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THE EFFECTS OF STRONG SHOCK WAVES ON MORTALITY RATES AND PERCENTAGES OF PULMONARY LESIONS IN RATS AS A FUNCTION OF THE NUMBER OF EXPOSURES

Patrick Vassout and Georges Parmentier

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Introduction

The effects of strong blast waves have been studied in particular */ since the Second World War. In general, authors have described the relationships which exist between such and such a parameter of the blast wave and the percentages of pulmonary or intestinal lesions, as well as the mortality rates, observed in subjects of a given species for a single exposure.

The literature reviews in [1] and [2] show that so far the parameter "number of exposures" has not been dealt with by the several investigators in question. Indeed, it would not seem very realistic to imagine that an individual could be subjected to a succession of pure blasts. The appearance of new weapons based on the principle of gas detonation, as well as the development of weapons which produce very high overpressure levels at the start of the blast pose the problem concerning the effect of the number of exposures to a strong blast wave on the extent of pulmonary lesions and on mortality rates.

We have therefore undertaken to study the "number of exposures" parameter on pulmonary lesions and mortality rates in the rat [3].

1. Experimental Apparatus

The experimental animals were female rats with an average body weight of 100 g. Each animal was placed in a wire mesh cage [1]. The cages were placed symmetrically around the explosive charge. With this arrangement it was possible to apply the same blast wave to each animal while changing as little as possible the pressure profile of the wave.

The explosive used was "plastit" made by Dottikom Co., Switzerland.

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*Numbers in the margin indicate pagination in the foreign text.

1.1. Determination of the Amounts of Explosive Required

By applying the laws of similarity valid for spherical explosives [4] [5], we determined the amounts of explosive necessary to obtain the desired overpressures while maintaining a constant duration of the positive first phase t_o.

1.2. Recording Pressure Changes

The pressure signals (Fig. 2) were recorded by means of KISTLER /3 6031 piczoelectric dynamic pick-ups placed in the tapered waves. These pick-ups were connected to BIOMATION 805 transistorized analog digital signal recorders. The pick-ups were installed at the same distance from the explosive charge as the experimental animals and measured the pressure in free space. The animals, placed on [word illegible], were exposed to the incident pressure and the pressure reflected by the ground. The pressure levels discussed here always refer to those which existed at the level of the animals. (Overpressure measured in free space multiplied by the reflection factor)

2. Results

2.1. Mortality Rates as a Function of the Number of Exposures

2.1.1. Determination of the Median Lethal Dose for Rats

The median lethal dose (LD_{50}) is the crest overpressure which for a given length of time T_o for the incident blast wave causes death in 50% of the animals exposed at the end of a given length of time after exposure, for example 24 hours.

Based on the studies of Richmond and White (1962) [6], done on many species of animals, we can estimate the crest overpressure corresponding to the LD_{50} for rats for a given t_o of the blast wave (LD_{50} = 3 bars for t_o = 2 ms). We have chosen as [word illegible] of the blast wave the value t_o = 2 ms. Indeed, according to these authors, beyond this length of time this parameter no longer has any effect on the mortality rate in rats.

For this 2-ms length of time we have studied the mortality rate in rats for a single exposure to an overpressure blast wave between

3 and 5 bars (Fig. 3). It should be noted that all of the overpressure less than 3 bars did not cause any mortality in our experiments.

It appears that the LD_{50} for rats, 24 hours after a single exposure, is located around 3.5 bars. We also find that the difference in overpressure necessary to go from a mortality rate of 10% to one of 90% five minutes after exposure is 1.5 bars in rats.

2.1.2. Effect of the Number of Exposures on Rat Mortality Rates /4

For the purpose of determining relationships between mortality rates, the number of exposures and crest overpressure, series of 40 animals were exposed to blast waves of $t_o = 2^M$ s produced at regular 4-minute intervals.

Fig. 4 shows the results obtained in the overpressure range between 2 and 4 bars. The dotted line curve which represents the LD_{50} reveals that a twofold increase in the level of the crest overpressure is offset by a 20-fold decrease in the number of exposures.

