FINAL REPORT

INVESTIGATION OF RELATIONSHIPS BETWEEN PHYSICAL PARAMETERS AND NEURO-PHYSIOLOGICAL RESPONSE TO HEAD IMPACT

CONTRACT DTRS - 57 - 86 - C - 00037

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JUNE 1988

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I - INTRODUCTION

In order to obtain data about human head tolerance, the Laboratory of Physiology and Biomechanics has developed a specific methodology for volunteer boxers (9).

Boxers are used because they expose themselves, in their normal body activities, to direct head impacts similar in nature to those experienced by vehicle occupants under crash conditions.

By means of appropriate experimental techniques this study aims to find out :

- the severity of the blows sustained during a boxing fight, in terms of physical measurements at head,
- the corresponding physiological effects, in medical terms, which may appear on the boxers,
- the mathematical functions, defined and computed from the measurements, which give the best fit with physiological effects ranked on a convenient injury scale.

This final report describes the specific experimental techniques, the different steps of analysis and the results obtained during the five fights.

II - METHODOLOGICAL ASPECTS

II.1. GENERAL ASPECTS

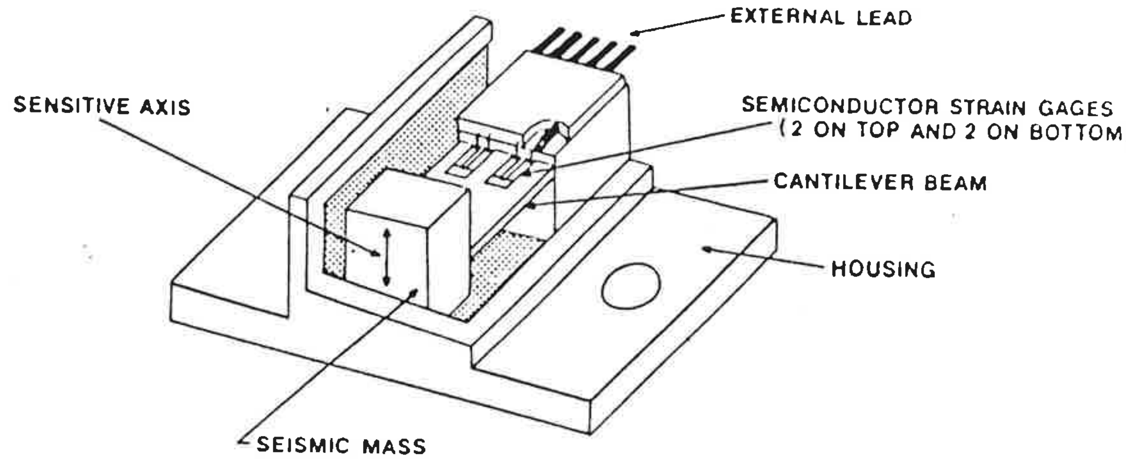
In this section, the transducers and the data acquisition system are described.

THE TRANSDUCERS :

Tridirectional accelerometers (type ENTRAN EGA 3D 500) were used. Their operating principle is the following :

ENTRAN accelerometers employ either a fully active or half active Wheatstone Bridge consisting of semiconductor strain gages. The strain gages are bonded to a simple cantilever beam which is end loaded with a mass (see figure 1). Under acceleration, a "g" force, the force on the cantilever is created by the g effect on the mass (F = mg). The accelerated mass creates a force which in turn provides a bending moment to the beam. This moment creates a strain (proportionnal to the acceleration) which results in a bridge unbalance. With an applied voltage, this unbalance produces a mV deviation at the bridge output, which is proportional to the acceleration vector.

The range of the accelerometric measures represents the recommended maximum peak 'g' level for a linear response.



© Entran's EGC-240 Accelerometer Cutaway

Figure 1.

DESCRIPTION OF THE DATA ACQUISITION SYSTEM

The data acquisition chain is built around two axes :

- a 14 track magnetic recorder, equipped with wide band heads,
- a PDP 1134 computer, used for preparation, controlling the recording, the transmission and processing of the data.

Recording

Along with the magnetic recorder, the following equipment makes up the recording part :

a) Four multiplexers :

- one is designated for the multiplexing of 12 binary functions giving these functions a high resolution in time (sampling at 64 KHz),
- each of the other multiplexers allows the recording on one track of 8 standard measurement tracks sampled at 8 KHz. These multiplexers allow recording of outputs of the 12 accelerometers.

b) A set of 6 removable multiplexers, carrying 48 channels, remote controllable conditioning amplifiers designed to feed and amplify the signals produced by the sensors. These sensors had to be given a small resistance representing their sensivity in order to automate the adjustment of the conditioning amplifier.

c) A coded timing clock which allows us to record, at the same time as the measurements, a signal allowing the location and re-reading of the time of each event to within 10 ms.

d) A commutator, with 128 inputs, which can connect any multiplexer input to an oscilloscope or a voltmeter, designed to check the adjustment of the conditioning amplifiers.

e) A control logic designed to automatically trigger the recorder at the moment of testing.

Re-reading

For the re-reading stage, we have :

a) 4 demultiplexers, one of which is specified for the high resolution in time binary functions. These demultiplexers have analogue outputs which are connected to matrices, enabling all the operations desirable on the original signals reformed here (recopying, re-reading, processing) ; their digital outputs are resynchronised to re-establish the order in which the data from the various recorder tracks should be and are then connected to the PDP 1134 inputs for processing.

b) A clock for decoding the recorded time and a device allowing us to create a signal marking the onset of the impact (corresponding to the start of processing).

c) A track selection device which can connect any demultiplexer to any recorder track. This allows us, through successive re-readings, to recognise and transmit all the informations recorded onto the tape with a reduced number of demultiplexers.

d) A remote control unit for the recorder which allows the magnetic tape to be controlled from the computer.

All the equipment described is manually and automatically adjustable independently of the PDP 1134 programs.

Data processing

The data processing equipment is completed by :

a) Two removable discs, each with a capacity of 5 million eight - bit bytes. These discs allow the storing of the programs and the data necessary for the processing of the on-site tests.

b) A high speed data link (1 megabit per second) linking the on-site computer to the computer center. This data link allows the data recorded during the test to be transmitted so that they can be processed at the computer center.

c) A terminal allowing dialogue with the computer.

d) A tektronix display terminal equipped with a reprographic device directly linked up to the PDP 1134 and via modems, to the computer center.

e) A benson plotting table for the graphic representation of the results.

Operating the system

a) Preparation of the test :

- setting up of a data block carrying all the information needed for the characterization of the test. The management of this data block is done locally on the Tektronix 4051 (creation, modification, edition, ...),
- installation of sensors, cabling, adjustment of those conditioning amplifiers which are not yet equipped with remote control devices,
- aid to the adjustment of the system thanks to a program stored on the PDP 1134 working from the data in the data block,
- checking the working and adjustment of the system before recording starts.

b) Recording :

- Recording onto magnetic tape of the zeros and the calibration marks for the various parameters under the control of the computer,
- recording of the service signals and the parameters during impact. The test is then recorded at a tape speed of 60 IPS which gives each measurement channel a band width of 2 KHz which is necessary for the parameters measured.

c) Transfer :

After the test, the more interesting blows are selected with respect to the acceleration level, the chain is put under the control of the computer for the re-reading of the interesting blows and the transfer of the data. The program then controls the magnetic tape, connects the tracks to the demultiplexers, carries out the re-reading of the tape at a speed of 3 3/4 IPS and stores the data necessary for the processing of the data onto a disc. To each blow corresponds a maximum number of 12 acceleration measurement channels. The blows are selected by reading the channels on tape using an oscilloscope. Then, the magnitude of each of the 12 channels is noted. In order to obtain interesting blows, in terms of violence, it was decided to take into account only the blows where at least one acceleration channel has a magnitude greater or equal to 70 g.

II.2. SPECIFIC ASPECTS

Development and construction of a particular headgear fitted to each volunter

In order to calculate linear and angular accelerations at the head center of gravity on the basis of peripheral acceleration measurements and to do so with the greatest accuracy, it is necessary that the transducers used should be as solidly fixed to the head as possible... This problem had always appeared to be one of the major difficulties inherent in this experimental method. In order to achieve this result, a helmet that covered the occipital part of each boxer head was built. Figure 2 shows one of these helmets. They are made of polyester fibres ; their internal shape was obtained by moulding the occipital part of the head of each of the boxers to whom the helmet would be fitted.

As figure 2 shows, the supports of each accelerometer are sunk into the outer part of the helmet and are linked one to another by light alloy plates which allow a considerable increase in stiffness. The indispensable orthogonality between the right lines linking the center of each transducer to the center of that one located at the top of the trihedral was achieved by means of an appropriate device as shown in figure 3. The total weight of a helmet with its 4 supports and 4 transducers is about 450 grams. In addition, the considerable contact surface between the helmets and the boxer's heads makes possible, in the unlikely event of a direct blow or fall upon the instrumentation, the transfer of forces to the head over a surface large enough to avoid all risk of injury even minor. This has been demonstrated by a test.

In order to increase the degree to which the helmet snugly fits the head and to flatten the boxers hair, a bathing cap stretched tightly over the head is placed under the helmet. To keep these various items in position, and in addition to the straps, adhesive textile strips, 2 centimeters wide, were used over the helmet as can be seen in figure 4.

The head acceleration transducer cables are brought together at the back of the boxer between his shoulder blades. They are held in position there with sufficient slack to allow all head movements. A harness is used for this. From the boxer's back, the cables are brought together in the form of a strand, risen to about four meters above the boxing ring where they are gripped by an operator who has the task of guiding them in accordance with the way in which the fight develops. The operator is positioned in a gantry above the ring.

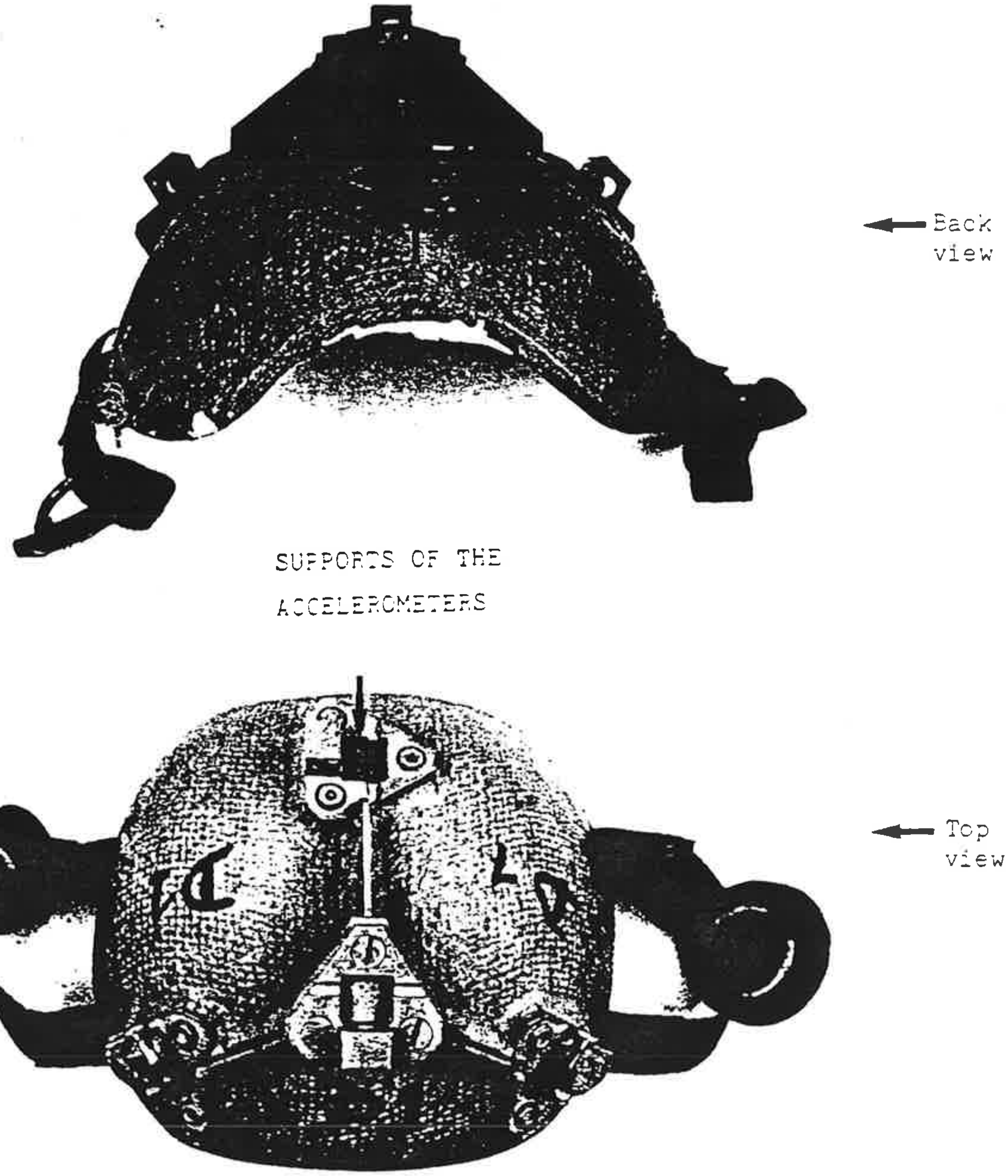


Figure 2. Boxer's headgear

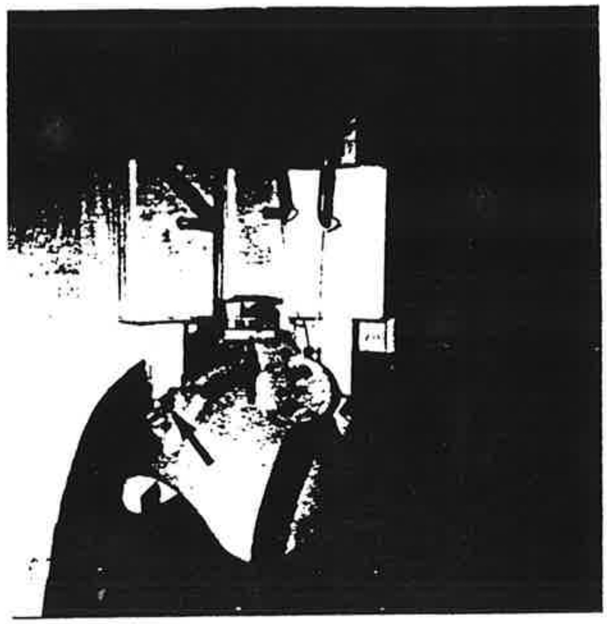


Figure 3. Device used for obtaining the orthogonality of the axes linking the center of the lateral transducers to the center of the 4th one with W.S.U. mounting

Figure 4. Headgear : Attaching devices on the head

Development and construction of a hand device

An appropriate device, made of stiff resin shown in figure 5 has been made so as to instrument the hands of boxers and to obtain an assessment of the violence of the blows administered by them. Its anterior section rests upon the third finger of the four fingers administering the blows. The central part of this has been designed so that a tri-directional accelerometer can be fitted into it. The fact that this device presses upon all four fingers simultaneously makes it possible to limit the pressures transferred and so to avoid all risk of injury to this part of the boxer's body also.

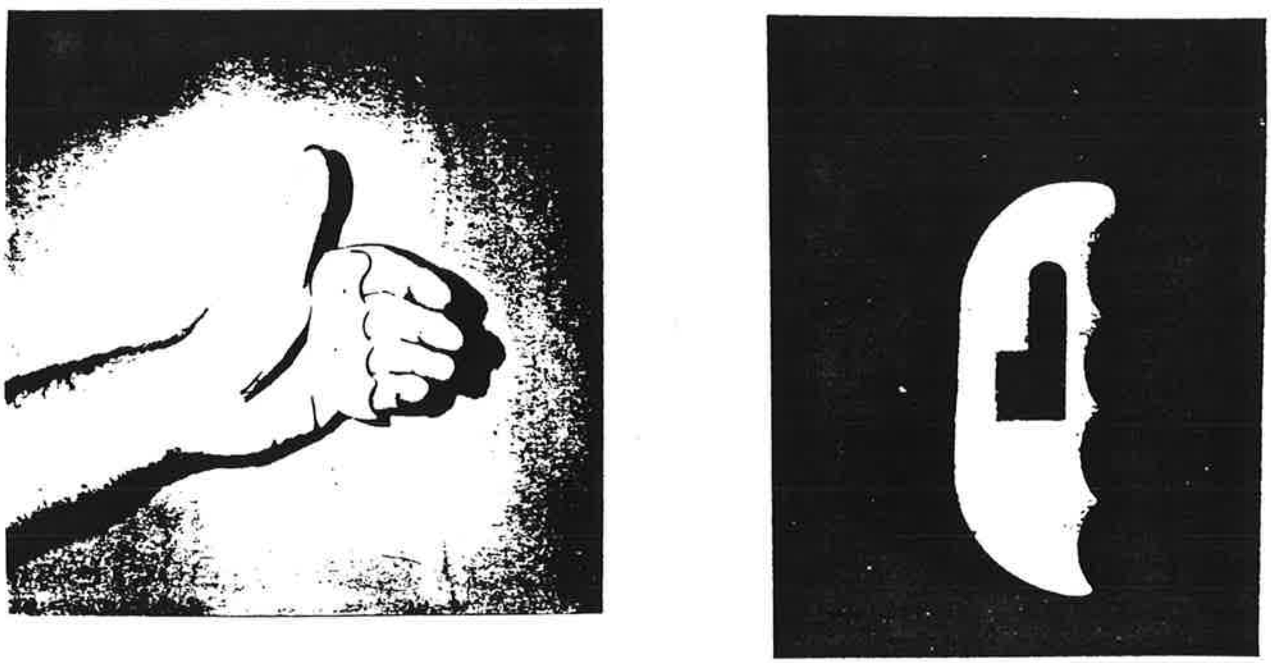


Figure 5. Hand device

The device is kept very tightly fitted on the upper part of the metacarpals using a stiff textile tissue. Tests have been performed (blows on a load cell) to try to determine the transfer function between measured acceleration and administrated force. The cables of transducers to instrument the hand are linked to the recording channels in the same way as those that are fitted to the head.

Filming procedure

Each fight is recorded on video at 25 frames/second to have a report of all the fight in real time.

For the technical approach, we used two kinds of cinematographical recordings :

- high speed cameras with 120 m magazines,
- high speed video systems.

We were interested by the video system because this system allowed a greater filming velocity than the classic cameras. The SPIN PHYSICS system had the capacity of recording 4 minutes at 500 frames/second, the high speed cameras have only 80 frames/second. So for the first fight we had a SPIN PHYSICS SYSTEM with a professional cameraman. In view of the very interesting results and help that this system brought us, during analysis of the fight, we decided to keep the same system with two cameras during analysis of the fight.

For the following fights, we could have a second such system but as it was in period of acceptance test it had some problems, particularly with the time base. It allowed filming of a large view. The respective positions of the cameras are described for the first fight on figure 6 and table 1 and for the four other fights in figure 7 and table 2.

The synchronizing of the cameras was of two kinds :

- by means of a pulse generator, giving impulses every 10 seconds on the synchronizing channel of the measurements tape in parallel with the base time of 0.100 second for the framing cameras, on one hand,

- on the other hand by an electronic flash in a corner of the ring synchronised with the previous pips, this flash was seen from all the cameras.
  As we did our best to get as high filming velocity as possible, we used cameras with larger magazines (120 meters instead of 30 meters). They allowed filming at a velocity of 80 frames per second, but it was impossible to make modifications to the electronics of these cameras and so we were not able to use IRIG code.

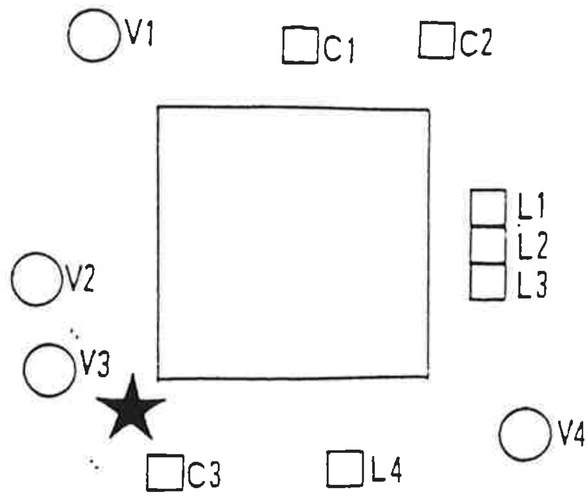


Figure 6. Cameras positions

Table 1. CAMERAS LOCATIONS
FIRST FIGHT

Camera Number	Type	Velocity frames/ second	Round	Remarks
V1	Video HSV 2000 Color	200	1-2-3	VHS - NTSC*
V2	Video HSV 200 Black/White	200	1-2-3	VHS - NTSC* gracious demons-tration by the constructor
V3	SPIN PHYSICS 2000 B/W	500	1-2-3	Close-up view
V4	VIDEO SONY	25	1-2-3	Report
C1	CAMERA "ECLAIR"	40	2	
C2	"	40	1-3	
C3	"	32	1-2	
L4	CAMERA "LOCAM"	80	3	
L1	"	80	1	
L2	"	80	2	
L3	"	80	3	

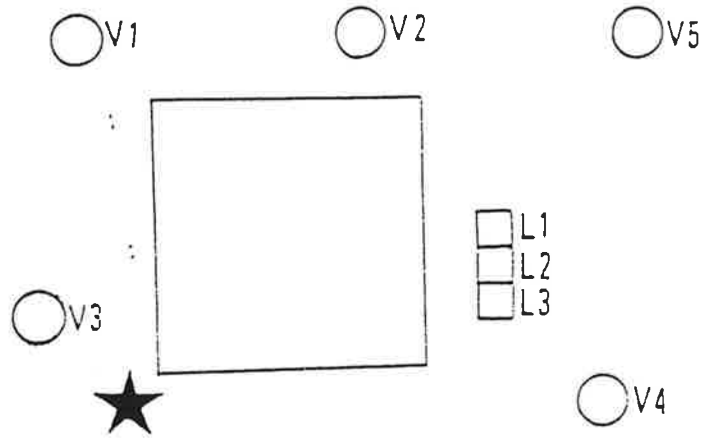


Figure 7. Cameras positions

Table 2. Cameras locations
FOUR LAST FIGHTS

Camera Number	Type	Velocity frames/ second	Round	Remarks
V1	Video Sony	25	1-2-3	Report
V2	Spin Physics 2000	500	1-2-3	) 2 views on the) same system)
V3	"	500	1-2-3	) close-up view
V4	"	500	1-2-3	) 2 views on the) same system but
V5	"	500	1-2-3	) no time base
L1	Camera "Locam"	80	1	) equipped with
L2			2	) 120 m magazines
L3			3	

III - COMPUTATION OF HEAD KINEMATICS

Different methods can be used in order to calculate the kinematics of the head (assumed to be undeformable solid) from measurements of accelerations at different points.

We used in particular :

- The 3-3-3 method, as developed by N. Alem (1) which uses 3 tri-axial transducers. The excessive number of measurement channels (9 instead of the 6 necessary and theoretically sufficient) allows, by means of a least square method, a reduction of the influence of unavoidable measurement errors.

- The Wayne State University method (2) which uses 9 sensitive axes of accelerometers, so that the terms which contain components of the angular velocity can be eliminated form the system of equations. Angular accelerations are then directly obtained from the measurements, and angular velocity becomes the integral of angular acceleration.

We used the two methods for the first blow and then only one, the second one for all the other as the results obtained for the first blow with the two methods were quite identical.

III.1. PREPARATION OF DATA FOR 9 GAMMA PROCESSING (PREP 9G)

We'll explain the preparation of data which is necessary for the computation of head kinematics.

It is a conversational programme written in Fortran IV plus, from Digital. It allows in particular to calculate the orientation matrices of triaxial transducers in relation to an anatomical coordinate system based either on Euler angles or angles which we call "projected angles".

This programme also requires the order of channels on the tape of accelerations data ; the sign of each channel (+ or -) by comparison with the reference direction ; the initial conditions of position and speed -linear and angular- the coordinates of the point at which linear acceleration and HIC are calculated, the wanted outputs....

III.2. 9 GAMMA PROCESSING PROGRAM G9 2011

G 9 2011 (9 Gamma Processing Programme, accepting up to 2000 samples per channel, 11th version) is written in Fortran IV.

This programme reads one by one all the useful acceleration channels on the tape (6 to 9 channels) and stores them as tables in the RAM memory.

This programme can :

- draw "raw data" (as a trace per transducer, including from one to three channels),
- calculate and draw the resultants of raw accelerations measured by triaxial transducers,
- calculate on the basis of each one of these resultants, the severity index (HIC or SI) "on transducers" and inscribe their value on the graphical outputs (these index only provide approximate values).

This programme can also -although this is no longer necessary for the calculation of linear acceleration at the centre of gravity- calculate and trace the three components of acceleration in each of the triaxial accelerometers according to the axes of the anatomical coordinate (by pre-multiplication of the measured acceleration vector by the inverse matrix of the matrix made up of the directional cosines of the three transducer axes).

After the foregoing, the central part of the processing -and the most delicate- is performed : integration of the differential equations linking :

(1) the components of the linear acceleration of an arbitrarily selected reference point,

(2) those of the angular acceleration and of the angular speed of the head, considered to be a solid,

(3) the coordinates of the centres of sensitivity of the transducers and the directional cosines of these channels,

(4) the accelerometric measurements.

The maximum values, and those exceeded by less than 3 ms, of the components and of the resultant of the angular speed and of the angular acceleration are calculated and printed out. The components of angular speed and acceleration can be drawn.

Then, in order to give the user the possibility of checking the reliability of the result, the calculation of acceleration at the centre of gravity is performed successively by adding to linear acceleration directly measured by the transducers the terms corresponding to angular acceleration and speed. If the data are perfect the curves obtained, drawn on the same graph should allow to be superimposed one into the other perfectly. The data are, of course, never perfect but the variation should remain small so that one may consider that the measurements are correct and that the final result is sufficiently reliable.

Then, the components and the resultant of the final effective linear acceleration at the centre of gravity are drawn, calculated by giving equal weight to all channels. The severity indicators (Amax, A3 ms) on each one of the components and on the resultant, SI, HIC and optionally the duration during which a given level of acceleration is exceeded) that can be calculated on the resultants on the transducers can of course be calculated at the centre of gravity.

Processing can then be terminated but one can also obtain, after this, calculation of the kinematics in relation to the ground. The stages of this calculation are : calculation of the Euler angles by integration of differential equations ; calculation of angular speed and acceleration and of linear acceleration at the laboratory coordinate system.

- Integration of linear acceleration at the laboratory coordinate system by a simple trapezoidal method, so as to obtain linear speed at the ground and integration of the parabolic arcs of the linear speed at the ground to obtain the trajectory.
  All these functions can of course be drawn.
  Finally a simplified visualisation of head kinematics represented by a three-dimensional rectangle set, seen from the three ground coordinate axes, is proposed.

III.3. <u>OPT 3D</u> (three dimensional calculation of positions)

The position of the helmet and the transducers in relation to anatomical characteristics (Frankfort plane) are given by photographs taken before the fight. The programme OPT 3D allows to do a three-dimensional calculation of positions, in translation and rotation of transducers and of the anatomical coordinates related to the head of the subject.

Figure 8 shows a boxer wearing his helmet. The equipment enabling determination of the position of the Frankfort plane is visible, as well as the struts and their supports which are replaced by triaxial accelerometers during the fights.

Table 3 gives the positions of the transducers for each fight

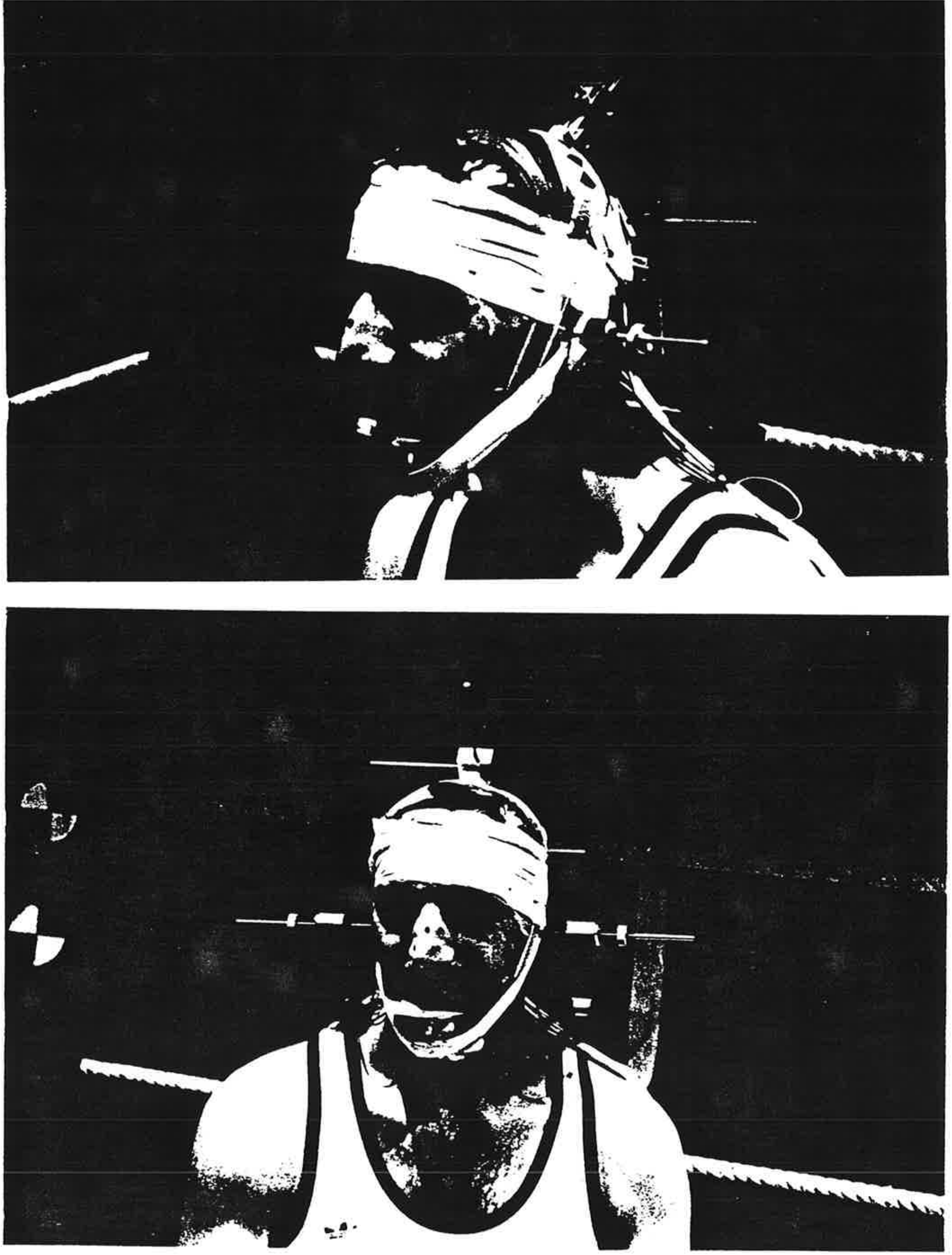


Figure 8

Table 3. Three dimensional positions of the transducers related to the head

TRANSDUCER			1st FIGHT	2nd FIGHT	3rd FIGHT	4th FIGHT	5th FIGHT
FRONTAL	COORDINATES (mm)	X	- 84.5	- 93.1	- 27.4	- 94.8	- 62.9
		Y	- 34.3	- 31.5	- 17.9	- 21.8	- 32.5
		Z	138.5	171.9	176.1	136.9	157.5
	EULER ANGLES (degrees)	Z	- 171.14	179.52	- 164.11	- 176.98	- 175.18
		X	- 40.43	- 46.77	- 70.25	- 38.57	- 61.95
		Y	- 90.46	- 91.08	- 107.91	- 81.36	- 93.67
RIGHT	COORDINATES (mm)	X	- 84.9	- 114.5	- 87.1	- 90.9	- 106.5
		Y	- 92.3	- 87.7	- 66.1	- 91.4	- 88.9
		Z	38.2	72.8	89.1	44.2	66.1
	EULER ANGLES (degrees)	Z	- 140.71	- 151.12	- 148.85	- 139.38	- 148.07
		X	12.54	7.26	- 11.03	10.15	- 5.42
		Y	151.70	148.09	131.16	158.69	139.59
LEFT	COORDINATES (mm)	X	- 102.2	- 111.9	- 85.0	- 107.7	- 109.78
		Y	22.4	28.2	49.3	22.5	26.9
		Z	38.9	74.3	101.2	30.5	69.6
	EULER ANGLES (degrees)	Z	- 22.29	- 31.59	- 30.63	- 20.93	- 28.44
		X	- 12.18	- 6.51	17.17	- 17.07	7.14
		Y	152.31	149.38	141.71	146.77	142.60
TOP	COORDINATES (mm)	X	- 137.1	- 152.9	- 104.9	- 144.56	- 135.3
		Y	- 41.8	- 29.4	- 13.7	- 36.82	- 33.3
		Z	76.1	115.8	149.7	73.49	119.0
	EULER ANGLES (degrees)	Z	- 171.41	178.88	- 176.74	- 171.99	- 117.55
		X	- 5.16	- 11.51	- 35.65	- 3.59	- 26.72
		Y	- 0.35	- 0.76	- 7.35	6.76	- 1.94

IV - RESULTS

IV.1. DESCRIPTION OF THE FIGHTS AND THE BOXERS

Each fight was organized between one boxer with the head instrumented and one boxer with the hands instrumented. The arbitrator was chosen by the "Fédération Française de Boxe" to ensure the good conduct of the fights and to be the "guarantee".

Each fight consisted of three rounds lasting three minutes, except the first fight for which the last round was stopped after two minutes and twelve seconds. The arbitrator had to stop the fight because the instrumented boxer was bleeding at the nose and began to show signs of wear, due to the difficulty of breathing, because of the helmet strapping.

The principal characteristics of the boxers, with the dates at which the fights were performed, are given in table 4.

IV.2. MEASURED RESULTS

After the fights, the selection of the blows is made with respect to the acceleration levels by reading the channels on tape using an oscilloscope. In order to retain only interesting blows, in terms of violence, we decided to take into account the blows where at least one acceleration channel had a magnitude greater or equal to 70 g.

Data files were created, including, for a given blow :

- the 12 accelerometric channels of the head of the first boxer,
- the 3 accelerometric channels of the hands of the second boxer.

We selected some a priori interesting blows for the different fights :

Fight Number	Number of selected blows	Number of validated blows
1	10	11
2	11	7
3	22	13
4	12	6
5	22	9

Table 4. Physical characteristics of the boxers

		1 4th March	2 23rd June	3 24th June	4 25th June	5 26th June
Head instrumented boxer	Age (years)	27	24	27	27	26
	Weight (kg)	83	96	80	78	76
	Size (m)	1.83	1.80	1.90	1.92	1.80
Other	Age (years)	19	27	27	26	27
	Weight (kg)	86	80	78	76	78
	Size (m)	1.95	1.90	1.92	1.80	1.92

A blow is eliminated if we see on the video tape that it is given on the helmet and (or) if the results of the calculation present some incoherence.

The measured data, the linear resultant acceleration at the level of each transducer are presented in tables 5 to 9 for each fight (see figure 10 for orientation of each acceleration).

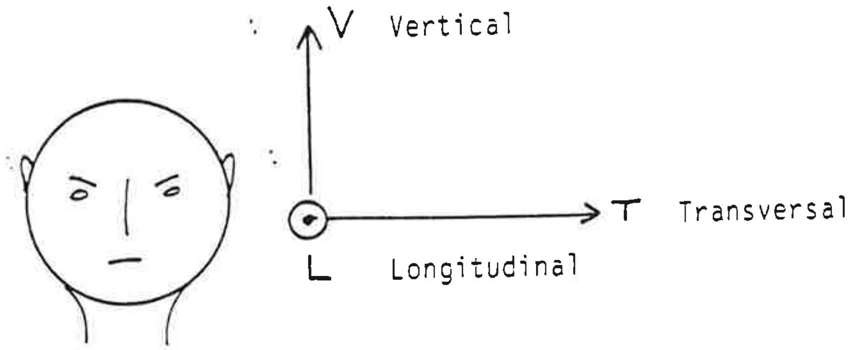


Figure 9.

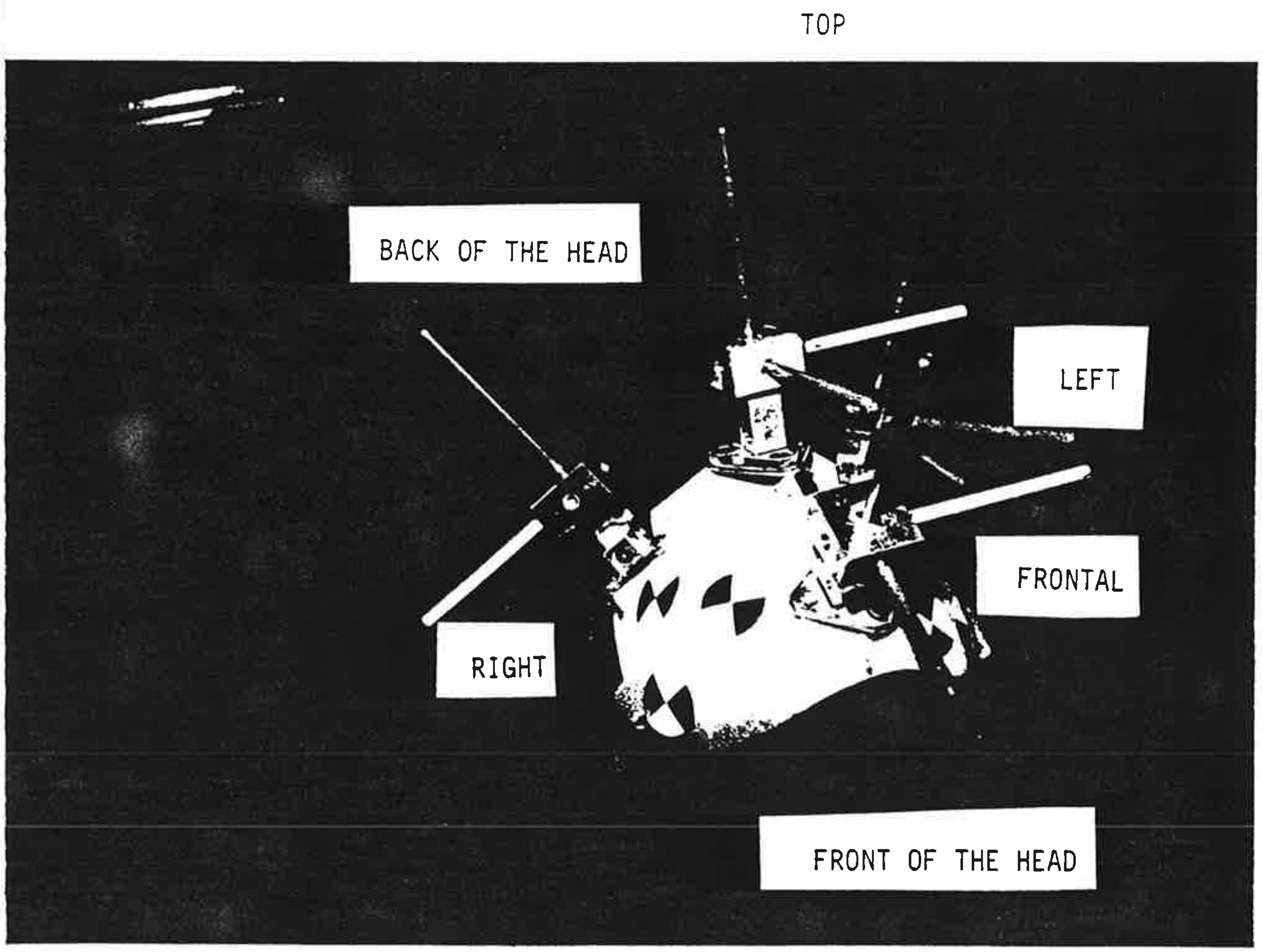


Figure 10. Orientation and localization of the accelerometers on the headgear

TABLE 5.

FIRST FIGHT - MEASURED RESULTANT ACCELERATIONS (G) PER TRANSDUCER FOR VALIDATED BLOWS

BLOW NB	FRONTAL	RIGHT	LEFT	TOP
B 51	32	40	29	72
B 52	39	29	19	20
B 53	38	30	39	46
B 54	129	15	43	142
B 55	56	40	66	62
B 56	89	33	87	104
B 58	129	26	38	92
B 59	52	37	112	109
B 510	68	13	48	92
B 511	66	47	31	102

Table 6.

SECOND FIGHT - MEASURED RESULTANT ACCELERATIONS PER TRANSDUCER
FOR VALIDATED BLOWS

BLOW NB	FRONTAL	RIGHT	LEFT	TOP
601	46	88	47	95
602	23	28	27	33
603	80	57	51	81
604	63	29	26	78
606	68	33	62	79
610	38	42	42	60
611	30	45	39	51

TABLE 7.

THIRD FIGHT : MEASURED RESULTANT ACCELERATIONS PER TRANSDUCER (G) FOR VALIDATED BLOWS

BLOW NB	FRONTAL	RIGHT	LEFT	TOP
702	69	147	86	197
703	74	52	80	80
704	32	97	51	97
705	123	25	47	65
706	36	29	41	52
707	58	32	63	90
708	115	35		60
709	18	21	66	53
710	32	37	57	75
712	27	21	21	32
713	22	38	56	62
719	57	54	32	81
722	96	111	61	181

TABLE 8.

FOURTH FIGHT - MEASURED RESULTANT ACCELERATIONS PER TRANSDUCER FOR VALIDATED BLOWS

BLOW NB	FRONTAL	RIGHT	LEFT	TOP
801	31	78	75	78
803	28	59	40	69
805	62	58	83	82
807	67	105	90	135
808	52	23	33	71
812	61	46	59	69

TABLE 9.

FIFTH FIGHT - MEASURED RESULTANT ACCELERATIONS

PER TRANSDUCER FOR VALIDATED BLOWS

BLOW NB	FRONTAL	RIGHT	LEFT	TOP
903	59	62	85	69
904	23	74	41	62
907	60	33	76	43
908	76	73	87	120
910	47	23	65	65
915	43	90	73	90
917	70	76	58	121
918	38	27	85	68
919	50	44	82	98

IV.3. VIDEO ANALYSIS

We then analysed the different views of the films, especially on the video SPIN PHYSICS system, in relation with the time base, in order to reject blows which could have occured on the helmet on one hand, and on the other hand to characterize the blows in term of the direction of the blow (right or left), the movement described by the head, the localization on the head (temporal...).

Figure 11 shows the the different kinds of head rotations.

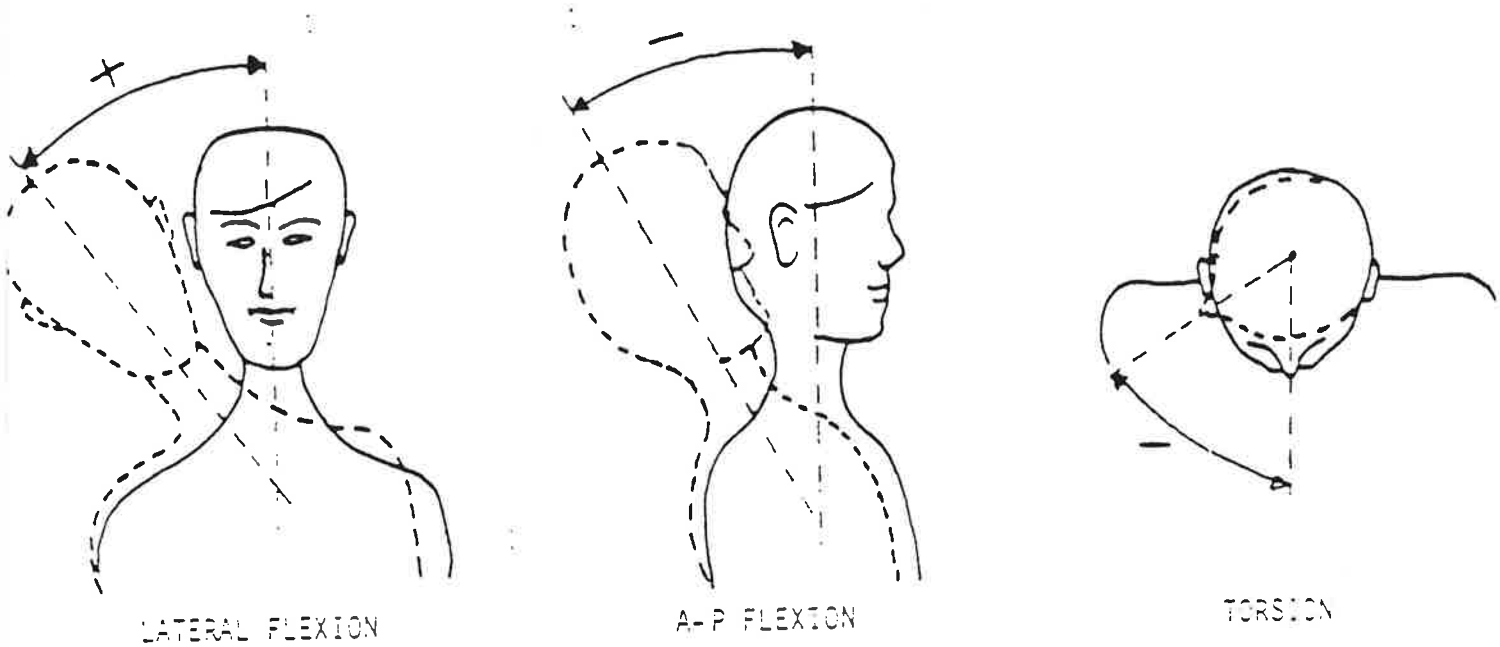


Figure 11. Definition of head rotation with corresponding signs

Tables 10 to 14 give a description of each blow for each fight.

The video analysis autorized us to classify the 47 validated blows on :

30 blows on the LEFT SIDE
associated with a right flexion and (or) a torsion movement

7 blows on the RIGHT SIDE
associated with a left flexion and (or) a torsion movement

11 other blows associated with Antero-Posterior flexion

TABLE 10. FIRST FIGHT : VIDEO ANALYSIS
(Validated blows are indicated by *)

Blow Reference number	Round	Type of blow	Head area involved	Movement of the head
* B 51	1	Right Hook	Left checkbone	Right torsion (-)
* B 52	1	Right Hook	Left temple	Right torsion (-) and small right lateral flexion (+)
* B 53	1	Straight Right	Left checkbone	Right torsion (-)
* B 54	1	Right Upper	Chin	A-P Flexion
* B 55	1	Right Hook	Left temple	Right torsion (-) and small right lateral flexion (+)
* B 56	2	Right Hook	Left fronto-temporal	A-P Flexion (-) and right lateral flexion (+)
B 57	2	Right Hook	Occipital	Impact on the helmet
* B 58	2	Right Hook	Left temporal	Left torsion (+) and right lateral flexion (+)
* B 59	2	Right Hook	Right fronto-temporal	A-P Flexion (-) and left flexion (+)
* B 510	3	Right Hook	Left parietal	Left torsion
* B 511	3	Right Hook	Left ear	Right lateral flexion (+)

TABLE 11. SECOND FIGHT - VIDEO ANALYSIS
(Validated blows are indicated by *)

Blow Reference number	Round	Type of blow	Head area involved	Movement of the head
* 601	1			
* 602	1	Left Hook	Right temporal	Torsion (+)
* 603	1	Right Hook	Left ear	Lateral flexion (+) and small torsion (-)
* 604	1	Right Hook	Left ear	Lateral flexion
605	2	Right Hook	Left parietal	Lateral flexion and small torsion (+) (blow on the helmet)
* 606	2	Right Hook	Left part of the occipital	Small torsion (+)
607	3	Right Hook	Left ear	Lateral flexion (blow on the helmet)
608	3	Right Hook	Left part of the occipital	Torsion (+) and small lateral flexion (+) (blow on the helmet (blow on the helmet)
609	3	Right Hook	Left ear	Lateral flexion (blow on the helmet)
*610	3	Right uppercut	Chin	A-P Flexion (-) and torsion (+)
* 611	3	Right uppercut	Left ear	Small lateral flexion (+)

TABLE 12. THIRD FIGHT : VIDEO ANALYSIS
(Validated blows are indicated by *)

Blow Reference Number	Round	Type of blow	Head area involved	Observations - Movement of the head
701	1	Straight left	Frontal	A-P flexion (-) (blow on the helmet)
*702	1	Straight left	Right temporal	Lateral flexion (-)
*703	1	Right Hook	Left temporal	Lateral flexion (+)
*704	1	Straight left	Left temporal	Torsion (-) and small A-P flexion (-)
*705	1	Straight left	Left temporal	A-P flexion (-)
*706	1	Straight left	Temporal	A-P flexion (-)
*707	1	Right Hook	Left temporal	Lateral flexion (+)
*708	1	Right Hook	Left checkbone	Torsion (-)
*709	1	Straight left	Frontal	A-P flexion (-) and small torsion (+)
*710	2	Straight left	Left part of the frontal	A-P flexion (-) and lateral flexion (+)
711	2	Right Hook	Top of the head	Direct impact on the helmet
*712	2	Left Hook	Right part of the bottom jaw	Torsion (+) and lateral flexion (-)
*713	2	Right Hook	Left temporal	Lateral flexion (+)
714	3	Right Hook	Top of the head	Direct impact on the helmet
715	3	Left Hook	Right ear	Lateral flexion (-) + impact on the helmet
716	3	Right Hook	Left temporal	Torsion (-) and small lateral flexion (+) + impact on the helmet
717	3	Right Hook	Left ear	Torsion (-) and small lateral flexion (+) + impact on the helmet
718	3	Right Hook	Left ear	Lateral flexion (+) and A-P flexion + impact on the helmet
*719	3	Right Hook	Left ear	Lateral flexion (+)
720	3	Right Hook	Left ear	No movement of the head - impact on the helmet
721	3	Left Hook	Right ear	Lateral flexion (-) - impact on the helmet
*722	3	Right Hook	Left parietal	Small torsion (-), small lateral flexion (+) and small A-P flexion (+)

TABLE 13. FOURTH FIGHT - VIDEO ANALYSIS
(Validated blows are indicated by *)

Blow Reference number	Round	Type of blow	Head area involved	Movement of the head
* 801	1	Left Hook	Right ear	Lateral flexion (-), torsion (-)
802	1	Right Hook	Left ear	Lateral flexion (+), (blow on the helmet)
* 803	1	Right Hook	Left parietal	Torsion (+), lateral flexion (-)
804	2	Right Hook	Left parietal	Torsion (+) (blow on the helmet)
* 805	2	Right Hook	Left ear	Lateral flexion (+)
806	2	Left Hook	Occipital	Torsion (-), A-P Flexion (+) (blow on the helmet)
* 807	3	Left Hook	Right ear	Torsion (-) lateral flexion (-), and A-P flexion (+)
* 808	3	Right Hook	Left ear	Lateral flexion (+)
809	3	Right Hook	Left part of the occipital	Torsion (+), A-P flexion (+) (blow on the helmet)
810	3	Left Hook	Right ear	Torsion, lateral flexion (-) (blow on the helmet)
811	3	Right Hook	Top of the head	Direct impact on the helmet
* 812	3	Right Hook	Left parietal	Lateral flexion (+)

TABLE 14. FIFTH FIGHT : VIDEO ANALYSIS
(Validated blows are indicated by *)

Blow Reference Number	Round	Type of blow	Head area involved	Observations - Movement of the head
*901	1	Right Hook	Top of the head	Direct impact on the helmet
902	1	Right Hook	Top of the head	Direct impact on the helmet
*903	1	Right Hook	Left ear	Small torsion (-)
*904	1	Straight left	Frontal	A-P flexion (-)
905	1	Left Hook	Top of the head	Direct impact on the helmet
906	1	Left Hook	Top of the head	Direct impact on the helmet
*907	1	Right Hook	Left temporal	Lateral flexion (+), and torsion (-)
*908	1	Right Hook	Left part of the occipital	A-P flexion (+) and lateral flexion (+)
909	1	Left Hook	Top of the head	Direct impact on the helmet
*910	2	Right Hook	Left parietal	Lateral flexion (+)
911	2	Straight left	Top of the head	Direct impact on the helmet
912	2	Left Hook	Top of the head	Direct impact on the helmet
913	3	Left Hook	Top of the head	Direct impact on the helmet
914	3	Straight left	Top of the head	Direct impact on the helmet
*915	3	Left Hook	Occipital	A-P flexion (+)
916	3	Straight left	Top of the head	Direct impact on the helmet
*917	3	Left Hook	Left part of the occipital	A-P flexion (+) and torsion (+)
*918	3	Left Hook	Left parietal	Lateral flexion (+)
*919	3	RIght Hook	Occipital	A-P flexion (+) and torsion (+)

IV.4. RESULTS OF CALCULATION

From the measured data, given in the tables 15 to 19, the resultant linear accelerations, HIC values, angular accelerations and velocities were determined at the centre of gravity of the head.

The HIC values range from 5 to 348 and the maximum linear accelerations range from 20 g (B57) to 159 g (705).

The maximum peak values of the angular acceleration as well as angular velocity are of a high level 16234 rd/s^2 (722) and 48 rd/s (702) respectively. These levels can be explained by the type of kinematics observed, which consists of larger angular displacements in comparison with the linear ones. Figure 12 shows maximum angular acceleration versus maximum angular velocity. Almost all the blows correspond to angular accelerations higher than 4000 rd/s^2. Figure 13 gives the 3 ms angular accelerations and velocities. These tables also display the ratio $\frac{a\ 3\ ms}{a\ max}$ in percent, which give an indication on the duration of the blow. For instance ratios of an order of magnitude of 30 % correspond to very brief duration of blows when a ratio of 80 % will correspond to blows of higher duration. This is illustrated on figure 14. The most brief blows produce highest peak linear accelerations whereas less brief blow produce a lesser head acceleration.

Among the 47 blows retained, we have chosen some cases -which seemed to be the more interesting- and for each the following curves are given :

- the raw data per transducer :
  (the curve not used by the calculation don't appear)
    - Left transducer
    - Right transducer
    - Top transducer
    - Frontal transducer
- the components of the linear acceleration at the center of gravity of the head,
- the resultant acceleration at the center of gravity,
- the angular acceleration and angular velocity of the head in the laboratory coordinate system,
- the head kinematics which are represented by a set of three-dimensional rectangles seen from the ground coordinate system.

The principal characteristics of these cases are given in table 20 :

BLOW NB	Resultant Acceleration (G)			Resultant angular acceleration (rd/s²)		Resultant angular velocity (rd/s)		HIC	Δt HIC (ms)
	a_{max}	$a_{3\ ms}$	$\frac{a_{3\ ms}}{a_{max}}$ (%)	$\dot{\omega}$ max	$\dot{\omega}$ 3 ms	ω max	ω 3ms		
B 51	30	26	87	5784	3709	33.27	33.12	22	8.6
B 52	29	24	83	4557	3020	20.01	19.84	17	8.1
B 53	37	27	73	4484	3145	30.14	29.87	22	5.0
B 54	59	40	68	11108	6850	28.38	27.96	64	7.0
B 55	35	21	60	6304	4592	20.49	20.36	16	15.5
B 56	55	38	69	8655	6219	35.24	33.35	67	11.5
B 58	66	34	52	9334	5875	36.99	36.19	59	6.2
B 59	71	45	63	10572	7545	40.78	39.23	94	6.6
B 510	23	20	87	6641	3995	31.85	29.96	15	19.5
B 511	46	28	61	7154	4689	25.65	25.57	26	7.6

TABLE 15. FIRST FIGHT COMPUTATION RESULTS
(Validated blows only)

BLOW NB	Resultant Acceleration (G)			Resultant angular acceleration (rd/s)		Resultant angular velocity (rd/s)		HIC	Δt HIC
	a_{max}	$a_{3\ ms}$	$\frac{a_{3\ ms}}{a_{max}}$ (%)	$\dot{\omega}$ max	$\dot{\omega}$ 3 ms	ω max	ω 3 ms		
601	56	39	70	6545	4863	20.39	19.39	61	11.50
602	23	18	78	4523	2887	16.55	15.63	8.6	6.12
603	133	49	37	9593	6267	24.44	19.36	241	2.51
604	61	35	57	4956	3985	19.56	19.45	58	10.13
606	54	36	67	7690	4533	34.10	31.75	55	12.75
610	61	43	70	3989	3831	29.18	28.59	80	6.62
611	82	41	50	3492	3214	20.57	20.43	98	3.25

TABLE 16. SECOND FIGHT COMPUTATION RESULTS
(Validated blows only)

BLOW NB	Resultant acceleration (G)			Resultant angular acceleration (rd/s²)		Resultant angular velocity (rd/s)			
	a_{max}	$a_{3\ ms}$	$\frac{a_{3ms}}{a_{max}}$ (%)	$\dot{\omega}$ max	$\dot{\omega}$ 3 ms	ω max	ω 3 ms	HIC	Δt_{HIC}(ms)
702	117	56	48	13648	4916	48.00	44.91	192	10.7
703	114	61	54	7354	5285	24.30	23.83	252	4.5
704	50	26	52	7581	1885	16.45	16.36	21	9.5
705	159	46	30	11956	4140	23.75	22.88	105	1.4
706	32	28	87	4393	3455	23.12	22.72	30	17.4
707	36	29	81	4529	3030	20.70	18.66	32	16.2
708	143	54	38	11551	5302	21.33	17.33	203	4.9
709	24	21	87	4532	3321	22.99	22.73	15	24.6
710	46	35	76	5169	4311	27.39	24.97	39	9.2
712	39	29	74	3918	2036	19.22	19.13	29	8.25
713	32	26	81	5265	4949	25.01	24.31	20	30
719	60	42	70	6626	5374	28.23	27.05	85	11
722	89	57	64	16234	4961	25.08	22.55	173	14.5

TABLE 17. THIRD FIGHT COMPUTATION RESULTS
(Validated blows only)

BLOW NB	Resultant Acceleration (G)			Resultant angular acceleration (rd/s)		Resultant angular velocity (rd/s)			
	a_{max}	$a_{3\,ms}$	$\frac{a_{3\,ms}}{a_{max}}$ (%)	$\dot{\omega}$ max	$\dot{\omega}$3 ms	ω max	ω3 ms	HIC	Δt (HIC) (ms)
903	135	78	58	10550	6781	29.20	24..39	348	6.75
904	72	50	69	4860	2971	23.88	21.97	135	11.74
907	126	78	62	7008	4467	19.32	19.11	201	8.51
908	117	79	67	11160	7951	38.99	36.28	342	14.63
910	39	24	61	5504	5101	21.97	19.78	27	16.37
915	105	39	37	9817	6257	38.31	36.46	122	16.25
917	96	48	50	9479	6447	35.21	33.75	123	10.75
918	55	36	65	6075	5434	26.69	25.41	44	13.38
919	76	44	58	9933	5791	30.92	28.96	98	13.00

TABLE 19. FIFTH FIGHT COMPUTATION RESULTS
(Validated blows only)

FIGURE 12.

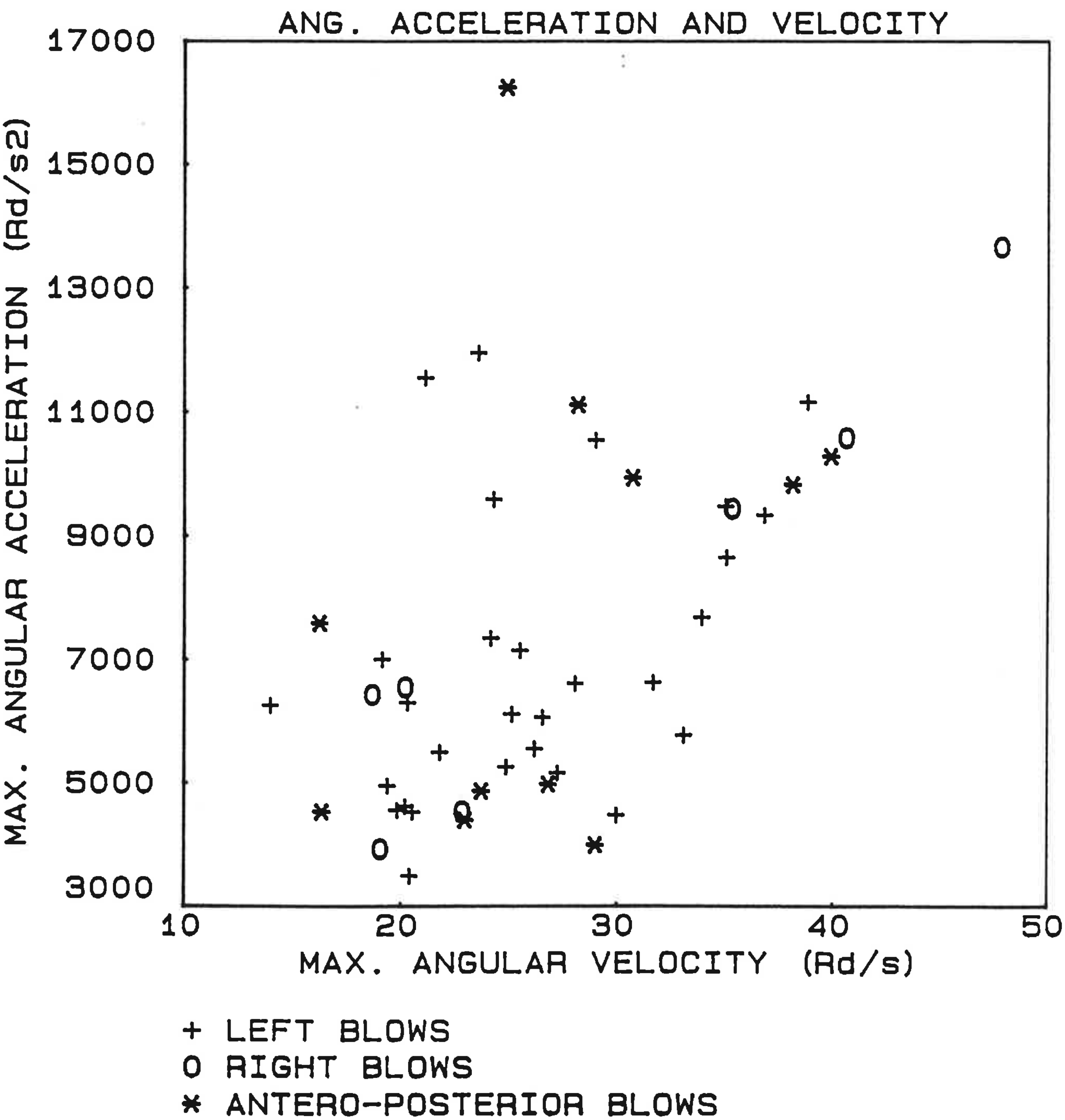

ANG. ACCELERATION AND VELOCITY
MAX. ANGULAR ACCELERATION (Rd/s2)
17000
15000
13000
11000
9000
7000
5000
3000
10
20
30
40
50
MAX. ANGULAR VELOCITY (Rd/s)
+ LEFT BLOWS
O RIGHT BLOWS
* ANTERO-POSTERIOR BLOWS

FIGURE 13.

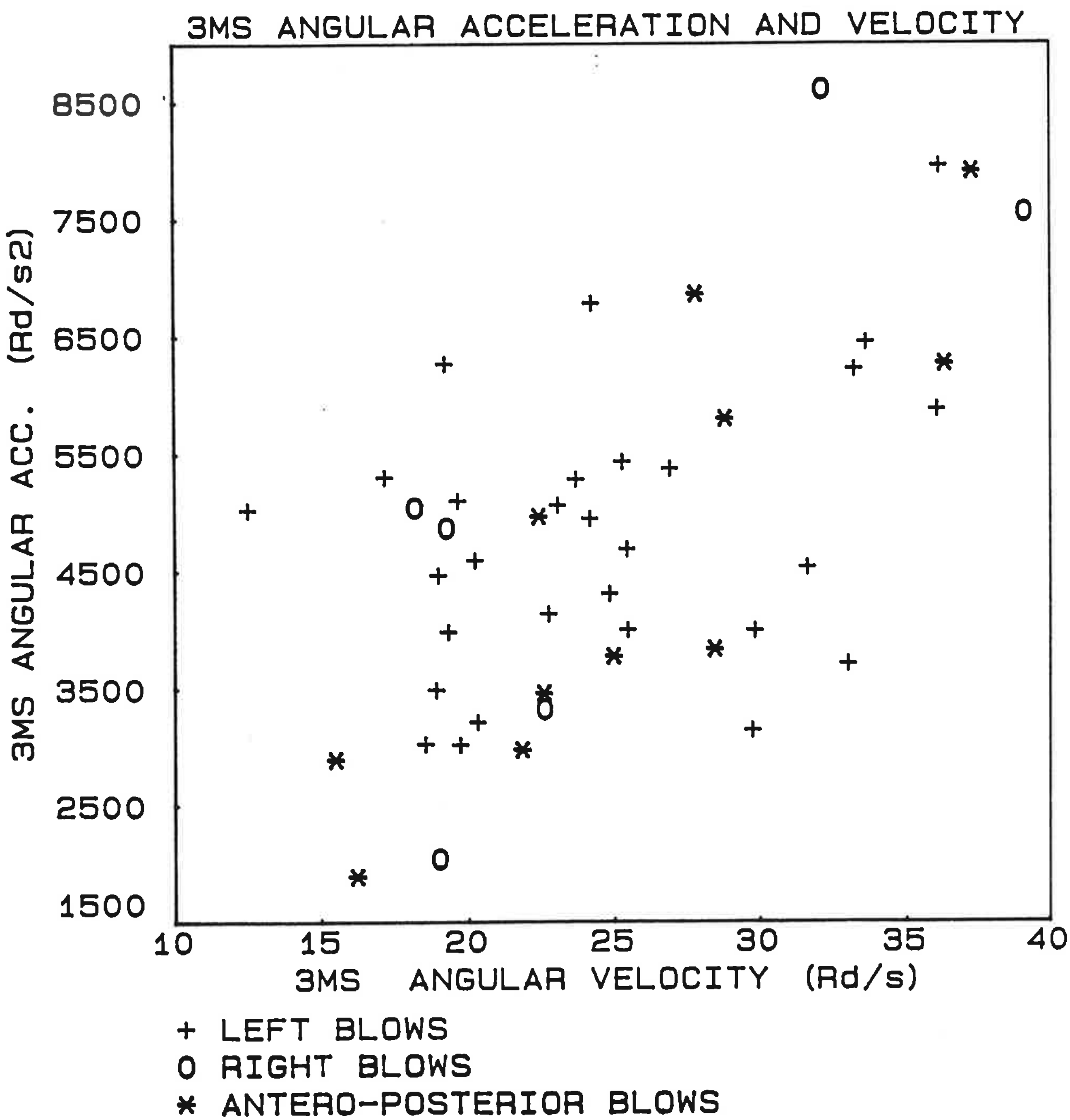

3MS ANGULAR ACCELERATION AND VELOCITY
3MS ANGULAR ACC. (Rd/s2)
8500
7500
6500
5500
4500
3500
2500
1500
10
15
20
25
30
35
40
3MS ANGULAR VELOCITY (Rd/s)
+ LEFT BLOWS
O RIGHT BLOWS
* ANTERO-POSTERIOR BLOWS

FIGURE 14.

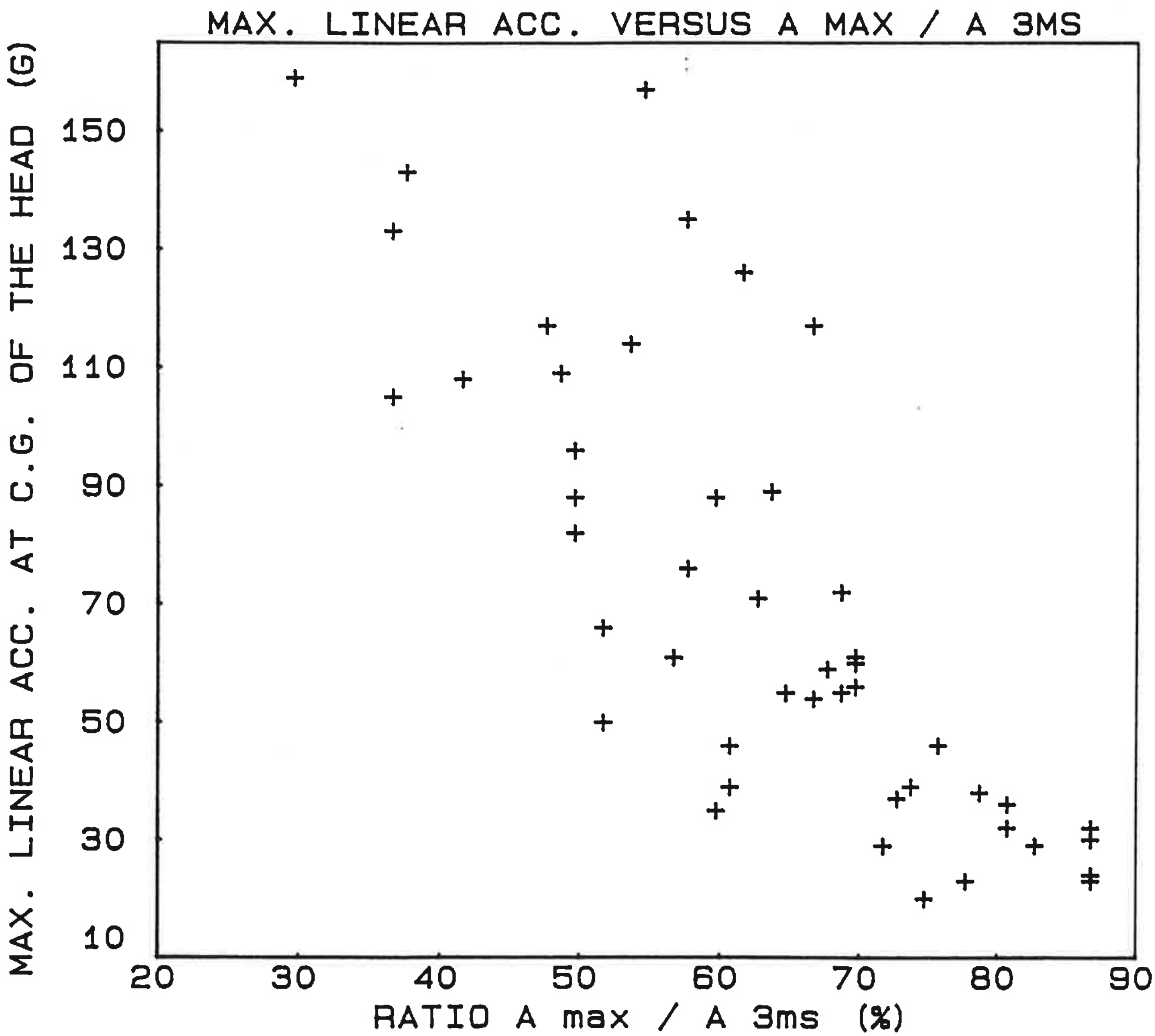

MAX. LINEAR ACC. VERSUS A MAX / A 3MS
MAX. LINEAR ACC. AT C.G. OF THE HEAD (G)
150
130
110
90
70
50
30
10
20
30
40
50
60
70
80
90
RATIO A max / A 3ms (%)

Table 20

Main results for 8 blows which seemed to be the more interesting as regards the violence

	HIC	$\dot{\omega}$ max rd/s^2	ω max rd/s
B56	67	8655	35
B59	94	10572	41
611	98	3492	21
702	192	13648	48
722	173	16234	25
807	170	9435	35
903	348	10550	29
908	342	11160	39

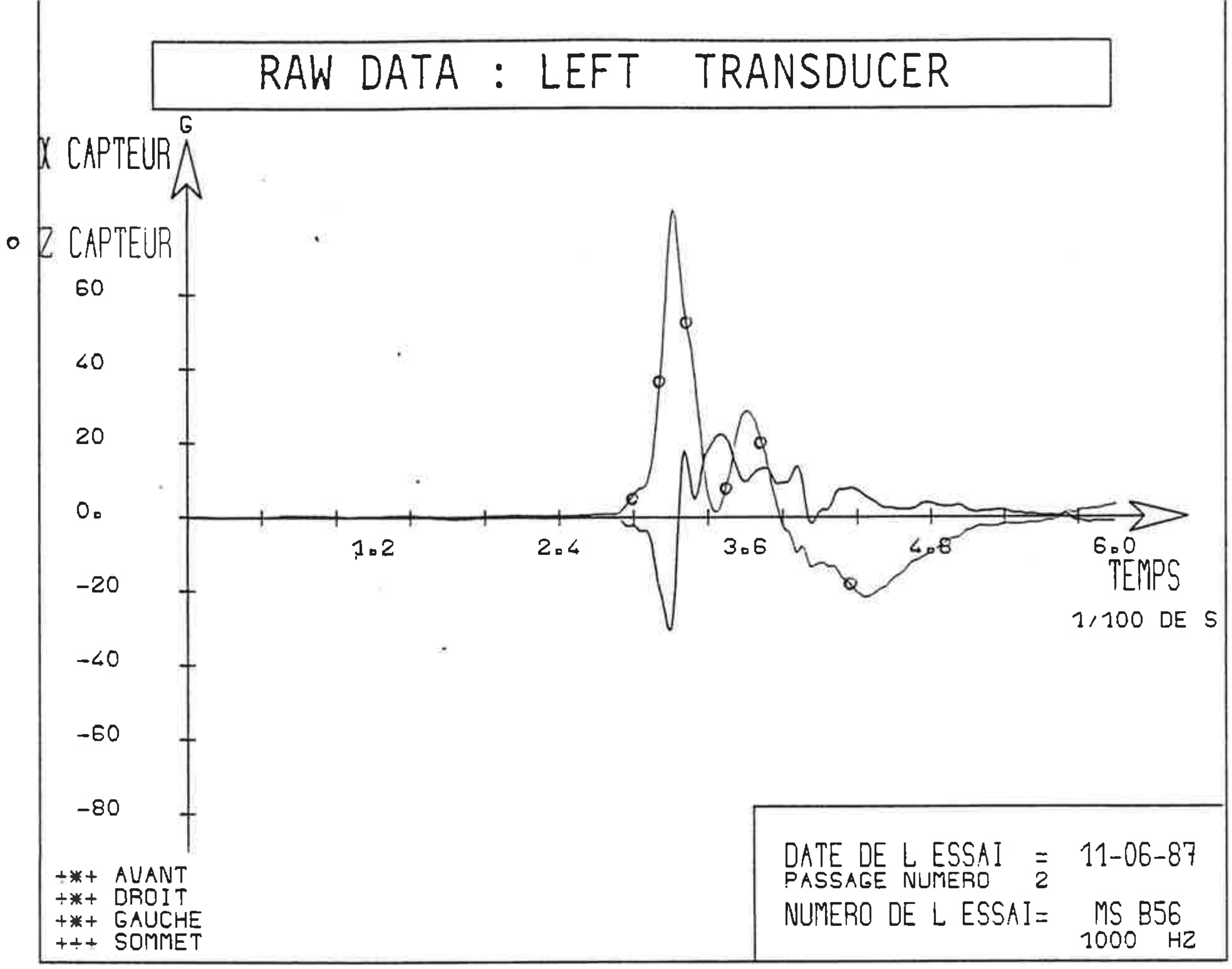
From the preceding tables, corresponding to the whole sample of blows analyzed (47 blows), we extracted some values, as global or partial average values ; they are given in table 21. The first column gives the general averages, whatever the direction of the blow ; the second and third columns give these values respectively for left and right side : the last column corresponds to all the other blows.

Table 21.
Average values for the whole sample of blows

	General Average	Average Left side	Average Right side	Average Others
NB of blows	47	29	7	11
a_{max}	70 ± 39	72 ± 41	72 ± 35	67 ± 38
$a_{3\ ms}$	40 ± 17	39.8 ± 16.6	47.9 ± 18.5	40 ± 19
max	7366 ± 2864	7015 ± 2333	7868 ± 3505	8271 ± 3946
3 ms	4813 ± 1521	4806 ± 1205	5188 ± 2266	4596 ± 1891
max	26.9 ± 7.4	26.2 ± 6.2	29.4 ± 11	26 ± 7
3 ms	25.1 ± 7.9	24.7 ± 6	28 ± 10	25.8 ± 6.7

Taking into account the rather high values of standard deviations, it can be said that the average values of the different parameters are of the same order of magnitude between the three categories of blows : left side, right side, other.

