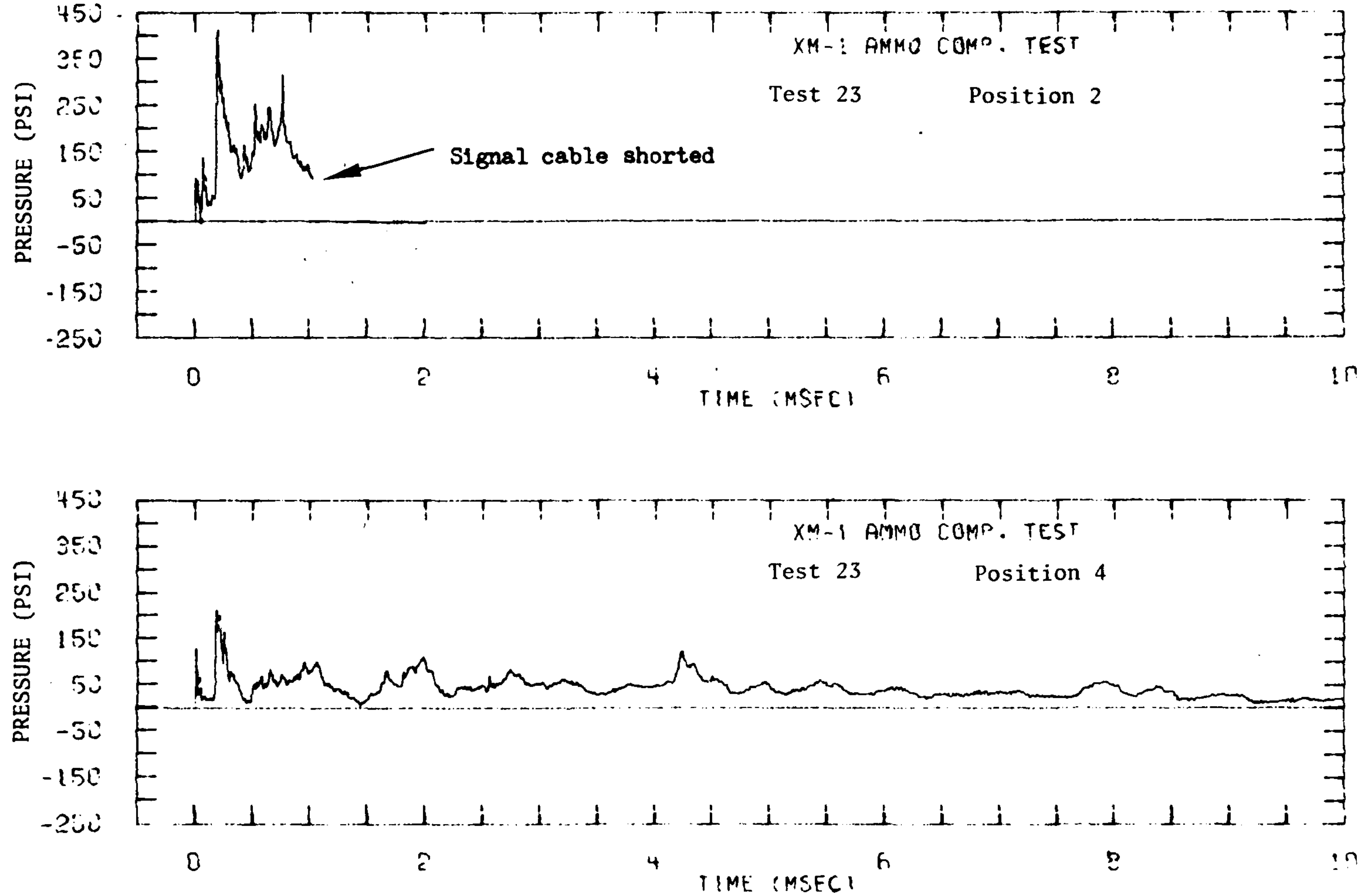


Figure A-88 Pressure Time Histories on Loading Door - Test No. 23

XXIV. BRL PROPELLANT TEST NO. 24

Date: 31 October 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1- to 2-inch propellant path) of a single, live propellant round stowed in the compartment with two 1-gallon jugs of water and to see what effect the water has on the burning propellant.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and grazed the live propellant 105mm round (APDS M392A1) on the gauge side of the compartment; it then penetrated 1-5/8 inches into the steel RHA witness plates located in the bottom of the compartment.

The projectile from the live propellant round did not separate from its cartridge case. The cartridge case sustained a hole 6 inches in diameter in the area of jet impact. The remaining portion of the case was intact. There was no damage to the thermocouple cases or the compartment.

The plastic water jugs in the compartment did not tear apart, but they did melt and flood the floor of the compartment. The floor was covered with unburned propellant.

No piezoelectric readings were obtained from this test. Mechanical crush gauges located in front of the compartment recorded pressures of 530 psi and 460 psi and crush gauges located in the rear, 330 psi and 480 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 400 psi in the nose and 400 psi in the base. No thermocouples were placed in the inert warheads, but both cartridge cases were instrumented with thermocouples. Maximum temperatures of 610°F were recorded in the HEP case and 760°F in the HEAT case.

The event screens failed to function properly.

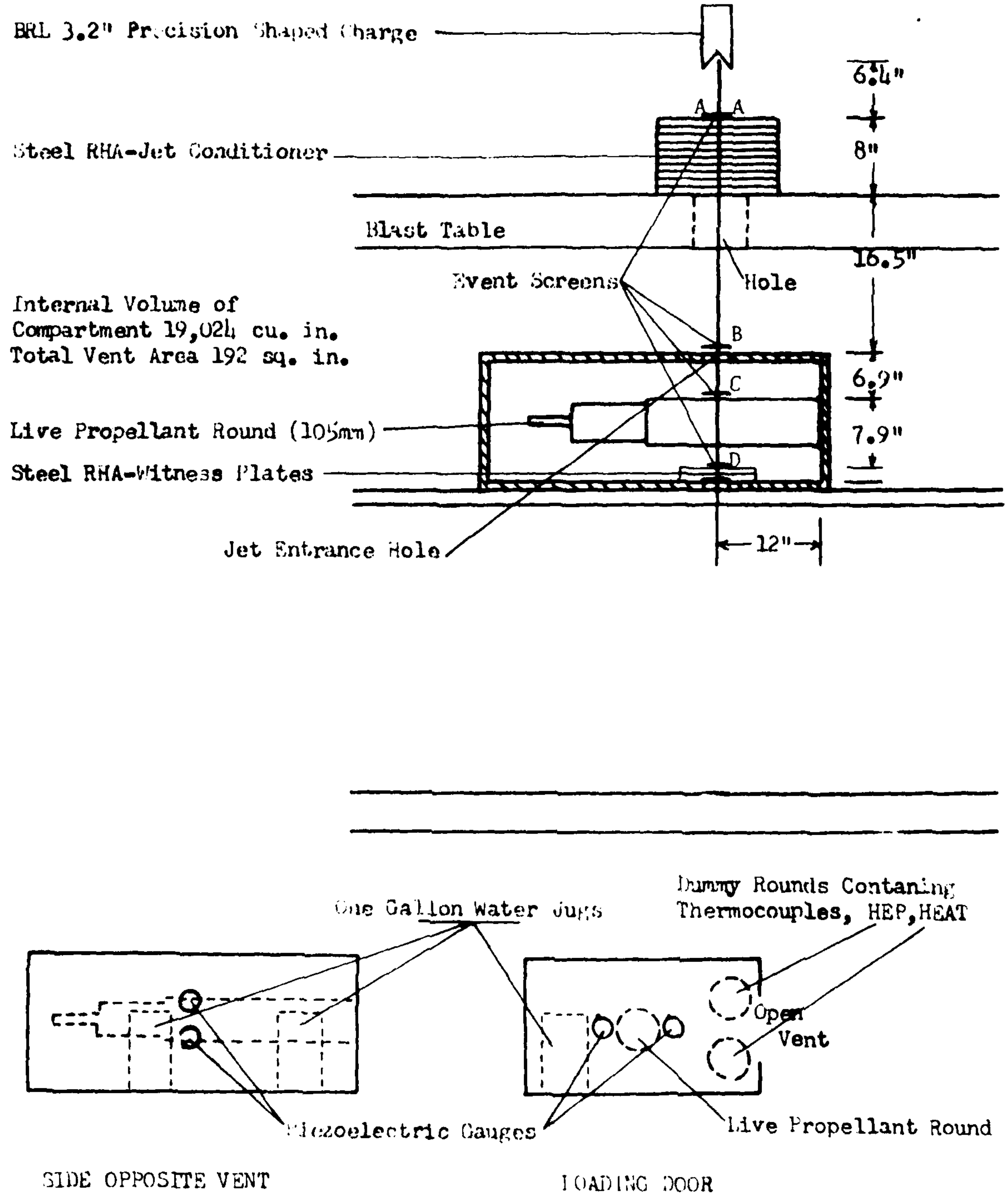


Figure A-89 Test Setup for Propellant Test No. 24

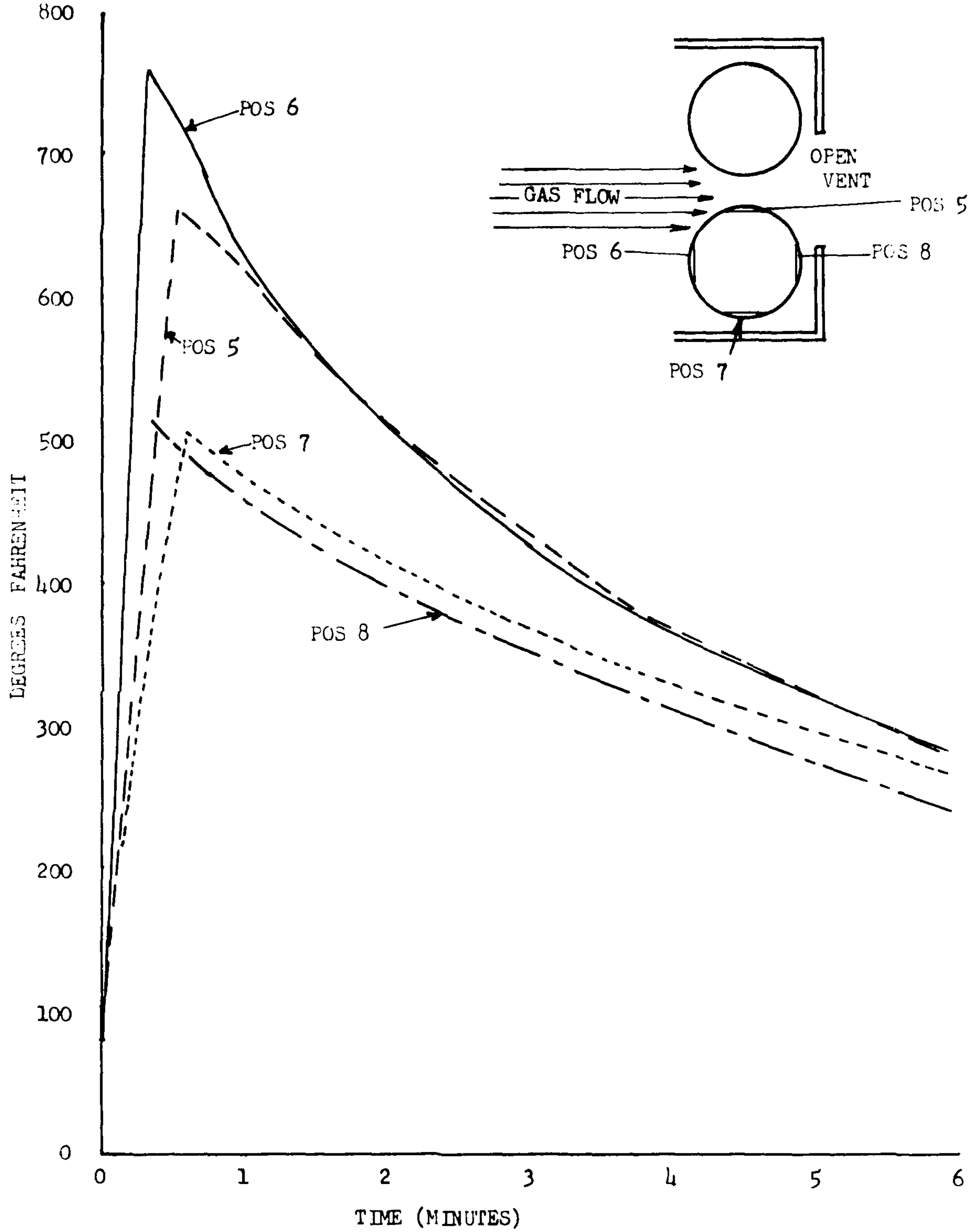


Figure A-90 Cartridge Case Temperature Time Histories - Test No. 24

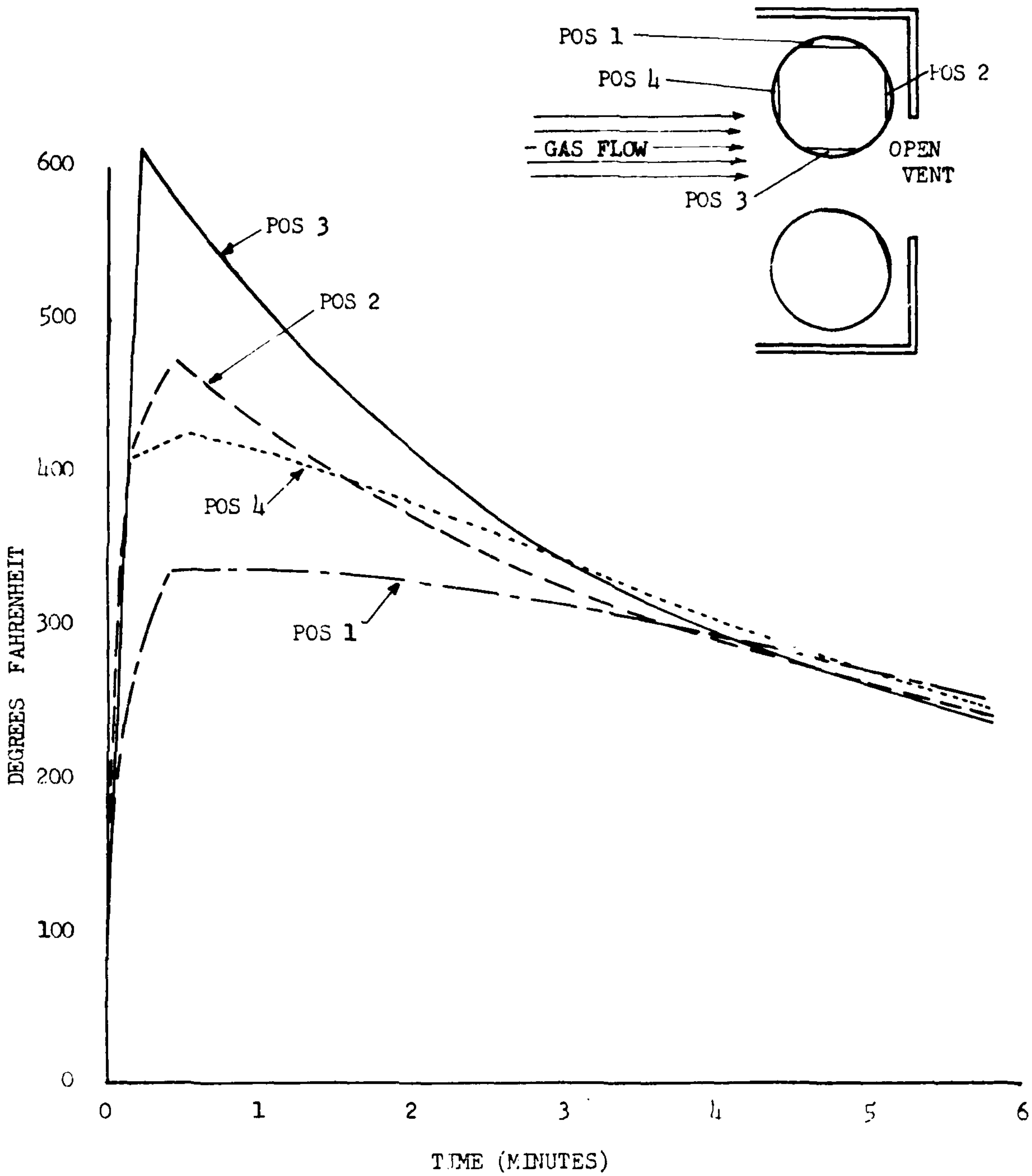


Figure A-91 Cartridge Case Temperature Time Histories - Test No. 24

XXV. BRL PROPELLANT TEST NO. 25

Date: 1 November 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammuntion compartment when a shaped charge jet with a 4.5-inch residual is fired through the edge (1-to 2-inch propellant path) of a single, live propellant round stowed in the compartment with two 1-gallon jugs of water to see what effect the water has on the burning propellant.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and grazed the live propellant 105mm round (APDS M392A2) on the gauge side of the compartment and penetrated 1-7/8 inches into the steel RHA witness plates located in the bottom of the compartment.

