RESTRAINT SYSTEM STUDY WITH A LIVING SUBJECT :

Methodology and results on three point belt restraint

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INTRODUCTION

The aim of this study is to compare several, usual or new restraint systems and to search their limits. It should enable to improve the safety belt in orthogonal frontal impact at 50 km/h. So the following restraint devices will be studied : the three point belt, static or with retractor
the three point belt with load limiter
the inflated belt
the preloaded belt
the steering wheel air bag with lap belt.

The research originality lies in the choice of a living animal as experimental model for dynamic tests.

I.CHOICE AND VALIDATION OF THE MODEL

The living animal was chosen because of its natural reaction abilities to impact stresses. In fact, during the tests, it keeps a muscle tone of great importance in the impact response. Moreover, the same animal may undergo several successive runs ; a clinical and radiological control is made after each run. In some cases, traumatic lesions may occur and can be observed on bones or visceral parts. An autopsy is undertaken in case or thoracic fracture.

The baboon was chosen because it has a natural sitting position, non affected by its tail. It is quite similar to man and its relatively mean stature makes easy the handling and the restraint system fitting. The used baboons are kept at the laboratory and weight from 20 to 25 kg.

Compared to the human skeleton, the baboon one has a similar vertebral spine with 7 cervical vertebrae, which enables comparable motions, certainly more realistic than these of dummies. However, anatomical differences are marked on the head - cynocephalus monkey (BIARD - 1), on the shoulders which are less broad and more sloping for the baboon, on the thoracic cage with a more circular and conical shape, then on the abdomen (higher abdominal wall) KAZARIAN (4).

II.METHODOLOGY

II.1. Run test conditions : the runs are performed with the dynamic sled of the ONSER Laboratory with a speed range from 30 to 65 km/h. On the basic platform, a special structure is fixed for the implantation of the seat and the belt anchorages and, if necessary, of the front vehicle compartment.

The deceleration characteristics of a small European car are simulated with reference to the frontal orthogonal barrier crash at 50 km/h speed (fig. 5, 6). The crush varies from 0,54 m to 0,60 m.

II.2. Animal position and physiological state : the baboon is sitting on a slightly padded, shell moulded seat (polyester reinforced glass-cloth), which offers a good lateral holding of the body. The angle between the seat and the back pans is 95°, the seat pan being 25° from horizontal.

Moreover, to ensure a good reproducibility of initial head and thorax positions, the baboon head is kept in natural position by an appropriate device during the sled travel, and is released just before the crash (Fig. 1). The animal is anaesthetized for preparation (Ketamine HCl) and the sled run is operated when it recovers its muscle tone (prehension reflex).

II.3. Biomechanical parameters :

The baboon state evaluation is issued from clinical and radiological surveys following each run ; then the animal behavior is observed. Yet, it must be emphasized that only noticable lesions can be revealed, such as clear fractures, pains, obvious clinical signs or baboon prostration.

The head deceleration is measured by a miniature triaxial accelerometer (JPB 212) put on the nose before the eyes. Therefore, a light rigid helmet is moulded on the baboon head (polyester reinforced glass-cloth) and the accelerometers and the film targets are secured on it.

The figure 2 presents for each baboon the accelerometer positions relative to the reference system issued from the center of gravity. The slight distance between these positions justifies the direct comparison of the measurement.

The thoracic deceleration is measured by a miniature triaxial accelerometer (Entran Devices 500g), stick on the skin behind the 7^{th} thoracic vertebra.

The belt loads are measured by axial tension transducers fixed at each anchorage point.

These parameters are recorded and digitalized for the computation of the usual severity criteria (resultant acceleration, HIC, SI).

The baboon motion is visualized by two high-speed cameras (500 or 1000 i/s), situated laterally and above the impact area. They give the head displacement and its rotation relative to the longitudinal plane.

III.STATIC OR RETRACTOR BELT RESTRAINT

III.1. Restraint system description : each restraint system is adjusted to the baboon stature and morphology. The three point belt (30 mm width and

13 % stretching under 10 KN load) and the anchorage positions are extrapolated according to the optimum positions described by CITROEN (2). These anchorage points appear on figure 4, the superior point 01 being situated at 155 mm from the baboon sagittal plane. The thoracic belt goes on the left clavicle. The belt adjustment (25 mm slack measured on the sternum) is made when the baboon is in right position with its head holding device and when the lap belt is in contact with the body.

In the retractor belt, only the webbing in contact with the baboon is reduced to 30 mm width. The other parts of the retractor are not modified and the webbing length reeled is 600 mm.

III.2. Static three point belt results : eight runs were conducted with two baboons (n° 16 and 24), weighting respectively 21 and 22 kg (fig. 3).