The main difference concerns the number of blows : the most part of blows was given on the left side compared to the other, directions.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G
o Z CAPTEUR
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-20
-40
-60
-80
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
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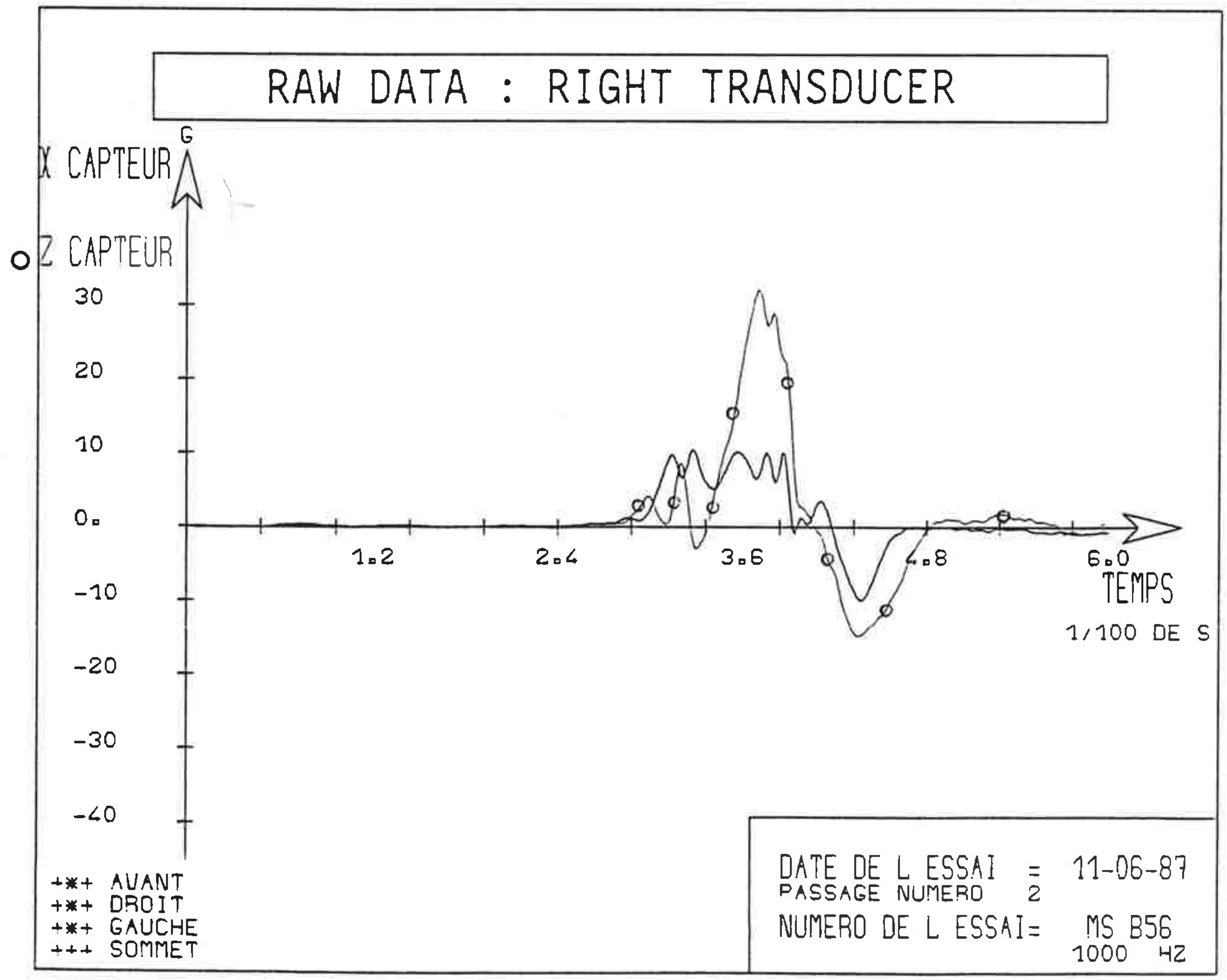
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ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G
o Z CAPTEUR
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0.
-10
-20
-30
-40
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
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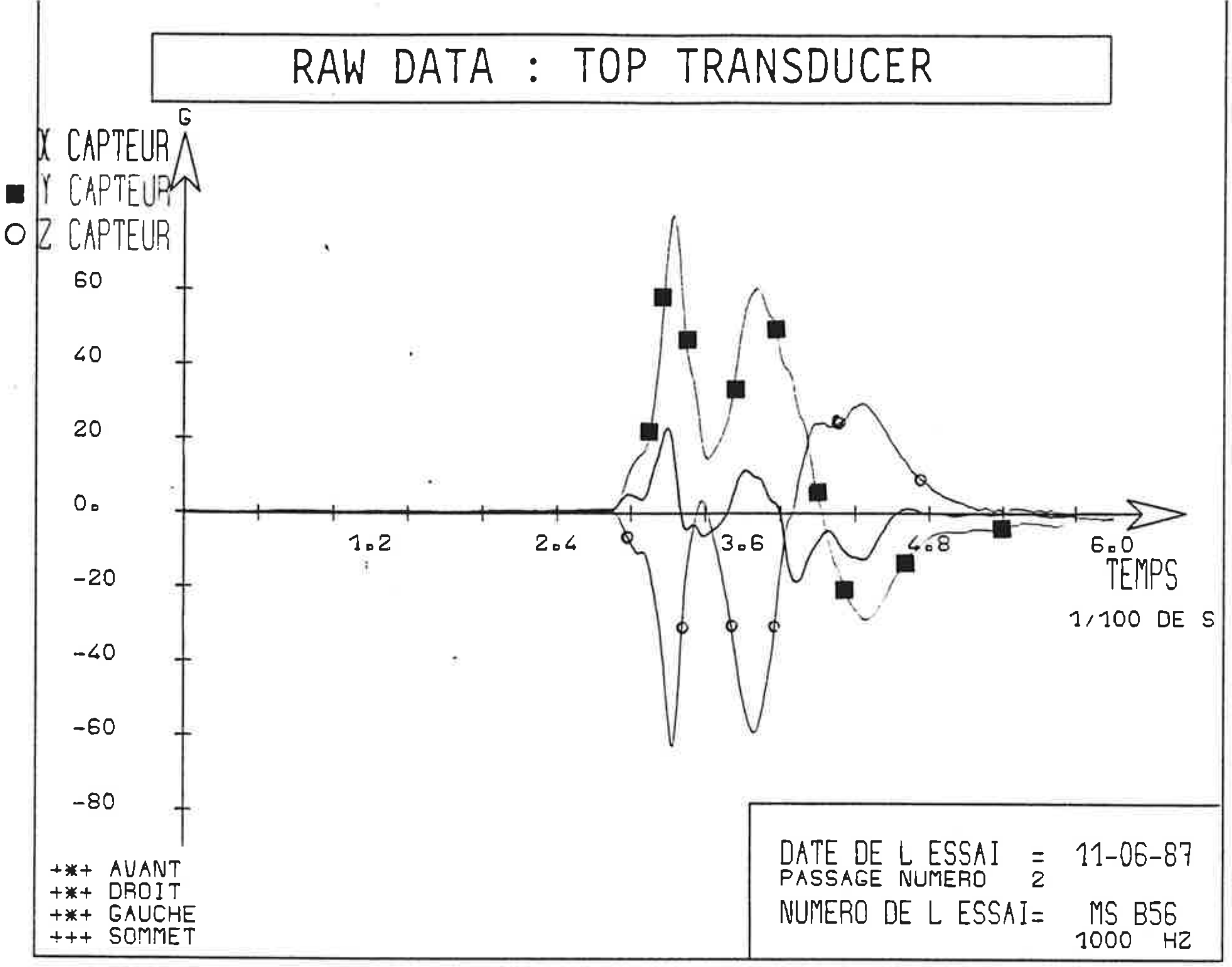
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ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G
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Y CAPTEUR
Z CAPTEUR
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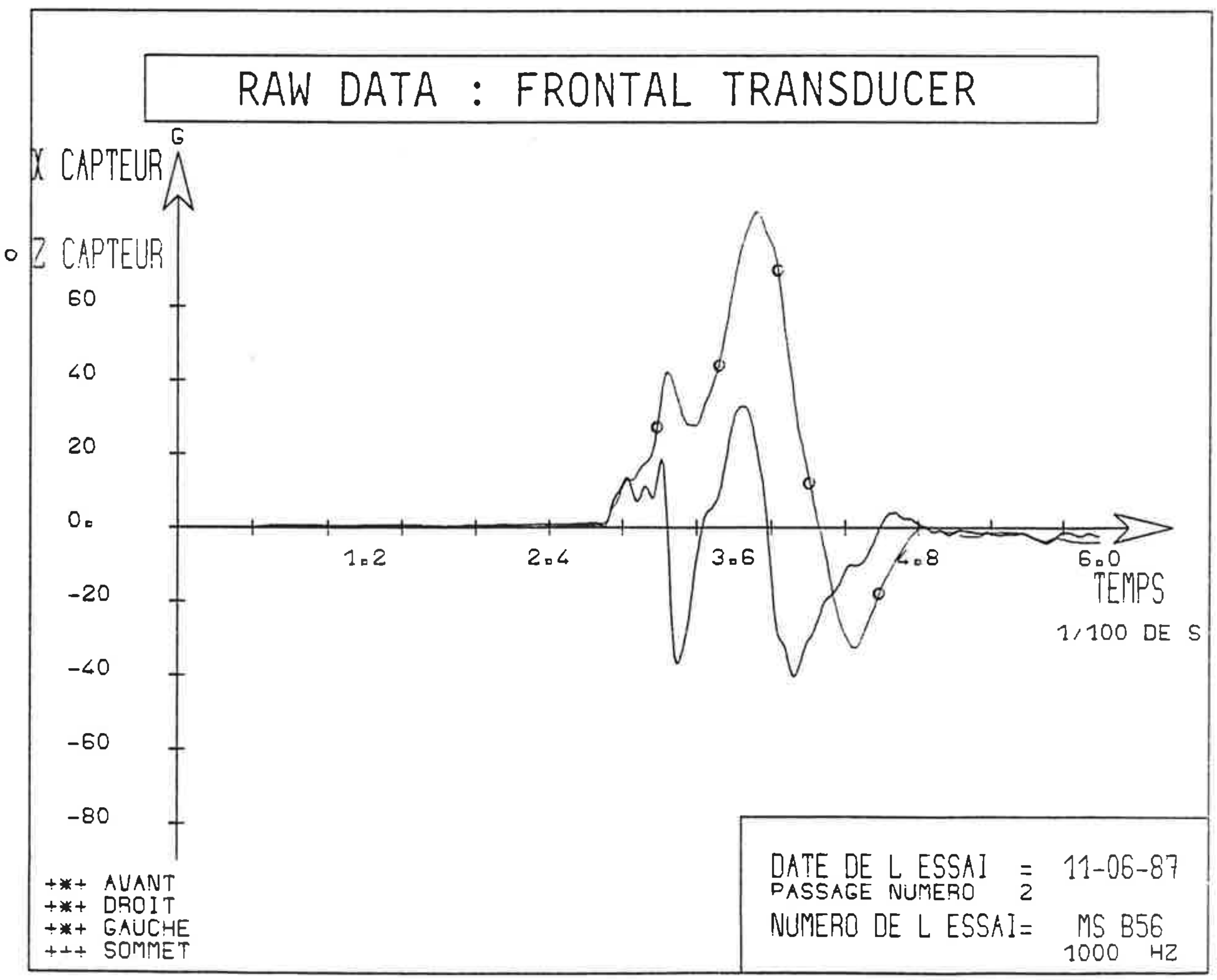
20
0.
-20
-40
-60
-80
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 11-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ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G
X CAPTEUR
Z CAPTEUR
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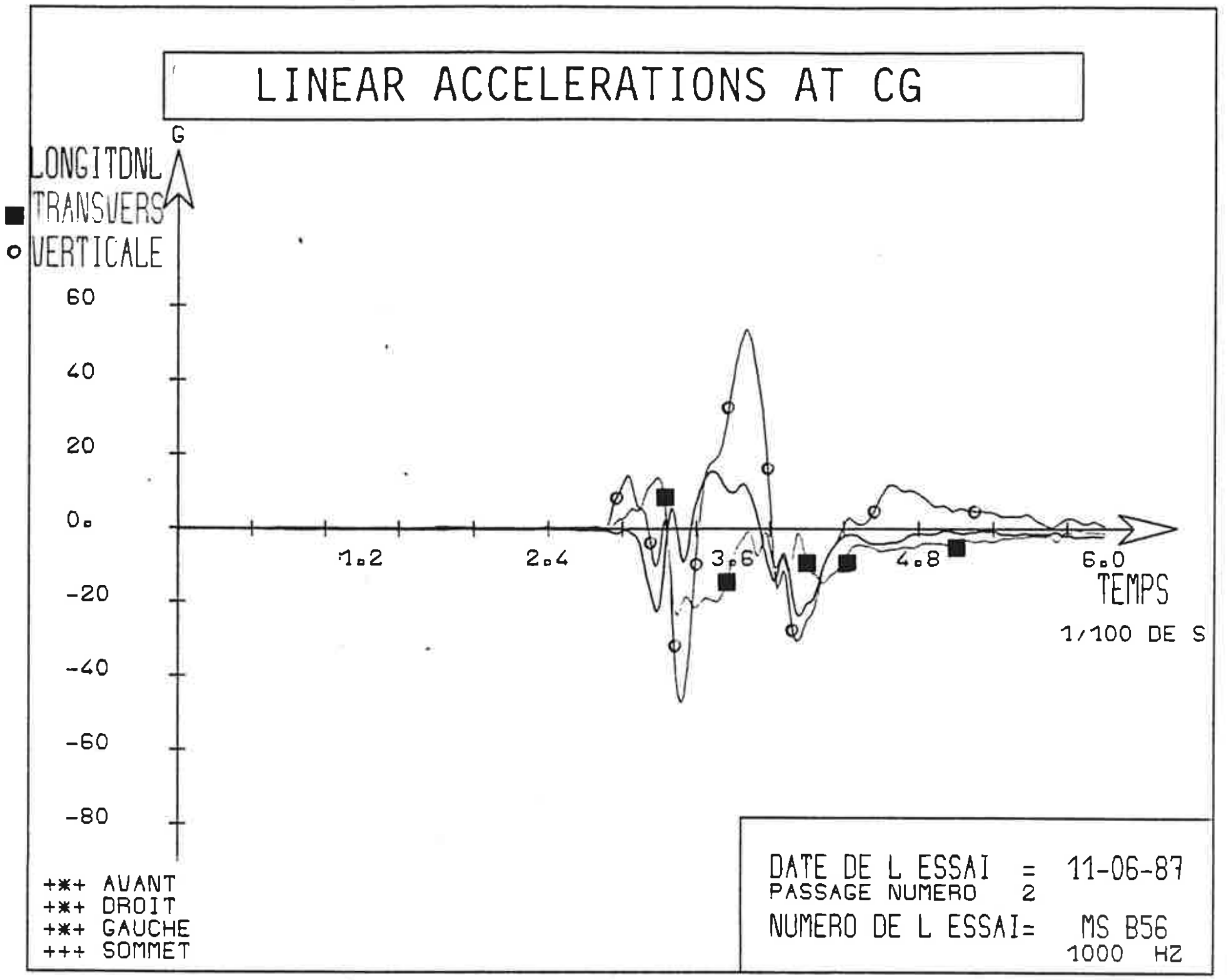
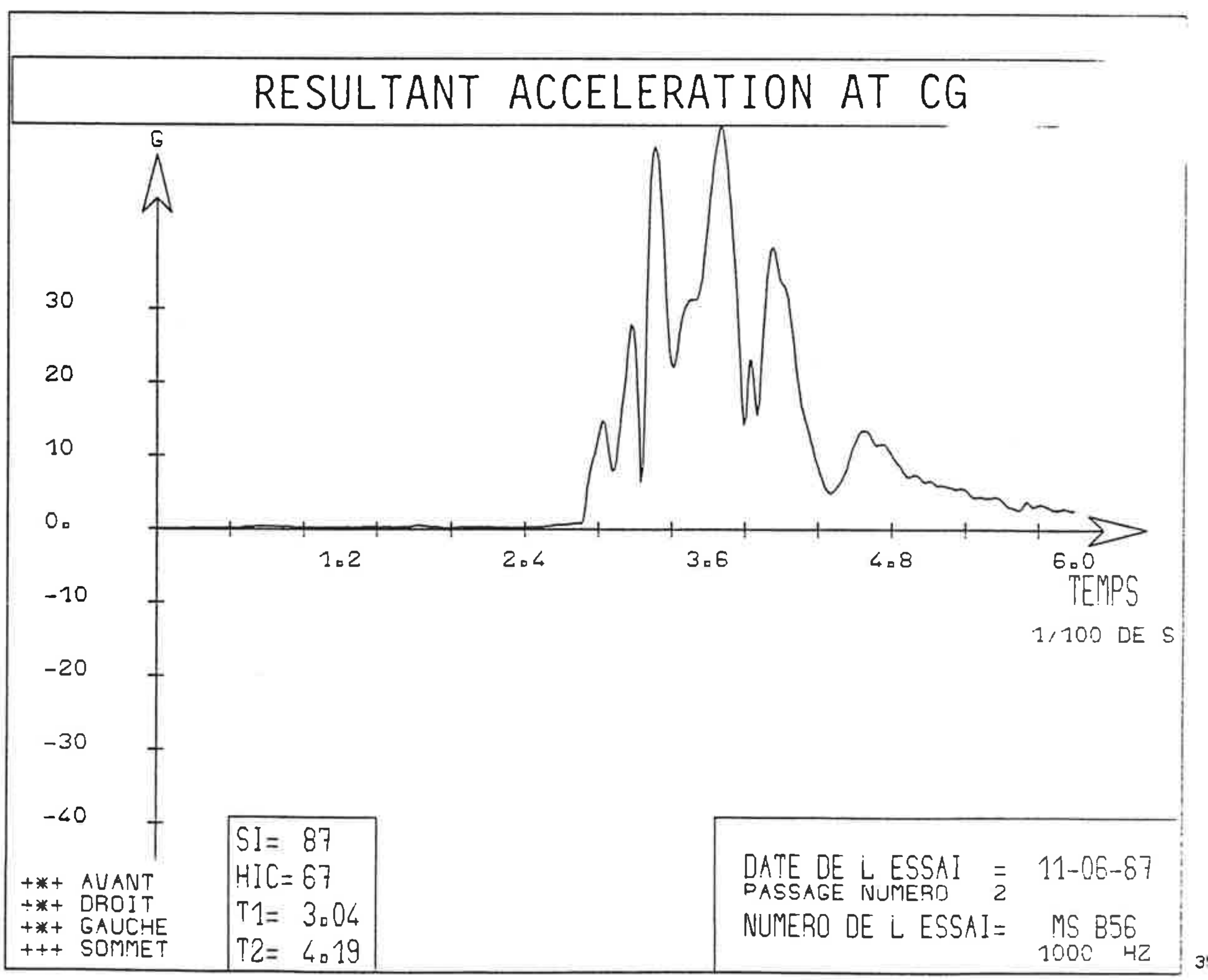
20
0.
-20
-40
-60
-80
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 11-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ


LINEAR ACCELERATIONS AT CG
G
LONGITDNL
TRANSVERS
VERTICALE
60
40
20
0.
-20
-40
-60
-80
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 11-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ
3


RESULTANT ACCELERATION AT CG
G
30
20
10
0.
-10
-20
-30
-40
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
SI= 87
HIC= 67
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T2= 4.19
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PASSAGE NUMERO 2
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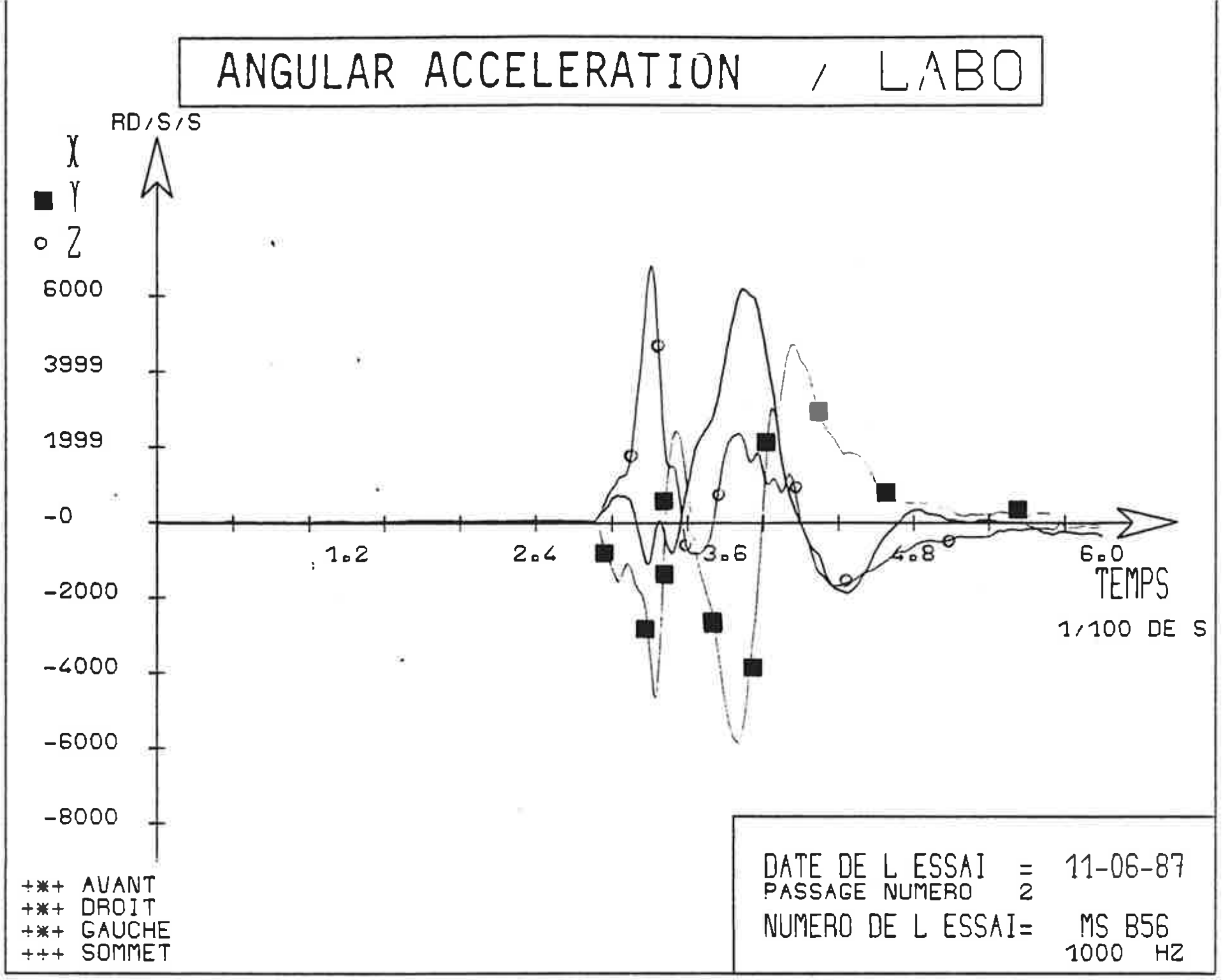
1000 HZ


ANGULAR ACCELERATION / LABO
RD/S/S
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Y
Z
6000
3999
1999
-0
-2000
-4000
-6000
-8000
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3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
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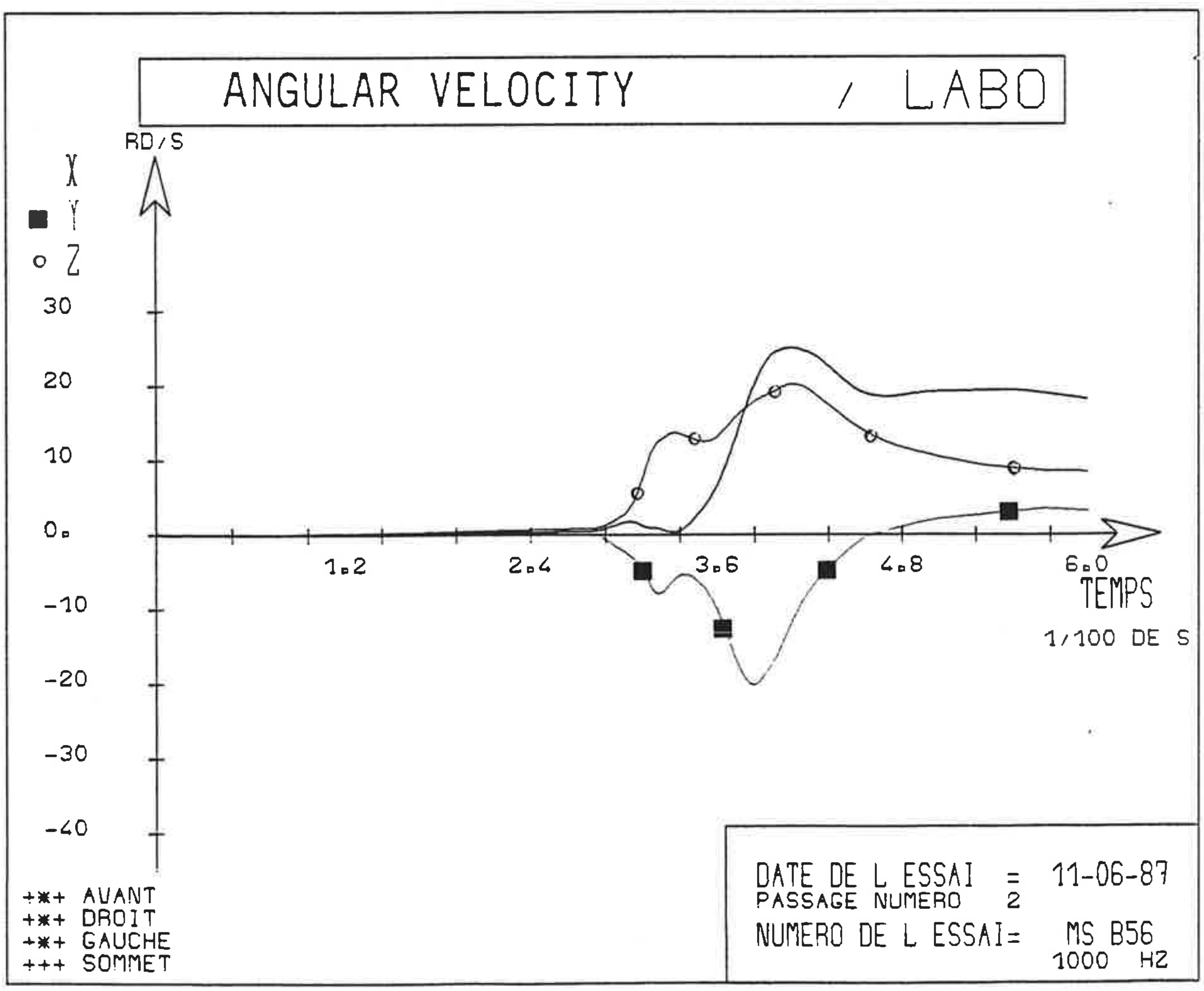
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ


ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
30
20
10
0.
-10
-20
-30
-40
1.2
2.4
3.6
4.8
6.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
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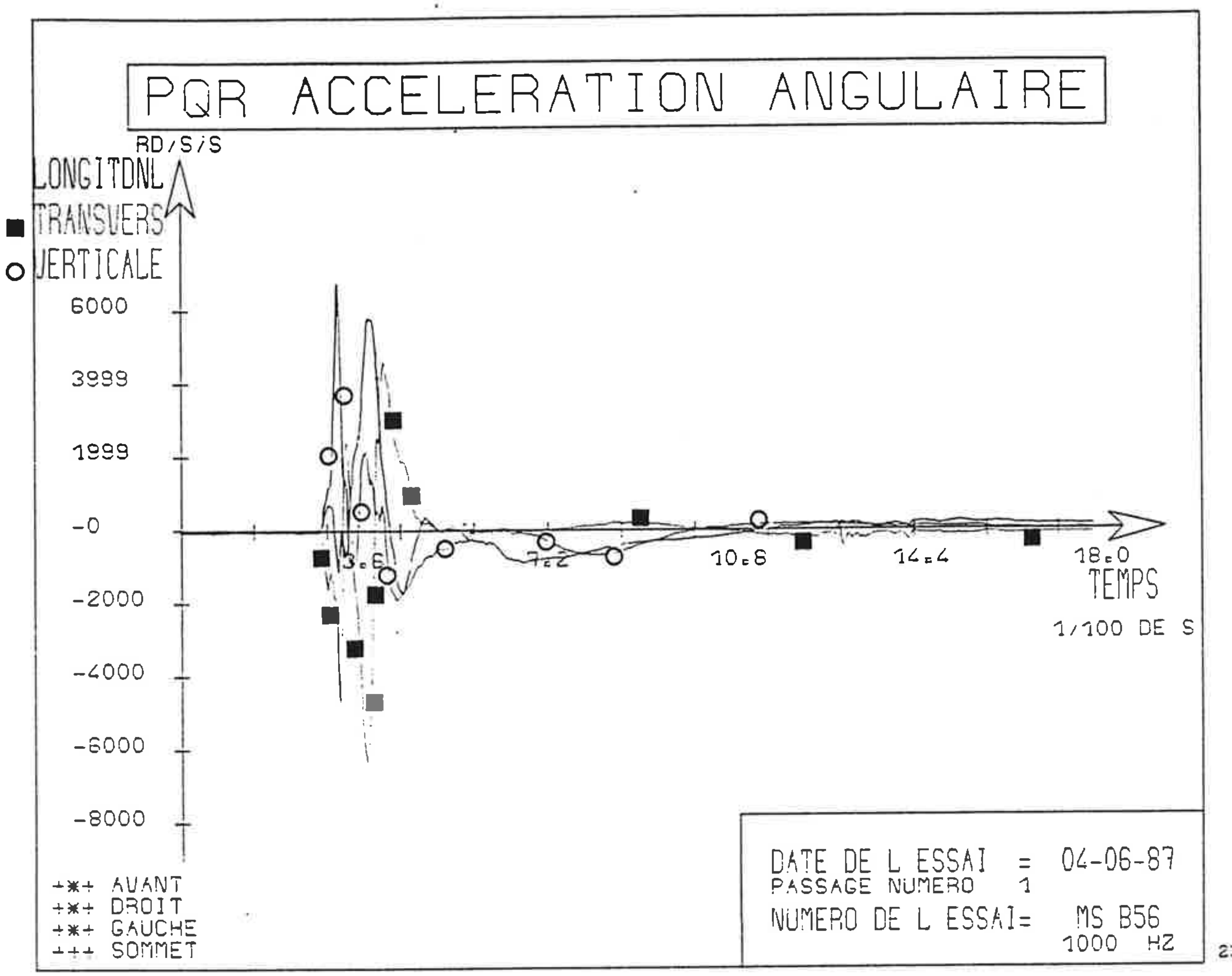
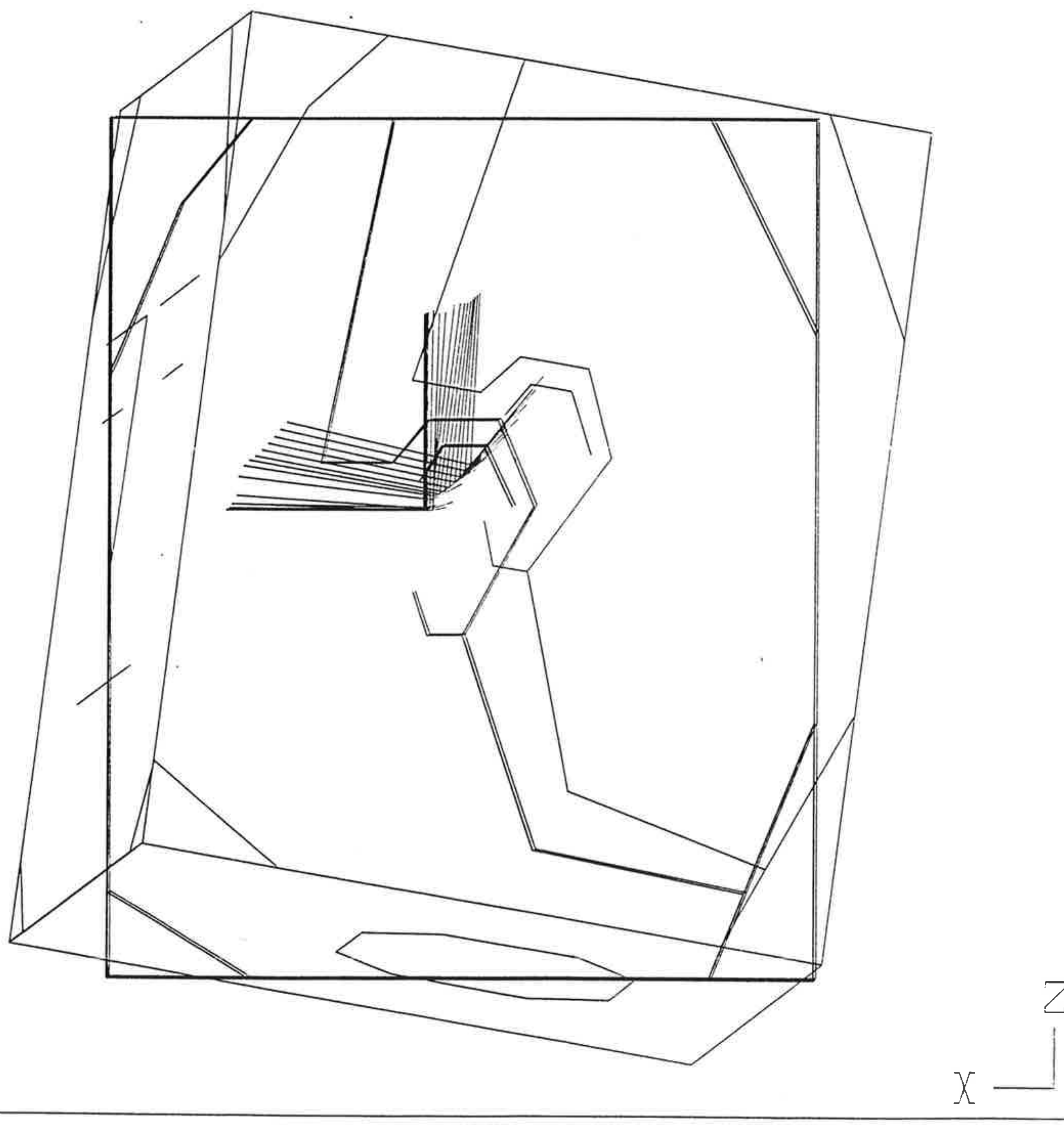
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B56
1000 HZ



ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW B56)

HEAD KINEMATICS FOR BLOW B56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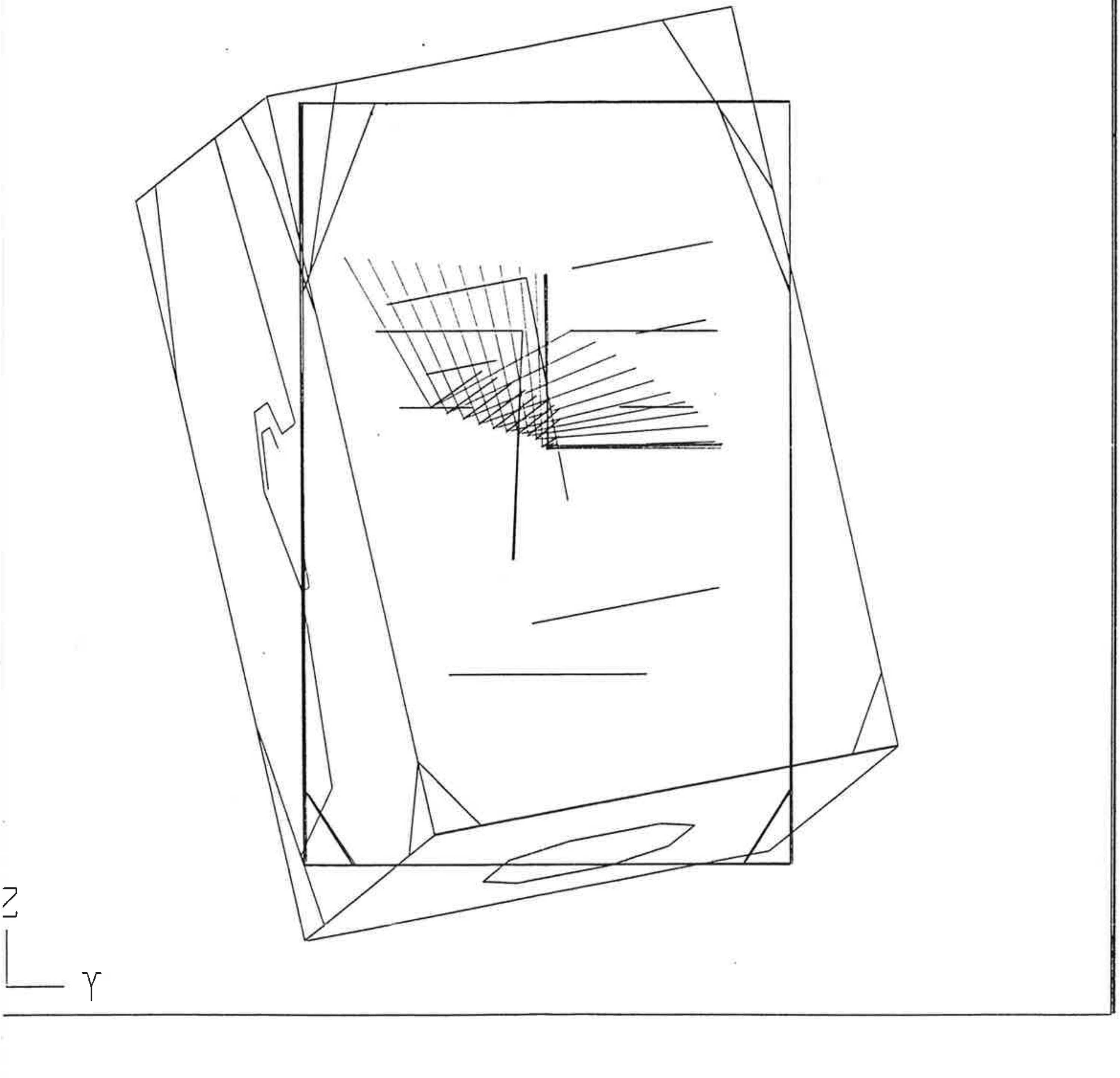
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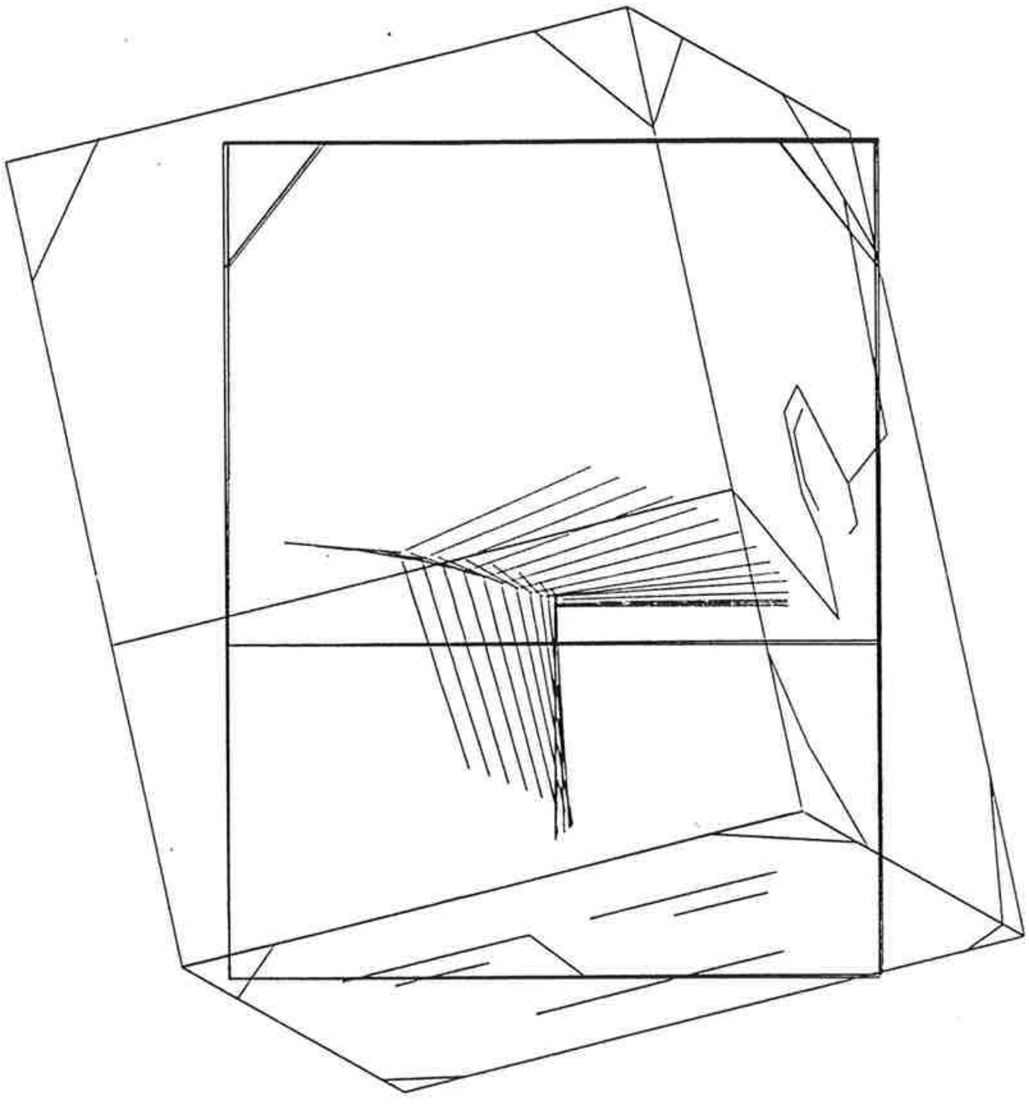
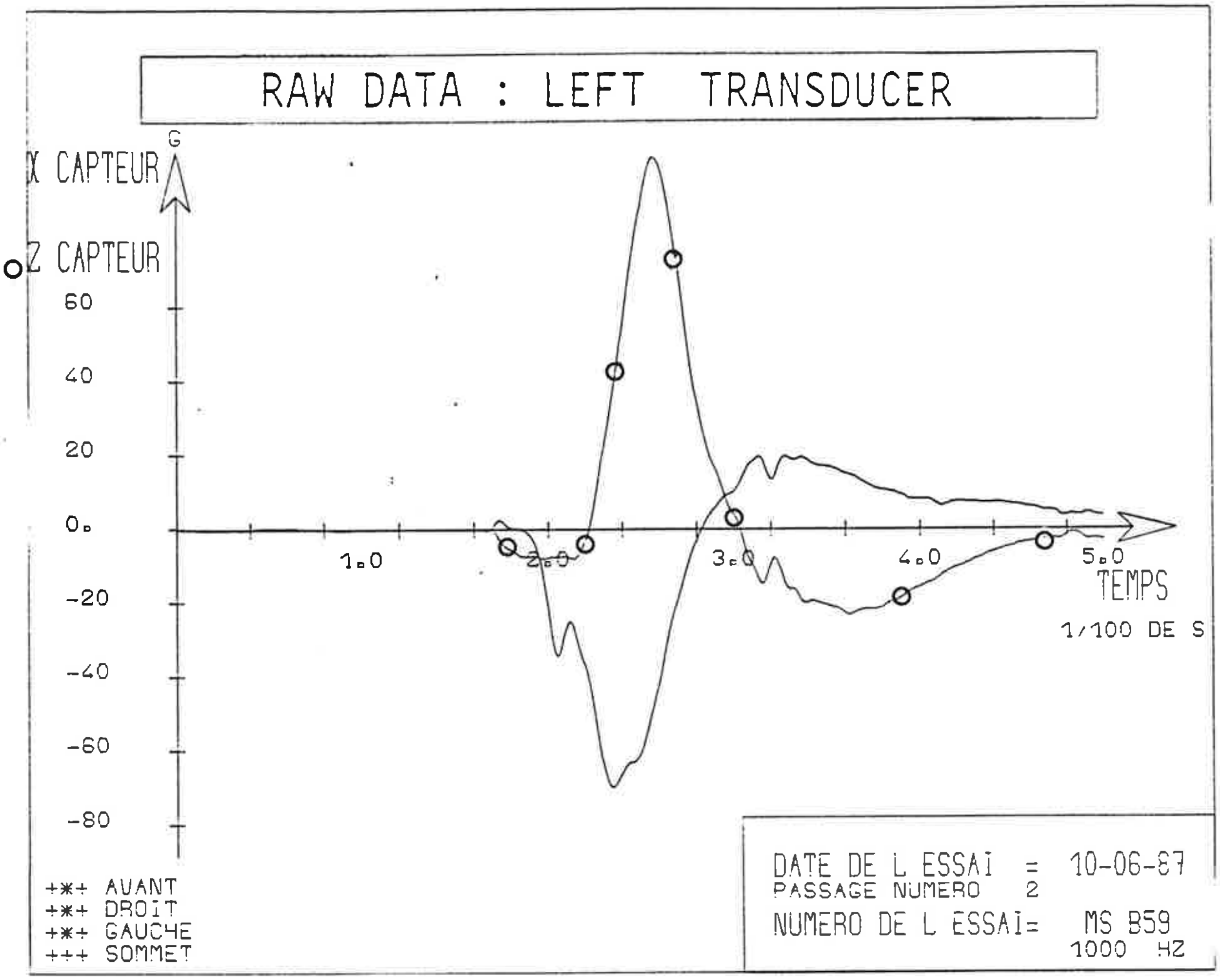
B56

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Z CAPTEUR
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2.0
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4.0
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TEMPS
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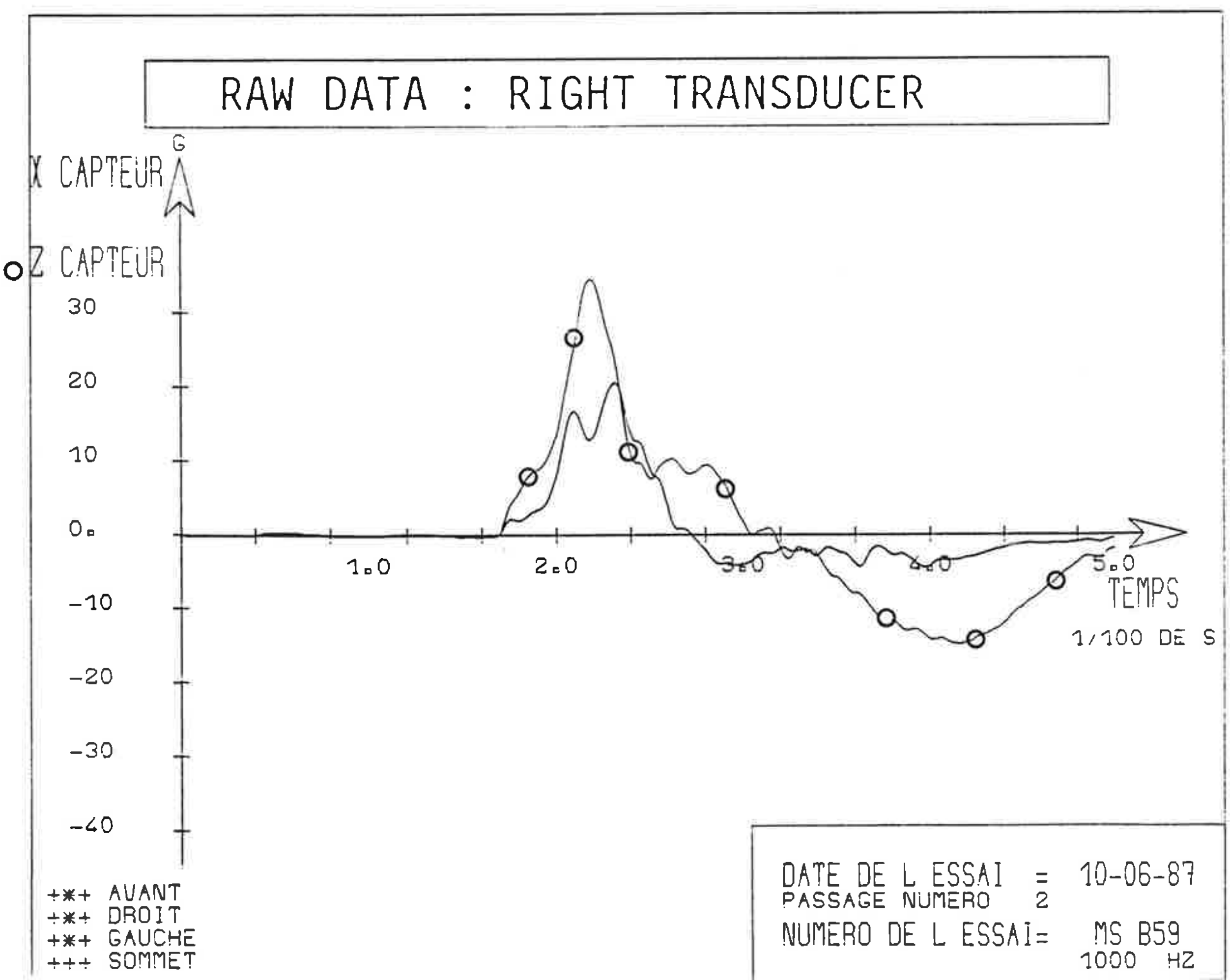
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2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
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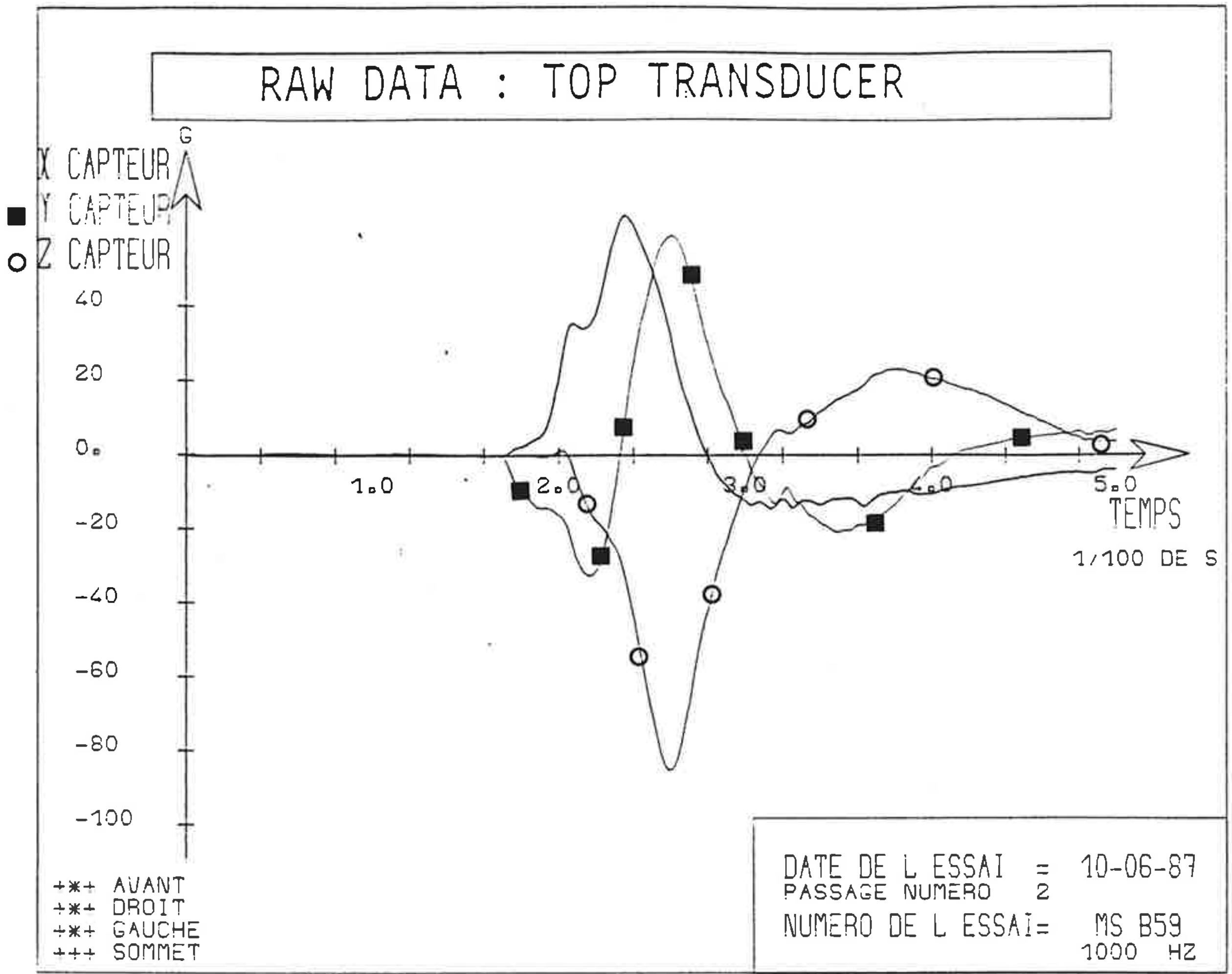
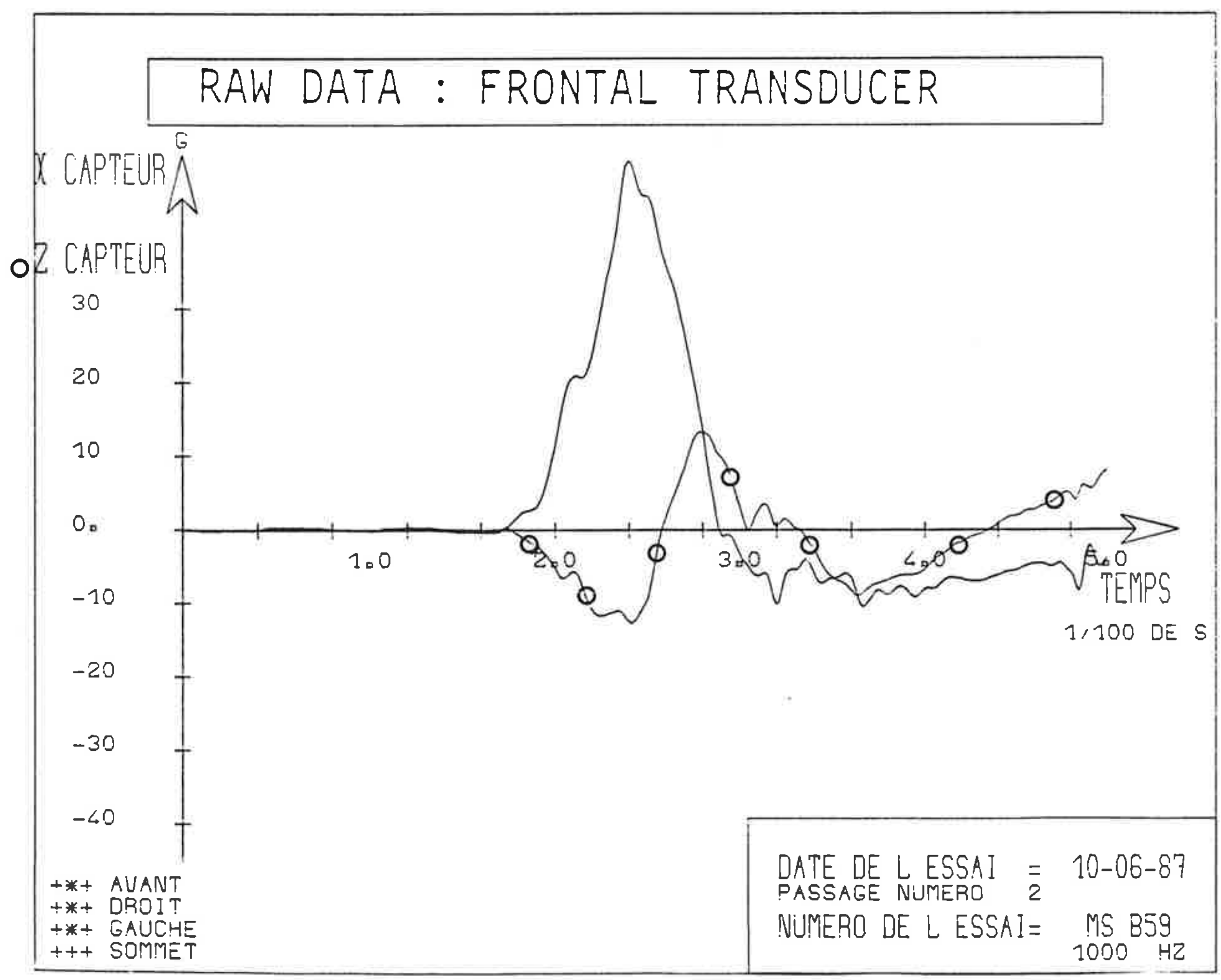
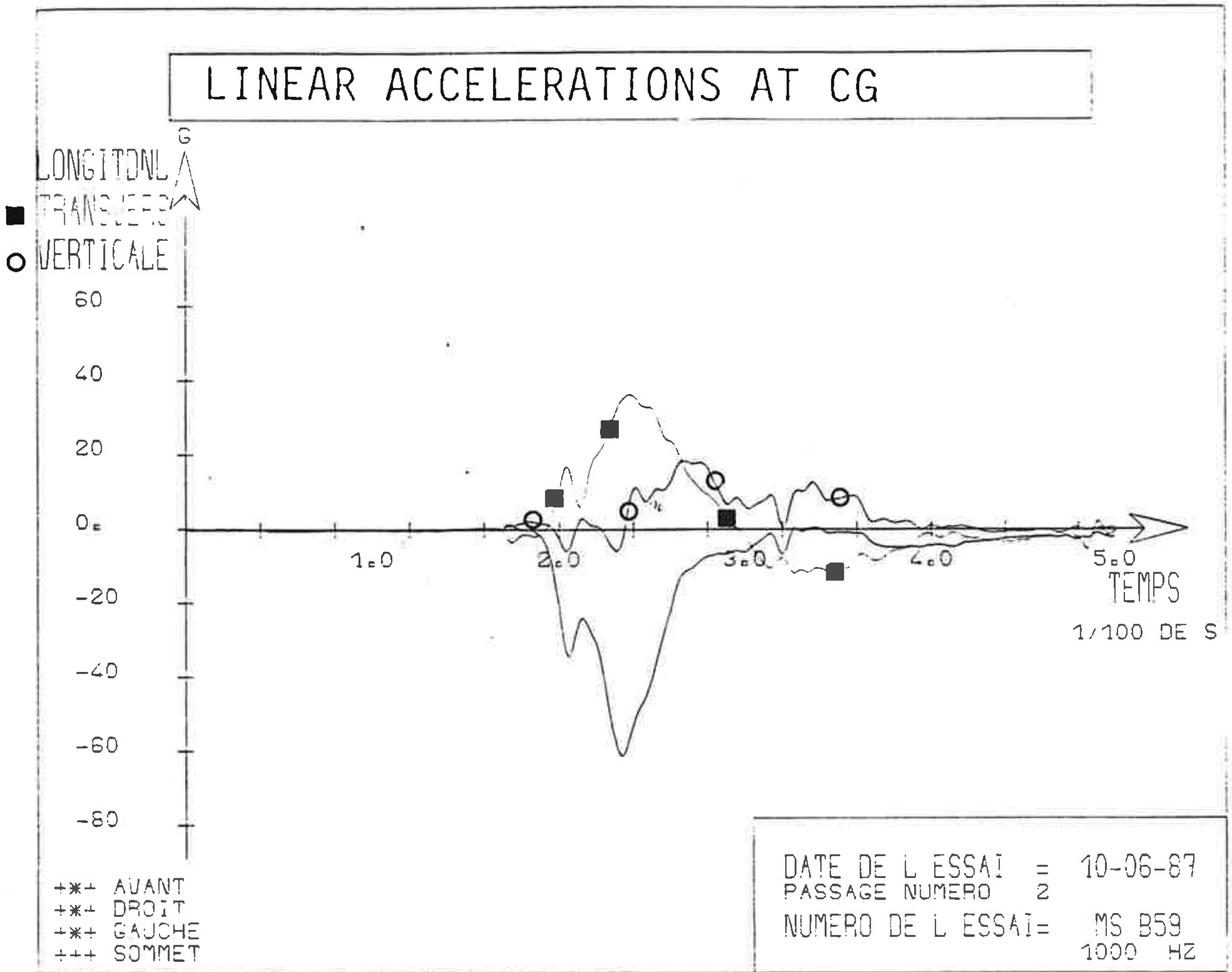
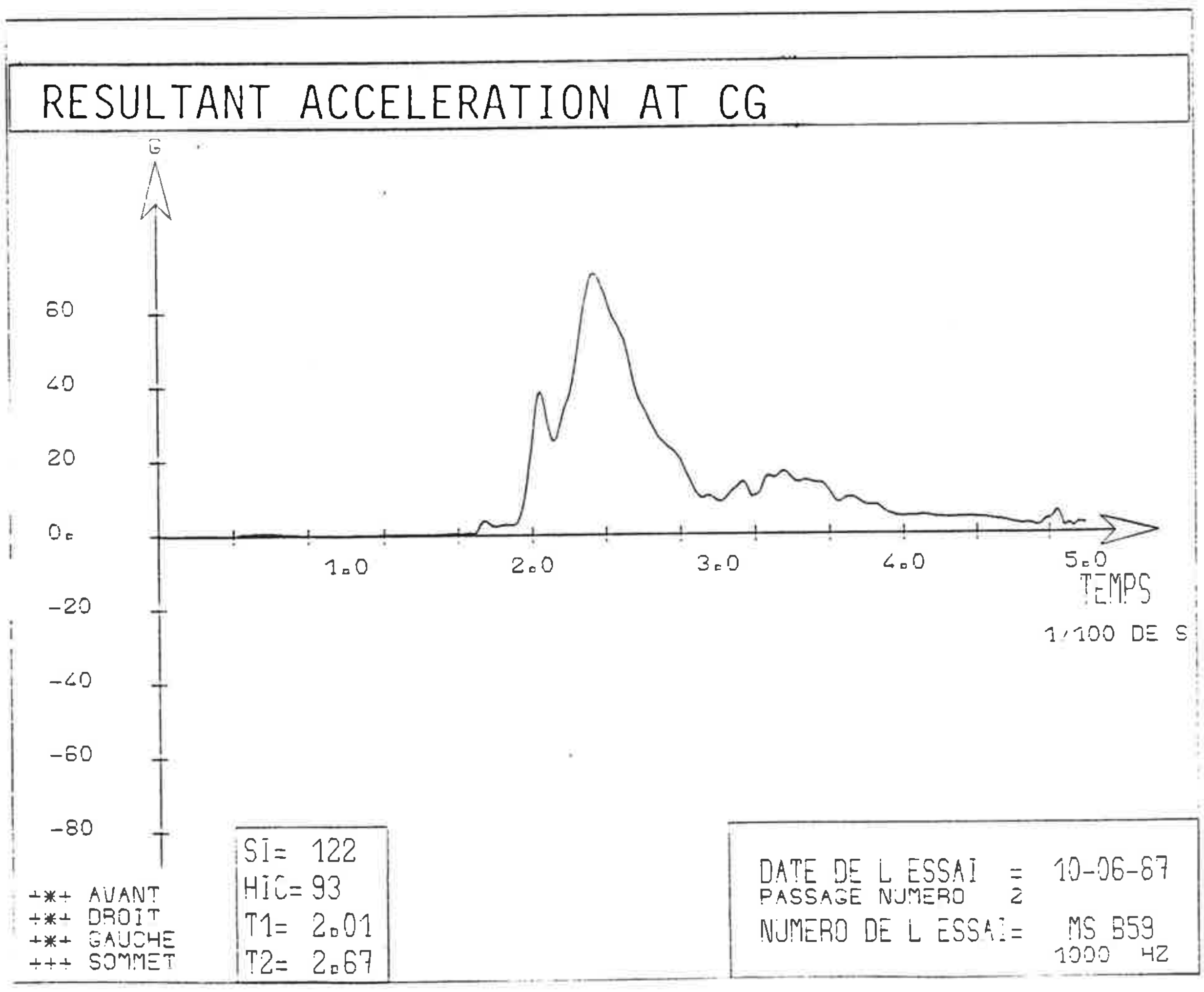
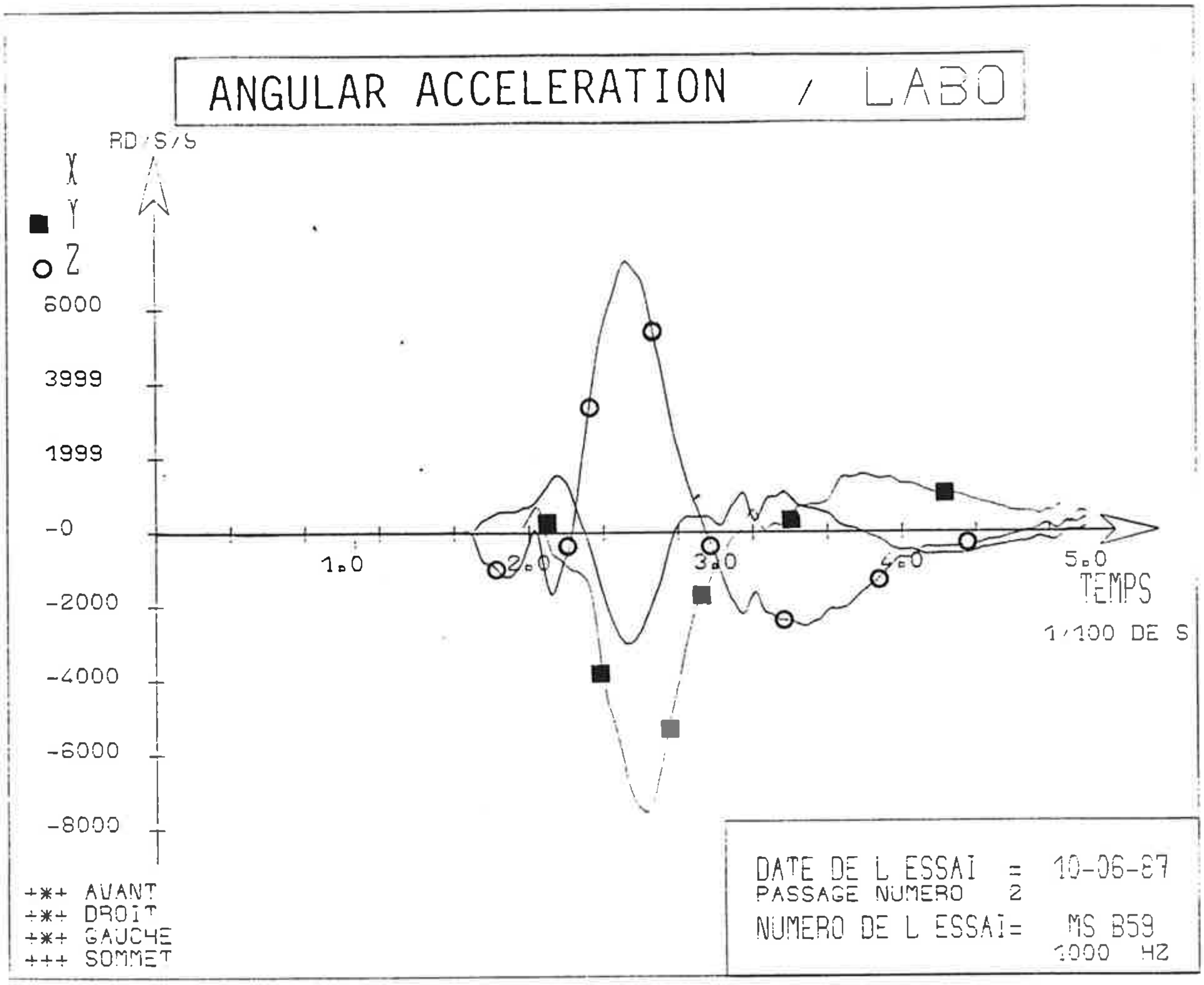
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ

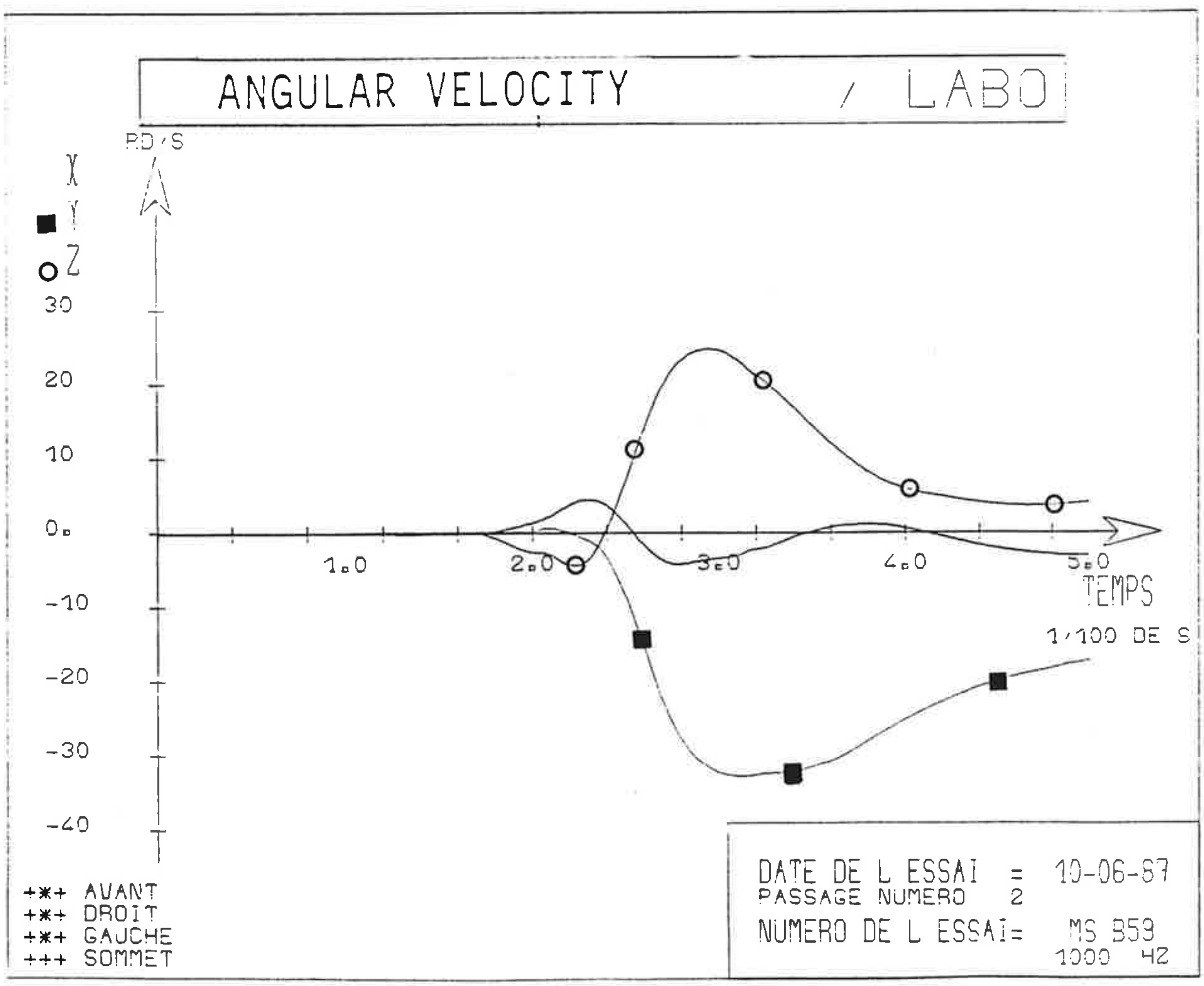

RAW DATA : TOP TRANSDUCER
X CAPTEUR
Y CAPTEUR
Z CAPTEUR
G
40
20
0.
-20
-40
-60
-80
-100
1.0
2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ

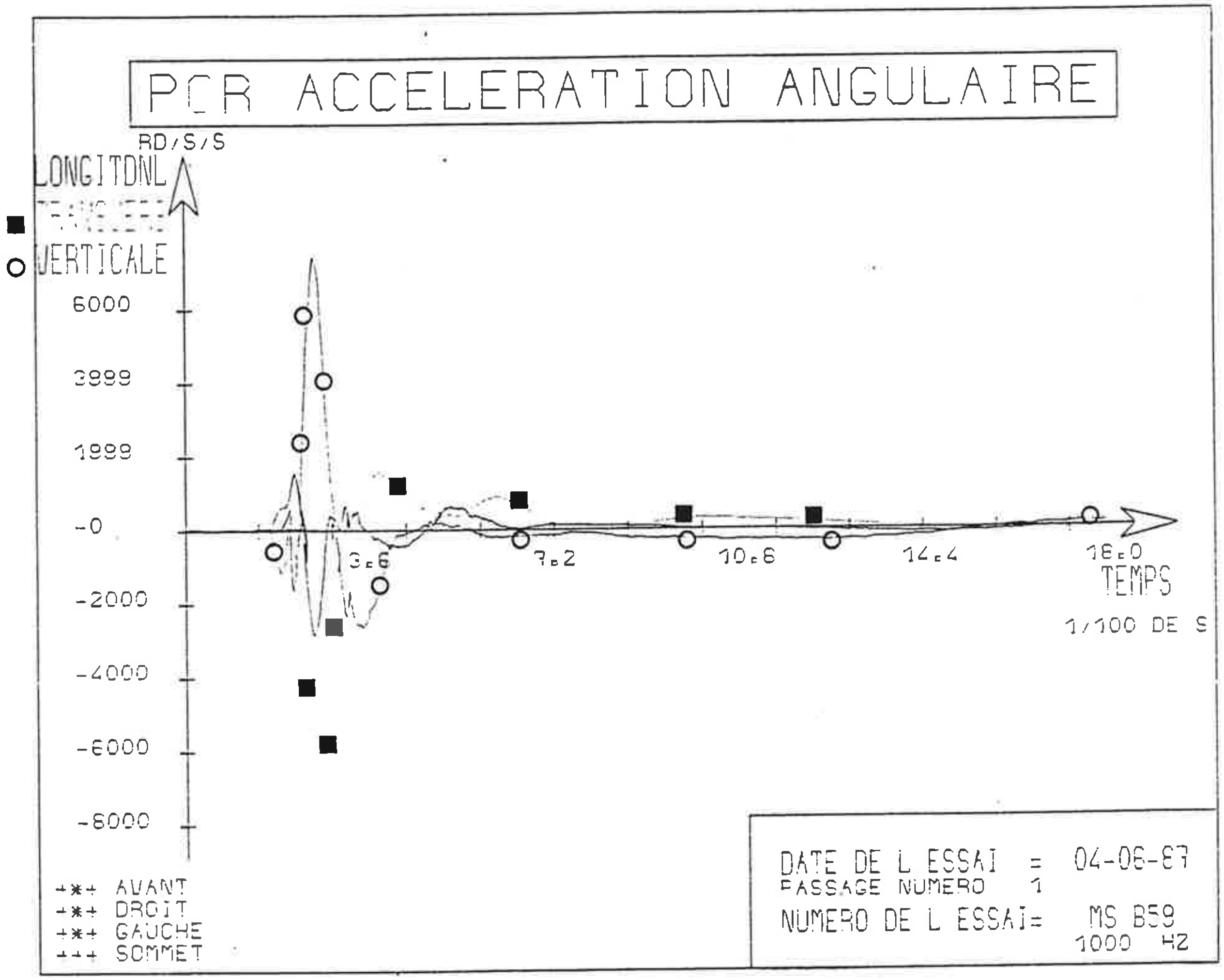

RAW DATA : FRONTAL TRANSDUCER
X CAPTEUR
Z CAPTEUR
G
30
20
10
0.
-10
-20
-30
-40
1.0
2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ


LINEAR ACCELERATIONS AT CG
G
LONGITDNL
TRANSVERS
VERTICALE
60
40
20
0.
-20
-40
-60
-80
1.0
2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ


RESULTANT ACCELERATION AT CG
G
60
40
20
0.
-20
-40
-60
-80
1.0
2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
SI= 122
HIC= 93
T1= 2.01
T2= 2.67
DATE DE L ESSAI = 10-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ

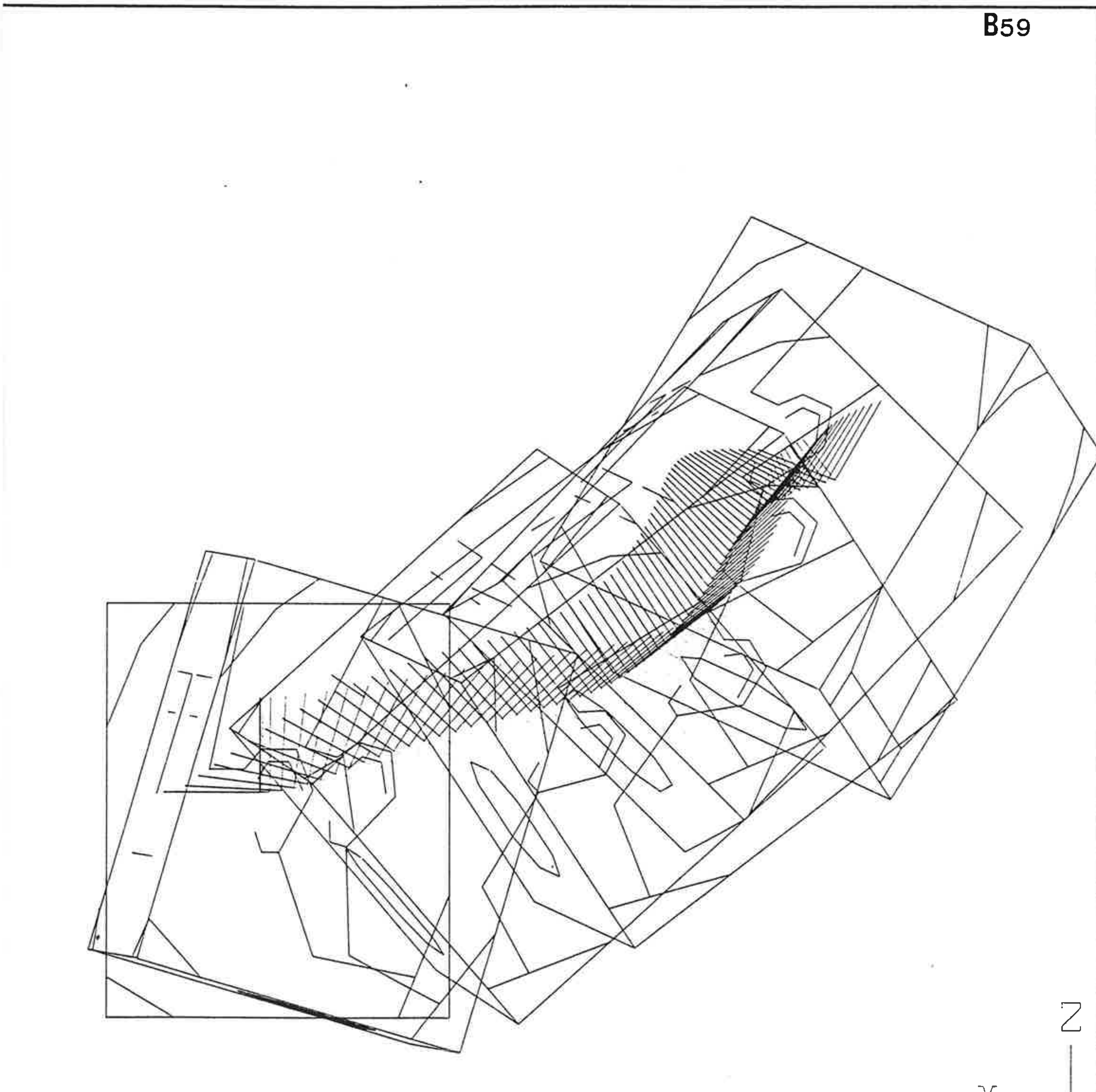

ANGULAR ACCELERATION / LABO
RD/S/S
X
Y
Z
6000
3999
1999
-0
-2000
-4000
-6000
-8000
1.0
2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ


ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
30
20
10
0.
-10
-20
-30
-40
1.0
2.0
3.0
4.0
5.0
TEMPS
1/100 DE S
+*+ AVANT
+*+ DROIT
+*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-06-87
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS B59
1000 HZ