The projectile from the live propellant round did not separate from its cartridge case. The cartridge case sustained a hole 6 inches in diameter in the area of jet impact. The remaining portion of the case was intact. There was no damage to the thermocouple cases or the compartment.

The plastic water jugs in the compartment did not tear apart, but they did melt and flood the floor of the compartment. The floor was covered with unburned propellant.

The piezoelectric transducers recorded peak pressures of 55 psi and 73 psi on the side of the compartment and 64 psi and 144 psi on the door. Mechanical crush gauges located in the front of the compartment recorded pressures of 240 psi and 490 psi and crush gauges located in the rear, 360 psi and 260 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 200 psi in the nose and 600 psi in the base. No thermocouples were placed in the inert warheads, but both cartridge cases were instrumented with thermocouples. Maximum temperatures of 350°F were recorded in the HEP case and 325°F in the HEAT case.

The event screens failed to function properly.

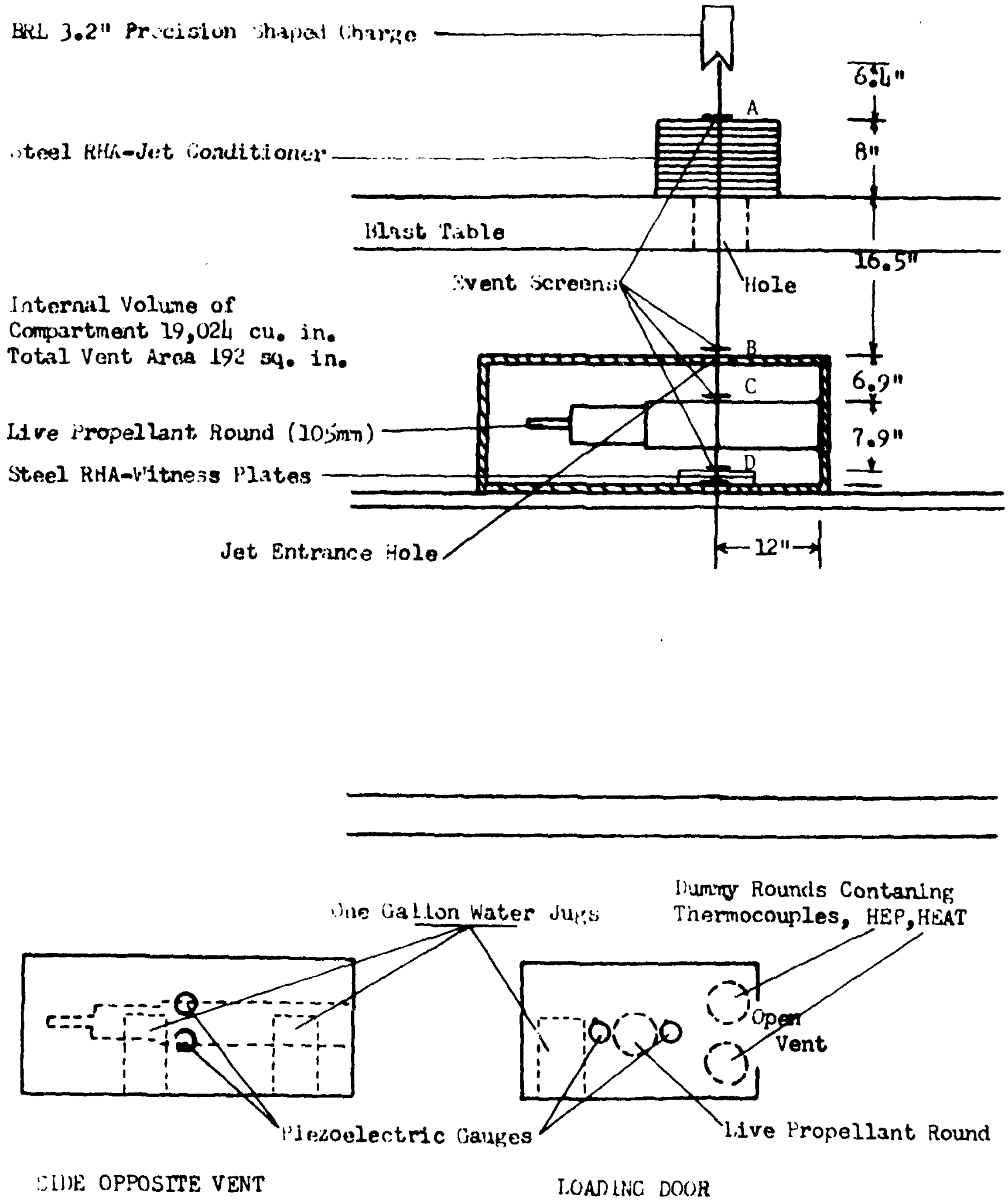
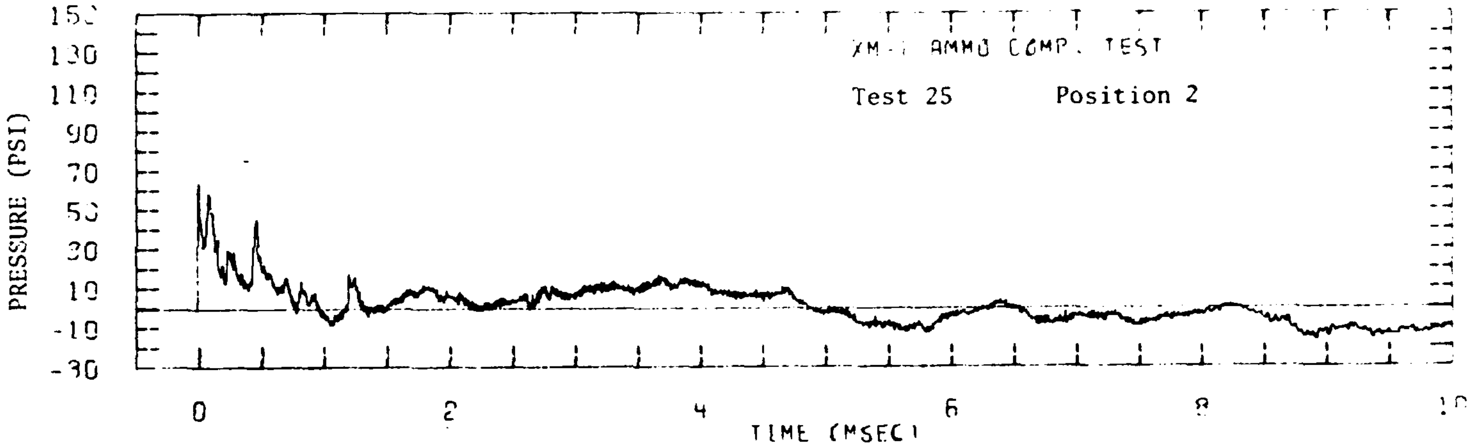