The whole motion of the baboon can be described by a first sequence of body translation followed, after the pelvis stopping, by the head and thorax flexion in the longitudinal plane. At the end of the maximum head displacement, the body rotates laterally with a greater amplitude for the head. The rebound sequence begins with a rearward movement of the thorax up to its contact with the seat, followed by the head extension.

The head trajectories (Fig. 4) show a good reproducibility for each baboon. Moreover, both animals have comparable motion amplitudes, mostly in X direction.

The head resultant deceleration (Fig. 5, 6) presents a larger dispersion, especially for the baboon 24. The curves have a regular shape and their maximum reaches 58 to 78 g. The HIC indices vary from 600 to 900, except for one run (baboon 24) the severity of which was greater but cannot be explained. It must be emphasized that these values are measured at an external point on the head but not at its center of gravity.

The thoracic resultant decelerations (Fig. 5, 6) are quite similar in their shapes and their amplitudes.

The belt loads (Fig. 7, 8) are highly reproducible, particularly their rise slope. The curve shapes and amplitudes are similar for both animals.

III.3. Retractor three point belt results : Seven runs have been conducted, 4 of them with the two preceeding baboons and the others with the baboon 21 and 26, weighting respectively 21,5 and 24 kg (Fig. 3).

The results do not show any marked differences between the two types of belts. The differences appearing on the belt loads and the head displacements of baboon 26 depend directly on its morphology : tall monkey of slightly higher weight. With the baboon 16 restrained by a retractor belt, the head runs more steeply down.

III.4. Lesional findings : these 15 runs with three point belts produced a few more or less severe injuries.

The baboon 24 suffered a large hematoma characteristic of the belt loads on the rib cage and the pelvis after the run 83. Three months later, the baboon suffered abdominal pains which did not persist (run 91).

The baboon 21 was severely shocked by the run 72, a respiratory help was necessary. Abdominal pains, blood in urine and prostration lasted 24 hours. An autopsy undertaken later, showed hematomae between the liver and the diaphragm and internal hematomae in the left kidney. This latter injury was directly caused by the lap belt.

The baboon 26 suffered a sternal fracture after the run 74 (disjunction of the 2nd and 3rd sternal pieces).

With reference with other runs performed in the same conditions, it seems that this frontal crash simulation at 50 km/h speed corresponds to the lesional level for the baboon restrained by a three point belt.

IV.FIRST APPROACH OF THE COMPARISON LIVING-DEAD ANIMAL

IV.1. Purpose : An evaluation attempt of the experimental human cadaver behavior can be obtained from the comparison of the animal state - living or dead - Such researches have been carried on for a few years, with interest to particular body segments (head - thorax) using models such as the pig (VIANO - 7, LOWENHIELM - 5) or the baboon (ROBBINS - 6). Our purpose is essentially the comparison of the whole baboon behavior with one restraint system, depending on its state - living or sacrified.

IV.2. Methodology : one baboon, restrained by a static three point belt, undergoes one or several runs in the above conditions. Then it is sacrificed, kept in a cool compartment (4°C) during four or five days. So it can be prepared for the same dynamic run. The preparation method used for human cadaver tests (FAYON - 3) is followed : lung insufflation, liquid perfusion for arterial repressurisation (maintened during the crash). An autopsy is made after the run.

IV.3. Comparison results : the test results with the sacrified baboons n° 16 and 24 are presented on figures 3 to 8 and can be compared to the living state runs.

The deceleration and load curves do not differ greatly for each baboon. One can notice only lower belt loads on the shoulder and mainly on the interior belt in the sacrificed state. Moreover, the thoracic deceleration curve is more filtered in that case.

The head trajectories , in the sacrificed state, run less steeply down and present a smaller transverse rotation.

The autopsies, undertaken just after each run, did not reveal severe injuries (only superficial hematomae at contact belt-thorax and abdomen).

CONCLUSION

These first results indicate the great interest of using a living model as experimental subject. The test results show a good reproducibility for each baboon and for several ones of close weight and stature.

The lesion patterns and locations observed with the three point belt restraint, are quite similar to those found in accidentology. But it appears to be necessary to investigate the behavior of several subjects to take account of anatomical dispersions.

So it seems interesting to go on with this study ; the living baboon will lead to a qualitative classification of different restraint systems, adjusted and fitted to this animal.

Moreover, the approach of the comparison living-dead animal, restrained by a three point belt did not reveal marked differences. When carrying on this study, two points of the methodology should be improved. First, the physiological state of the living animal must be carefully controlled before and after each run. Secondly, it is important to ensure a good reproducibility of the sacrificed baboon preparation conditions.

