MODELING OF THE NON-AUDITORY RESPONSE TO BLAST OVERPRESSURE

Design and Field Test of a Blast Overpressure Test Module

ANNUAL/FINAL REPORT

James H.-Y. Yu
Edward J. Vasel
James H. Stuhmiller

JANUARY 1990

Supported by

U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701-5012

Contract No. DAMD17-85-C-5238

JAYCOR
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San Diego, California 92121-1190

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The surface loading, expressed as a pressure-time history, differs significantly from the so-called free-field pressure variation that has been widely reported. The two differ both because of reflection, whose effects have been studied under simplified conditions, and because of the geometric effects of the body's shape, orientation to the blast, and relation to surrounding objects, including the ground plane. This latter difference has never been adequately described.

If animal exposures to blast are to be properly interpreted, the pressure loading on the body surface must be measured directly. Attempts to place pressure gauges on the animal are extremely difficult and are not practical in routine studies.

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The device has been used in numerous field studies and promises to provide a standard technique for blast determination in all environments.

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Edward J. Vasel
James H. Stuhmiller
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CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

It has been conclusively determined by field testing, in which the thorax and lung dynamics are directly measured, and by computational simulation, that it is the surface loading on the body which is the direct coupling between the blast field and the biophysical response (Fig. 1).

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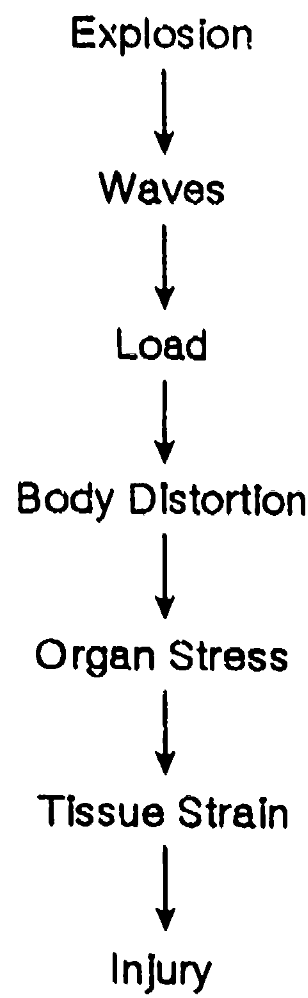


Figure 1. Common mechanical sequence of injury.

2. BLAST OVERPRESSURE TEST MODULE DESIGN FEATURES

The primary design considerations for the test module were: a simple 2-D geometry; low fabrication cost; ease of instrumentation and mobility; and proper material strength and mounting stability to endure repeated high blast exposures.

The unit consists of a 12 in. diameter, 30 in. long aluminum tubular test module with mounting supports. Figure 2 shows the horizontal mounting configuration which was designed to measure the sheep torso loading and ground plane gap effect. An alternate vertical mounting configuration designed to measure seated sheep torso loading is shown in Figure 3. The mounting supports are made of welded steel. The vertical and horizontal mounts for the loading test module were designed based on a maximum face-on loading of 2900 kPa for a free field blast pressure of 700 kPa.

The test module instrumentation consists of four fixed, 500 kHz, PCB model 102M125 pressure transducers, installed circumferentially around the test module to measure the blast loading from different directions. Two additional fixed face-on transducers were installed to verify the loading uniformity along the frontal surface. The transducers were installed on the module through Delrin mounts to suppress the noise output. All transducer output cables are protected in a flexible metal conduit.

Another pressure transducer on a free flying piston was also installed near the fixed face-on transducers to verify the surface compliance effect of the animal body. This would be analogous to the chest wall movement in the test animal during blast exposure. The piston was designed with a mass-to-area ratio of 3.1 grams/cm^2 to approximate a sheep's chest wall. Figure 4 shows the moving piston transducer installation. Field tests revealed that the movable piston showed the same face-on pressure value as the neighboring fixed transducers. Therefore, in subsequent field tests the movable piston was replaced with a fixed mounted transducer.

Figure 5 shows details of the retractable wheels and the module alignment guide for proper orientation.