Figure A-92 Test Setup for Propellant Test No. 25



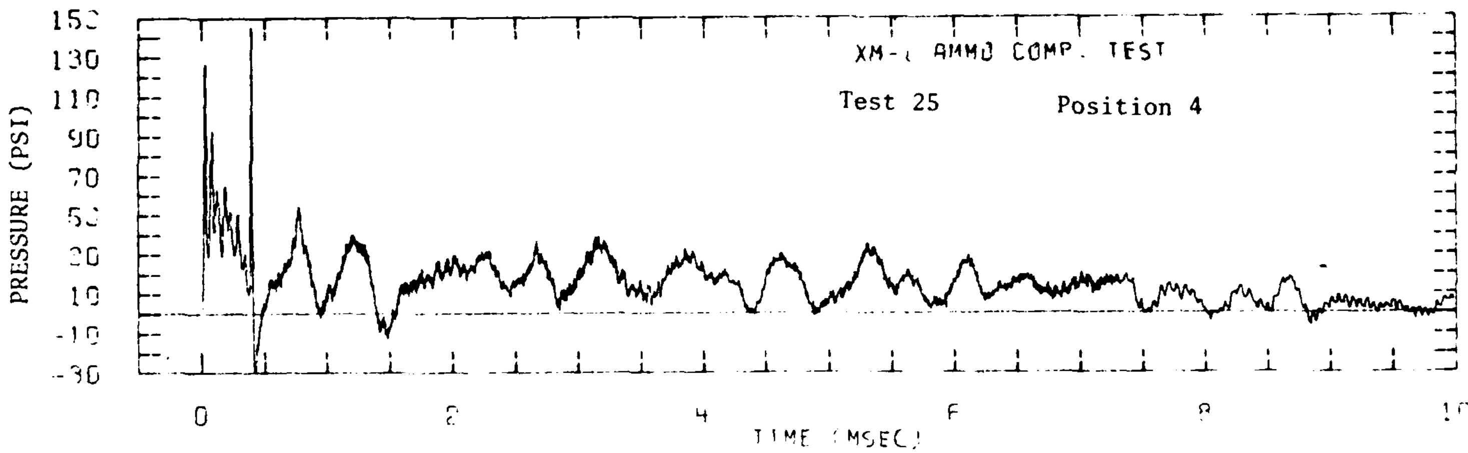


Figure A-93 Pressure Time Histories on Compartment Door - Test No. 25

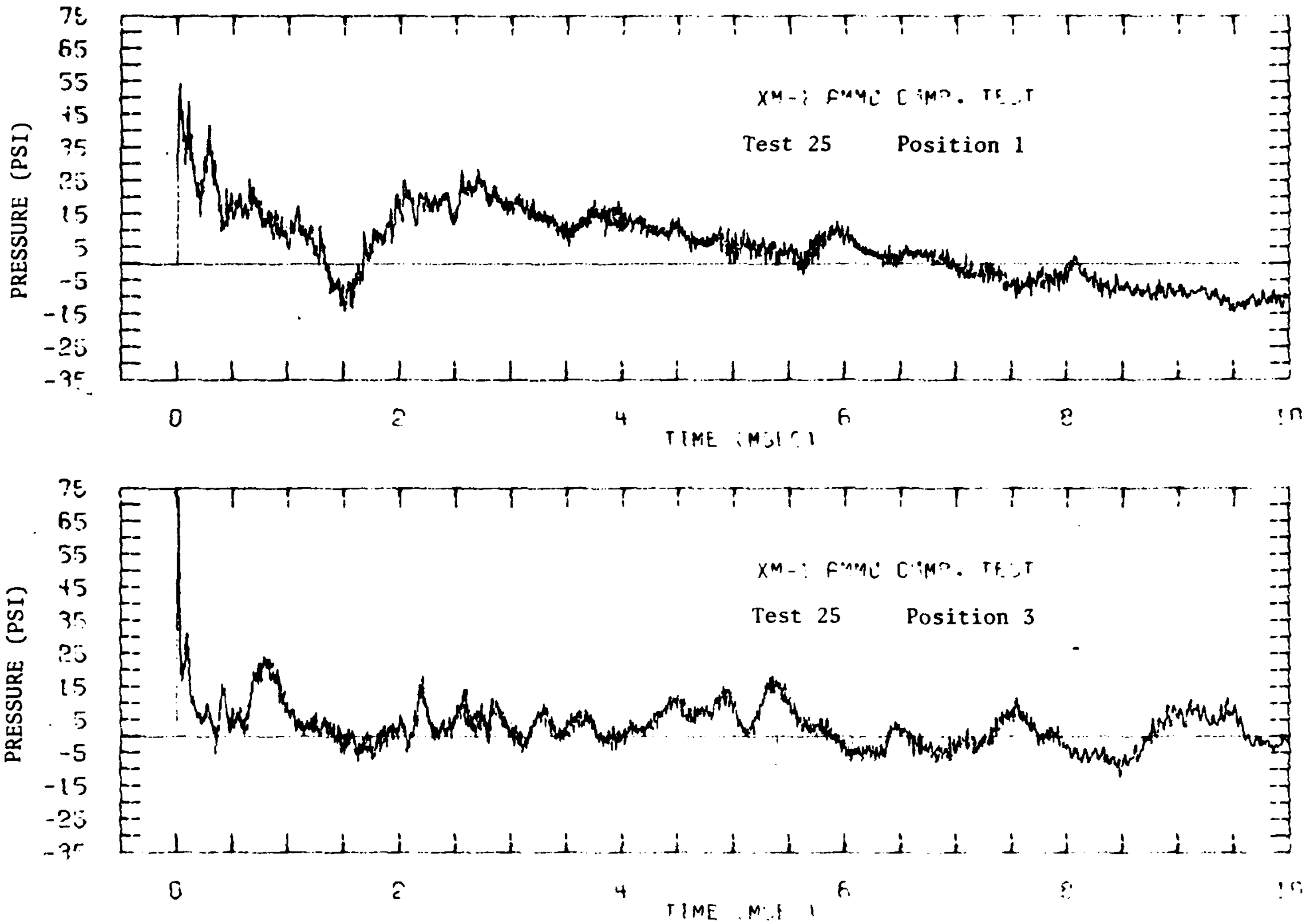


Figure A-94 Pressure Time Histories on Loading Door Test No. 25

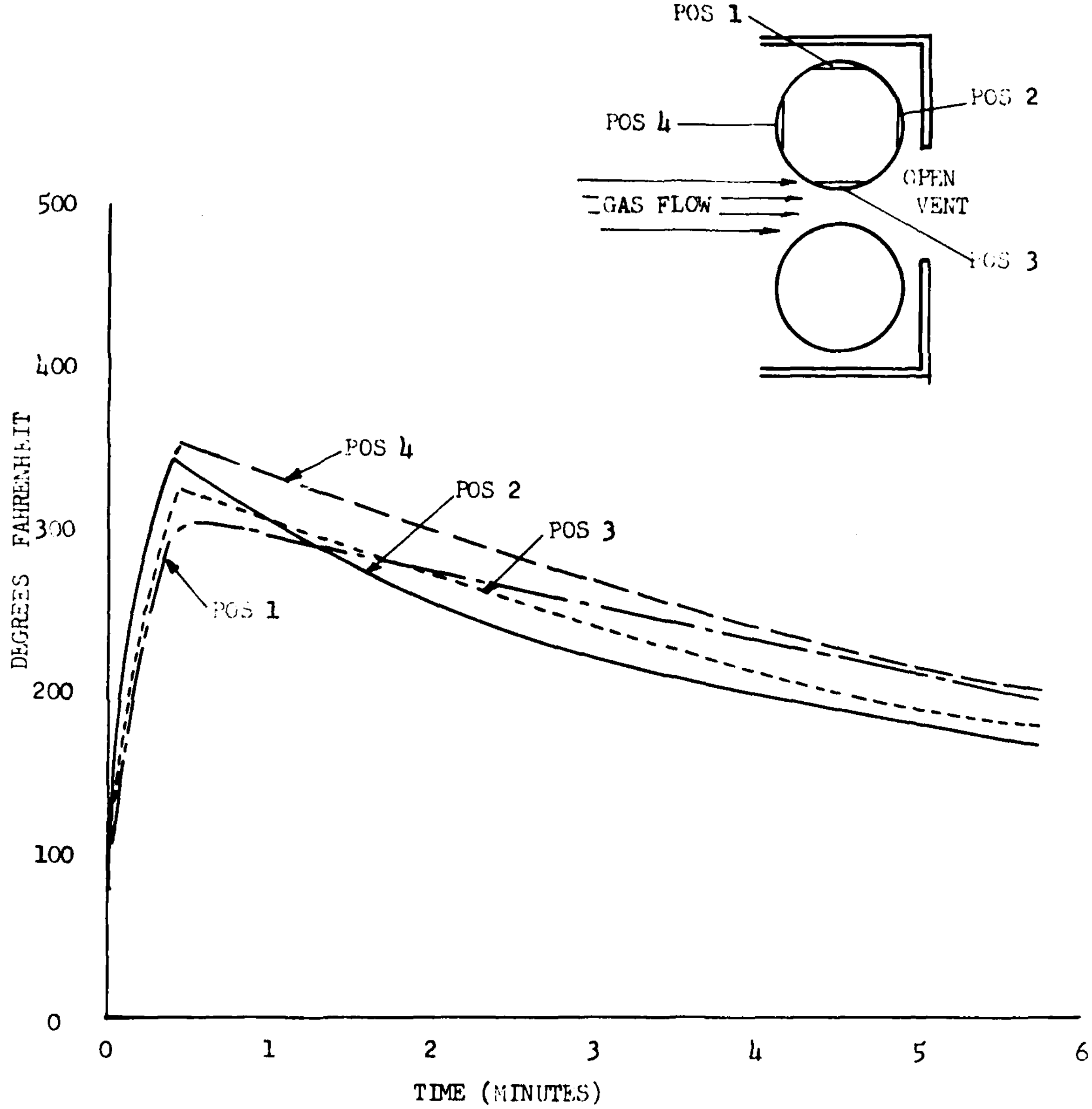


Figure A-95 Cartridge Case Temperature Time Histories - Test No. 25

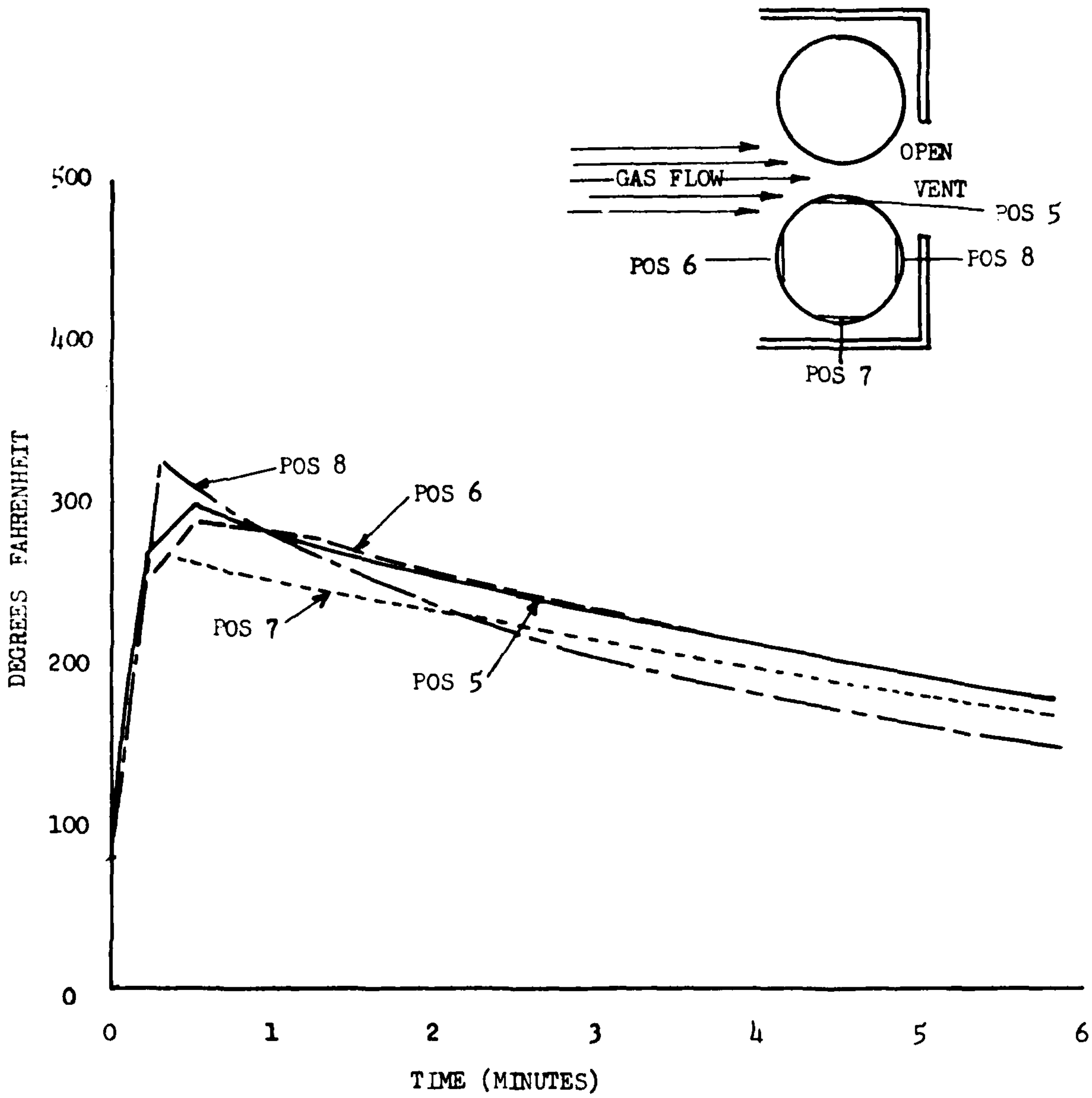


Figure A-96 Cartridge Case Temperature Time Histories - Test No. 25

XXVI. BRL PROPELLANT TEST NO. 26

Date: 6 November 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the center line (5-inch propellant path) of a single live propellant round stowed in the compartment with two 1-gallon jugs of water and to see what effect the water has on the burning propellant.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then penetrated 1 inch into the steel RHA witness plates located in the bottom of the compartment.

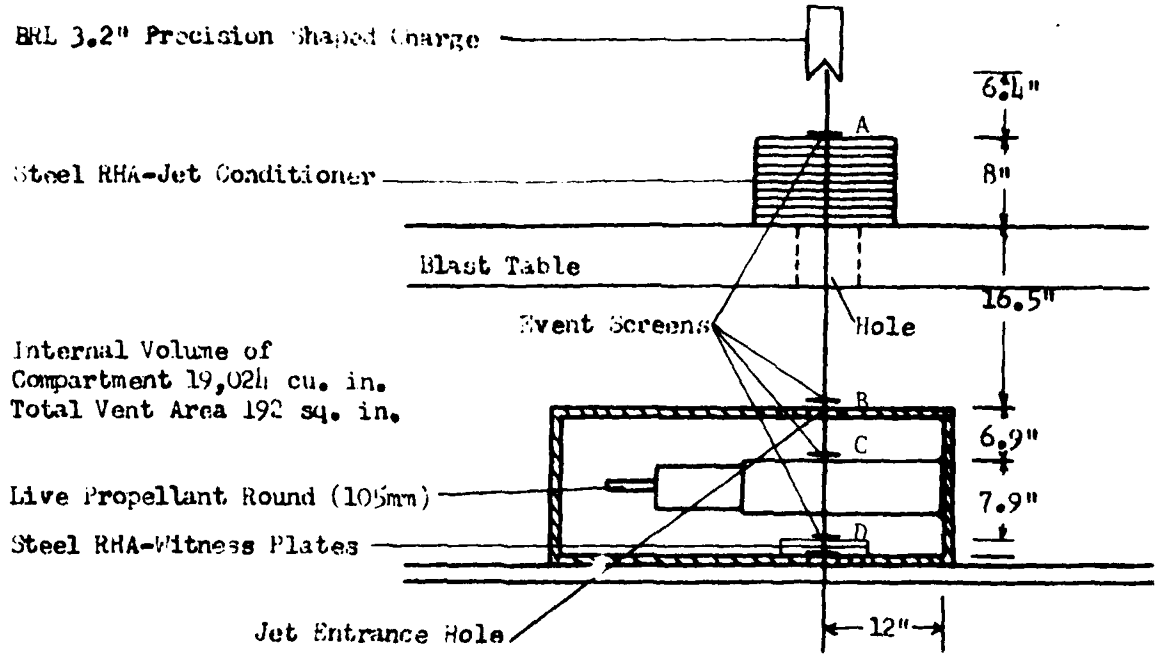
The projectile from the live propellant round separated from its cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was in two pieces. Both thermocouple cases were dented and one of the cases had a small hole in it. There was no damage to the compartment.

The plastic water jugs tore apart and flooded the floor of the compartment. The floor was covered with unburned propellant.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 160 psi and 365 psi, those on the door, 516 psi and 530 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 380 psi and 480 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 900 psi in the nose and 1500 psi in the base. There were no thermocouples placed in the inert warheads for this test, but both cartridge cases were instrumented with thermocouples. Maximum temperatures of 275° and 310°F were recorded in the HEP case and HEAT case.

The event screens failed to function properly.



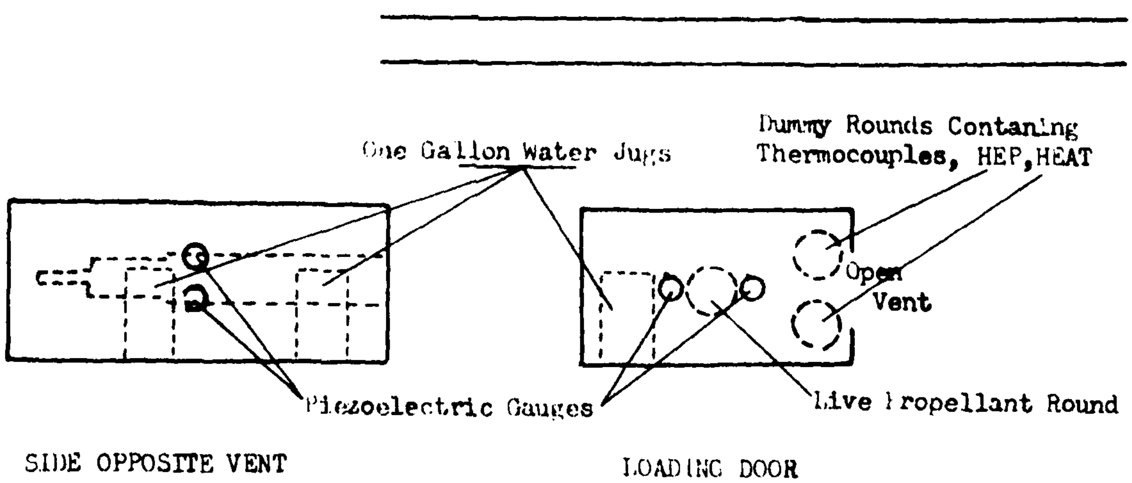
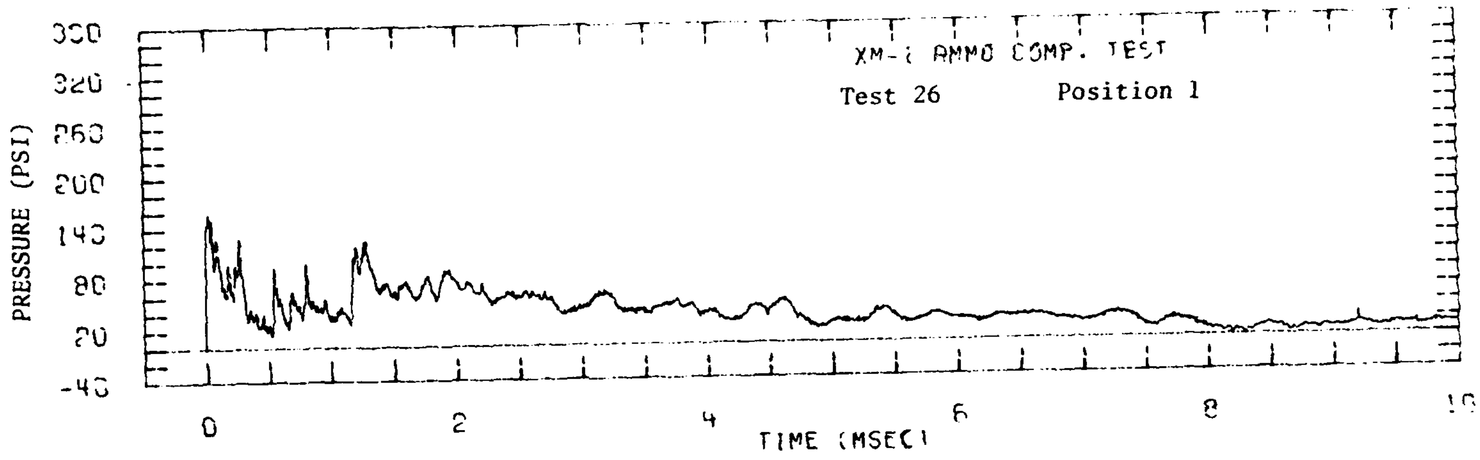