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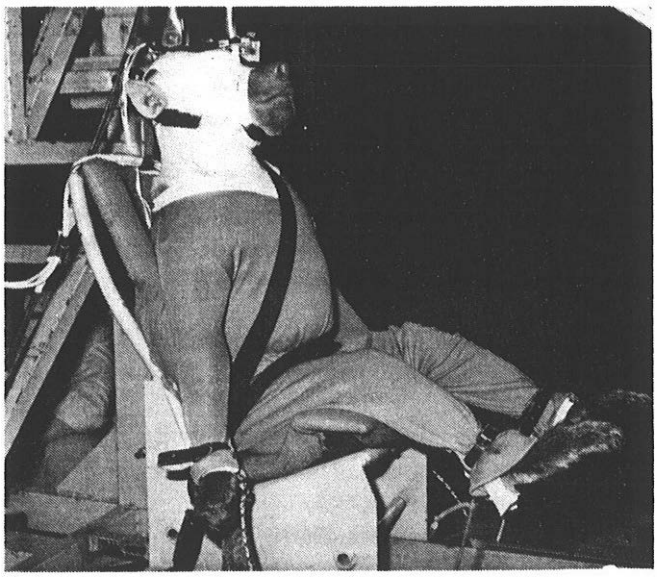


Fig.1 : Initial Position of the Baboon - Three Point Belt Restraint

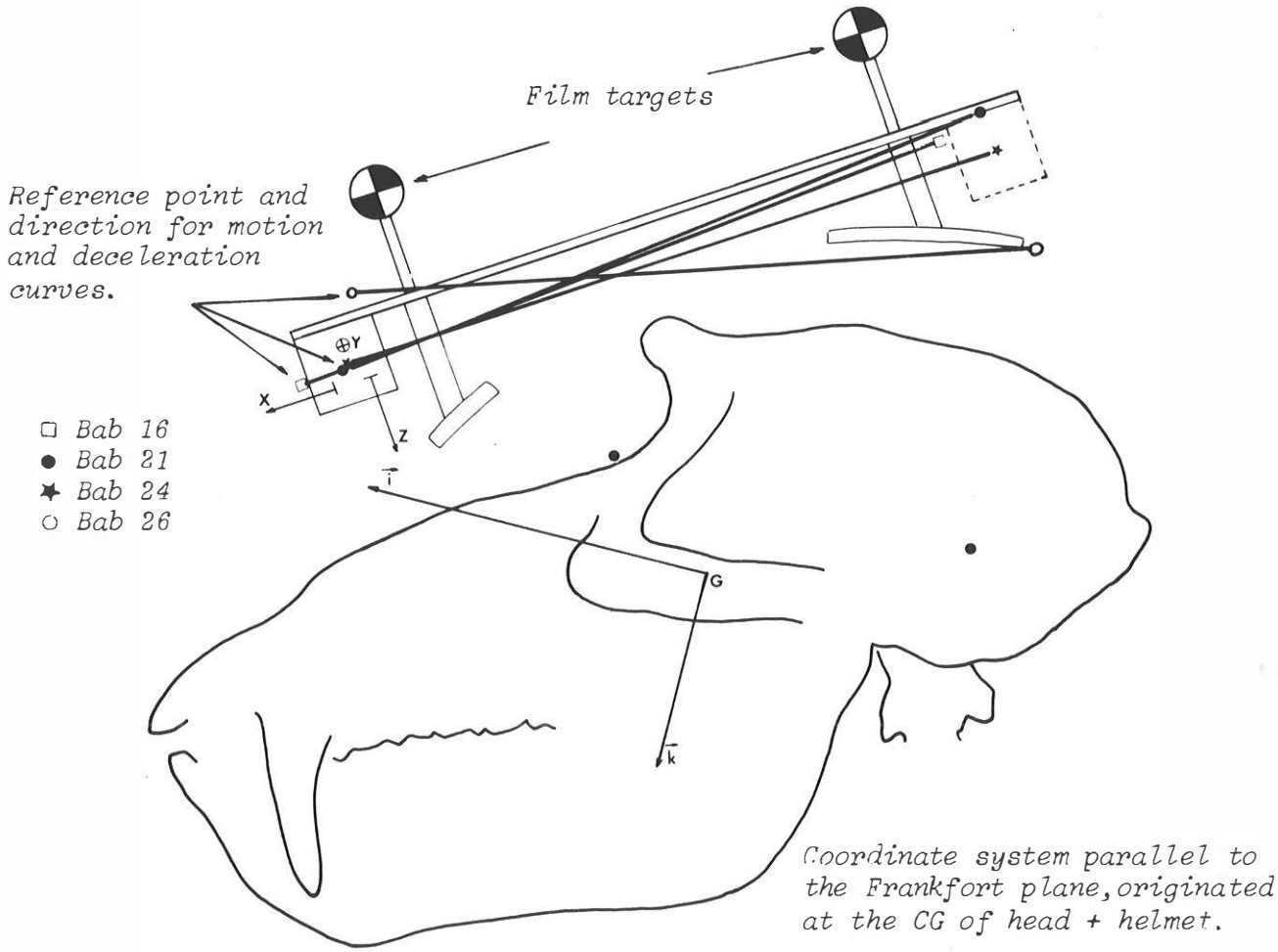


Fig.2 : Measurement Points on the Baboon Head

		STATIC BELT								RETRACTOR BELT							DEAD ANIMAL	
TEST n°		75	76	77	83	86	90	91	121	72	73	74	87	88	89	117	112	130
Sled n°		16	16	16	24	24	24	24	24	21	26	26	16	16	16	24	16	24
HEAD	γ_R(g)	73	70	60	56	78	63	70	92	67	68	67	82	85	95	76	68	63
	HIC	930	831	655	607	872	741	764	1360	733	795	1124	921	839	1258	1105	805	622