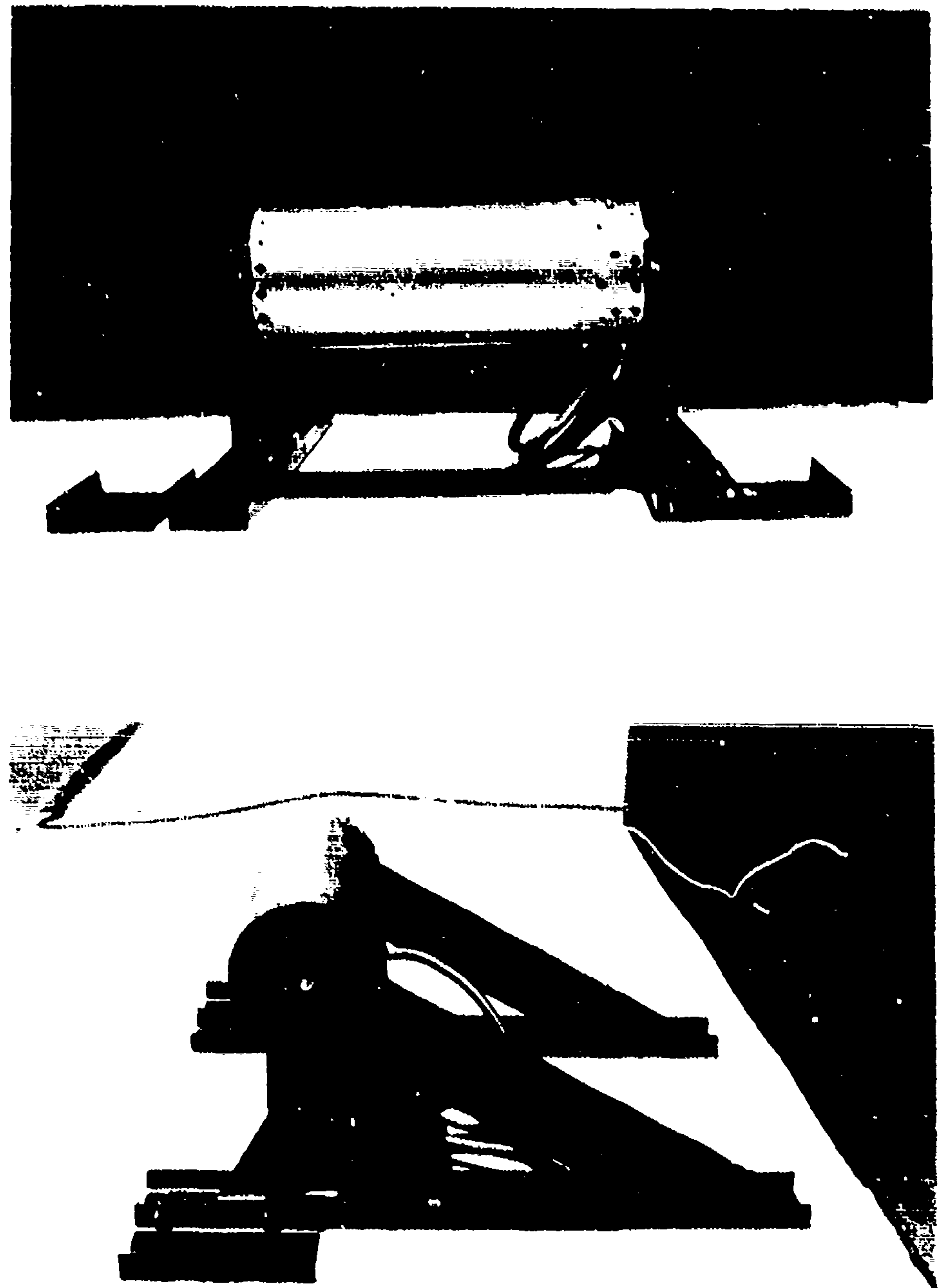


Figure 2. Test module horizontal configuration.

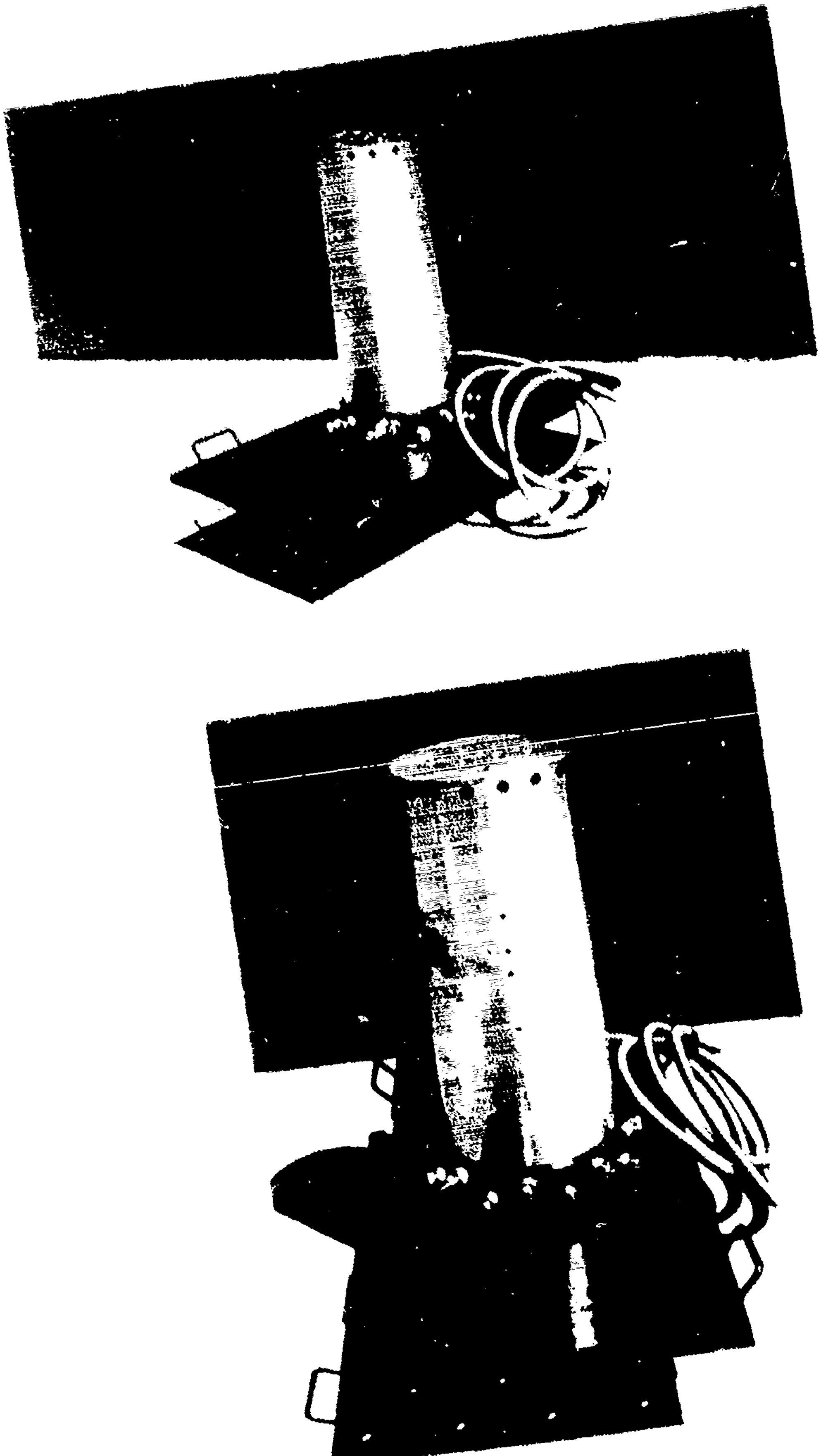


Figure 3. Test module vertical configuration.