Figure A-97 Test Setup for Propellant Test No. 26



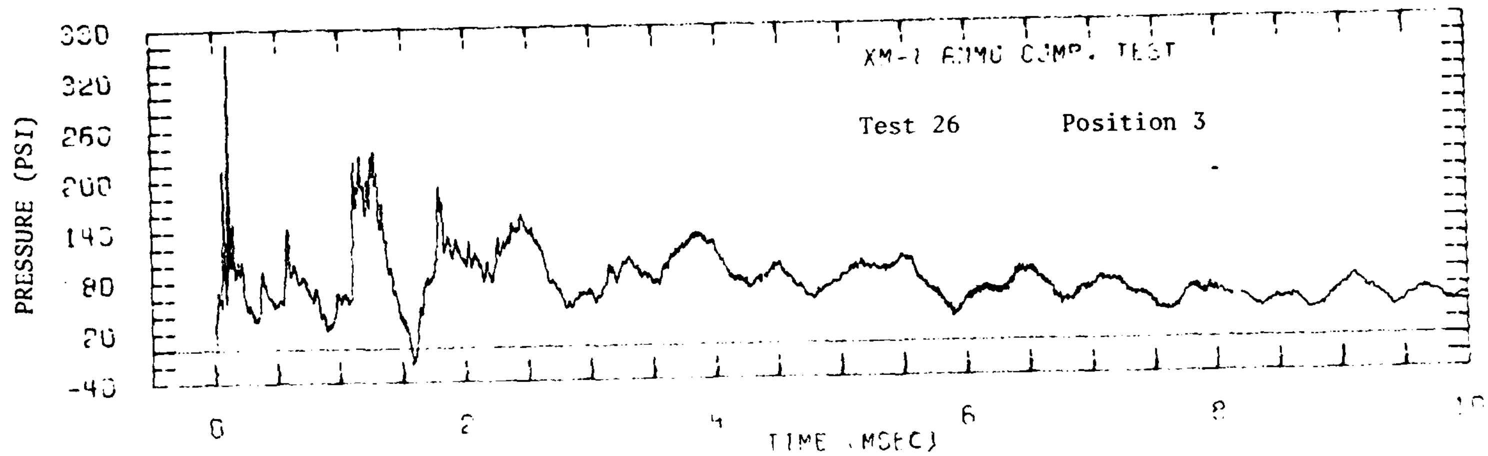
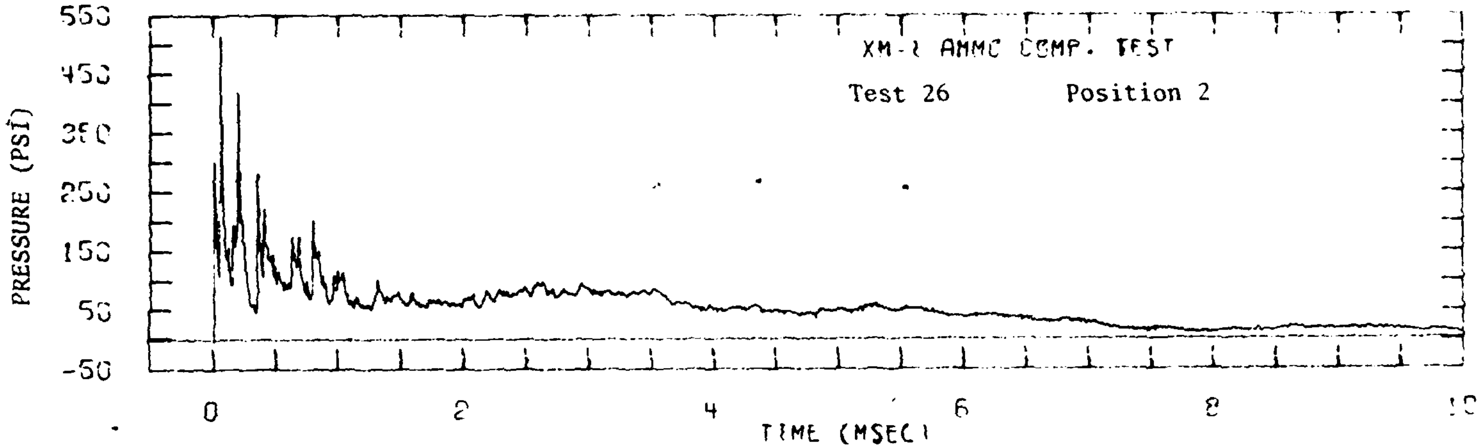


Figure A-98 Pressure Time Histories on Compartment Wall - Test No. 26



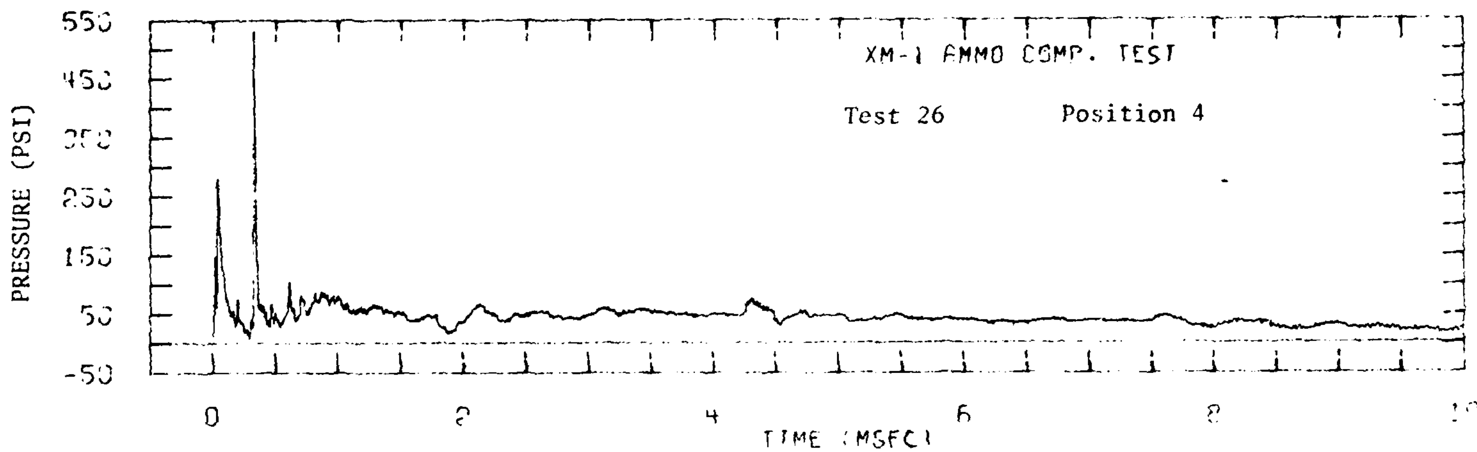


Figure A-99 Pressure Time Histories on Loading Door _ Test No. 26

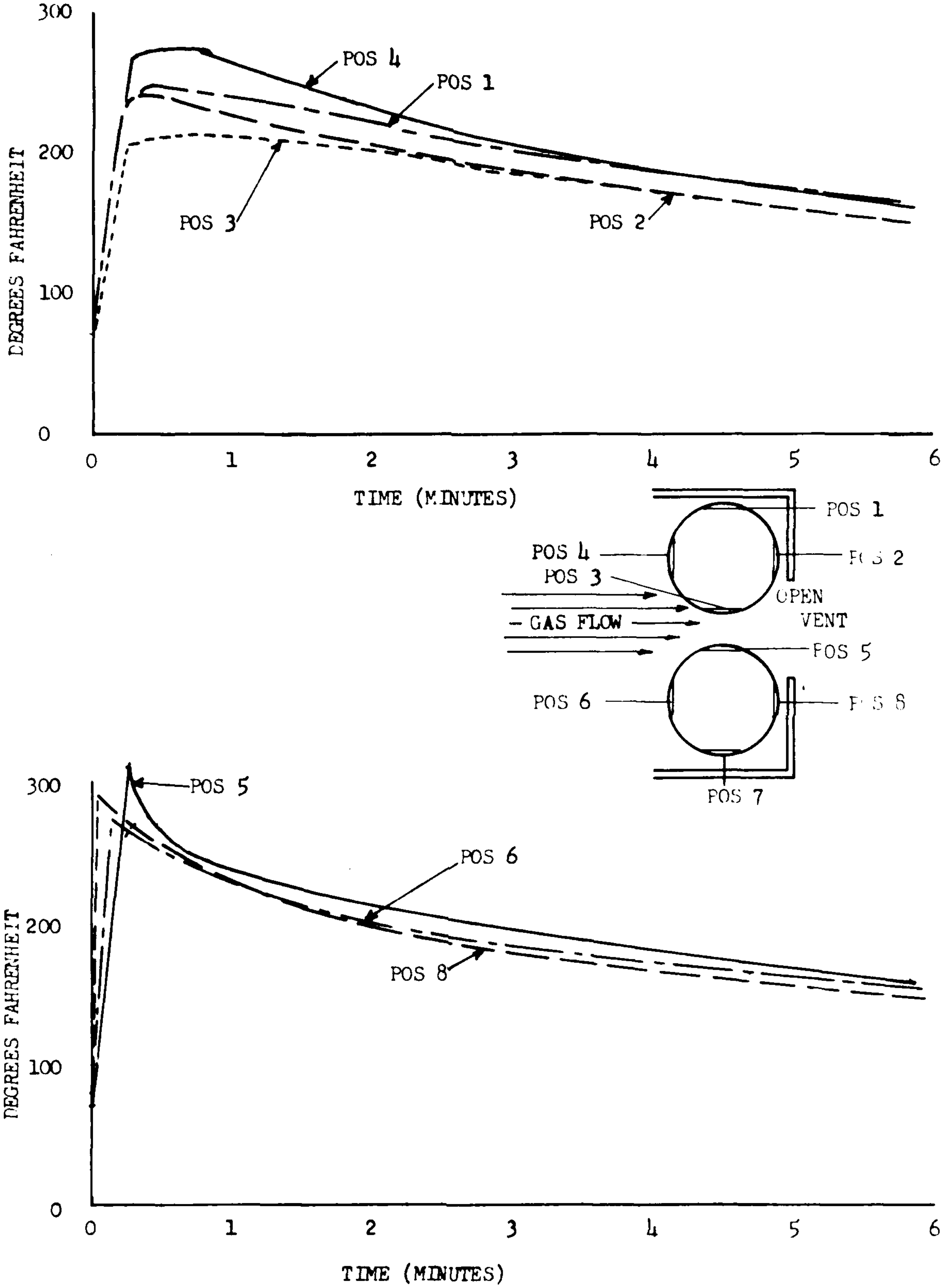


Figure A-100 Cartridge Case Temperature Time Histories - Test No. 26

XXVII. BRL PROPELLANT TEST NO. 27

Date: 8 November 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment with two 1-gallon jugs of water and to see what effect the water has on the burning propellant.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment and passed through the live propellant 105mm round (APDS M392A2) striking the primer; it then penetrated 1-1/2 inches into the steel RHA witness plates located in the bottom of the compartment.

The projectile from the live propellant round separated from its cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was in two pieces. Both themocouple cases were dented and one of the cases had a small hole in it. There was no damage to the compartment.

The plastic water jugs tore apart and flooded the floor of the compartment. The floor was covered with unburned propellant.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 185 psi and 278 psi; those on the door, 831 psi and 283 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 420 psi and 450 psi and crush gauges located in the rear, 250 psi and 360 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 900 psi in the nose and 5800 psi in the base. No themocouples were placed in the inert warheads, but both cartridge cases were instrumented with thermocouples. A maximum temperature of 500°F was recorded in the HEP case and a maximum temperture of 350°F was reoorded in the HEAT case.

The average jet-tip velocity between points A and B was 3.8mm/μsec; between A and D, 2.7mm/μsec. The event screen on top of the live propellant round did not function properly.

AD-A081 778 ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND ABERD--ETC F/6 19/1
SHAPED CHARGE JET/PROPELLANT INTERACTIONS IN A VENTED COMPARTME--ETC(U)
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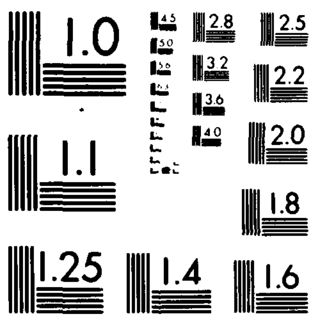

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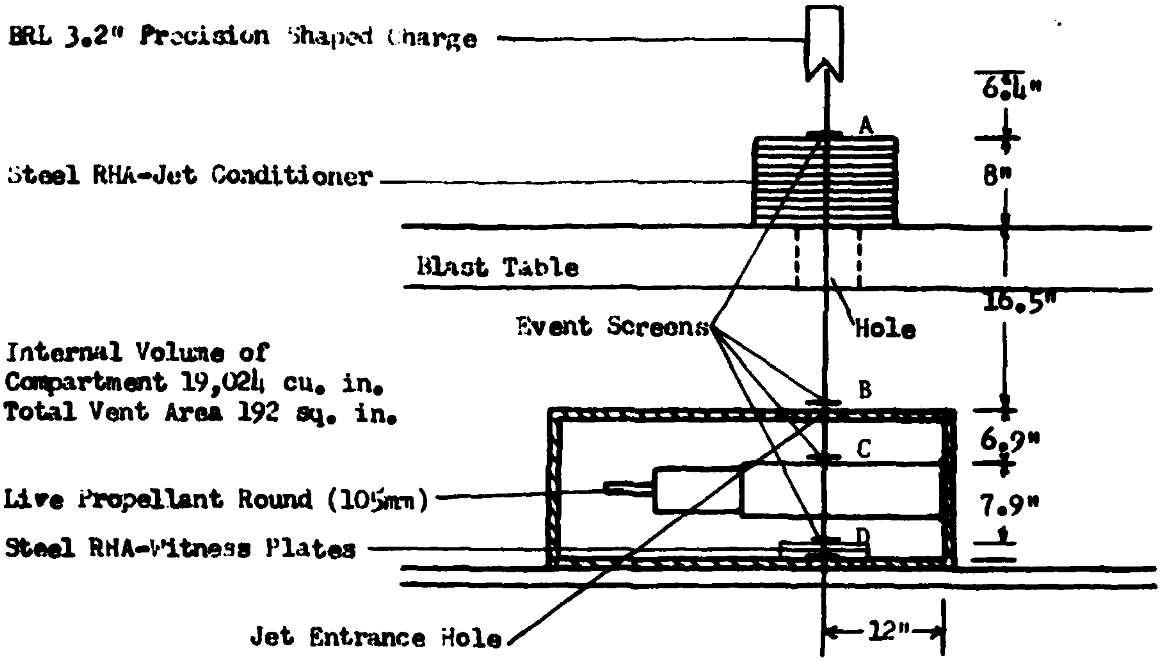