	dx (mm)	355	330	320	300	305	300	285	310	325	385	390	350	325	365	310	290	240
THORAX	γ_R(g)	45	40	35	48	40	34	38	40	-	44	41	35	38	33	40	30	37
	SI	418	331	290	452	350	290	240	379	-	340	335	242	302	242	270	209	305
BELT LOAD (daN)	O_1	375	310	340	355	370	315	340	290	400	380	400	320	355	325	335	320	310
	O_2	505	425	450	460	490	450	440	395	605	570	560	400	485	435	490	340	400
	O_3	130	90	90	120	145	50	80	100	150	110	130	110	120	110	175	70	130

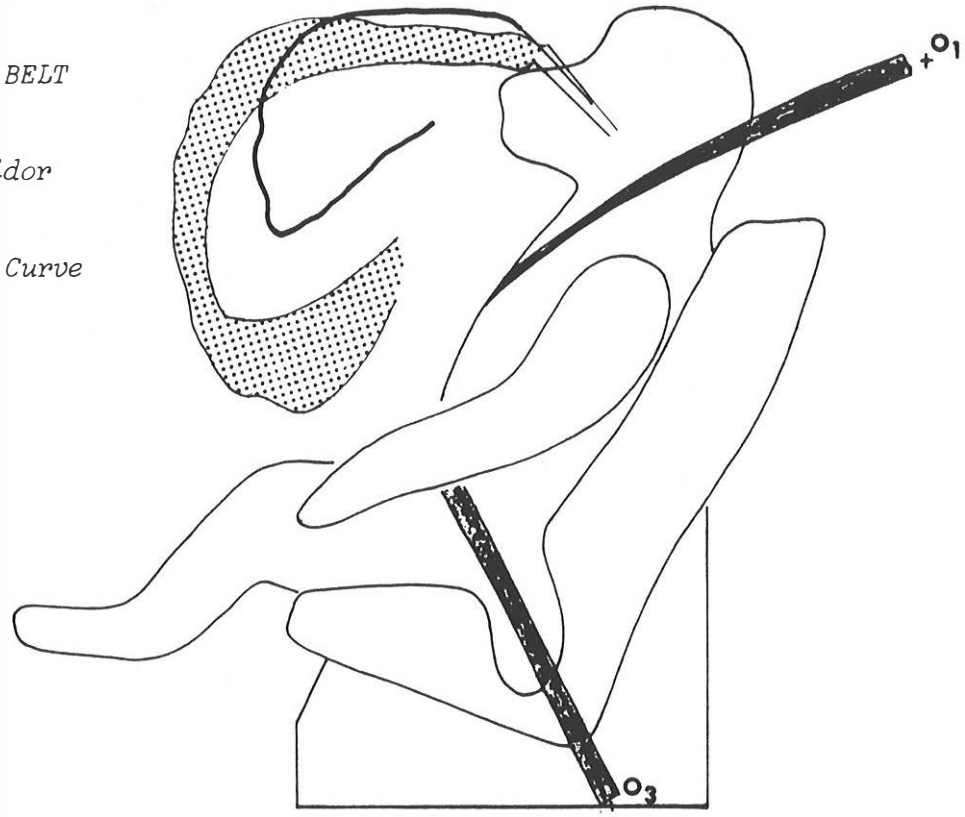
Fig.3 : Tests Results - Three Point Belt Restraint

