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TITLE: NEW AIRBLAST CRITERIA FOR MAN

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NEW AIR BLAST CRITERIA FOR MAN

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INTRODUCTION

The purpose of this report is to present direct-airblast casualty criteria for personnel in the open and in foxholes. The criteria relate the incident blast overpressure required to produce 1-, 50-, and 99-percent incidences of casualties as a function of the overpressure duration. Hopefully, the information presented will contribute to establishing safe limits for personnel.

Injuries from the direct-overpressure effect are usually to the hollow or gas containing organs of the body. The lungs are considered to be the target organ because their disruption by the blast permits air to enter the circulation leading to an early death from coronary and cerebral air embolism. Associated with lung hemorrhage are bloody froth in the upper respiratory tract and an increase in respiratory rate. Contusions in the lining of the gastrointestinal tract and perforations at higher blast levels are common features of direct-blast effects. Hearing loss from eardrum rupture and neurosensory lesions in the inner ear are the more far reaching direct blast effects.

DEFINITIONS OF A CASUALTY

There are several definitions of a casualty. One is death or a person incapable of performing any task. Another is a person reduced to below 50 percent of his undegraded performance level. Still another is percent incapacitation, which relates the percent that the man's performance is degraded. In this report, a casualty is defined as a combat ineffective (CI), a person who can not perform his assigned task at 5 minutes.

Human incapacitation is almost always influenced by subjectivity and by the circumstances of the casualty as well as the severity of the trauma. The only available direct-airblast criteria are based on the severity of the observed injury in animals, and it is necessary to define incapacitating lesions as injuries which, had they occurred in man, would almost certainly produce a casualty. Once the criteria are formulated, one then looks for information from accidental explosions to evaluate them. Unfortunately, well-documented cases of human exposure to blast are rare--that is, the weight of the explosive and the exact distance from the explosion and, also, the explosions usually occur inside structures or it may not all detonate at once.

Recently, the need arose to evaluate existing direct-blast criteria for personnel and, if need be, formulate new ones. Blast criteria have not been scrutinized because for conventional ordnance fragments provide the dominant effect. Because of their very short duration, blast waves of very high overpressures (that occur close-in to the charge) are required for blast injuries. In the case of nuclear blasts, having very long-durations, much lower overpressures can inflict injury. However, other effects usually override direct-blast such as nuclear, thermal, and blast displacement.

Kokanakis at BRL reviewed the state-of-the-art for blast incapacitation and concluded that existing criteria were too stringent, Reference 1. He suggested that the LD₁ lethality curve is too severe a measure of incapacitation and would underestimate casualty production as well as the effectiveness of blast producing weapons. The LD₁ criteria state that fifty percent of the personnel exposed to a one-percent lethal airblast overpressure would become casualties from lung hemorrhage. The lung hemorrhage would be severe enough to produce bloody froth in the trachea, mouth, nose, and increase the respiratory rate. Exertion could be fatal. This LD₁ curve reported by Bowen,

Reference 2, was based on the dose-response curves of about a dozen species of animals exposed to blasts of different positive durations from high explosives in the open and in shocktubes. Actually, more than three quarters of the animals given an LD₁ level of blast sustain severe lung injury.

Kokanakis proposed relating the blast overpressure required to produce threshold lung injury to 99 percent incapacitation (defined as the percent degradation in performance). He also proposed blast overpressures for a 50-percent incidence of eardrum rupture as the threshold for incapacitation, Figure 1.

For our purposes, we did not consider threshold lung injury as incapacitating. At threshold levels, the lesions consist of petechial hemorrhages (pinhead sized) which we find have no affect on respiration or blood gas concentrations. Although eardrum rupture may result in hearing loss and, thus, correspond to a casualty by definition (unable to hear), we would only consider severe ear injury as possibly casualty producing, i.e., eardrum completely destroyed and disruption of the ossicular chain that occur at the higher overpressures.