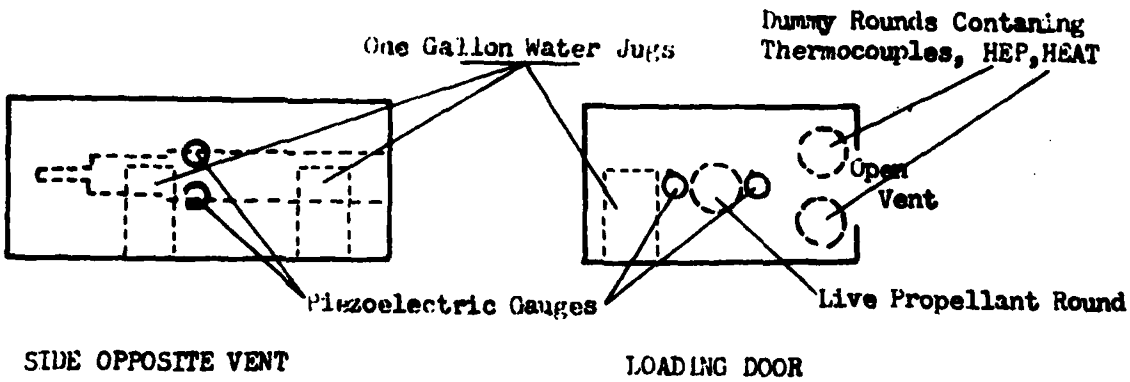


Figure A-101 Test Setup for Propellant Test No. 27

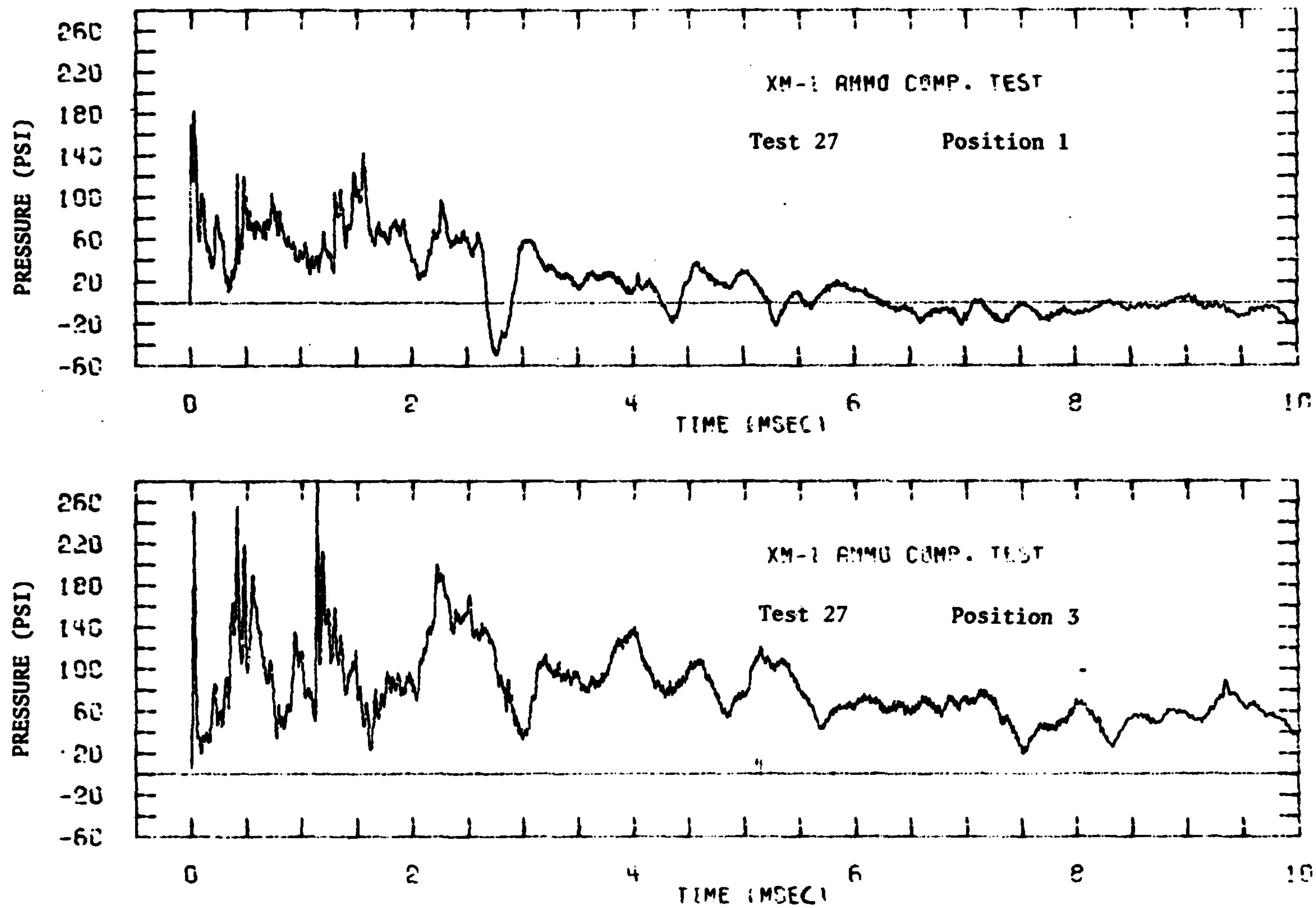
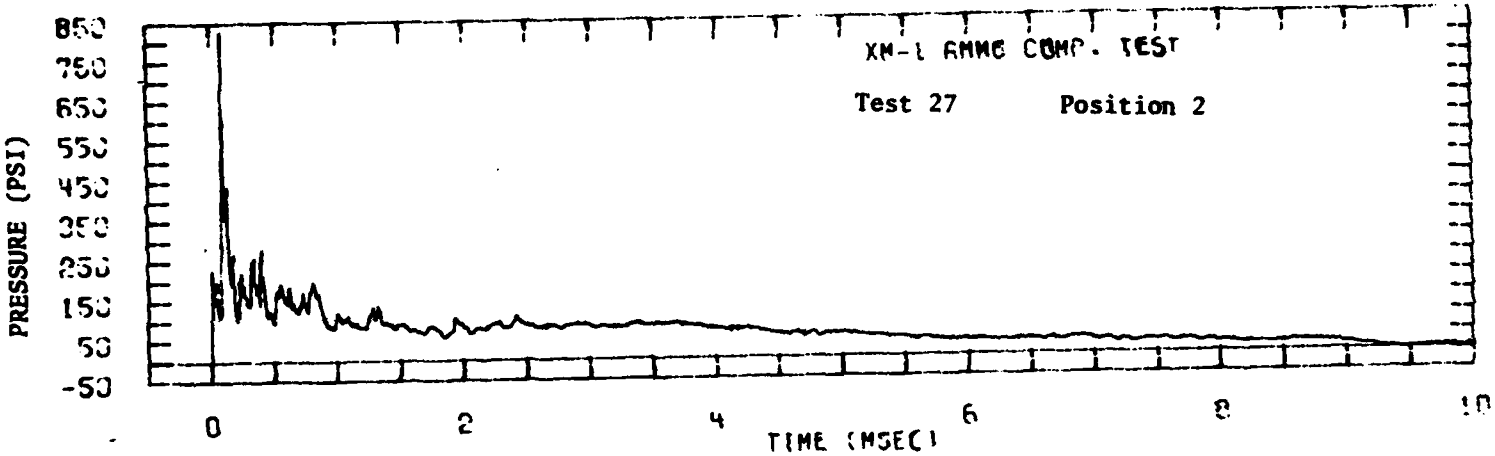


Figure A-102 Pressure Time Histories on Compartment Wall - Test No. 27



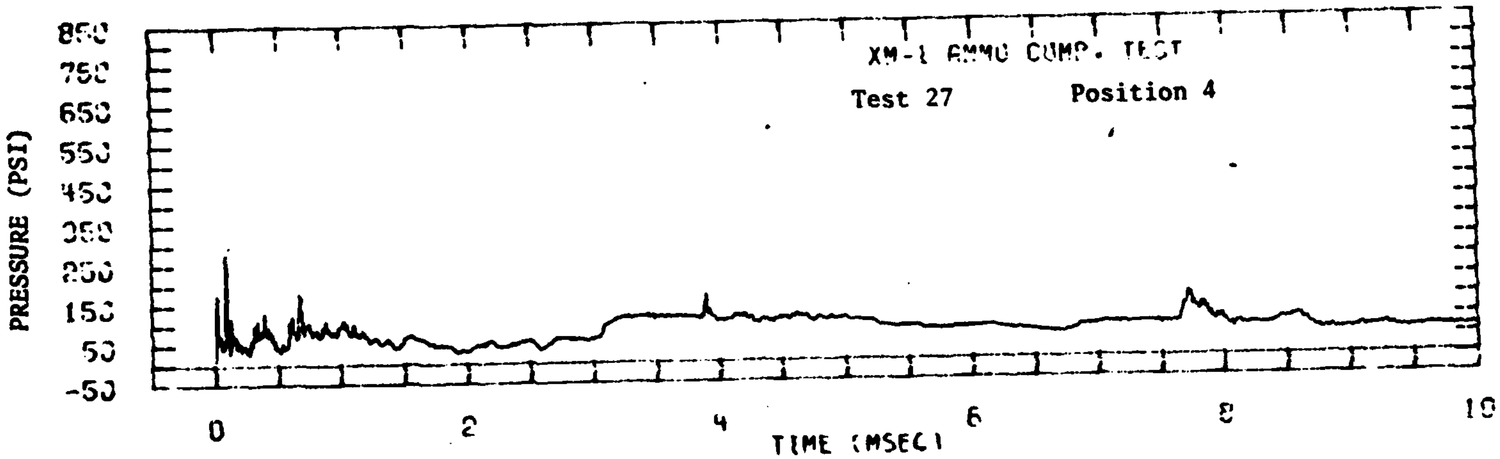


Figure A-103 Pressure Time Histories on Loading Door - Test No. 27

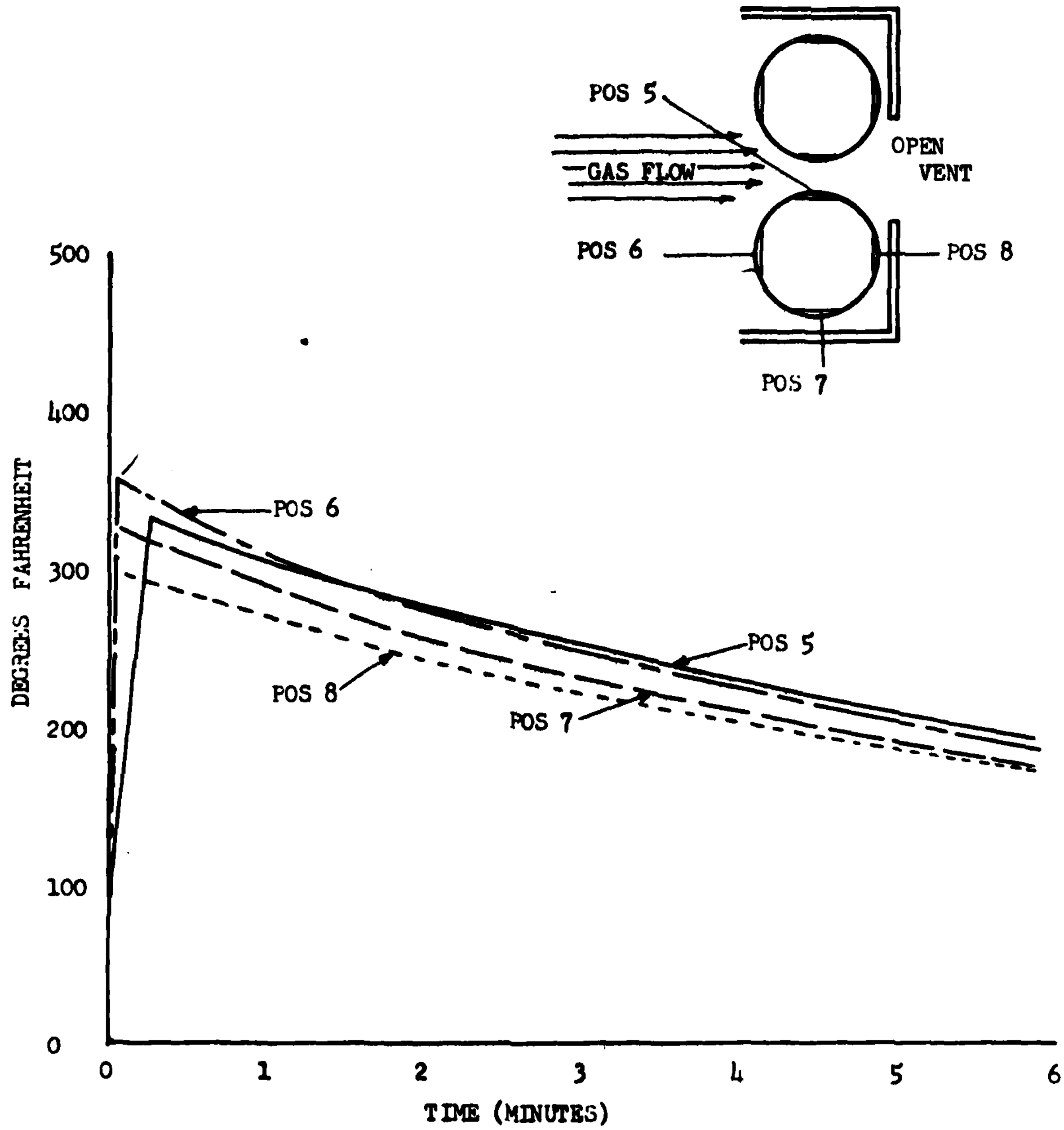


Figure A-104 Cartridge Case Temperature Time Histories - Test No. 27

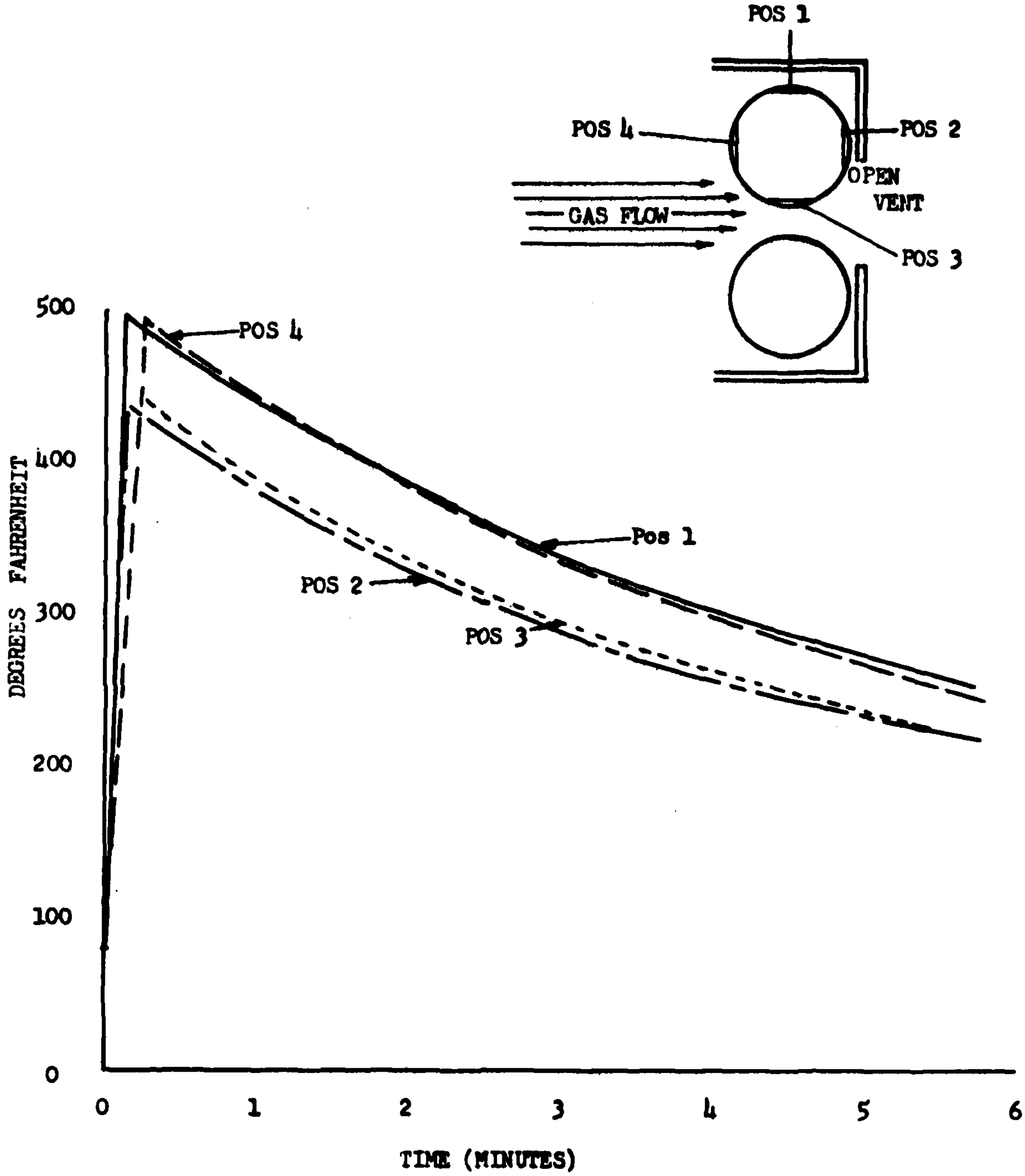


Figure A-105 Cartridge Case Temperature Time Histories - Test No. 27

XXVIII. BRL PROPELLANT TEST NO. 28

Date: 22 November 1974

Objectives

This test was designed to study the environmental conditions present in a vented ammunition compartment when a shaped charge jet with a 4.5-inch residual is fired through the center line (5-inch propellant path) of a single, live propellant round stowed in the compartment with two 1-gallon jugs of water and to see what effect the water has on the burning propellant.