BABOON·24

STATIC THREE POINT BELT

Curves Corridor

Dead Animal Curve



BABOON 16

Curves Corridor

Static Belt

Retractor Belt

Dead Animal static Belt

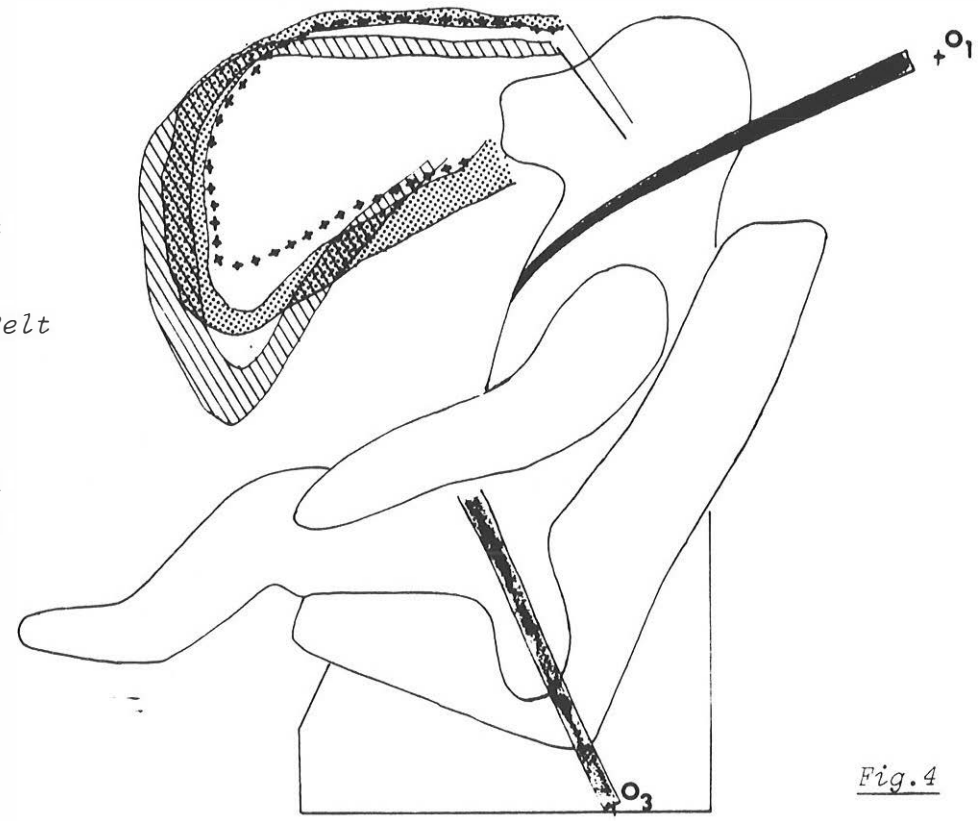


Fig.4

BABOON 16 - THREE POINT BELT AT 48 km/h

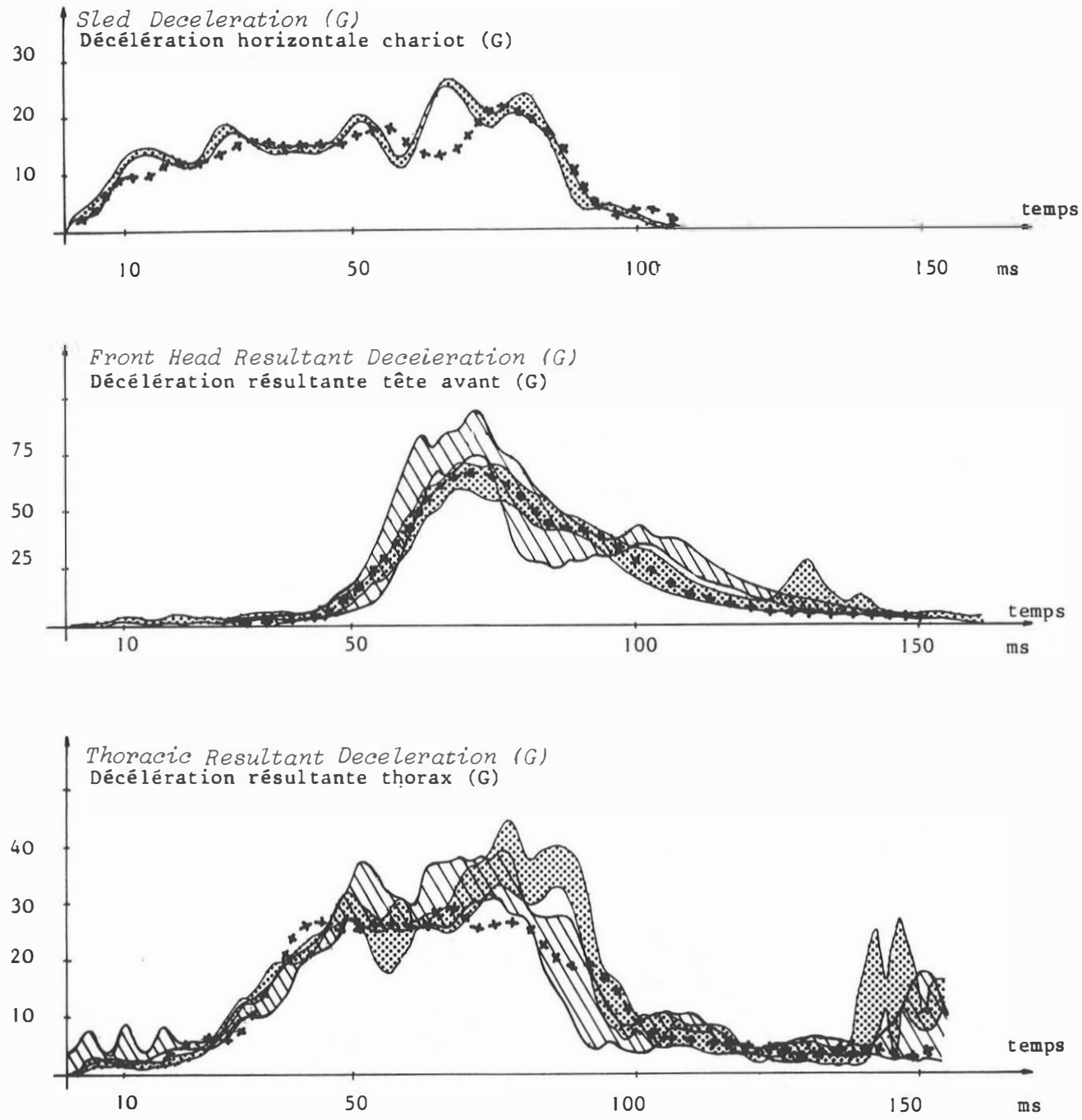


Fig.5 *Curves Corridor - Static Belt Tests (3 runs)*

Curves Corridor - Retractor Belt Tests (3 runs)