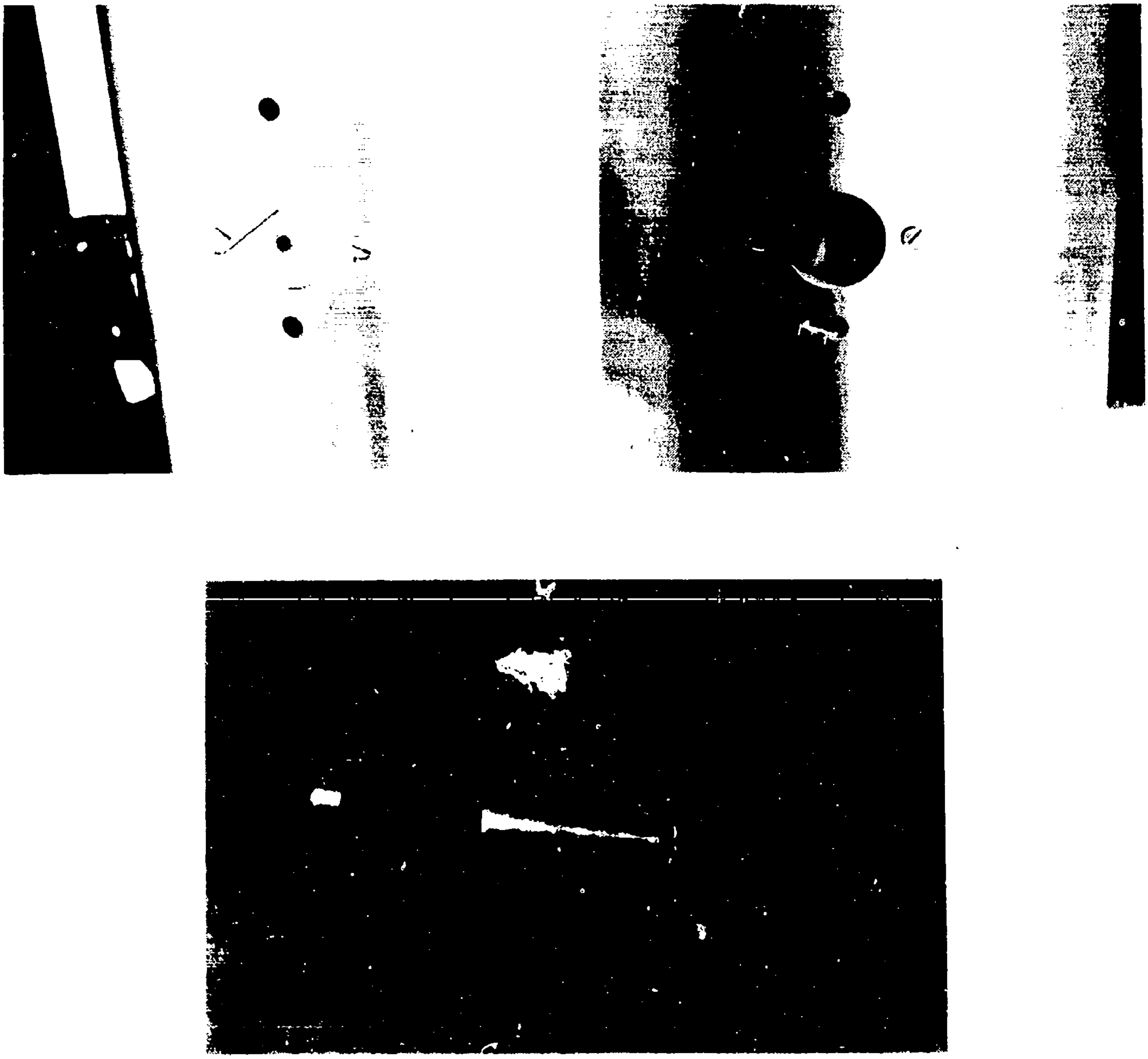


Figure 4. Piston assembly.

Figure 5a. Retractable wheel for the horizontal configuration.

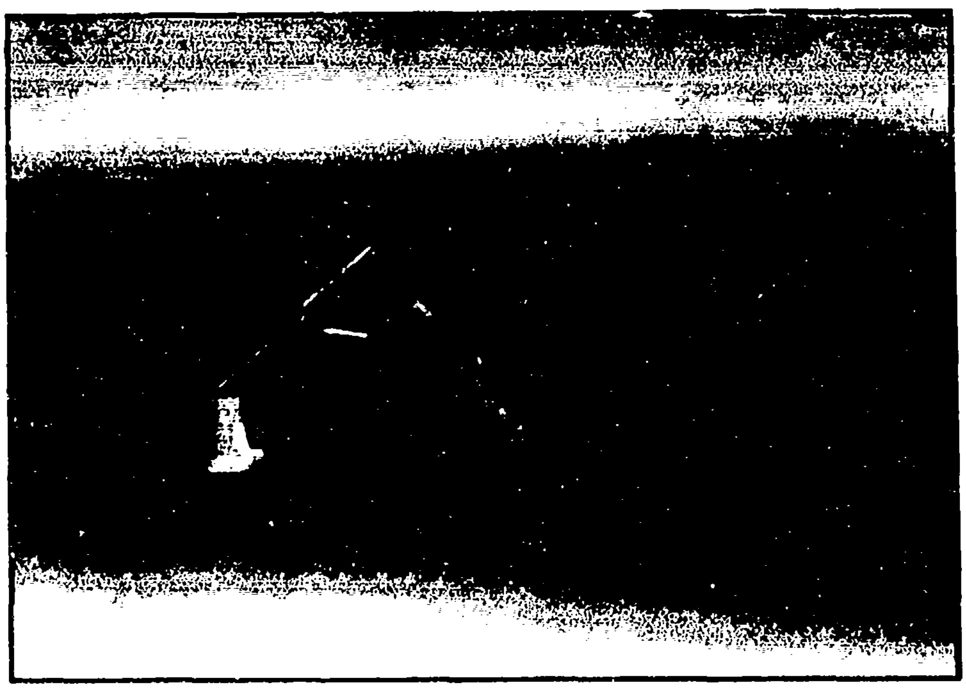


Figure 5b. Tool to square transducer positions to blast reference plane.

3. TEST MODULE SIGNAL OUTPUT NOISE REDUCTION TECHNIQUES

Preliminary field tests indicated that under certain conditions the blast output signals exhibited a significant amount of resonance noise. A typical example of this "ringing" noise from a 160 kPa free-field test shot is shown in Figure 6. Although these resonance signals could be eliminated with electronic filters, it could also attenuate the high frequency characteristics of the blast signal. Therefore, it was decided to modify the test module mechanically to reduce the system resonance.

A combined approach to suppress the noise signal involved the installation of new transducer isolation mounts, module internal stiffeners, and an external dampening jacket. This combination proved to be very effective. Details of each approach is described below.

The reference ringing signal of the test module was calibrated in the lab with PCB pressure transducers and an accelerometer. A series of strong mechanical impacts were applied to verify the effect of each approach. The setup for these calibration tests is shown in Figure 7.

Floating O-Ring Transducer Mounts

Although Delrin transducer mounts provide some damping effect on ringing noise over direct metal mounting, the outputs were not satisfactory. A new floating O-ring mount, shown in Figure 8, was conceived and designed. Here, silicon O-rings are used to "float" the transducers, different density materials and minimum vibration path are incorporated to reduce the ringing amplitude. Laboratory tests showed that this design was especially effective in suppressing the high frequency vibrations.

Internal Nodal Stiffeners

The internal nodal stiffening plate assembly is shown in Figure 9. The stiffening plates are fabricated from 1" thick PVC plate. They can be easily tightened or removed by adjusting the locknuts. A 1/4" rubber liner was installed for each stiffening plate to ensure full internal wall contact. The stiffeners reduce the test module vibration nodal lengths, and thus allow for faster noise dampening. The combined effect of the stiffeners and the O-ring transducer mounts provided a noise reduction of over 90% as illustrated in Figure 10.