ONE-HALF LD₅₀ CRITERIA

The newly proposed direct blast criteria relate a 50-percent incidence of combat ineffectives (CI) to one-half the LD₅₀ blast level reported by Bowen, Reference 2. It assumes that 50 percent of the personnel exposed to LD₅₀/2 airblasts would become CI from lung hemorrhage. A review of pertinent blast-dose response data from animals supports this assumption. There was sufficient lung damage to increase the lung weight, produce bloody froth in the upper respiratory tract, and increase the respiratory rate. At LD₅₀/2 blast levels, the animals also sustained contusions of the gastrointestinal tract and ear injury of a severe form in about half the cases. A 99-percent incidence of CI was set at the LD₁ level and the 1-percent CI level was found by extrapolation

downward using the average slope taken from the animal dose-response curves. The $LD_{50/2}$ blast curve is about 30 percent lower than the LD_1 curve and about twice the lung threshold curve.

Figures 2, 3, and 4 present the percent-CI curves as a function of maximum incident overpressure and duration of the positive pulse. Basically, the curves are those from Bowen, Reference 2, with the 50- and 1-percent CI curves added. Figure 2 applies to man standing or prone broadside to the blast wherein the dynamic pressure was added to the incident side-on overpressure. Figure 3 gives the percent-CI curves applicable to man prone end-on to the blast where the incident overpressure alone represents the airblast dose. Figure 4 shows the incident blast overpressure required for the indicated percent CI for personnel against or close to a reflecting surface oriented normal to the wave. In this instance, the reflected overpressure represents the airblast dose. Over the 1- to 10-msec duration range, the incident overpressure associated with CI_{50} decreases by a little over a factor of 3 for the broadside and reflecting geometries of exposure. Over the same span of durations, the CI_{50} for the end-on situation drops by a factor of 5. All these curves apply to blast waves that have the maximum overpressure at the leading edge of the wave. They should be used with reservations to estimate man's response to more complex blast waves that occur within enclosures.

The threshold lung injury curve in the figure was set at one-fifth the LD_{50} and was based on the aforementioned interspecies studies. As already mentioned, the threshold lung injury was a trivial lesion. However, at overpressure levels required for this lesion, one would expect a high probability of ear injury.

DIRECT BLAST CRITERIA FOR PERSONNEL IN FOXHOLES

Curves showing the incident overpressures necessary to produce 1-, 50-, and 99-percent CI for personnel crouching in foxholes as a function of the duration of the incident wave is presented in Figure 5. The curves apply to a standard two-man open foxhole (2x6x4.5 ft deep) oriented side-on to the blast. These curves are based on the data points showing the response of animals exposed to blast in the standard foxhole or ones of comparable geometries. The datum point for man was estimated for long-duration waves, Reference 3. Data points for sheep in the standard foxhole were obtained with 64-lb and 1-ton charges, Reference 4. Those for goats in open trenches side-on were from a test using 0.75 tons, Reference 5. The other datum point for goats, at 100 msec-duration, was obtained on a 100-ton shot with subjects in the open portion of a half-covered foxhole, Reference 6. Dogs were in the standard foxhole side-on to the blast from a 40-kt shot, Reference 7. The 50-percent CI curve was first established from this data and then the 99-percent and 1-percent CI curves were drawn 30 percent above and below it. The 99-percent CI curve is equivalent to an LD_1 curve.

In the side-on orientation, this foxhole affords more protection from the blast than when it is end-on. Little protection is provided to the occupants when the incident shock has a high angle of incidence. A crouching position is better than prone because the highest overpressures occur at the bottom of the foxhole.

DISCUSSION

A review of the published and unpublished information on animal response to an airblast indicates the $LD_{50}/2$ direct airblast criteria is sound. Data for sheep exposed to airblasts

of short duration (3-5 msec), Reference 8, intermediate durations (15 msec), Reference 9, and dogs given long-duration blasts (400 msec), Reference 10, all support the proposed criteria. A well-documented case of human exposure to the accidental detonation of a 3.5-lb uncased charge indicates that casualty predictions by the criteria are assured, Reference 11.