Approach

The objectives of this test were accomplished by firing a shaped charge jet through a live propellant round stowed in an ammunition compartment. The event was recorded on film and the desired environmental conditions were recorded with a combination of piezoelectric transducers, mechanical crush gauges, thermocouples, and event screens.

Results

The shaped charge jet entered the compartment, passed through the live propellant 105mm round (APDS M392A2), struck the primer, exited, and penetrated 1 inch into the steel RHA witness plates.

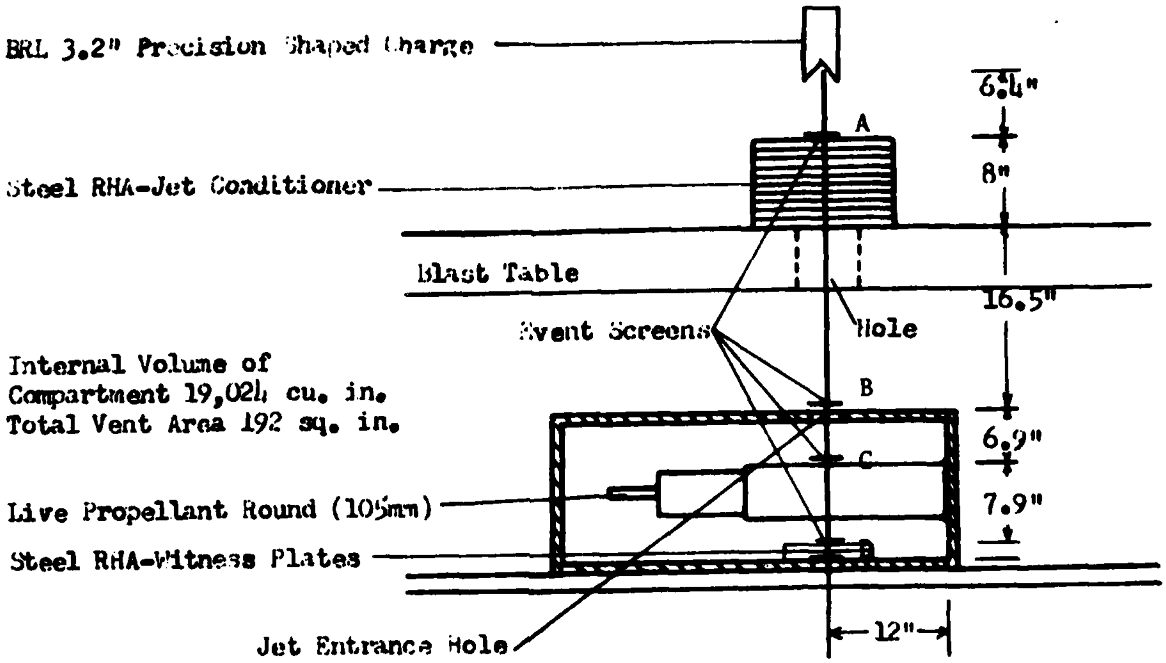
The projectile from the live propellant round separated from its cartridge case. The cartridge case was torn in half in the area of jet impact; both sections were split open. The primer was in two pieces. Both thermocouple cases were dented and cracked. There was no damage to the compartment.

The plastic water jugs tore apart and flooded the floor of the compartment. The floor was covered with unburned propellant.

The piezoelectric transducers on the side of the compartment recorded peak pressures of 257 psi and 405 psi; those on the door, 738 psi and 401 psi. Mechanical crush gauges located in the front of the compartment recorded pressures of 610 psi and 590 psi and crush gauges located in the rear, 870 psi and 660 psi.

The mechanical crush gauges in the live propellant cartridge case recorded pressures of 1500 psi in the nose and 4800 psi in the base. No thermocouples were placed in the inert warheads, but both cartridge cases were instrumented with thermocouples. Maximum tempertures recorded for the HEP case and the HEAT case were 260°F and 250°F respectively.

The average jet-tip velocity between point A and B was 4.3mm/μsec; between points A and D, 3.0mm/μsec. The event screen on top of the live round failed to function properly.



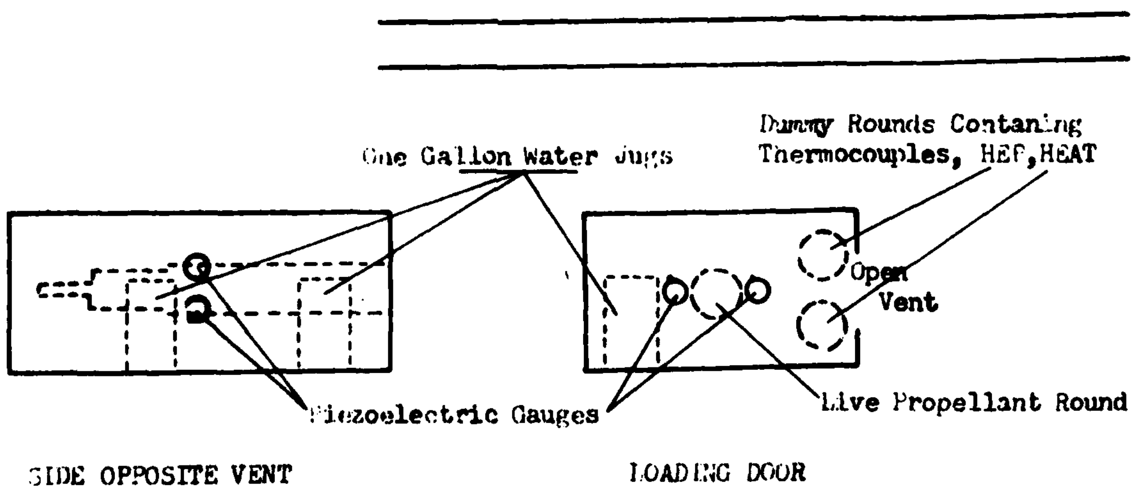


Figure A-106 Test Setup for Propellant Test No. 28

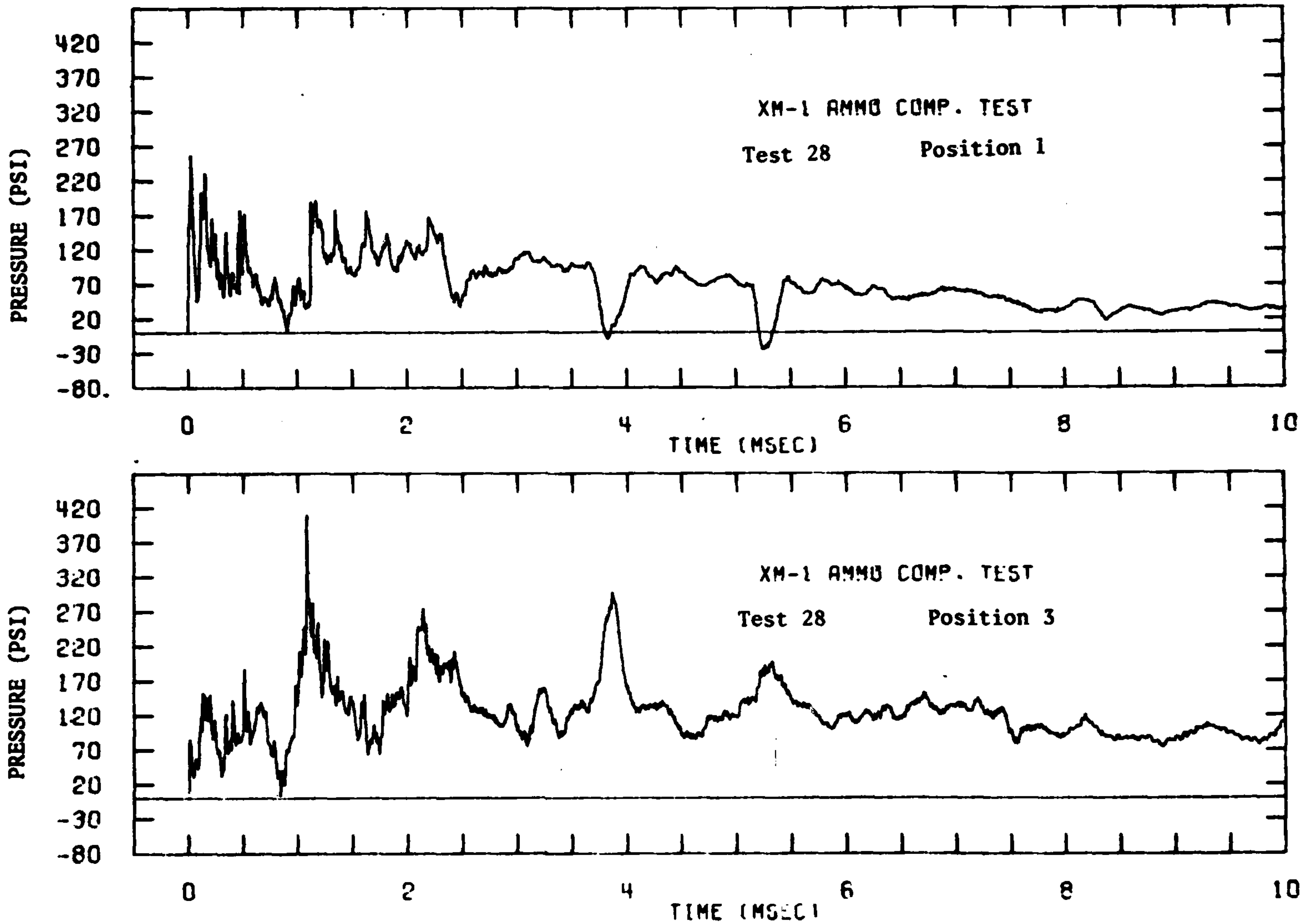
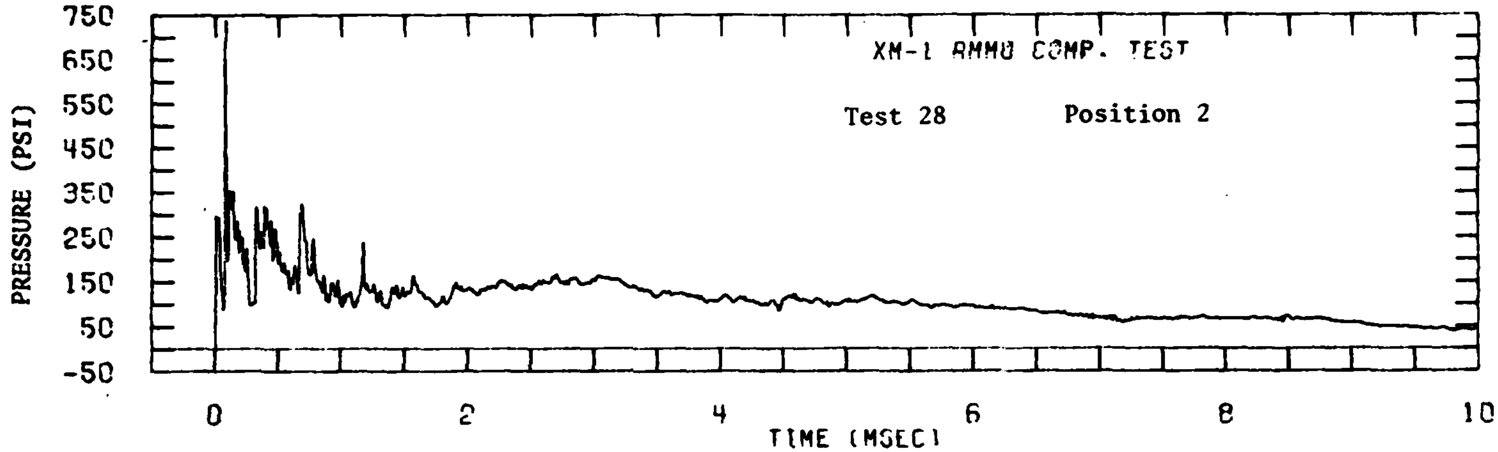