System Dampening Jacket

The system dampening jacket is a 1/4" thick rubber sleeve fitted over and secured to the test unit using adhesive and hose clamps. Holes are cut in the sleeve to allow the transducers to be flush mounted to the outer surface of the rubber jacket. The rubber jacket was found to further suppress the system vibration. Figure 11 shows a typical dampening jacket installation.

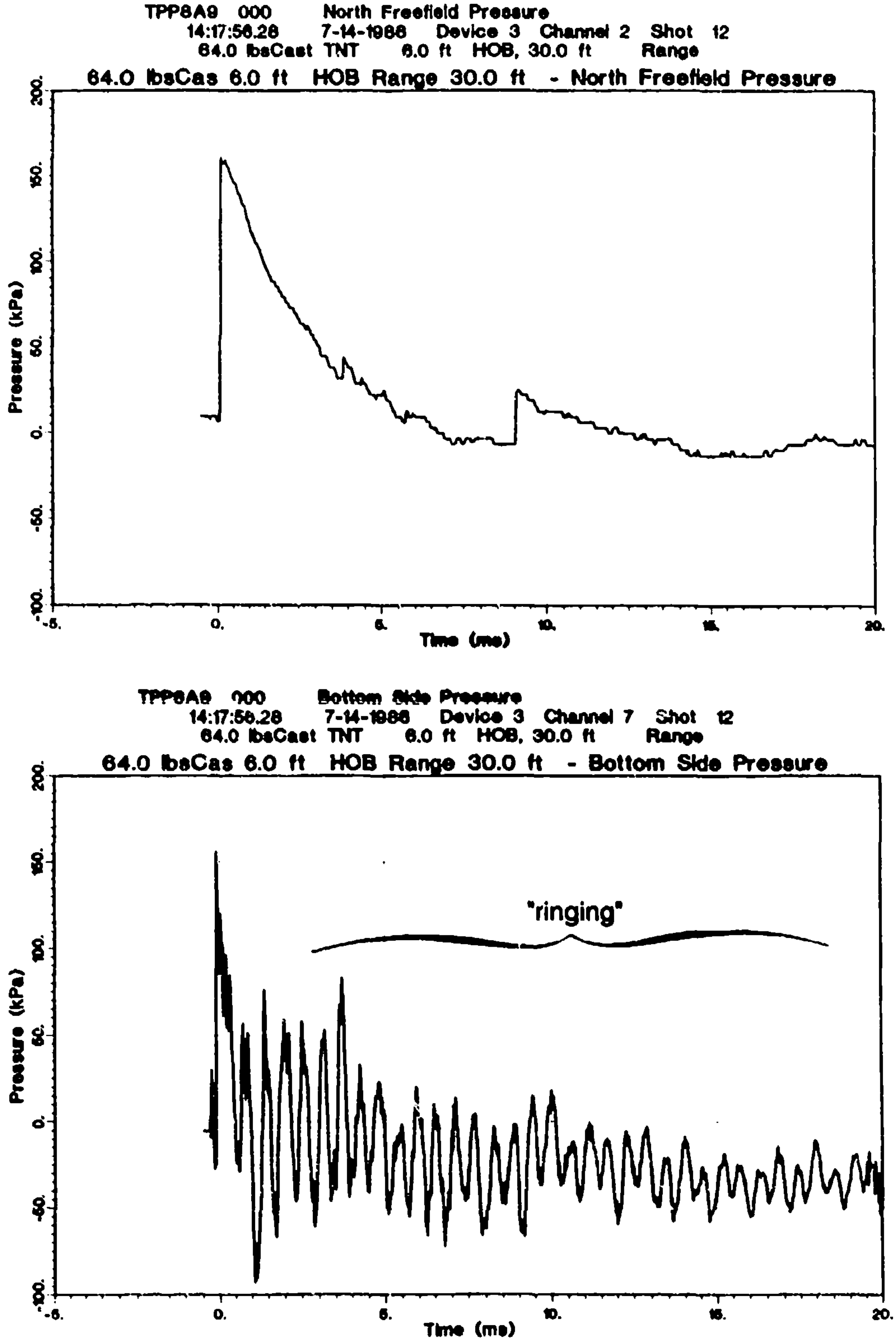


Figure 6. Comparison of free field and test module outputs before transducer noise suppression modifications.