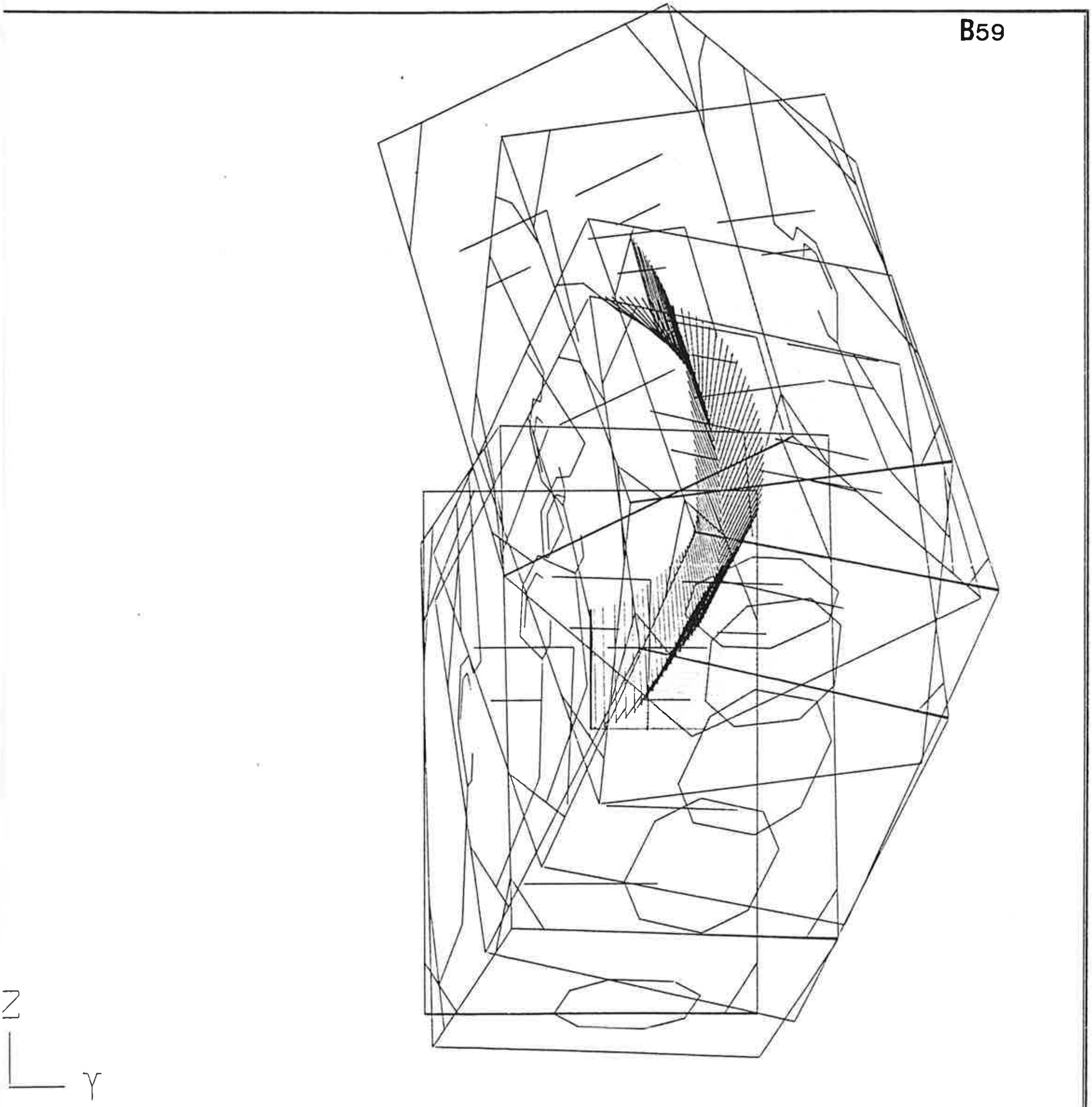


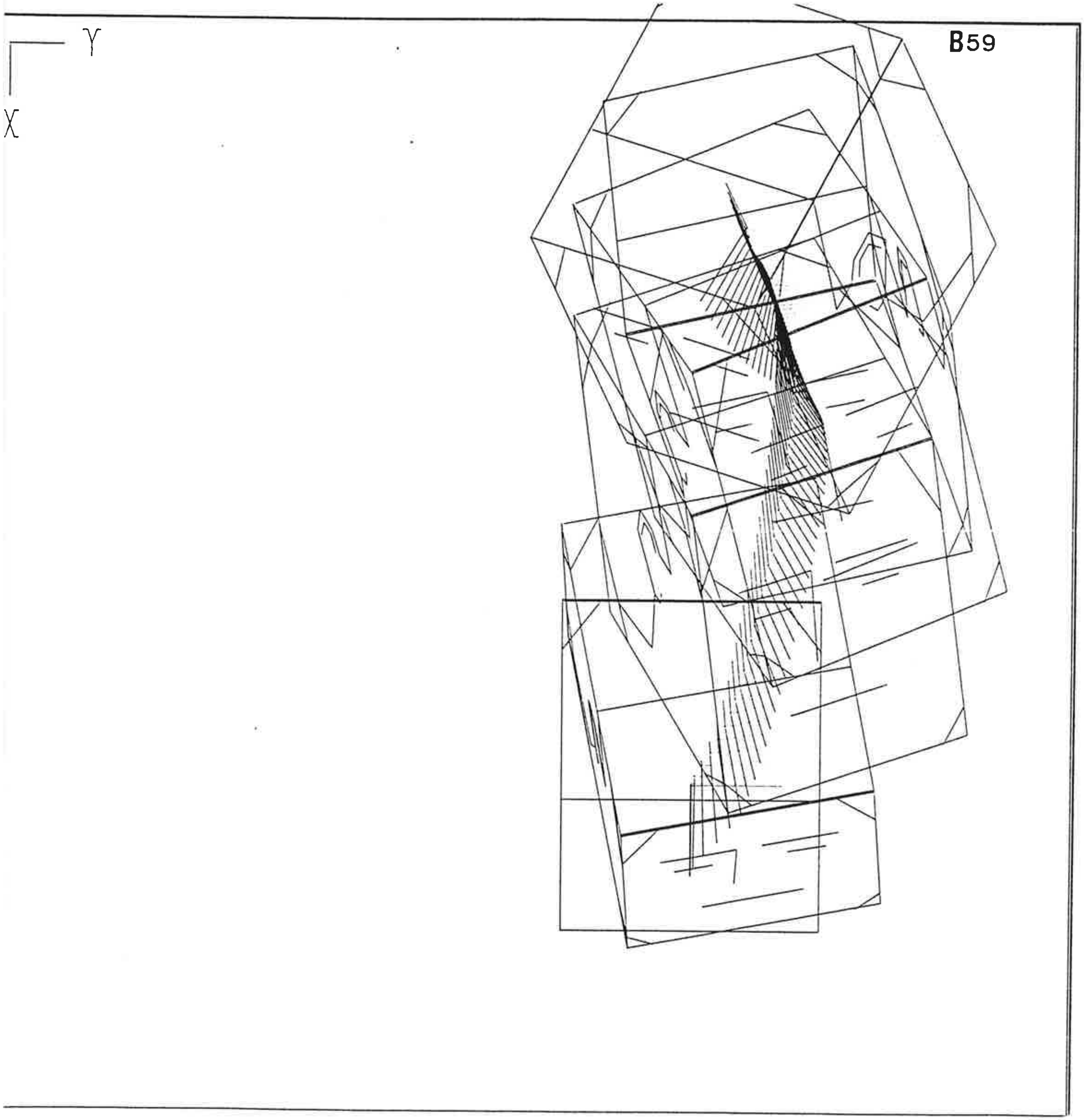
ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW B59)

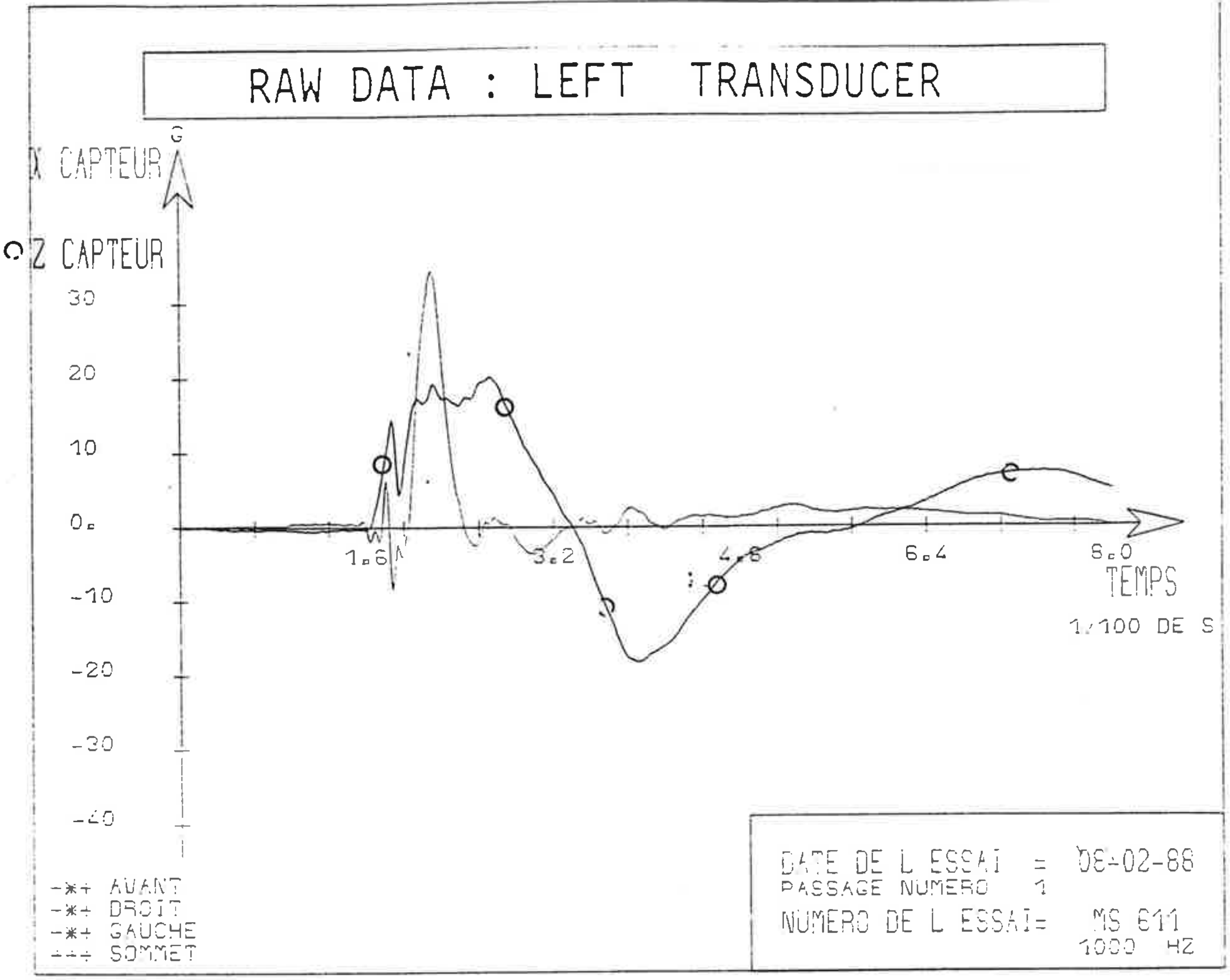
HEAD KINEMATICS FOR BLOW B59

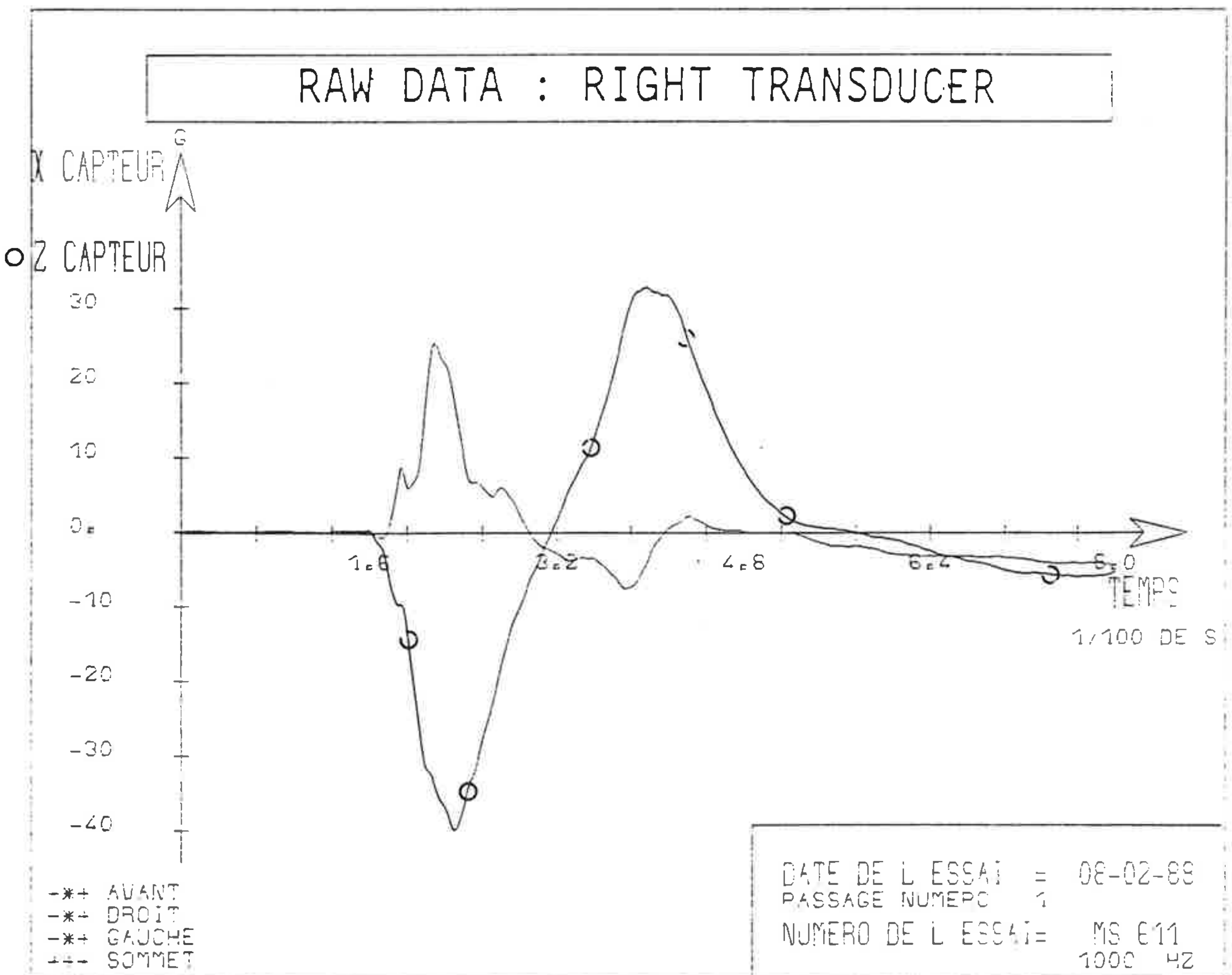

Z
X

B59

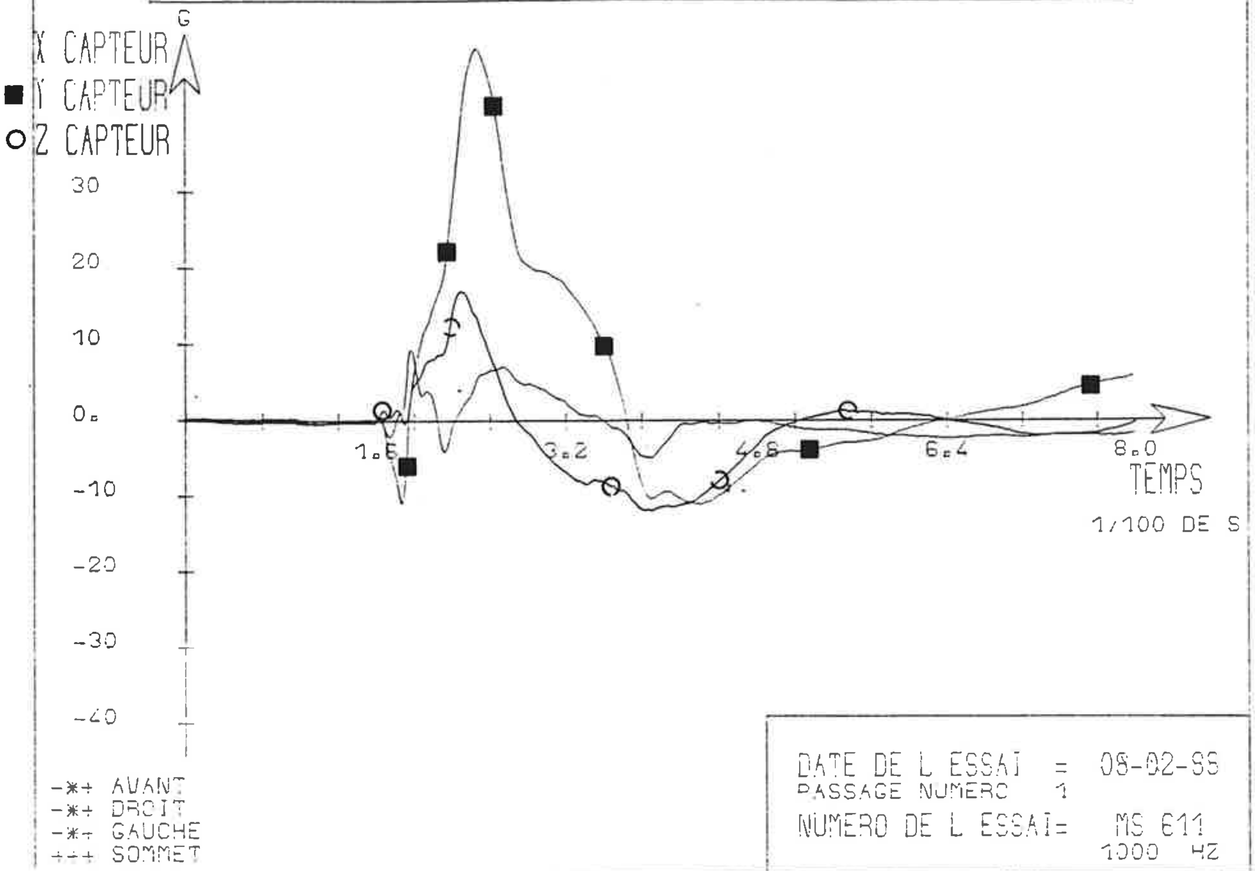



Y
X
B59

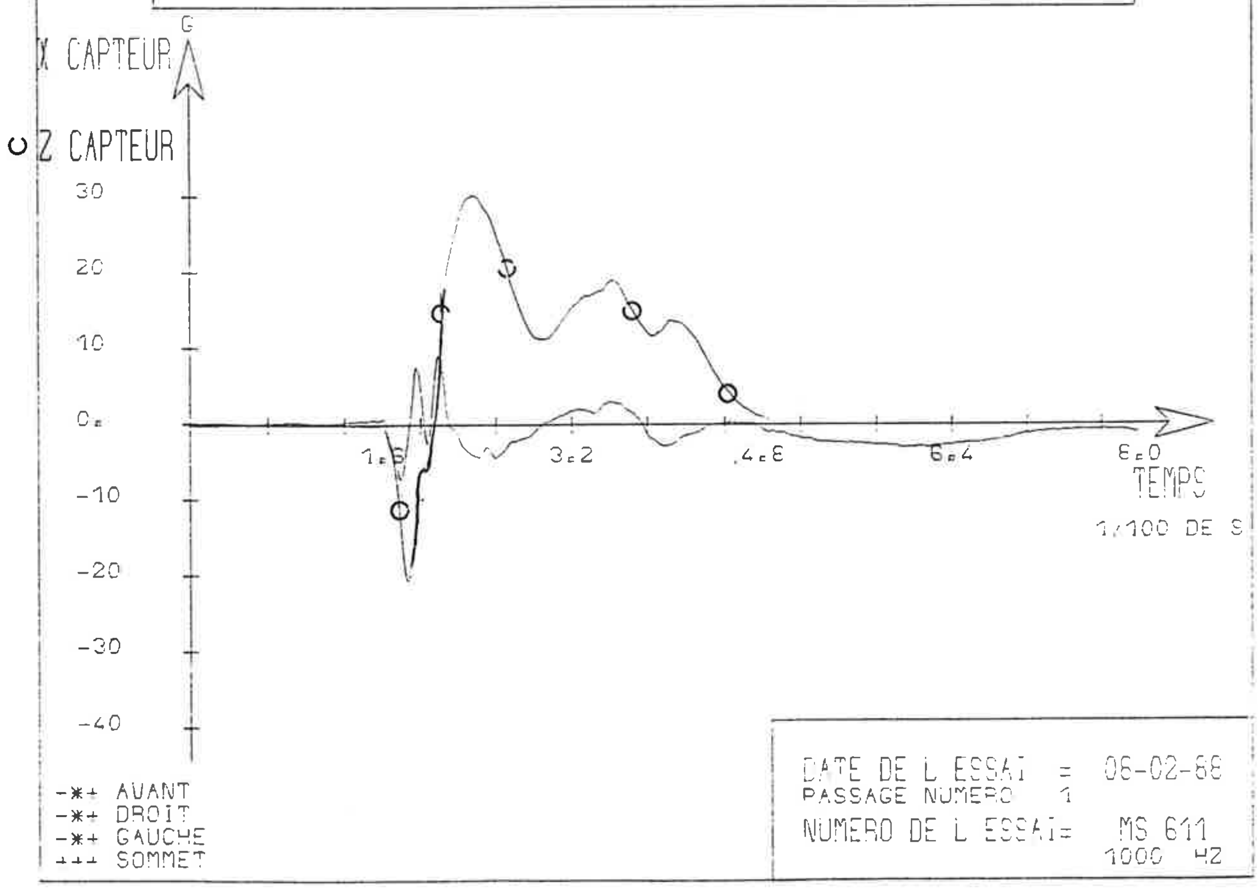

RAW DATA : LEFT TRANSDUCER
X CAPTEUR
G
Z CAPTEUR
30
20
10
0.
-10
-20
-30
-40
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 08-02-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 611
1000 HZ


RAW DATA : RIGHT TRANSDUCER
X CAPTEUR
G
Z CAPTEUR
30
20
10
0.
-10
-20
-30
-40
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 08-02-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 611
1000 HZ

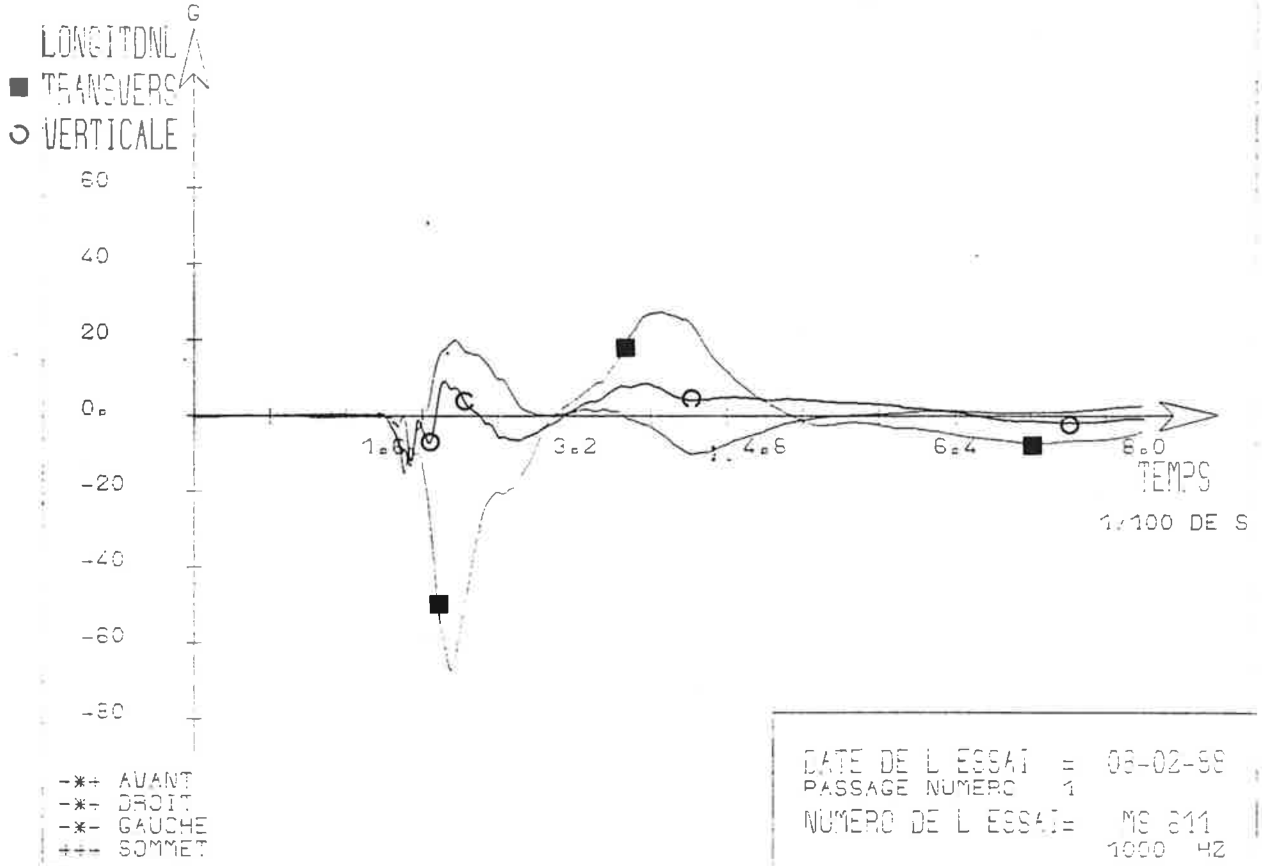
RAW DATA : TOP TRANSDUCER



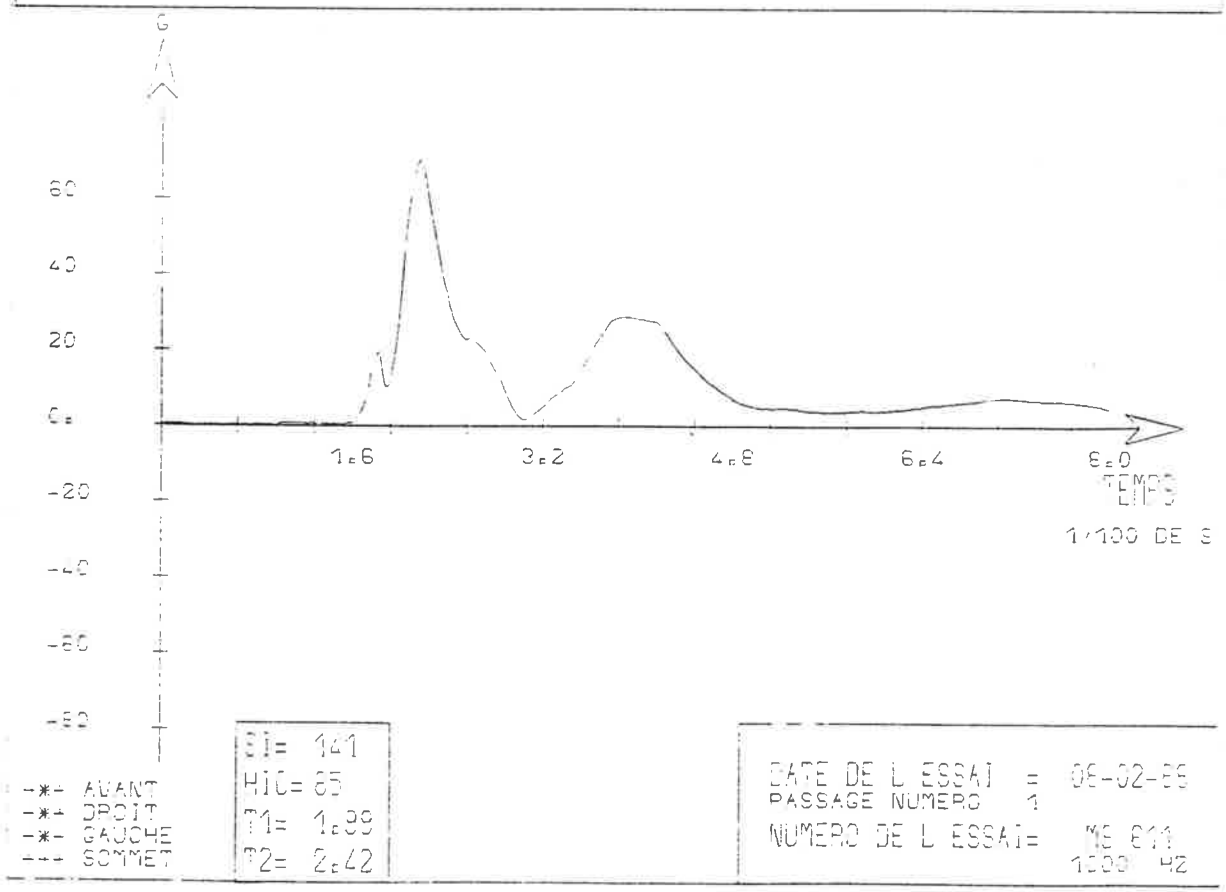
RAW DATA : FRONTAL TRANSDUCER

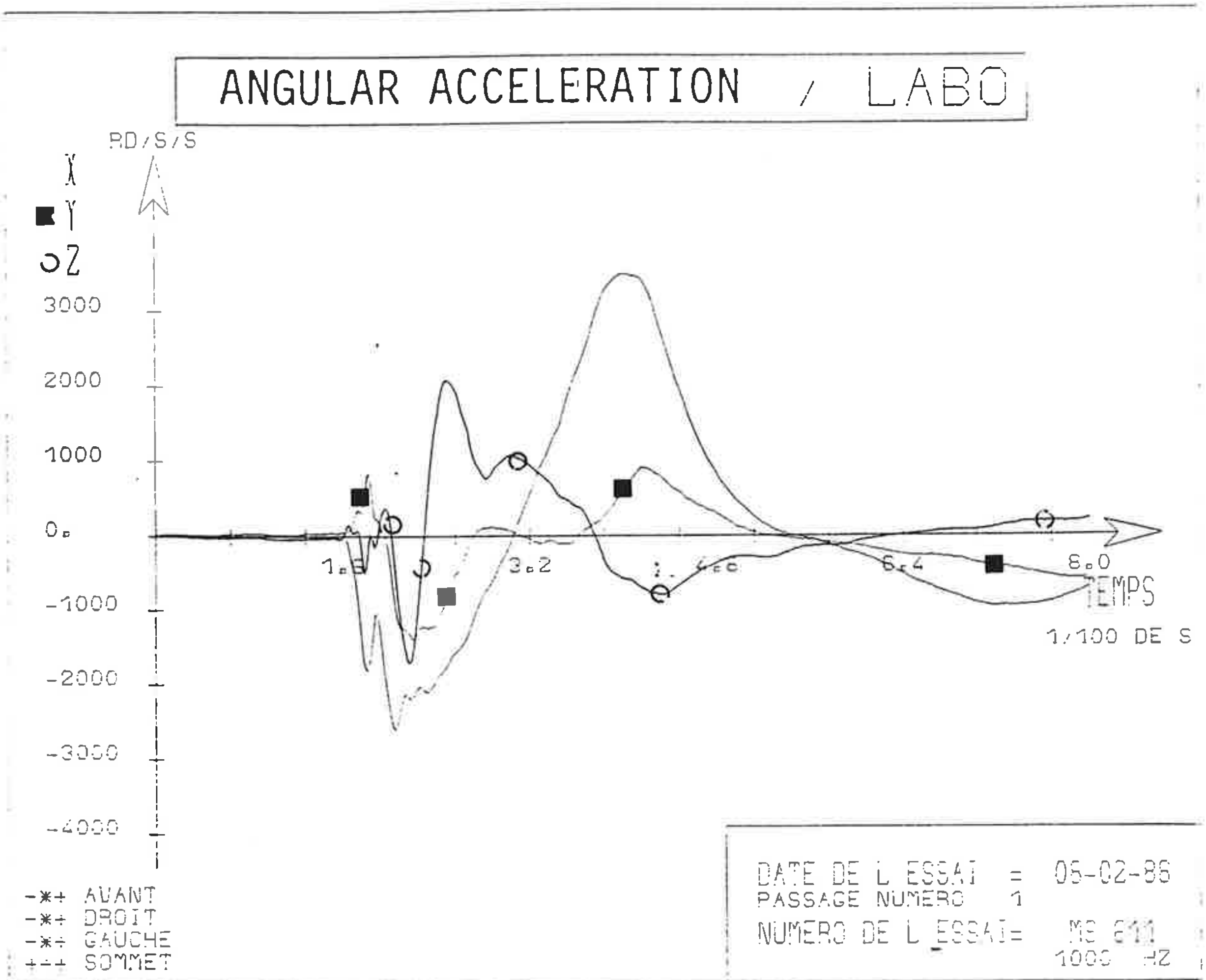


LINEAR ACCELERATIONS AT CG

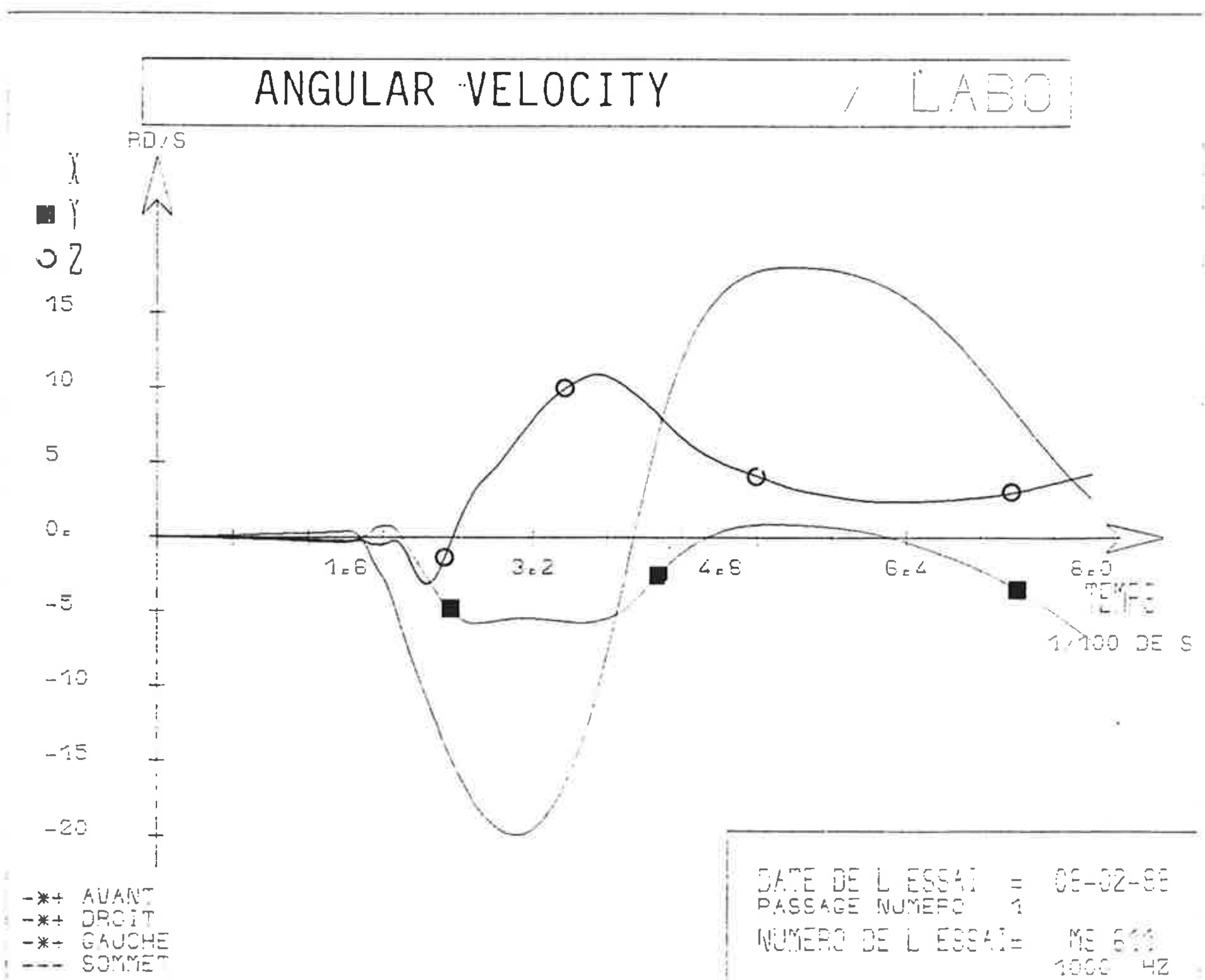


RESULTANT ACCELERATION AT CG

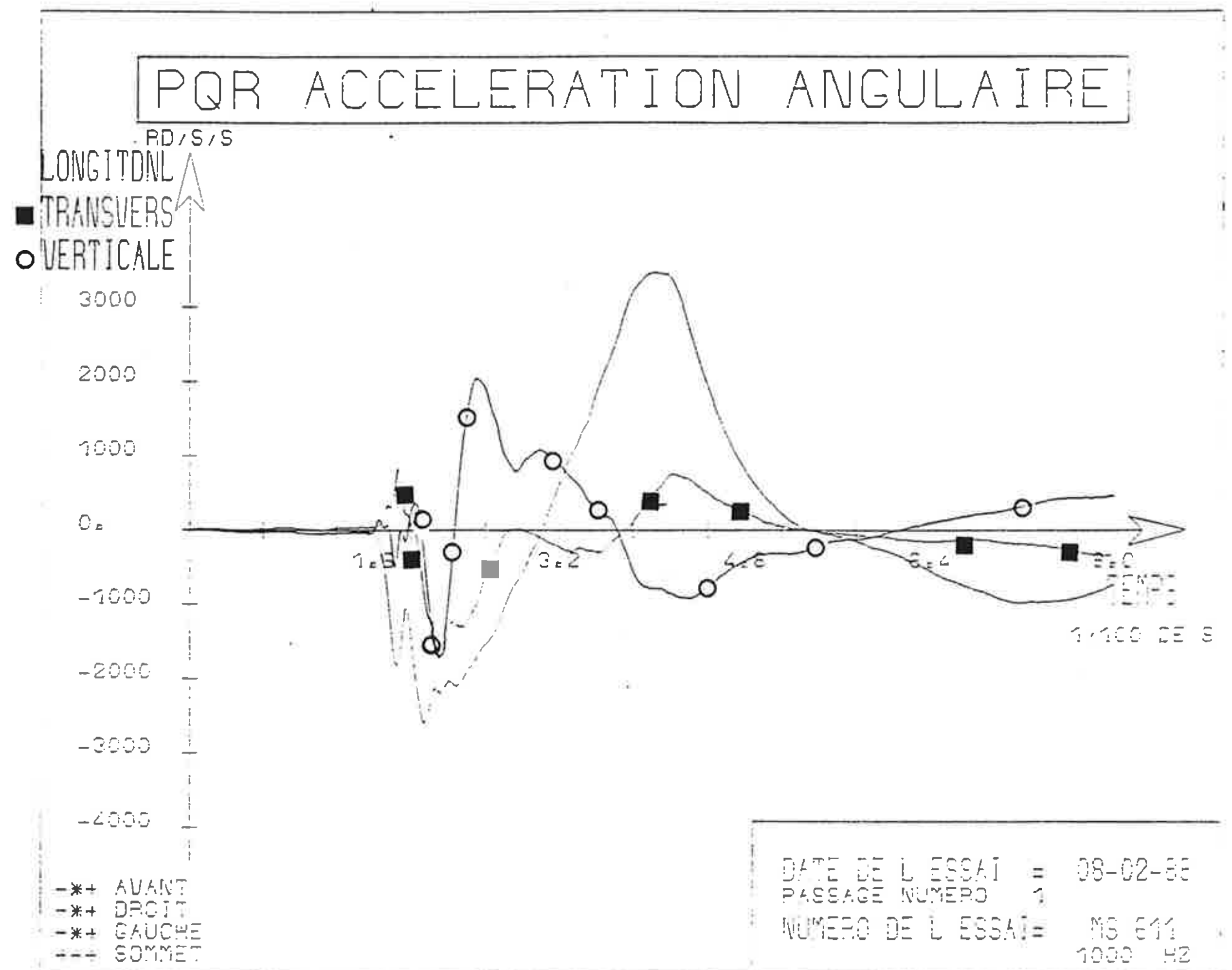




ANGULAR ACCELERATION / LABO
RD/S/S
X
Y
Z
3000
2000
1000
0.
-1000
-2000
-3000
-4000
3.2
6.4
8.0
TEMPS
1/100 DE S
DATE DE L ESSAI = 06-02-86
PASSAGE NUMERO 1
NUMERO DE L ESSAI=
1000 HZ
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET

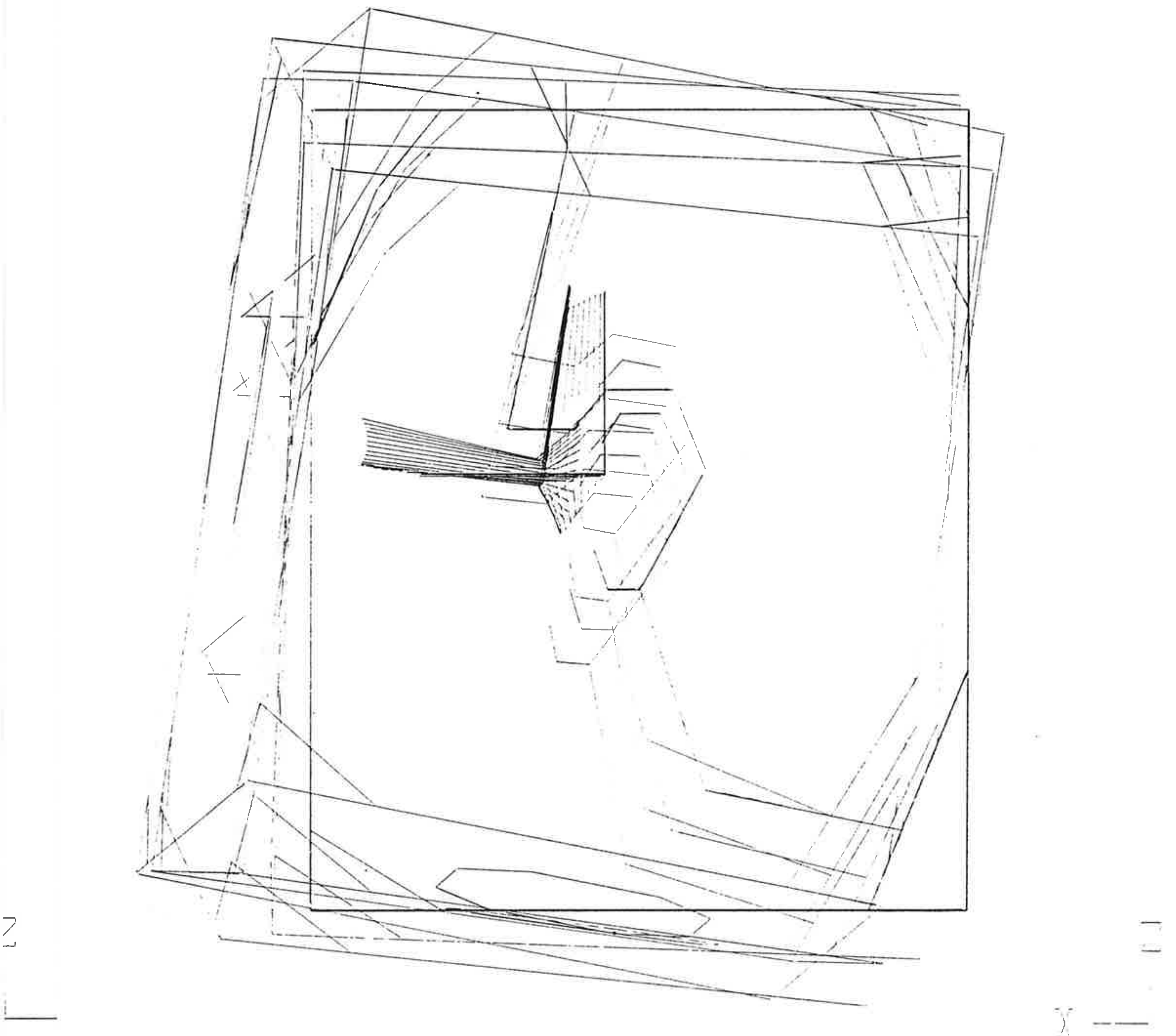


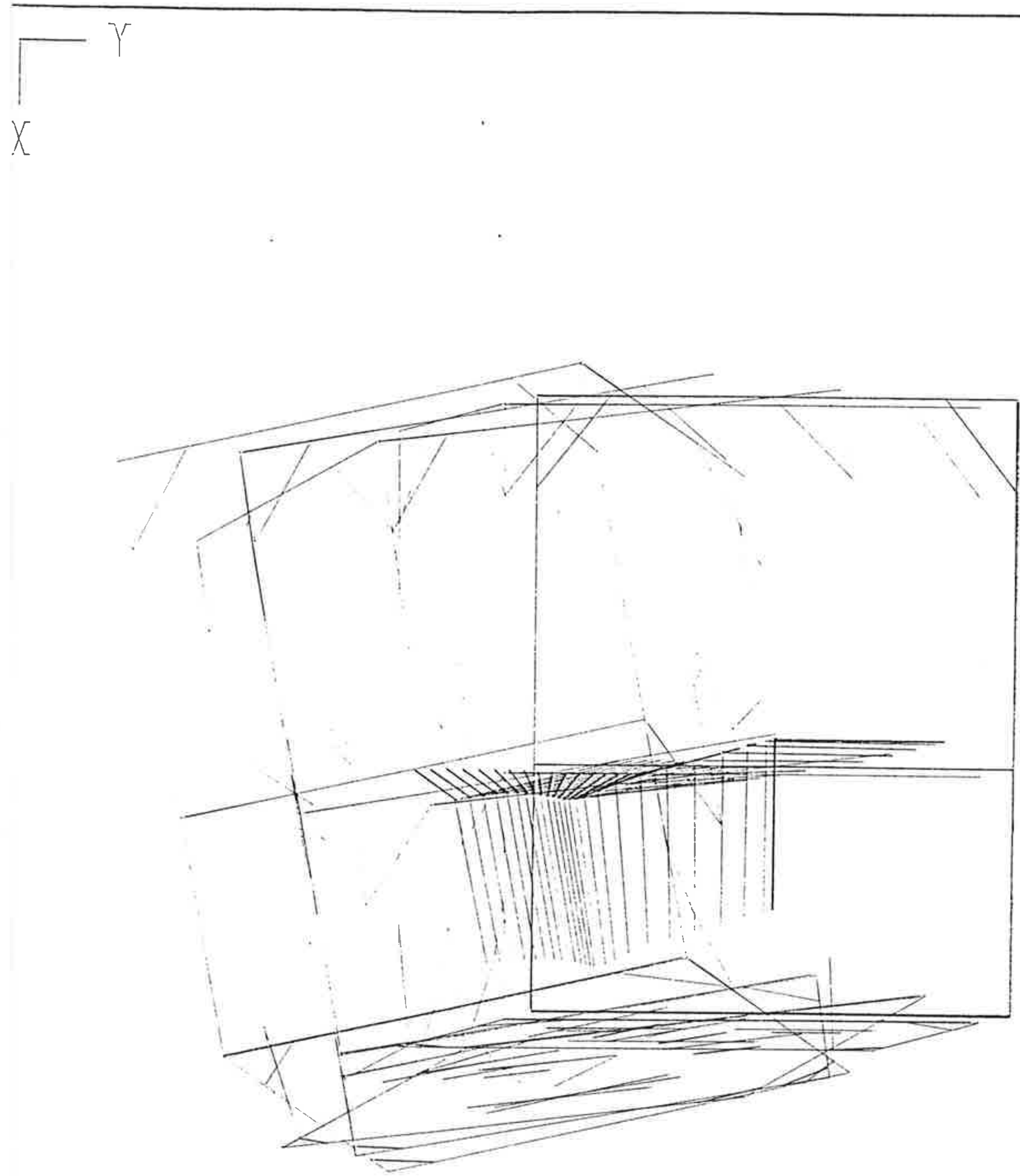
ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
15
10
5
0.
-5
-10
-15
-20
1.6
3.2
4.8
6.4
TEMPS
1/100 DE S
DATE DE L ESSAI
PASSAGE NUMERO 1
NUMERO DE L ESSAI=
1000 HZ
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
--- SOMMET

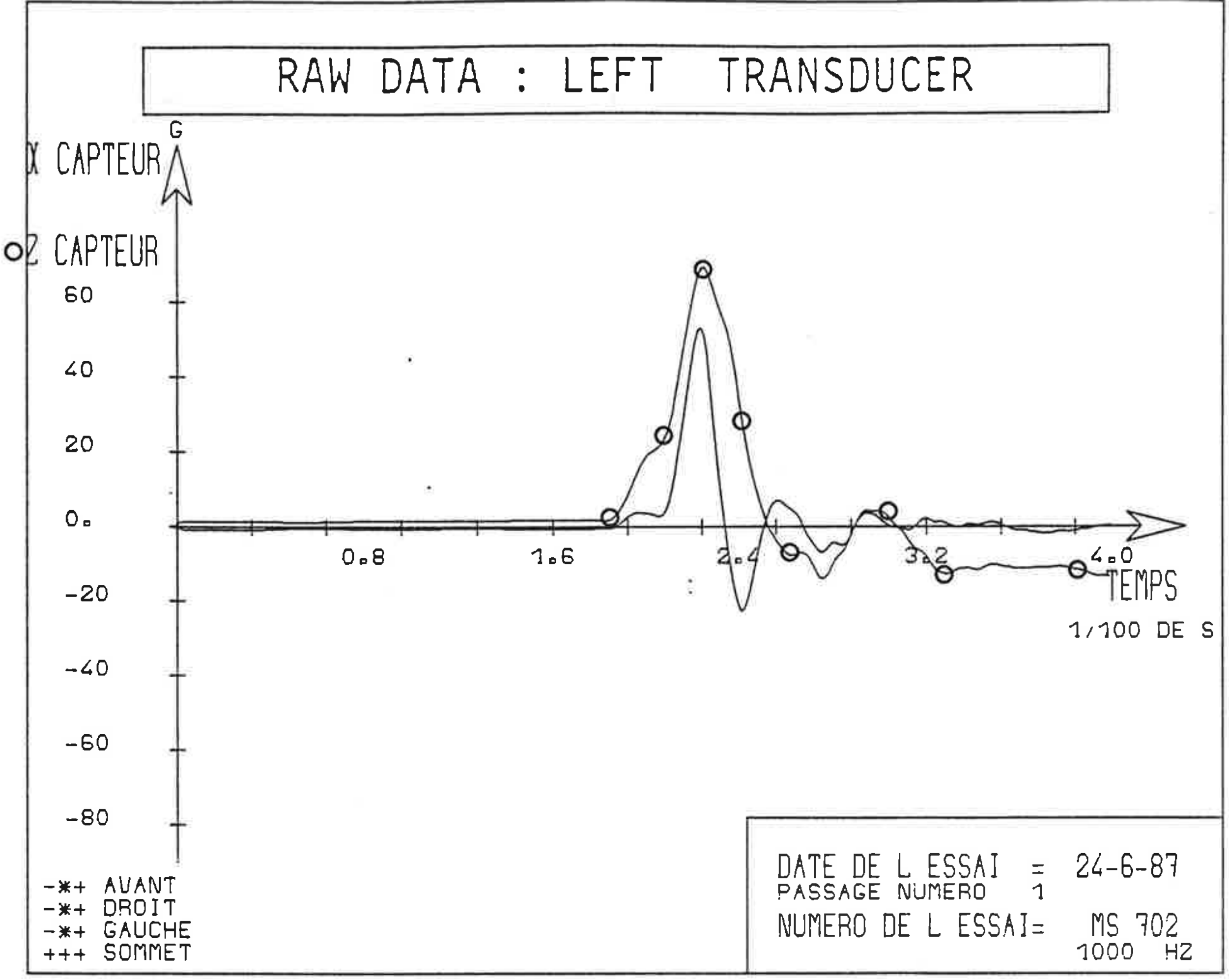


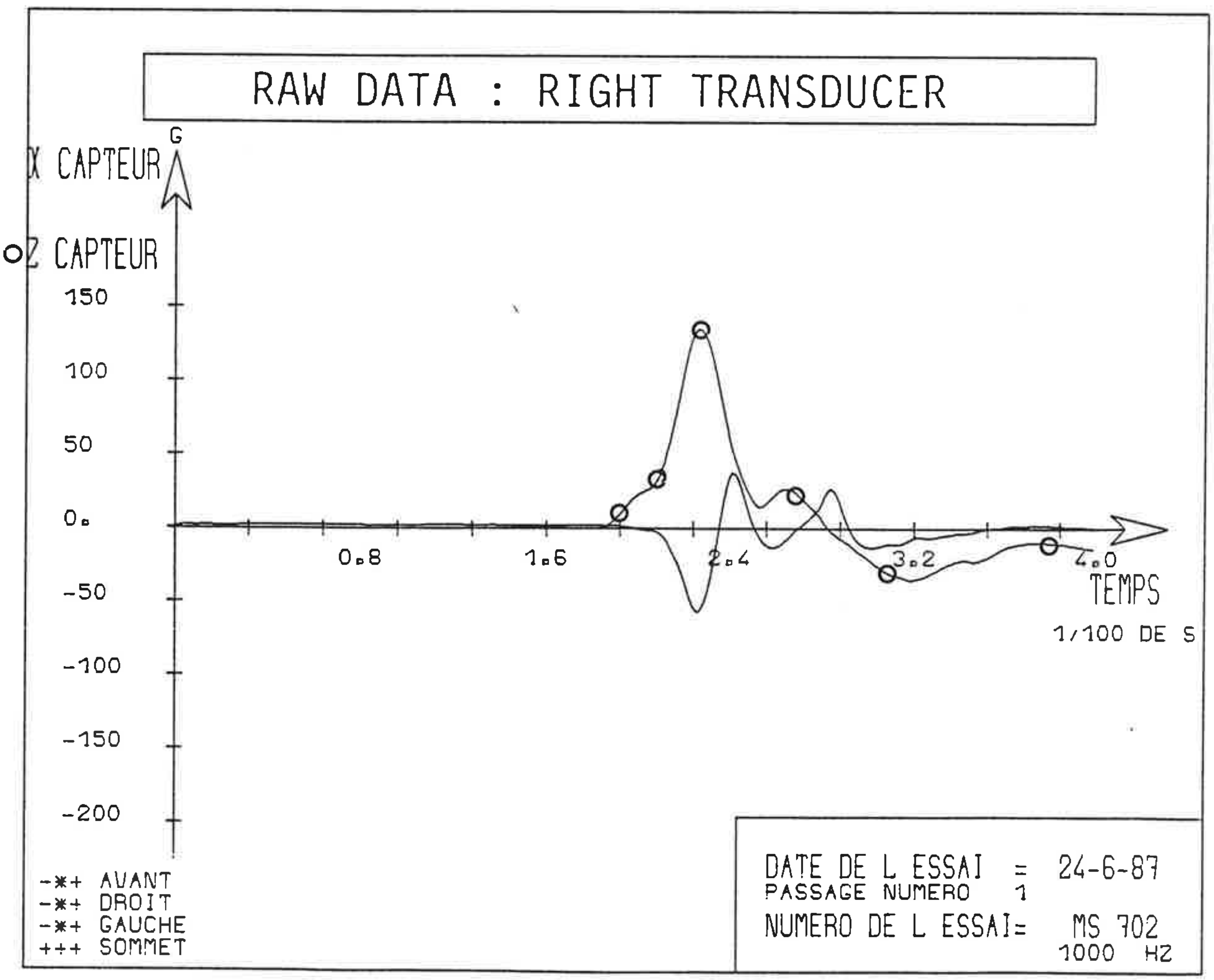
ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW 611)

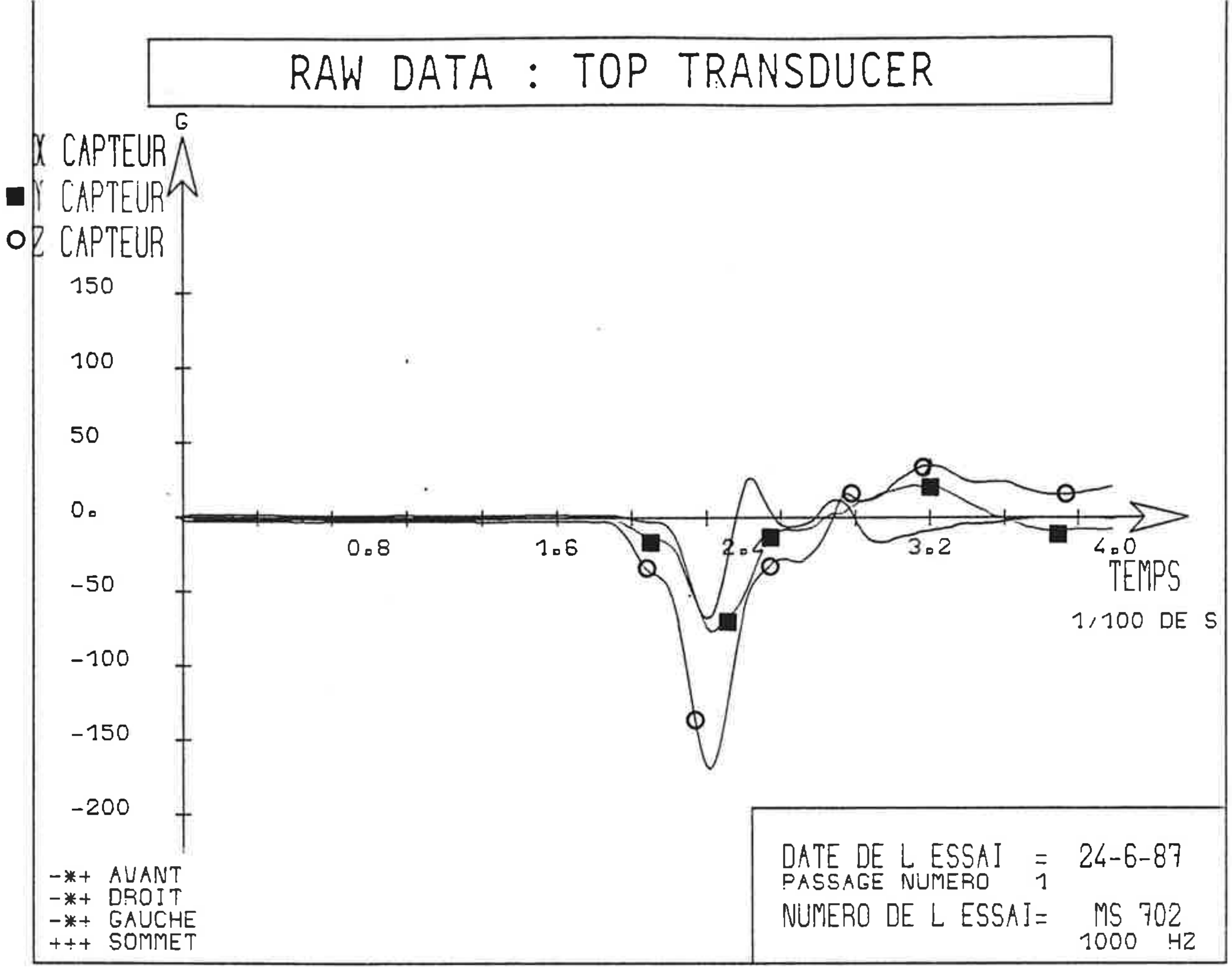
HEAD KINEMATICS FOR BLOW 611

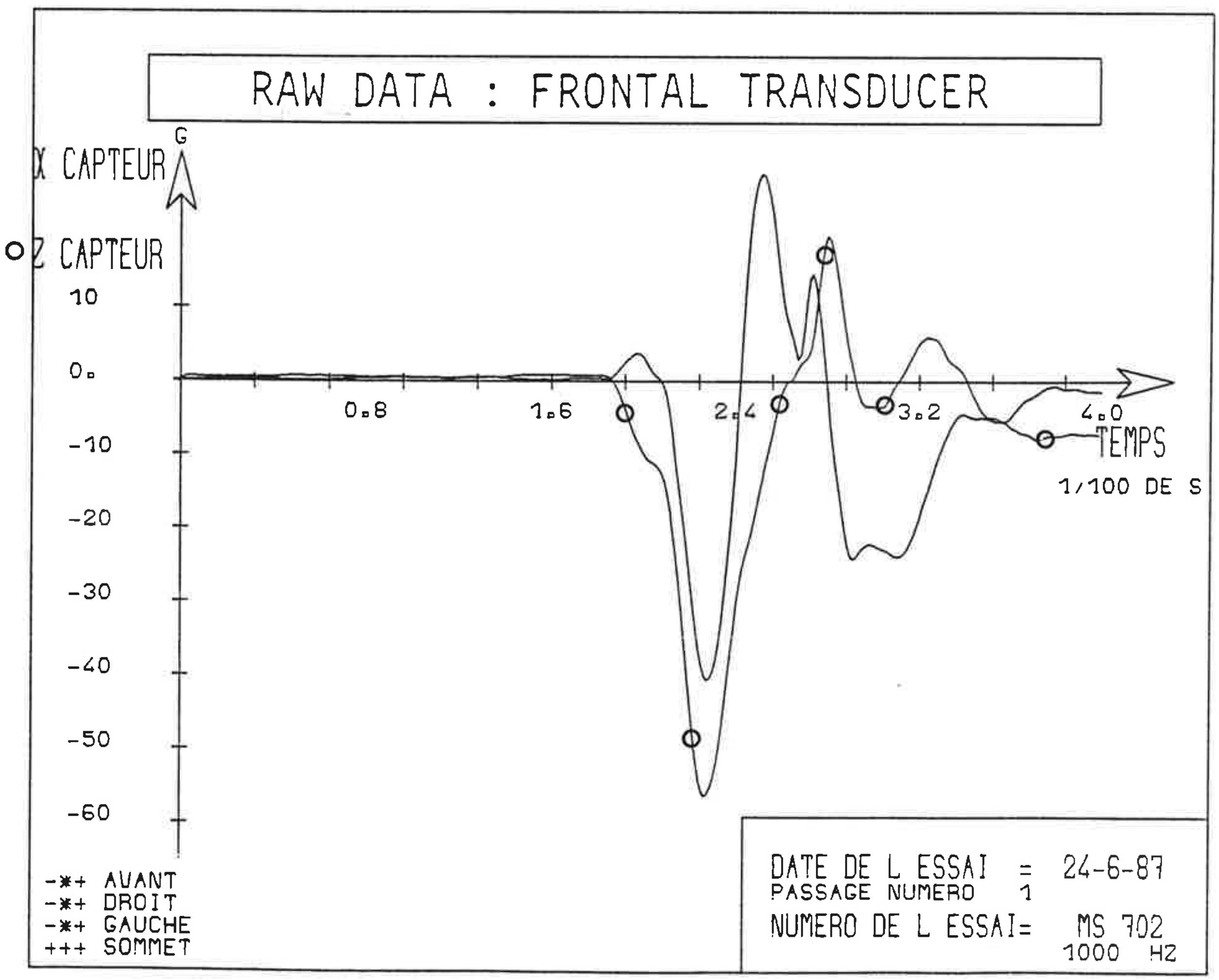


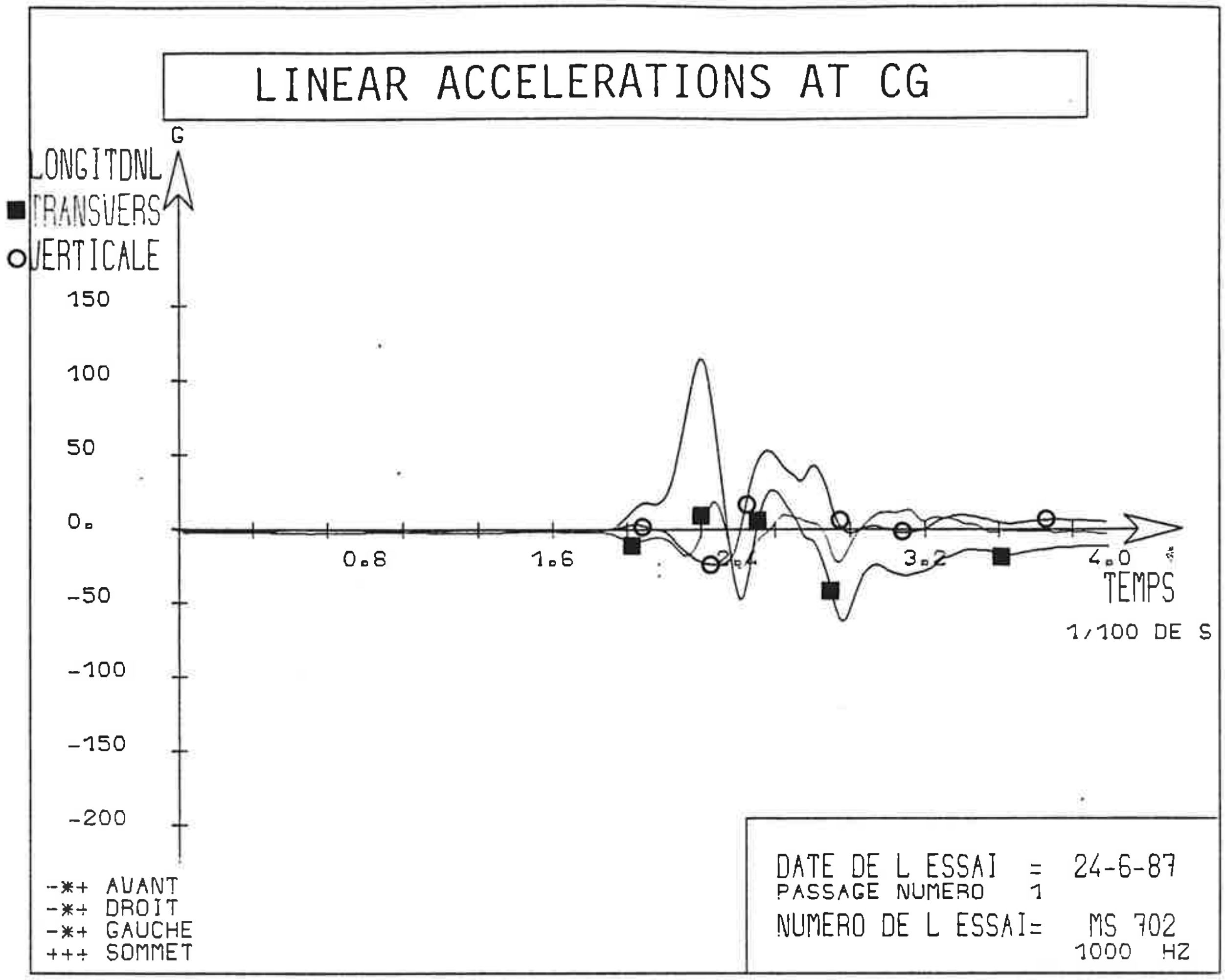

Y
X

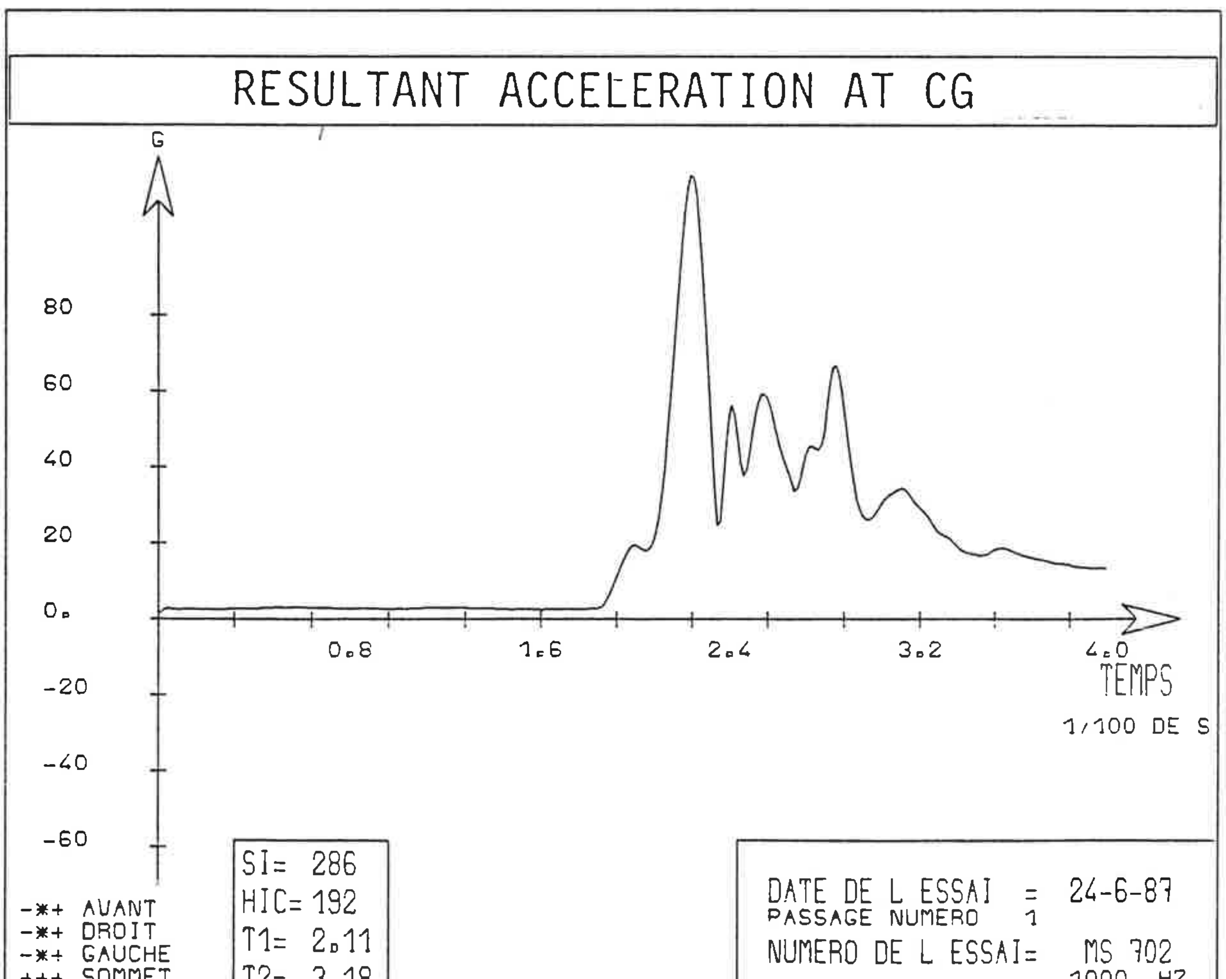

RAW DATA : LEFT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ

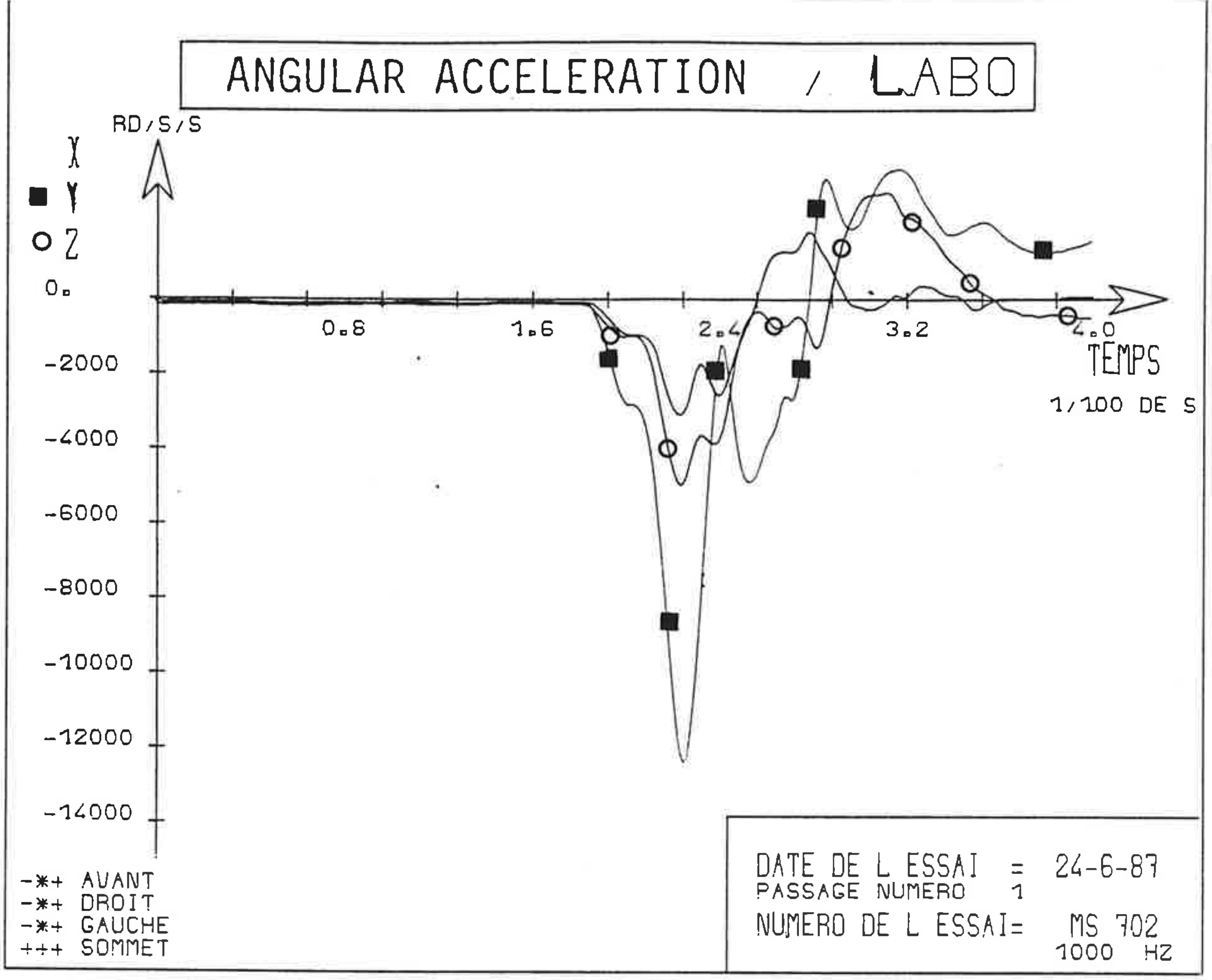

RAW DATA : RIGHT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
150
100
50
0.
-50
-100
-150
-200
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ

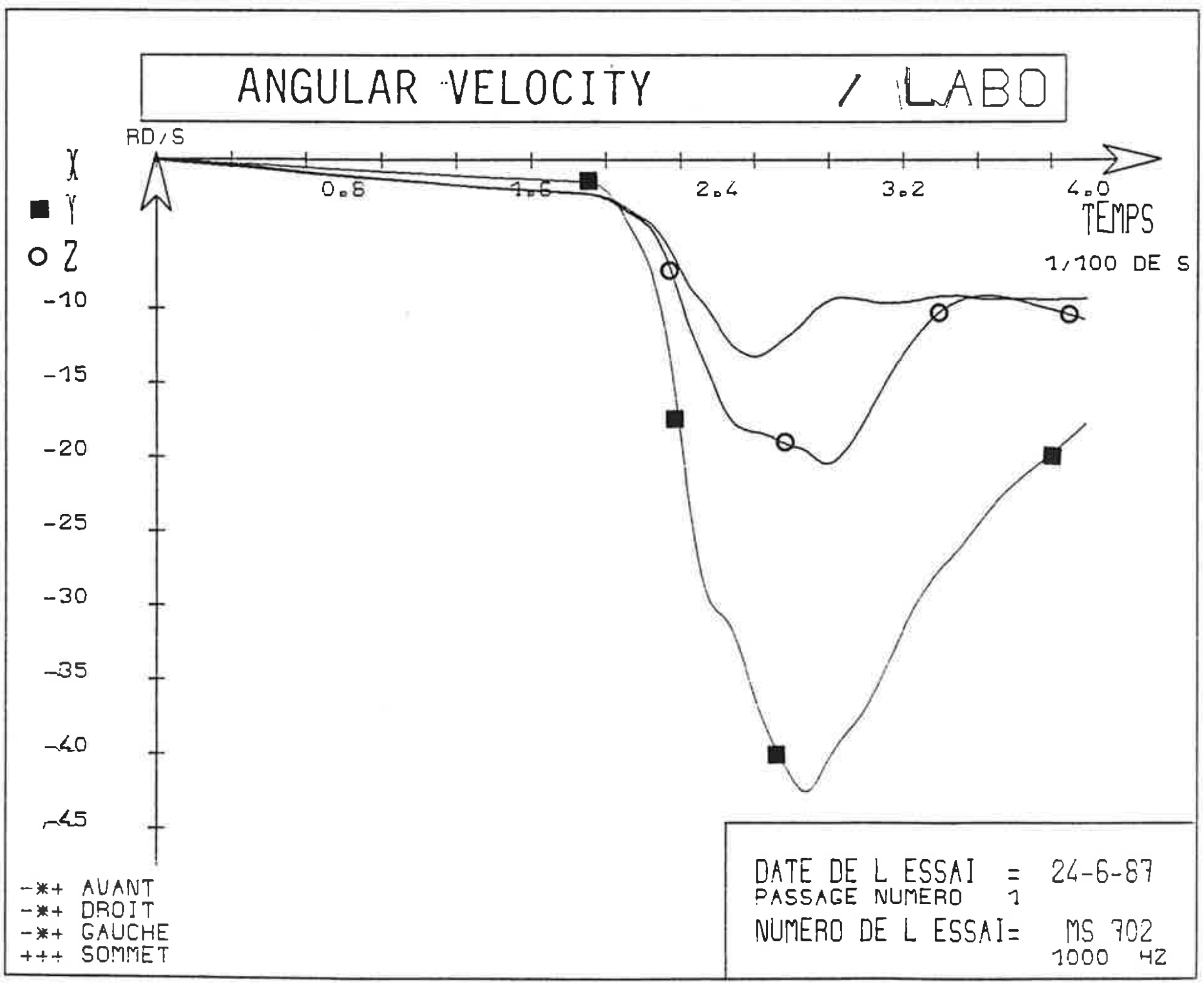

RAW DATA : TOP TRANSDUCER
G
X CAPTEUR
Y CAPTEUR
Z CAPTEUR
150
100
50
0.
-50
-100
-150
-200
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ

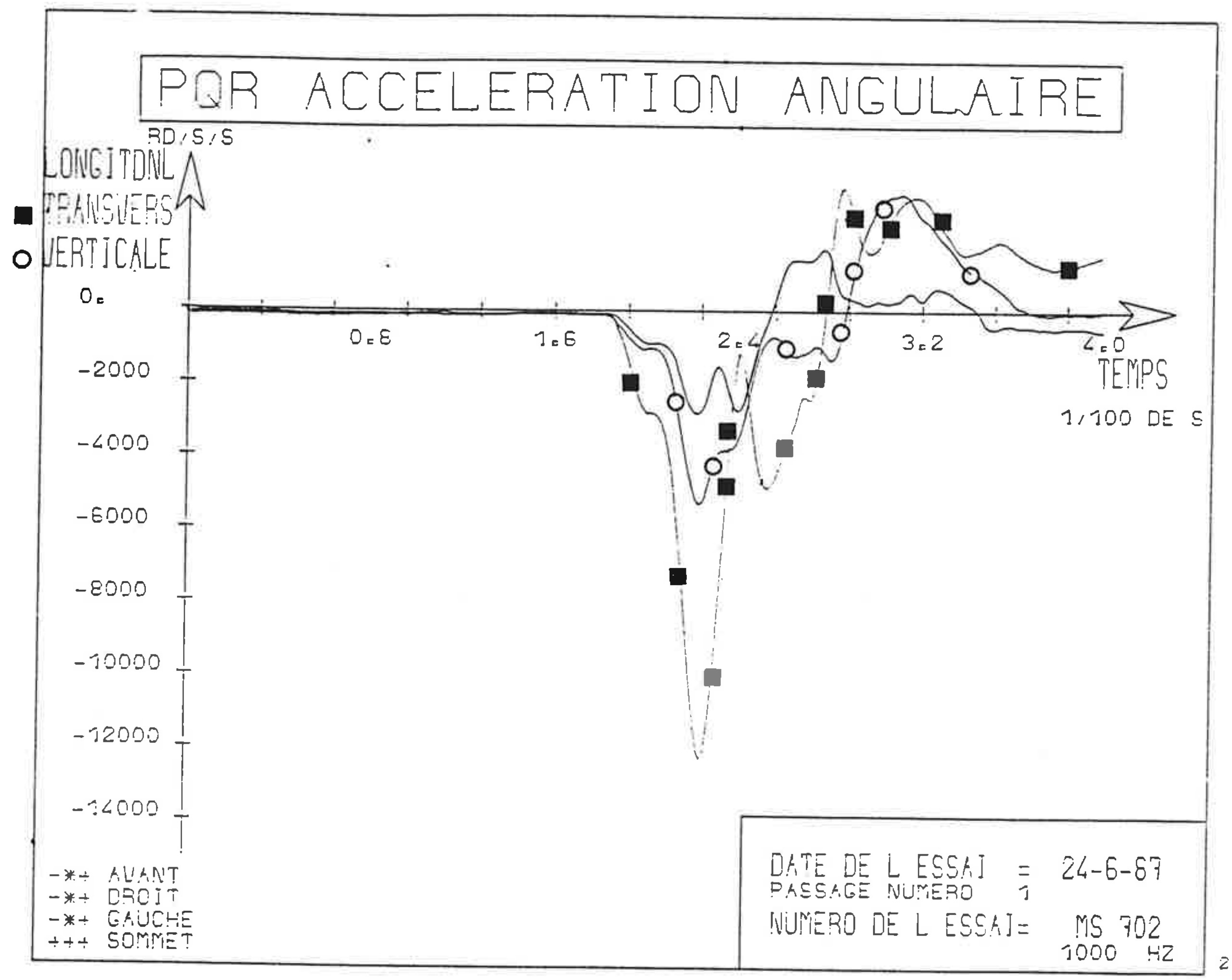

RAW DATA : FRONTAL TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
10
0.
-10
-20
-30
-40
-50
-60
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ


LINEAR ACCELERATIONS AT CG
G
LONGITDNL
TRANSVERS
VERTICALE
150
100
50
0.
-50
-100
-150
-200
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ


RESULTANT ACCELERATION AT CG
G
80
60
40
20
0.
-20
-40
-60
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
SI= 286
HIC= 192
T1= 2.11
T2= 3.18
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ

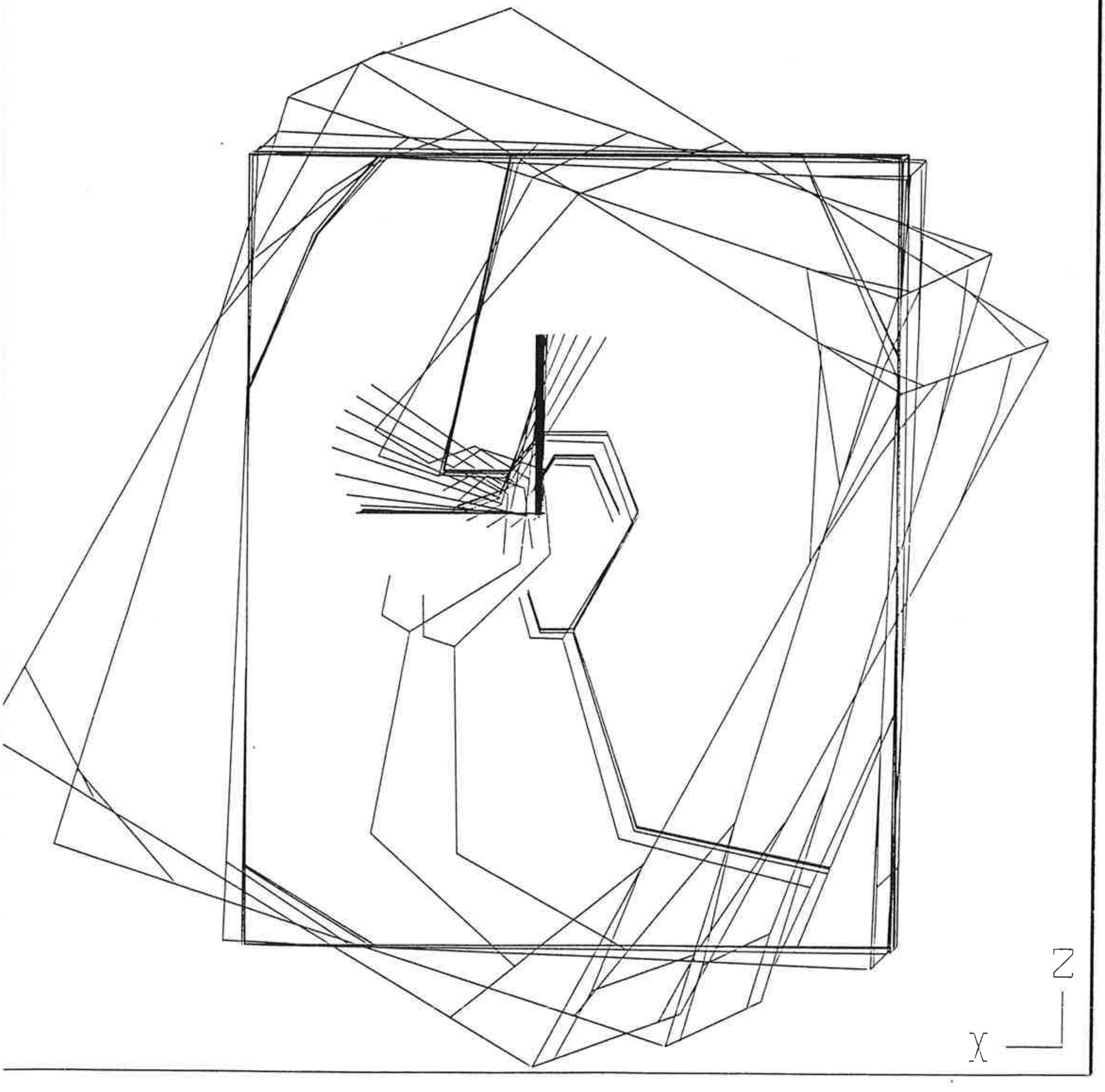

ANGULAR ACCELERATION / LABO
RD/S/S
X
Y
Z
0.
-2000
-4000
-6000
-8000
-10000
-12000
-14000
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ

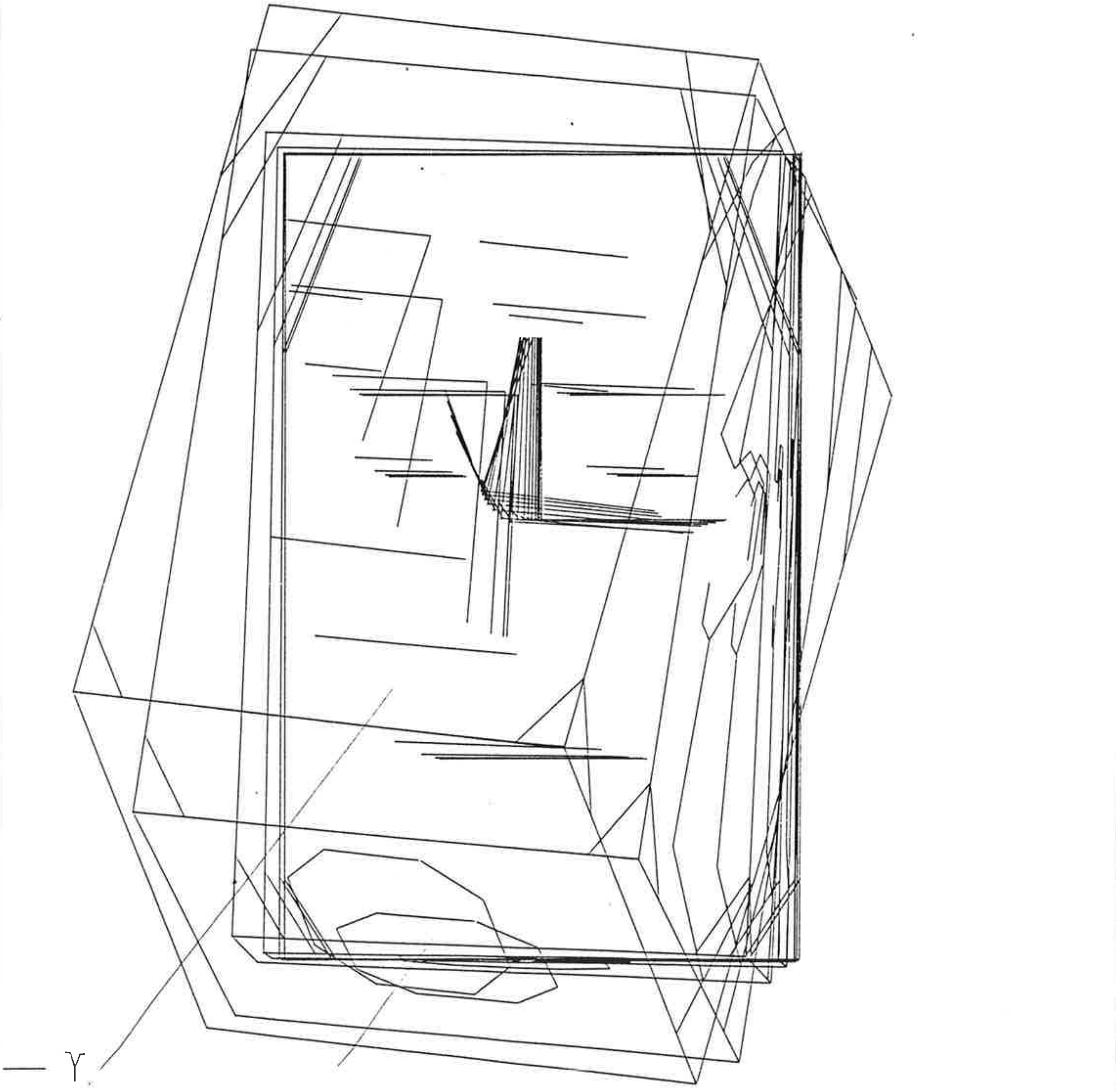

ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
-10
-15
-20
-25
-30
-35
-40
-45
0.8
1.6
2.4
3.2
4.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 24-6-87
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 702
1000 HZ

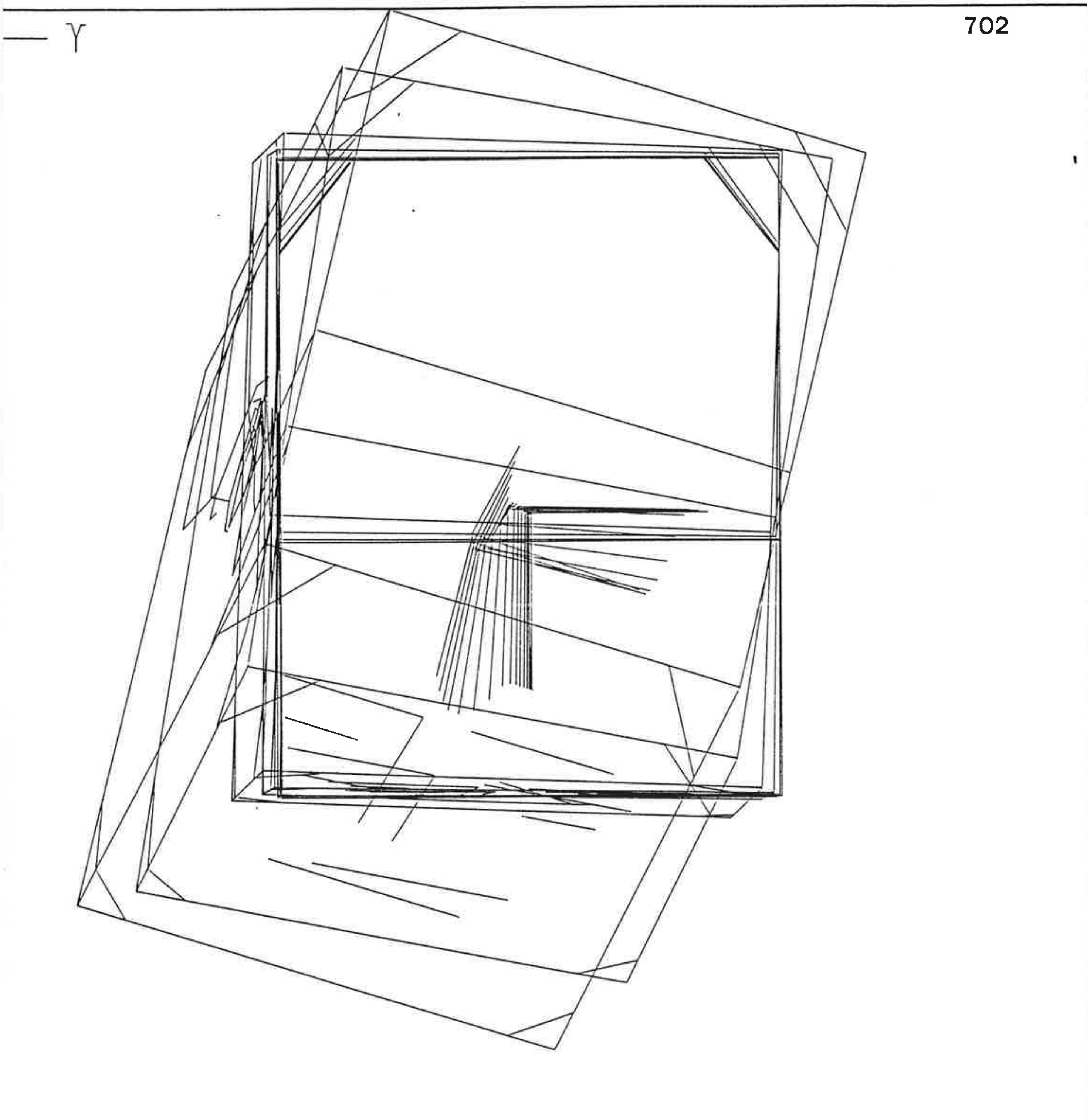


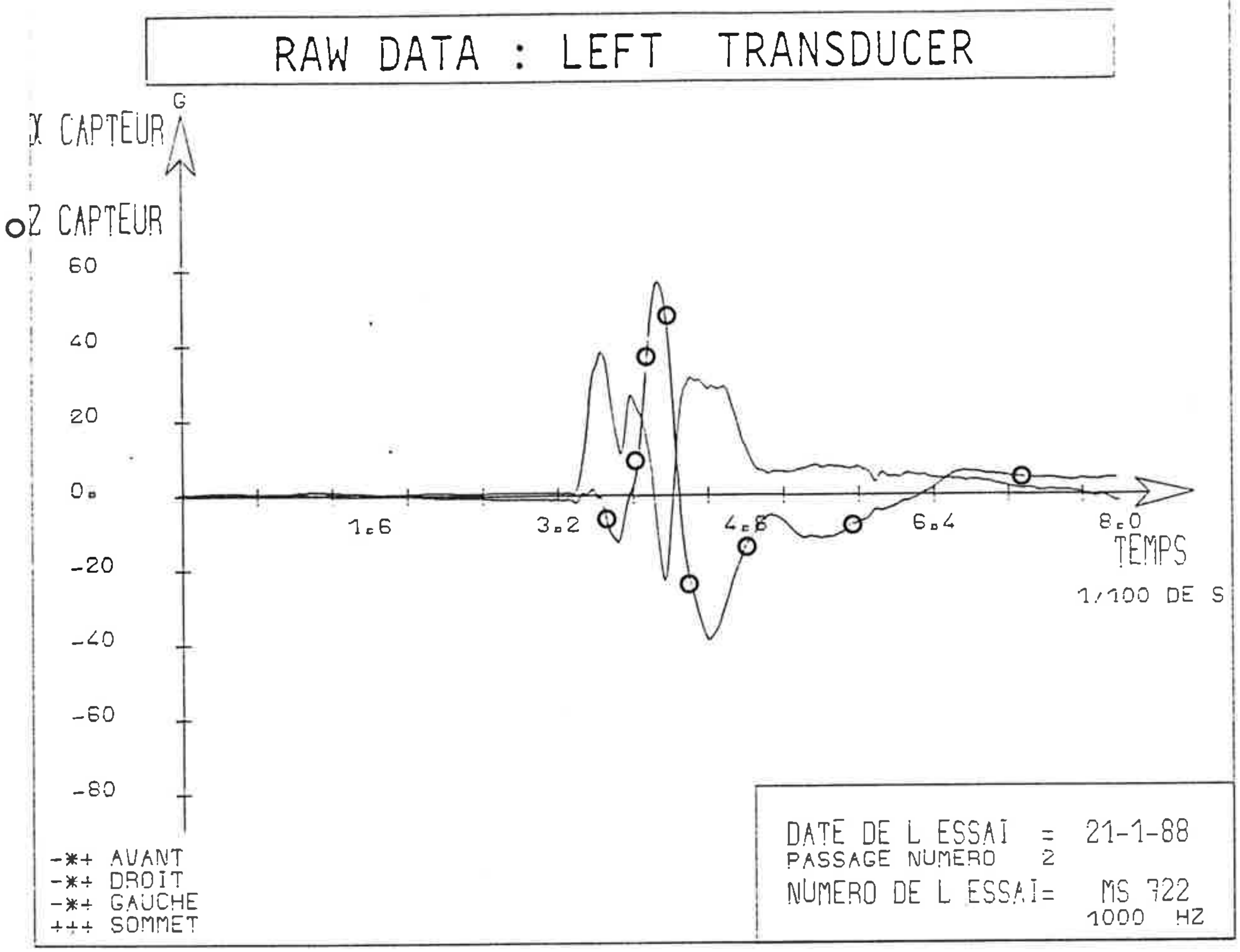
ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW 702)

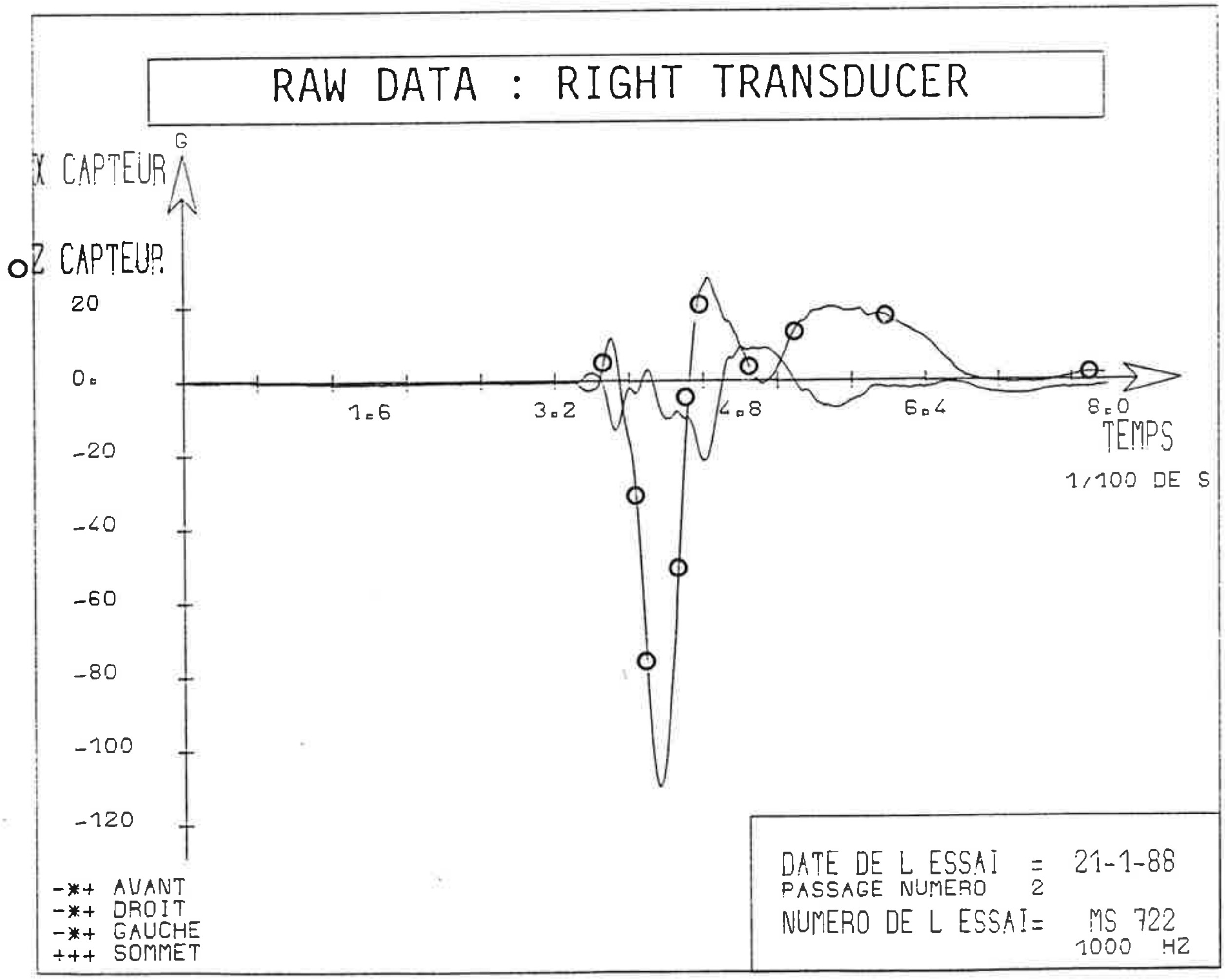
HEAD KINEMATICS FOR BLOW 702

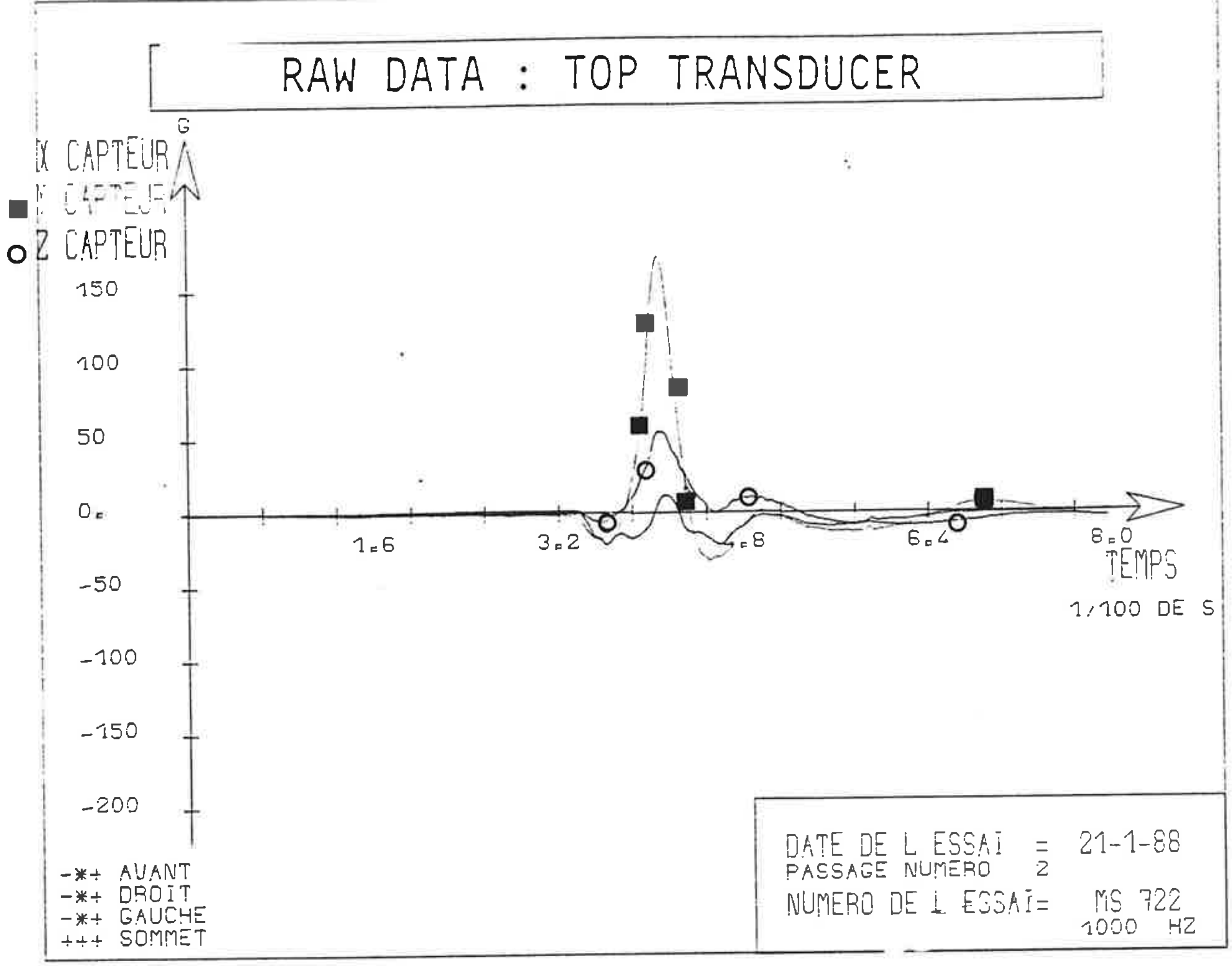

Z
X

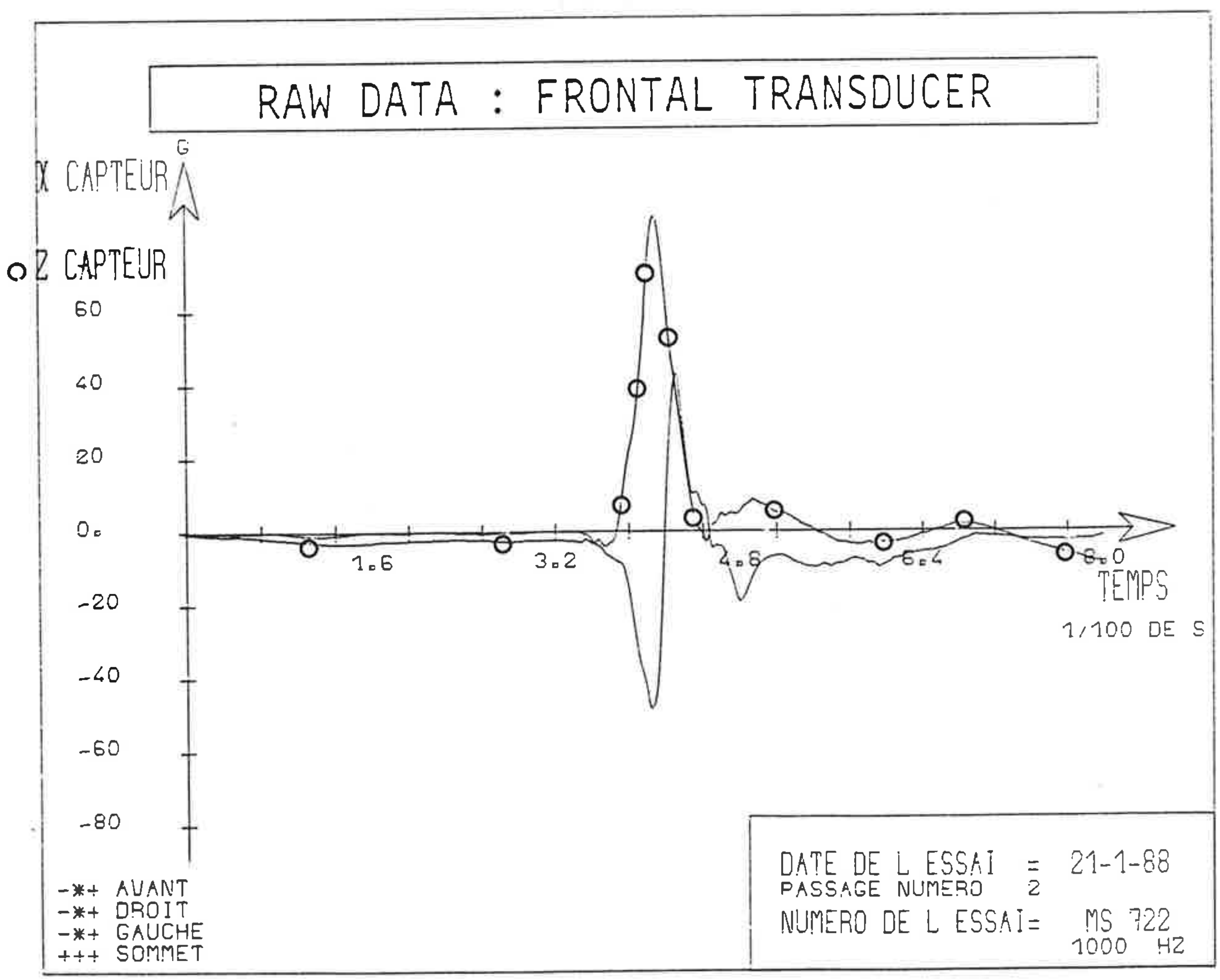

Y

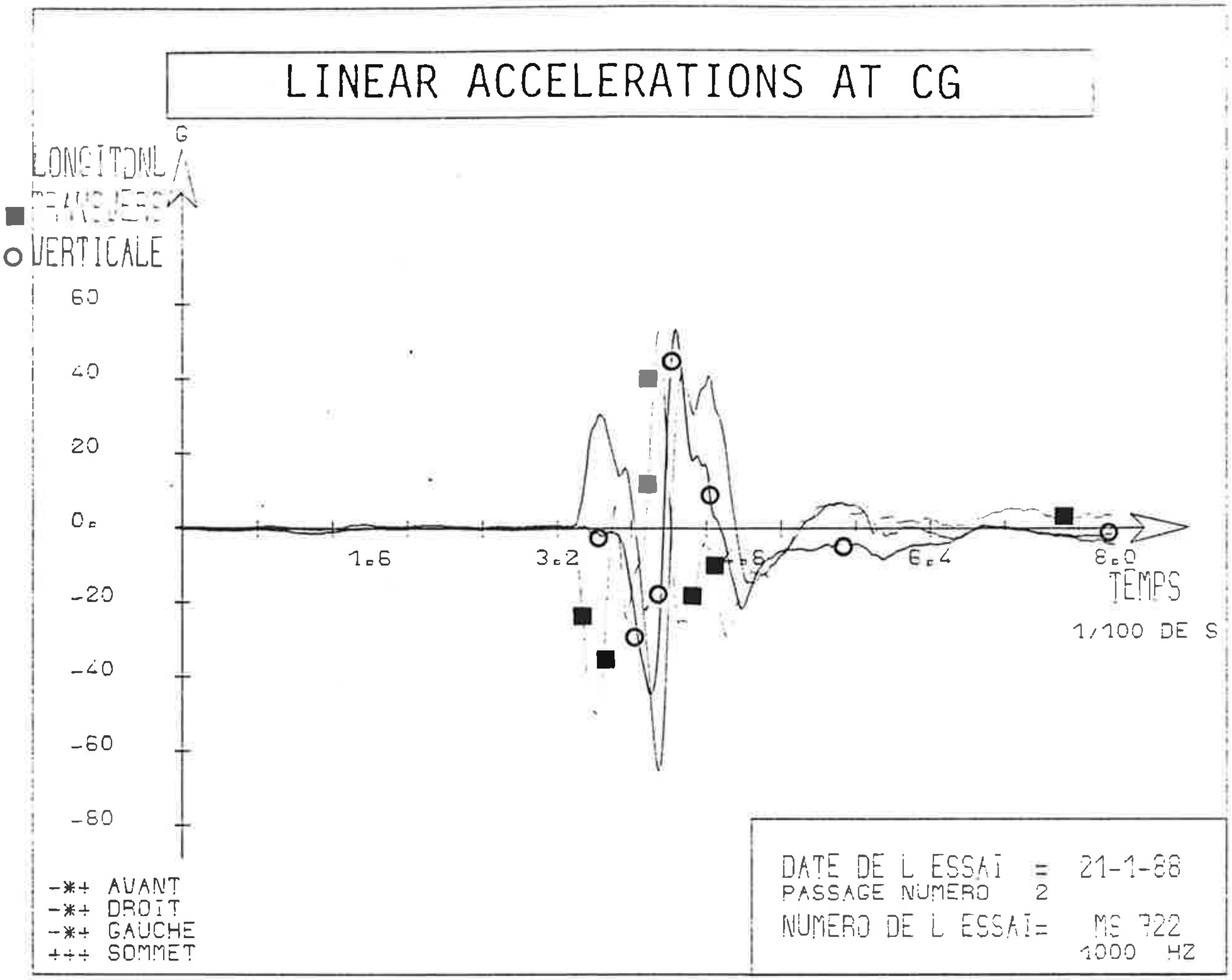


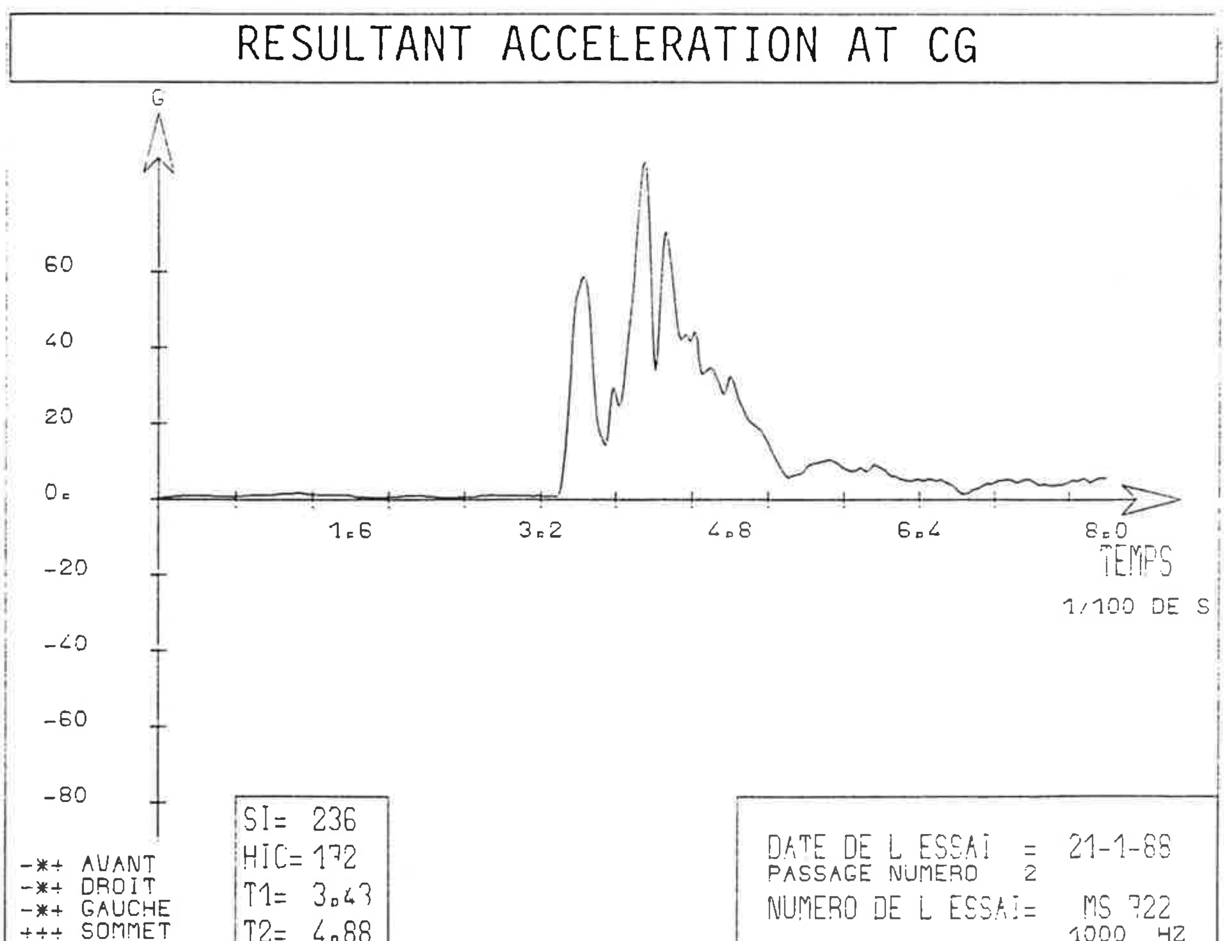

RAW DATA : LEFT TRANSDUCER
X CAPTEUR
G
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ

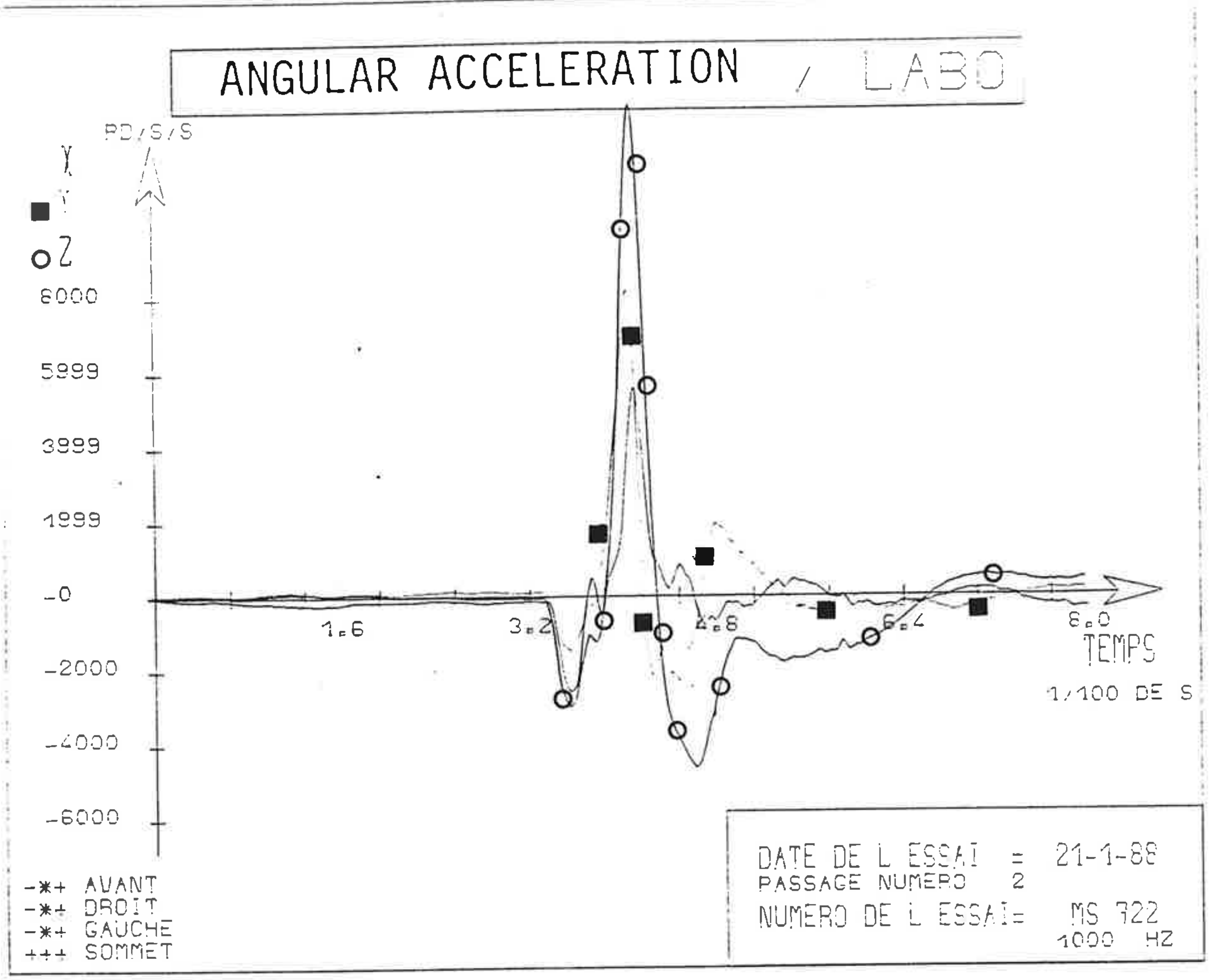

RAW DATA : RIGHT TRANSDUCER
X CAPTEUR
G
Z CAPTEUR
20
0.
-20
-40
-60
-80
-100
-120
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ


RAW DATA : TOP TRANSDUCER
X CAPTEUR
Z CAPTEUR
G
150
100
50
0.
-50
-100
-150
-200
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ

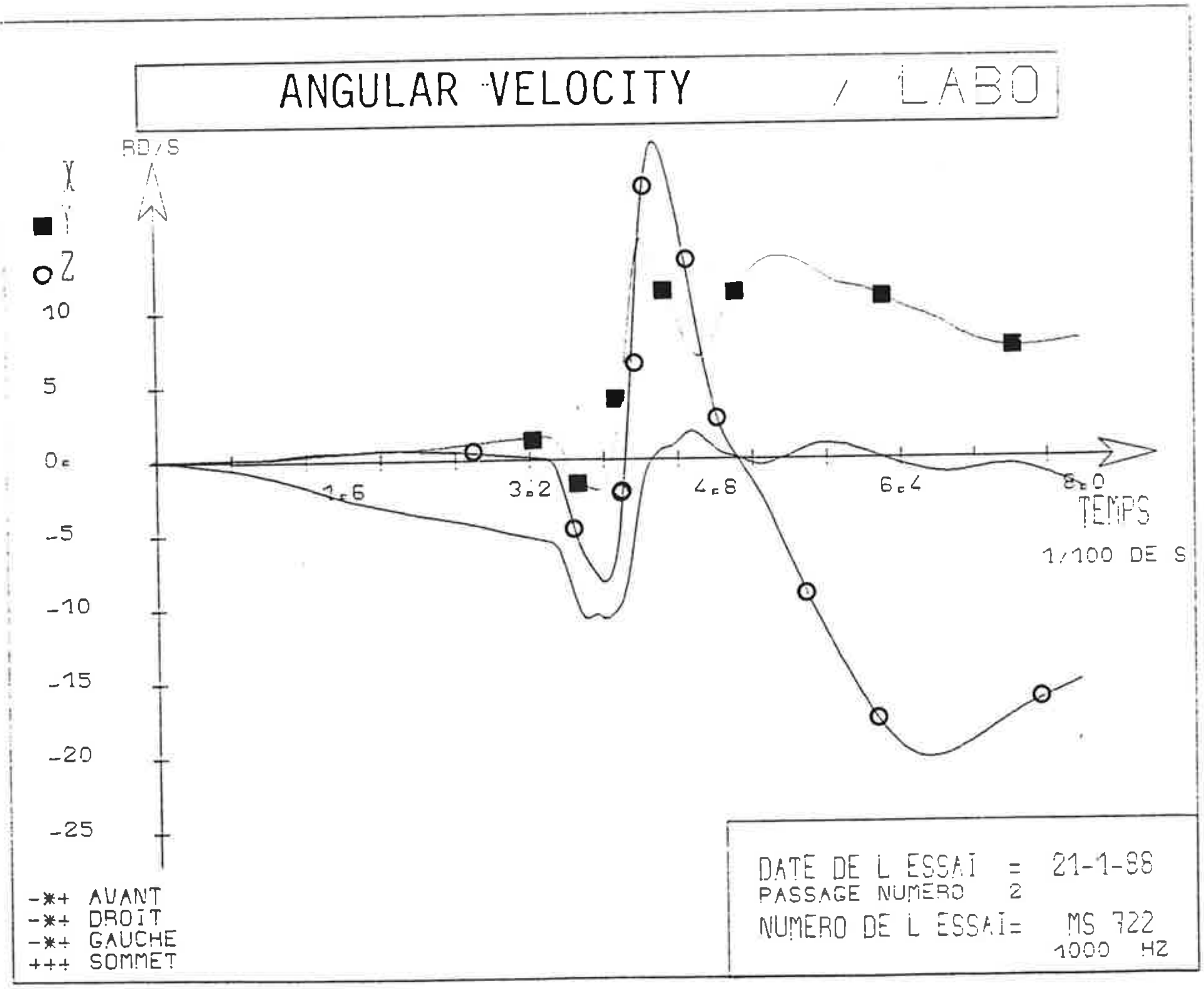

RAW DATA : FRONTAL TRANSDUCER
X CAPTEUR
Z CAPTEUR
G
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ


LINEAR ACCELERATIONS AT CG
G
LONGITDNL /
TRANSVERS
VERTICALE
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ

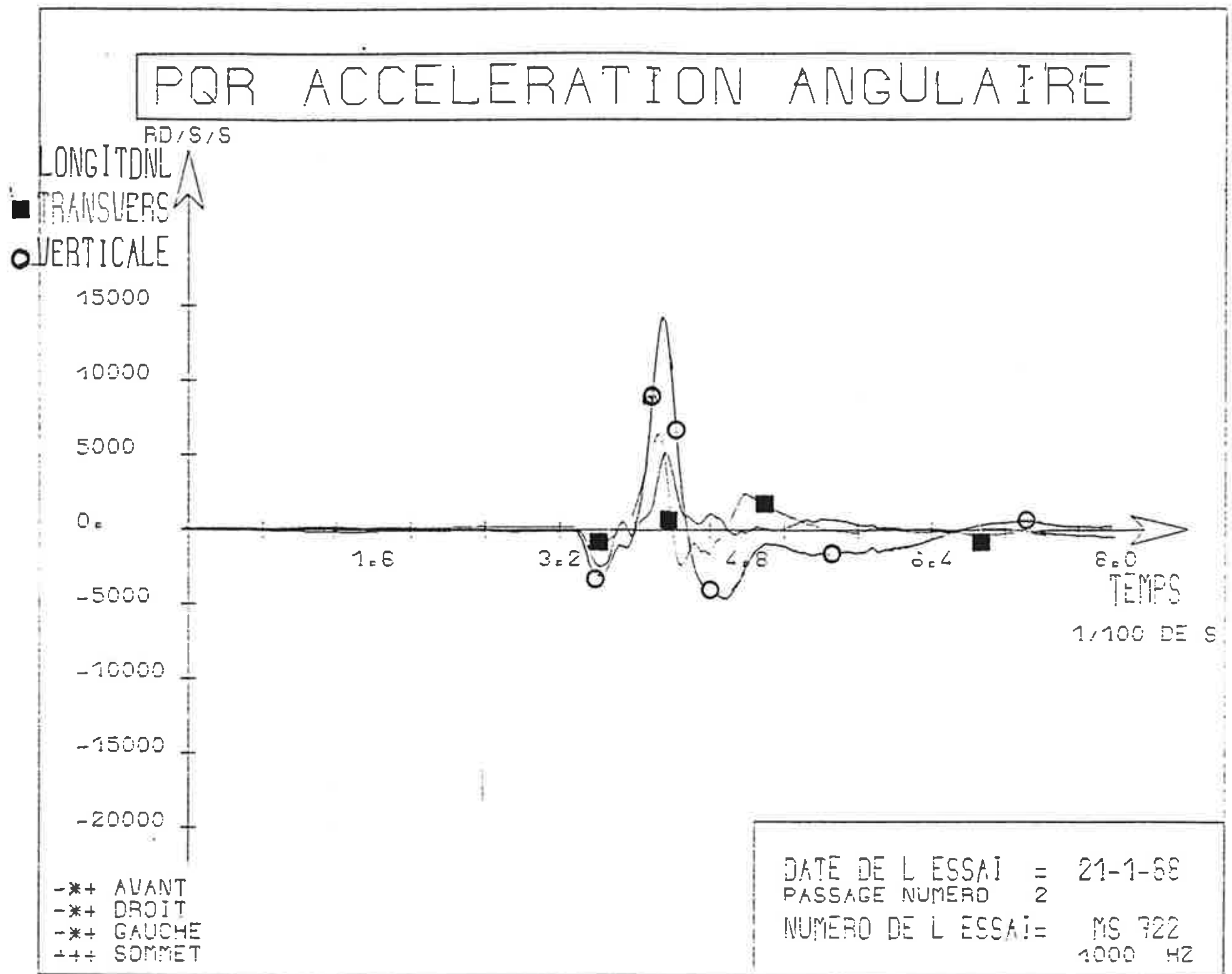

RESULTANT ACCELERATION AT CG
G
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
SI= 236
HIC= 172
T1= 3.43
T2= 4.88
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ



ANGULAR ACCELERATION / LABO
RD/S/S
X
Y
Z
6000
5999
3999
1999
-0
-2000
-4000
-6000
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET

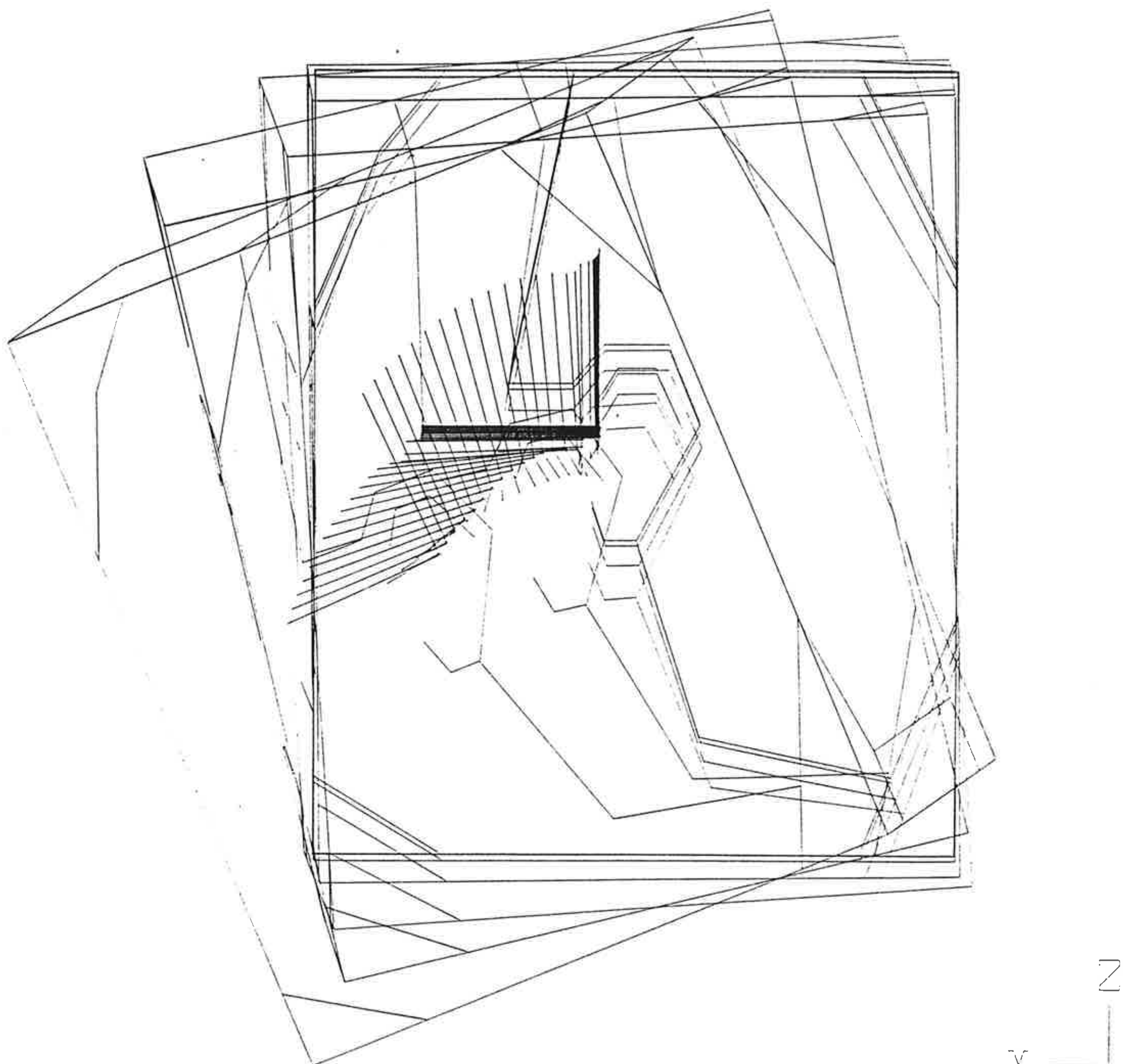


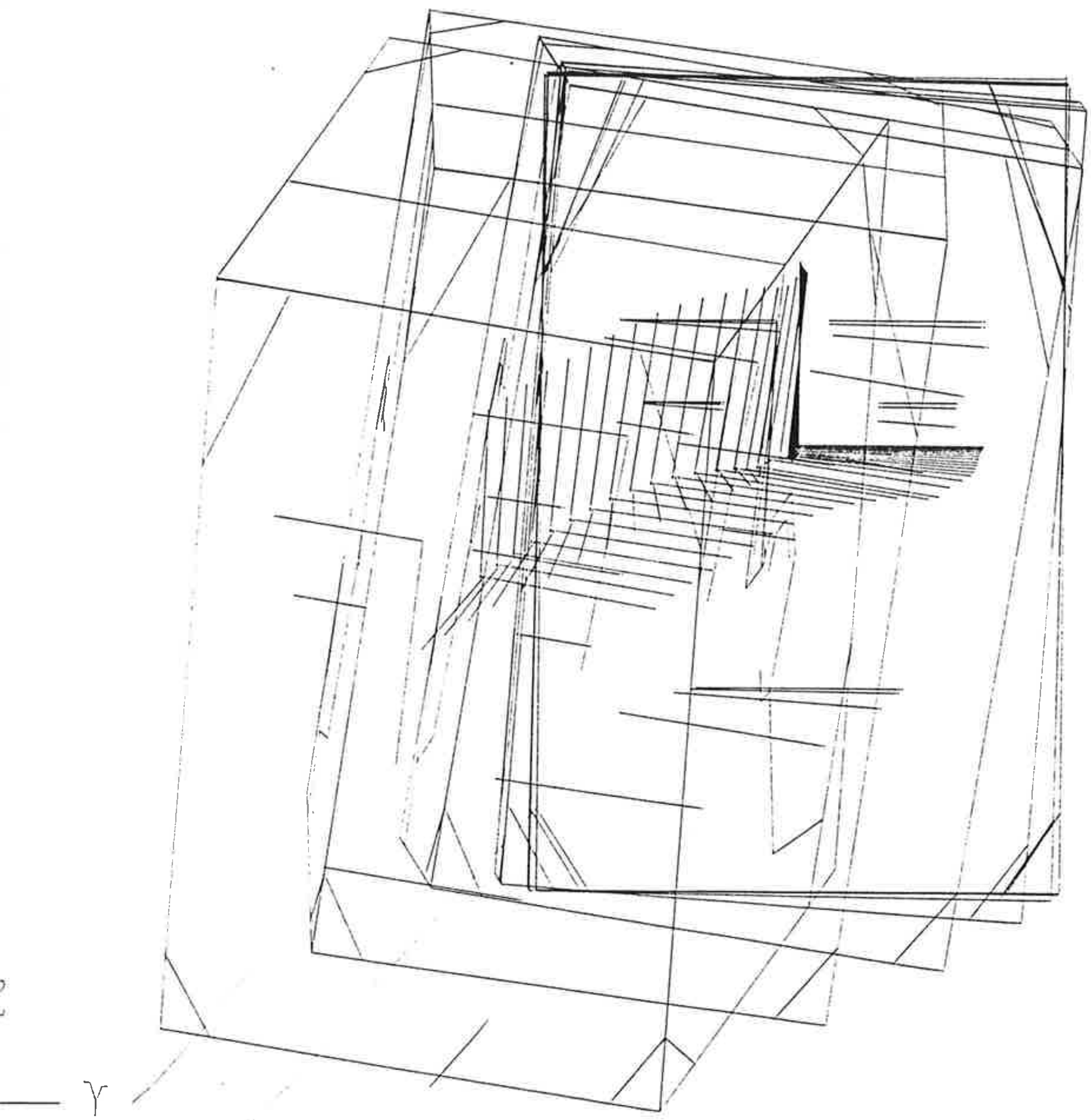
ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
10
5
0.
-5
-10
-15
-20
-25
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
DATE DE L ESSAI = 21-1-88
PASSAGE NUMERO 2
NUMERO DE L ESSAI= MS 722
1000 HZ
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET

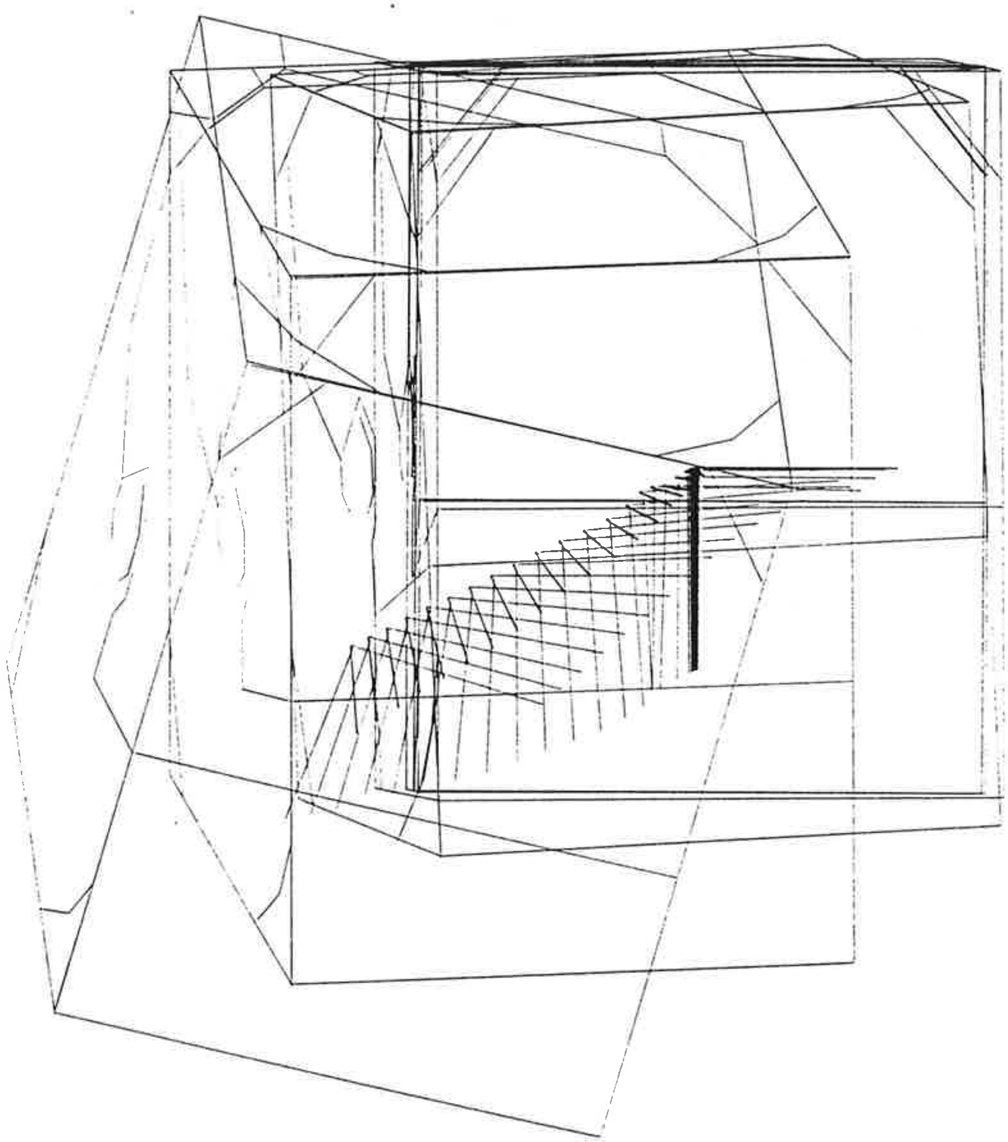


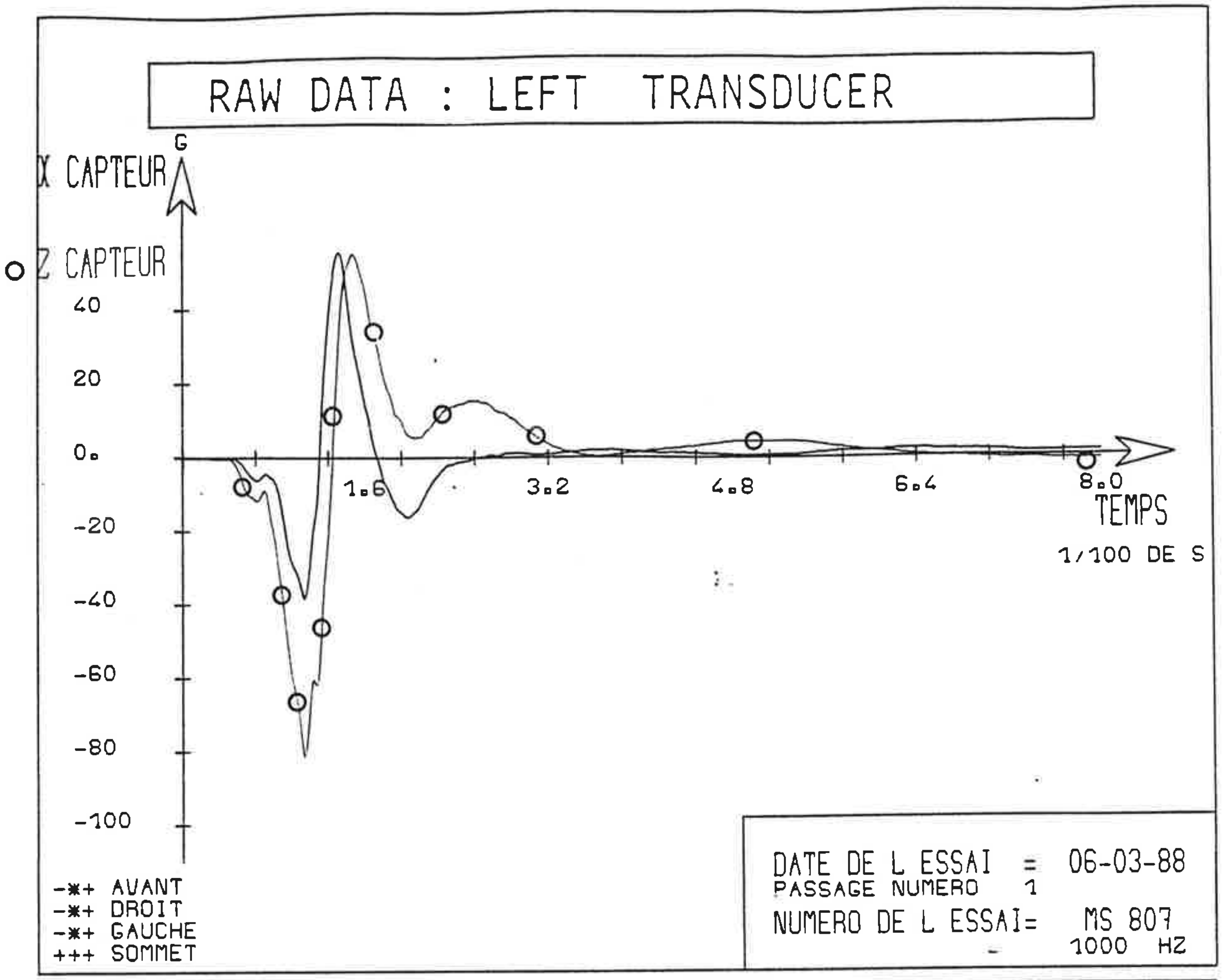
ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW 722)

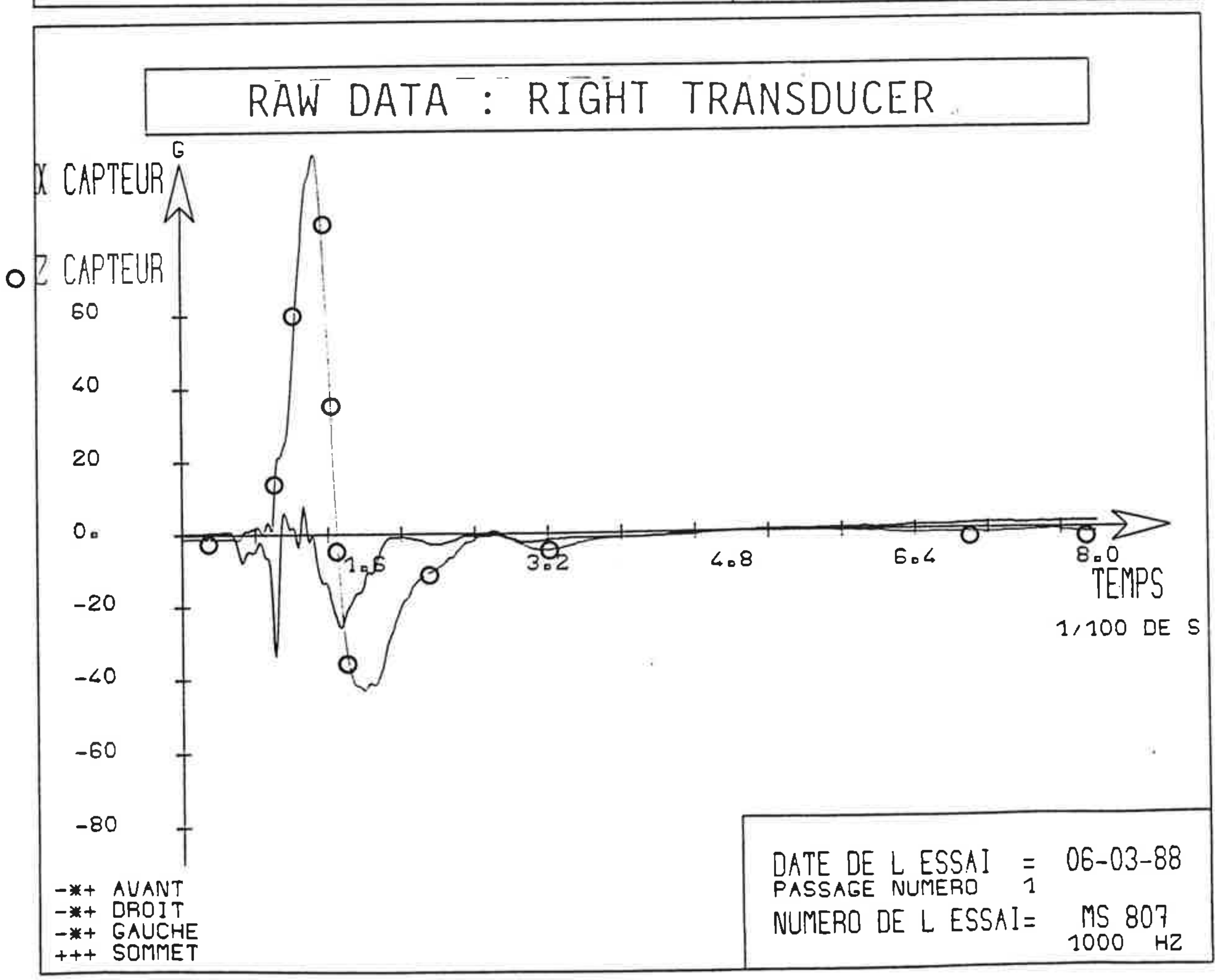
HEAD KINEMATICS FOR BLOW 722

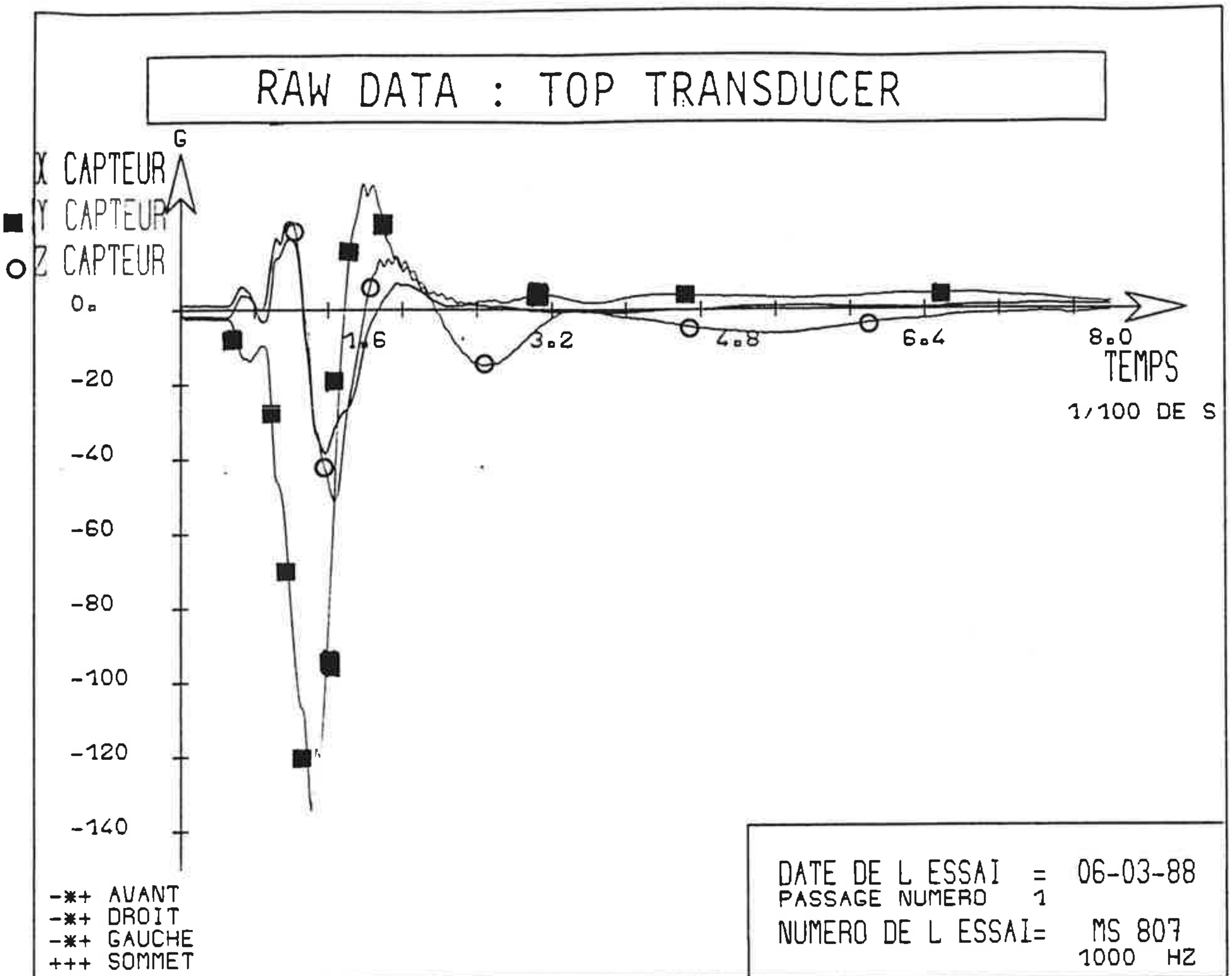

Z
X

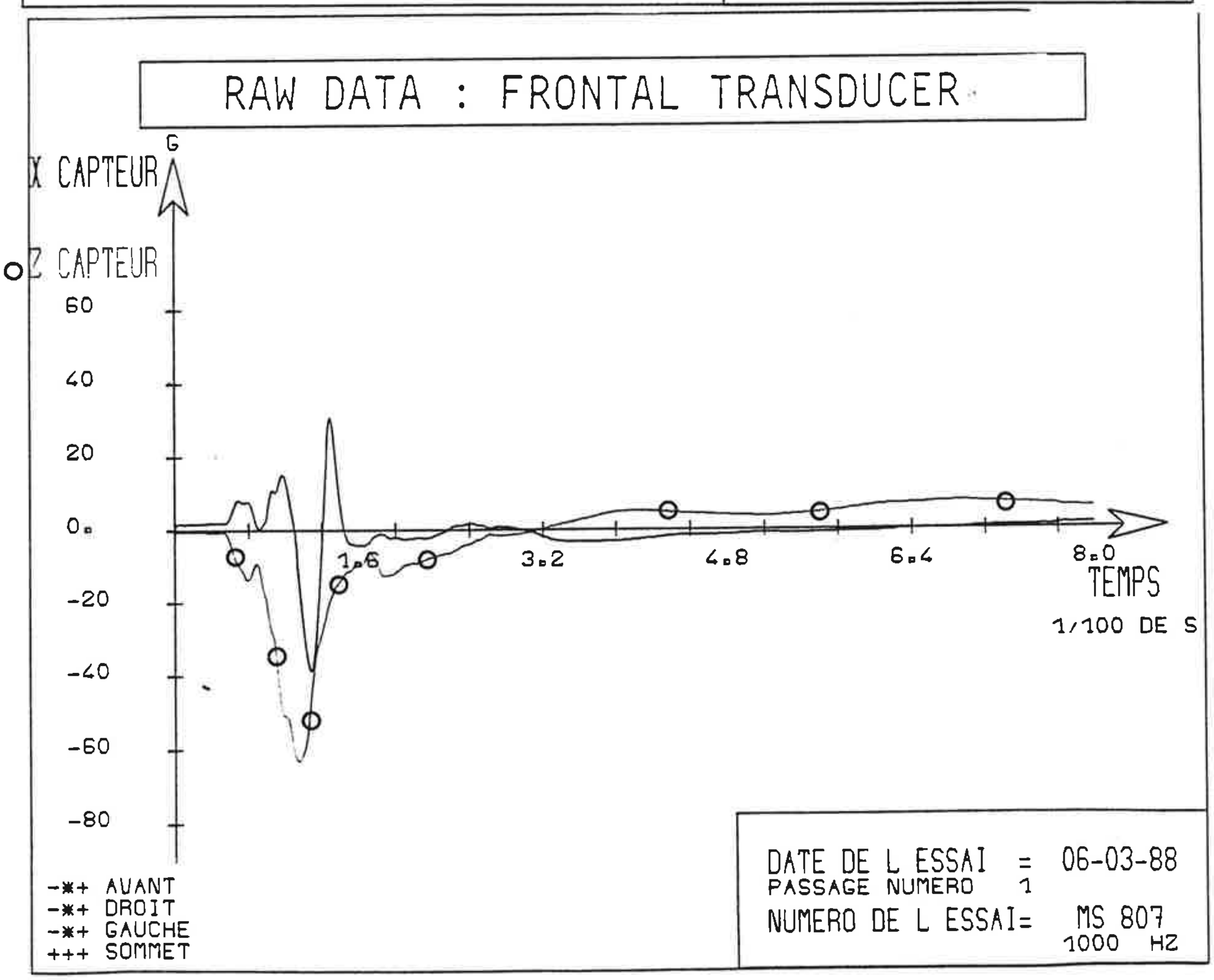

Y

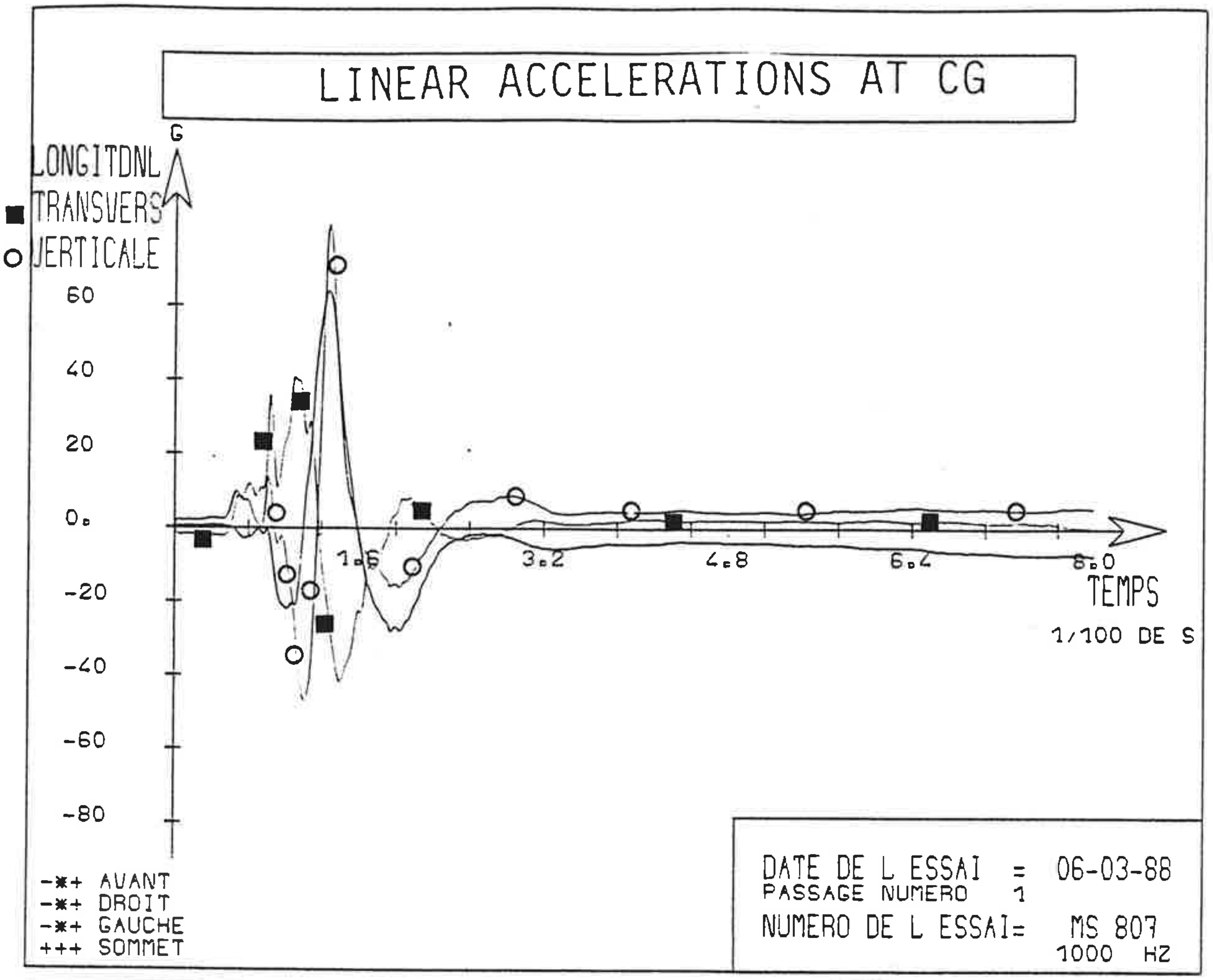



RAW DATA : LEFT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
40
20
0.
-20
-40
-60
-80
-100
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ

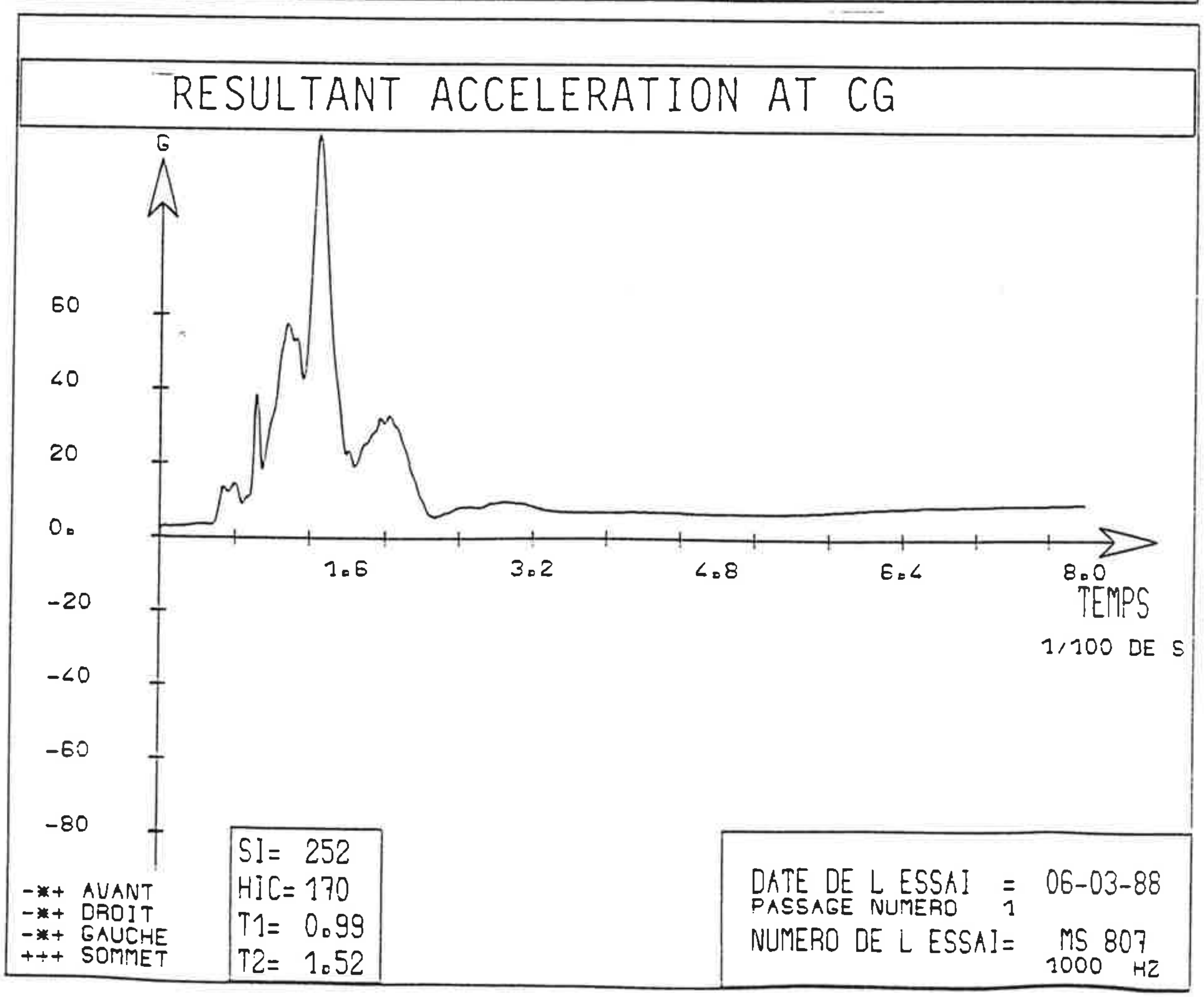

RAW DATA : RIGHT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ


RAW DATA : TOP TRANSDUCER
G
X CAPTEUR
Y CAPTEUR
Z CAPTEUR
0.
-20
-40
-60
-80
-100
-120
-140
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ

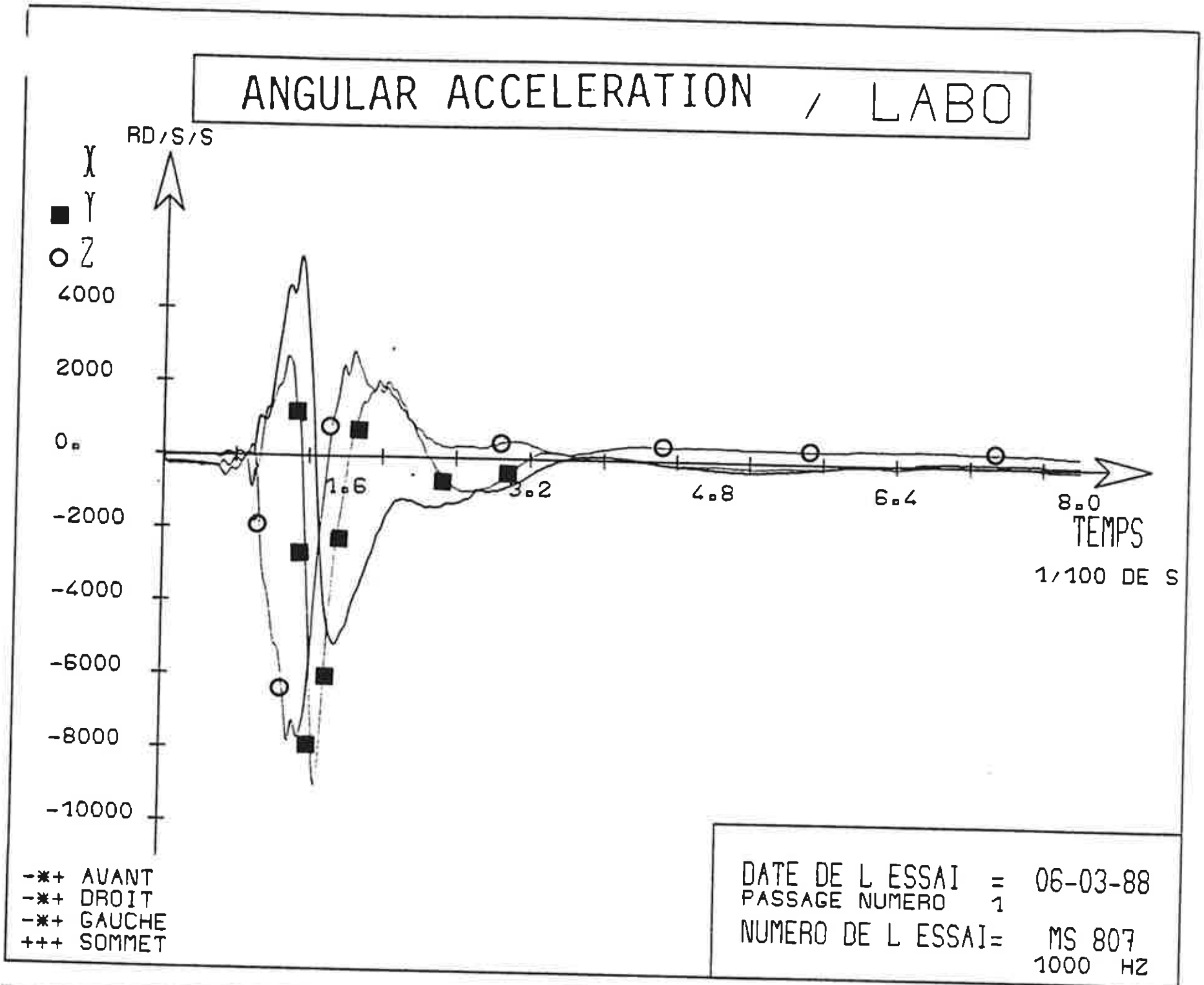

RAW DATA : FRONTAL TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ

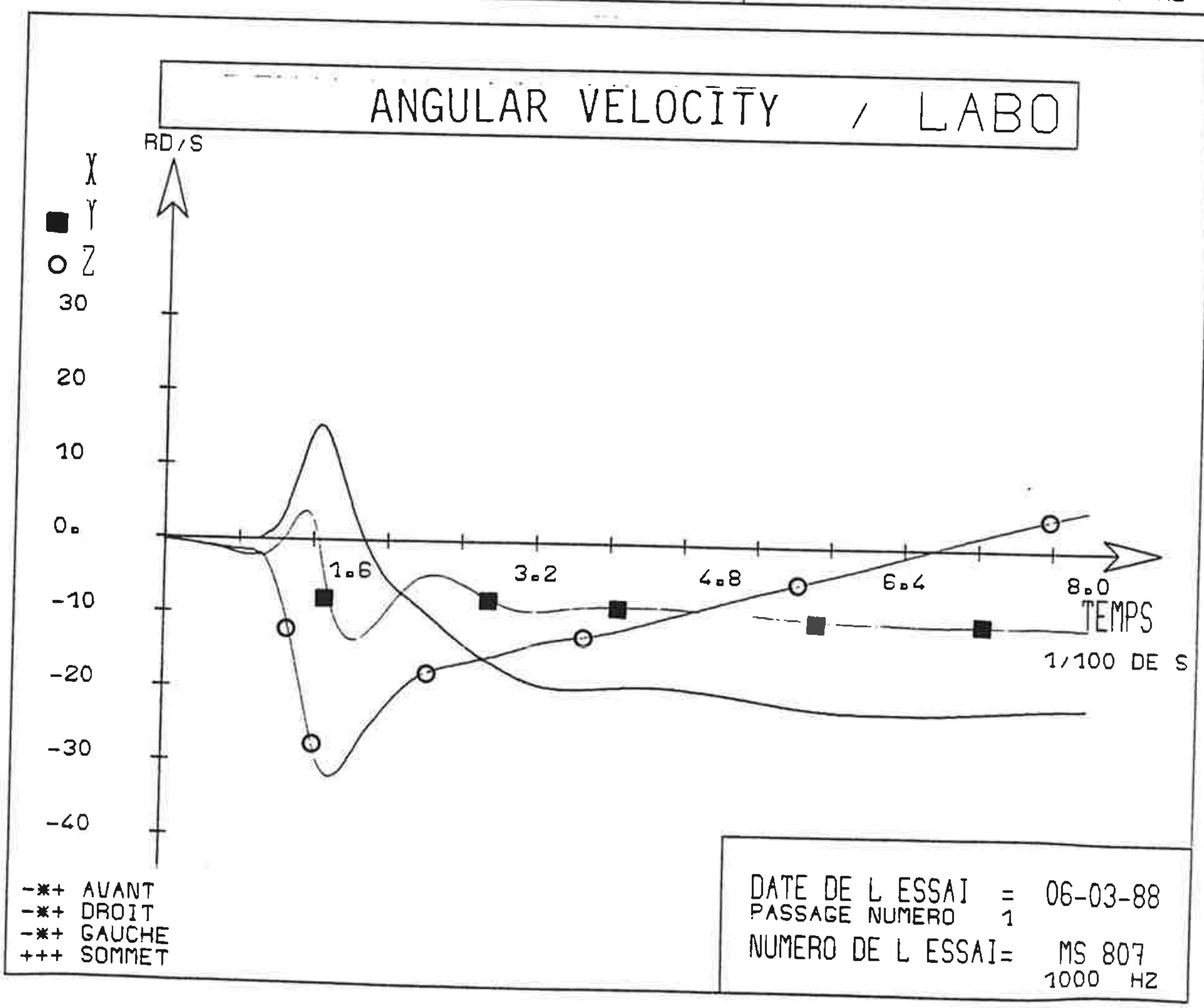


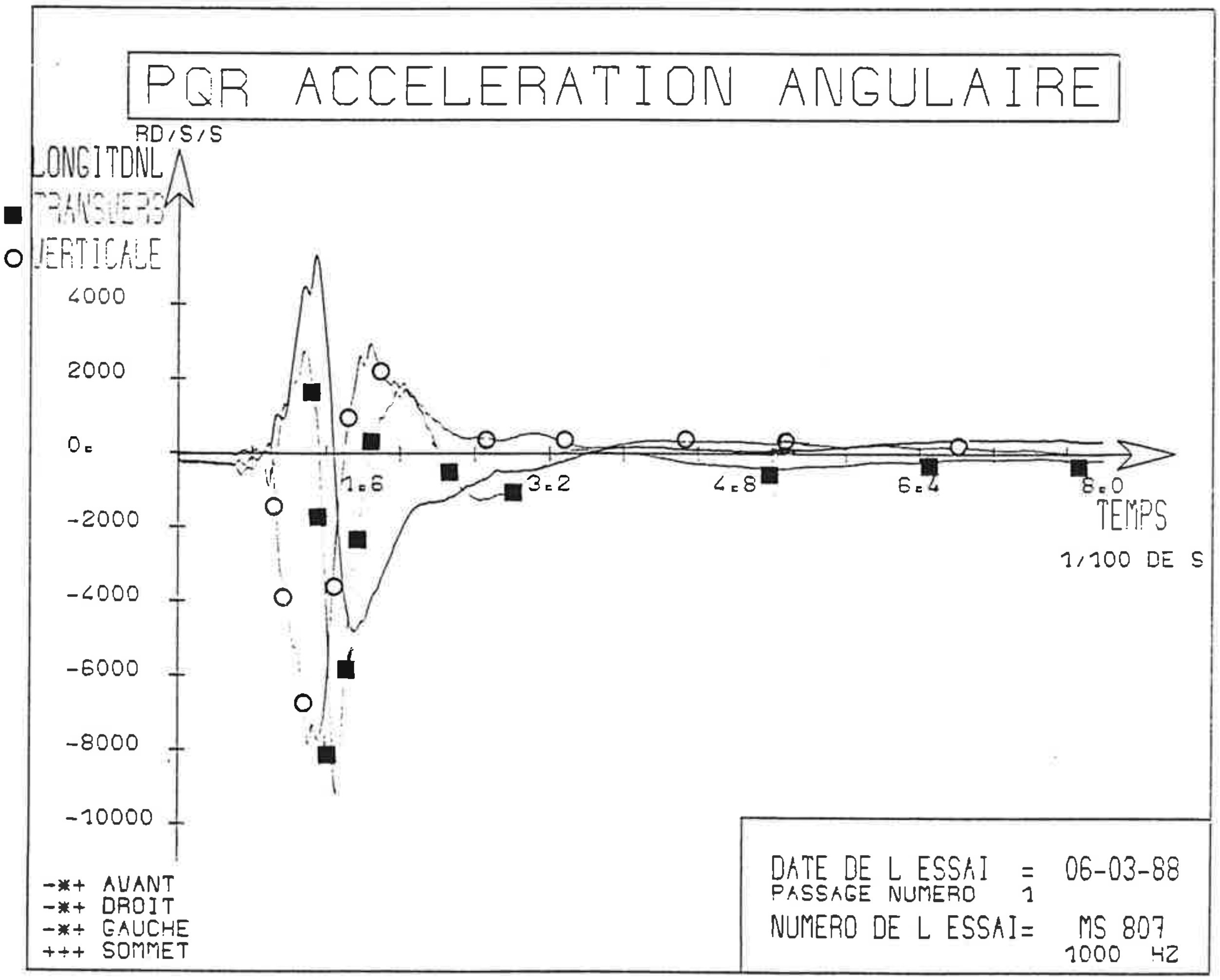
LINEAR ACCELERATIONS AT CG
G
LONGITDNL
TRANSVERS
VERTICALE
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ



RESULTANT ACCELERATION AT CG
G
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
SI= 252
HIC= 170
T1= 0.99
T2= 1.52
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ

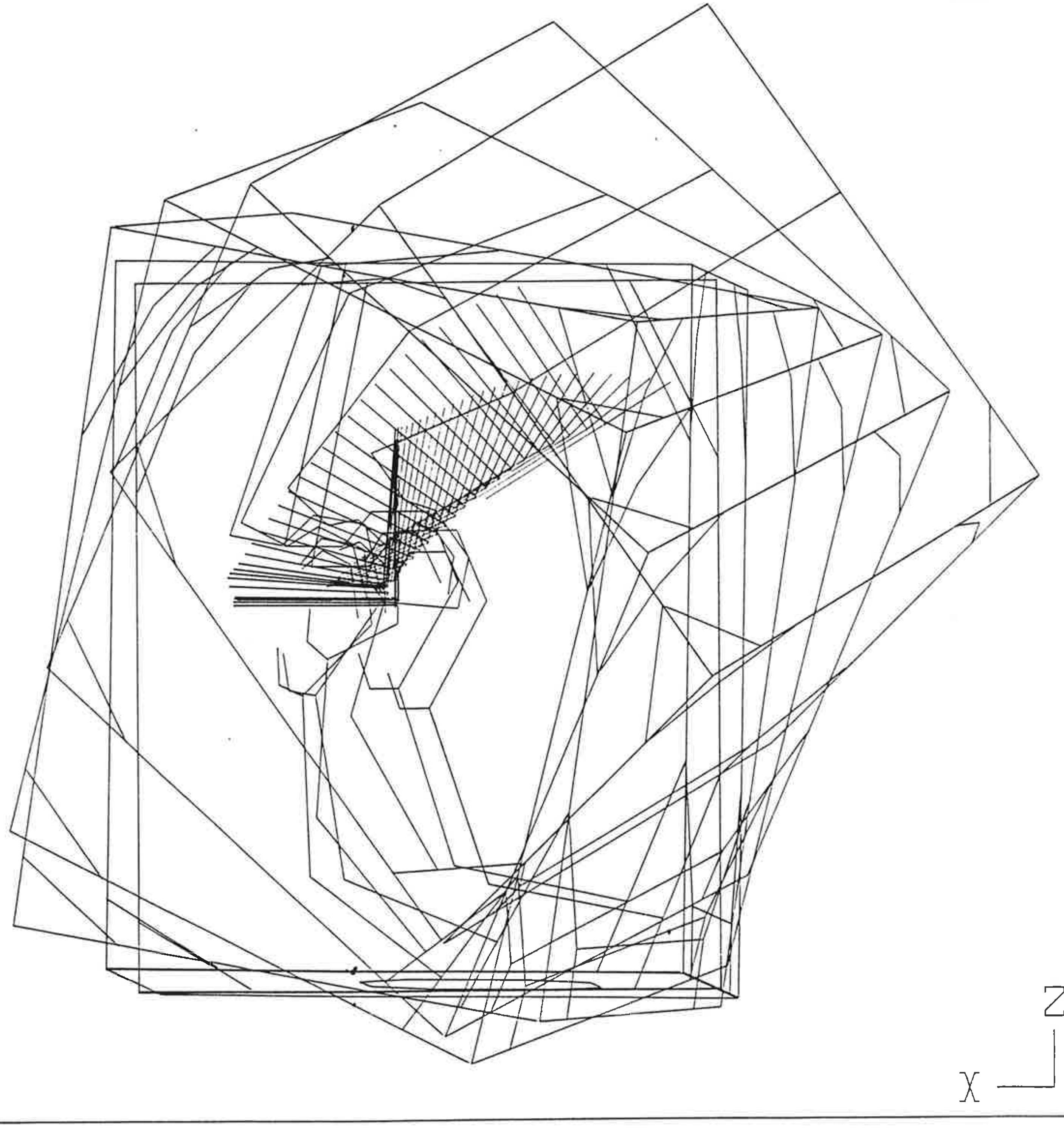

ANGULAR ACCELERATION / LABO
RD/S/S
X
Y
Z
4000
2000
0.
-2000
-4000
-6000
-8000
-10000
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ

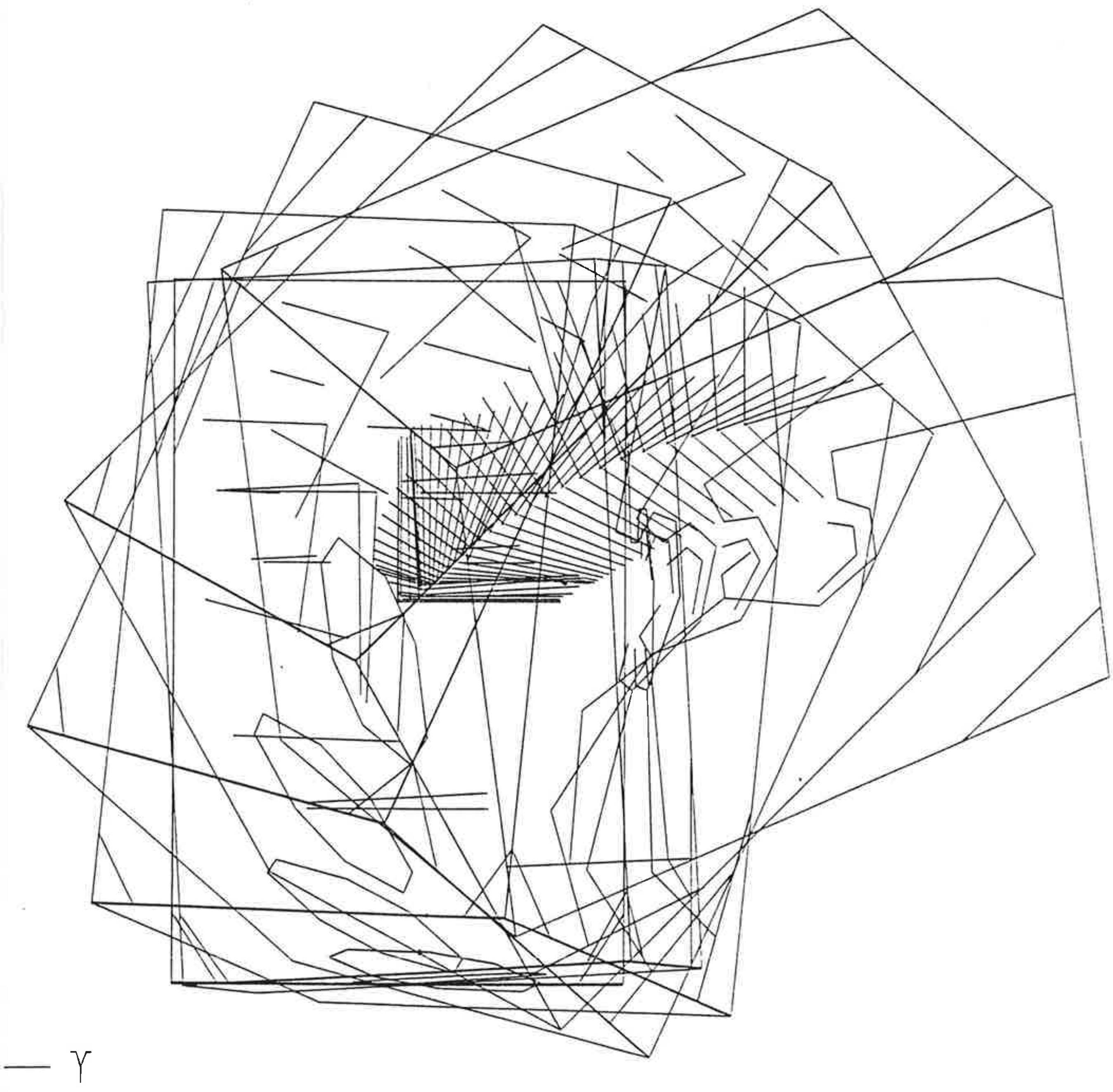

ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
30
20
10
0.
-10
-20
-30
-40
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 06-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 807
1000 HZ

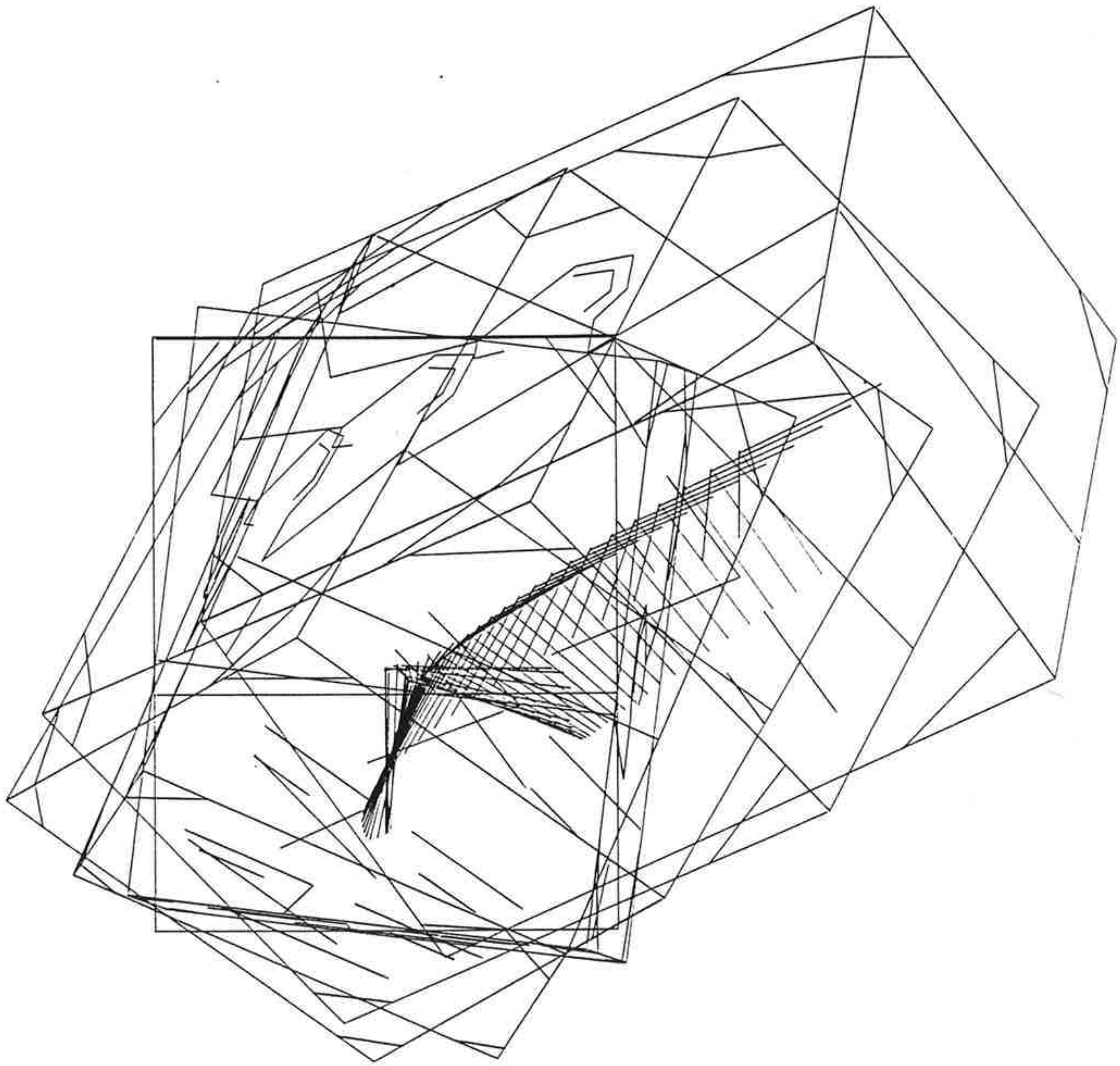


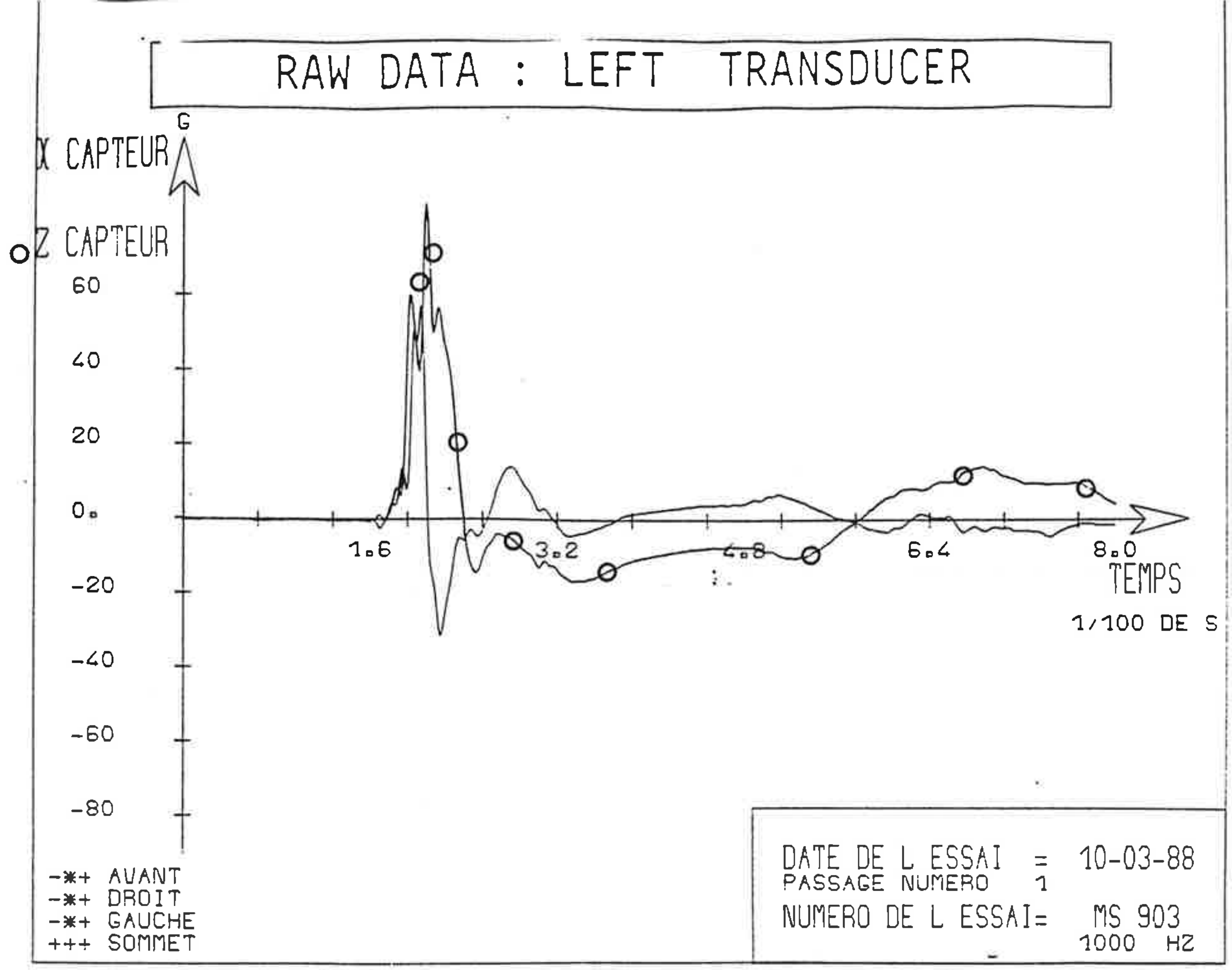
ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW 807)

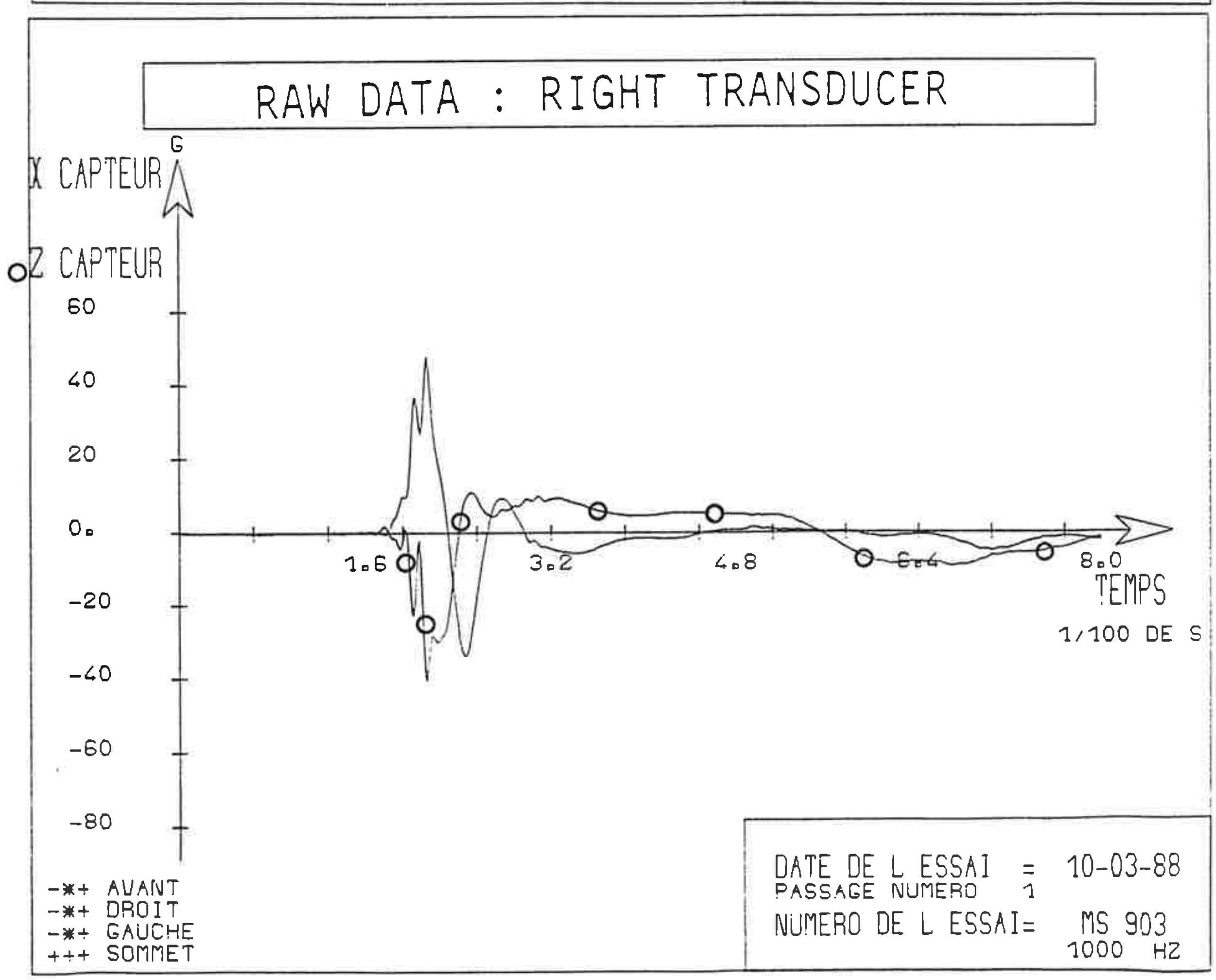
HEAD KINEMATICS FOR BLOW 807

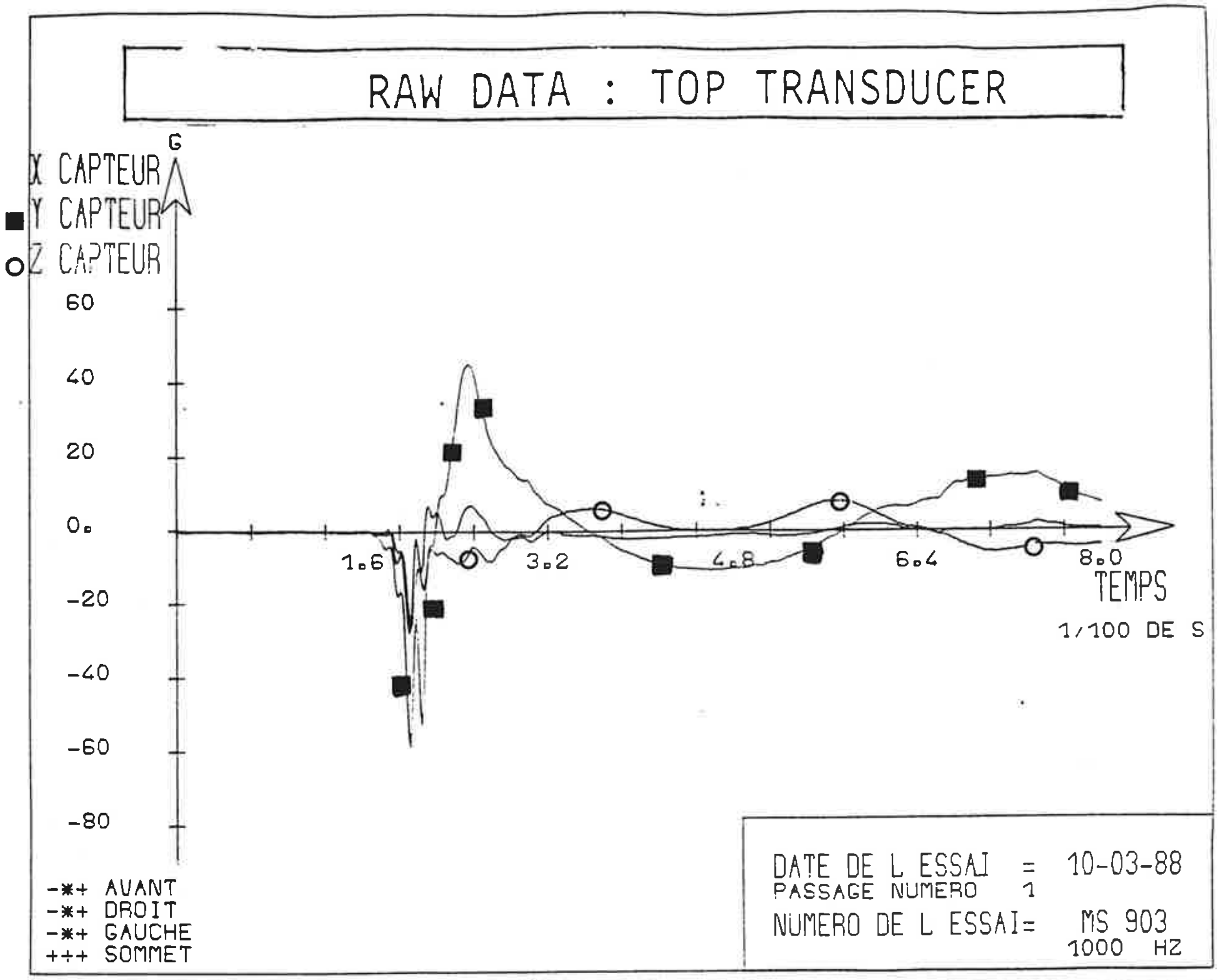

Z
X

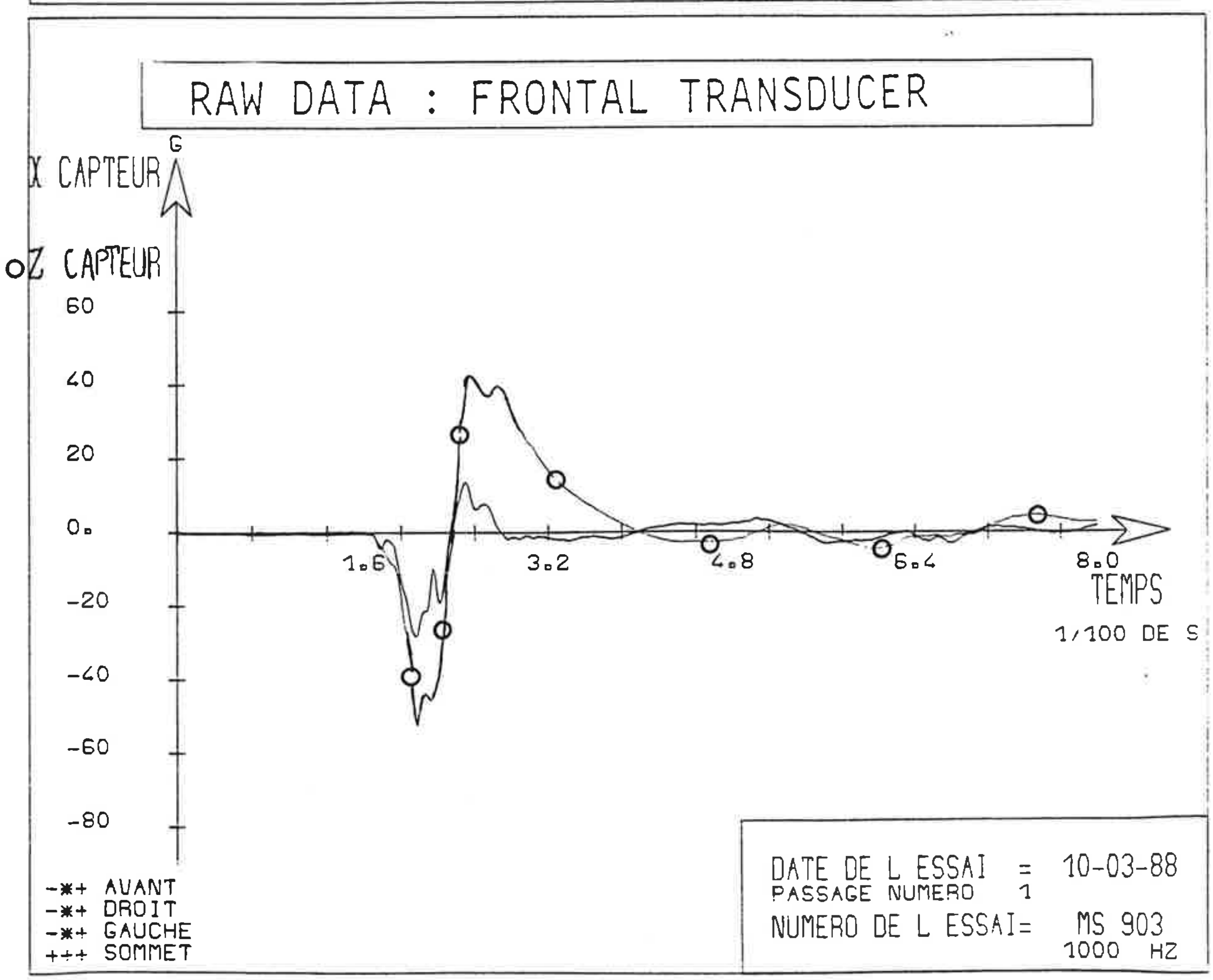

Y

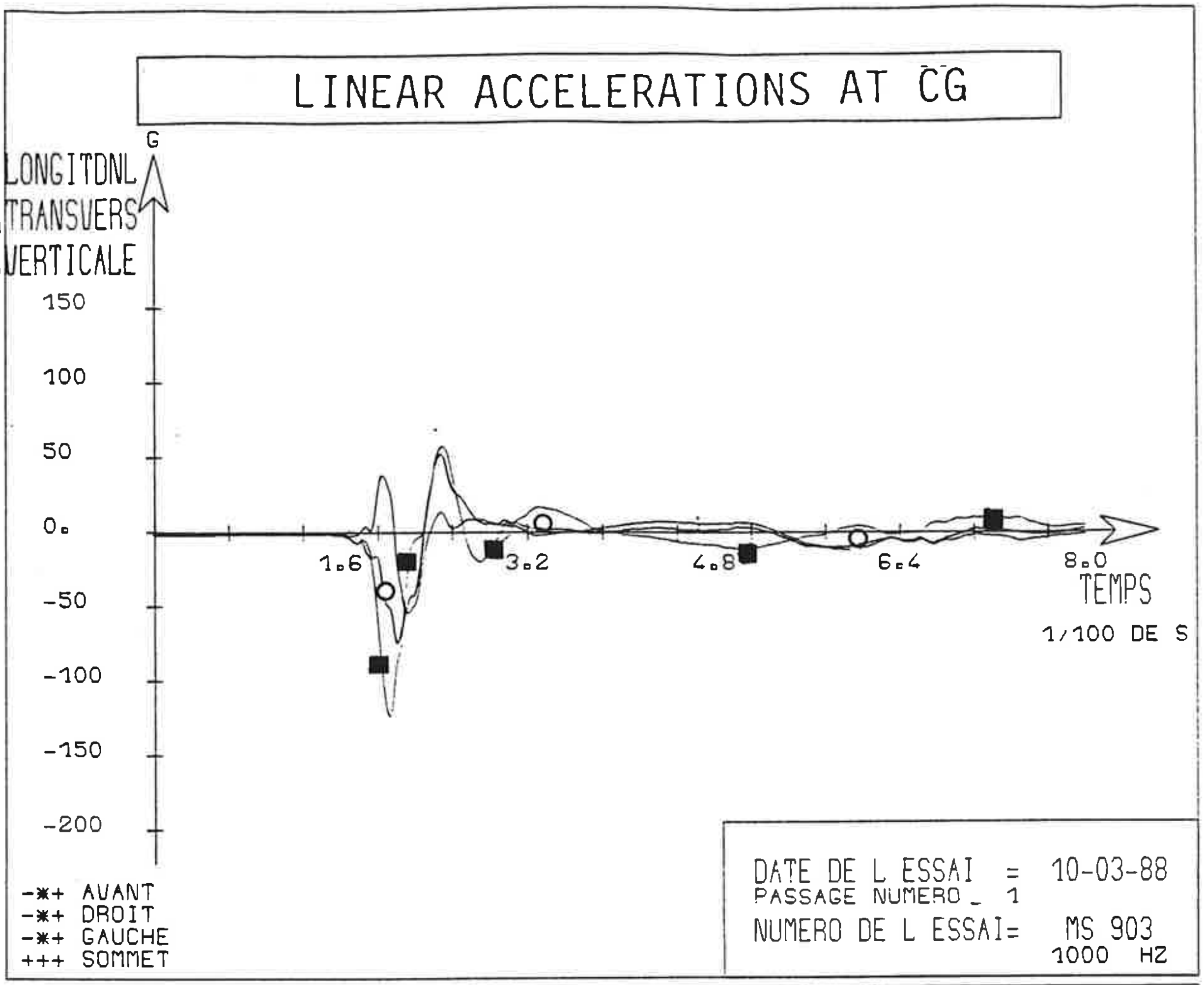


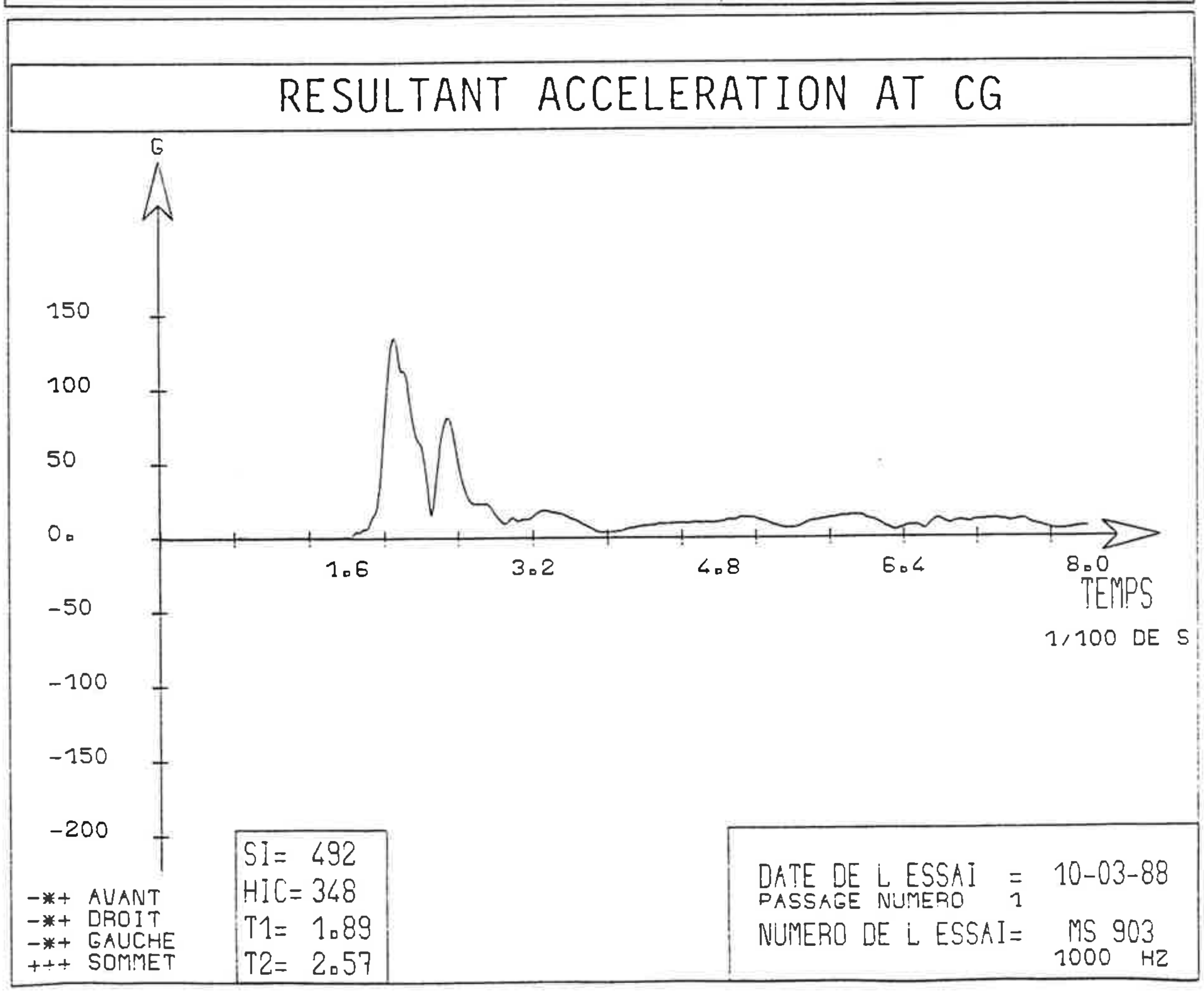

RAW DATA : LEFT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ

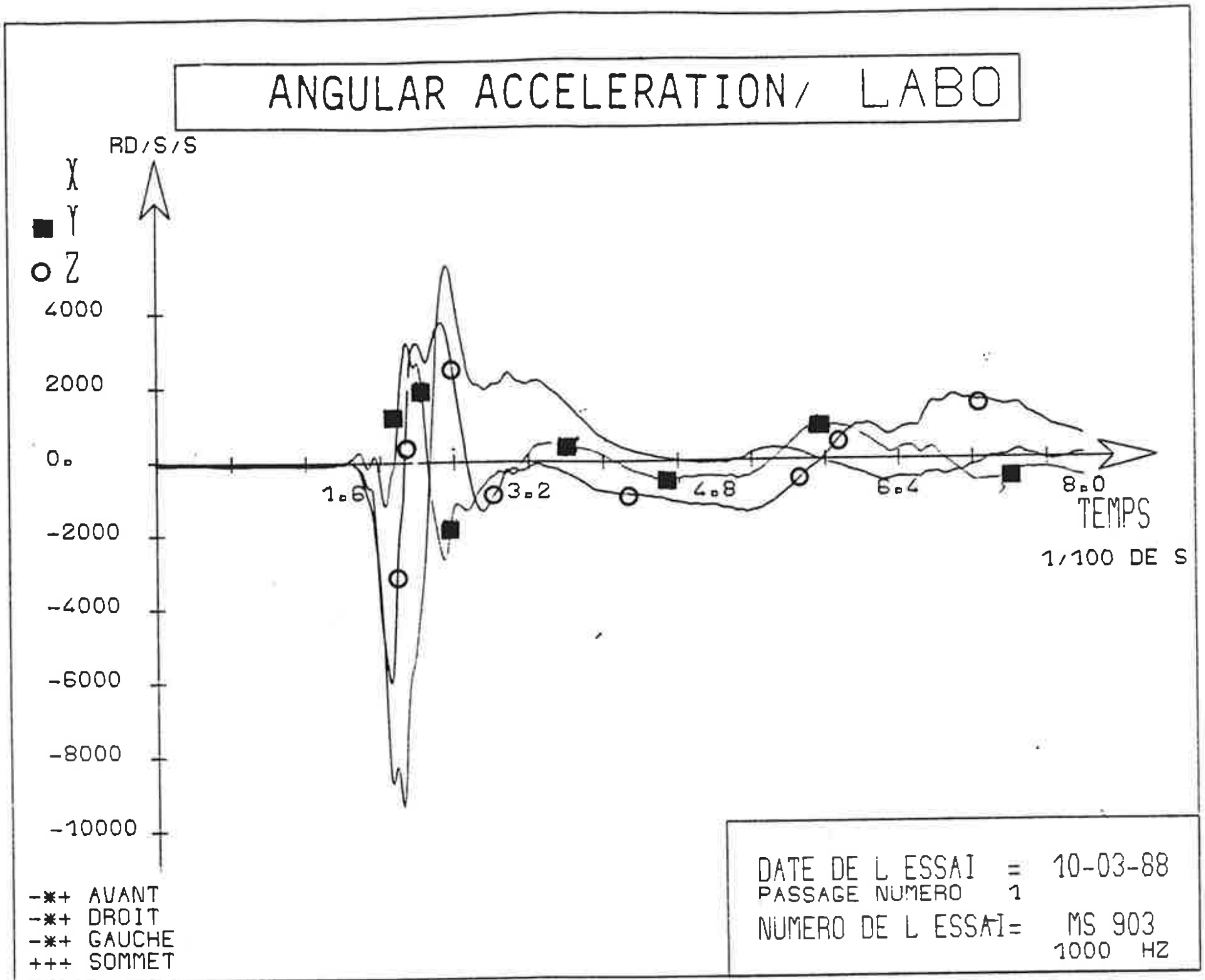

RAW DATA : RIGHT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ


RAW DATA : TOP TRANSDUCER
G
X CAPTEUR
Y CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ

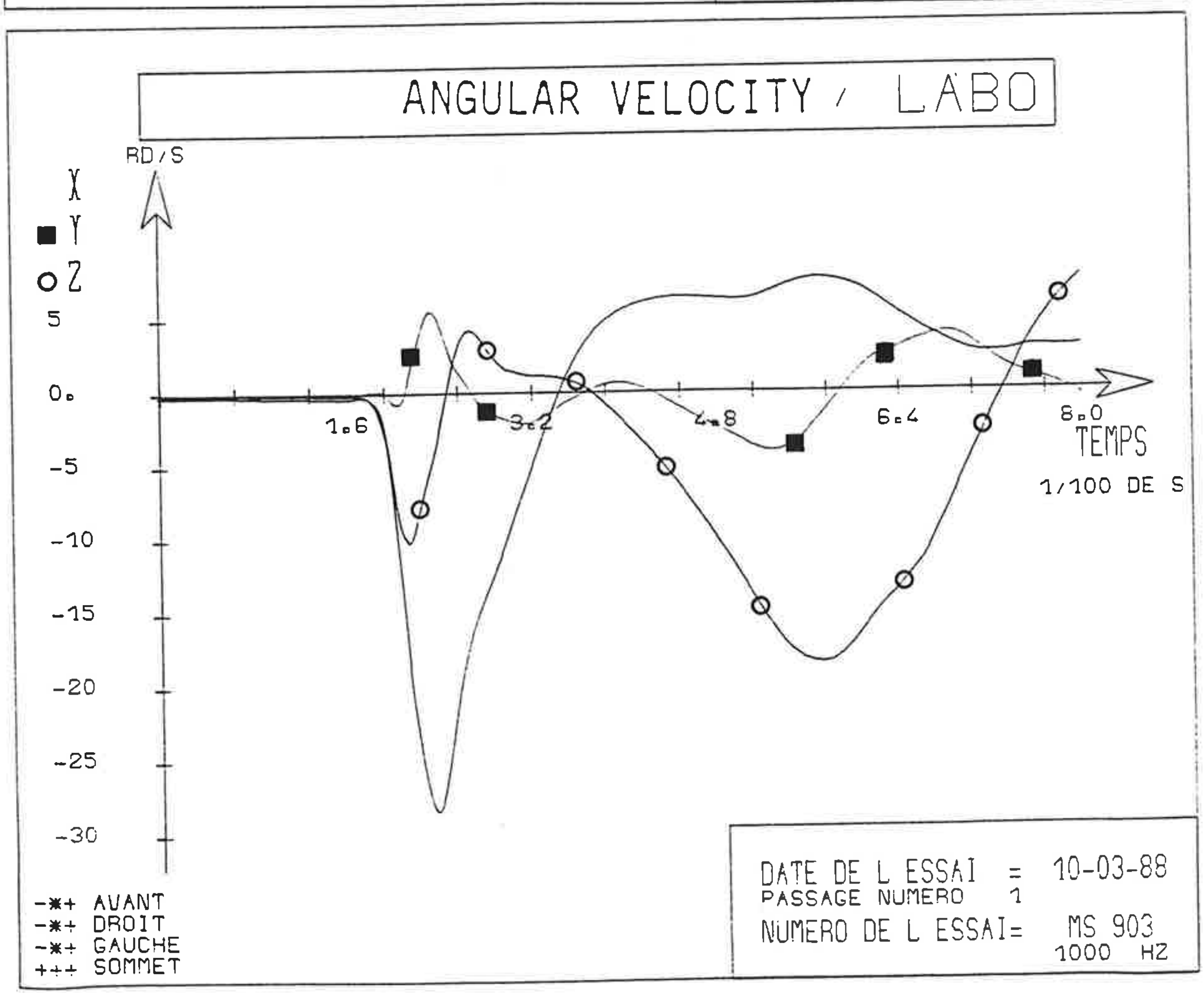

RAW DATA : FRONTAL TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ


LINEAR ACCELERATIONS AT CG
G
LONGITDNL
TRANSVERS
VERTICALE
150
100
50
0.
-50
-100
-150
-200
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ

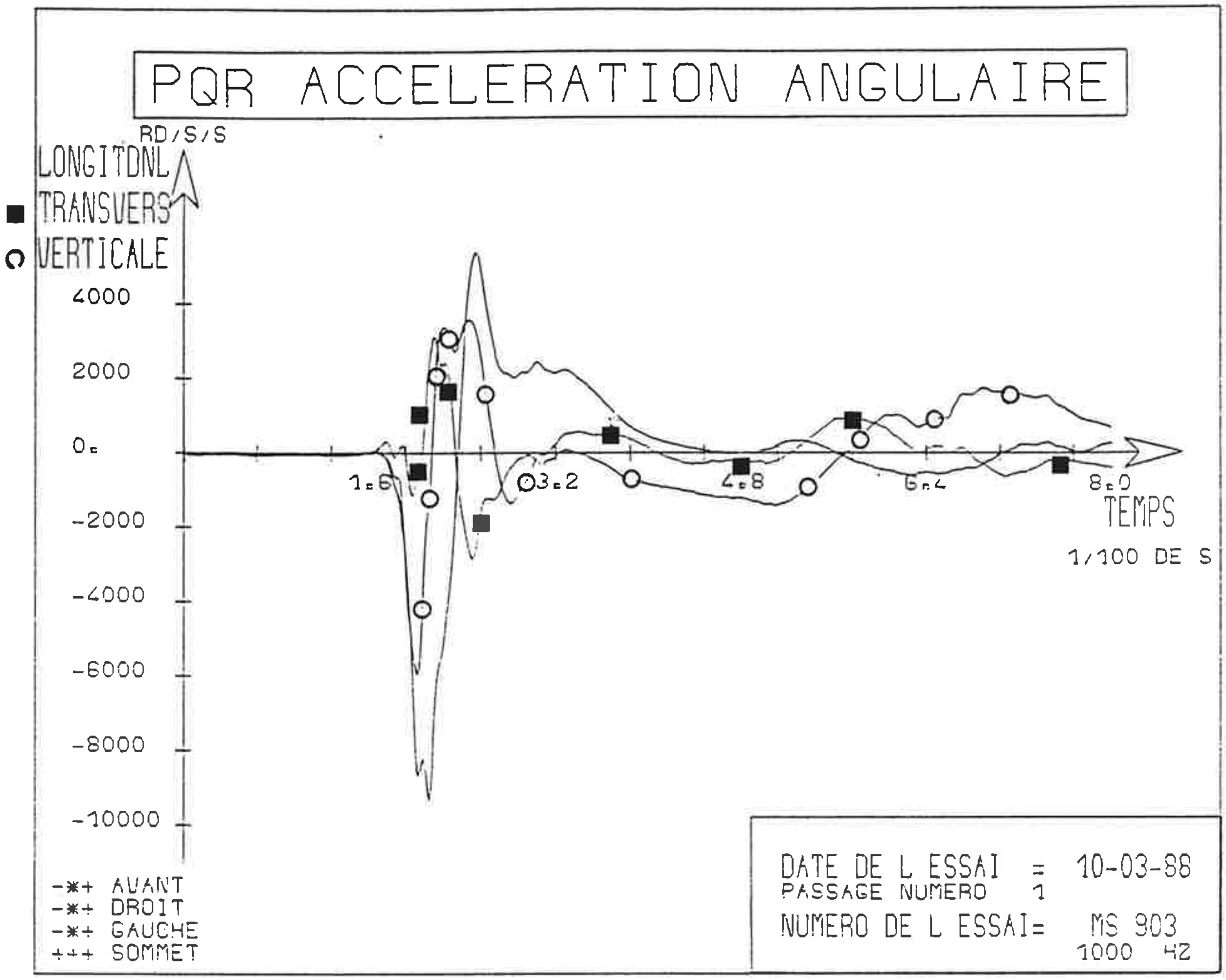

RESULTANT ACCELERATION AT CG
G
150
100
50
0.
-50
-100
-150
-200
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
SI= 492
HIC= 348
T1= 1.89
T2= 2.57
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ



ANGULAR ACCELERATION/ LABO
RD/S/S
X
Y
Z
4000
2000
0.
-2000
-4000
-6000
-8000
-10000
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ

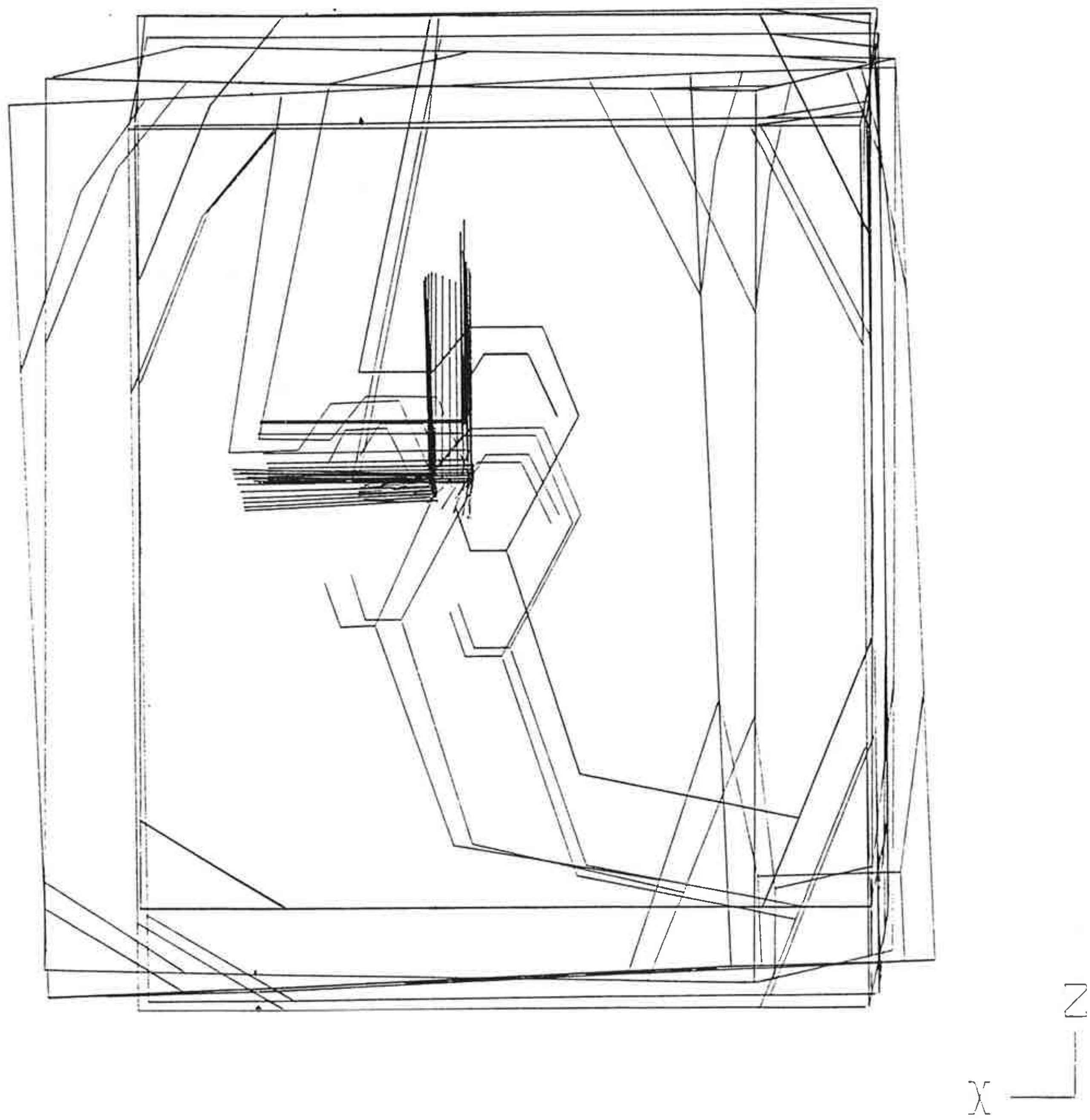


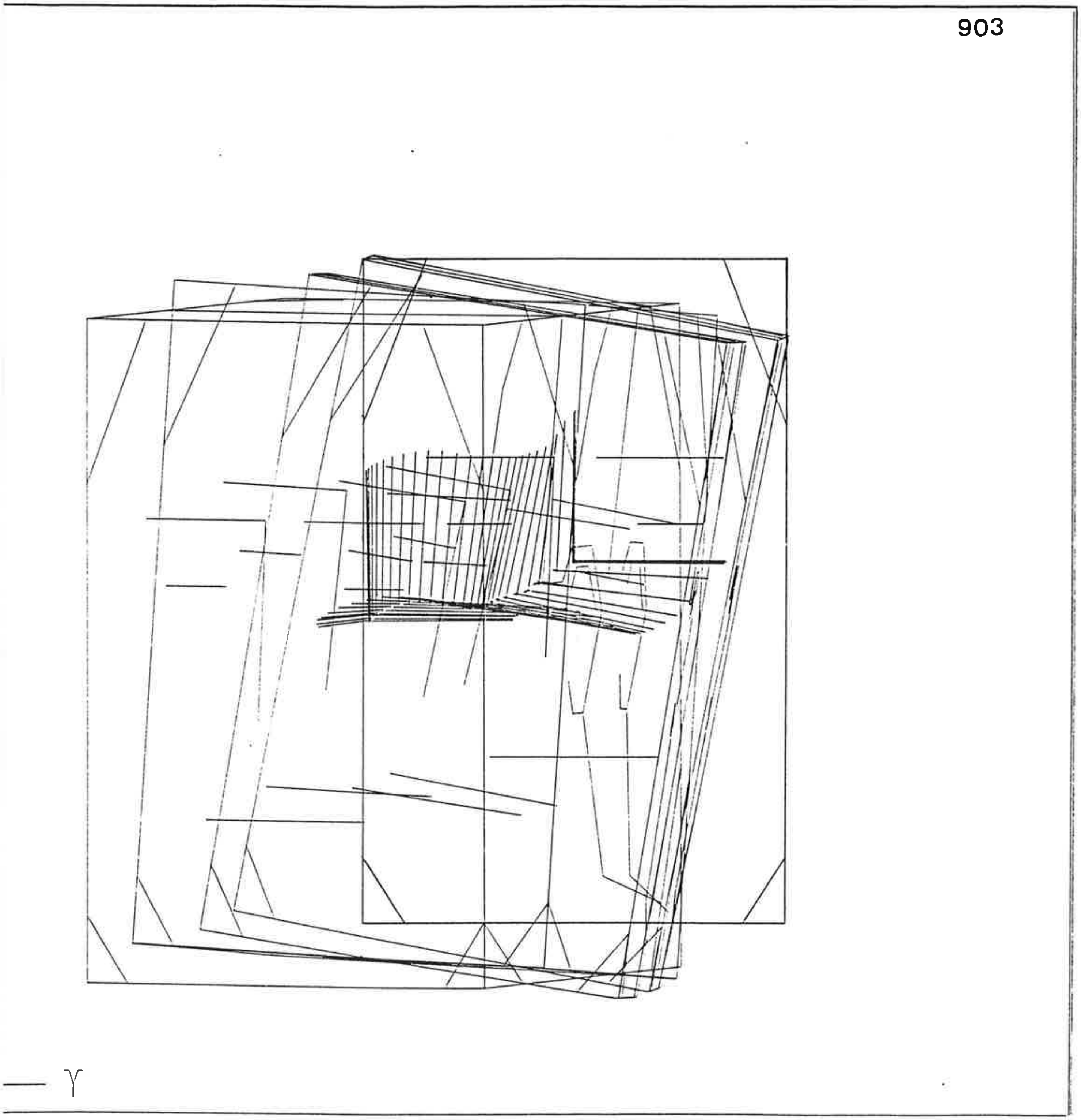
ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
5
0.
-5
-10
-15
-20
-25
-30
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 903
1000 HZ

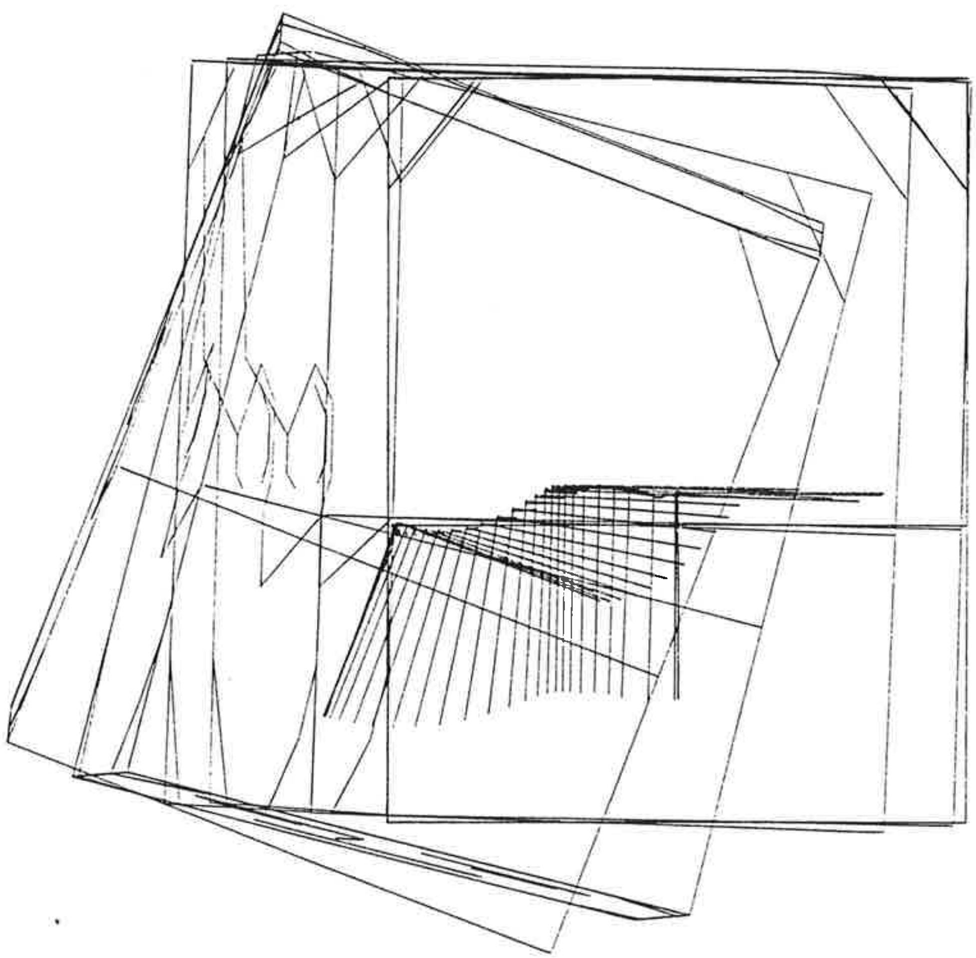


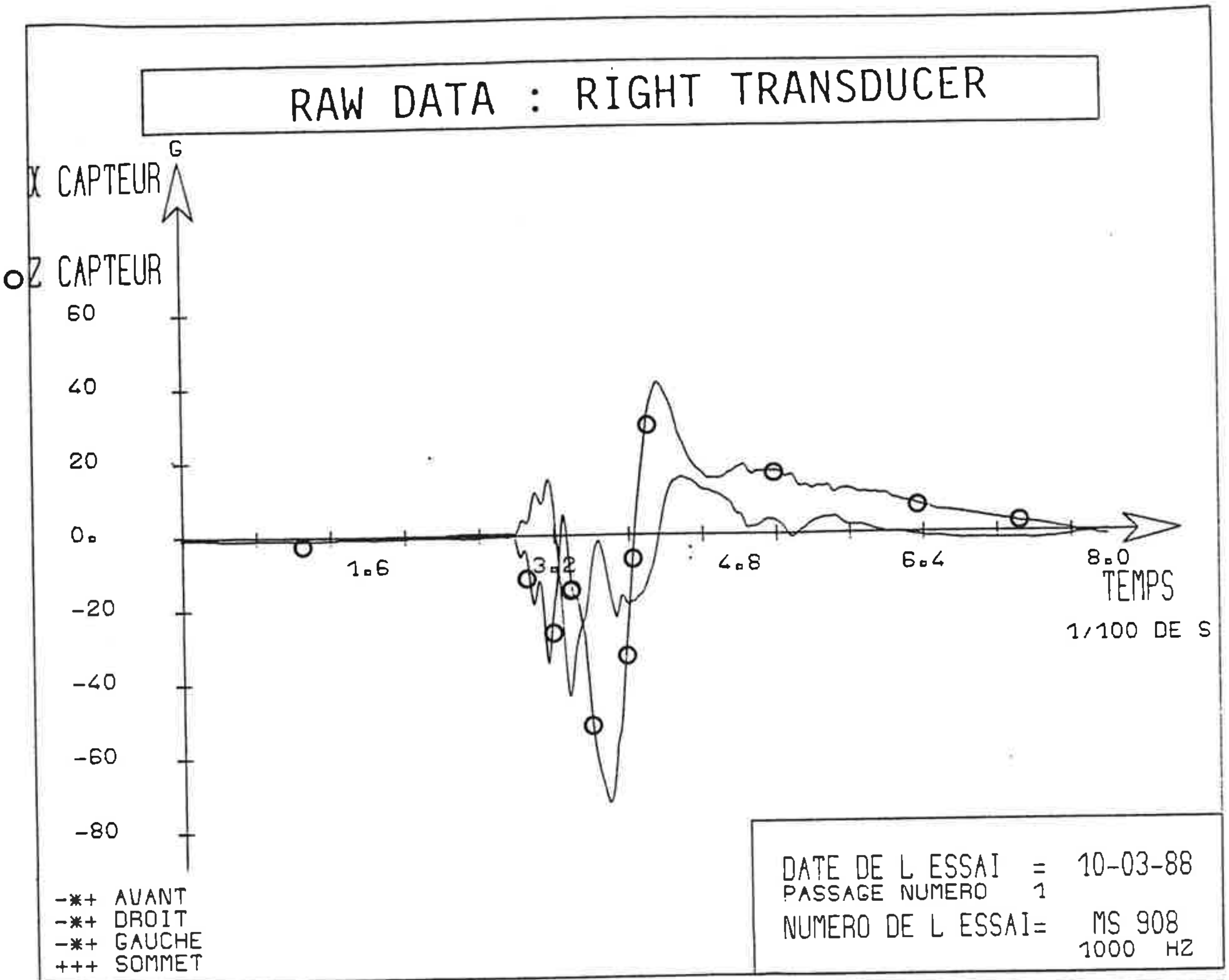
ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW 903)