2.2. Percentages of Pulmonary Lesions Due to Exposure to Strong Blast Waves

2.2.1. Definition of Lesion Criteria Used in our Experiments

Fig. 3 shows that a single exposure to a wave overpressure blast wave less than 3 bars does not cause any mortality. However, autopsy reveals that the animals have hemorrhagic pulmonary lesions ranging from simple petechia to a completely hemorrhagic lobe. We have taken as the lesion threshold the small hemorrhage isolated on a single lobe according to the criteria proposed by Richmond et al. [7].

2.2.2. Determination of the Overpressure which Causes Pulmonary Lesions in 50% of the Experimental Animals

As in previous experiments, we first of all studied the influence of a single exposure to varied crest overpressures on the rate of pulmonary lesions.

The overpressure which causes the appearance of pulmonary lesions in 50% of the experimental animals is situated around 500 mbars (Fig. 5). An overpressure of 2.5 bars lasting for the same amount of time (2 ms) causes lesions to appear in all of the animals exposed.

2.2.3. Effect of the Number of Exposures on the Percentage of Animals Showing Pulmonary Lesions /5

Groups of 40 animals were exposed to series of blast waves all lasting t_o = 2 ms and of overpressures ranging between 32 and 500 mbars. The results obtained are plotted in Fig. 6. Note that for a constant percentage of animals with lesions (dotted line curve), a two-fold increase in the number of exposures must be compensated for by a quartering of the crest overpressure. This result shows a different relationship between the wave overpressure and the number of exposures experienced from [word illegible] observed on the basis of mortality rates.

3. Trial Extrapolation for a Theoretical Animal Weighing 70 kg and Conclusion

Many authors such as Zuckerman 1941 [10], White 1959 [9] Richmond 1968 [7] and Jones 1969 [9] think that it is possible to extrapolate the results obtained in animals to man. They indicate that the LD_{50} applicable to man would be on the order of 10 bars for a blast wave lasting 2 ms (t_o). These authors also think that the threshold for the appearance of pulmonary lesions in man surround one-fourth of the LD_{50}, or around 2.5 bars.

As for the effect of the number of exposures on mortality rate, extrapolations of our results to man indicates that twenty exposures to a crest overpressure of 5 bars lasting 2 ms (t_o) experienced at intervals on the order of 5 [word illegible] would cause death in 50% of the subjects exposed.

As for the effect of the number of exposures on the appearance of pulmonary lesions, we fear that lesions might appear in man for crest overpressure values plainly less than those currently accepted (2.5 bars for a t_o of [word missing] where the subject is exposed to a series of strong blast waves).