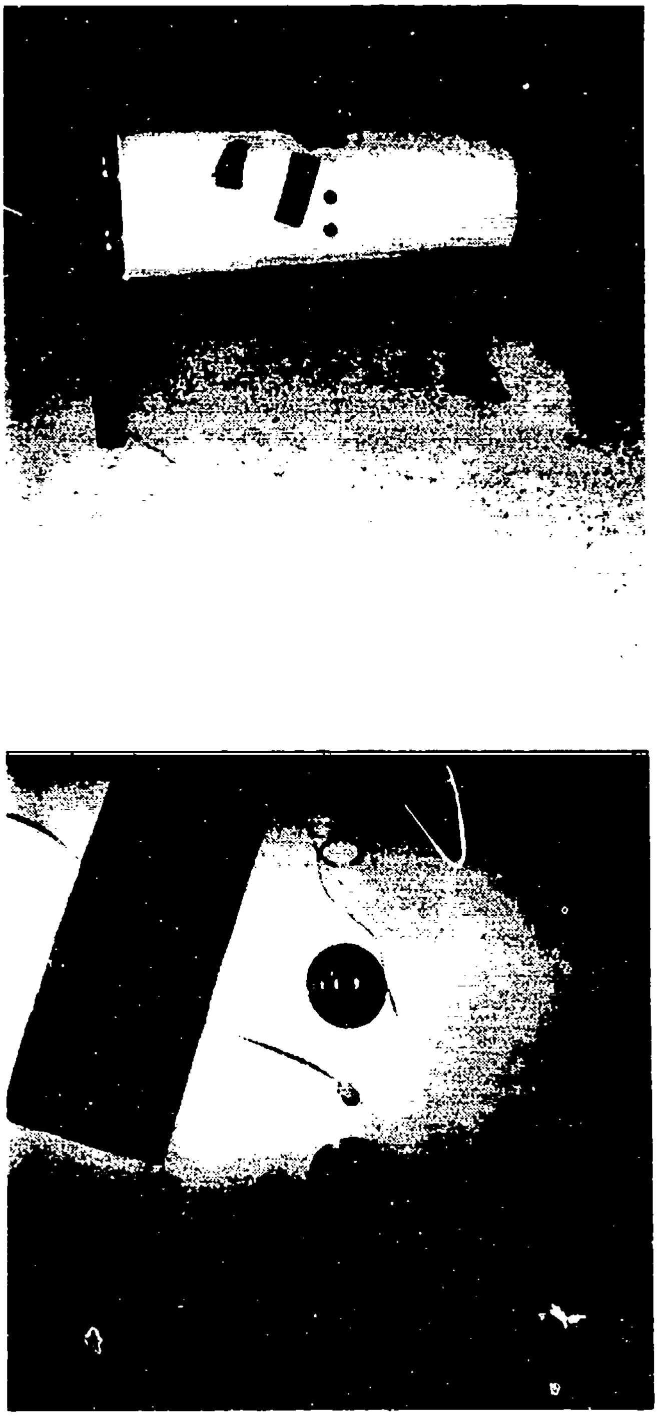
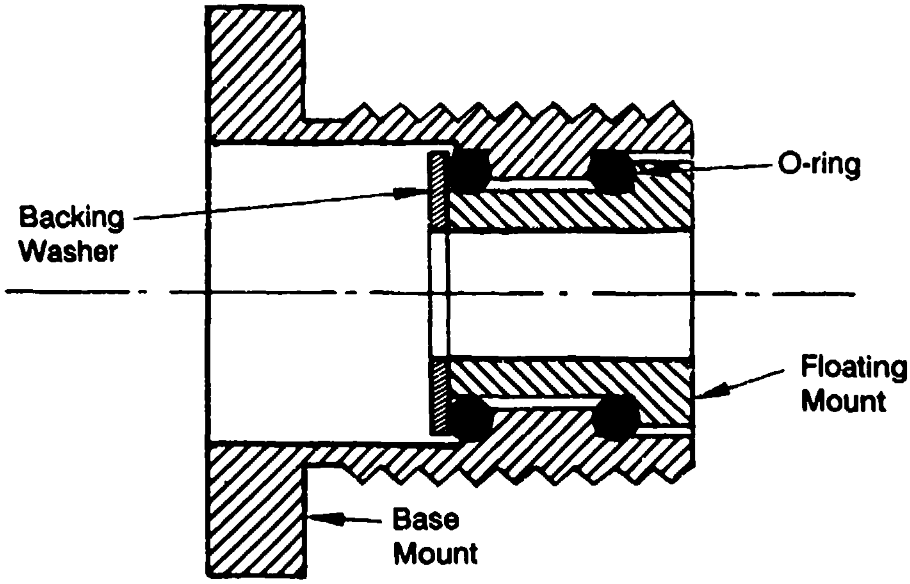


Figure 7. Laboratory test setup for ringing calibration.



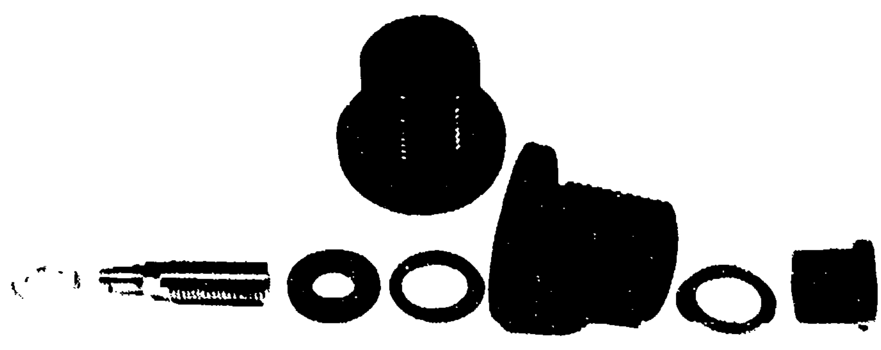


Figure 8. Floating O-ring transducer mount assembly.

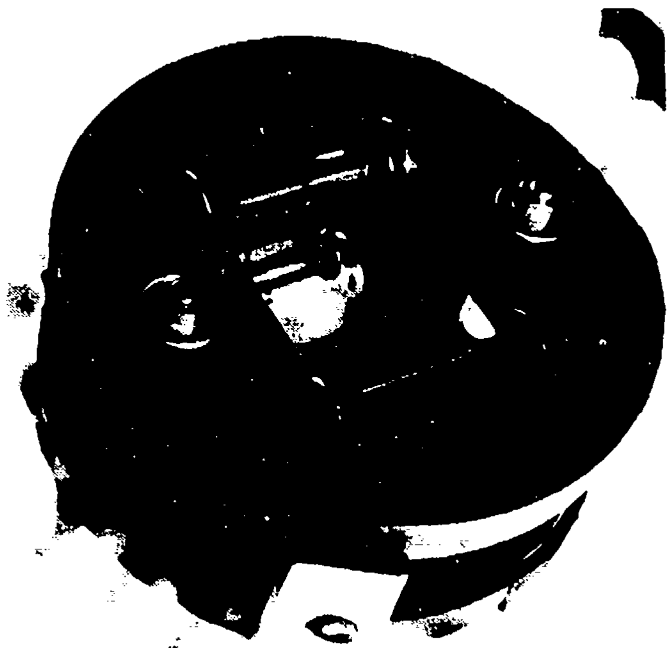


Figure 9a. Top view of internal nodal stiffener assembly.

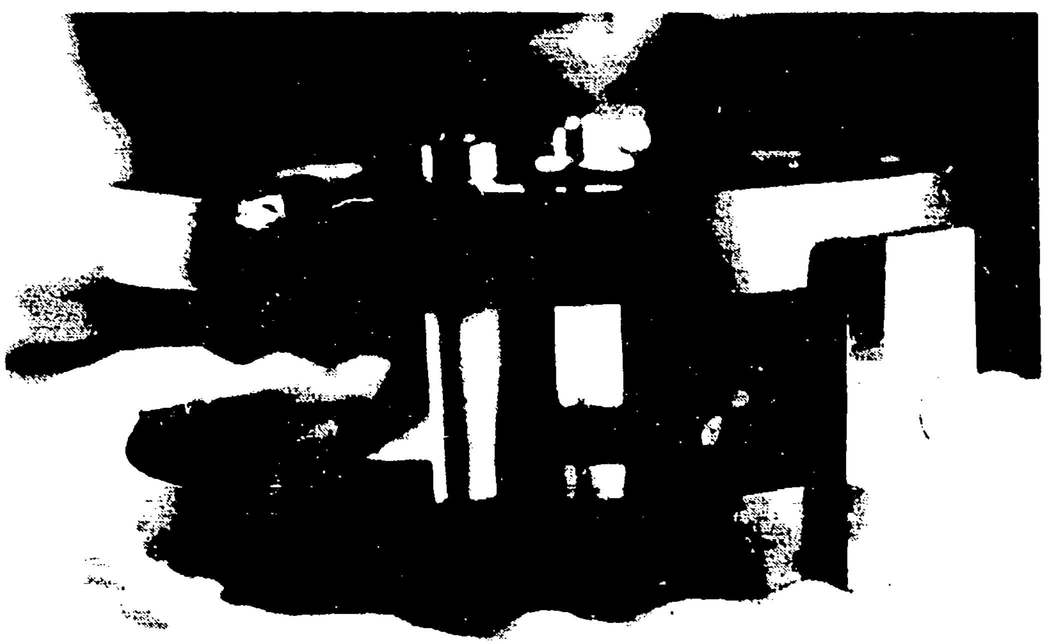


Figure 9b. Transducer mount position when internal nodal stiffener assembly is installed.