Dead Animal Curve - Static Belt Test

BABOON 24 - THREE POINT BELT AT 48 km/h

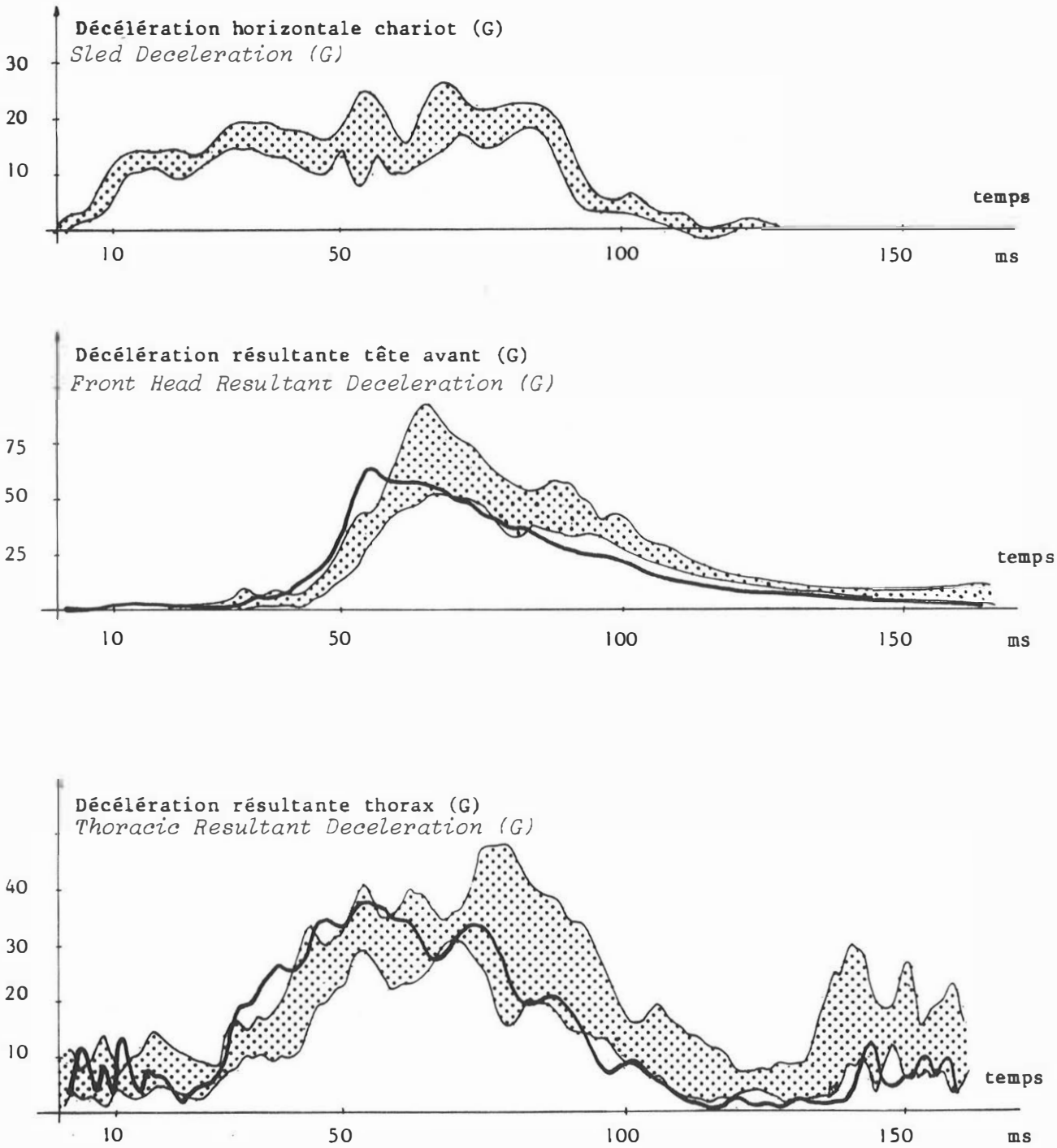


Fig.6 Curves Corridor - 5 Static Belt Tests