Figure A-107 Pressure Time Histories on Compartment Wall - Test No. 28



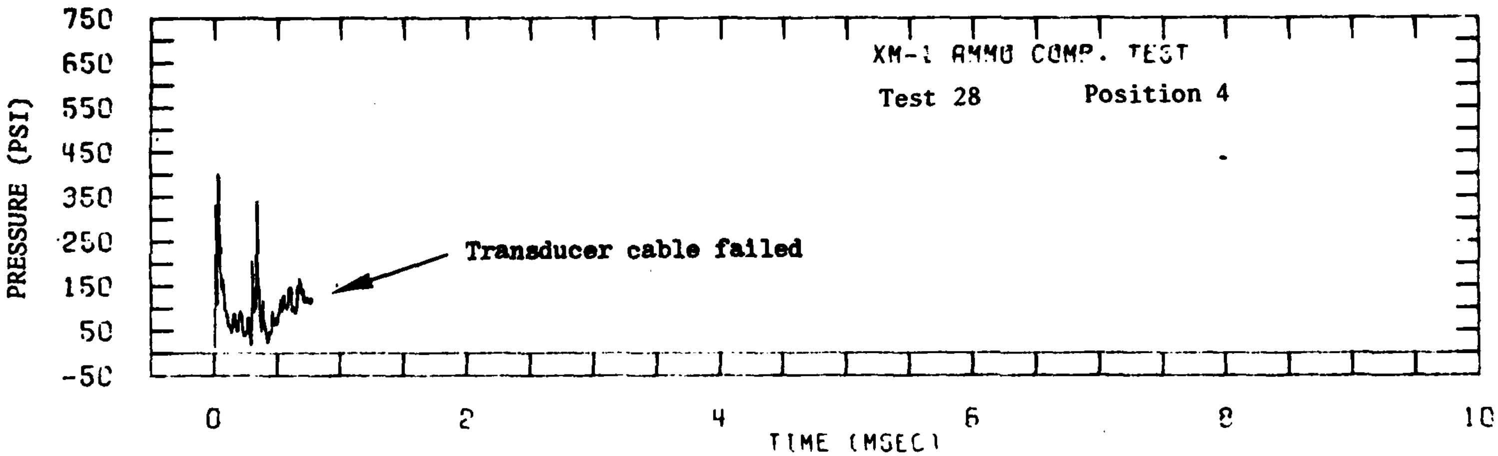


Figure A-108 Pressure Time Histories on Loading Door - Test No. 28

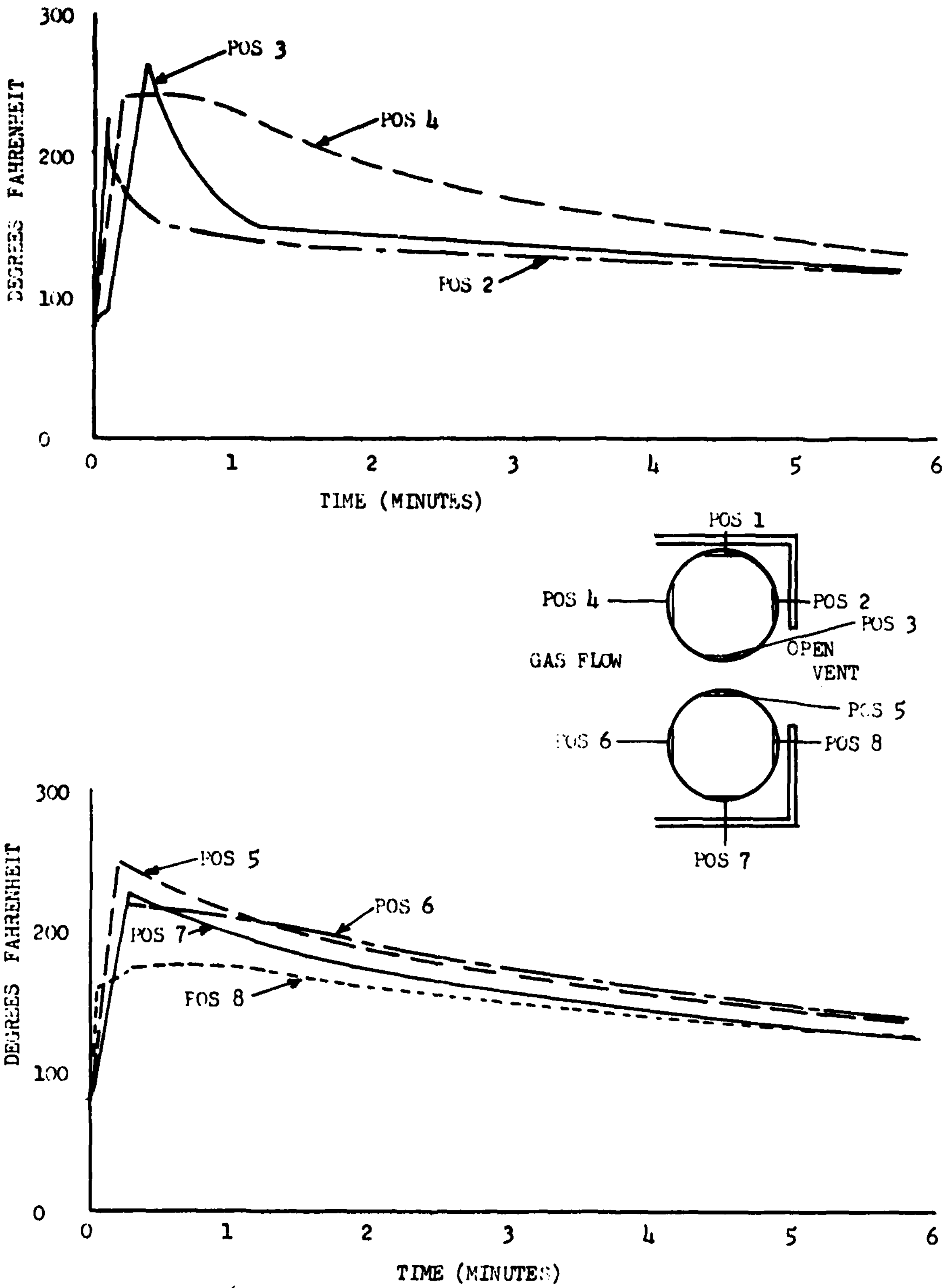


Figure A-109 Cartridge Case Temperature Time Histories - Test No. 28

A P P E N D I X   B

This Appendix contains BRL Interim Report No. 260, "Blast Instrumentation for Explosions in Partially Vented Chambers," authored by R. Abrahams, G. Couler, and C. Kingery. This IMR was published in July 1974.

I. INTRODUCTION

The Terminal Effects Division (formerly Terminal Ballistic Laboratory was asked by the Vulnerability/Lethality Division (formerly Vulnerability Laboratory) to develop and test instrumentation capable of measuring the pressure build-up inside of an ammunition storage box when the propellant in a 105mm round was initiated. The environment created by a round loaded with M-30 propellant, when initiated by its primer, was estimated to have a case bursting pressure of about 10,000 psi and a burning temperature of about 3000°F. Records obtained by the Materiel Test Directorate (MTD) indicated a very rapid burning of the propellant but not detonation.

A. Background

The MTD has the responsibility for documenting the blast environment within munition blow-out compartments being developed for the XM1 tank. Because of the extreme pressures and thermal buildup plus the acceleration and vibration of the compartment walls, MTD was finding it difficult to get consistent records. Therefore, TED, having some experience in making blast measurements in extreme environments, was asked to recommend and check out instrumentation capable of recording the pressure impinging on the wall of the compartment, as a function of time.

B. Objective

The objectives of the TED effort were as follows:

1. Recommend gauges and recorder system adequate to document the pressure versus time within the ammunition compartment when the M-30 propellant in a 105mm round was initiated.

2. Set up a system, fire the round, and check the reliability of the results.

II. TEST PROCEDURE

Standard test procedure was followed in designing the experiment. Gauges were selected, calibrated, and integrated with the proper amplifiers and recorder system.

Test Chamber

The test chamber was a duplicate of one constructed for firings being conducted by MTD. The chamber's dimensions and the experimental setup are presented in Figure B-1.

Instrumentation

Refer to Figure B-2 for the instrumentation setup diagram.

Beginning with shot 2 (shot 1 revealed the waveform that had to be measured), the instrumentation concept was to use two different types of piezoelectric transducers. One was a fast almost totally non-resonant though somewhat temperature sensitive Tourmaline bar gauge (ST4) with a settling time of about one microsecond, to measure the high frequencies of the pressure fronts. The other was a more temperature-stable though quite resonant quartz gauge (617A) with a filtered settling time of about 30 microseconds, to measure the slower average fill pressure without much baseline shift. Ideally, if both gauges could be placed at the same measurement point, it would be possible to subtract the thermal response of the bar gauge by comparing it to the quartz gauge output. Actually, if the gauges are placed close together, it is possible to compare the two pressure histories and make a judgment as to how the bar response should be adjusted to cancel its thermal response and leave only the pressure history.

The 80KHz FM tape recorder has a settling time greater than 10 microseconds and thus could not be relied on to measure the high frequencies in the pressure pulses. Therefore, as shown, two transient recorders were used together with the tape on the bar gauge channel. These recorders are electronic storage devices with a settling time of about two microseconds. Two were used in order to record the data at different sampling rates. They were chosen over oscilloscopes because they require no pre-trigger pulse and their timebase can be effectively expanded in the reproduce mode through the use of an oscilloscope sweep magnifier.

Shot One

The first shot was fired at the TBL range 1146. A single round was suspended in the middle of a vented storage box. A Kistler gauge, Model 617-A, and a Bytrex gauge, Model HFG-1000-SE were mounted in the removable end plate of the box. The Kistler gauge was mounted in an adapter with a series of "O" rings which were designed to dampen the effects of acceleration and ringing of the box panels. (See Fig. B-3.) The Bytrex gauge, a semiconductor, strain-bridge type transducer with two active arms, was mounted in a port coupled by a copper tube and a fill chamber to give a fill time of one millisecond.

Shot Two

Based on results from Shot 1, two changes were made in the test design for Shot 2. The Kistler gauge was used again with the same type mount but a 40KHz filter was introduced into the system to eliminate any noise due to the natural frequency of the gauge.

The second change was the replacement of the Bytrex gauge with a Susquehanna Instruments gauge, Model ST-4. This gauge was shock mounted and the signal was unfiltered. The instrumentation system as used for Shot 2 is shown in Figure B-2.

III. RESULTS

The results from Shots 1 and 2 were both successful in that records were obtained from all gauges, and it was determined that the build-up of gas pressure within the chamber is not a relatively slow rise but is made up of many sharp shocks and reflections. Therefore, based on the results from Shot 1, the slower response Bytrex gauge was replaced by a high response ST-4 for Shot 2.

The pressure impinging on the wall of the compartment as a function of time as recorded by the Kistler and Bytrex gauges is presented in Figure B-4. Here it is obvious that the Bytrex gauge recorded excessive accelerations and would require some further studies in mounting techniques for use in this type of environment. It is also too slow in response to follow the separated shocks. Therefore, a Susquehanna ST-4 was installed in place of the Bytrex for the second shot. The individual shocks and reflections can be seen on Kistler record in Figure B-4.

The test setup for Shot 2 was the same as Shot 1 with the exception of the replacement of the ST-4 gauge for the Bytrex gauge. The pressure versus time recorded by the Kistler and the ST-4 are shown in Figure B-5. It should be noted that the traces are not identical because of the difference in location and the nonsymmentry of phenomenon.

In comparing the records from the Kistler gauge used on both shots, here again differences are noted. This indicates that ignition of the propellant and the bursting of the shell casing is not repeatable and will vary from shot to shot.

The gauge output was recorded on magnetic tape and also on a Biomation Transient Recorder Model 802. Figure B-6 and B-7 are presentations of the ST-4 record from the Biomation recorder played back at various oscilloscope sweep speeds.

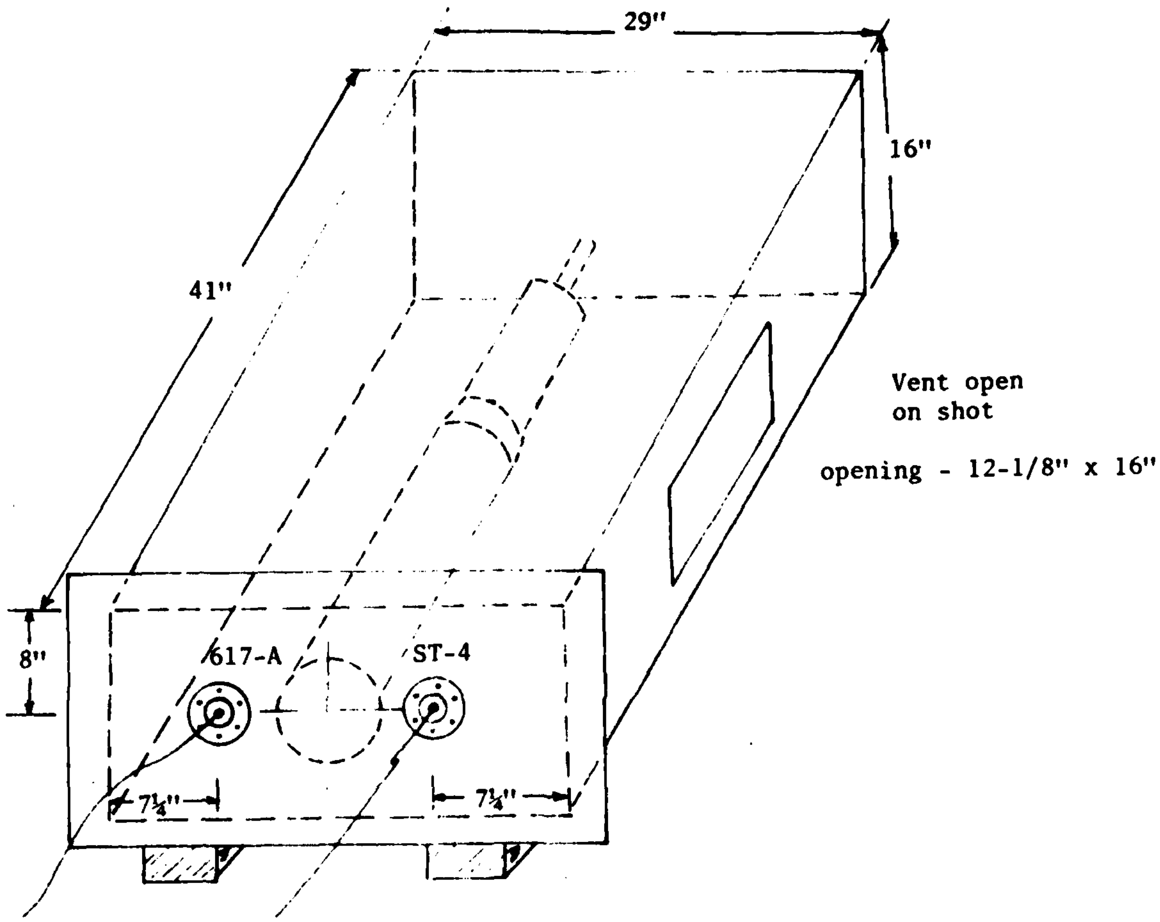
IV. CONCLUSIONS

The conclusions to be made from this limited series of tests are that reasonable records of the pressure environment on the walls of an ammunition storage container in which the propellant in a 105mm round has been initiated can be made if the following guidelines are established:

1. The transducer must be properly protected from mechanical vibration. Therefore, an "O" ring shock-proof port is recommended.

2. The transducer must be properly protected from the thermal environment. Therefore, the use of a silicon grease heat protection method is recommended.

3. The transducer must have high response capabilities, and the band width of the recording system must be 80 KHz or more if the peak shocks are to be measured.



NOTES

(1) Single round - 105mm suspended in center of box from wires
(2) Box made of 1" steel plate.
(3) Fired at TBL - 1146 Bldg - Range