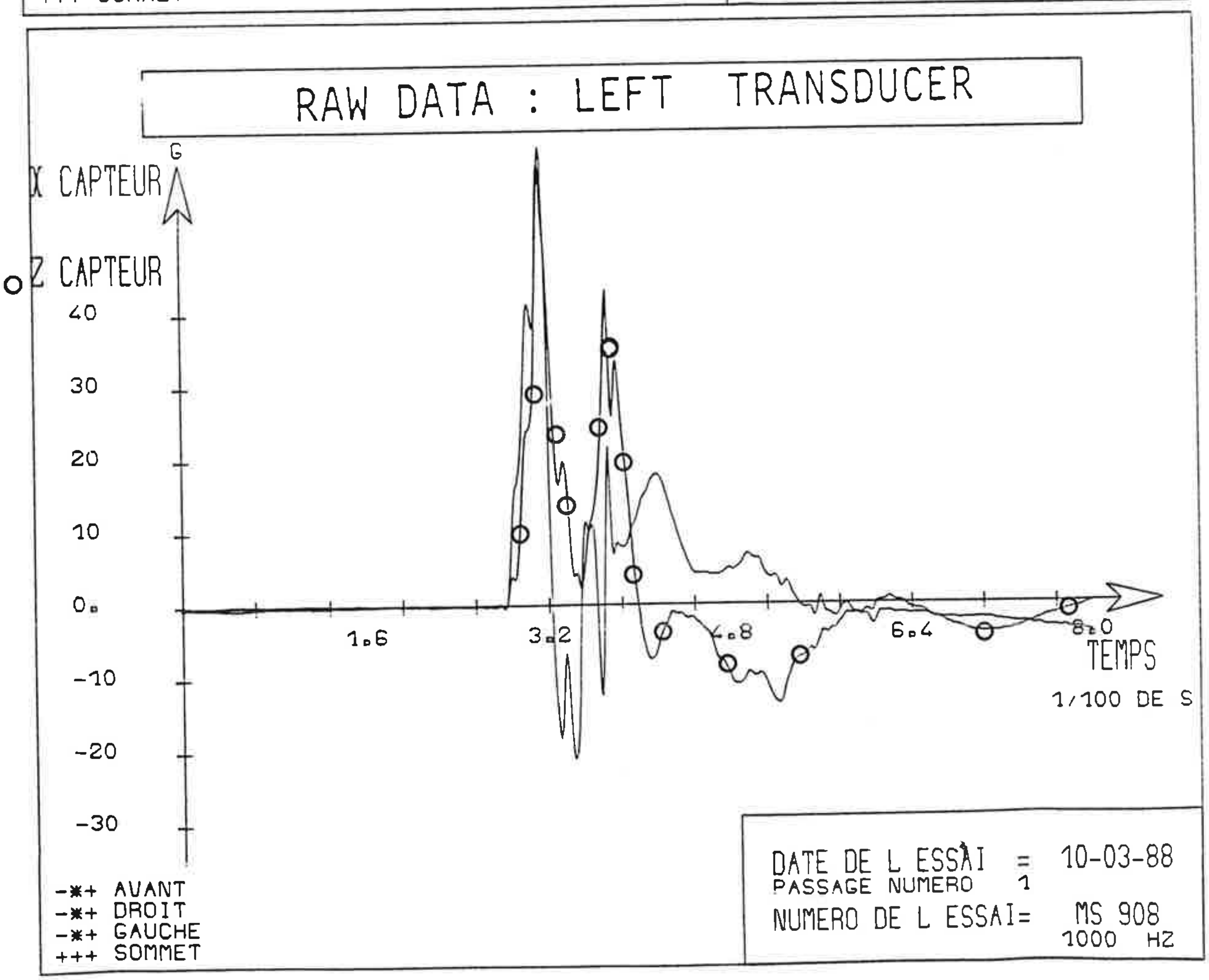
HEAD KINEMATICS FOR BLOW 903

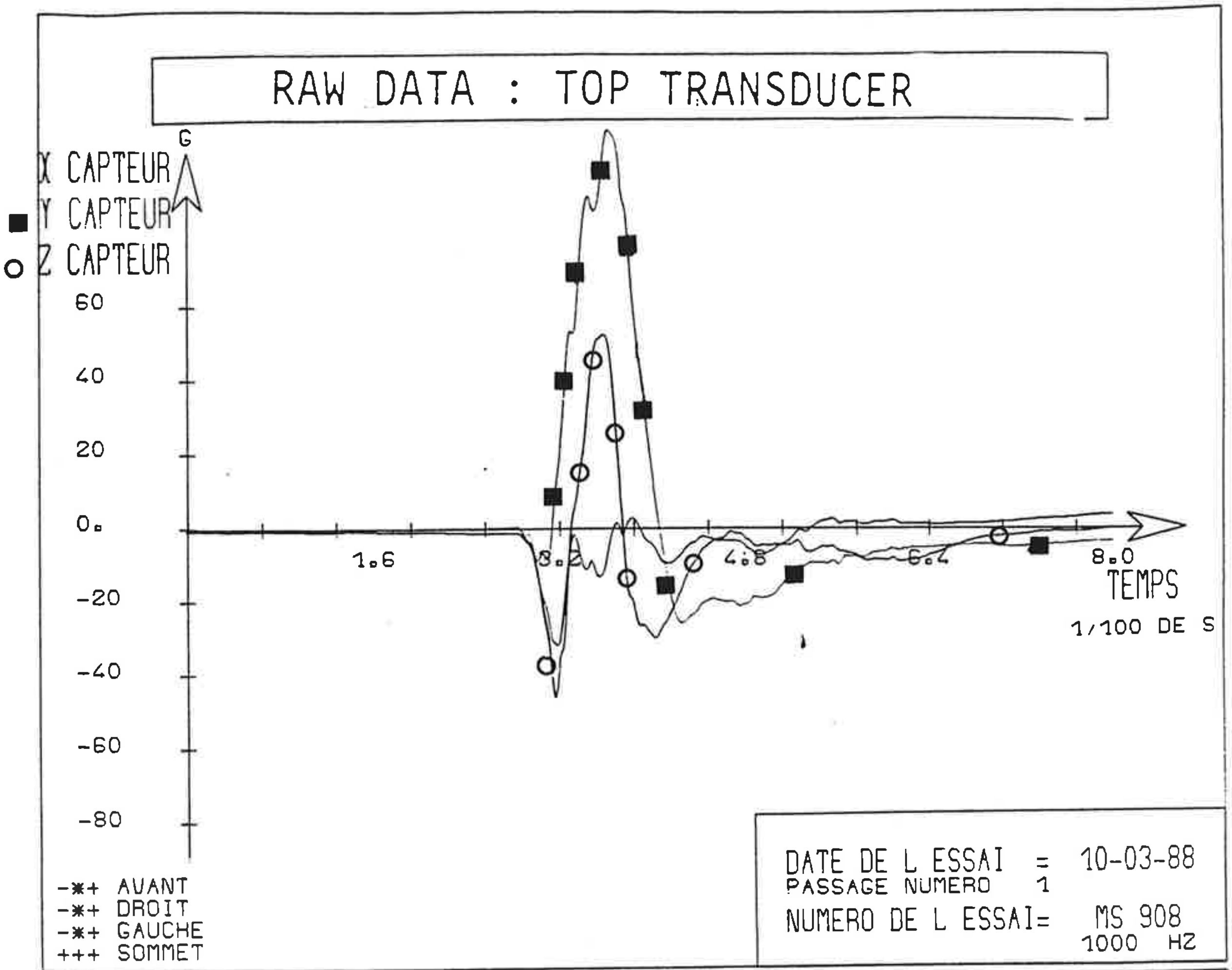

Z
X

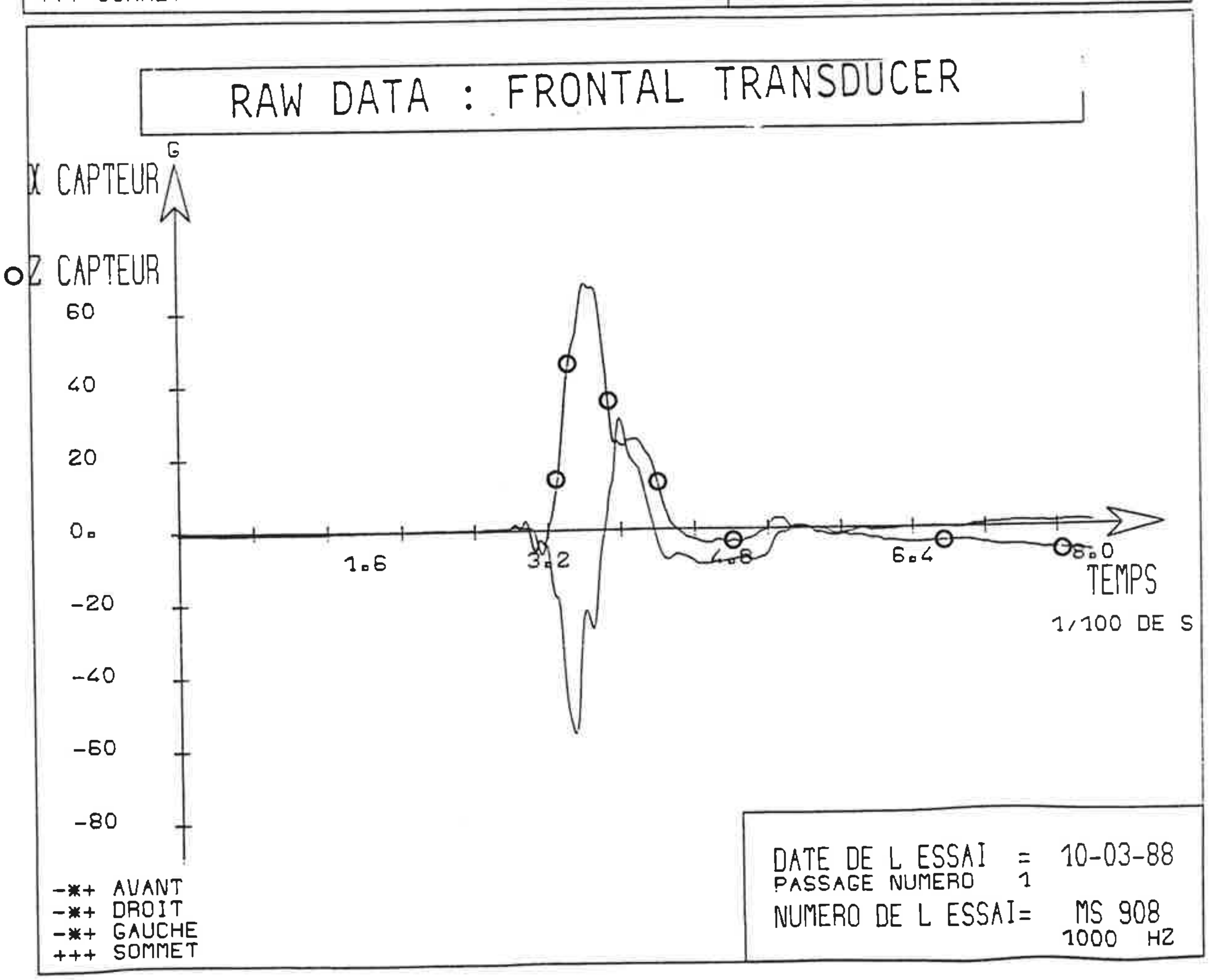

Y

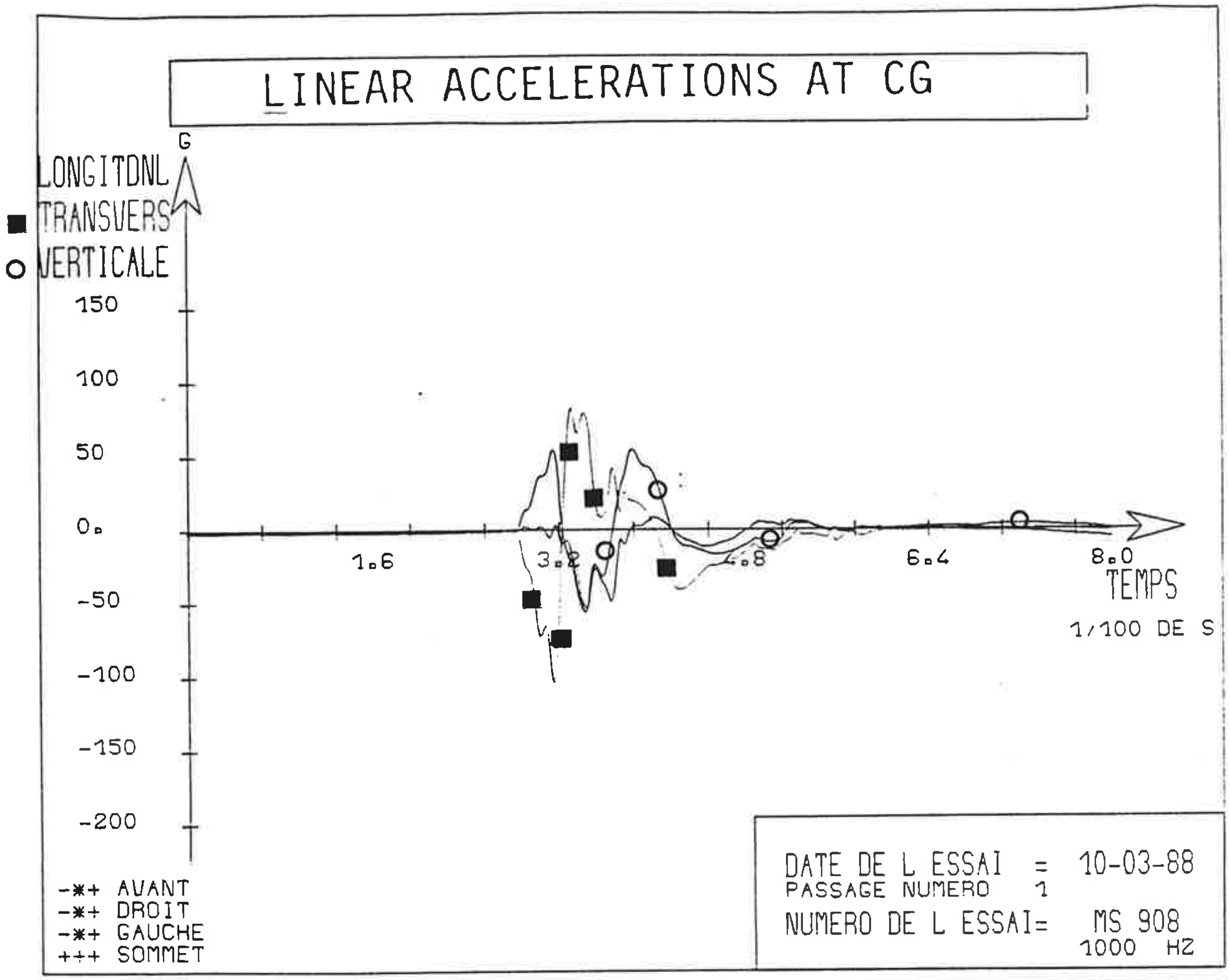



RAW DATA : RIGHT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ

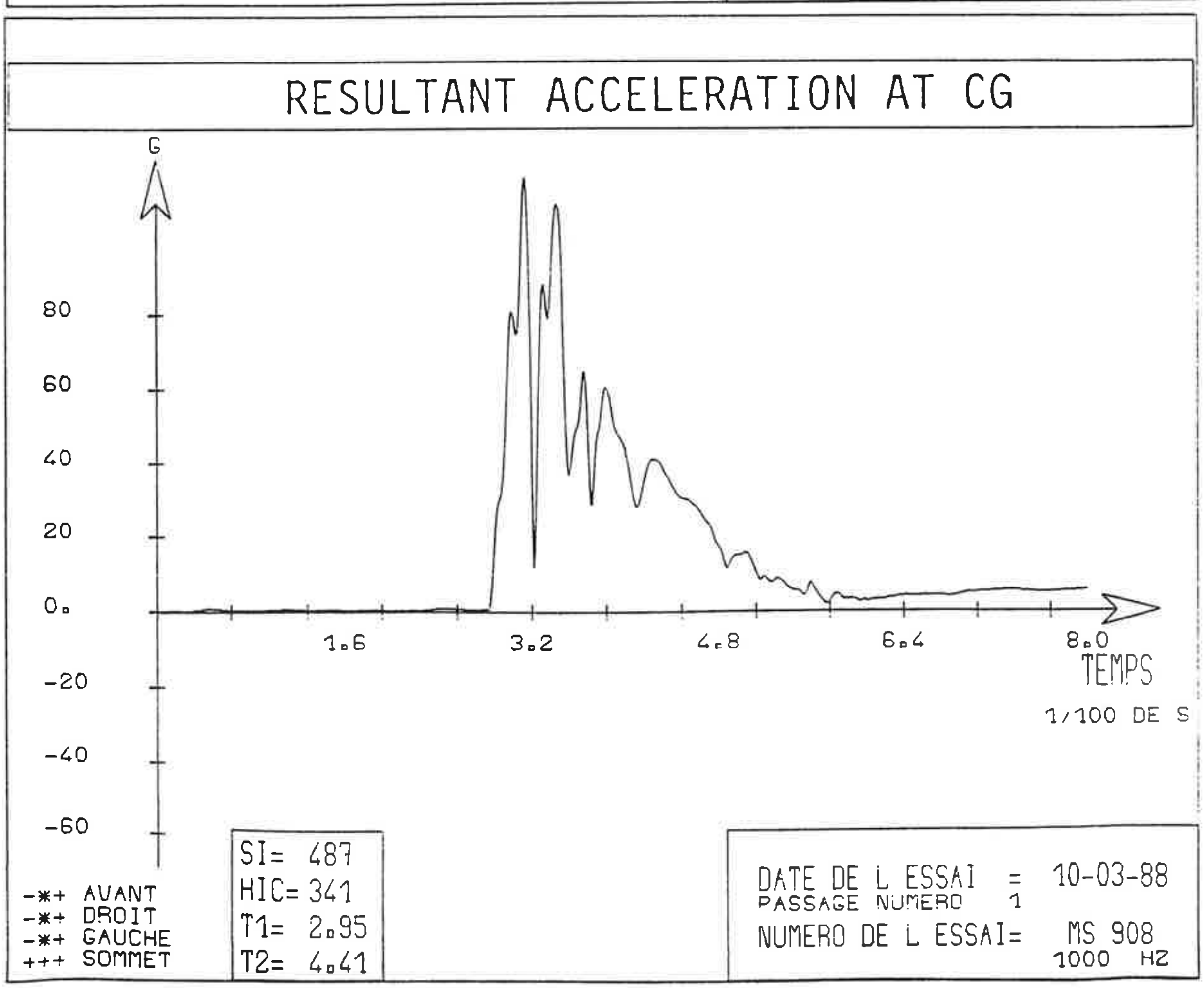

RAW DATA : LEFT TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
40
30
20
10
0.
-10
-20
-30
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ


RAW DATA : TOP TRANSDUCER
G
X CAPTEUR
Y CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ

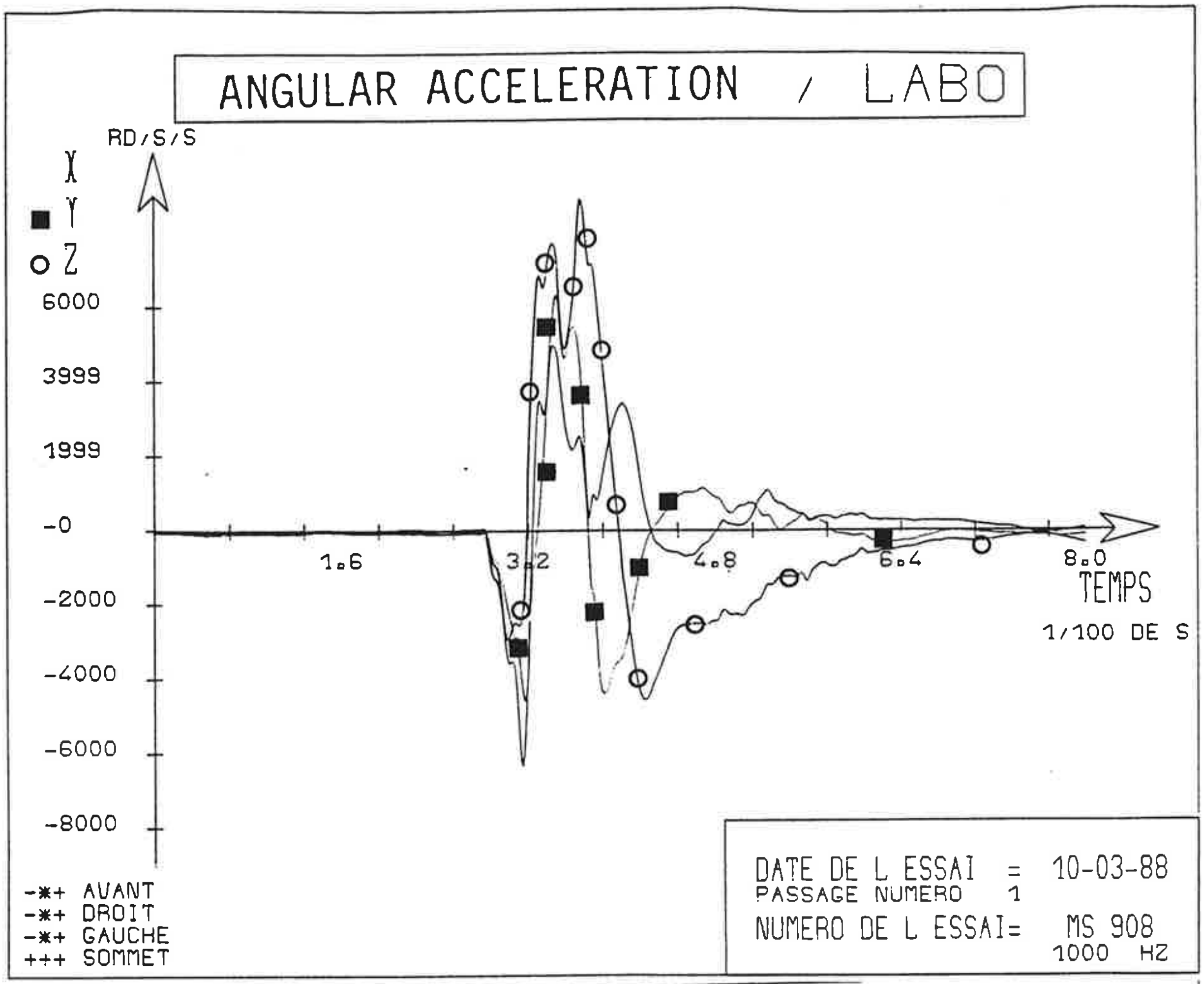

RAW DATA : FRONTAL TRANSDUCER
G
X CAPTEUR
Z CAPTEUR
60
40
20
0.
-20
-40
-60
-80
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ

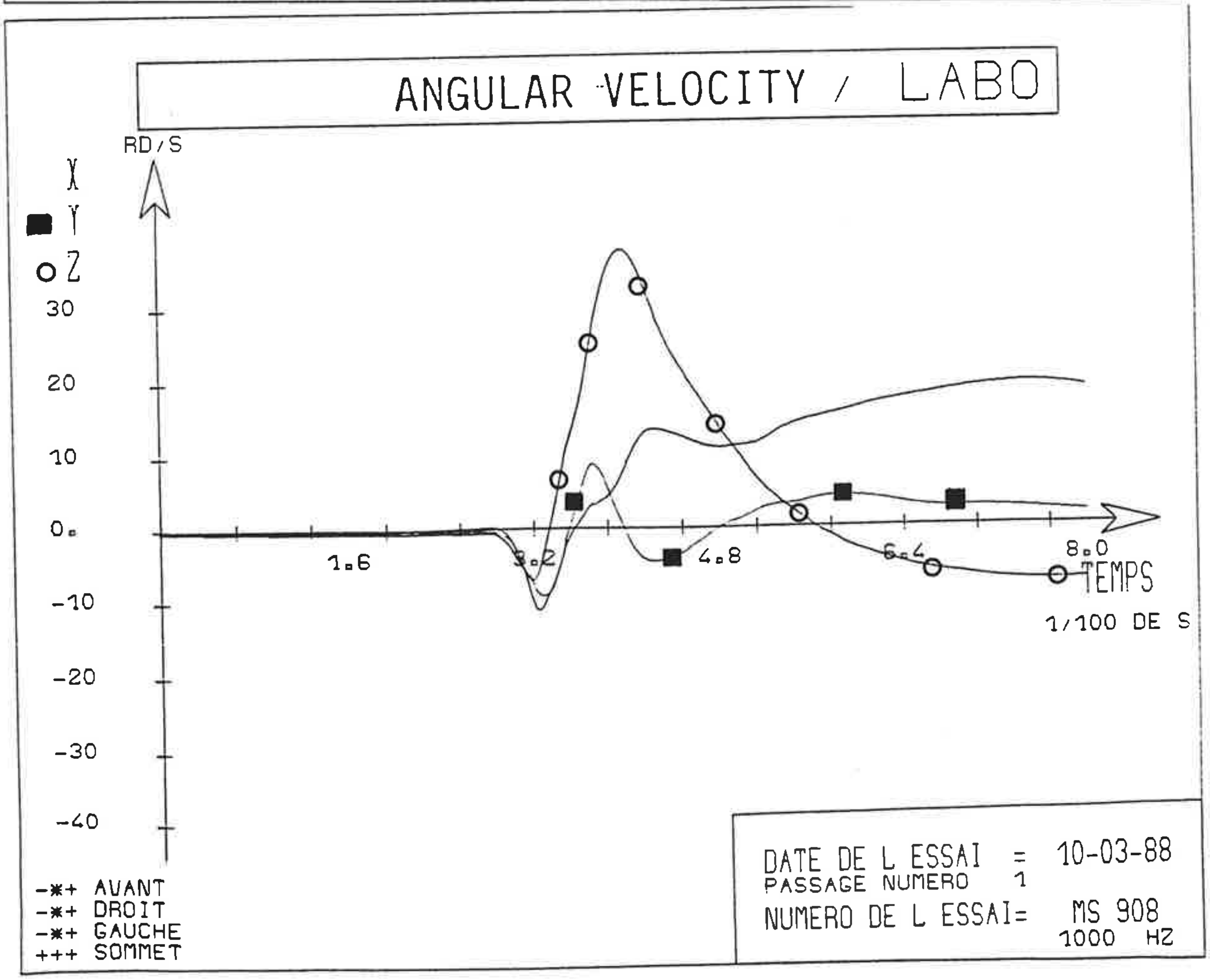


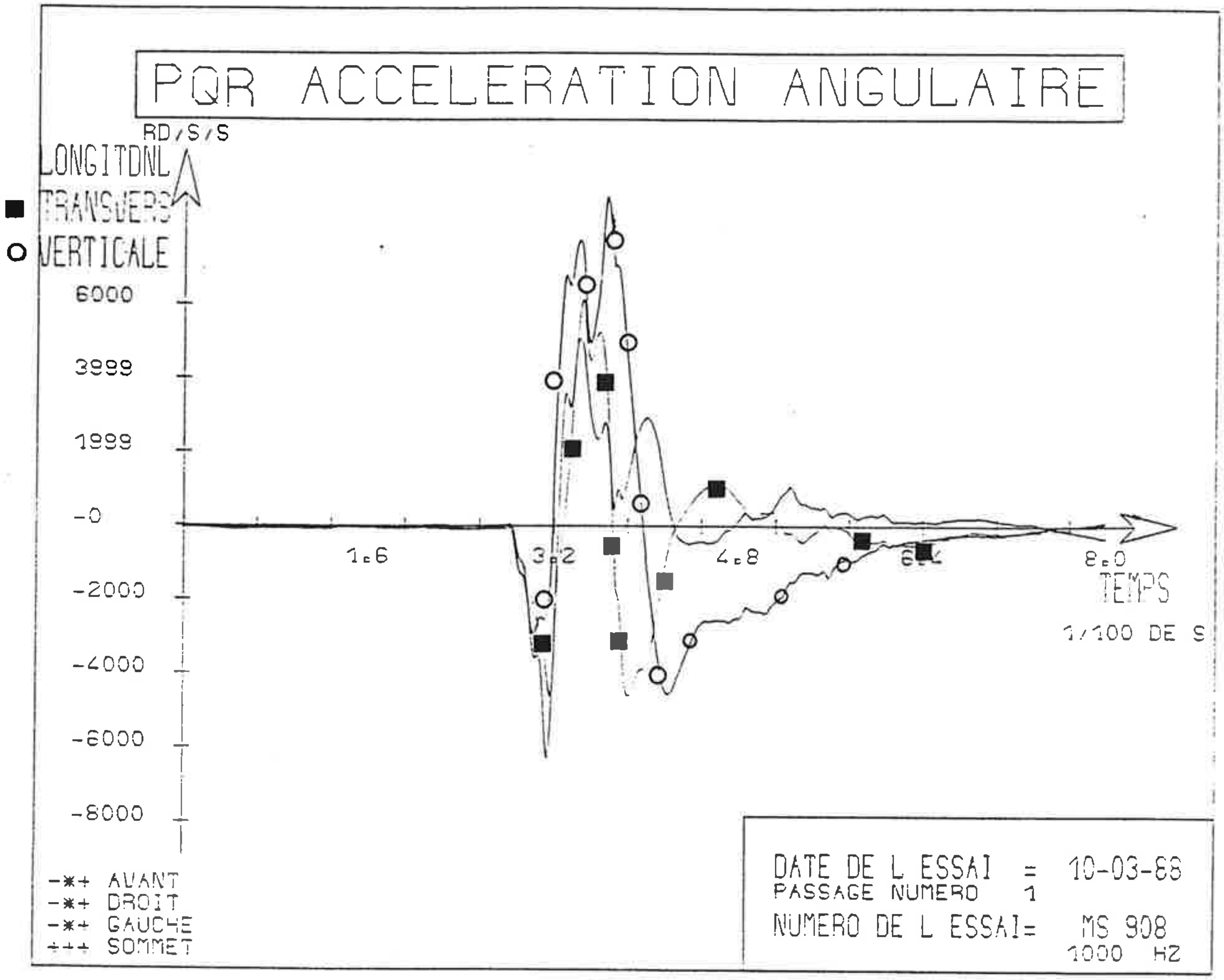
LINEAR ACCELERATIONS AT CG
G
LONGITDNL
TRANSVERS
VERTICALE
150
100
50
0.
-50
-100
-150
-200
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ



RESULTANT ACCELERATION AT CG
G
80
60
40
20
0.
-20
-40
-60
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
SI= 487
HIC= 341
T1= 2.95
T2= 4.41
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ

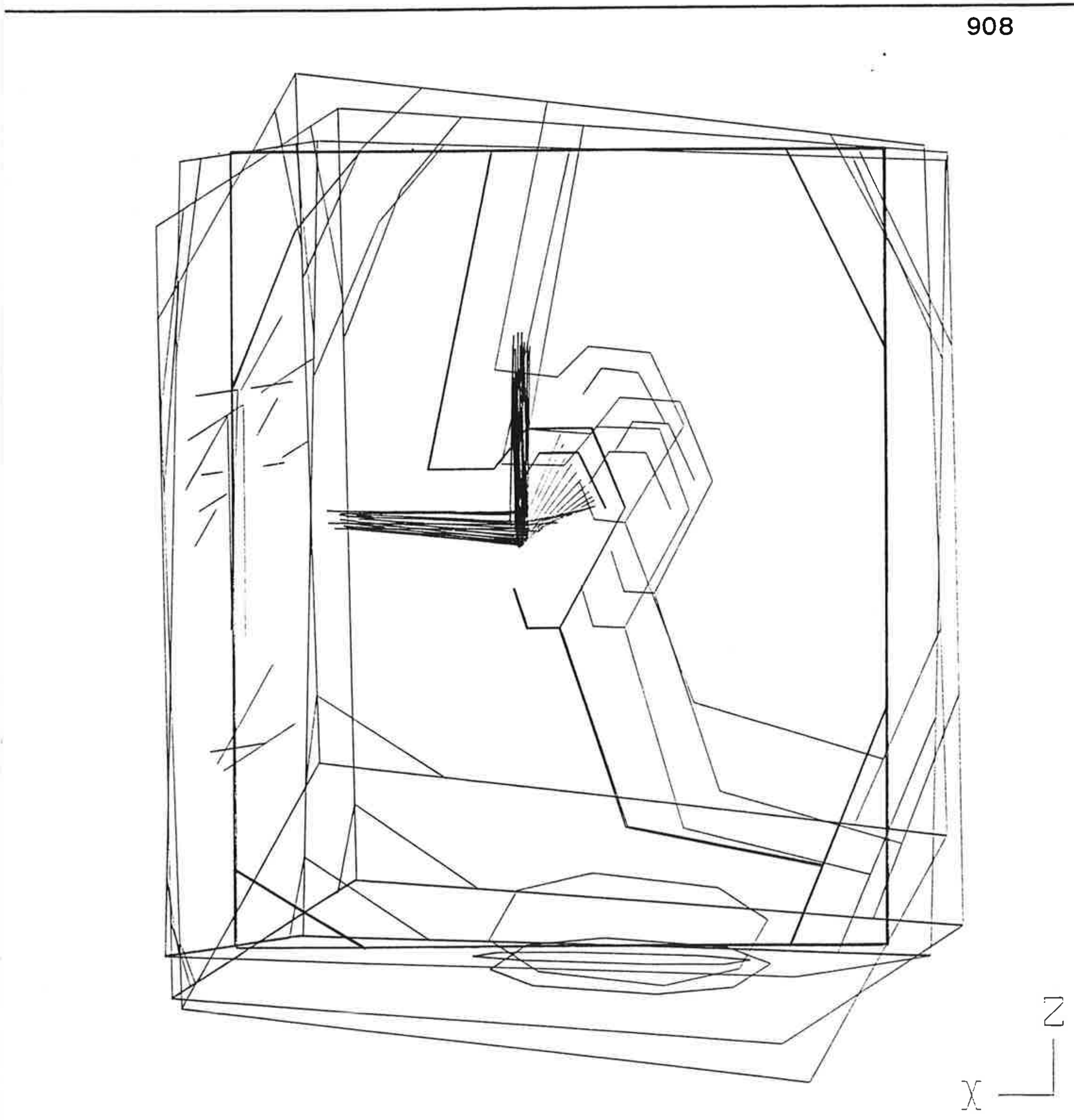

ANGULAR ACCELERATION / LABO
RD/S/S
X
Y
Z
6000
3999
1999
-0
-2000
-4000
-6000
-8000
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ

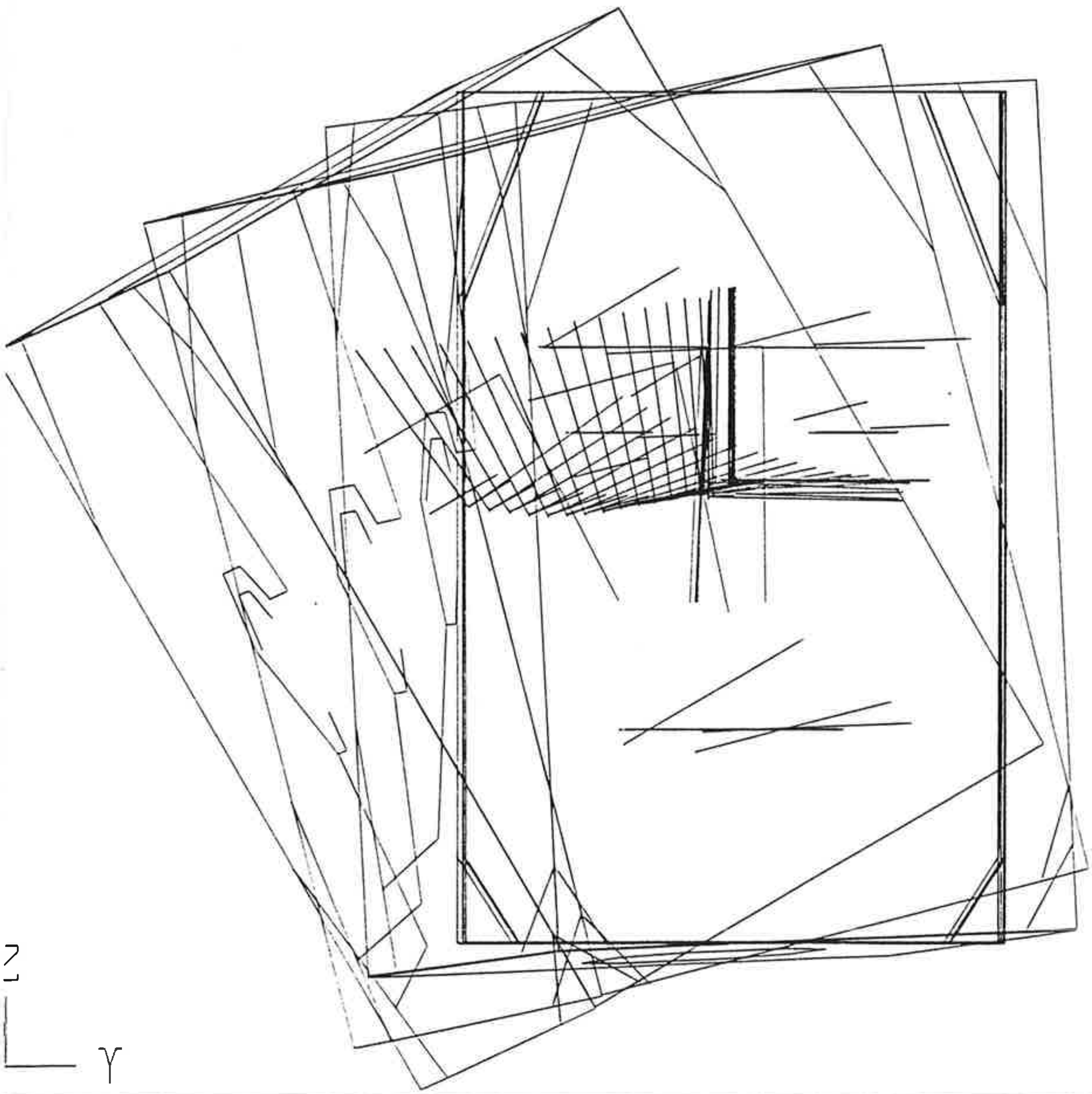

ANGULAR VELOCITY / LABO
RD/S
X
Y
Z
30
20
10
0.
-10
-20
-30
-40
1.6
3.2
4.8
6.4
8.0
TEMPS
1/100 DE S
-*+ AVANT
-*+ DROIT
-*+ GAUCHE
+++ SOMMET
DATE DE L ESSAI = 10-03-88
PASSAGE NUMERO 1
NUMERO DE L ESSAI= MS 908
1000 HZ

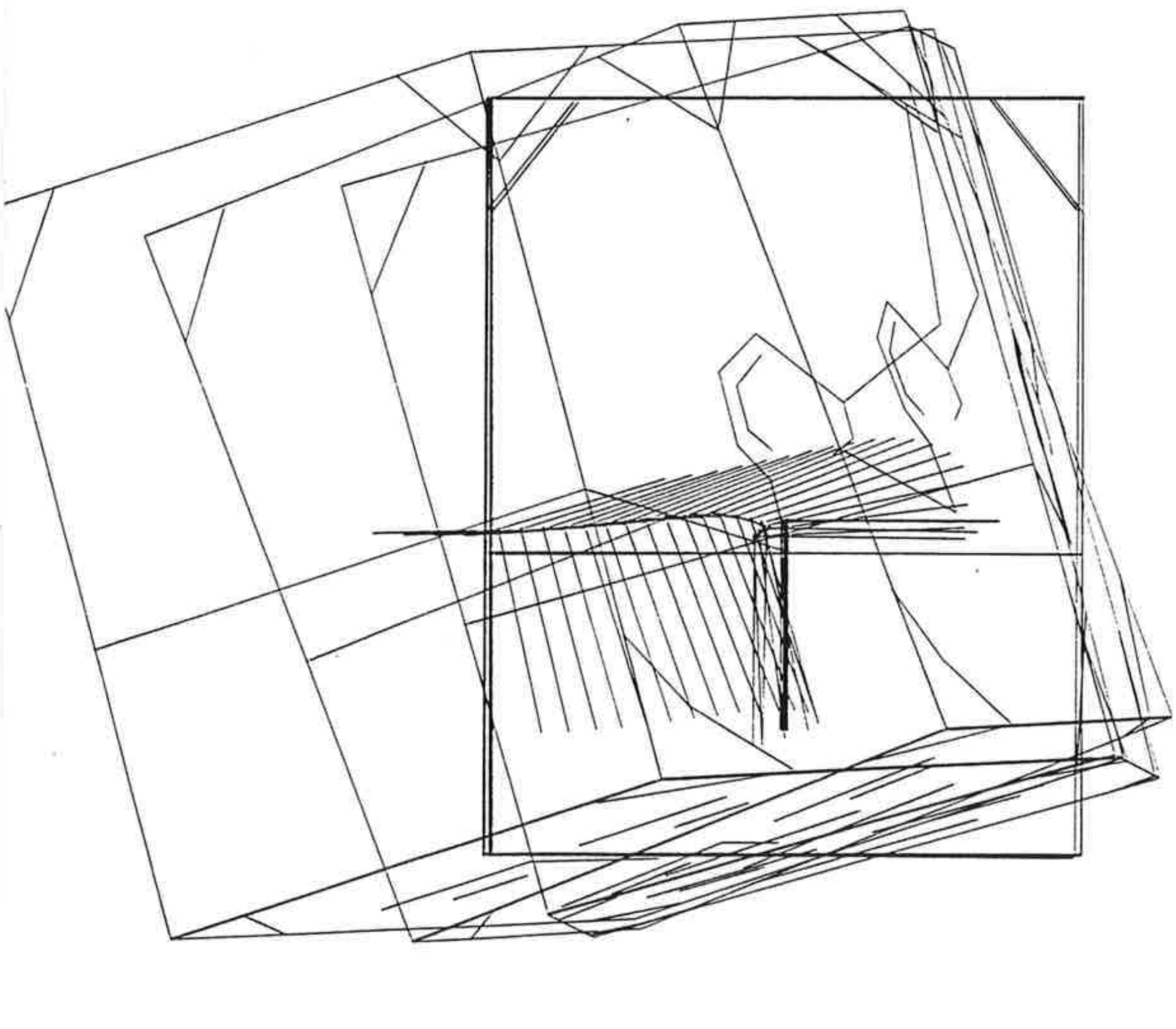


ANGULAR ACCELERATION IN THE ANATOMICAL COORDINATE SYSTEM (BLOW 908)

HEAD KINEMATICS FOR BLOW 908


908
Z
X

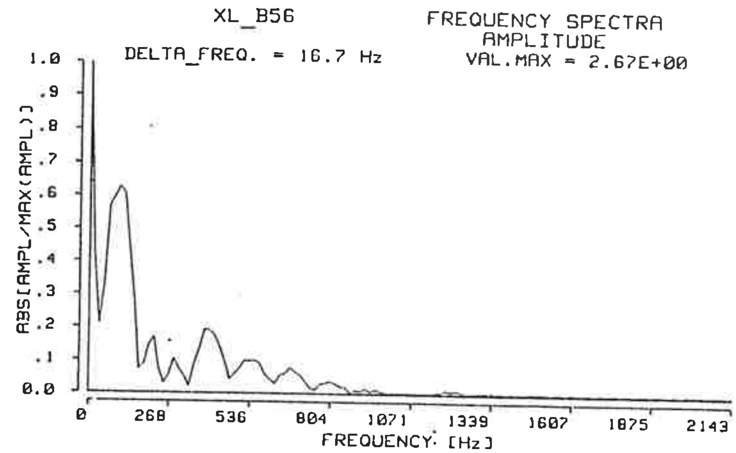

Z
Y

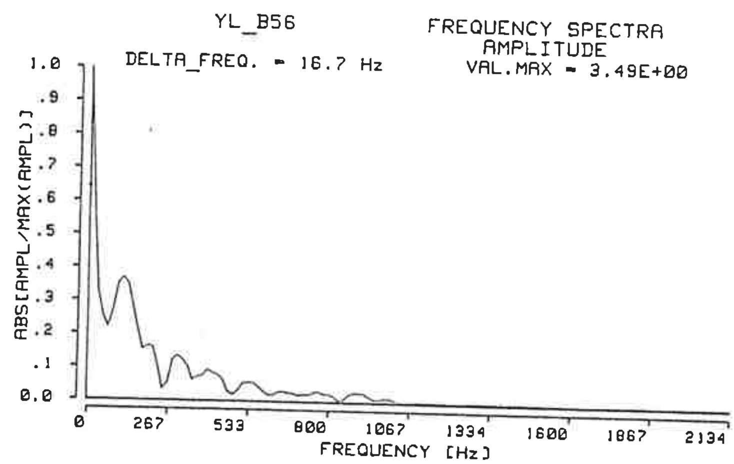


IV.5. SPECTRAL ANALYSIS

A spectral analysis of the linear acceleration at the center of gravity (x, y, z components) and of the angular acceleration was performed. The curves were digitized and the analysis processing was made, using a micro computer Hewlett Packard. Results are given on figures 15 to 32. Generally speaking the peaks are below 250 Hz ; there is an exception for blow 714, whose spectrum is different and extends up to 560 Hz.

In fact, the blow occurred on the helmet ; it is nevertheless analyzed and given as an other example, to see the differences.





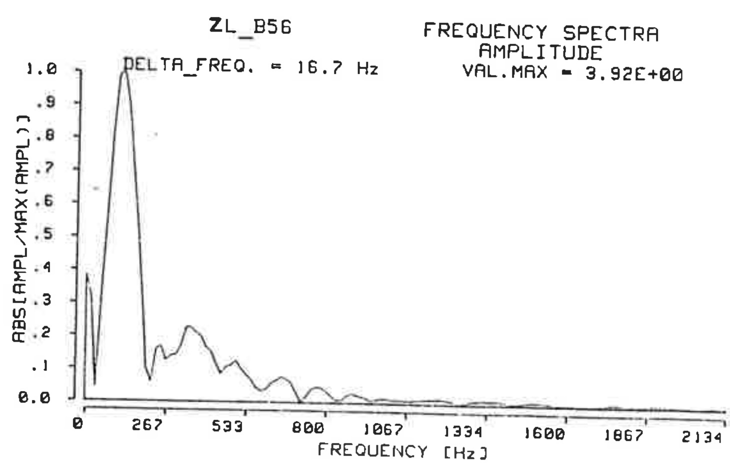
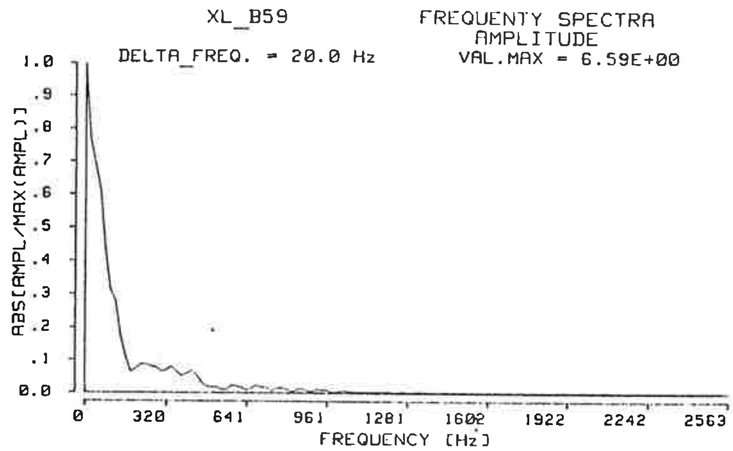
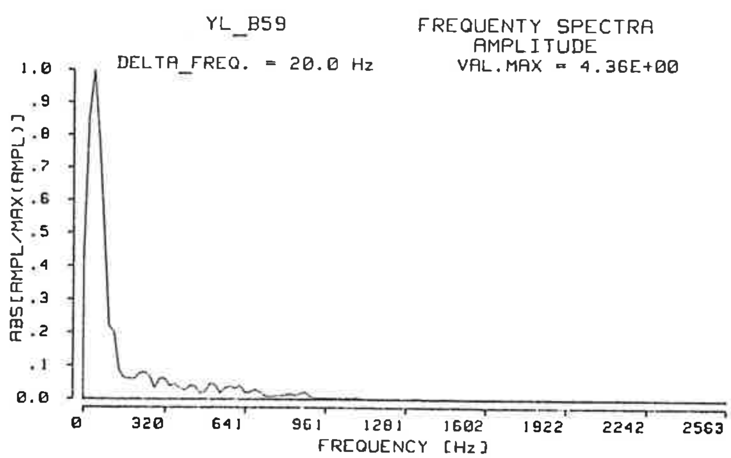


Figure 15. BLOW B56 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION





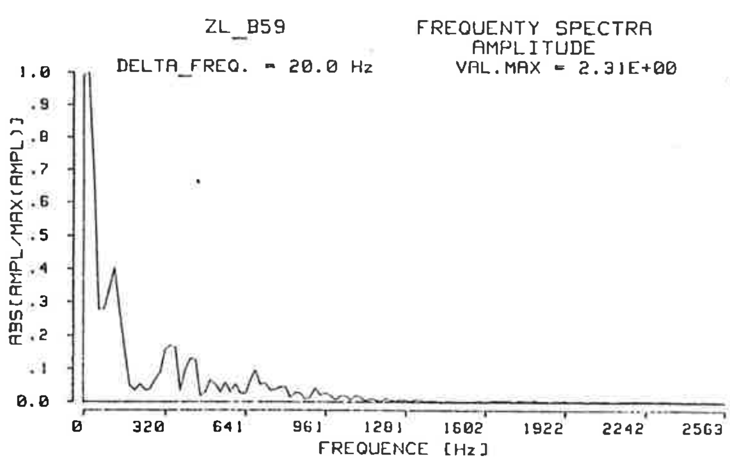
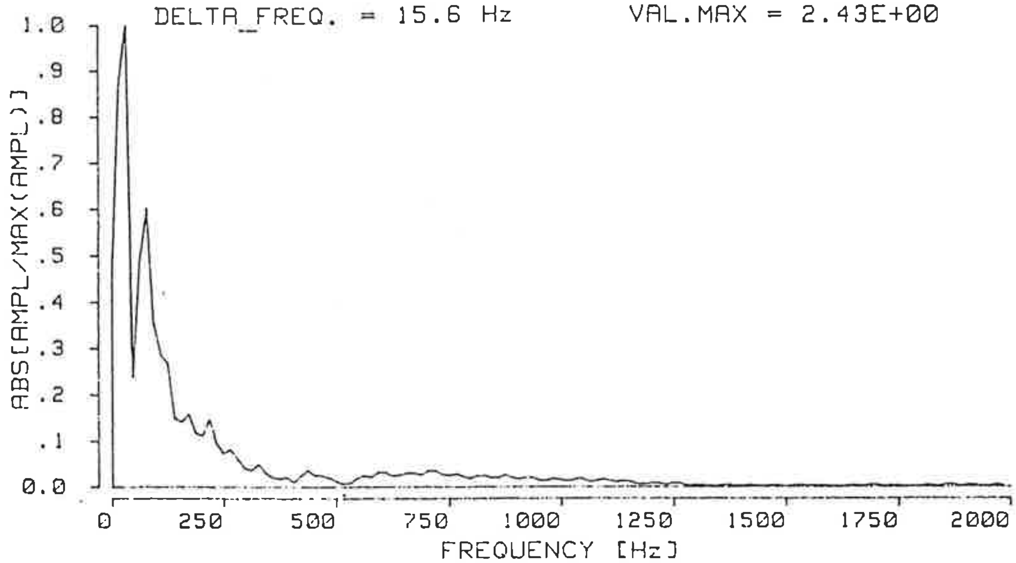
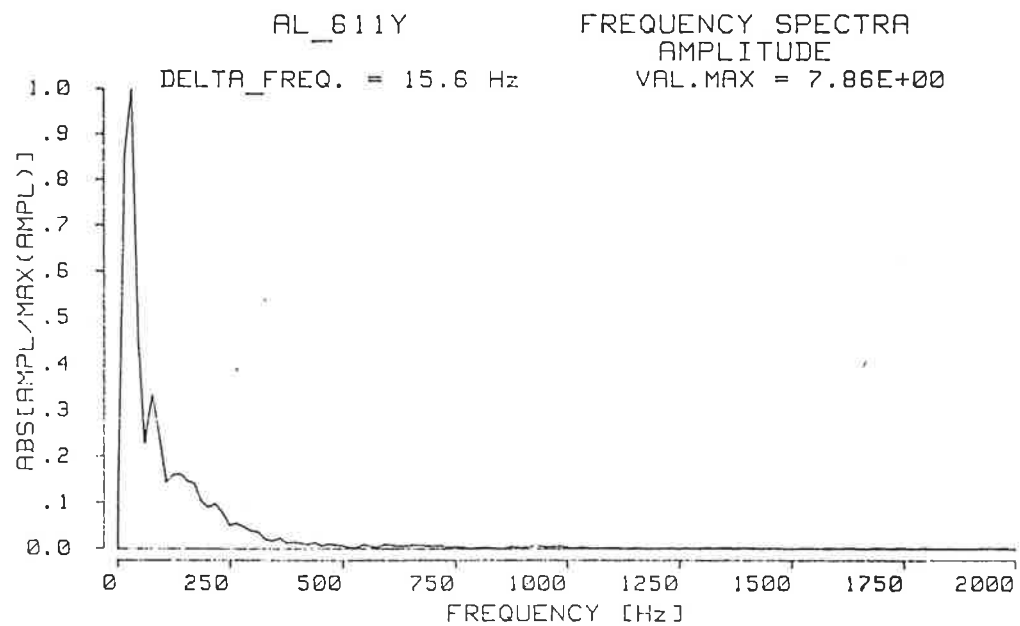


Figure 16. BLOW B59 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION





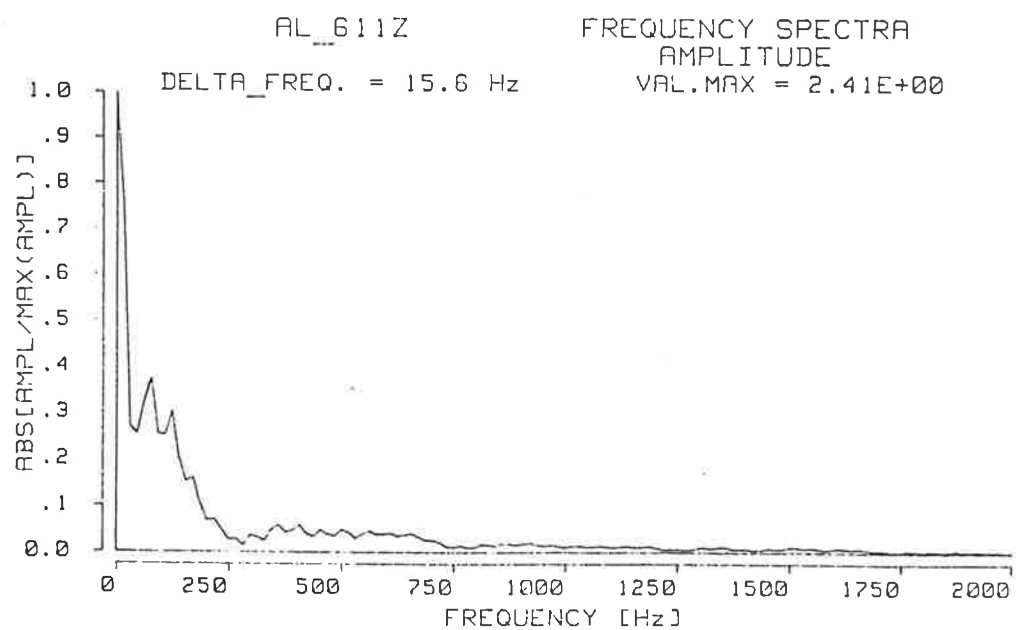


Figure 17. BLOW 611 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION

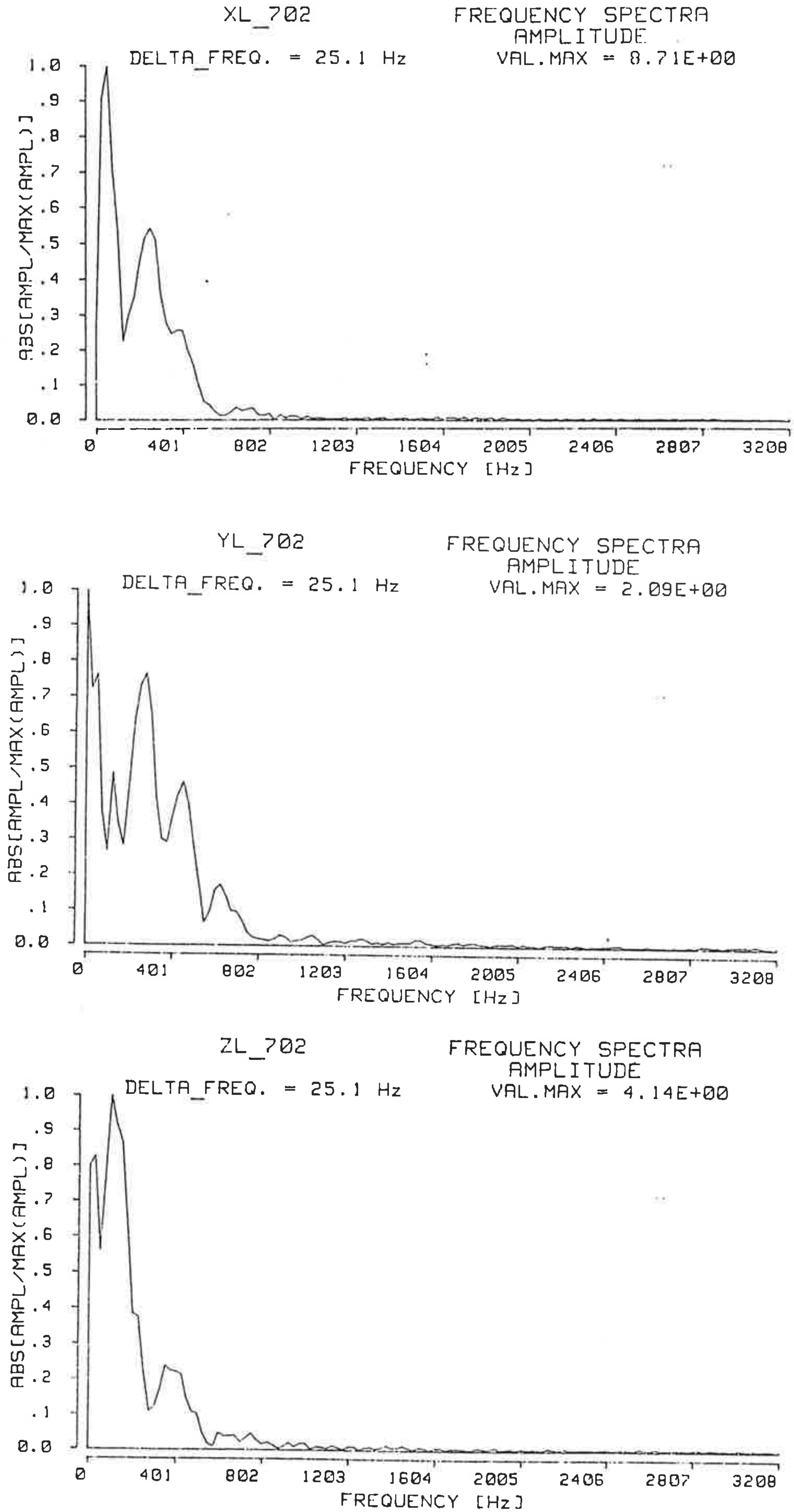
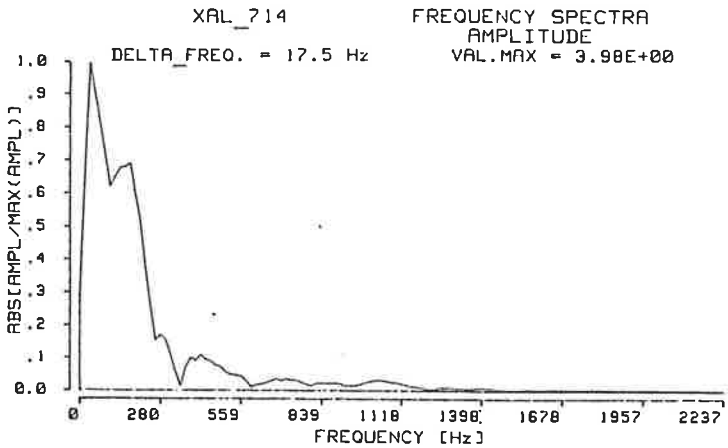
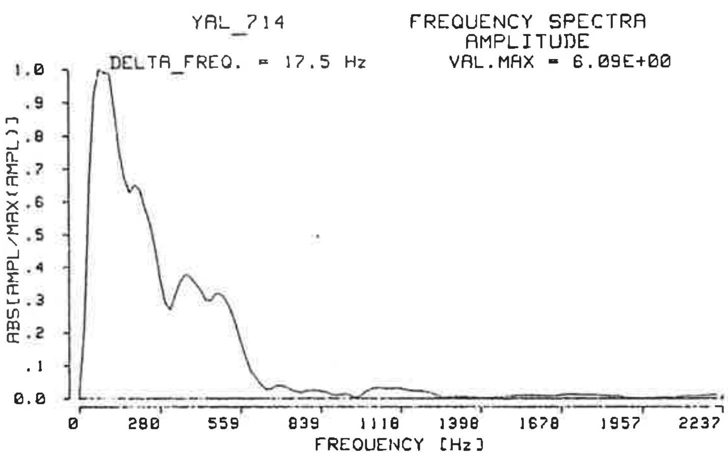


Figure 18. BLOW 702 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION





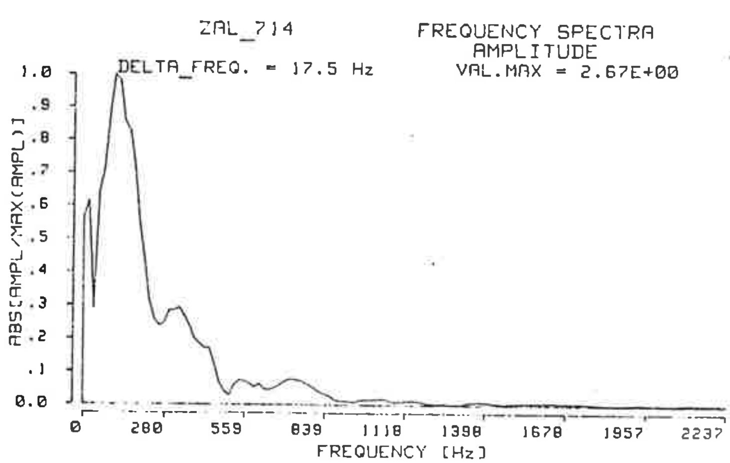


Figure 19. BLOW 714 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION BLOW ON THE HELMET

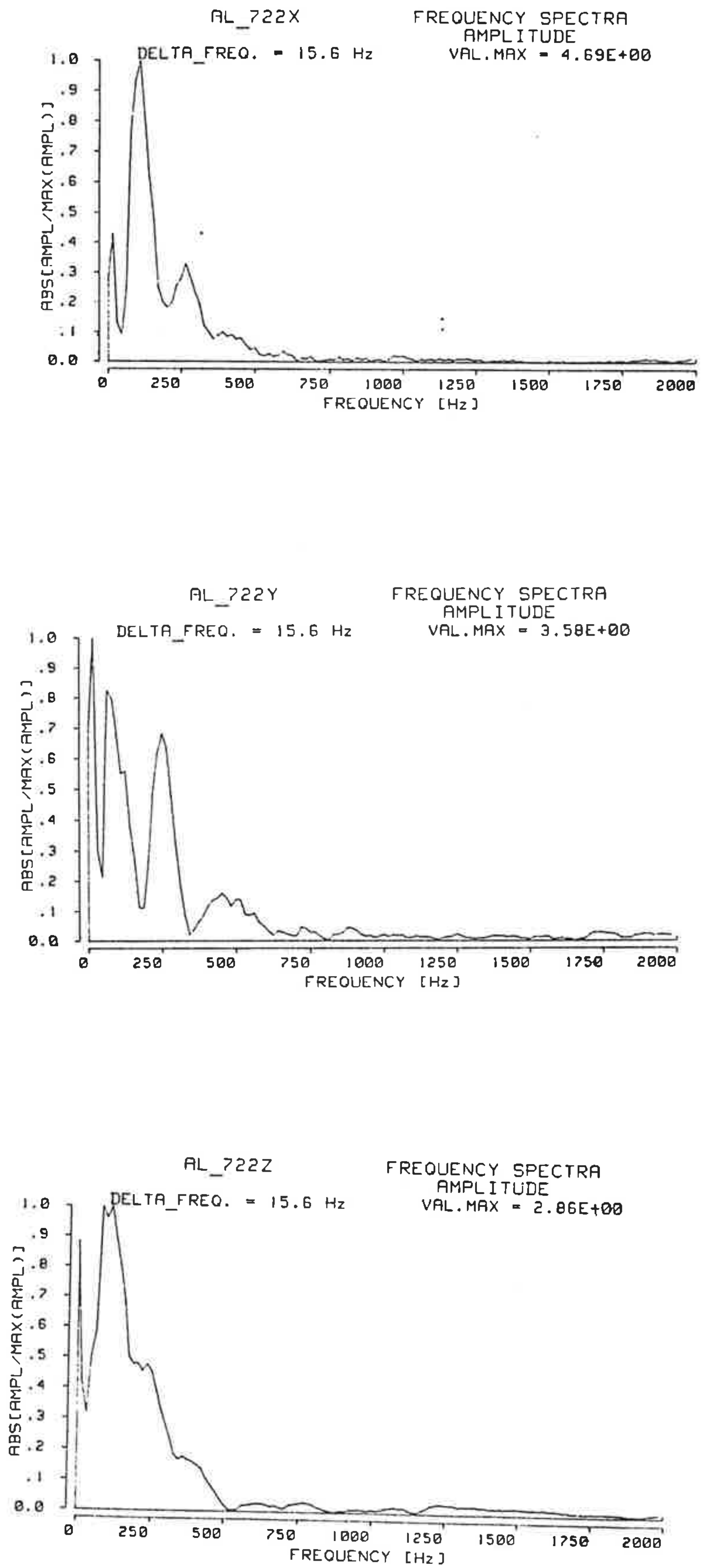


Figure 20. BLOW 722 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION

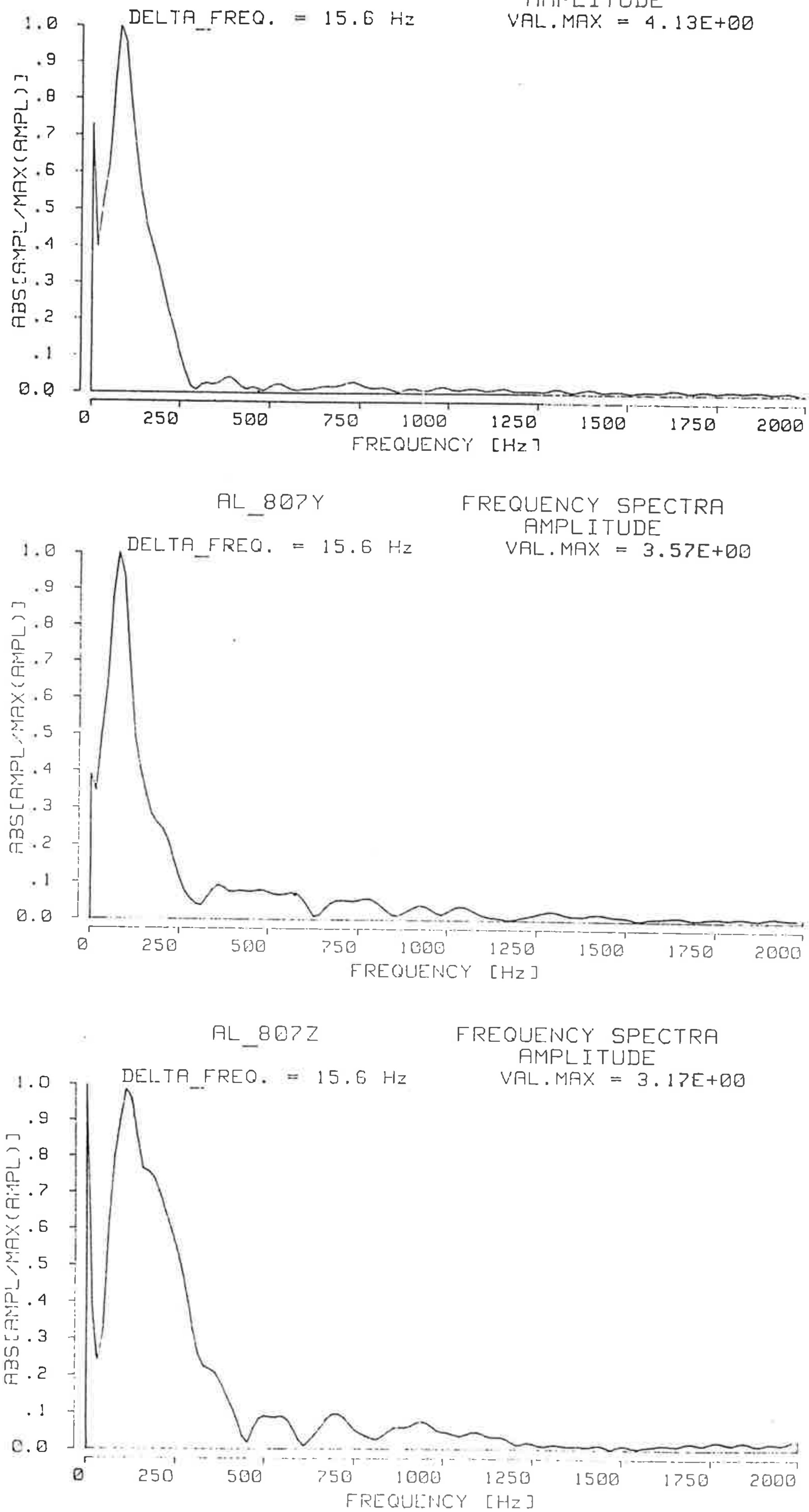


Figure 21. BLOW 807 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION

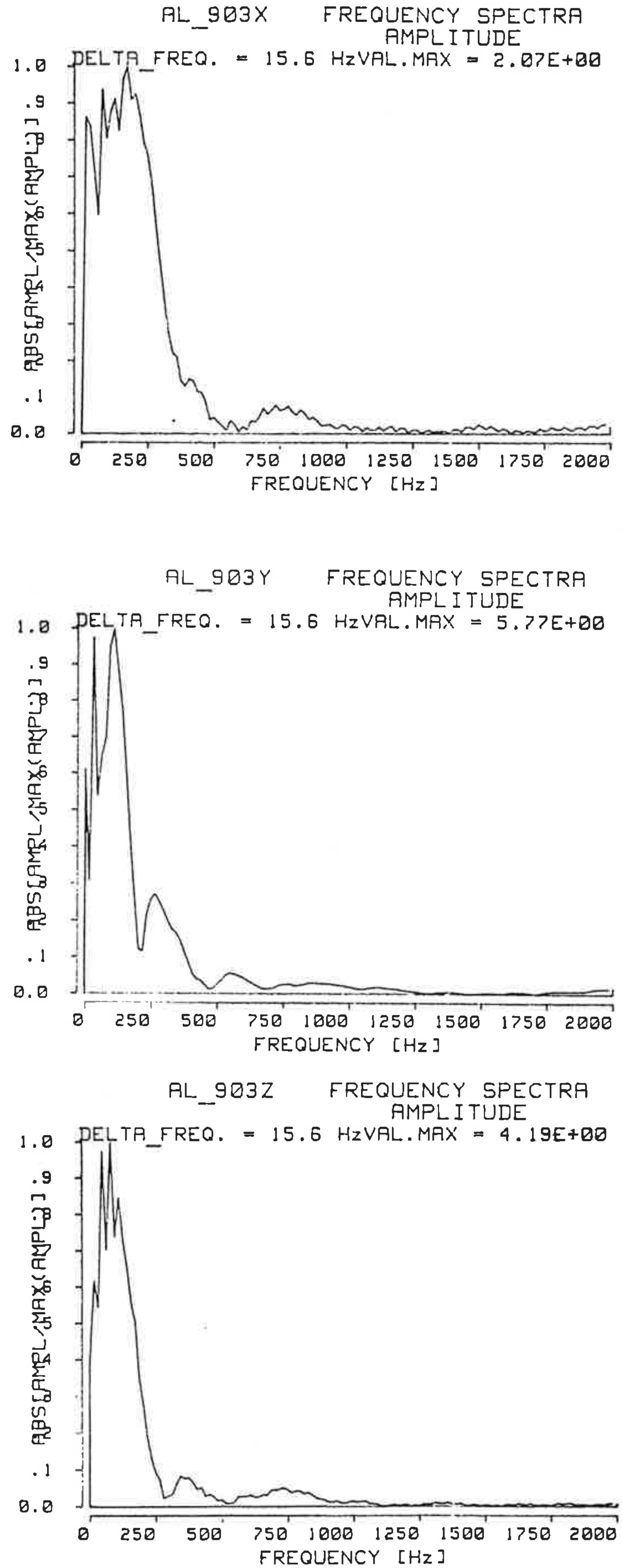


Figure 22. BLOW 903 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION

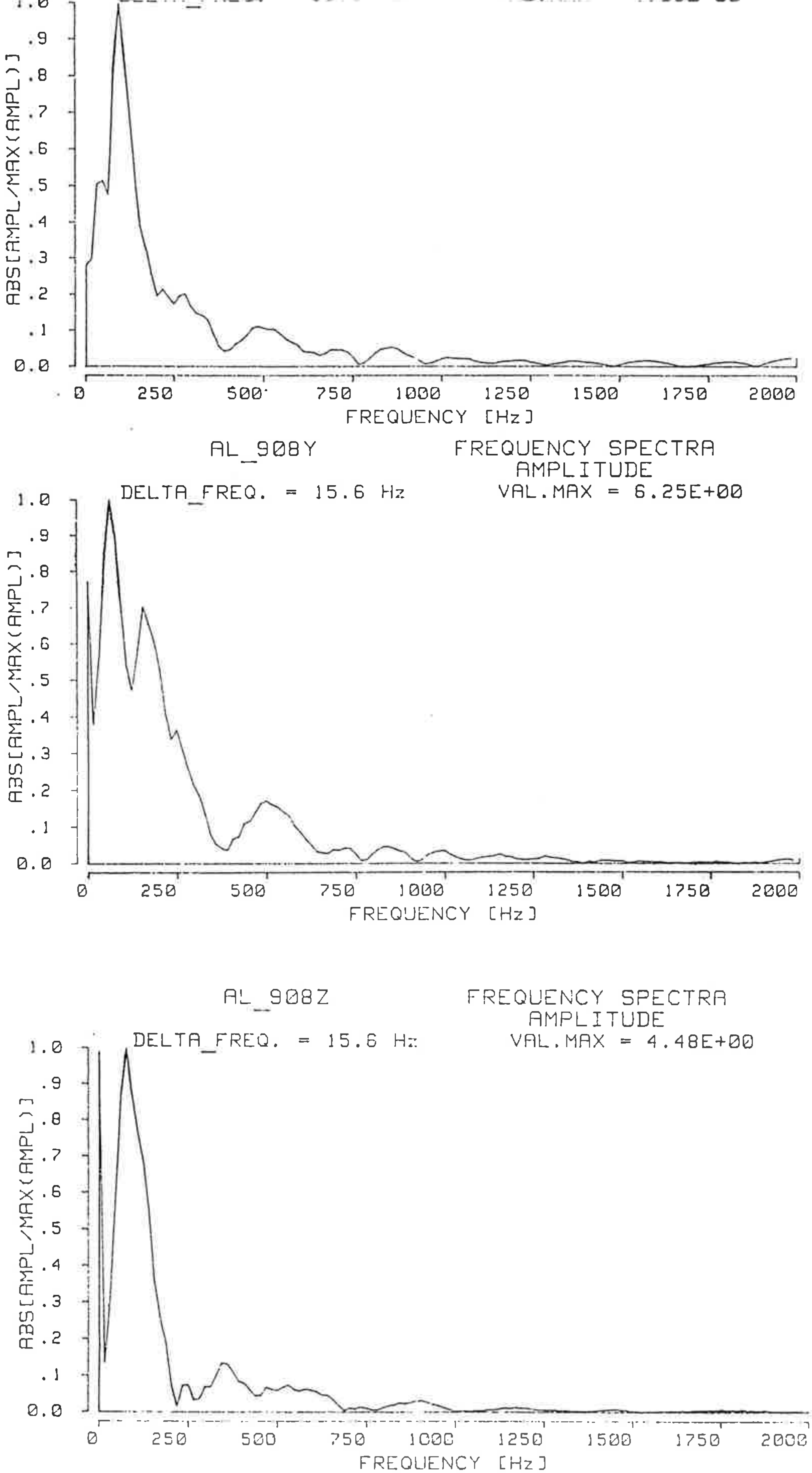


Figure 23. BLOW 908 SPECTRAL ANALYSIS OF THE LINEAR ACCELERATION

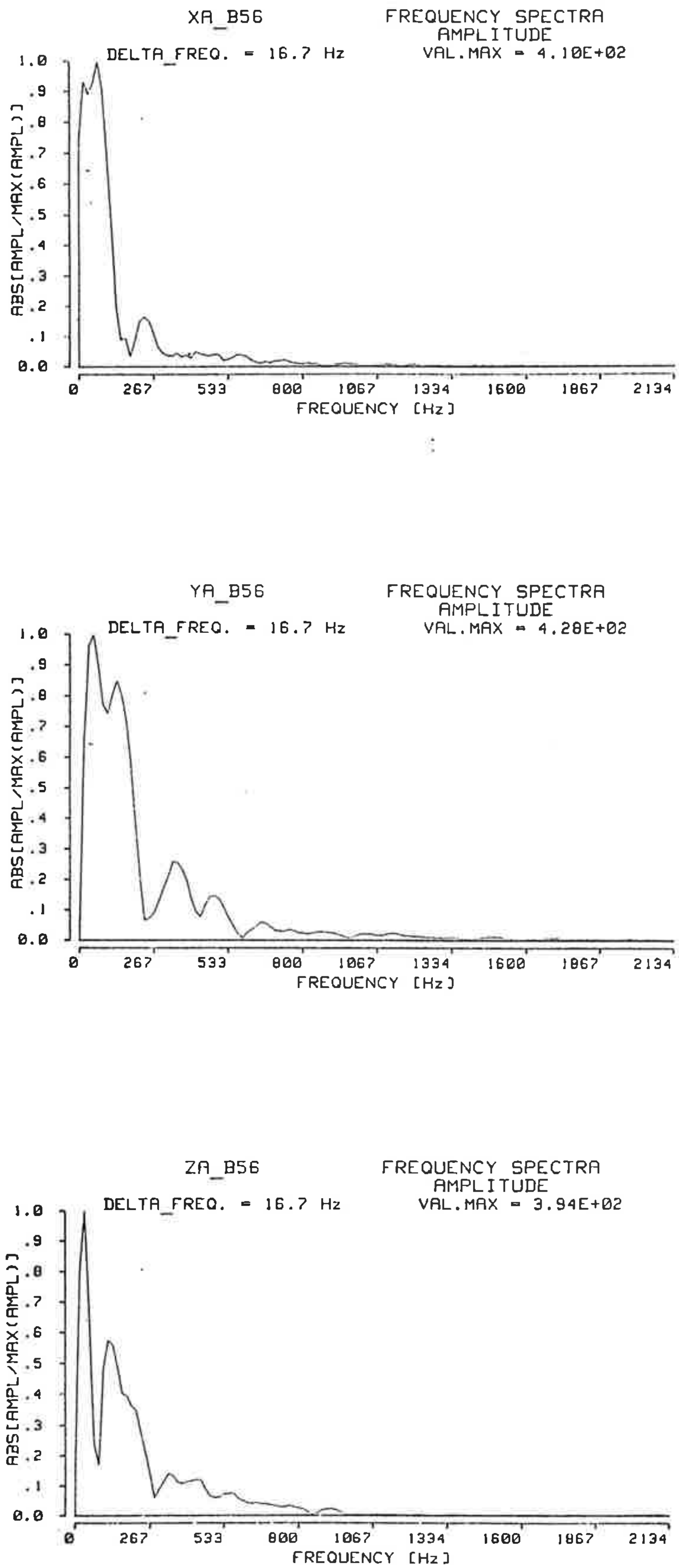
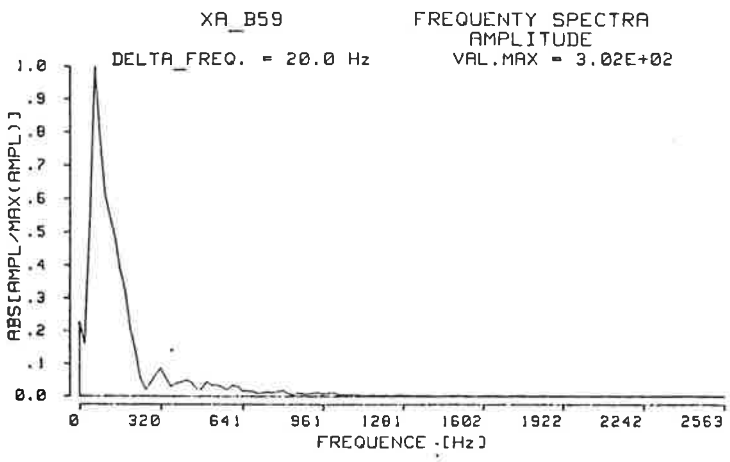
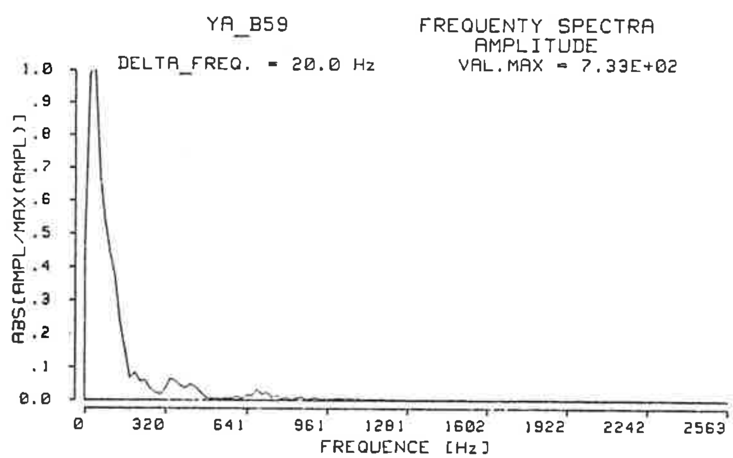