Dead Animal Curve - Static Belt Test

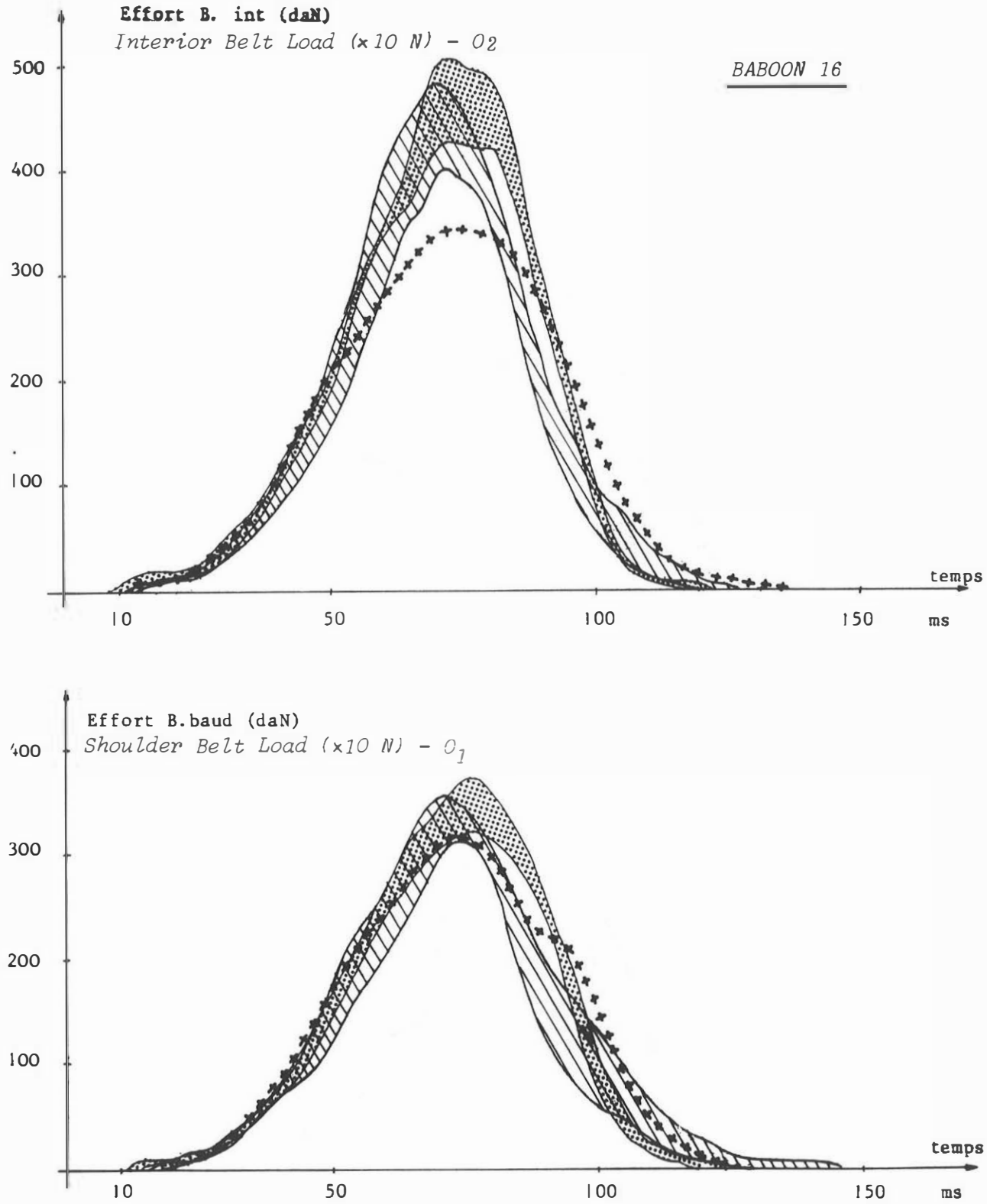


Fig.7 Curves Corridor - Static Belt Tests (3 runs)