* Fletcher II from Canvas report

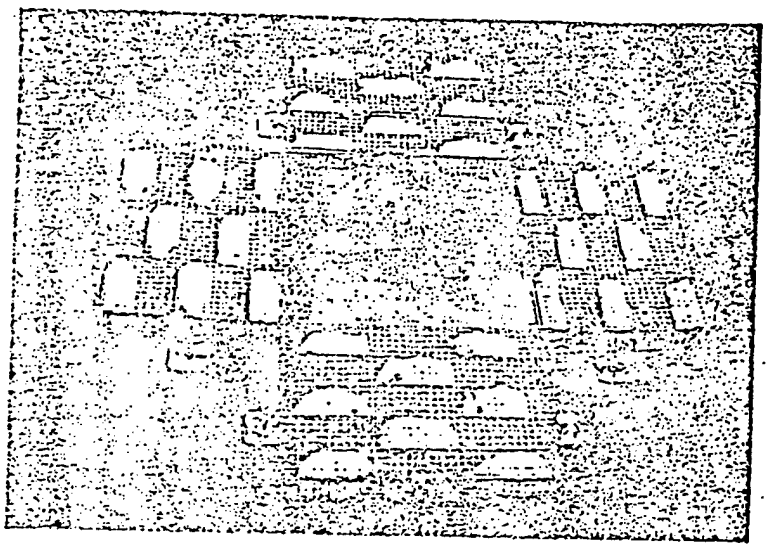

Fig. 1. Arrangement of Rat Cages

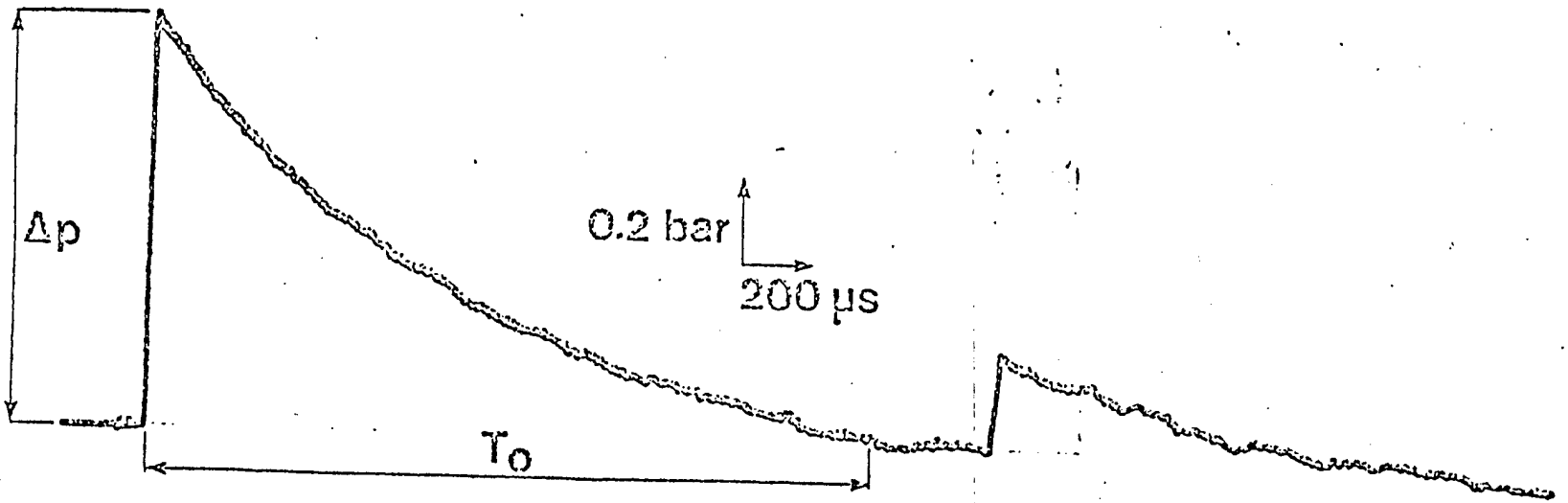

Fig. 2. Typical recording of pressure signals for an explosive mass.

A Poids de "Plastit" [g]	Distance [cm]	Δp [bar]	B Temps écoulé après une exposition						
			5mn	30mn	1 h	2 h	4 h	C 24 h	nbre d'animaux
1096	270	3	0	8	8	8	11	28	36
1280	270	3,5	9	15	34	35	38	53	68
1371	267	4	35	35	35	39	45	58	31
1560	267	4,5	49	74	77	83	89	91	35
1770	269	5	97	100					35

Fig. 3. Mortality rates observed after an exposure to blast waves of variable Δe and constant t_o (2 ms) in rats weighing 100 g.

Key: a. Weight of "plastit" in grams
b. Elapsed time after explosion
c. Number of animals