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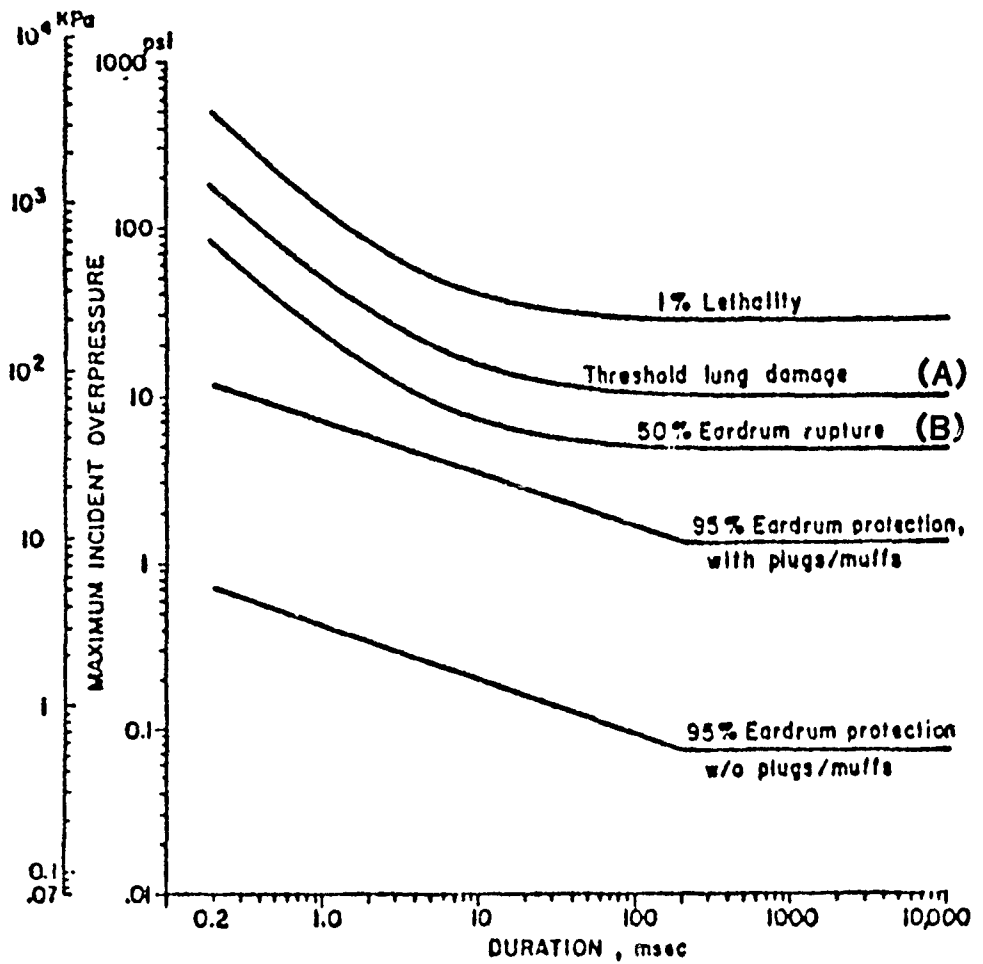