Curves Corridor - Retractor Belt Tests (3 runs)

Dead Animal Curve - Static Belt Test

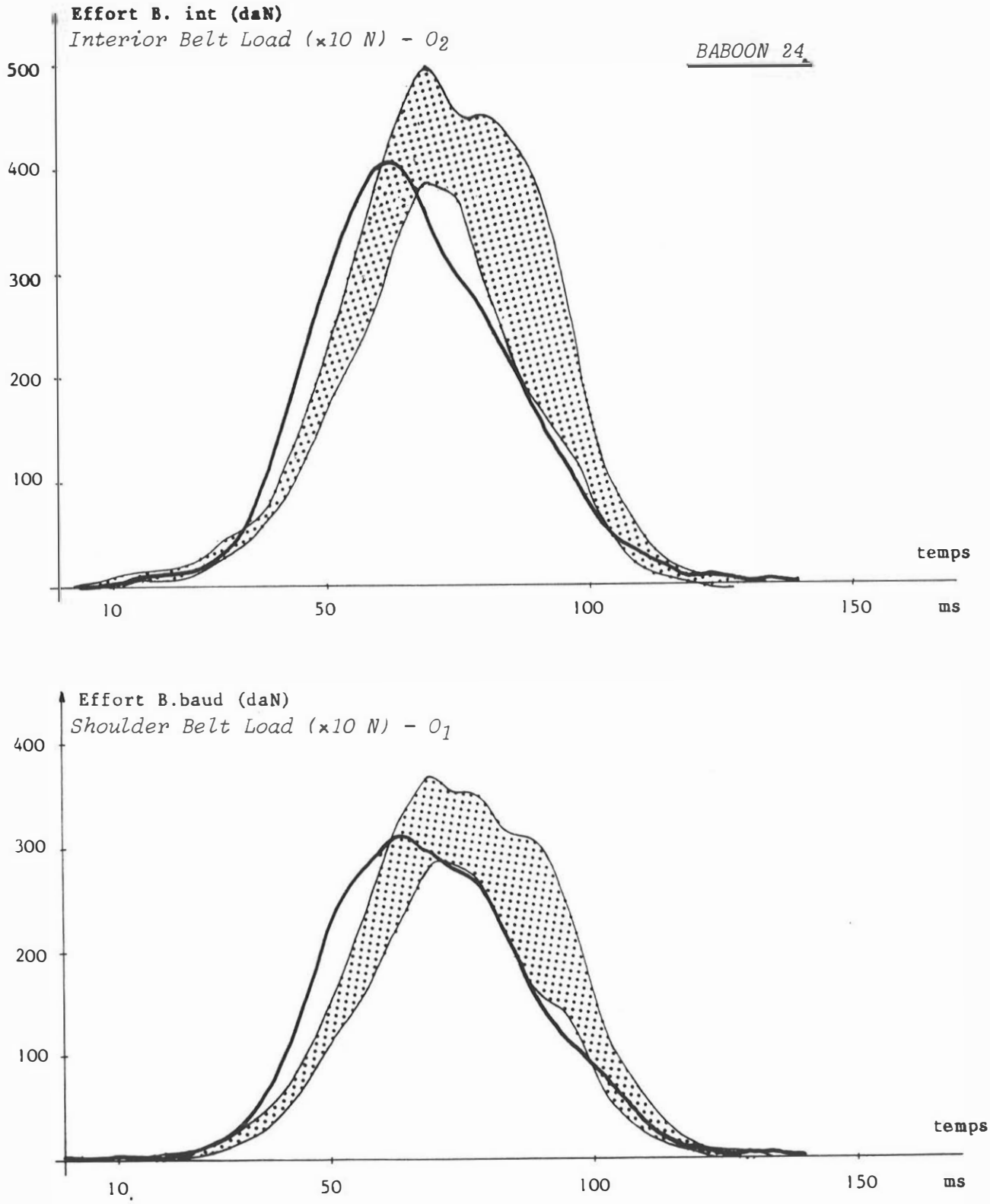


Fig.8 Curves Corridor - 5 Static Belt Tests

Dead Animal Curve - Static Belt Test