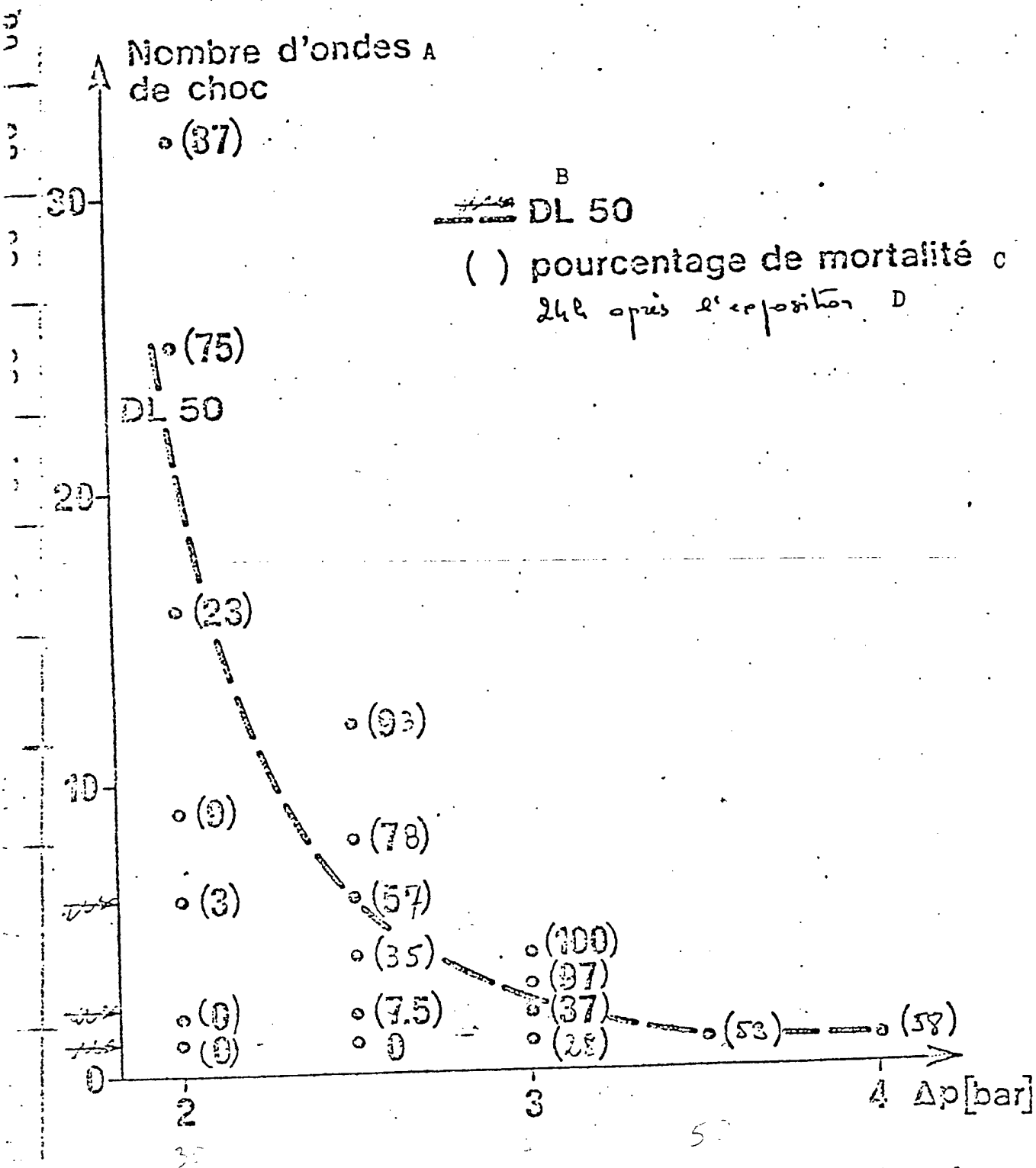

Fig. 4. Effect of the number of blast waves experienced as a function of overpressure with a constant t_o (2 ms) on mortality rate in rats.

Key: a. Number of blast waves
b. LD_{50}
c. Mortality rate
d. 24 hours after exposure

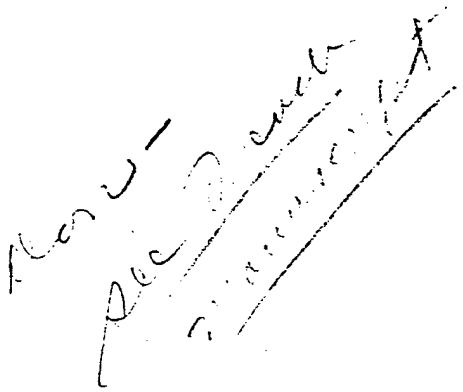

Fig. 5. [Caption illegible]