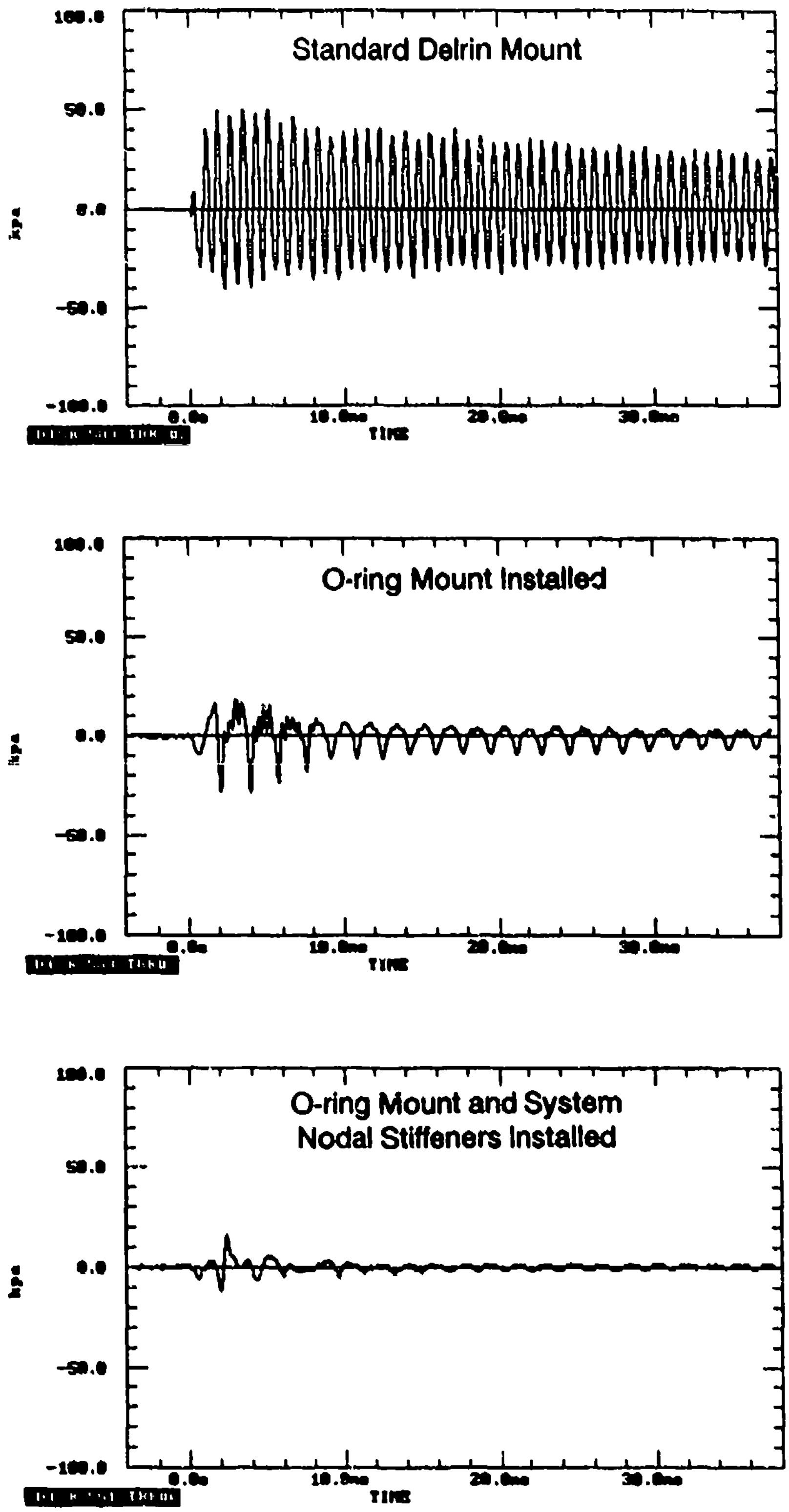


Figure 10. Effect of O-ring mount and nodal stiffeners on ringing noise suppression.

Figure 11. Test module with system dampening jacket installed.

4. FIELD TESTS

The test module fitted with the O-ring mounts, internal stiffeners, and the dampening jacket was field tested at the Los Alamos Albuquerque test site. In order to differentiate "signal" from "noise," a pair of freestanding pressure gauges were placed next to the transducers on the test module. As can be seen in Figure 12, the data with the transducer noise reduction system installed has output signals comparable to the freestanding probes. Additional field tests showed that the noise reduction system worked equally well for the vertical setup.

The modified test module was used to measure blast loading for field animal tests. Figure 13 shows the setup of the test module, the sheep and the C-4 charge. A comparison of the outputs from a carefully mounted sheepskin pressure transducer and that from the test module is shown in Figure 14. Both the peak and the A-duration match well with each other, and prove the validity of using the module measurement as a substitute. Figure 15 shows a typical set of body loading signals from the test module. Note the asymmetry of the loading signals and the effect induced by the proximity to the ground plane.