Figure B-1. Ammunition Test Compartment

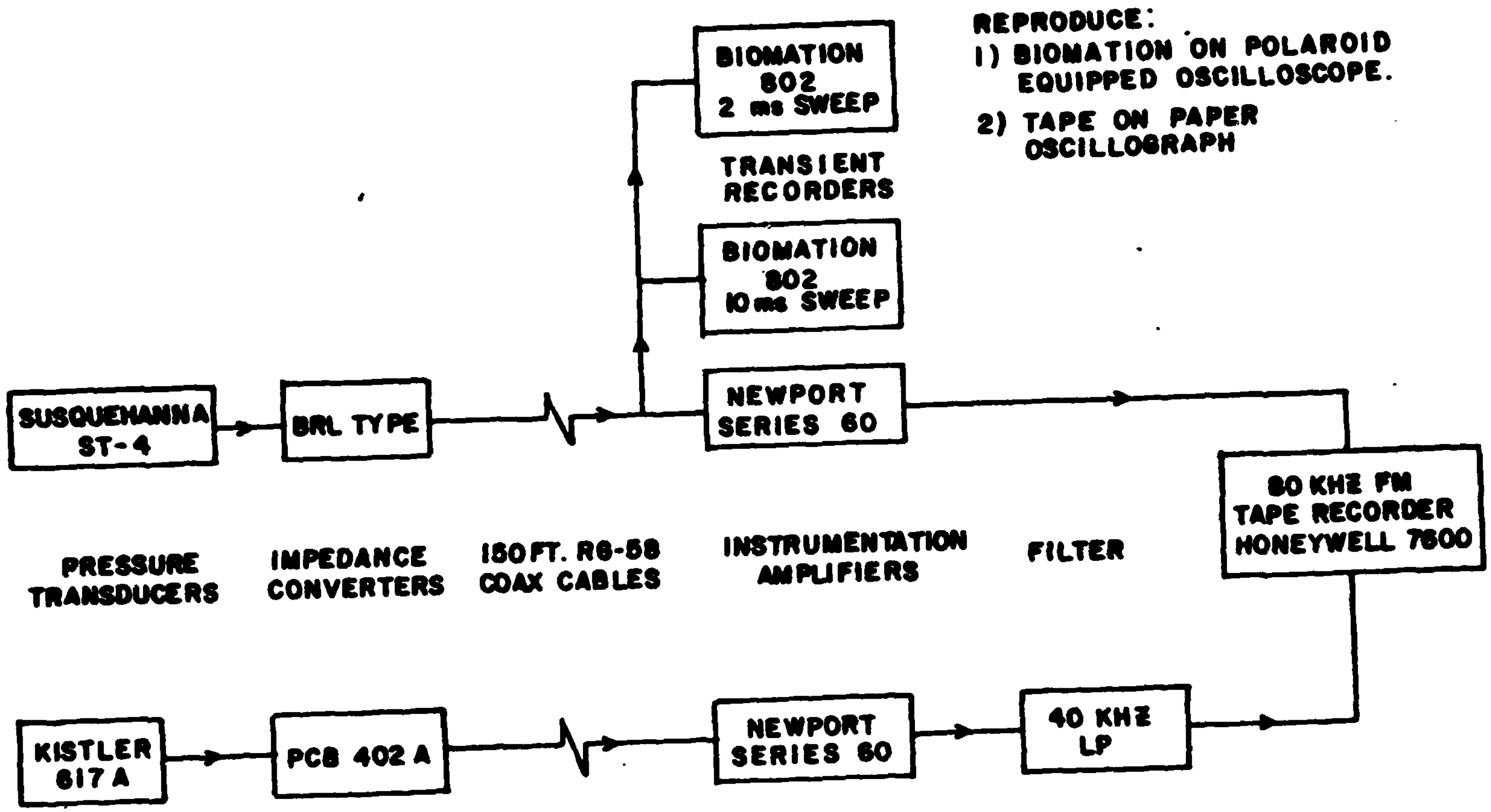
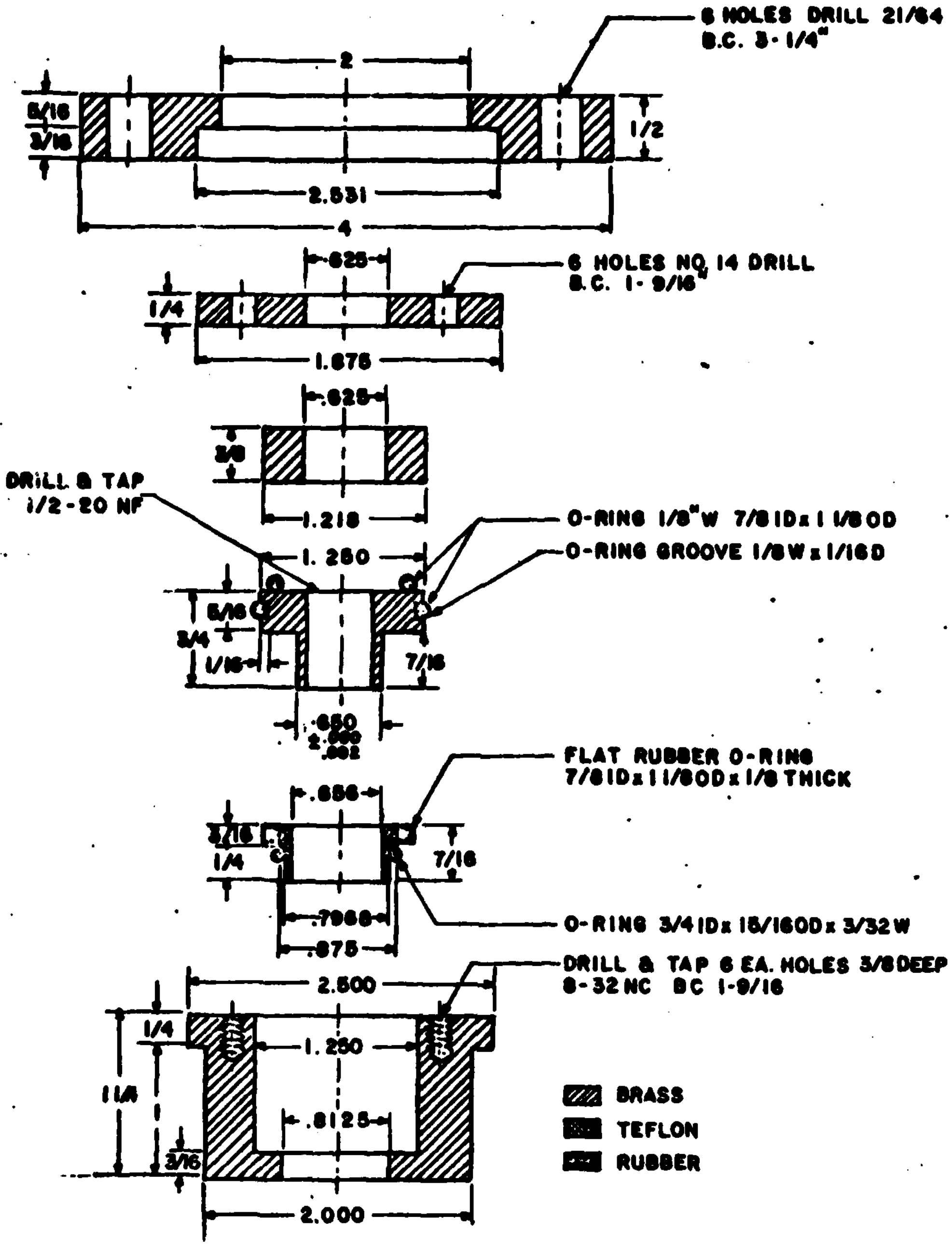


Figure B-2. Instrumentation Setup Diagram



NOTE:
ASSEMBLE IN ORDER SHOWN

Figure B-3. Shock Isolation Transducer Port

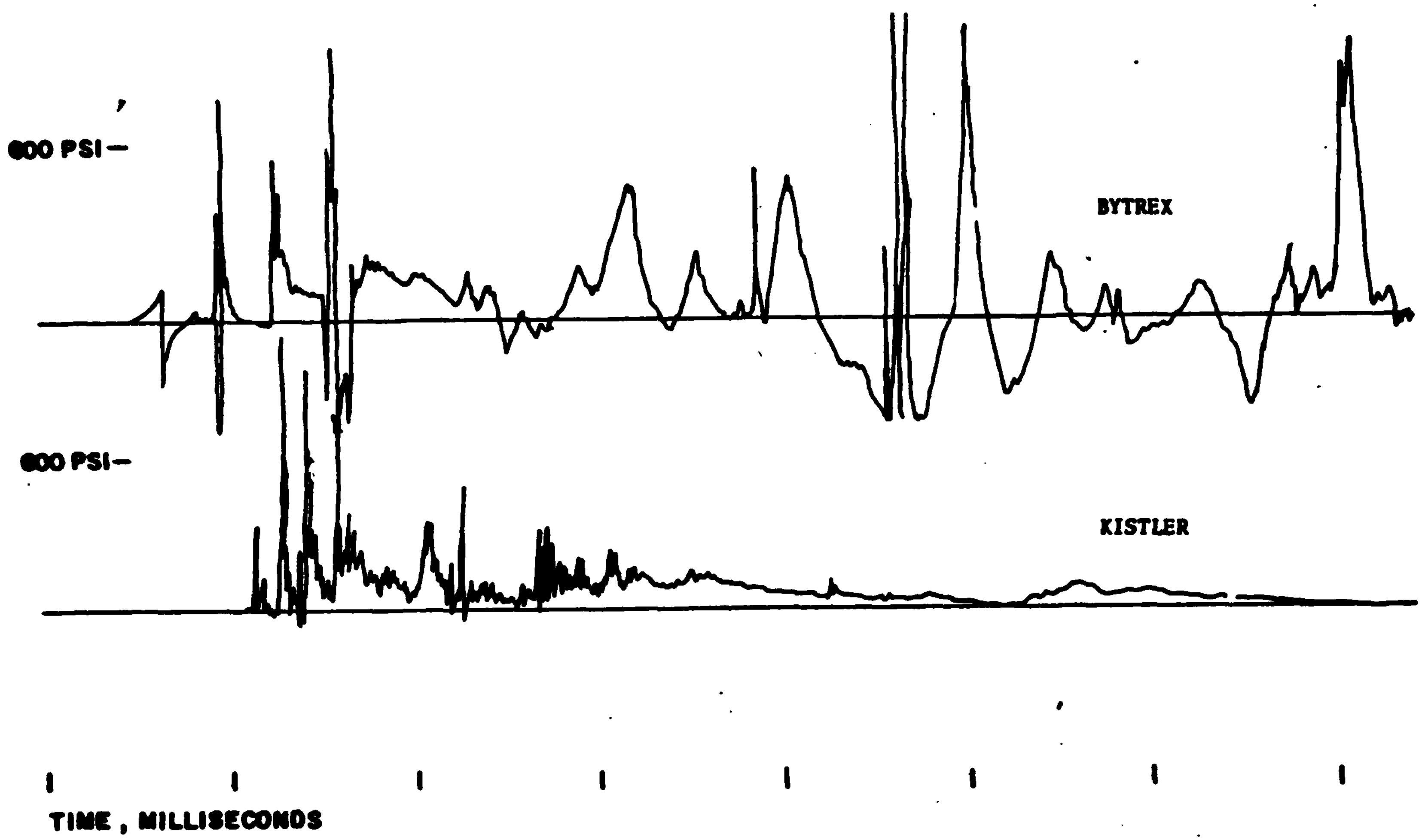


Figure B-4. **Traces from Shot 1**

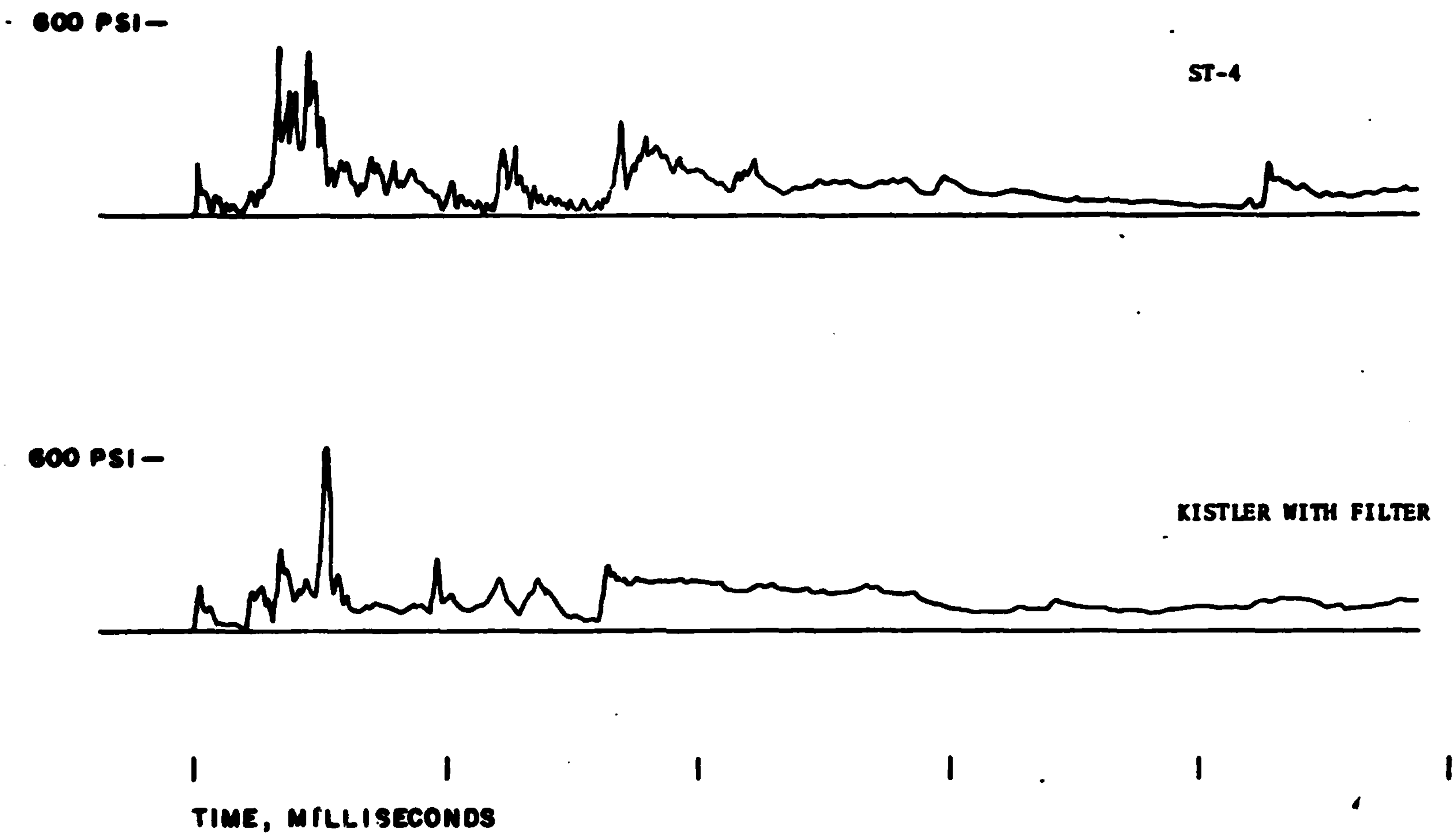
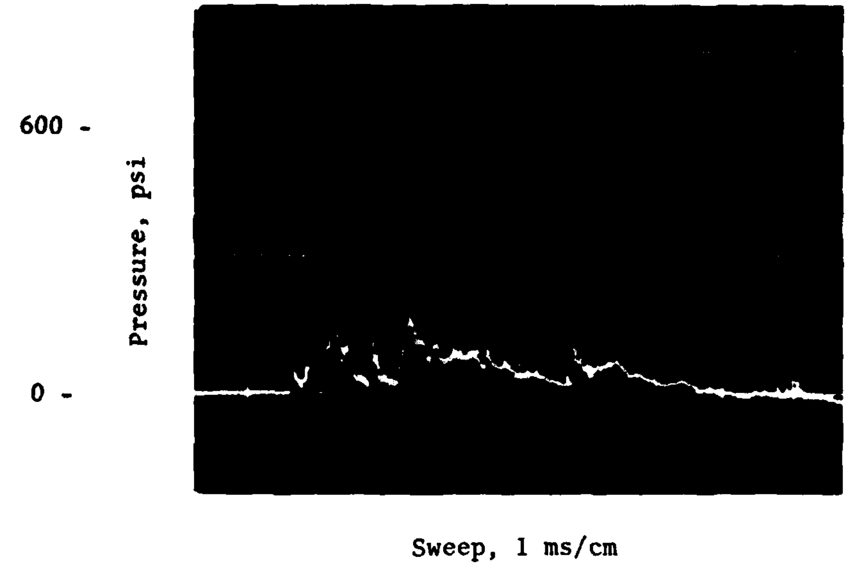


Figure B-5. Traces From Shot 2



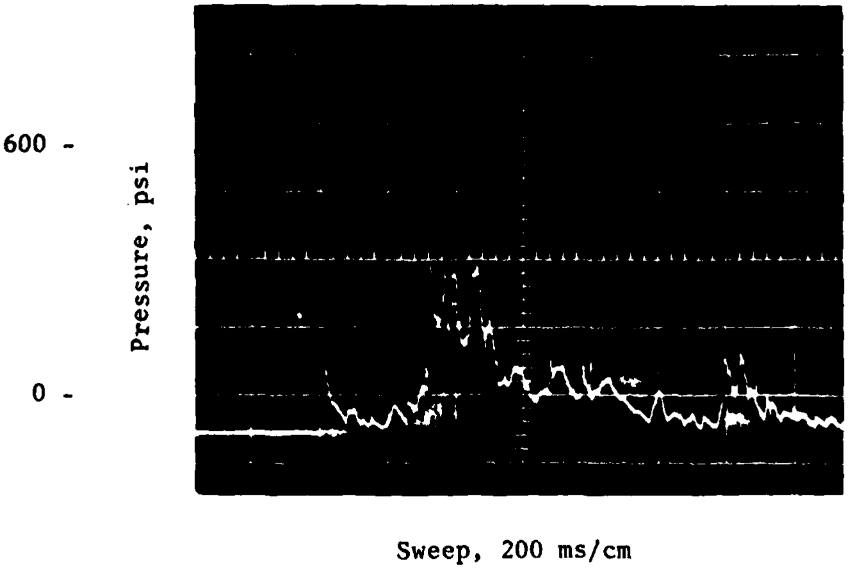


Figure B-6. **Traces from ST-4 Transducer on Biomation**

Sweep - 40μsec/cm
Figure B-7. **Fast Sweep - ST -4 Transducer on Biomation - Shot 2, BRL**

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