Key: a. Percent of animals with lesions

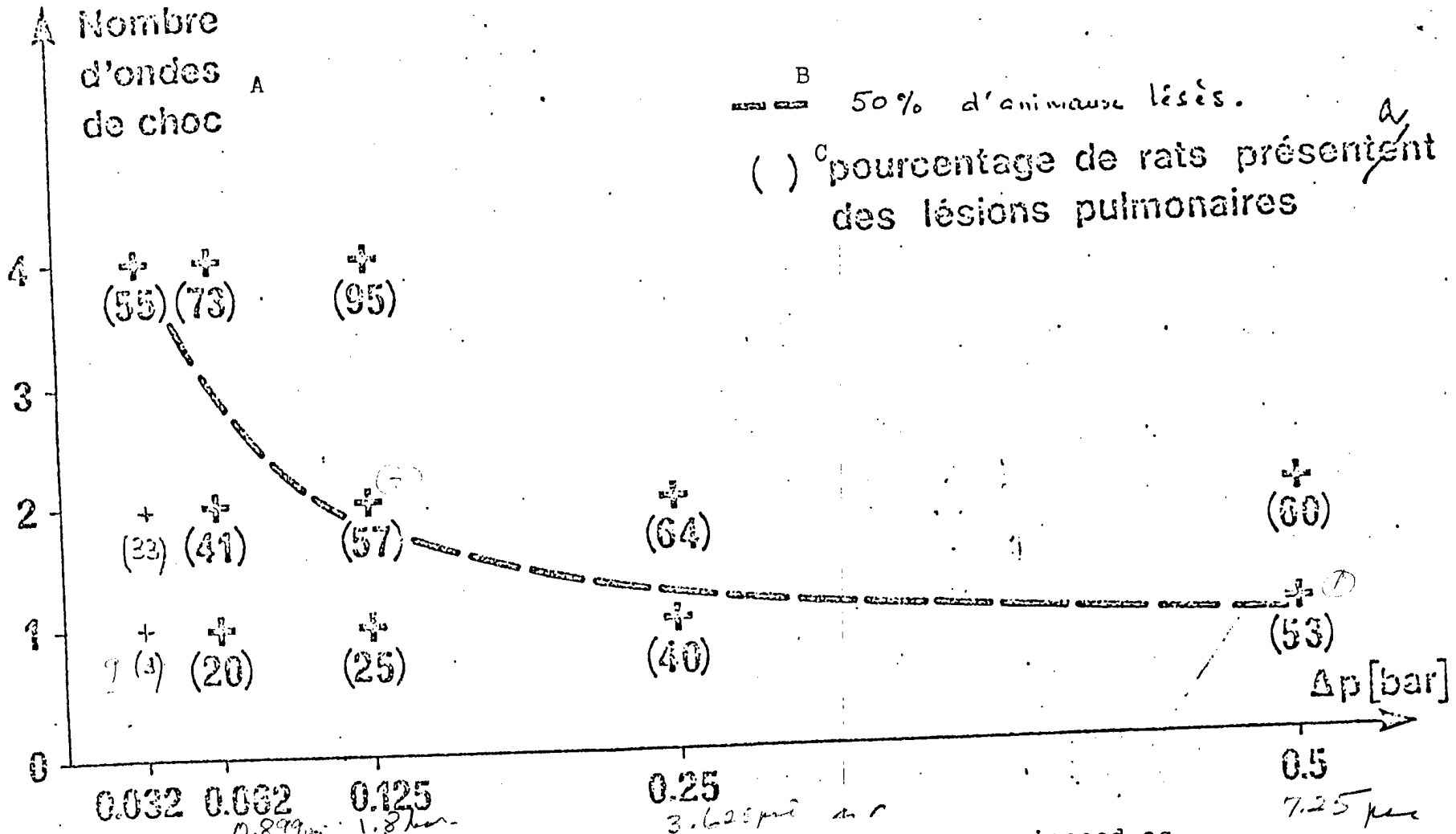

Fig. 6. Effect of the number of blast waves experienced as a function of the overpressure of constant t_o (2 ms) on the percentage of rats with lesions.