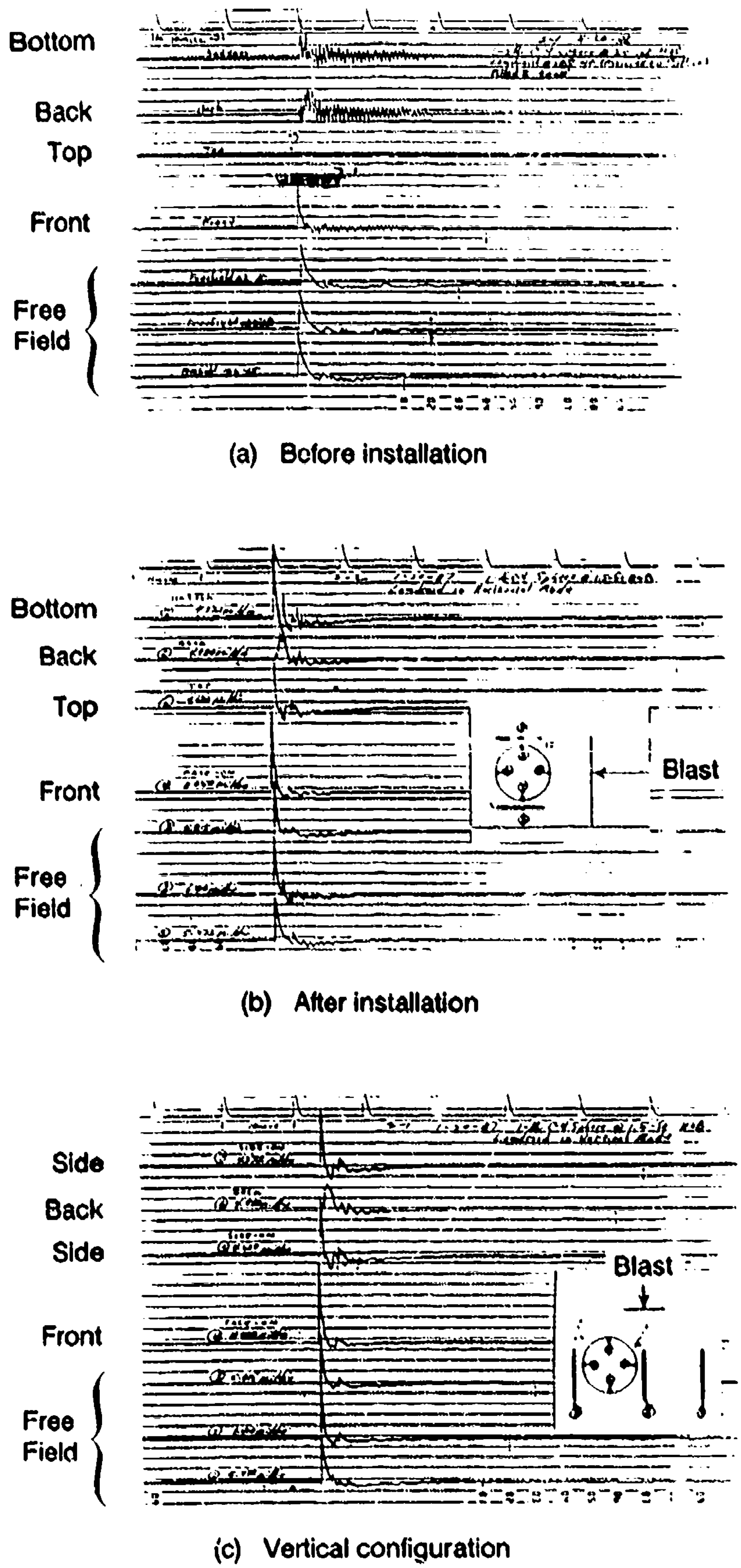


Figure 12. Effect of transducer noise reduction system on test module outputs.

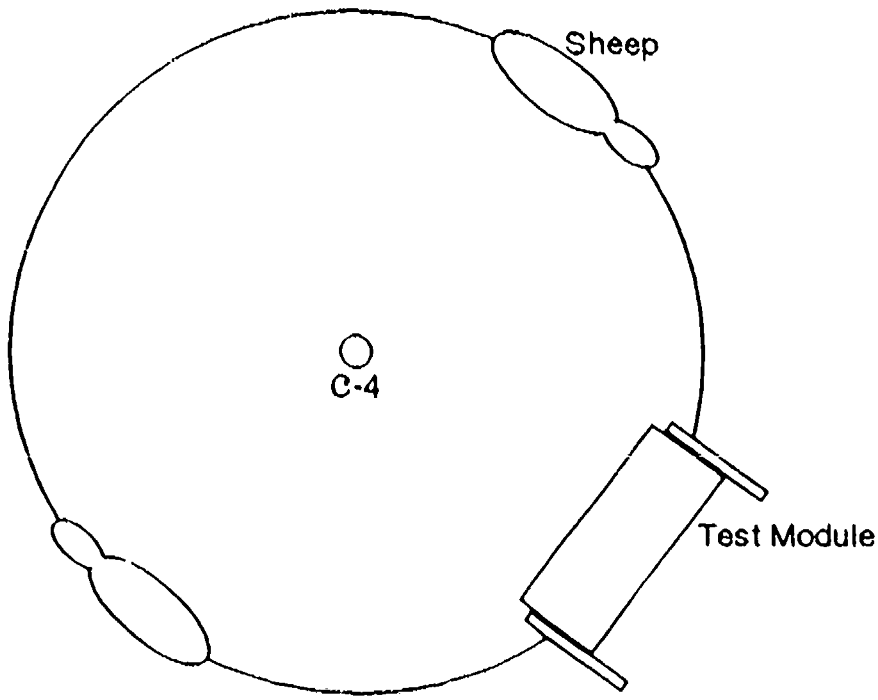


Figure 13. Blast loading test arrangement.