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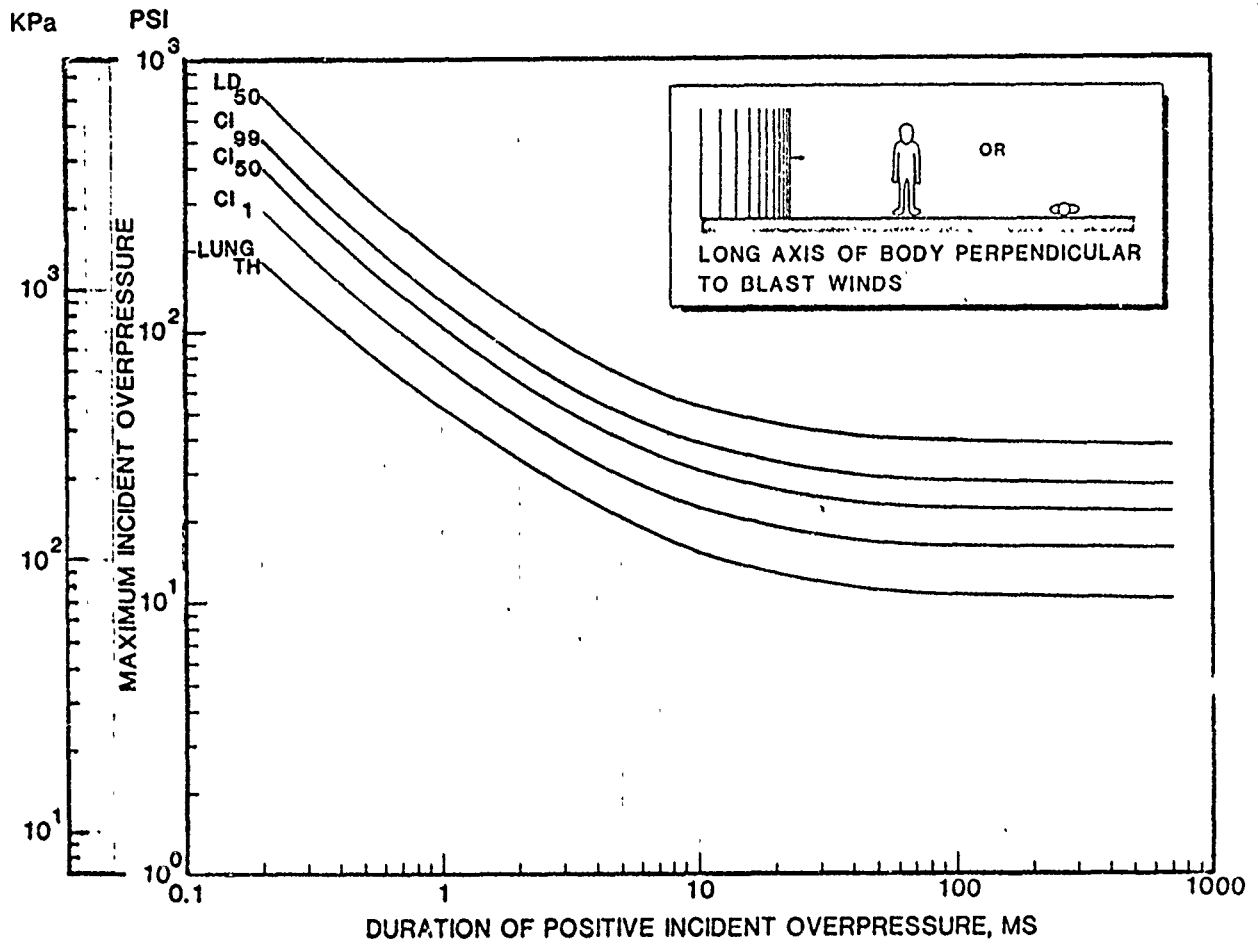


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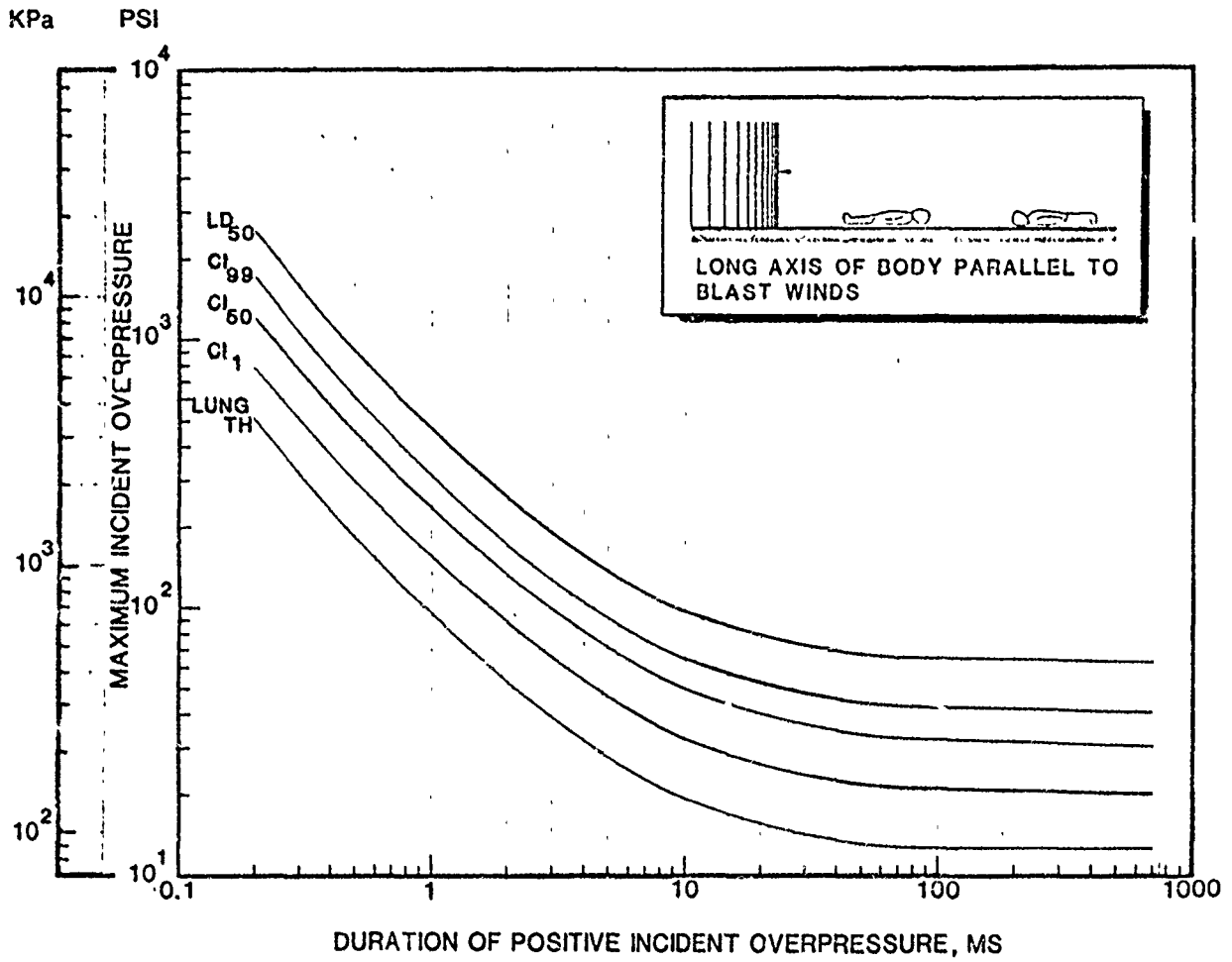