Figure 24. BLOW B56 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION





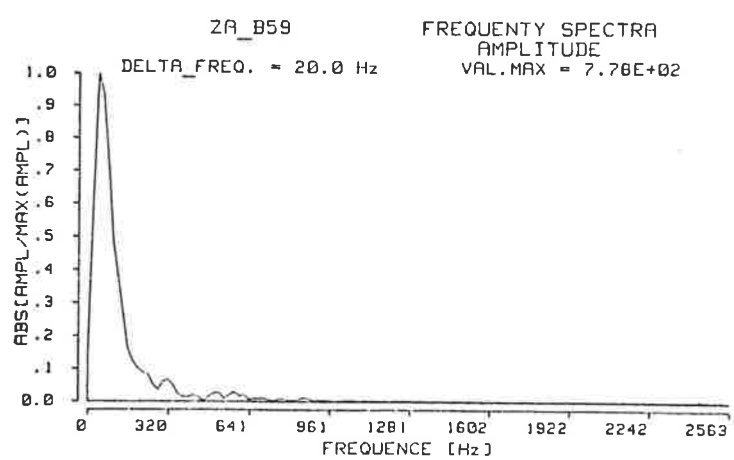


Figure 25. BLOW B59 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION

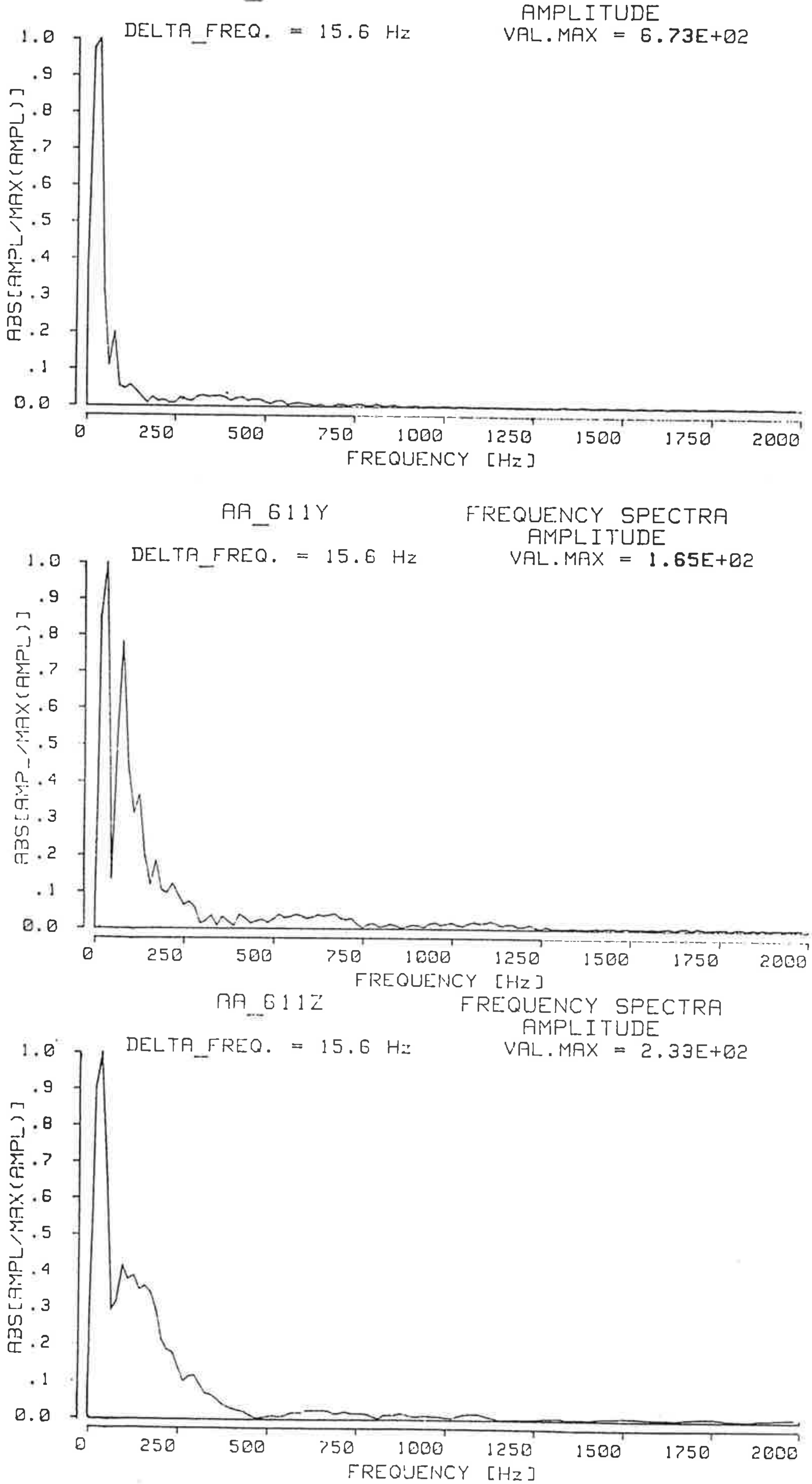


Figure 26. BLOW 611 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION

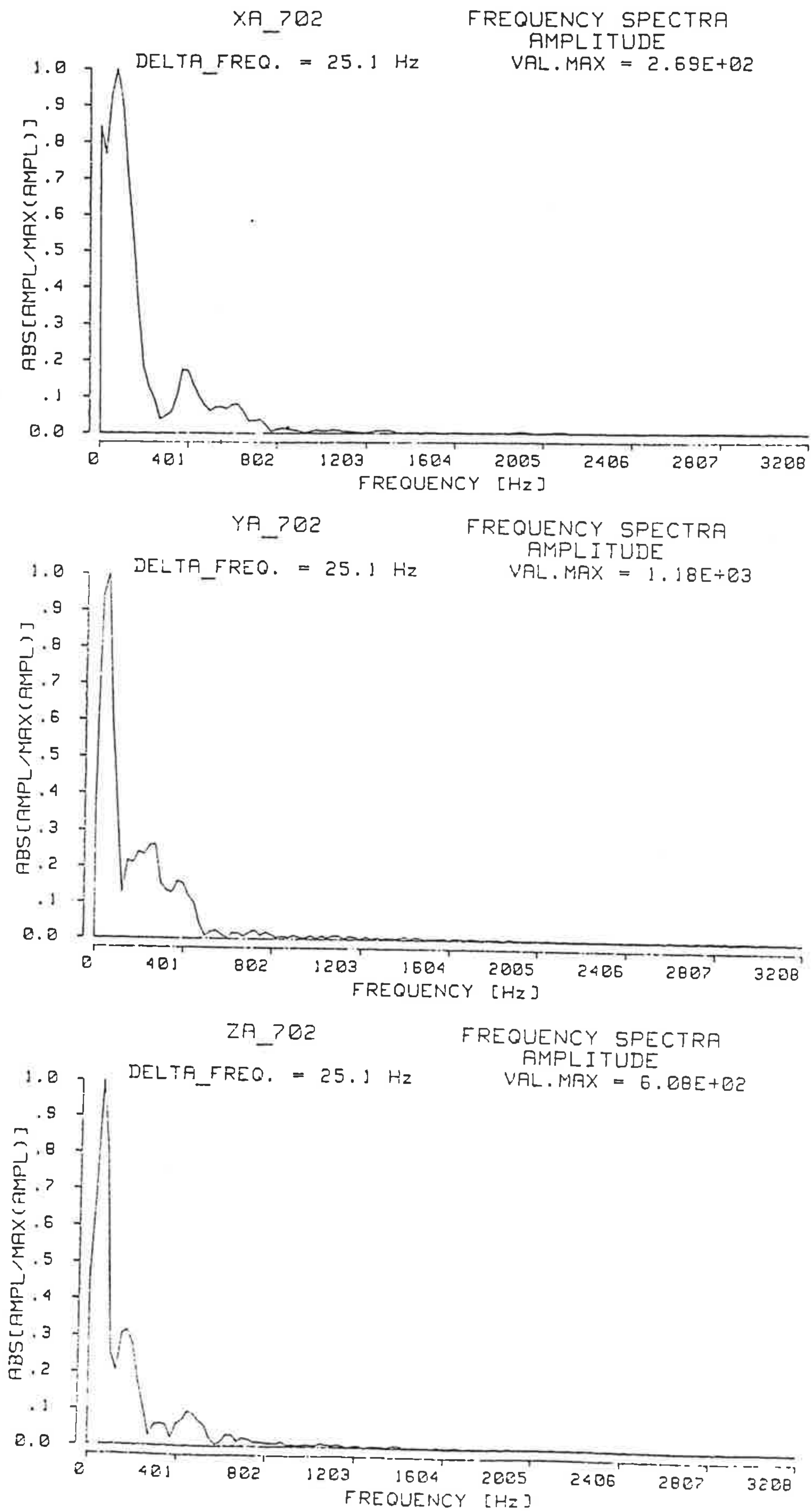
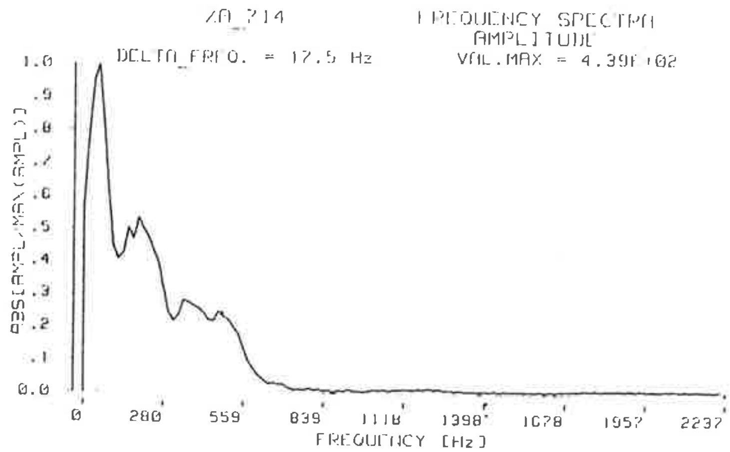
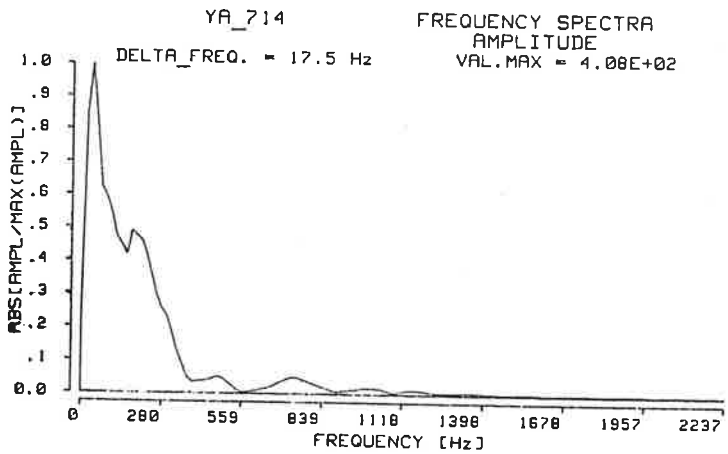


Figure 27. BLOW 702 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION





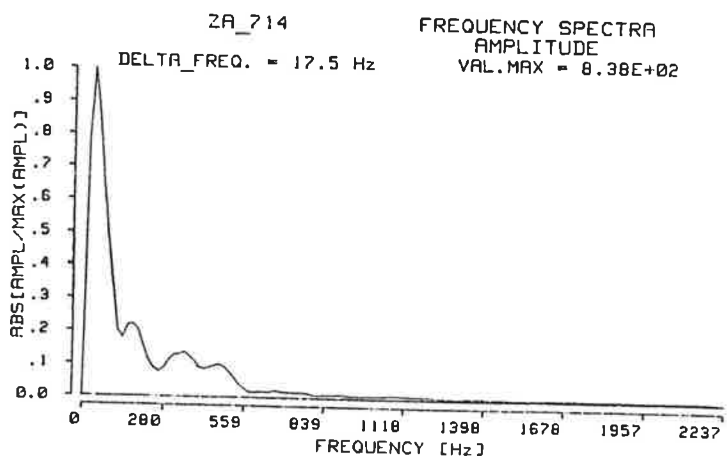
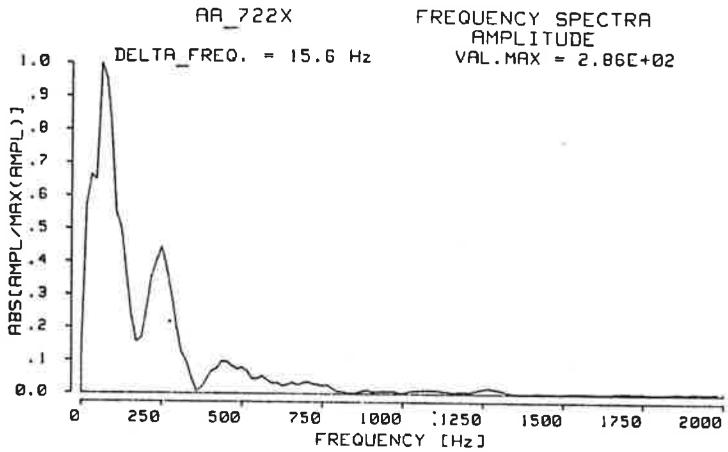
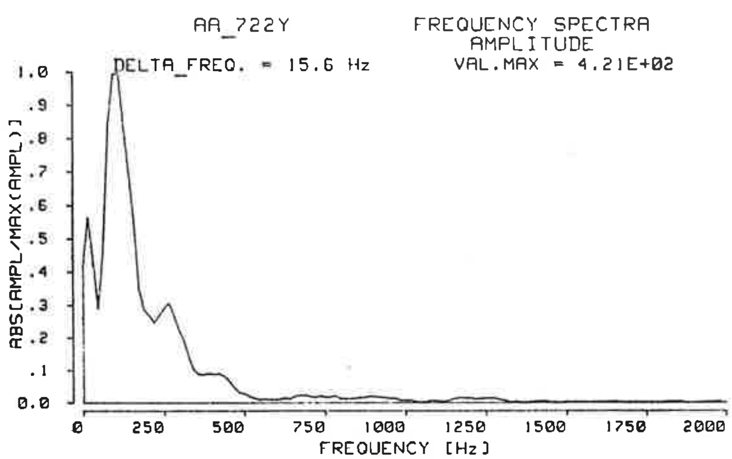


Figure 28. BLOW 714 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION





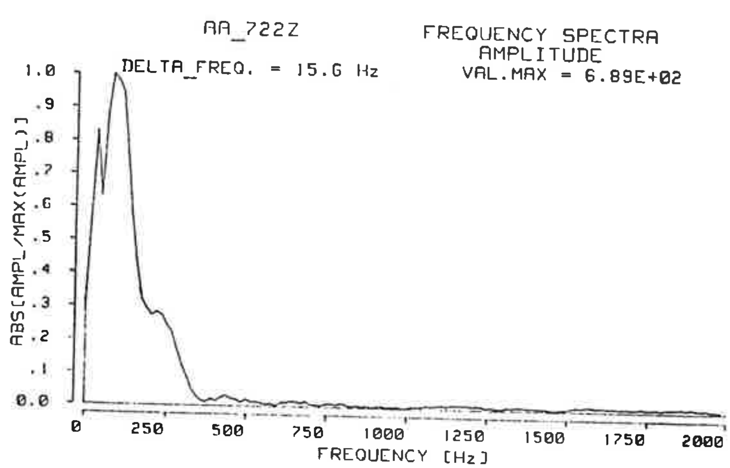


Figure 29. BLOW 722 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION

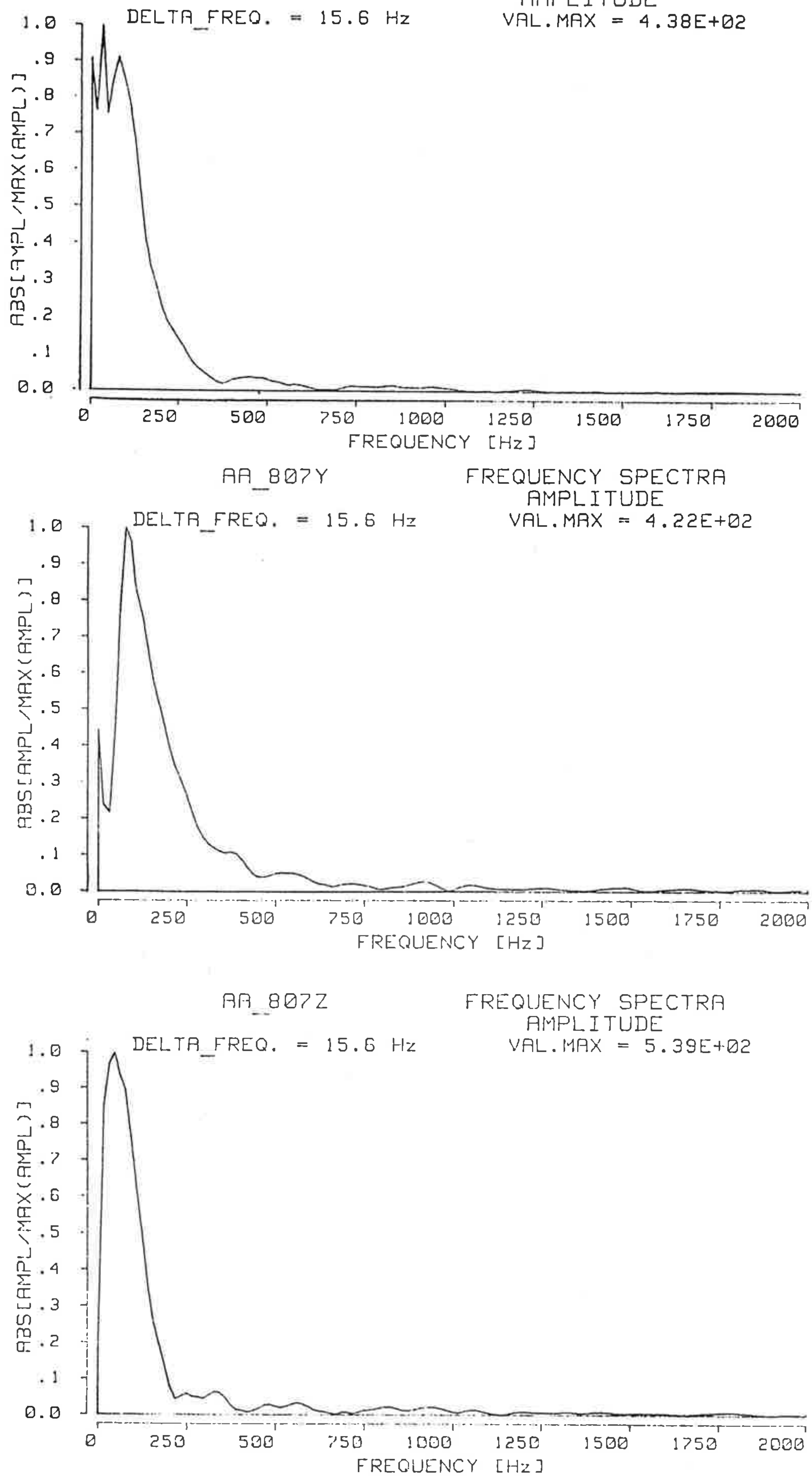


Figure 30. BLOW 807 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION

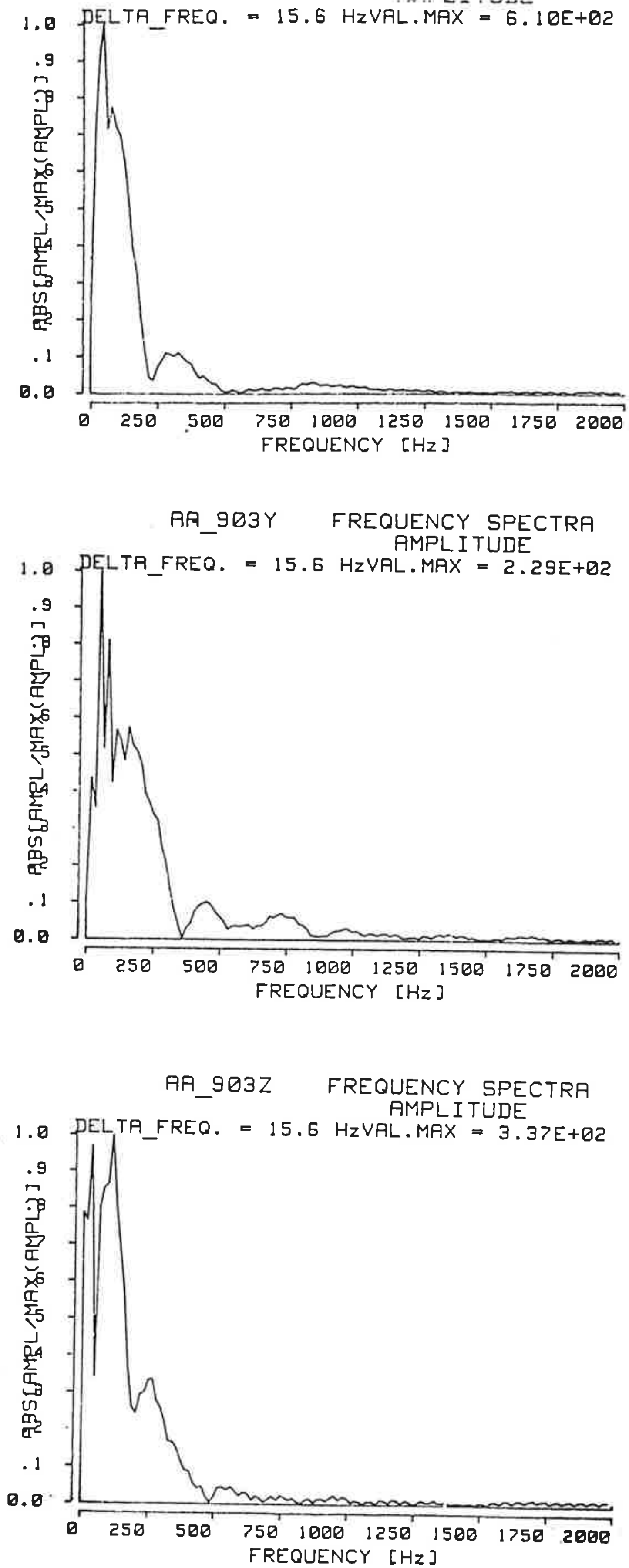


Figure 31. BLOW 903 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION

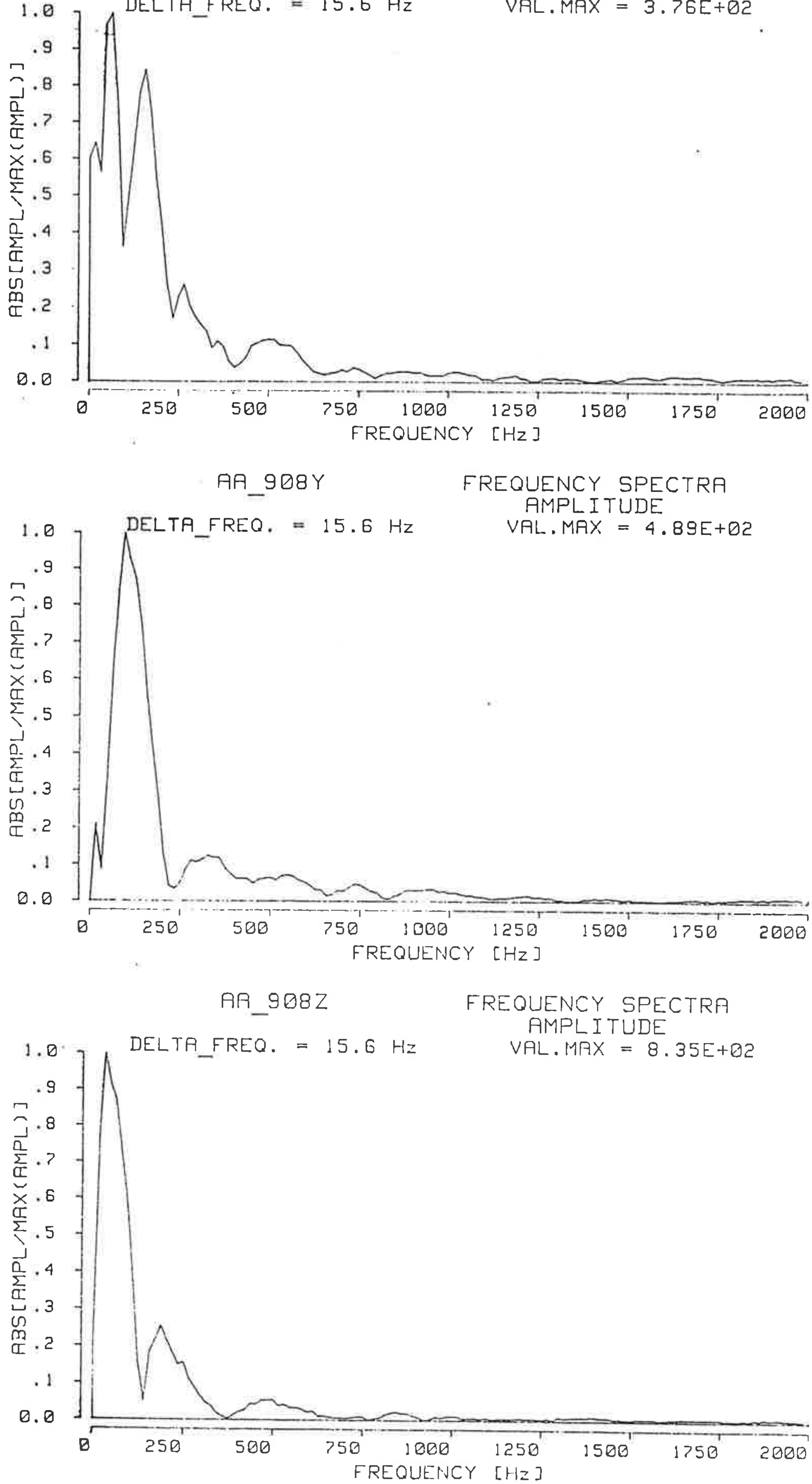


Figure 32. BLOW 908 SPECTRAL ANALYSIS OF ANGULAR ACCELERATION

V - PSYCHOLOGICAL AND PHYSIOLOGICAL TESTS

V.1. THE ELECTROENCEPHALOGRAM OF THE BOXER

The aim of this recording is to detect possible disturbances of the electroencephalogram, resulting from the blows received by the boxer during the fight.

Four silver electrodes are stuck on the frontal and parietal areas of the boxer's head, the occipital area being covered by the helmet supporting the accelerometers (see figure 33).

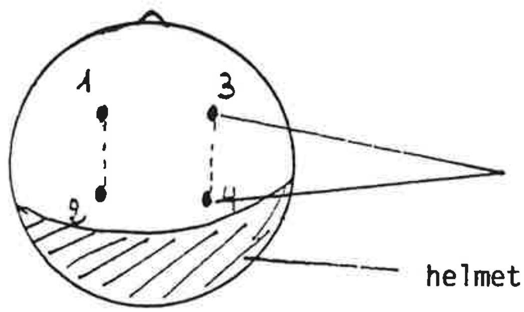


Figure 33.

Transfer of the signal is achieved by telemetry with the aim of not hindering the boxer's movements.

The signal of two derivation (1 - 2 and 3 - 4) is recorded on a magnetic tape and at the same time plotted on paper during the fight.

One is mainly interested in the variations in the electroencephalogram during the following periods :

- before the match,
- between the rounds,
- after the match.

This recording was performed for the first fight. It was not possible to record the electroencephalogram for the four other fights because of technical problems. We analysed the recordings from the first fight and made some spectral analysis (figures 34 to 36). One can see that the β waves characteristic of an active situation, generally, present between 12 to 20 Hz, appear also on the curves. Those results seem to be logical in the context of this study.

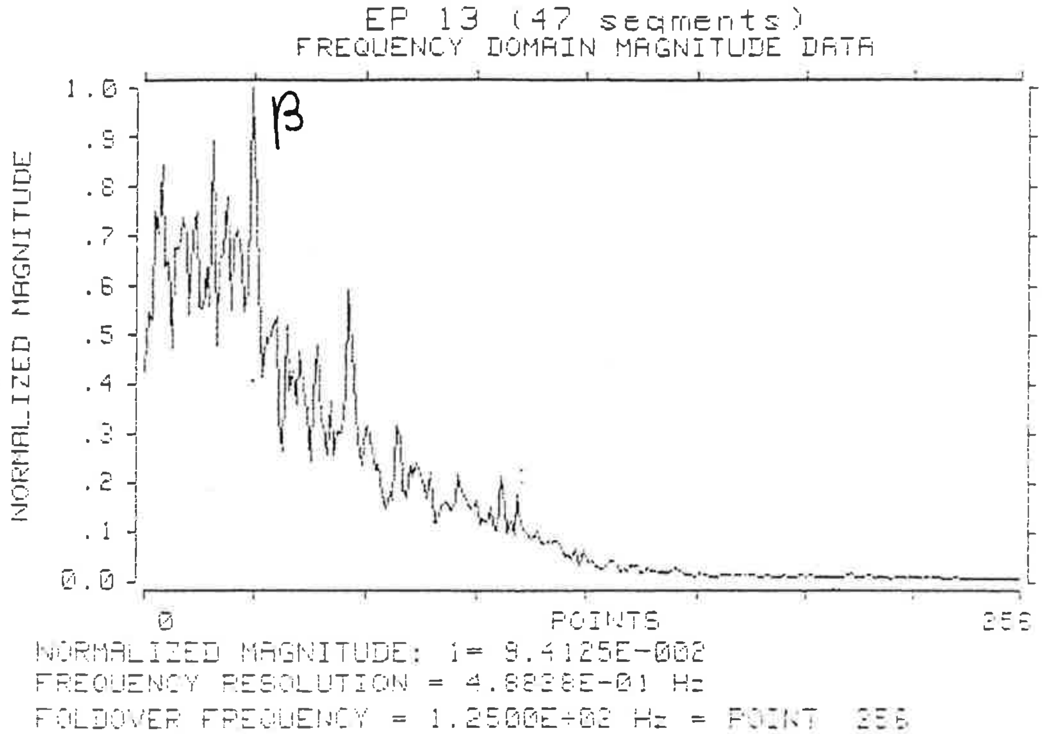


Figure 34. Spectral Analysis of E.E.G. before the fight

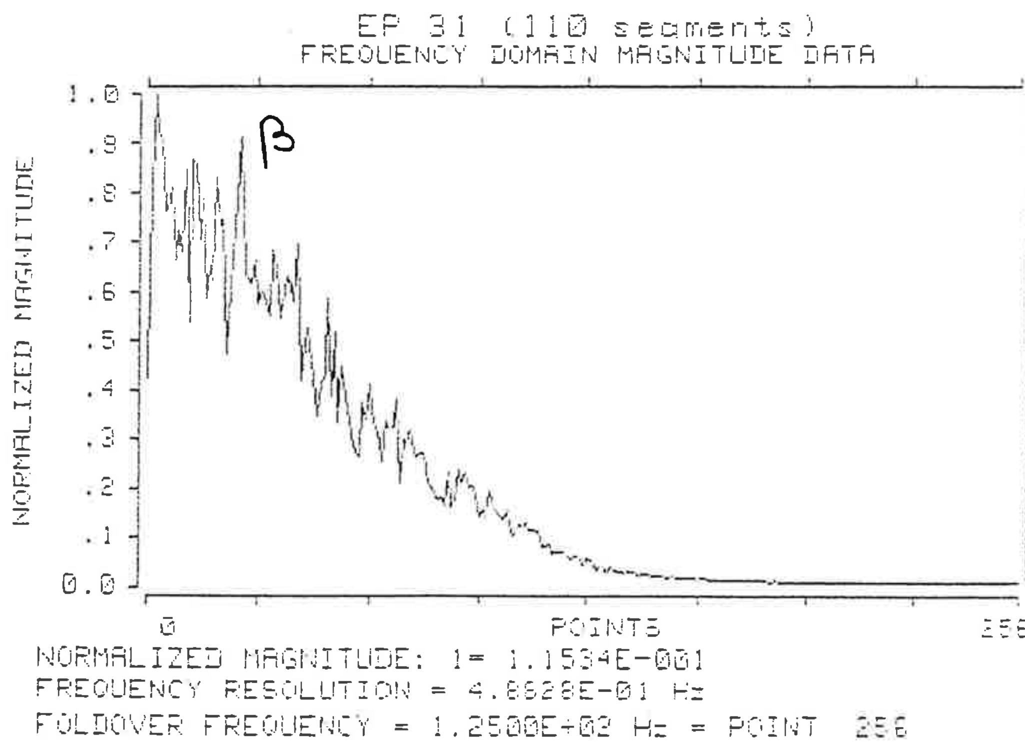


Figure 35. Spectral analysis of E.E.G. after the second round

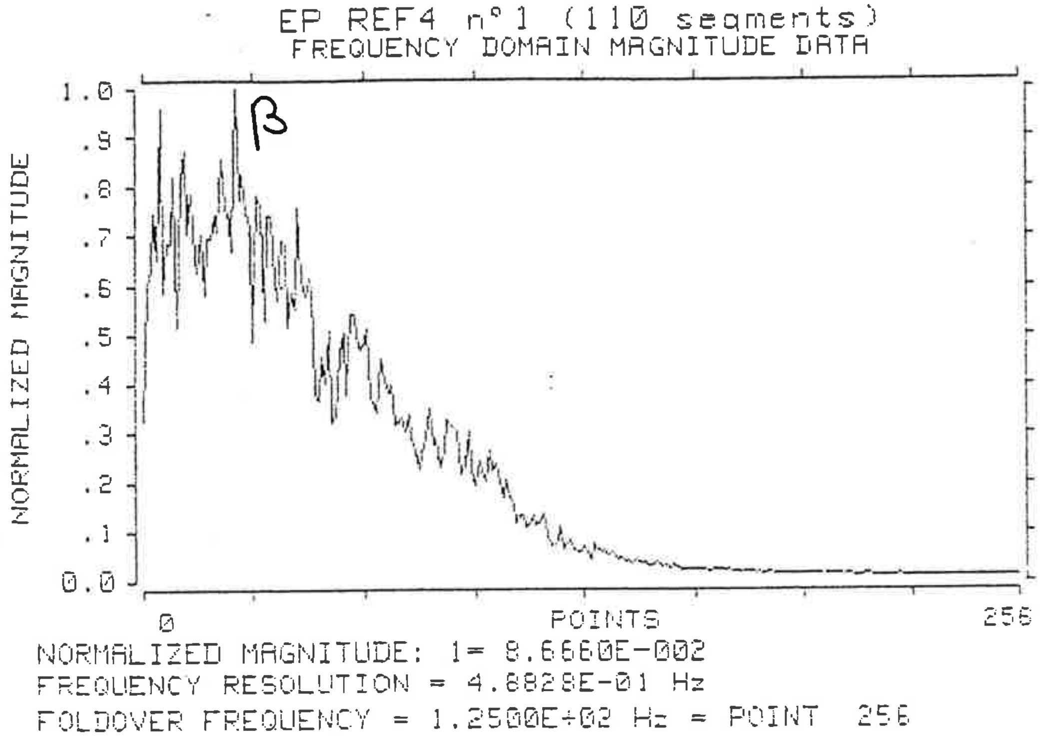


Figure 36. Spectral Analysis at the end of the fight

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EVENT RELATED POTENTIAL ASSESSMENT OF ATTENTION AND THE ORIENTING REACTION IN BOXERS BEFORE AND AFTER A FIGHT

Bernard RENAULT and Françoise BRETON

INTRODUCTION

The aim of this study was to shed some light on brain injuries following blows to the head by means of the methods of both cognitive psychology and electrophysiology. More precisely, boxers' attention mechanisms and their capacity of orienting towards a significant stimulus were investigated using event related potentials (ERPs) of the brain in dichotic listening situations, before and after a fight. These types of psychological mechanisms are known to be very fundamental both in animals and in humans for protection against environmental dangers. Therefore, it is of great interest to know the level of intensity of a blow to the head that is capable of reducing such survival capacity, even if it is for only a short period of time. More practically, just after a car acccident involving a blow to the head, it may be very important to be able to react as quickly as possible to further dangers and this study was thus undertaken in order to assess some of the limits under which normal behavior following head injury remains possible.

As pointed out by Hillyard (1985), following his pioneer study (Hillyard et al., 1973), the selection of attended from unattended inputs first makes a significant modification on sensory processing at 50-80 msec after stimulus onset. This is disclosed by larger amplitudes of the ERPs to attended stimuli. Furthermore, Naatanen et al. (1978) and Naatanen and Gaillard (1983) have described two types of ERPs related to the phenomenon of orientation: i) the mismatch negativity (MMN), which reflects a mismatch in an automatic pre-perceptual cerebral comparison process occuring (towards 100 msec) after a change in a repetitive, homogeneous stream of stimuli and ii) a sharp negative wave, N2b, peaking around 200 msec in the central region of the scalp, which forms a complex with a subsequent positive wave, the P3a, and which is related to the orienting reflexe per se.

In ERP experiments involving dichotic listening, a fast sequence of brief tone pips is usually presented to the subject in each ear. The subject's attention is directed to the "relevant" stimuli, those which either have a certain pitch or which occur in a given ear (location). For example, subjects are instructed to press a response-key each time an occasional deviant stimuli (for example, with higher pitch) is presented among the relevant standard stimuli, that is, stimuli occuring in a certain ear. In such experiments, the ERPs to the relevant stimuli (be they standards or deviants) are negatively displaced in relation to the ERPs to the irrelevant stimuli. This negative displacement can be demonstrated by substracting the ERP to the irrelevant stimuli from those to the relevant stimuli; the resulting waveform is called Nd (Hansen and Hillyard, 1980) or Processing Negativity - PN - (Naatanen et al. 1978). Naatanen (1982) has proposed that the PN reflects a matching or comparison process between the sensory input and the "attentional trace" which is actively formed and maintained in a selective attention condition. The maintenance of the attentional trace is only possible, however, for those physical features which are frequently present and therefore provide frequent reinforcement for the trace. When a subject's task is to discriminate, say, occasional deviant tones of higher pitch delivered to the designated ear among the standard stimuli, the attentional trace is only maintained for the location (that is, the ear in which "relevant" tones are heard) of the relevant standard tones and of deviant target tones, the pitch of the targets being too infrequently presented to be maintained in the trace. Within the framework of Naatanen's theory, only the features of the relevant stimuli (location in this case) separating them from the irrelevant ones are maintained in the attentional trace. Furthermore, the infrequent auditory stimuli, which physically deviate from the frequent standards, elicit a MMN which is independant of the direction of attention. This MMN is clearly seen when one substracts ERP to standard tones from the deviants in a passive condition. This MMN is followed by the N2b-P3a complex (Renault and Lesèvre, 1979; Renault et al., 1980) whether subjects actively ignore or attend to the deviants in one or both ears (Naatanen et al, 1982; Naatanen, 1982). Thus the MMN is generated by a cerebral process underlying passive stimulus discrimination; this process also causes conscious perception of occasional changes in both actively unattended or attended stimulus sequences. In other words, the MMN system could send an "interrupt" to the limited-capacity system whose ongoing activity is then halted briefly, eliciting an orienting reaction (N2b-P3a) towards the deviant tone in order to respond appropriately (Ohman, 1979; Rohrbaugh, 1984).

We used location-selection conditions in this study; the relevant and irrelevant tones were of same pitch (1000 hz) but appeared (at random) in opposite ears. Intermixed within these standard tones, deviant tones (2000 hz) appeared randomly in 20% of the cases. Four conditions were used: 1) a passive condition where subjects were told to ignore the tones in both ears; 2) a right attention condition where subjects had to detect the deviants in the right ear; 3) a left attention condition (detect left deviants) and 4) a divided attention condition where subjects had to detect both right and left deviants. This experiment allowed us to study both attention mechanisms and the orienting reaction by measuring: i) the processing negativity; ii) the mismatch negativity and iii) the N2b-P3a complex. The reaction time to deviant tones was also measured in order to quantify the general level of performance.

METHOD

Subjects

Five boxers never having served in similar experiments participated in the study. Their age ranged from 25 to 28 years old. They were seen twice, in the morning and at the end of the afternoon, before and after a fight which took place elsewhere. The time interval between the begining of each EEG recording was about eight hours. Each recording lasted two hours and the second recording was done about one hour and an half after the fight.

Experimental design

Standard or "frequent" (80%), low pitch tones (1000 Hz) and deviant, or rare (20%), high pitch tones (2000 Hz) were presented randomly, through earphones, to each ear. The interstimulus intervals were at random, between 400 and 800 msec. Each tone lasted 10 msec; its intensity was adjusted for each subject, at the begining of each experiment, in order to obtain the same subjective intensity for both ears. Two selective attention situations (attend right and attend left) were recorded, during which subjects were required to respond as quickly as possible by a fore-finger displacement of their preferential hand over a photoelectric cell as soon as they detected a target (high pitch tone) in the attended ear. Subjects were told to withhold their response for all other stimuli: standards (low pitch tones) in both ears and deviants in the non-attended ear. A divided attention condition was also recorded where the subjects' task was to detect deviants in both ears. These three attention situations each comprized 500 stimuli which were presented in blocks of 250 stimuli lasting about 2.5 minutes. The order of these attention situations was distributed across subjects according to a latin-square design. These situations were preceeded by a passive situation (same stimuli, no task) where the subjects were told to pay no attention at all to the sounds. For all situations, subjects were ask to keep their eyes closed and to avoid blinking and eye movements.

Electrophysiological recording and data processing

The EEG was recorded from 9 equally-spaced electrodes, affixed with collodion along a line going from the right temporal (T4) to the left temporal (T3) region. Electrodes were referenced to linked ears; horizontal and vertical electro-oculograms were recorded simultaneously in order to control eye movements. The band pass of the amplifiers was 0.25 to 30 Hz. The EEG was digitized on-line at a sampling rate of 125 Hz. Average ERPs, time-locked to each type of stimulus were obtained off-line, for each condition and for each electrode site. Thus the data base of this study consisted of 1440 different average ERPs (two types of stimulus X two ears X four situations X before and after the fight X five subjects X 9 electrodes). Only trials for which the EEG data were not contaminated by various artefacts (particularly eye movements) and for which the behavioral response were correct, were included in these ERP averages. The baseline was the average EEG amplitude over the 200 msec preceding the stimulus, the averaging window going on until 600 msec after the stimulus.

For the nine average ERPs of the montage, for each condition and for each subject, a spatio-temporal map (Rémond, 1961) was calculated. On these maps, amplitude variations between two successive electrodes are obtained by a second order interpolation and are represented in the form of isopotential lines as a function of time on the abscissa and of electrode location on the ordinate. The following substractions of spatio-temporal maps were computed for both standard and deviant stimuli, before and after the fight: attention minus passive; attention minus inattention; divided attention minus passive. These 12 substractions yielded processing negativities. Furthermore, the mismatch negativity (MMN) and the N2b were evidenced, before and after the fight, by substracting standards from deviants in the passive condition (MMN alone) and in the inattention, divided attention and selective attention conditions (MMN plus N2b).

RESULTS

I) THE DATA BASE

Figures 1 to 4 depict spatio-temporal mapping of event-related-potentials for standards and for deviants, before and after the fight, in the four experimental conditions. These figures are grand means, across subjects, of individual data. The N1 wave, negative, on going from 40 to 150 msec, is noticeable on all these maps; the P2 wave, positive between 150 and 250 msec is only seen in response to standard tones. In the case of deviants, this wave disappears (except in the passive condition) and an N2 wave, negative, arises between 150 and 500 msec post stimulus. Note that P2 tends to be higher in inattentive and passive conditions and that N2 is higher in selective and divided attention conditions.

FIG. 1: Spatio-temporal maps of ERPs obtained in response to standard tones, before the fight. Thin isopotential lines represent the negative potential, thick lines the zero potential and dotted lines the positive potential. Between two isopotential lines the potential increases by 1µv. Peaks are indicated by the sign + or -.

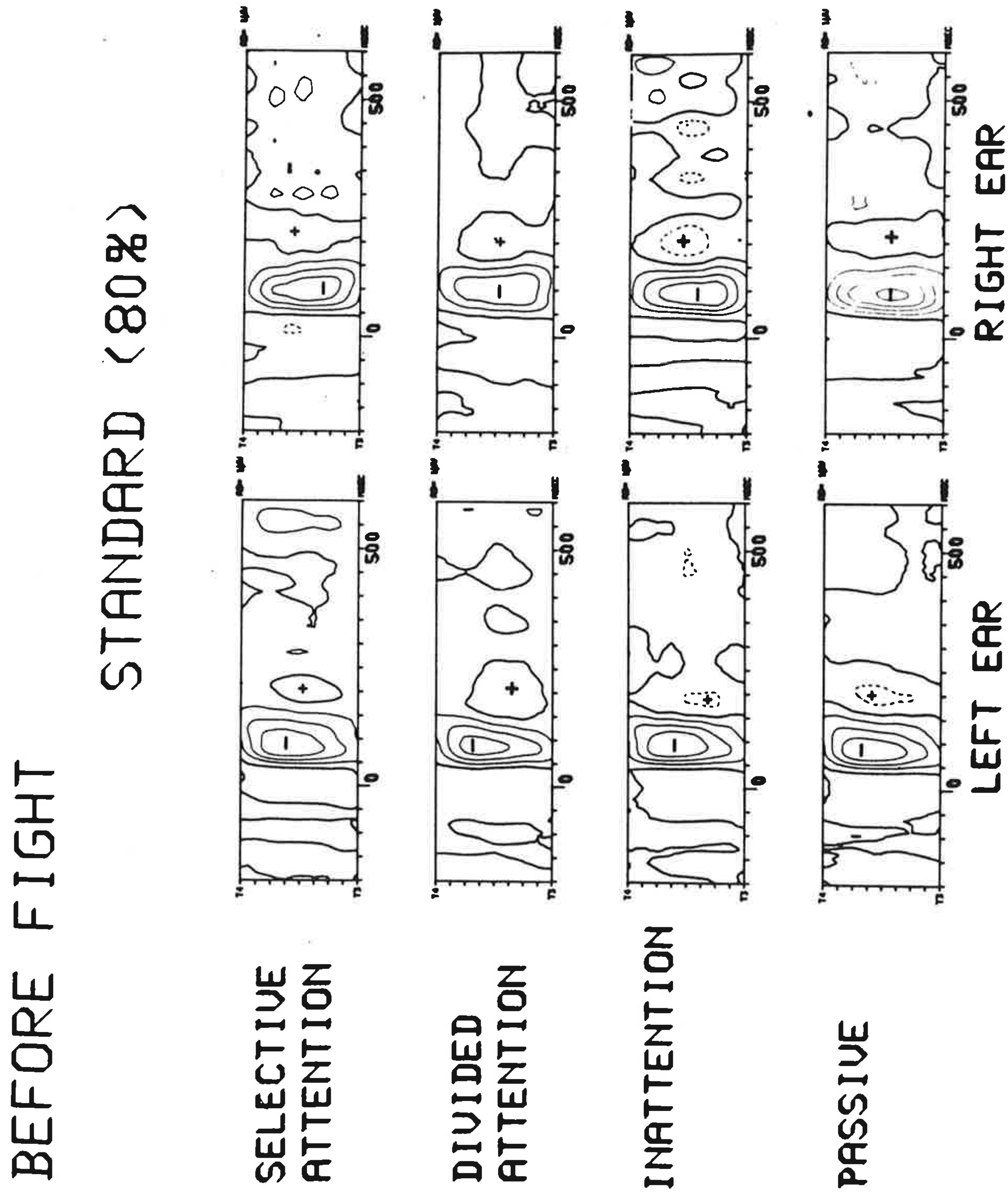


FIG. 2: Spatio-temporal maps of ERPs obtained in response to standard tones, after the fight. Same representation as in fig.1.

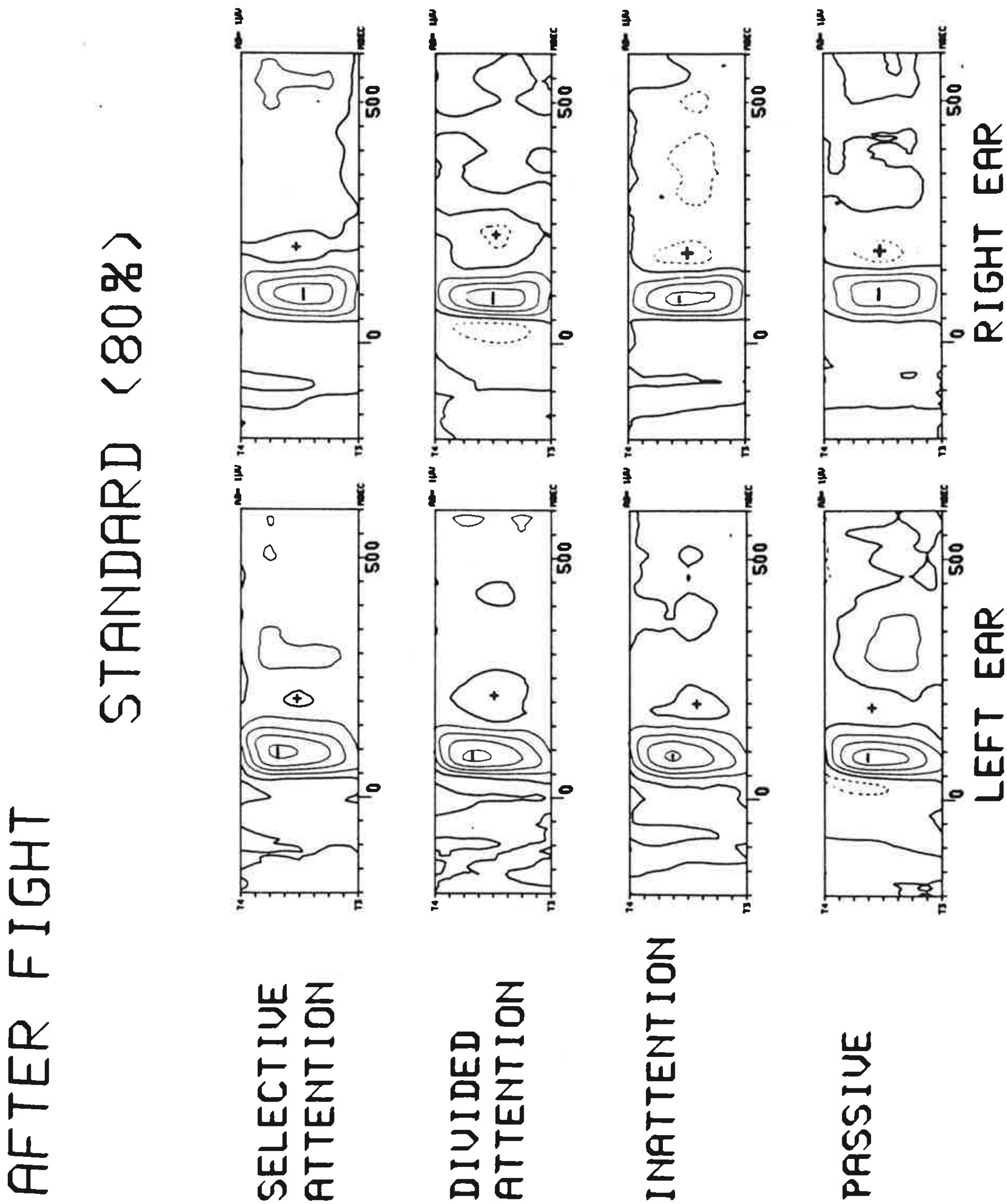


FIG. 3: Spatio-temporal maps of ERPs obtained in response to deviant tones, before the fight. Same representation as in fig. 1.

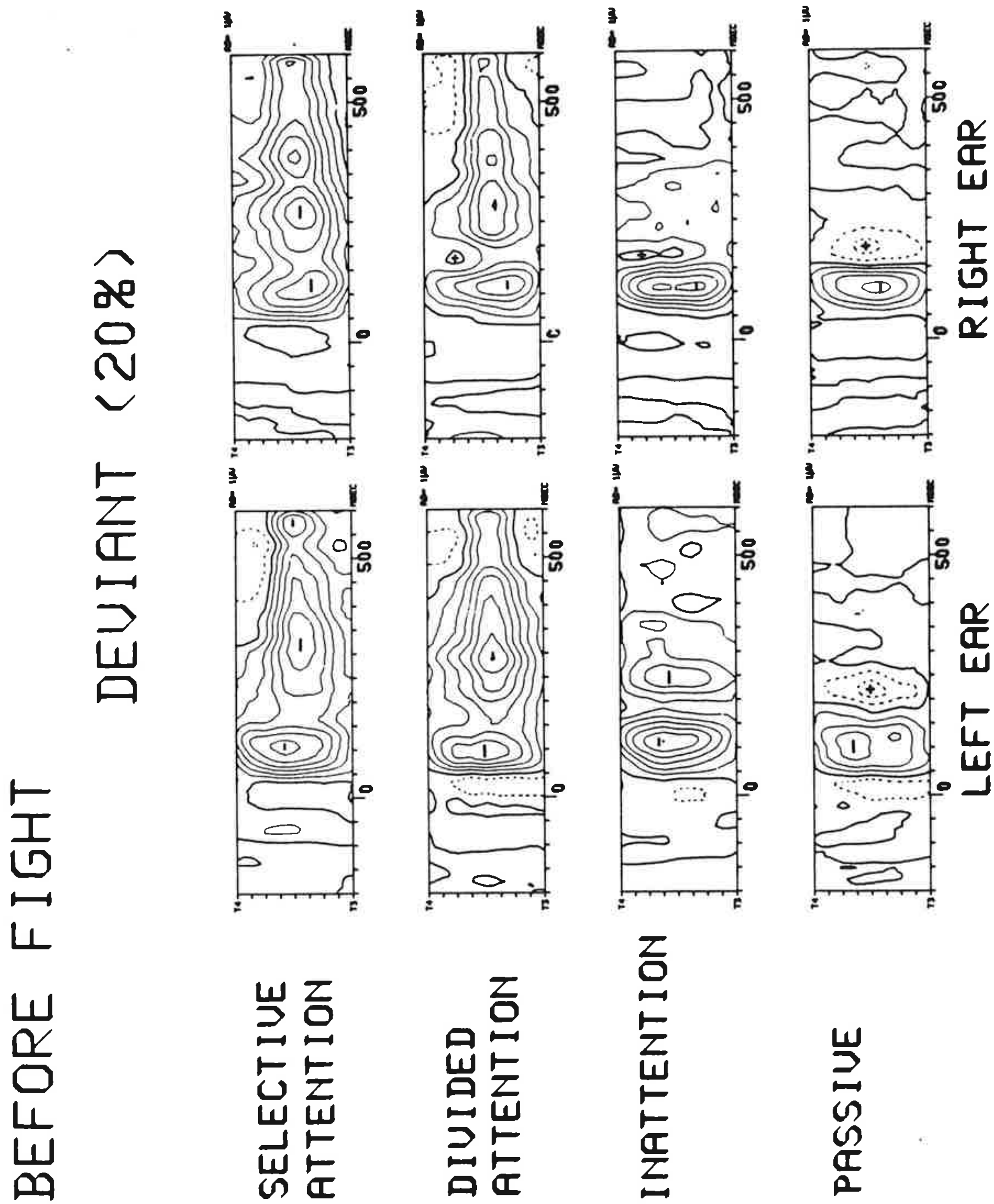
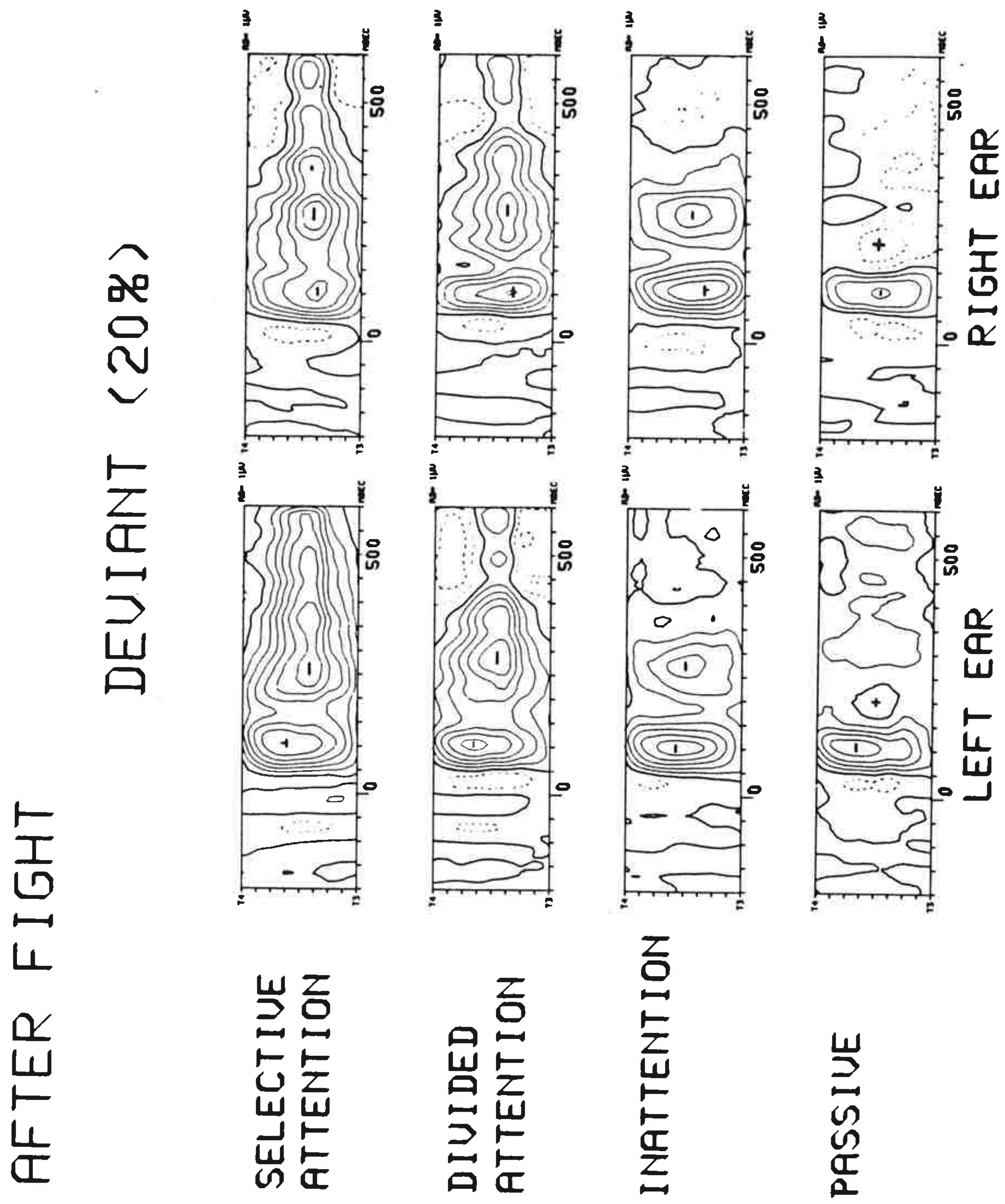


FIG. 4: Spatio-temporal maps of ERPs obtained in response to deviant tones, after the fight. Same representation as in fig. 1.



Substraction spatio-temporal maps allowed to illustrate the processing negativity - PN - (fig. 5 and 6) and the orienting reaction (fig. 7 and 8). These substaction were used in order to define several time intervals in which amplitude of resulting waves were measured. Concerning the PN, a window from 100 msec to 300 msec was chosen for measuring the average ERP amplitude across the montage (from T3 to T4). This window includes the small PN observed in response to standards as well as the major part of the noticeable PN observed in response to deviants. The average amplitude of the MMN was measured from 100 to 150 msec and the average amplitude of N2b from 170 to 500 msec. These measurements were made by a computer program taking into account the interpolated values between two successive electrodes. They were made for each subject and in each condition and then submitted to successive analyses of variance in order to test the significance level of the differences between conditions and between the before- and after-fight situations.

II) THE PROCESSING NEGATIVITY (PN)

Data were evaluated in a five-factor analysis of variance (ANOVA) in which the factors were: "fight" (before and after); "location of the tone" (right or left); "pitch" (standard or deviant); "attention conditions" (selective, divided, inattention, passive); and "subjects" (1-5). This analysis showed a significant effect of both attention conditions ($F_{3,24} = 22.63$, $p<.001$) and pitch ($F_{1,8} = 31.78$, $p<.001$). The interaction between these two factors was also significant ($F_{3,24} = 16.11$, $p<.001$). None of the other factors depicted any significant effect. In particular, there was no effect of the fight on the amplitude of the processing negativity. As shown in table I and in fig. 5 and 6, and confirmed by the ANOVAs, deviant and standard tones did not vary to the same extent in different attention conditions; the PN recorded for standards was of lower amplitude than the one recorded for deviants. In fact, separate ANOVA for standards and deviants revealed that attention conditions significantly modified ERPs to deviants ($F_{3,24} = 27.68$, $p < .001$) whereas modifications for standards tended towards the significance level ($F_{3,24} = 2.81$ compared to 3.01 for $p < .05$). However, for each of these separate ANOVAs, no effect of the fight was evidenced.

		BEFORE FIGHT				AFTER FIGHT			
		STANDARDS		DEVIANTS		STANDARDS		DEVIANTS	
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
ATTENTION	x	-.95	-.73	-3.42	-3.97	1.14	-.78	-3.87	-3.51
	sd	.94	.99	2.62	2.25	.94	1.22	2.14	2.15
DIVIDED	x	-.51	-.59	-3.02	-2.27	-.70	-.45	-2.73	-2.17
	sd	1.09	.91	1.85	3.25	.97	.82	2.09	2.18
INATTENTION	x	-.46	-.48	-2.47	-1.92	-.79	-.16	-2.24	-2.92
	sd	1.23	1.08	1.95	2.23	.94	.96	1.93	1.43
PASSIVE	x	-.42	-.72	-.47	-.20	-.44	-.18	-1.24	.06
	sd	1.37	.68	2.06	1.60	.82	.98	2.11	1.10

TABLE I : Mean amplitudes (x) and standard deviations (sd) during the time window of the Processing Negativity (100 msec to 300 msec after stimulus onset). PN amplitude is obtained when one compare Attention to Passive , Attention to Inattention and Divided to Passive.

FIG. 5: Spatio-temporal maps of the Processing Negativity obtained by substracting passive from attention (ATT-PAS), inattention from attention (ATT-INA) and passive from divided (DIV-PAS). Means of right and left stimuli before the fight.

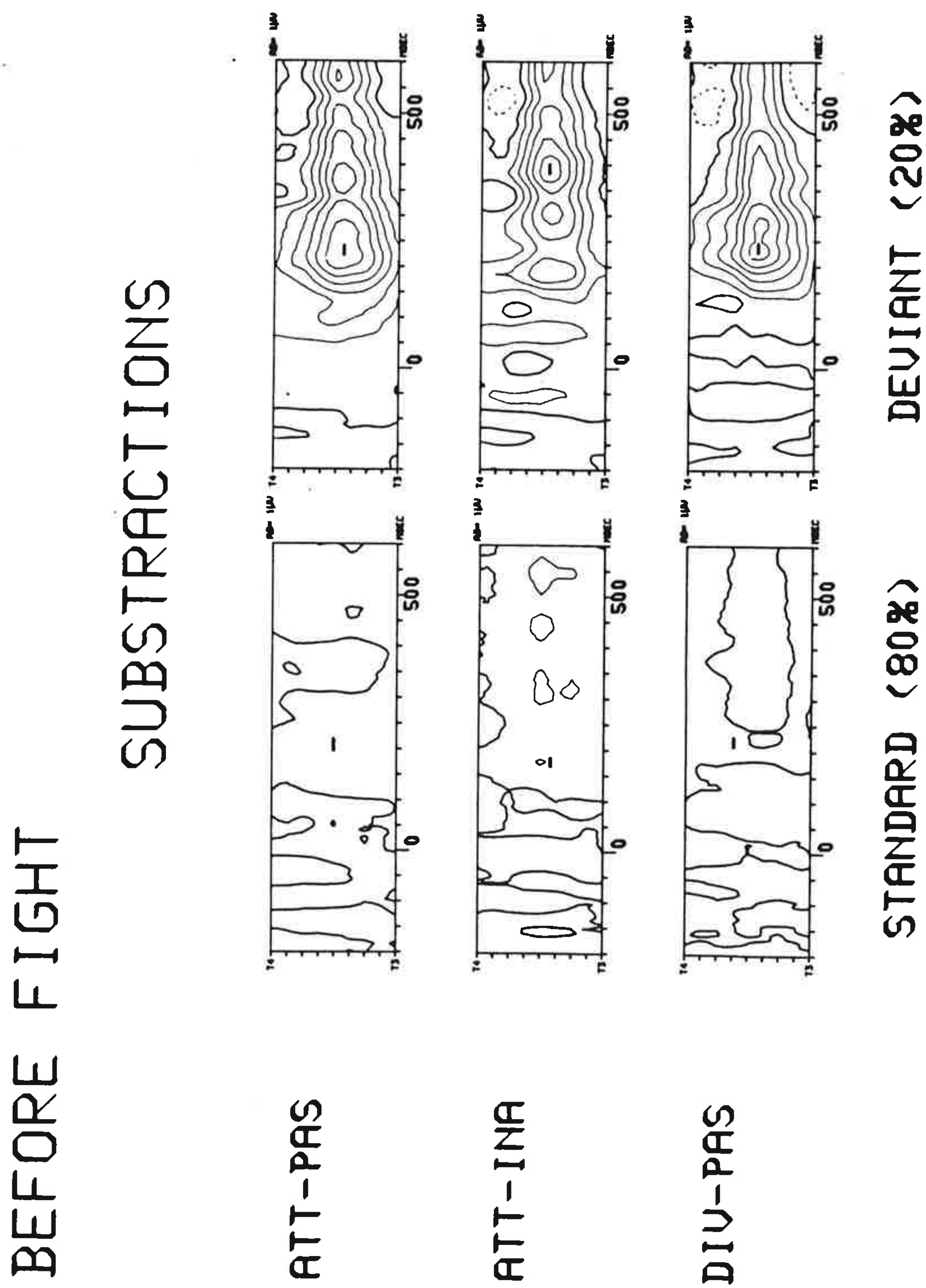


FIG. 6: Same as figure 5, after the fight.

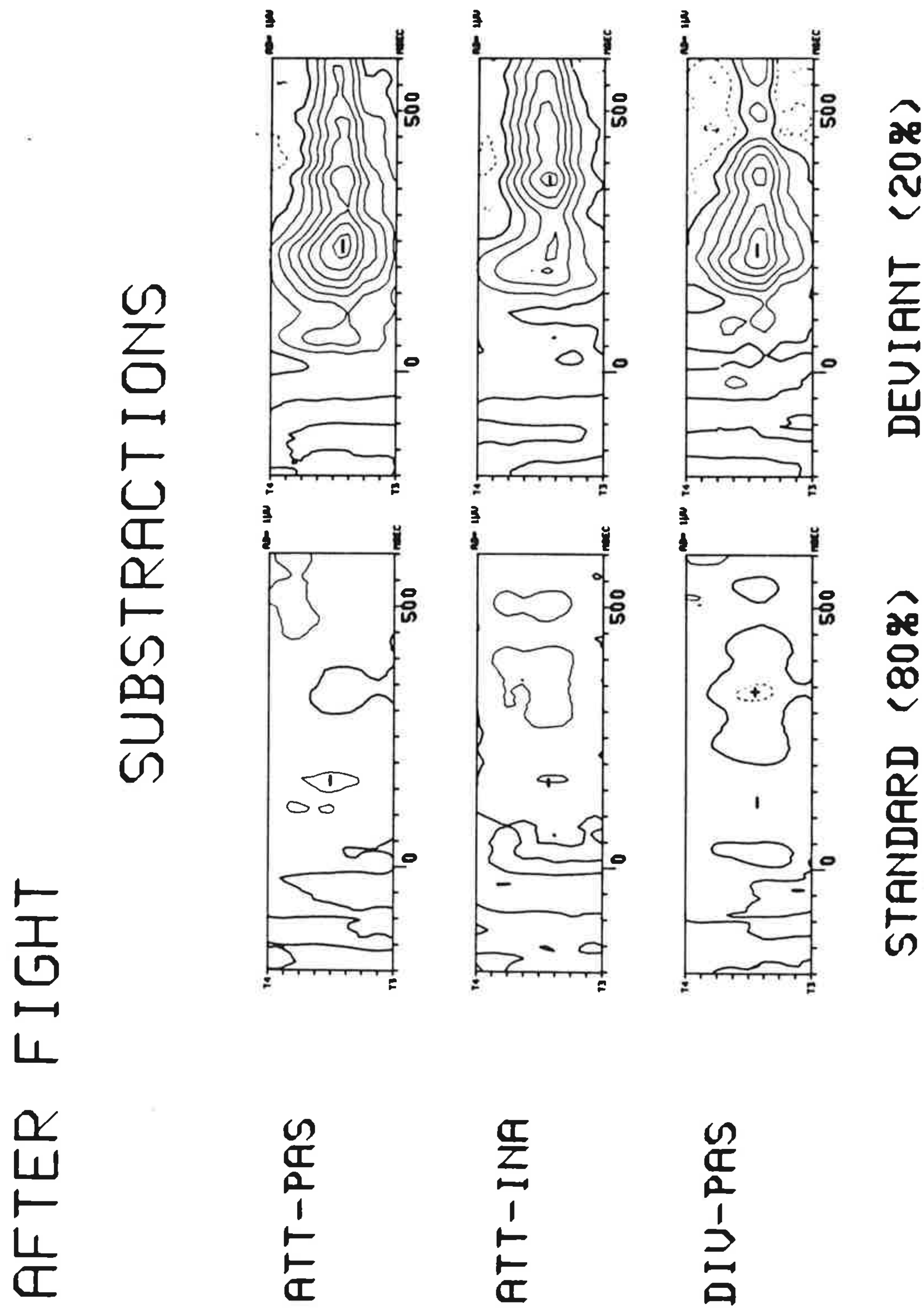


FIG. 7: Spatio-temporal maps of MMN and N2b obtained in substracting standards from deviants. Means of right and left stimuli before the fight.

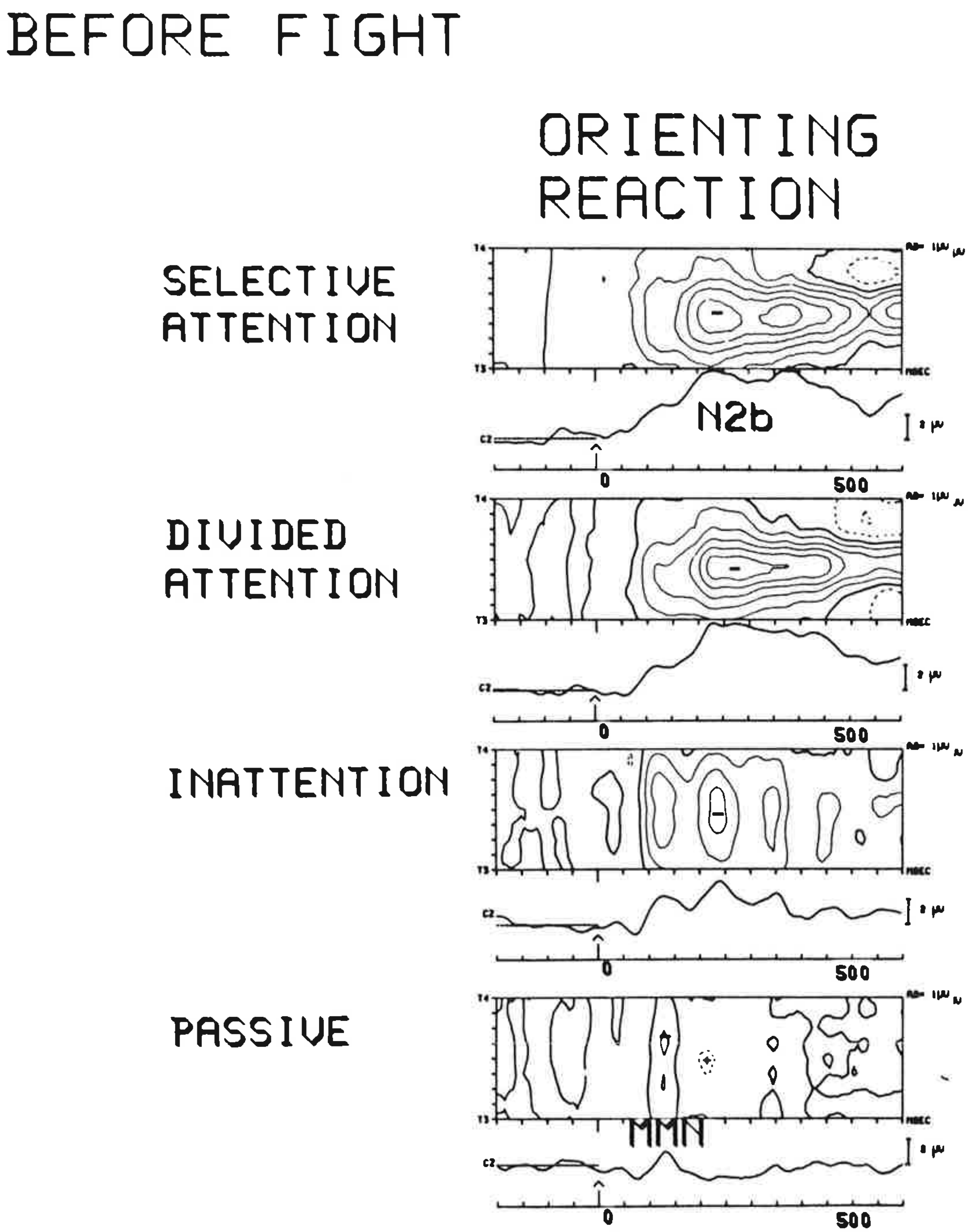
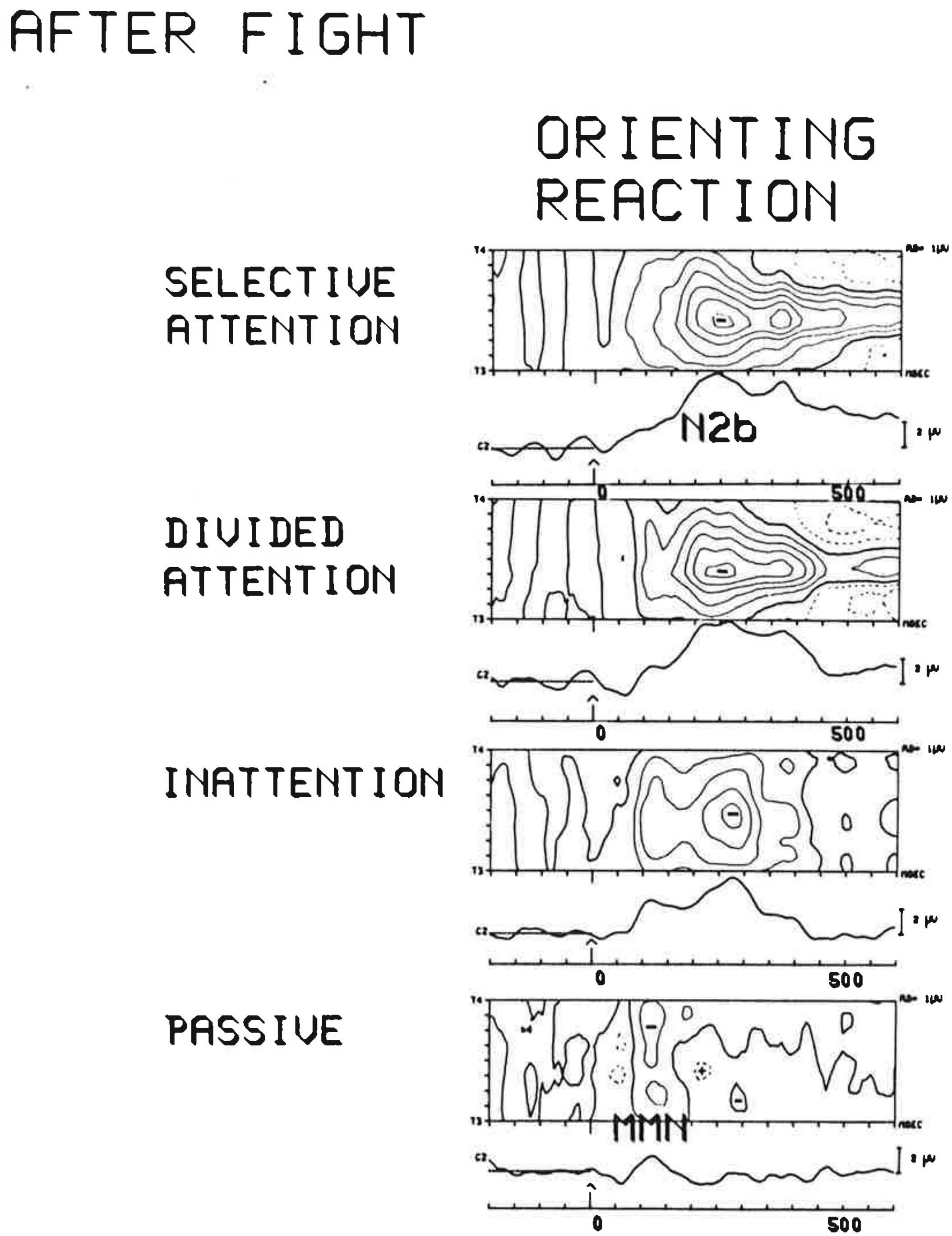


FIG. 8: Same as figure 7, after the fight.



III) THE MISMATCH NEGATIVITY (MMN)

The five-factor ANOVA evidenced a significant effect of the tone pitch between 100 and 150 msec, thus confirming a more negative ERP amplitude for deviants than for standards (respectively $-3.44\ \mu v$ and $-2.15\ \mu v$, $F_{1,8} = 40.35$, $p < .001$). This difference varied significantly according to attention conditions ($F_{3,24} = 6.27$, $p < .01$) and therefore, separate ANOVAs for each attention conditions were subsequently done. They all confirmed the existence of a MMN (at a minimum significance level of .01). However, none of these analyses revealed an significant effect of the fight (see Table II).

		BEFORE FIGHT				AFTER FIGHT			
		STANDARDS		DEVIANTS		STANDARDS		DEVIANTS	
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
ATTENTION	x	-2.29	-2.41	-4.66	-4.08	-2.60	-2.36	-4.30	-3.75
	sd	1.28	1.08	2.25	1.42	1.24	1.17	2.70	1.09
DIVIDED	x	-1.74	-2.05	-2.95	-3.11	-2.32	-2.12	-3.23	-2.96
	sd	1.07	.95	1.29	1.75	.79	.68	1.60	.98
INATTENTION	x	-2.19	-2.30	-4.05	-3.76	-2.28	-1.89	-3.74	-4.19
	sd	1.13	1.43	1.28	2.32	.68	1.08	1.55	1.35
PASSIVE	x	-2.02	-2.43	-2.45	-2.71	-1.62	-1.71	-3.13	2.05
	sd	1.17	.53	1.51	1.41	.87	.86	.92	.89

TABLE II : Mean amplitudes (x) and standard deviations (sd) of ERPs in the latency window of the MMN (100 msec to 150 msec). MMN amplitude is obtained when one compare deviants to standards.

IV) THE ORIENTING REACTION (N2b)

The five-factor ANOVA evidenced significant effects of both tone pitch (F1,8 = 23.10, p<.001) and attention conditions (F3,24 = 14.84, p<.001). The interaction between these two factors was also significant (F3,24 = 7.43, p <.01). Subsequent analyses, for each attention condition confirmed the existence of an N2b (see also fig. 7 and 8 and table III) and also revealed an effect of the fight. This effect was a significant interaction between fight, tone pitch and right or left ear of delivery in the case of the attention condition only (F1,8 = 5.64, p<.05).

		BEFORE FIGHT				AFTER FIGHT			
		STANDARDS		DEVIANTS		STANDARDS		DEVIANTS	
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
ATTENTION	x	-.24	-.23	-2.39	-3.25	-.64	-.25	-3.21	-2.08
	sd	.49	.54	2.00	1.86	.59	.63	.58	1.06
DIVIDED	x	-.15	-.04	-2.70	-1.51	-.23	.16	-1.47	-1.14
	sd	.58	.26	1.77	2.63	.56	.34	1.79	1.59
INATTENTION	x	.36	.26	-1.27	-.70	-.18	.62	-.91	-1.31
	sd	.69	.76	1.63	.98	.71	.52	.38	1.33
PASSIVE	x	-.01	-.18	.10	.27	-.18	.20	-.64	.78
	sd	.61	.28	1.42	1.05	.64	.85	1.88	1.64

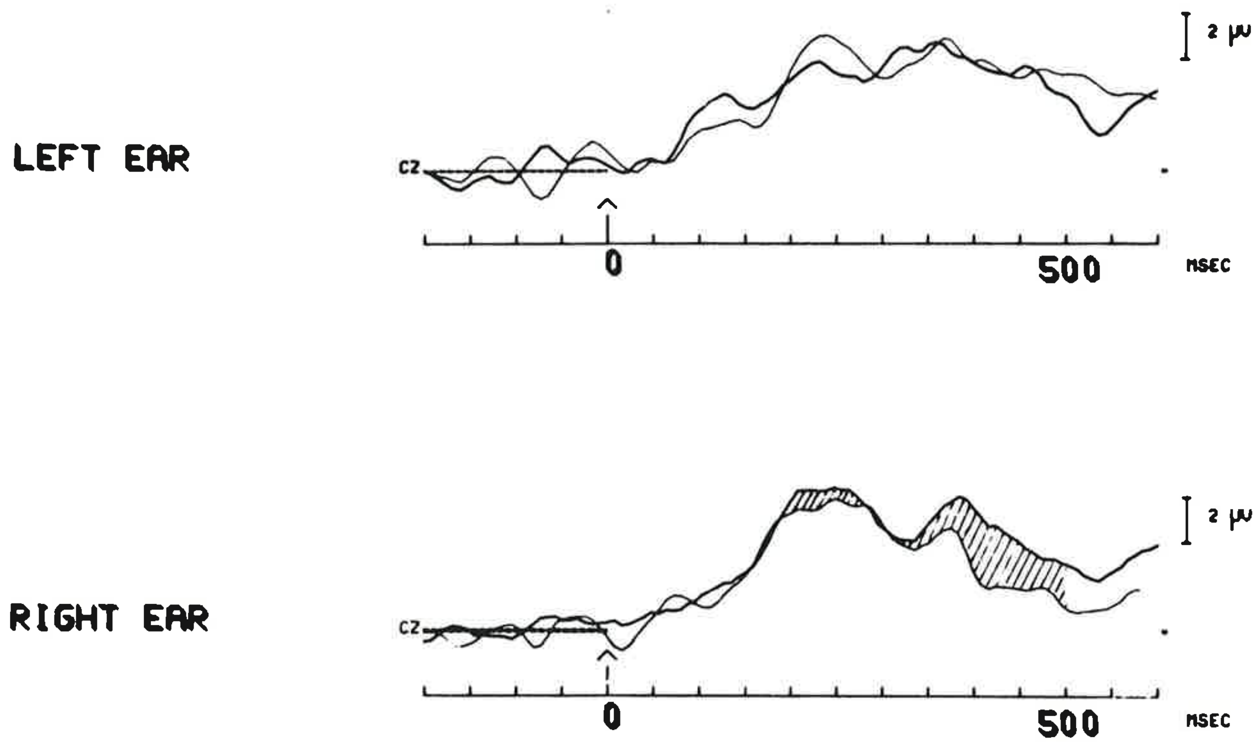
TABLE III : Mean amplitudes (x) and standard deviations (sd) of ERP amplitudes within the time window of N2b (170 msec to 500 msec)

In order to better understand this effect, we computed, for each subject, the mean amplitude of the difference between deviant and standard ERPs within the 170-500 msec time window. Mean values across subjects are presented in table IV. It should be noted that standard deviations (across subjects) are the lowest in the attention condition after the fight. This explains the significant effect of fight which was only found in this condition; differences are also noticeable for the divided and inattention conditions but remain below the significant level. Moreover, it should be pointed out that the difference between before and after the fight, for the attention condition, is only due to a lower N2b when stimuli are delivered in the right ear (see also fig. 9).

		BEFORE FIGHT		AFTER FIGHT	
		STANDARDS-DEVIANTS		STANDARDS-DEVIANTS	
		LEFT	RIGHT	LEFT	RIGHT
ATTENTION	x	-2.14	-3.02	-2.58	-1.83
	sd	2.25	1.98	.73	.92
DIVIDED	x	-2.56	-1.47	-1.24	-1.30
	sd	1.81	2.73	1.73	1.57
INATTENTION	x	-1.64	-.95	-.73	-1.93
	sd	1.45	1.35	.92	1.33

TABLE IV : Mean amplitudes (x) and standard deviations (sd) of N2b obtained after substractions of standards from deviants

FIG. 9: Sustractions of standards from deviants, for right and left stimuli; Cz recordings. Thick lines represent MMN and N2b before the fight and thin lines refers to the same waves after the fight. Note the hachured difference for right stimuli only.



V) BEHAVIORAL DATA

In order to assess the general educational level of the subjects, they underwent the Wechsler adult intelligence test (WAIS). Four subjects were within the low-to-normal limits (verbal IQ and performance IQ between 81 and 90); one subject was within the average normal limits (verbal 104, performance 115).