Key: a. Number of blast waves
b. 50% of animals with lesions
c. Percentage of rats with pulmonary lesions

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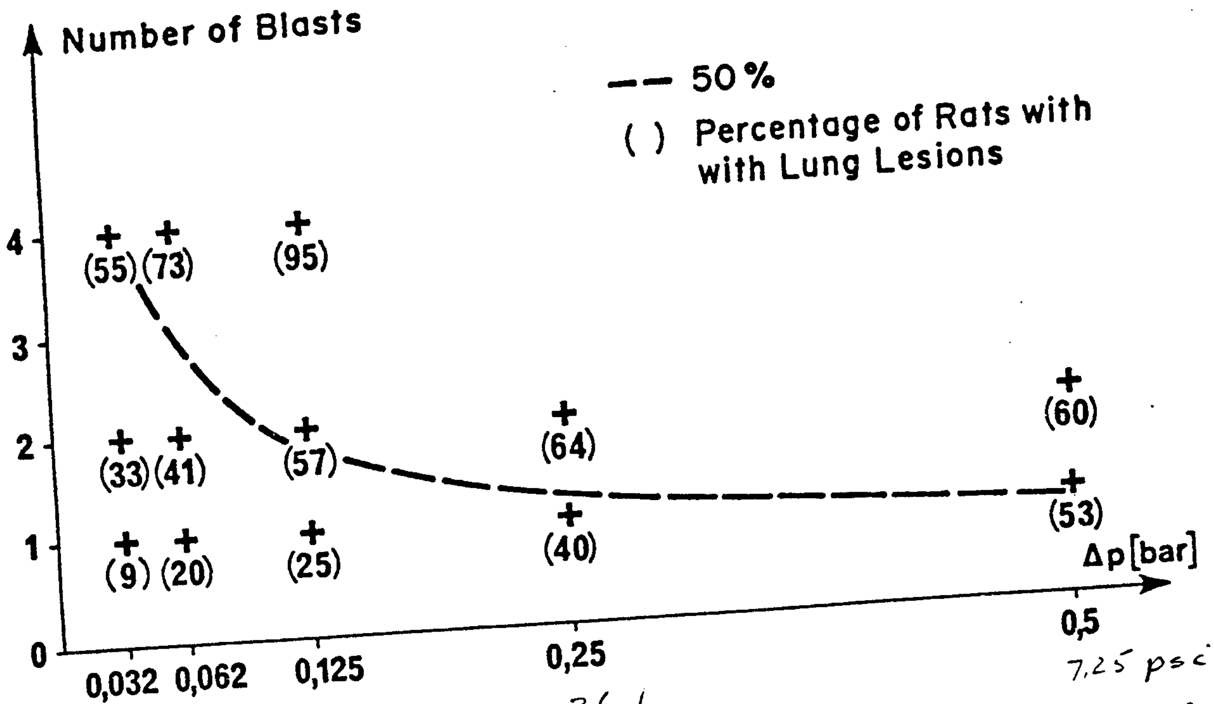

Figure 4. Effect of the Number of Blast Waves Experienced as a Function of the Overpressure of 2-Msec Duration on the Percentage of Rats with Lesions.

ISL

1psi is ~ 1/50 of the LD50 [illegible]

sheep 1950s [illegible], the LD50 was [illegible] say 65 then 1/50 of that 1.3 psi [illegible] of 75psi [illegible] 1.5psi