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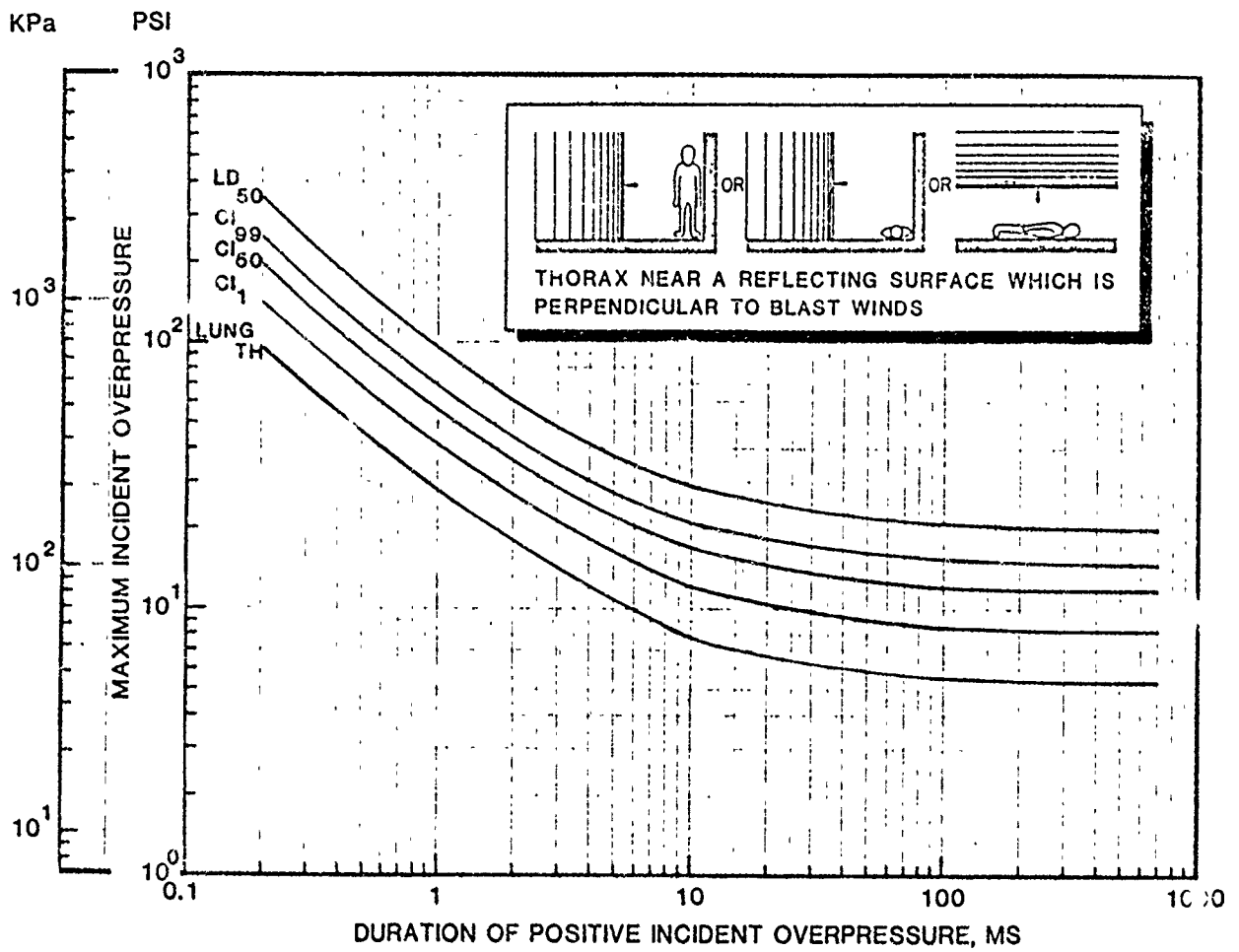