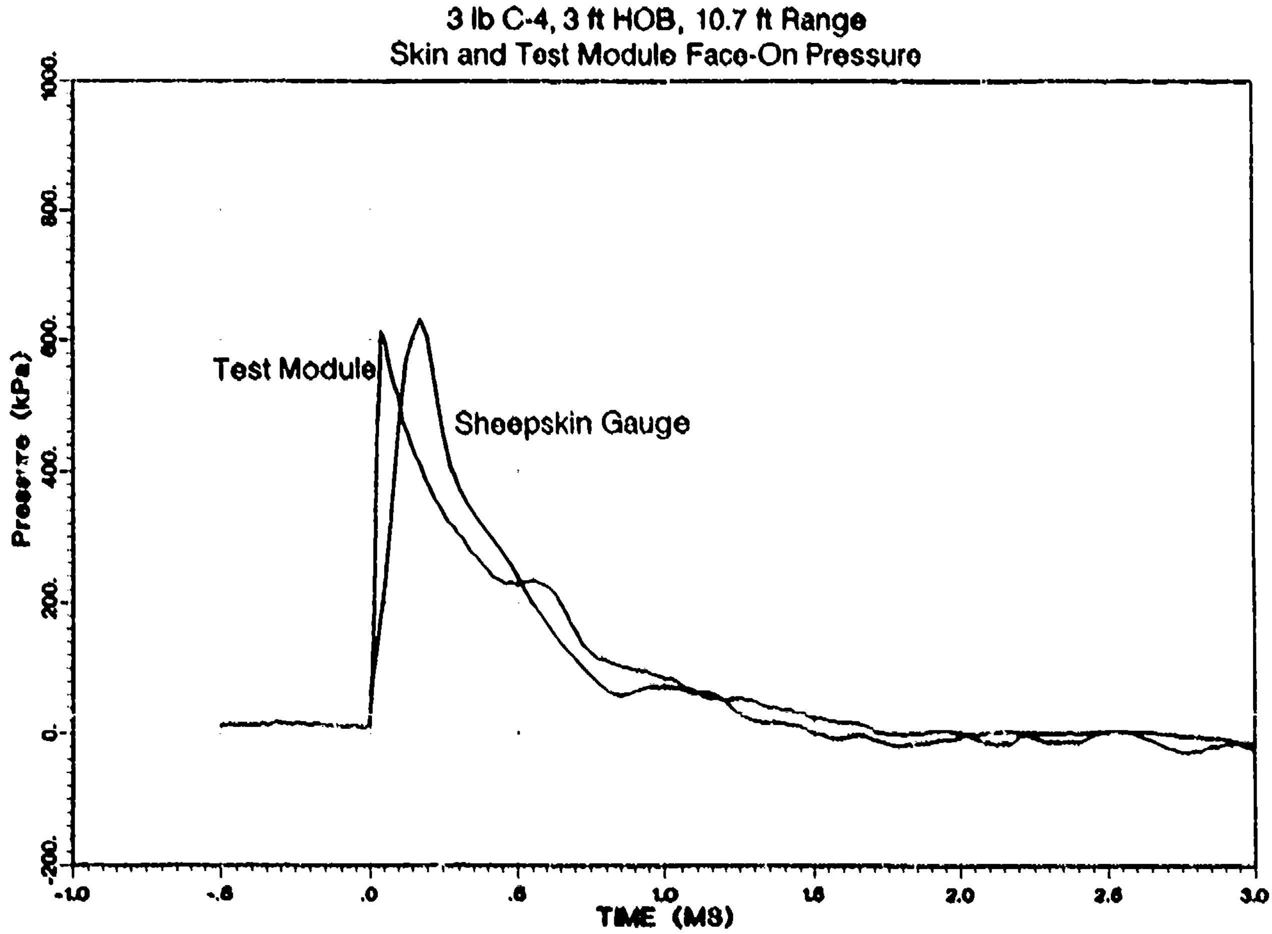


Figure 14. Comparison of sheep and test module blast loading data.

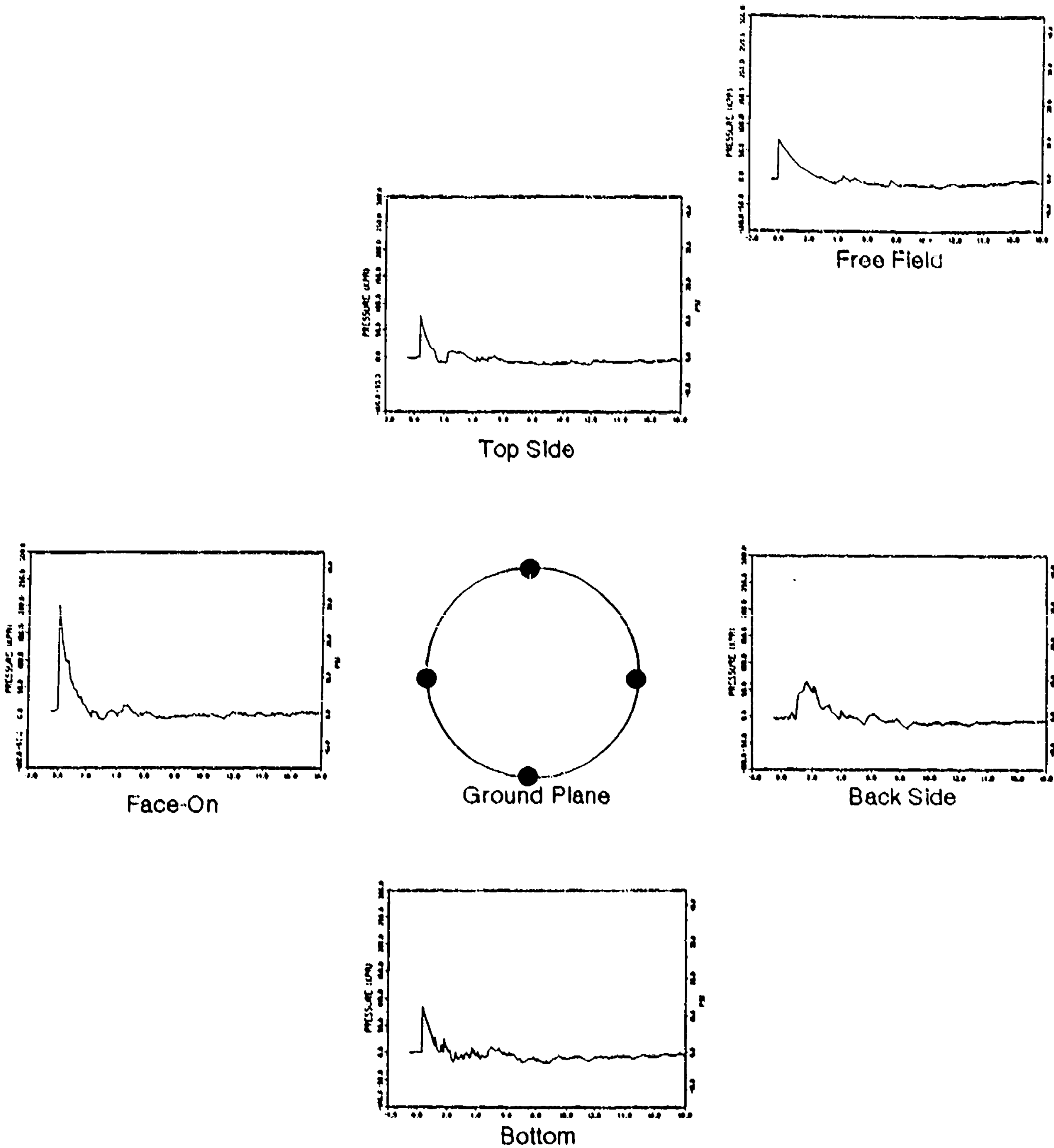


Figure 15. Blast loading distribution on the test module (free field pressure = 75 kPa).

5. CONCLUSIONS

The blast overpressure test module has proven to be a convenient tool for gathering blast loading data on test animals. It serves as a valuable substitute for test animals to gather blast loading. It can be conveniently installed in either the vertical or horizontal configuration to emulate a seated or standing test animal. Its rugged construction also allows for data collection in any harsh environment within the design guidelines. Data from these tests will be an essential link in predicting blast related animal injury.

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