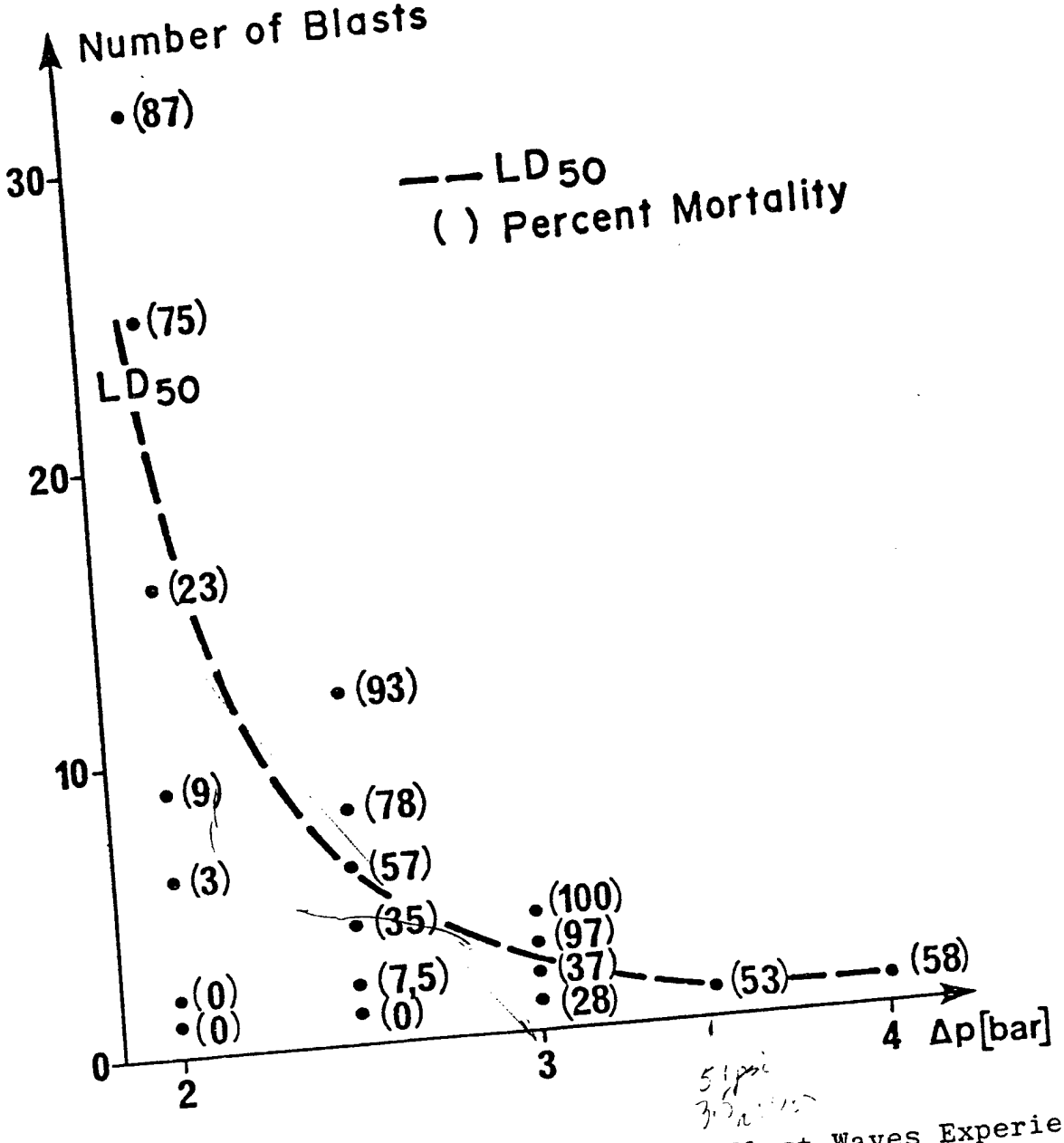

Figure 3. Effect of the Number of Blast Waves Experienced as a Function of Overpressure with a Constant 2-Msec Duration on Mortality Rate in Rats.

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16. Abstract

This study of pulmonary lesions and mortality rates caused in rats by exposure to strong shock waves of constant duration revealed that with regard to the pulmonary lesions, twice the number of exposures is compensated for by quartering the overpressure of the wave crest, and with regard to the mortality rates, it revealed that halving the overpressure of the wave crest is offset by a 20-fold increase in the number of exposures.

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