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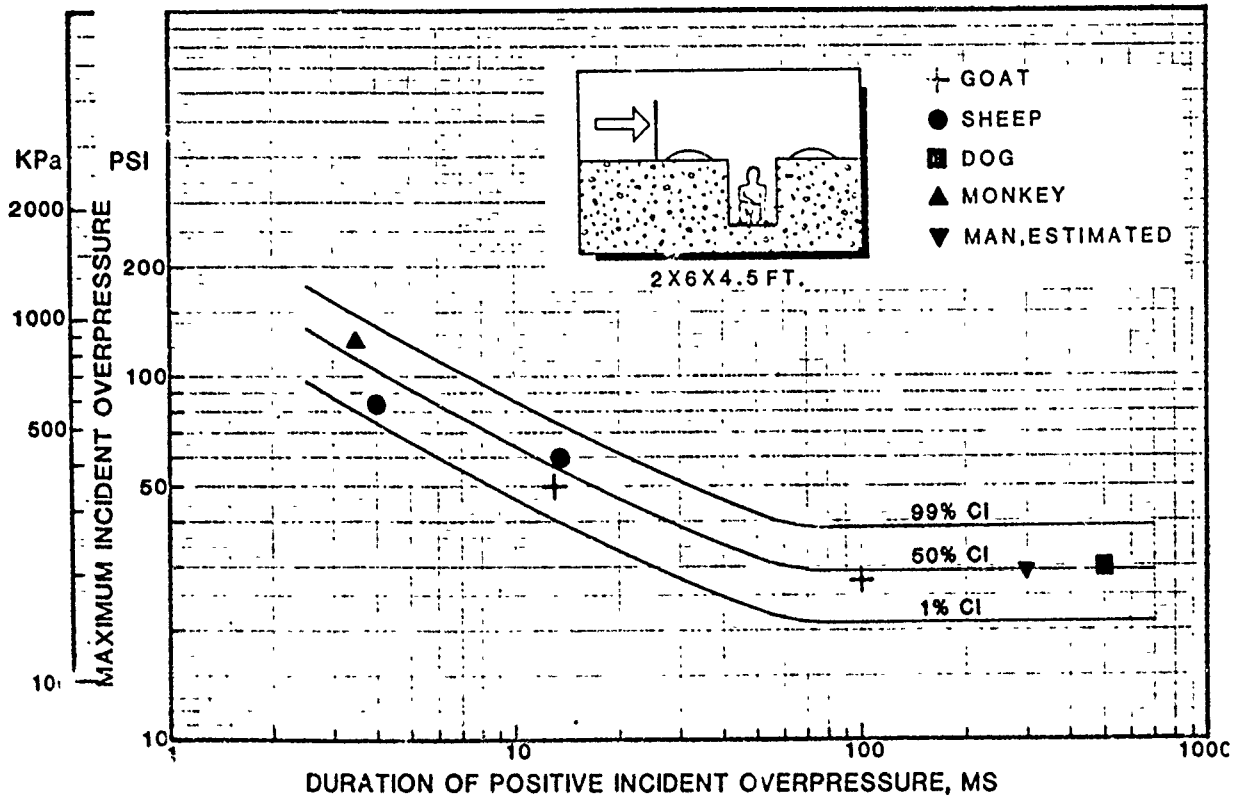


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