The reaction time (RT) data, obtained in response to deviants in the selective attention and divided attention conditions, were submitted to an ANOVA with fight (before, after), attention (selective, divided) and ear of delivery (right, left) as factors. No effect of the fight was found on these data. Means and standard deviations across subjects are given in table V. However, it should be noted that the percentage of errors only increased for the right attention condition, when compared before and after the fight, whereas it remained the same for the three other conditions.

		BEFORE FIGHT		AFTER FIGHT	
		STANDARDS-DEVIANTS		STANDARDS-DEVIANTS	
		LEFT	RIGHT	LEFT	RIGHT
ATTENTION	x+sd	427+55.2	435.4+47.4	453.6+88.58	466+51
	errors	6.2%	3.2%	6.6%	5.8%
DIVIDED	x+sd	418.4+67.17	410.0+67.17	415.8+24.52	417.6+41.36
	errors	6%	2.8%	7%	2.8%

TABLE V : RT mean amplitudes (x) and standard deviations (sd) for the five subjects and percentage of errors.

DISCUSSION AND CONCLUSION

Let us first emphasize that Event-Related-Potential data obtained in this study are in general agreement with other ERP studies of attention and of the orienting reaction (for reviews see Naatanen, 1982; Hillyard and Kutas, 1983). The fact that the processing negativity fails to reach the significance level for standard tones in the attention condition is probably due to the small number of subjects since this waveform is in general of small amplitude (1 or 2 uv) and thus difficult to demonstrate. However, attention mechanisms and orienting towards rare stimuli significantly modified ERPs and we were therefore able to study the effect of the fight. This revealed only one effect: the N2b obtained in response to right deviant tones was of lower amplitude after than before the fight in the right attention condition. In other words this effect means that the orienting reaction towards stimuli delivered in the right ear was reduced by the fight and therefore the ability to detect and to react towards such stimuli was partially impaired. Although the reaction time did not significantly increase in relation to the fight, this impairment is further supported by behavioral data since false responses, in the right attention condition, increased from 3.2% (before) to 5.8% (after the fight). Since right ear stimuli are first processed by the left hemisphere this suggests a relative deficit of this hemisphere in the processing of deviant (rare) stimuli. Now, the analysis of blows during fights showed that the number of blows (across subjects) of considerable intensity was higher on the left side than on the right side of the head (29 versus 7, see the first part of this report). This therefore further supports the possibility of an impairment of the left cerebral hemisphere as revealed by this Event-Related-Potential study.

Taking into account the methodology we used, these results means that even after about one hour and a half following head injury, a deficit in the brain functions of human being can be evidenced, although his behavior remains in the normal range. It would therefore be of great interest in the future to continue along this line of research by recording ERPs of the brain in boxers before and <u>just after</u> fights.

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VI - DISCUSSION - CONCLUSIONS

In the framework of a research on head tolerance to impact, the Laboratory of Physiology and Biomechanics of Peugeot S.A./ Renault Association has engaged a programme with volunteer boxers, in cooperation with I.R.O. (France), under contract with the DOT.

Five fights, consisting of 3 rounds each, were performed between volunteer boxers equipped with accelerometric measurement devices. From these fights, 47 blows were selected as "interesting" (that means with a sufficiency preselected violence level) and processed as individual impacts with their own violence and kinematics.

Independently from the severity of the blows, it was noted that 62 % were from the left side against 15 % from the right side ; their intensities were on an average of the same order of magnitude.

As regards angular accelerations, they were in all cases higher than 3500 rad/s^2, exceeding the values considered as tolerance limit for volunteers, given in the literature already available. The maximum value obtained was 16000 rd/s^2, in association with an angular velocity of 25 rad/s.

The maximum angular velocity was 48 rad/s with a corresponding angular acceleration of a rather high level : 13600 rad/s^2. These values are reported in table 22 together with other data available, related to animals, cadavers, and volunteers.

These results represent sets of values, never seen on volunteers, without problems ; they widely exceed those already given as proposed tolerance limits by other authors.

In complement to physical measurements, tests of Event Related Potential Assessment of Attention and Orienting Reaction were performed by the Laboratoire d'Electrophysiologie et de Neurophysiologie Appliquée, in Hôpital de la Salpêtrière, Paris.

Clinical examinations of the boxers before and after the fight did not reveal any anomaly at all in their behaviour.

The data recorded were analysed in a statistical way for all boxers together. This very sophisticated analysis did not indicate any anomaly in the results, only a small effect in one parameter as a whole, after the fight : the ability to detect and to react towards stimuli delivered in the right ear was partially impaired, although the behaviours of the boxers remain in the normal range.

This particular effect is an illustration of the capability of the Event Related Potential of Attention and Orienting Reaction to reveal a possible very limited disturbance in the neurophysiological state : false responses, in the right attention condition, increased from 3.2 % (before) to 5,8 % (after the fight).

This limited effect has to be situated in the whole results, emphasazing that :

- no effect of the fight on the reaction time data,
- no effect of the fight on 32 pairs of mean amplitudes and standard deviations during the time window of the Processing Negativity,
- no effect of the fight on 32 pairs of mean amplitudes and standard deviations of ERPs in the latency window of the MMM (mismatch negativity)

The conclusions of this study are necessarily limited, given the small number of subjects and it would be of great interest in the future to continue along this line of research.

Table 22. Summary of proposed tolerance limits for different surrogates in terms of head angular acceleration and velocity

REFERENCE	TYPE OF TEST	TOLERANCE LIMITS PROPOSED
OMMAYA 1967 (5)	Primate Tests	7500 rd/s^2
OMMAYA 1971 (6)	Primate Tests	1800 rd/s^2 and 60-70 rd/s
LOWEHIELM (7) 1975	Cadaver Tests Mathematical Model	4500 rd/s^2 and 50-70 rd/s
EWING (8) 1975	Volunteers	* 1700 rd/s^2 and 32 rd/s
A.P.R. 1988	Volunteer Boxers	* 16000 rd/s^2 and 25 rd/s * 13600 rd/s^2 and 48 rd/s

* These values represent levels tolerated by volunteers without injuries.

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VIII - ANNEX : PRELIMINARY TESTS

To validate the calculation method (acceleration of the Centre of Gravity of the head with the 9-GAMMA Program) used for the volunteer boxers, some preliminary tests were performed at first with a PART 573 Dummy and then with a human subject (M.S. 319).

VIII.1. TEST WITH PART 572 DUMMY

The dummy head was impacted in an antero-posterior direction at the level of the forehead. Its occipital area was equipped with a special rigid skull cap -a headgear- which supported three triaxial miniature accelerometers. A fourth triaxial accelerometer was screwed inside the dummy's head (near the center of gravity) in order to verify the good agreement between the accelerations calculated at the center of gravity by means of the three peripheral acceleration transducers and the acceleration directly measured by the 4th transducer (inside the head).

The method of calculation used was the 3-3-3 method described in the report (page 16). The results are :

- calculated HIC = 469,
- measured HIC = 415,

which displays a good similarity of the results and so validates the method of calculation. The calculation was obtained with only eight accelerations due to a missing channel.

VIII.2. TEST WITH HUMAN SUBJECT (M.S. 319)

A test similar to the preceeding one was performed with a human cadaver (Nb 319, male, 69 years, 1.72 meter). The subject was wearing a headgear identical to that of the volunteer boxers. A Wayne State University support with four triaxial miniature transducers was mounted on the headgear. A 5th transducer was screwed on the head, in the frontal area (picture 1).

This test was performed to demonstrate that the use of the Wayne State University method allows the calculation of resultant accelerations and HIC in all points of the head and consequently at the center of gravity of the head (as a matter of fact, it is impossible to put a transducer at the center of gravity of the head of the human subject).

The appended figure shows on one side the measurement results of the screwed transducer and on the other side the calculated results at the same point (1, 2). The calculation method used was the Burkhard method. These results show a good agreement and validate the methodology used.

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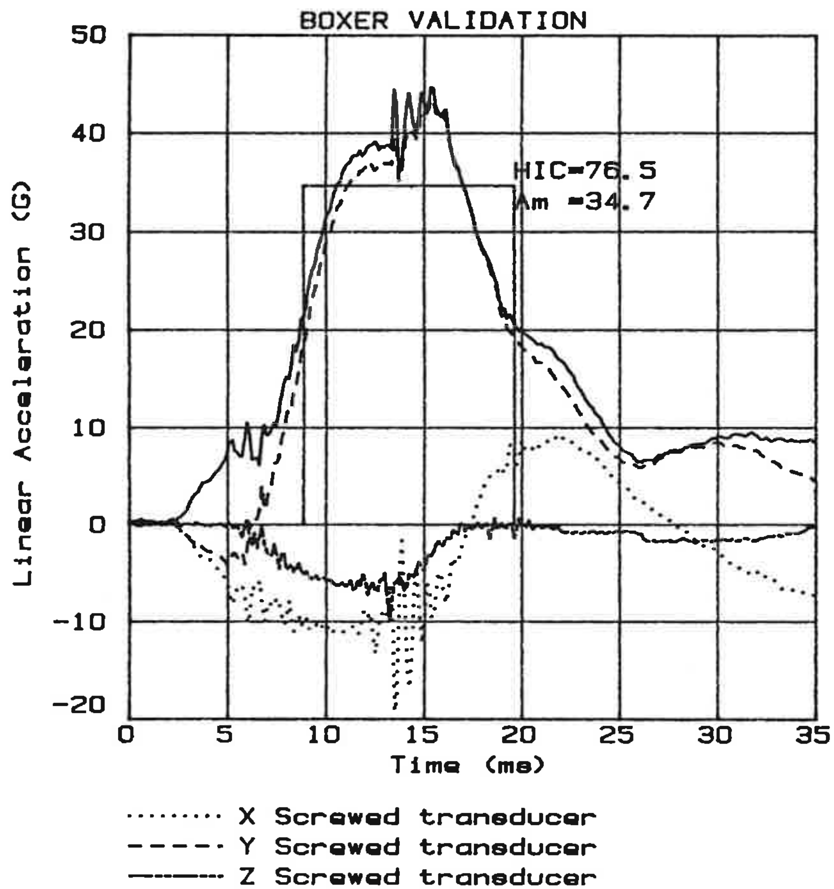
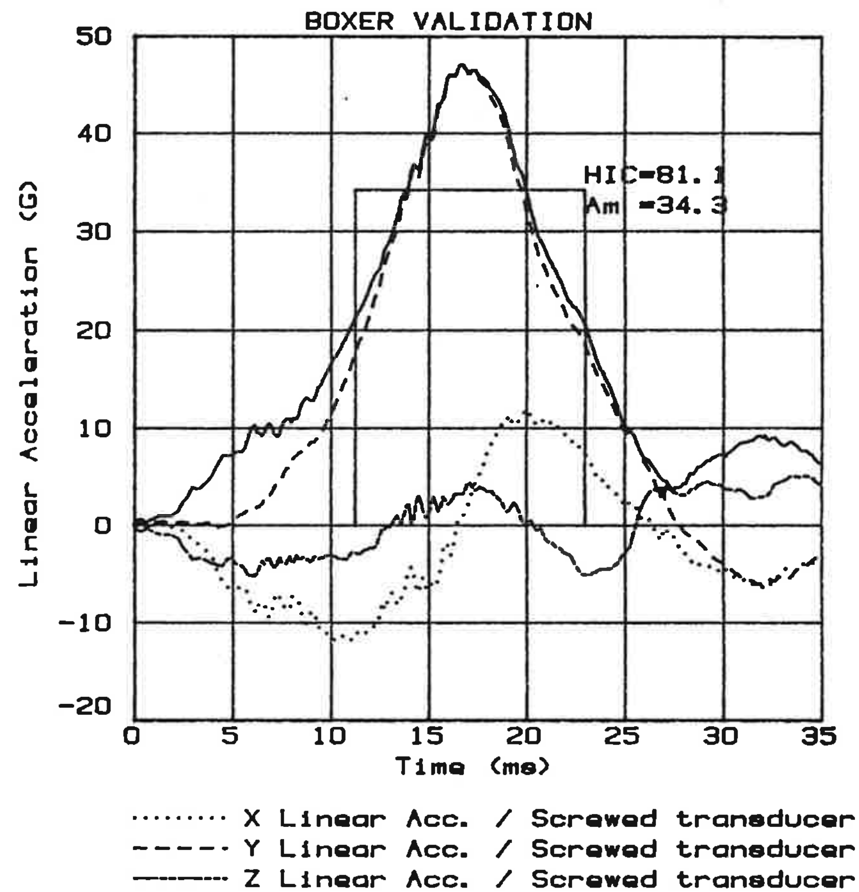
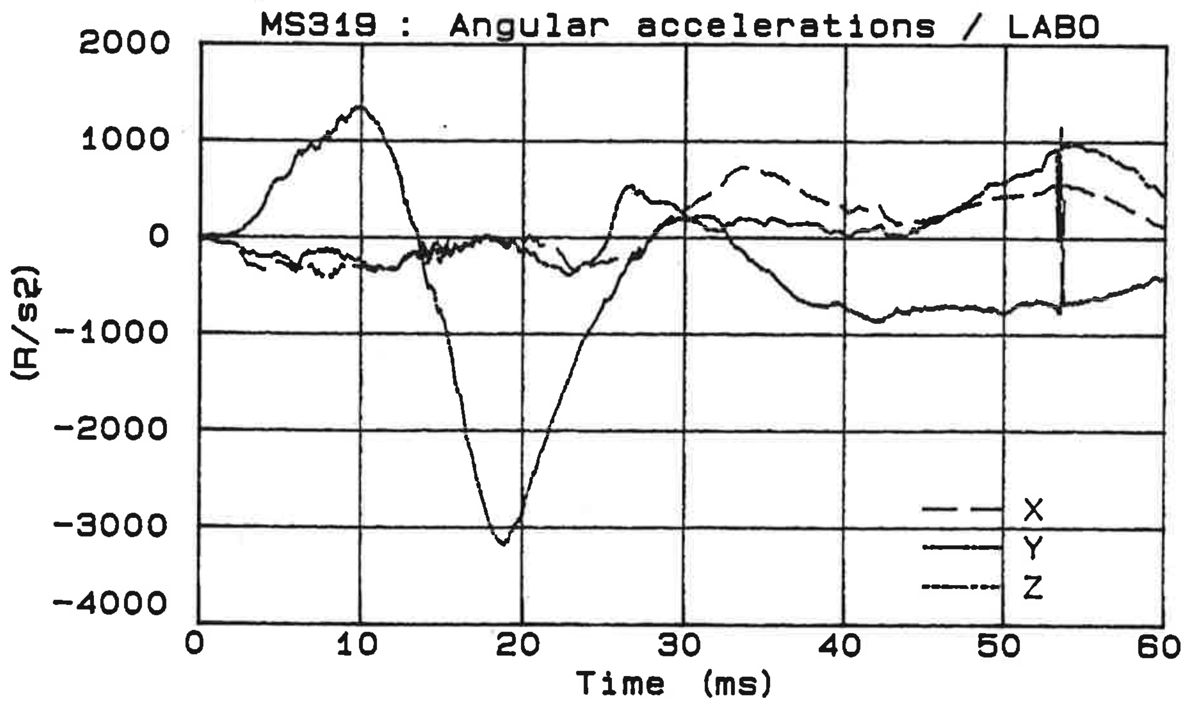


MEASURED ACCELERATIONS



CALCULATED ACCELERATIONS


MS319 : Angular accelerations / LABO
2000
1000
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(R/s2)
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10
20
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40
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Time (ms)
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Y
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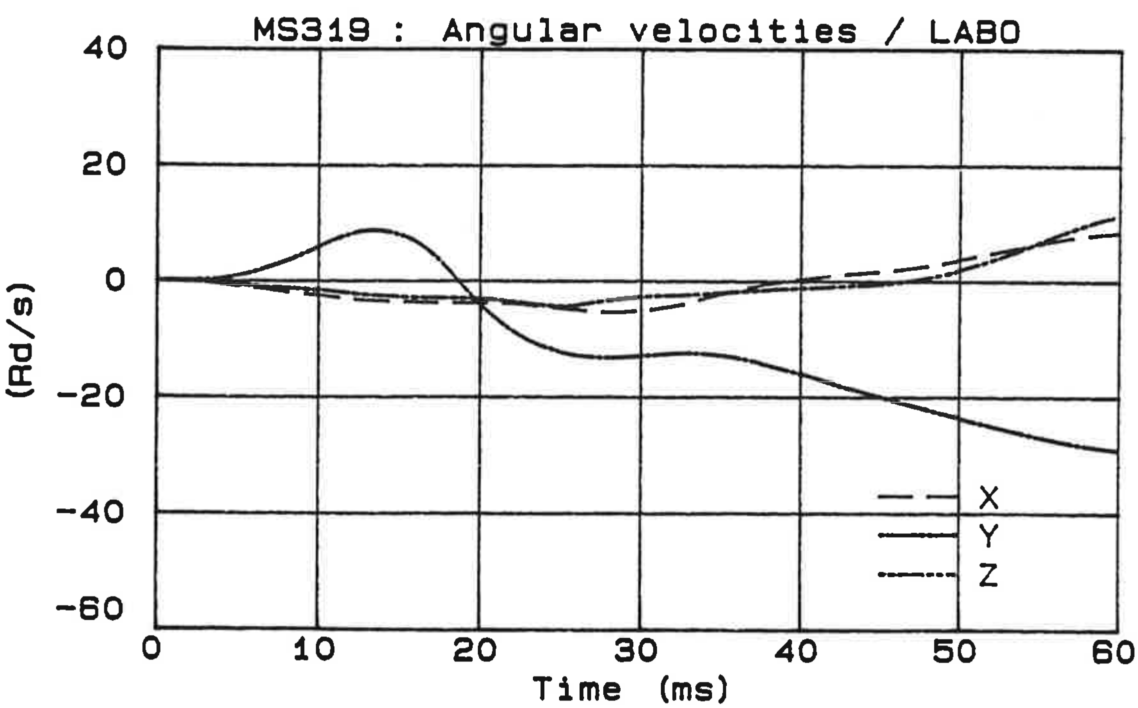
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20
0
-20
-40
-60
(Rd/s)
0
10
20
30
40
50
60
Time (ms)
X
Y
Z

PICTURE 1. SUBJECT INSTRUMENTATION

Measurement Data Format

Tape in: 1600 BPI
ACSII Code
80 Characters record
File No Label

Format in FORTRAN Language

For each blow

-Blow Descriptive: One record

Title of blow	: 5A4
	2X
Number of channel	: I4
	2X
For Other Application	F6.2
	2X
"	A2

-For Each Channel

-Channel descriptive: One Record

Title of Channel	:15A4
	2X
Number of Record for Digitized Data	: I4
	1X
Unit	: A4
	1X
Signe	: A4
	1X
Period of Sampling rate in MicroSeconds	: F4.0

-Digitized Data Records

Format: 10F8.2 for Each Record
Record Number is in Channel Descriptive

```
C****************************** PREP9G **********************************
C    CE PROGRAMME PRINCIPAL PREPARE LES DONNEES POUR LE PROGRAMME
C       9 GAMMA - FONCTIONNE SUR PDP    06-11-84 (P.MACK)
C    INCLUT LE MONTAGE EWING
C************************************************************************
      INTEGER*4 NS(3), NHZ
      REAL*8    DATE
      DIMENSION XGO(3), XP(3,3), IPV(3,3), ANG(3,3), RO(3,9), ICOM(40),
     *          IP(3), COEF(3)
      BYTE      NOMFIC(20), FINNOM(5), VAC(80), NOMC(9,3), NOMUT(15),
     *          DIRV(3)
C
C MONTAGE EWING :
C 3 TYPES DE REPERES : T=TETE  M=MONTAGE  C=CAPTEUR
C TABLEAUX POUR LE MONTAGE EWING :
C PMT(3,3) MATRICE DE PASSAGE DU REPERE MONTAGE AU REPERE TETE
C          (COMPOSANTES DES VECTEURS DU REPERE M DANS LE REPERE T)
C          A EMPLIR AVEC LES 3 ANGLES D'EULER /Z,Y,X DONNES PAR
C          L'UTILISATEUR
C MCM(3,6) COMPOSANTES DES 6 VECTEURS MC, DANS LE REPERE M
C          MATRICE DONNEE PAR EWING, MISE EN DATA
C MCT(3,6) COMPOSANTES DES 6 VECTEURS MC, DANS LE REPERE T
C          MATRICE OBTENUE PAR PRODUIT PMT*MCM
C TMT(3)   VECTEUR TM, DANS LE REPERE T
C          (POSITION DE L'ORIGINE DU REPERE MONTAGE, DANS LE REPERE T
C          FOURNI PAR L'UTILISATEUR
C TCT(3,6) MATRICE DES 6 VECTEURS TC, DANS LE REPERE T
C          OBTENUS PAR ADDITION DE TMT A CHACUN DES 6 VECTEURS DE MCT
C CDM(3,6) MATRICE DES COSINUS DIRECTEURS DE CHACUNE DES 6 VOIES,
C          DANS LE REPERE M - DONNEE PAR EWING
C CDT(3,6) IDEM, DANS LE REPERE TETE - OBTENUE PAR PRODUIT PTM*CDM
C
      REAL*4    PMT(3,3), MCM(3,6), MCT(3,6), TMT(3), TCT(3,6),
     *          CDM(3,6), CDT(3,6)
C
      DATA   MCM/  .06735,  .06735, -.00178,  .06286,  .06286, -.00178,
     *            -.00449,  .00449, -.00178, -.00449, -.00449, -.00178,
     *             .00000,  .00000, -.00178,  .06735, -.06735, -.00178/,
     *       CDM/ -.02470, -.03156, -.99920,  .71426, -.69786,  .05310,
     *            -.70591, -.70760,  .03155,  .71466, -.69876,  .03153,
     *            -.00243,  .03209, -.99948, -.00520, -.01721, -.99984/
      DATA   FINNOM /'.','9','G','D',"0/, XGO /.00989,0.,.02132/,
     *       LDA, LTT /1,5/, DEGRAD/.017453292/, DIRV/'L','T','V'/
C-----------------------------------------------------------------------
      TYPE 10
 10   FORMAT (' PREPARATION DES DONNEES POUR LE PROGRAMME G92011'/
     * 'OQUEL EST VOTRE NOM ? ',$)
      ACCEPT 20, LU, (NOMUT(J),J=1,LU)
C
      TYPE 15
 15   FORMAT (' NUMERO DU MS ? (3 CHIFFRES) : ',$)
      ACCEPT 20, LN, (NOMFIC(J),J = 1,LN)
 20   FORMAT (Q,80A1)
      IF (LN.GT.0) GO TO 25
      LN = 1
      NOMFIC(1) = '0'
 25   DO 30 J = 1,5
 30   NOMFIC (LN + J) = FINNOM (J)
      OPEN (UNIT = LDA,TYPE ='NEW',NAME = NOMFIC, ACCESS ='SEQUENTIAL',
     *      DISPOSE ='SAVE', CARRIAGE CONTROL ='LIST')
      WRITE (LTT,40) (NOMFIC(J), J =1,LN+5)
 40   FORMAT (' FICHIER OUVERT : ',<LN+5>A1/' DATE (8 CARACTERES)'
     * ' (EXEMPLE : 01-11-81) : ',$)
      WRITE (LDA,50) (NOMFIC(J),J = 1,LN)
 50   FORMAT (' MS ',<LN>A1)
      ACCEPT 60, DATE
      WRITE (LDA,60) DATE
 60   FORMAT (A8)
C
 70   TYPE 80
 80   FORMAT (' NUMERO DU PASSAGE ? (4 CARACTERES) : ',$)
      ACCEPT 20, LV, (VAC(J), J = 1,LV)
      IF (LV.GT.4) GO TO 70
      WRITE (LDA,90) (VAC(J), J = 1,LV), (NOMUT(J),J=1,LU)
 90   FORMAT (<LV>A1,<6-LV>X,<LU>A1)
C
      TYPE 100
 100  FORMAT (' COMMENTAIRES POUR CE PASSAGE (80 CARACTERES) : ')
      ACCEPT 20, LV, (VAC(J), J = 1,LV)
      WRITE (LDA,110) (VAC(J), J = 1,LV)
 110  FORMAT (80A1)
C
```

```
C115  ICONF = 1
 115  TYPE 120
 120  FORMAT (' LE MONTAGE ''EWING'' EST-IL UTILISE ? (0=NON 1=OUI) ',$)
C120  FORMAT (' CONFIGURATION DES CAPTEURS : '/
C    *   ' (1) - 9 GAMMA (3 TRIAXES) NORMAL OU INCOMPLET' /
C    *   ' (2) - MONTAGE EWING (6 CAPTEURS MONOAXES)'/' REPONSE : ',$)
C
C    *   ' (2) - 9 GAMMA DEFECTUEUX (6 A 9 VOIES SUR 3 A 7 CAPTEURS'/
C    *   '         DONT AU MOINS UN TRIAXE)' /
C    *' (3) - 9 GAMMA DEFECTUEUX SUR 3 A 9 CAPTEURS SANS UN '
C    *         'SEUL TRIAXE'/
C    *   ' (4) - MONTAGE EWING (6 CAPTEURS MONOAXES)' /
C    *   ' (5) - MONTAGE WAYNE STATE (1 TRIAXE + 6 MONOAXES BIEN'
C    *         ' POSITIONNES)'/' REPONSE :  ',$)
      ACCEPT *, ICONF
      IF (ICONF.LT.0.OR.ICONF.GT.1) GO TO 115
      ICONF = ICONF + 1
      WRITE (LDA,150), ICONF
      IF (ICONF.NE.2) GO TO 145
C-----------------------------------------------------------------------
C  TRAITEMENT DU CAS DU MONTAGE EWING
C-----------------------------------------------------------------------
C
C  EMPLISSAGE DE LA MATRICE DE PASSAGE MONTAGE --> TETE
C
      TYPE *, 'POSITIONNEMENT DU MONTAGE'
      TYPE 370
      ACCEPT *, IANG
      TYPE 380
      ACCEPT *, (ANG(J,1),J=1,3)
      DO 122 J=1,3
 122  ANG(J,1) = ANG(J,1) * DEGRAD
      CALL CAPISO (IANG, ANG, PMT)
C
C  EMPLISSAGE DE MCT, PUIS TCT
C
      CALL PRODMT (PMT, MCM, MCT, 3,3,6, 3,3,3)
      TYPE 210
      ACCEPT *, (TMT(J),J=1,3)
      DO 123 J=1,3
 123  TMT(J) = TMT(J) * .001
      DO 124 I=1,6
      DO 124 J=1,3
 124  TCT(J,I) = TMT(J) + MCT(J,I)
      CALL PRODMT (PMT, CDM, CDT, 3,3,6, 3,3,3)
C
C  ECRITURE DANS LE FICHIER
C
      NCAP = 6
      WRITE (LDA,150) NCAP
      TYPE *,'RANGS DES 6 VOIES DU MONTAGE DANS LE FICHIER DES ACCELERA
     *TIONS'
      DO 128 I=1,NCAP
      TYPE 126, I
 126  FORMAT (' VOIE',I2,' : RANG ',$)
 128  ACCEPT *, ICOM(I)
      TYPE *, 'SIGNES D''INVERSION (+ OU -) DES VOIES :'
      DO 132 I=1,NCAP
      TYPE 130, I
 130  FORMAT (' VOIE',I2,' : SIGNE ',$)
 132  ACCEPT 134, VAC(I)
 134  FORMAT (A1)
      DO 140 I=1,NCAP
      WRITE (LDA,136) I
 136  FORMAT ('EWING',I2)
      WRITE (LDA,340), (TCT(J,I),J=1,3)
      WRITE (LDA,150) ICOM(I)
      WRITE (LDA,137) VAC(I)
 137  FORMAT (A1,'**')
      WRITE (LDA,139) (CDT(J,I), J=1,3)
 139  FORMAT (F14.7)
 140  CONTINUE
      GO TO 440
C-----------------------------------------------------------------------
C  TRAITEMENT DU MONTAGE 9 GAMMA NORMAL
C-----------------------------------------------------------------------
 145  TYPE 147
 147  FORMAT (' NOMBRE TOTAL DE CAPTEURS DONT (AU MOINS) UNE VOIE A '
     *        'BIEN FONCTIONNE : ',$)
      ACCEPT *, NCAP
      WRITE (LDA,150) NCAP
 150  FORMAT (I2)
```

```
C-----------------------------------------------------------------------
C                     UTILISATION DU SUPPORT ETOILE
C-----------------------------------------------------------------------
      TYPE 160
 160  FORMAT (' LE SUPPORT ETOILE A TROIS BRANCHES A-T-IL ETE UTILISE ?'
     * ,' ( 1=OUI  0=NON ) : ',$)
      ACCEPT *, IREP
      I1 = 1
C I1 : NUMERO DU FUTUR CAPTEUR (AYANT AU MOINS UNE VOIE) A ENTRER
C
      TYPE 165
 165  FORMAT (' DESIREZ-VOUS FAIRE DES CORRECTIONS D''ETALONNAGE DES',
     *        ' CAPTEURS ? (1=OUI,0=NON) ',$)
      ACCEPT *, ICORR
C
      IF (IREP.NE.1) GO TO 360
      TYPE 170
 170  FORMAT (' SOUS QUELLE FORME SONT RENTREES LES DONNEES ?'/
     *         ' (1) - COORDONNEES ET 3 ANGLES PROJETES DU CAPTEUR 1'/
     *         ' (2) - COORDONNEES ET 3 ANGLES D''EULER DU CAPTEUR 1'/
     *         ' (3) - COORDONNEES DES 3 CAPTEURS'/
     *         ' REPONSE : ',$)
      ACCEPT *, IREP
C
 180  DO 280 I=1,3
      TYPE 190, I
 190  FORMAT (' NOM (9 CARACTERES) DU CAPTEUR ',I1,' : ',$)
      ACCEPT 110, (NOMC(J,I), J=1,9)
C
      IF ((I.GT.1).AND.(IREP.EQ.1)) GO TO 220
      TYPE 210
 210  FORMAT (' COORDONNEES X Y Z (EN MM) :')
      ACCEPT *, (XP(J,I), J=1,3)
      DO 215 J = 1,3
 215  XP(J,I) = .001 * XP(J,I)
C
 220  DO 235 J=1,3
      TYPE 230, DIRV(J), (NOMC(K,I), K=1,9)
 230  FORMAT (' RANG DE LA VOIE ',A1,' DU CAPTEUR ',9A1,' SUR '
     *        'LA BANDE : ',$)
 235  ACCEPT *, IPV (J,I)
      IP(I) = IPV(1,I) + IPV(2,I) + IPV(3,I)
      IF (IP(I).EQ.0) GO TO 255
C
      TYPE 240
 240  FORMAT (' SIGNE D''INVERSIONS DES VOIES L,T,V (3 SIGNES ACCOLES) '
     *        ,': ',$)
      ACCEPT 250, NS(I)
 250  FORMAT (A3)
C
      IF (ICORR.EQ.0) GO TO 255
      TYPE 252
 252  FORMAT (' VOULEZ-VOUS CORRIGER L''ETALONNAGE DE CE CAPTEUR ?',
     *        ' (0-1) ',$)
      ACCEPT *, ICORC
      IF (ICORC.EQ.0) GO TO 255
      TYPE 253
 253  FORMAT (' DONNEZ LES COEFFICIENTS (SANS SIGNES) PAR LESQUELS'/
     *         'VOUS VOULEZ MULTIPLIER LES VOIES L,T,V DU CAPTEUR'/
     *         '(0 OU 1 POUR UNE VOIE IMPLIQUE : PAS DE CORRECTION ',
     *         'POUR CETTE VOIE)')
      ACCEPT *, (COEF(J),J=1,3)
C
 255  IF (IREP.EQ.3) GO TO 280
      IF (I.GT.1) GO TO 280
 260  TYPE 380
      ACCEPT *, (ANG(J,I), J=1,3)
      DO 280 J=1,3
      ANG(J,I) = ANG(J,I) * DEGRAD
 280  CONTINUE
      CALL ETOILE (IREP, RC, ANG, XP)
 310  DO 350 I=1,3
      IF (IP(I).EQ.0) GO TO 350
      I1 = I1 + 1
      WRITE (LDA,110) (NOMC (J,I), J=1,9)
      WRITE (LDA,340) (XP   (J,I), J=1,3)
      WRITE (LDA,330) (IPV (J,I), J=1,3)
 330  FORMAT (40I2)
      IF (ICORR.EQ.0) GO TO 333
      IF (ICORC.EQ.0) GO TO 333
      WRITE (LDA,331) NS(I), (COEF(J),J=1,3)
 331  FORMAT (A3,3(F11.7,3X))
```

```
      GO TO 334
  333 WRITE (LDA,250) NS(I)
  334 L = 3*I - 3
      DO 335 M=1,3
  335 ANG(M,I) = ANG(M,I)/DEGRAD
      WRITE (LDA,340) ((RO(M,K+L),K=1,3),ANG(M,I),M=1,3)
  340 FORMAT (3F14.7,F18.5)
  350 CONTINUE
      IF (I1.GT.NCAP) GO TO 440
C-----------------------------------------------------------------------
C         UTILISATION DE CAPTEURS TRIAXES ISOLES
C-----------------------------------------------------------------------
      IF (I1.NE.1) TYPE 355
  355 FORMAT (' CAPTEURS SUPPLEMENTAIRES')
  360 TYPE 370
  370 FORMAT (' DEFINITION DES ANGLES DES CAPTEURS'/' (1) - ANGLES PRO'
     *        'JETES'/' (2) - ANGLES D''EULER/ZYX'/' REPONSE (1) : ',$)
      ACCEPT *, IANG
C
      DO 430 I = I1,NCAP
      TYPE 190, I
      ACCEPT 110, (NOMC(J,1), J=1,9)
      TYPE 210
      ACCEPT *, (XP(J,1), J=1,3)
      DO 372 J = 1,3
  372 XP(J,1) = .001 * XP(J,1)
      DO 375 J=1,3
      TYPE 230, DIRV(J), (NOMC(K,1), K=1,9)
  375 ACCEPT *, IPV (J,1)
      TYPE 240
      ACCEPT 250, NS(1)
      IF (ICORR.EQ.0) GO TO 379
      TYPE 252
      ACCEPT *, ICORC
      IF (ICORC.EQ.0) GO TO 379
      TYPE 253
      ACCEPT *, (COEF(J),J=1,3)
  379 TYPE 380
  380 FORMAT (' VALEUR DES ANGLES (EN DEGRES) - ROTATIONS / OZ,OY,OX :')
      ACCEPT *, (ANG(J,1), J=1,3)
      DO 390 J=1,3
  390 ANG(J,1) = ANG(J,1) * DEGRAD
      CALL CAPISO (IANG, ANG, RO)
      WRITE (LDA,110) (NOMC (J,1), J=1,9)
      WRITE (LDA,340) (XP    (J,1), J=1,3)
      WRITE (LDA,330) (IPV (J,1), J=1,3)
      IF (ICORR.EQ.0) GO TO 393
      IF (ICORC.EQ.0) GO TO 393
      WRITE (LDA,331) NS(1), (COEF(J),J=1,3)
      GO TO 394
  393 WRITE (LDA,250) NS(1)
  394 DO 400 M=1,3
  400 ANG(M,1) = ANG(M,1)/DEGRAD
      WRITE (LDA,340) ((RO(M,K),K=1,3),ANG(M,1),M=1,3)
  430 CONTINUE
C-----------------------------------------------------------------------
C        DONNEES DE L'EXPERIENCE
C-----------------------------------------------------------------------
  440 TYPE 450
  450 FORMAT (' NOMBRE TOTAL DE POINTS DONNES : ',11X,$)
      ACCEPT *, NPT
  460 FORMAT (I5)
C
      TYPE 470
  470 FORMAT (' NOMBRE DE POINTS UTILISES POUR LE CALCUL : ',$)
      ACCEPT *, NPU
      IF (NPU.LE.NPT) GO TO 475
      TYPE *, 'ATTENTION : DOIT ETRE < AU CHIFFRE PRECEDENT'
      GO TO 440
  475 WRITE (LDA,460) NPT
      WRITE (LDA,460) NPU
C-----------------------------------------------------------------------
      TYPE 480
  480 FORMAT (' INTERVALLE DE TEMPS (EN MICROSECONDES) ENTRE DEUX DONNEE
     *S D''ACCELERATIONS :'/' (OU REPONDEZ 0 SI CE SONT DES DONNEES POIN
     *TEES QUI SE TROUVENT'/16X,'DANS UN FICHIER DE TYPE .DMS'/13X,'-1 S
     *I LES DONNEES PROVIENNENT D''UNE BANDE FOURNIE PAR L''UTAC)'/' REP
     *ONSE : ',$)
      ACCEPT *, DT
      IF (DT.GT.0.) DT = DT * .000001
      WRITE (LDA,340) DT
C
```

```
      TYPE 490
 490  FORMAT (' FREQUENCE DE FILTRAGE (1000) : ',$)
      ACCEPT 500, NHZ
      WRITE (LDA,500) NHZ
 500  FORMAT (A4)
C
      IF (DT.LT.0.) GO TO 515
      TYPE 510
 510  FORMAT (' NUMERO DE L''ENREGISTREMENT DU TITRE DE L''ESSAI (1) : '
     *        ,$)
      ACCEPT *, NEA
      WRITE (LDA,460) NEA
C
 515  TYPE 520
 520  FORMAT (' CHOIX DU POINT DE REFERENCE'/
     *         ' (-2) - CENTROIDE'/
     *         ' (-1) - CENTRE DE GRAVITE'/
     *         ' ( 0) - ORIGINE DU REPERE ANATOMIQUE'/
     *         ' ( N) - N NUMERO DU CAPTEUR PRIS COMME REFERENCE'/
     *         ' REPONSE (-2) : ',$)
      ACCEPT *, IREP
      WRITE (LDA,530) IREP
 530  FORMAT (I2)
C
      TYPE 540, XGO
 540  FORMAT (' O.K. POUR X,Y,Z  C.D.G. =',3F8.5/
     *         ' REPONSE (OUI=1  NON=0) : ',$)
      ACCEPT *, IREP
      IF (IREP.EQ.1) GO TO 555
      TYPE 550
 550  FORMAT(' NOUVELLES COORDONNEES DU CENTRE DE GRAVITE (EN MM) : ',$)
      ACCEPT *, (XGG(J), J=1,3)
      DO 552 J=1,3
 552  XGO(J) = XGG(J) * .001
 555  WRITE (LDA,340) (XGO(J), J=1,3)
C
      TYPE 560
 560  FORMAT (' ANGLES D''EULER INITIAUX (DEGRES) TETE / OZ,OY,OX LABO')
      ACCEPT *, (XGG(J), J=1,3)
      WRITE (LDA,595) (XGO(J), J=1,3)
C
      TYPE 570
 570  FORMAT (' COMPOSANTES P,Q,R (DEGRES/S) DE LA VITESSE ANGULAIRE',
     *         ' INITIALE (0 0 0) : ')
      ACCEPT *, (XGG(J), J=1,3)
      WRITE (LDA,595) (XGO(J), J=1,3)
C
      TYPE 580
 580  FORMAT (' POSITION INITIALE (METRES) / X,Y,Z LABO (0 0 0) : ')
      ACCEPT *, (XGG(J), J=1,3)
      WRITE (LDA,595) (XGO(J), J=1,3)
C
      TYPE 590
 590  FORMAT (' VITESSE INITIALE (M/S) / X,Y,Z LABO : ')
      ACCEPT *, (XGG(J), J=1,3)
      WRITE (LDA,595) (XGO(J), J=1,3)
 595  FORMAT (3F14.4)
C-----------------------------------------------------------------------
C   LECTURE DES COMMANDES ET DES ORDRES DE TRACE
C-----------------------------------------------------------------------
      OPEN (UNIT=2, NAME='COMM9GD.DAT', TYPE='OLD', ACCESS='SEQUENTIAL',
     *        DISPOSE='SAVE')
      TYPE 600
 600  FORMAT ('0COMMANDES DES CALCULS, IMPRESSIONS ET TRACES :'/
     *         ' VOULEZ-VOUS DES SORTIES TYPIQUES COMPLETES (0-1) ? ',$)
      ACCEPT *, IREP
      READ (2,610) NCOM, (ICOM(J),J=1,NCOM)
 610  FORMAT (I2/80I1)
      IF (IREP.EQ.1) GO TO 680
      TYPE 620
 620  FORMAT (' VOULEZ-VOUS (1=OUI,0=NON) :'/)
      DO 670 I=1,NCOM
      READ (2,630) VAC
 630  FORMAT (80A1)
      IF (ICOM(5).EQ.0.AND.I.EQ.6) TYPE 640
 640  FORMAT (' TOUS LES CALCULS ET TRACAGES SUIVANTS SONT INTERDITS'
     *         ' DU FAIT DE CETTE REPONSE')
      IF (ICOM(5).EQ.0.AND.I.GT.5.AND.I.LT.20) GO TO 660
      TYPE 650, I, (VAC(J),J=1,50)
 650  FORMAT (I3,' : ',50A1,$)
      ACCEPT *, ICOM(I)
      GO TO 670
```

```
00        660   ICOM(I) = 0
00        670   CONTINUE
00       C
00        680   CLOSE (UNIT=2)
00              WRITE (LDA,690) (ICOM(J),J=1,NCOM)
00        690   FORMAT (80I1)
00              CLOSE (UNIT=LDA)
00              STOP
00              END
```

```
//FORT.SYSIN DD *
C------------------------------ G92011 ----------------------------C
C PROGRAMME '9 GAMMA'   17-12-84                                    C
C TRACE DE LA TETE                                                  C
C ACCEPTE LES CAPTEURS INCOMPLETS                                   C
C CALCULE ACC ET VIT ANGUL MAX ET 3 MS                              C
C TESTE LE DEBUT DES DONNES ACCELEROMETRIQUES PAR LES PREMIERS CARAC-  C
C -TERES NON NUMERIQUES                                             C
C  AVEC CE PROGRAMME UNIQUE, LE TRACAGE SE FERA ON-LINE OU OFF-LINE C
C  SELON LA PROCEDURE DE COMPILATION UTILISEE (LODON9G OU LODOF9G.JCL) C
C  LE JEU DE DONNEES DEVRA ETRE PRECEDE DE LA LONGUEUR DU BUFFER    C
C  POSSIBILITE DE CORRIGER LES ETALONNAGES DE CAPTEURS (PAR COEF)   C
C  NB DE POINTS, SIGNES ET COEFF DE CORRECTION D'ETALONNAGE INTERVIEN- C
C  NENT DES LE DEPART (DONNEES BRUTES)                              C
C------------------------------------------------------------------C
      EXTERNAL SFCT8, FCTRK8, EULER
      COMMON /TAB/ RAM(2005,9), GAM(2001,9), GAMA(9,2001), ALPH(9,2001),
     *                DELTAT, NPTM
      COMMON /ANAT/ XPC(3,7), XPV(3,9), XC(3), DX(3,9), XGO(3), C(9,3),
     *     NV, RO1(3,3), RO2(3,3), RO3(3,3), ANG(3,3), R69(6,9), TRE(80)
      DIMENSION  ANGLE(9,2005), POSIT(9,2001), PEUL(3,3,2001), RO(3,9),
     *           IAVC(2,9), ICC(4,7), IPV(3), AE(3,3), B(3,3), ICG(3,3),
     *      IPV3(3), IPV1(3), A(2005), PCSIN(3,4), IBUF(270), TRA(20),
     *      IGAM(2001,9), RAM1(2005), RAM2(2005), RAM3(2005), RAM4(2005),
     *      COEF(3,7)
      LOGICAL*1 SELVOI(80,3), CHIF(9)
      EQUIVALENCE  (ANGLE,RAM), (POSIT,GAM), (PEUL,GAMA), (RO,RO1),
     *  (RAM1,RAM(1,1)),(RAM2,RAM(1,2)),(RAM3,RAM(1,3)),(RAM4,RAM(1,4)),
     *  (IGAM,GAM), (ICG,TRE(50)), (AE,TRE(60)), (B,TRE(70)), (TRA,TRE)
      INTEGER*2 NCA(24), LXYZ(3) /'X','Y','Z'/, IRA(3)
      COMMON /PLOT/ IPLOT,IGC,NBL,IDATE(2),NESSAI(2),NS(3,7),NEME,NHZ,
     *             DUREE,NPTS,DTT,NCAP,NOMCAP(140)
      INTEGER*4 LLONG(20)/'LONG','ITUD','E'/,   LMOYN(20)/'MOYE','NNE'/,
     *          LTRAN (3)/'TRAN','SVER','S'/,   LBLAN(20)/1H ,1H /,
     *          LVERT (3)/'VERT','ICAL','E'/,   NPLUS/'+'/,
     *          LROTX (3) /'ROT/','AXE ','X'/,  LX(20) /' ','X'/,
     *          LROTY (3) /'ROT/','AXE ','Y'/,  LY (3) /' ','Y'/,
     *          LROTZ(20) /'ROT/','AXE ','Z'/,  LZ (3) /' ','Z'/,
     *          LCX(20) /'X CA','PTEU','R'/,
     *          LCY (3) /'Y CA','PTEU','R'/,
     *          LCZ (3) /'Z CA','PTEU','R'/
      DATA  NUTAC/0/, NPT/0/, DEGRAD/0.017453292/, JBAND/10/, ICC/28*0/,
     *      NETS/1/, LBAND/5/, GE/9.80665/, NCA/24*0/,
     *      IPV3/3*1/, IPV1/1,2*0/
      DATA SELVOI/'V','O','I','E','S',75*' ','V','O','I','E','S',75*' ',
     *           'V','O','I','E','S',75*' '/,
     *      CHIF/'1','2','3','4','5','6','7','8','9'/
      REAL*4 CHOIX(5)/'NON','OUI','RIEN','P-C','R-K'/,
     *       CARNUM(15)/'0','1','2','3','4','5','6','7','8','9',
     *        ' ','.','+','-','E'/
      INTEGER*4 IMP(21),
     *   ITP(8,3)/26,'X1  ',' ACC','ELER','ATIO','N LI','NEAI','RE',
     *              26,'Y1  ',' ACC','ELER','ATIO','N LI','NEAI','RE',
     *              26,'Z1  ',' ACC','ELER','ATIO','N LI','NEAI','RE'/,
     *      IT4(7)/21,'P   ','VITE','SSE ','ANGU','LAIR','E'/,
     *      IT5(8)/26,'P   ','ACCE','LERA','TION',' ANG','ULAI','RE  '/,
     *      IT6(7)/24,'X   ','ACCE','LERA','TION',' MOY','ENNE'/,
     *      IT7(8)/27,'1   ','ACCE','LERA','TION',' RES','ULTA','NTE'/,
     *      IT8(7)/23,'ACCE','LERA','TION',' RES','ULTA','NTE'/,
     *      IT9(9)/31,'ACCE','LERA','TION',' RES','ULTA','NTE ',
     *            'MOYE','NNE'/,
     *      IT10(2)/1,'G'/, IT11(2)/4,'RD/S'/, IT12(3)/6,'RD/S','/S'/,
     *      IT13(7)/23,'RESU','LTAN','TE A','CCEL','ERO ','1'/,
     *      IT14(8)/25,'DONN','EES ','BRUT','ES'/,
     *      IT16(3)/5,'DEGR','E'/, IT17(2)/4,'MM/S'/, IT18(2)/2,'MM'/
      INTEGER*4 IT19(5)/14,'ANGL','ES D',4H'EUL,'ER'/,
     *      IT20(7)/24,'VITE','SSE ','ANGU','LAIR','E / ','LABO'/,
     *      IT21(7)/22,'ACCE','L AN','GULA','IRE ','/ LA','BO'/,
     *      IT22(7)/21,'ACCE','L LI','NEAI','RE /',' LAB','O'/,
     *      IT23(7)/23,'VITE','SSE ','LINE','AIRE',' / L','ABO'/,
     *      IT24(6)/19,'X   ','POSI','TION',' / L','ABO'/,
     *      ITA(6,3)/19,'(ACC','EL L','ONGI','T) X','1',
     *              19,'(ACC','EL T','RANS','V) Y','1',
     *              19,'(ACC','EL V','ERTI','C) Z','1'/
C-------------------------------------------------------------------
C  DEBUT DE LA LECTURE DES DONNEES
C-------------------------------------------------------------------
      READ (5,3010) LBUF
 3010 FORMAT (I3)
      WRITE (6,6010)
 6010 FORMAT (1H1,30(1H*)/' * PROGRAMME ''9 GAMMA'' G92011 *'/1X,30
     * (1H*)/1H0,28(1H*),' IMAGE DES DONNEES-CARTES ',28(1H*),
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```
     * 17(1H=),' INTERPRETATICN ',17(1H=))
C
      READ (5,3070) TRA, NESSAI
      WRITE (6,6020) TRA, NESSAI
 6020 FCRMAT (' *',20A4,'* NUMERO DE L''ESSAI = ',2A4)
C
      READ (5,3070) TRA, IDATE
      WRITE (6,6030) TRA, IDATE
 6030 FCRMAT (' *',20A4,'*  DATE  DE L''ESSAI = ',2A4)
C
      READ(5,3070) TRA, NEME
      WRITE (6,6040) TRA, NEME
 6040 FCRMAT (' *',20A4,'*   PASSAGE NUMERO',7X,A4)
C
      READ(5,3050) (TRE(J), J=61,80)
 3050 FCRMAT (20A4)
      WRITE(6,6050) (TRE(J), J=61,80)
 6050 FCRMAT(' *',20A4,'* (CCMMENTAIRES TRACE)')
C
      READ (5,3060) TRA, ICCNF
 3060 FCRMAT (20A4,T1,I2)
      WRITE (6,6060) TRA, ICCNF
 6060 FCRMAT (' *',20A4,'* CCNFIGURATICN DES CAPTEURS : ',I2)
C ICCNF N'EST PAS ENCORE UTILISE - PREVU POUR LE MCNTAGE 'WAYNE STATE U'
      READ (5,3060) TRA, NCAP
      WRITE (6,6070) TRA, NCAP
 6070 FCRMAT (' *',20A4,'* NB DE CAPT DCNT UNE VOIE A FCNCTIONNE : ',I2)
C---------------------------------------------------------------------------
C  LECTURE DES NOMS DES CAPTEURS, DE LEURS CCCRDONNEES, DES SIGNES
C  DE DEVIATICN DES VOIES, DES ANGLES / REPERE DE FRANCFORT,
C  DE LA POSITION DES VOIES ET DES MATRICES DE COSINUS DIRECTEURS
C   REMPLISSAGE DES TABLEAUX DE TRAVAIL XPV, ICC, IAVC, C
C---------------------------------------------------------------------------
      NV = 0
      DC 100 I = 1,NCAP
      L = 20*I-20
      DC 10 J = 1,20
 10   NCMCAP(L+J) = LBLAN(2)
      PRINT 6080, I
 6080 FCRMAT (1X,82('='),' DCNNEES CAPTEUR',I2)
      READ (5,3070) TRA, (NCMCAP(L+J),J=1,3)
 3070 FCRMAT (20A4,T1,20A4)
      PRINT 6090, TRA, (NOMCAP(L+J),J=1,3)
 6090 FCRMAT (' *',20A4,'* NCM = ',3A4)
      PRINT 6100
 6100 FCRMAT (1X,82('='),' CCCRDONNEES X,Y,Z (EN M)')
      READ (5,3175) TRA, (XPC (J,I) , J=1,3)
 30   PRINT 6110, TRA
 6110 FCRMAT (' *',20A4,'*  ')
      READ (5,3135) TRA, IRA
 3135 FCRMAT (20A4,T1,40I2)
      PRINT 6120, TRA, IRA
 6120 FCRMAT (' *',20A4,'* RANG DES VCIES SUR LA BANDE =',3I2)
      DC 35 J=1,3
      IF (IRA(J).GT.24) GO TC 36
 35   CCNTINUE
      GC TC 40
 36   PRINT 6125
 6125 FCRMAT (' ERREUR : RANG DE VCIE SUPERIEUR A 24')
      GC TO 9999
 40   READ (5,3140) TRA, (NS (J,I),J=1,3), (CCEF(J,I),J=1,3)
 3140 FCRMAT (20A4,T1,3A1,3(F11.7,3X))
      PRINT 6130, TRA, (NS(J,I),J=1,3)
 6130 FCRMAT (' *',20A4,'* INVERSICNS DE SENS = ',3A1)
      DC 50 J=1,3
      IF (CCEF(J,I).NE.0.) GC TO 6C
 50   CCNTINUE
      GC TO 70
 60   PRINT 6135, (COEF(J,I),J=1,3)
 6135 FCRMAT (' CCEFFICIENTS CORRECTEURS ',3F8.5)
 70   PRINT 6160
      DC 80 L = 1,3
      READ (5,3175) TRA, (RC(L,J),J=1,3)
 80   PRINT 6140, TRA, LXYZ(L), LXYZ(4-L)
 6140 FCRMAT (' *',20A4,'* CCMP SELCN',A3,'FRANCFORT * ANGLE ',
     *        'AUTOUR DE C',A2)
      DC 100 J=1,3
      IF (IRA(J).LE.0) GC TC 100
      NV = NV+1
      IF (NV.LE.9) GO TO 85
      PRINT 6150
 6150 FCRMAT (' PLUS DE 9 VCIES - TERMINE !')
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```
      GC TO 9999
 85   NCA (IRA(J)) = NV
      DC 90 L=1,3
      XPV(L,NV) = XPC(L,I)
 90   C  (NV,L) = RO (L,J)
      ICC(J,I)  = NV
      ICC(4,I) = ICC(4,I) + 1
      IAVC(1,NV)= J
      IAVC(2,NV)= I
 100  CCNTINUE
C-----------------------------------------------------------------------
C   DCNNEES DE L'EXPERIENCE
C-----------------------------------------------------------------------
      PRINT 6160
 6160 FCRMAT (1X,82('='))
      READ (5,3160) TRA, NPT
 3160 FCRMAT (20A4,T1,I5)
      WRITE (6,6170) TRA, NPT
 6170 FCRMAT (' *',20A4,'* NB DE PTS PAR VOIE EN DONNEES =',I5)
C
      READ (5,3160) TRA, NPTM
      PRINT 6180, TRA, NPTM
 6180 FCRMAT (' *',20A4,'* NB DE PTS UTILISES POUR LE CALCUL =',I5)
C
      READ(5,3175) TRA, DELTAT
      IF (DELTAT) 101,102,103
C
 101   NUTAC = 1
      WRITE (6,6190) TRA
 6190 FCRMAT (' *',20A4,'* DELTAT < C IMPLIQUE DCNNEES UTAC')
      GC TO 104
C
 102   NUTAC = 2
      PRINT 6200, TRA
 6200 FCRMAT(' *',20A4,'* DELTAT=0 IMPLIQUE DCNNEES POINTEES, DT=.0002')
      DELTAT = .0002
      GC TC 104
C
 103   WRITE (6,6210) TRA, DELTAT
 6210 FCRMAT (' *',20A4,'* DT ENTRE 2 DCNNEES ACC =',F10.7,' S')
      LBAND = 9
C
 104   READ (5,3170) TRA, NHZ
 3170 FCRMAT (20A4,T1,A4)
      WRITE (6,6220) TRA, NHZ
 6220 FCRMAT (' *',20A4,'* FREQUENCE DE FILTRAGE = ',A4,' HZ')
      IF (NUTAC.EQ.1) GO TC 105
C
      READ (5,3160) TRA, NETS
      PRINT 6230, TRA, NETS
 6230 FCRMAT (' *',20A4,'* NUMERO ENREGIST. TITRE ESSAI =',I5)
C-----------------------------------------------------------------------
C LECTURE DES COORDONNEES DU C.G.,  DES PCSITIONS ET VITESSES INITIALES
C ET CHCIX DU PCINT DE REFERENCE
C-----------------------------------------------------------------------
 105   PRINT 6240
 6240 FCRMAT (1X,82('='),' PCINT DE REFERENCE')
      READ (5,3060) TRA, IREF
      PRINT 6250, TRA, IREF
 6250 FCRMAT (' *',20A4,'*  ',I2)
C
      PRINT 6260
 6260 FCRMAT (1X,82('='),' CCCRD X,Y,Z DU CENTRE DE GRAVITE (EN M)')
      READ(5,3175) TRA, (XGG (I) , I=1,3)
      PRINT 6340, TRA
C
      PRINT 6280
 6280 FCRMAT (1X,82('='),' ANGLES D''EULER INITIAUX (EN DEGRE)')
      READ (5,3175) TRA, (PCSIN(I,1), I=1,3)
      PRINT 6340, TRA
C
      PRINT 6300
 6300 FCRMAT (1X,82('='),' VITESSE ANGULAIRE INITIALE /X,Y,Z (DEG/S)')
      READ (5,3175) TRA, (PCSIN(I,2), I=1,3)
      PRINT 6340, TRA
      DC 140 K = 1,2
      DC 140 I=1,3
 140  PCSIN(I,K) = POSIN(I,K) * DEGRAD
C
      PRINT 6320
 6320 FCRMAT (1X,82('='),' PCSITION (X,Y,Z) INITIALE (EN M)')
      READ (5,3175) TRA, (PCSIN(I,3), I=1,3)
```

```
      PRINT 6340, TRA
C
      PRINT 6330
 6330 FCRMAT (1X,82('='),' VITESSE INITIALE (EN M/S)')
      READ (5,3175) TRA, (PCSIN(I,4), I=1,3)
 3175 FCRMAT(20A4,T1,3F14.7)
      PRINT 6340, TRA
 6340 FCRMAT (' *',20A4,'*')
C-----------------------------------------------------------------------
C LECTURE DES COMMANDES
C-----------------------------------------------------------------------
      READ(5,3180) TRA, IMP
 3180 FCRMAT (20A4,T1,80I1)
      PRINT 6350, TRA, (I,IMP(I),CHCIX(IMP(I)+1),I=1,4),
     *              IMP(5),CHCIX(IMP(5)+3)
      PRINT 6360, (I,IMP(I),CHOIX(IMP(I)+1),I=6,20), IMP(21)
 6350 FCRMAT (1X,82('='),' CCMMANDES DES CALCULS, TRACAGES ET EDITICNS'/
     * ' *',20A4,'* VOIR DETAIL PAGE SUIVANTE'/1X,82('*')/1H1,47('-')/
     * ' = CCMMANDES DES CALCULS, TRACAGES ET EDITIONS ='/1X,47('-')/
     * I3,' *',I2,' = ',A4,'PCUR TR DCNNEES BRUTES'/
     * I3,' *',I2,' = ',A4,'PCUR CALC ET TR RESULTANTES AUX ACCELERCS'/
     * I3,' *',I2,' = ',A4,'PCUR CALC INDICES SEV AUX ACCELEROS'/
     * I3,' *',I2,' = ',A4,'PCUR TR DCNNEES SELON FRANCFORT'/
     * '   5 *',I2,' = ',A4,'PCUR CALCUL VIT ET ACC ANGUL')
 6360 FCRMAT (I3,' *',I2,' = ',A4,'PCUR TR VITESSES ET ACC ANGULAIRES'/
     * I3,' *',I2,' = ',A4,'PCUR TR ACCEL X,Y,Z AU C.D.G.'/
     * I3,' *',I2,' = ',A4,'PCUR TR RESULTANTES AU C.D.G.'/
     * I3,' *',I2,' = ',A4,'PCUR CALC INDICES SEV SUR LES 3 RESULT'/
     * I3,' *',I2,' = ',A4,'PCUR TR ACCEL MCY X,Y,Z'/
     * I3,' *',I2,' = ',A4,'PCUR TR RESULT MCY'/
     * I3,' *',I2,' = ',A4,'PCUR CALC INDICES SEV SUR LA RES MOY'/
     * I3,' *',I2,' = ',A4,'PCUR TRACER ANGLES EULER'/
     * I3,' *',I2,' = ',A4,'PCUR TRACER VITESSES ANGUL'/
     * I3,' *',I2,' = ',A4,'PCUR TRACER ACCEL ANGUL'/
     * I3,' *',I2,' = ',A4,'PCUR TRACER ACCEL LIN'/
     * I3,' *',I2,' = ',A4,'PCUR TRACER VIT LIN'/
     * I3,' *',I2,' = ',A4,'PCUR TRACER PCS LIN'/
     * I3,' *',I2,' = ',A4,'PCUR VISUALISER LA TETE'/
     * I3,' *',I2,' = ',A4,'PCUR IMPRESSICN DES MATRICES'/
     *' 21 *',I2,' =',5X,'NIVEAU D''IMPRESSICN DES INDICES'/1X,47('-')/)
C-----------------------------------------------------------------------
C     IMPRESSICN DE ICC ET IAVC
C-----------------------------------------------------------------------
      PRINT 6370, NV, (J,IAVC(1,J),IAVC(2,J),(NOMCAP(20*IAVC(2,J)-20+K),
     *             K=1,3),(C(J,L),L=1,3),J=1,NV)
 6370 FCRMAT (1H0,I2,' VCIES'/2X,7('-')/(10X,'VCIE',I2,' = VOIE',I2,
     *        ' DU CAPTEUR',I2,' : ',3A4,5X,3F10.6))
C
      PRINT 6380, NCAP, (I,ICC(4,I),(ICC(J,I),J=1,3),I=1,NCAP)
 6380 FCRMAT (1H0,I2,' CAPTEURS'/2X,10('-')/
     * (15X,'LE CAPTEUR',I2,' CCNTIENT',I2,' VCIES :',3I3))
C-----------------------------------------------------------------------
C                       INITIALISATICNS
C-----------------------------------------------------------------------
      NPT  = NPT  + 1
      NPTM = NPTM + 1
      DC 160 I = 1,9
 160  GAMA(I,1) = 0.
      DC 170 I = 1,4
 170  RAM (1,I) = 0.
      NEL = -10
      IF (IMP(1)+IMP(2)+IMP(4)+IMP(5).EG.0) GC TO 180
      IPLOT = 0
      IGO = 0
      CALL TRA001(JBAND,-1,LBUF,IBUF,NEL)
      CALL PCARA (-1.,45.,0,9H9 GAMMA -,9,0.5,0.5,0.,-1.)
      CALL PCARA (0.,-.5,2,TRE(61),80,C.5,0.5,0.,-1.)
      CALL TRAA (0.,0.,0)
C-----------------------------------------------------------------------
C                     LECTURE  DES ACCELERATICNS
C-----------------------------------------------------------------------
 180    IF (NUTAC-1) 190,250,200
C
 190  REWIND LBAND
C
 200  NETS = NETS - 1
      IF (NETS.LE.0) GO TC 220
      DC 210 I=1,NETS
 210  READ (LBAND,3185)
C
 220  DC 230 J=1,100
      READ (LBAND,3185) TRE
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      DC 230 J = 1,80
      DC 225 K = 1,15
      IF (TRE(J).EQ.CARNUM(K)) GO TC 230
 225  CCNTINUE
      GC TO 240
 230  CCNTINUE
C
      FRINT 6390, TRE
 6390 FCRMAT ('OPAS DE CARACTERE NON NUMERIQUE -',
     *        ' DERNIER ENREGISTREMENT TESTE : '/1X,80A1/)
      GO TO 9900
C
 240  I = I + NETS
      WRITE (6,6400) I, TRE
 6400 FCRMAT ('ONUMERO ENREGIST. TITRE ESSAI =',I5/1H0,80A1/)
 250  M = 0
      N = 0
      DC 330 I = 1,NV
 260  N = N + 1
      M = M + 1
      K = NCA (N)
      IF (K.EQ.0) GO TO 260
      L1 = IAVC(1,K)
      L2 = IAVC(2,K)
 270  IF (NUTAC.EQ.1) GO TC 280
      READ (LBAND,3185) TRE
 3185 FCRMAT (80A1)
      READ (LBAND,3190) (GAMA(K,J),J=2,NPT)
 3190 FCRMAT (10F8.0)
      GC TO 320
C
C LECTURE SELCN LE FORMAT 'UTAC'
C
 280  READ (LBAND,6410) TRE, NP, DELTAT, SENS, MIN, MAX
 6410 FCRMAT (80A1,T1,I5,2E15.7,2I7,I2)
      NP = NP + 1
      IF (MIN.LT.-9999.OR.MAX.GT.99999) GC TC 290
      READ (5,6420) (IGAM(J,K), J=2,NP)
 6420 FCRMAT (16I5)
      GC TC 300
 290  READ (5,6430) (IGAM(J,K), J=2,NP)
 6430 FCRMAT (8I9)
 300  DC 310 J = 2,NP
 310  GAMA(K,J) = IGAM(J,K) * SENS
 320  M = M - 1
      NN = N - M
      IF (M.EQ.0) GO TO 322
      PRINT 6440, NN, TRE
 6440 FCRMAT (' RANG',I3,' *',80A1,'* = VCIE SAUTEE')
      GC TC 270
C
C  CN FAIT INTERVENIR LE SIGNE ET LE CCEFF CCRRECTEUR EVENTUEL
C
 322  CC=COEF(L1,L2)
      IF (CC.EQ.0.) CO = 1.
      IF (NS(L1,L2).NE.NPLUS) CC = -CC
      IF (CC.EQ.1.) GO TC 330
      DC 324 J=2,NPTM
 324  GAMA(K,J)=GAMA(K,J) * CC
 330  PRINT 6450,NN,TRE,K,L1, (NOMCAP(20*L2+L-20),L=1,3)
 6450 FCRMAT (' RANG',I3,' *',80A1,'* VCIE',I2,' = ',I2,1X,3A4)
C
 340  ECHDT = (NPT -1) * DELTAT * 100.
      ECHRT = (NPTM-1) * DELTAT * 100.
      DTT = DELTAT
      PRINT 6460, ECHDT, ECHRT
 6460 FCRMAT ('ODUREE DU  CHOC  =',F8.3,' CS'/
     * ' DUREE DU CALCUL =',F8.3,' CS')
C---------------------------------------------------------------------
C   TRACAGE DES DONNEES BRUTES
C---------------------------------------------------------------------
      IF (IMP(1).LE.0) GO TC 550
      NPTS  = NPTM
      DUREE = ECHRT
      DC 540 I=1,NCAP
      DC 530 J=1,3
 530  IT14 (5+J) = NOMCAP (20*I+J-20)
      CALL TRC9G8 (IT14,LCX,IT10,0,ICC(1,I),GAMA(ICC(1,I),1),
     *             GAMA(ICC(2,I),1),GAMA(ICC(3,I),1),9,1.)
 540  CALL TICOU8 (ICC(1,I),0,0,1,LCY,LCZ)
C---------------------------------------------------------------------
C  CALCUL ET TRACAGE DES ACCELERATICNS RESULTANTES ET DES INDICES
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```
C      EN CHACUN DES ACCELERCMETRES
C-----------------------------------------------------------------------------
 550   NPTS  = NPTM
       DUREE = ECHRT
       IF (IMP(2)+IMP(3) .EG. C) GO TC 580
       IT = 1
       IE = 0
       DC 551 K=1,3
 551   IPV(K) = 0
       DC 570 I = 1,NCAP
       IE = IE+1
       IPV(IE) = 1
       IF ((IMP(2).EQ.0).CR.(IMP(3).EG.1)) GC TO 567
       DC 555  J=1,NPTM
 555   RAM(J,I) = 0.
       DC 560 K=1,3
       I1 = ICC(K,I)
       IF (I1.EQ.0) GO TO 560
       DC 560 J=1,NPTM
       RAM(J,IE) = RAM(J,IE) + GAMA(I1,J) * GAMA(I1,J)
 560   CCNTINUE
       DC 565 J=1,NPTM
 565   RAM(J,IE) = SQRT(RAM(J,IE))
 567   PRINT 6470, I, (NOMCAP(20*I-20+J),J=1,3)
 6470 FCRMAT (1H1,34X,64(1H+)/35X,'+ CALCULS D''INDICES SUR ',
     * 'L''ACCELEROMETRE NUMERO',I2,' = ',3A4,'+'/35X,64(1H+)/)
       CALL SIHIC9 (ICC(1,I),GAMA(ICC(1,I),1),GAMA(ICC(2,I),1),
     * GAMA(ICC(3,I),1), 9, RAM(1,IE), NPTM, DELTAT, IMP(21), A, 1., 1)
       IF ((IMP(2).EQ.0).OR.(IE.LT.3.AND.I.LT.NCAP)) GO TC 570
       CALL TRC9G8 (IT13,NOMCAP(IT),IT1C,
     *               IMP(3),IPV,RAM1,RAM2,RAM3,1,1.)
       CALL TICOU8 (IPV,-19,1,C,NOMCAP(IT+20),NOMCAP(IT+40))
       IT = IT + 60
       IE = 0
       DC 570 K=1,3
       IPV(K) = 0
 570   CCNTINUE
C-----------------------------------------------------------------------------
C  CHANGEMENT D'UNITE DE G (EN M/S2) DANS GAMA, CORRECTIONS D'ETALONNAGE
C-----------------------------------------------------------------------------
 580   DC 600 I = 1,NCAP
       DC 600 K=1,3
       L = ICC(K,I)
       IF (L.EG.0) GO TO 600
       DC 590 J = 1,NPTM
 590   GAMA(L,J) =  GAMA(L,J) * GE
 600   CCNTINUE
C
       IF (IMP(20).GT.0) PRINT 6480, ((C(J,I),I=1,3),J=1,NV)
 6480 FCRMAT ('OMATRICES DE CCSINUS DIRECTEURS'/(10X,3F10.7))
C-----------------------------------------------------------------------------
C  TRACAGE DES ACCELERATICNS CORRIGEES
C-----------------------------------------------------------------------------
       IF (IMP(4).LE.0) GO TC 710
       DC 620 I = 1,3
 620   IPV(I) = 0
       IT = 1
       DC 630 I = 1,NCAP
       IF (ICC(4,I).NE.3) GC TC 630
       K = ICC(1,I)
       CALL TRANSP (C(K,1),RC,3,3,9,3)
       CALL PRODMT (RO,GAMA(K,1),POSIT(3*IT-2,1),3,3,NPTM,3,9,9)
       IPV(IT) = I
       IT = IT + 1
       IF (IT.GT.3) GO TO 640
 630   CCNTINUE
C
 640   DC 700 K = 1,3
       CALL TRC9G8 (ITA(1,K),NCMCAP(20*IPV(1)-19),IT10,
     *              0,IPV,PCSIT(K,1),PCSIT(K+3,1),PCSIT(K+6,1),9,GE)
 700   CALL TICOU8(IPV,-15,1,C,NOMCAP(20*IPV(2)-19),NOMCAP(20*IPV(3)-19))
C
 710   IF (IMP(5).LE.0) GO TC 1110
C-----------------------------------------------------------------------------
C  CALCUL DES ACCELERATICNS ANGULAIRES ET DES VITESSES ANGULAIRES
C-----------------------------------------------------------------------------
       CALL SCAL8 (IMP(5),IMP(20),PCSIN(1,2),IREF)
C-----------------------------------------------------------------------------
C   TRACAGE DES VALEURS DE VITESSE ANGULAIRE ET D'ACCELERATION ANGULAIRE
C-----------------------------------------------------------------------------
       IF (IMP(21).LE.0) GO TC 720
       CALL SIHIC9 (IPV3,ALPH(1,1),ALPH(2,1),ALPH(3,1),
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     *                  9, RAM1, NPTM, DELTAT, IMP(21), A, 1., 3)
      CALL SIHIC9 (IPV3,ALPH(4,1),ALPH(5,1),ALPH(6,1),
     *                  9, RAM1, NPTM, DELTAT, IMP(21), A, 1., 2)
  720 IF(IMP(6).LE.0) GO TO 730
      CALL TRC9G8 (IT4,LLONG,IT11,
     *                  0,IPV3,ALPH(1,1),ALPH(2,1),ALPH(3,1),9,1.)
      CALL TICOU8 (IPV3,19,2,0,LTRAN,LVERT)
      CALL TRC9G8 (IT5,LLONG,IT12,
     *                  0,IPV3,ALPH(4,1),ALPH(5,1),ALPH(6,1),9,1.)
      CALL TICOU8 (IPV3,24,2,0,LTRAN,LVERT)
C-----------------------------------------------------------------------
C SELECTION DE 3 COMBINAISONS DE VOIES
C-----------------------------------------------------------------------
  730 IF (IMP(7)+IMP(8)+IMP(9).EQ.0) GO TO 890
      IE = 1
      DO 735 I=1,NCAP
      IF (ICC(4,I).NE.3) GO TO 735
      DO 732 K=1,3
  732 ICG(K,IE) = ICC(K,I)
      IF (IMP(20).GT.0) PRINT 6490, IE, (ICG(K,IE),K=1,3)
      IE = IE+1
      IF (IE.GT.3) GO TO 760
  735 CONTINUE
      DO 750 I=1,NCAP
      IF (ICC(4,I).NE.2) GO TO 750
      DO 742 K=1,3
      L = ICC(K,I)
      IF (L.EQ.0) GO TO 740
      ICG(K,IE) = L
      CALL TRANSP (C(L,1),RO(1,K),1,3,9,3)
      GO TO 742
  740 M = K
  742 CONTINUE
      DO 745 J=1,NV
      CALL TRANSP (C(J,1),RO(1,M),1,3,9,3)
      CALL PRDVEC (RO,RO(1,2),RO(1,4))
      PS = ABS(PRSCAL(RO(1,3),RO(1,4)))
      IF (PS.LE.PM.AND.J.GT.1) GO TO 745
      PM = PS
      ICG(M,IE) = J
  745 CONTINUE
      IF (IMP(20).GT.0) PRINT 6490, IE, (ICG(K,IE),K=1,3)
 6490 FORMAT (' SELECTION',I2,' = VOIES',3I2)
      IE = IE + 1
      IF (IE.GT.3) GO TO 760
  750 CONTINUE
      IF (IE.GT.2) GO TO 760
      PRINT 6500
 6500 FORMAT (' MOINS DE DEUX CAPTEURS TRI OU BI AXES')
      GO TO 890
C-----------------------------------------------------------------------
C     CALCULS  ACCELERATION AU C.D.G. D'APRES LES 3 COMBINAISONS
C     DE VOIES
C-----------------------------------------------------------------------
  760 IE = IE - 1
      DO 770 I = 1,IE
      DO 770 K=1,3
      SELVOI(6+K,I) = CHIF(ICG(K,I))
      DO 770 J=1,3
  770 DX(J,3*I+K-3) = XGG(J) - XPV(J,ICG(K,I))
      DO 800 J = 1,NPTM
      CALL MATPRV (RO1,3,ALPH(1,J),ALPH(2,J),ALPH(3,J))
      CALL PRODMT (RO1,RO1,RO2,3,3,3,3,3,3)
      CALL MATPRV (RO1,3,ALPH(4,J),ALPH(5,J),ALPH(6,J))
      DO 780 I = 1,3
      DO 780 K = 1,3
  780 ANG(K,I) = RO2(K,I) + RO1(K,I)
      CALL PRODMT (ANG,DX,RO,3,3,9,3,3,3)
      DO 800 I = 1,IE
      I3 = 3*I-3
      DO 790 K = 1,3
      L = ICG(K,I)
      TRE(K) = GAMA(L,J)
      DO 790 M=1,3
      TRE(K) = TRE(K) + RO(M,I3+K) * C(L,M)
  790 AE(K,M) = C(L,M)
      CALL INVMA3(AE,B)
      CALL PRODMT(B,TRE,TRE(4),3,3,1,3,1,1)
  800 CALL TRANSP(TRE(4),GAM(J,I3+1),3,1,1,2001)
C-----------------------------------------------------------------------
C   TRACAGE DES ACCELERATIONS X,Y,Z AU CG
C-----------------------------------------------------------------------
```

```
      IF(IMP(7).LE.0) GO TO 850
      DO 830 I = 1,3
      IPV(I) = 0
  830 IF (I.LE.IE) IPV(I) = 1
      DO 840 I = 1,3
      CALL TRC9G8 (ITP(1,I),SELVOI(1,1),IT10,
     *   0,IPV,GAM(1,I),GAM(1,I+3),GAM(1,I+6),1,GE)
  840 CALL TICOU8 (IPV,22,1,0,SELVOI(1,2),SELVOI(1,3))
C-------------------------------------------------------------------------------
C   TRACAGE DE LA RESULTANTE DE L ACCELERATION EN CG
C-------------------------------------------------------------------------------
  850 IF (IMP(8)+IMP(9).EQ.0) GO TO 890
      IF (IMP(8).EQ.0.OR.IMP(9).EQ.1) GO TO 860
      DO 855 I=1,IE
      M = 3*I
      L = M-1
      K = L-1
      DO 855 J=1,NPTM
  855 RAM(J,I) = SQRT (GAM(J,K)*GAM(J,K)+GAM(J,L)*GAM(J,L)
     *                + GAM(J,M)*GAM(J,M))/ GE
      GO TO 875
  860 DO 870 I=1,IE
      PRINT 6510, I, (NOMCAP(20*I-20+J),J=1,3)
 6510 FORMAT (1H1,28X,76(1H*)/29X,'* CALCULS D''INDICES AU C.G. D''A',
     * 'PRES L''ACCELEROMETRE NUMERO',I2,' = ',3A4,'*'/29X,76(1H*)/)
  870 CALL SIHIC9 (IPV3,GAM(1,3*I-2),GAM(1,3*I-1),GAM(1,3*I),1,RAM(1,I),
     *            NPTM, DELTAT, IMP(21), A, GE, 1)
  875 IF (IMP(8).EQ.0) GO TO 890
  880 CALL TRC9G8 (IT8,SELVOI(1,1),IT10,
     *            IMP(9),IPV,RAM1,RAM2,RAM3,1,1.)
      CALL TICOU8 (IPV,24,2,1,SELVOI(1,2),SELVOI(1,3))
  890 DO 895 J=1,3
  895 DX(J,1) = XGO(J)-XO(J)
      DO 905 J=1,NPTM
      CALL MATPRV (RO1,3,ALPH(1,J),ALPH(2,J),ALPH(3,J))
      CALL PRODMT (RO1,RO1,RO2,3,3,3,3,3,3)
      CALL MATPRV (RO1,3,ALPH(4,J),ALPH(5,J),ALPH(6,J))
      DO 900 I = 1,3
      DO 900 K = 1,3
  900 ANG(K,I) = RO2(K,I) + RO1(K,I)
      CALL PRODMT (ANG,DX,TRE,3,3,1,3,1,1)
      DO 905 I = 7,9
  905 ALPH(I,J) = ALPH(I,J) + TRE(I-6)
C-------------------------------------------------------------------------------
C   TRACAGE DES ACCELERATIONS X,Y,Z AU CG
C          D'APRES LE POINT DE REFERENCE
C-------------------------------------------------------------------------------
      IF(IMP(10).LE.0) GO TO 910
      CALL TRC9G8 (IT6,LLONG,IT10,0,IPV3,
     *            ALPH(7,1),ALPH(8,1),ALPH(9,1),9,GE)
      CALL TICOU8 (IPV3,22,3,0,LTRAN,LVERT)
C-------------------------------------------------------------------------------
C     CALCUL INDICES ET TRACAGE ACCELERATION AU C.D.G. D'APRES LE
C        POINT DE REFERENCE
C-------------------------------------------------------------------------------
  910 IF (IMP(11)+IMP(12).EQ.0) GO TO 980
      IF ((IMP(11).EQ.0).OR.(IMP(12).EQ.1)) GO TO 930
      DO 920 J=1,NPTM
  920 RAM4 (J)  = SQRT (ALPH(7,J)*ALPH(7,J)+ALPH(8,J)*ALPH(8,J)+
     *                  ALPH(9,J)*ALPH(9,J))/ GE
      GO TO 960
  930 PRINT 6520
 6520 FORMAT (1H1,37X,59(1H*)/38X,'* CALCULS D''INDICES AU C.G. D''A',
     * 'PRES LE POINT DE REFERENCE *'/38X,59(1H*)/)
      CALL SIHIC9 (IPV3,ALPH(7,1),ALPH(8,1),ALPH(9,1),9,RAM4, NPTM,
     *            DELTAT, IMP(21), A, GE, 1)
C-------------------------------------------------------------------------------
C     TRACAGE DE LA RESULTANTE AU CG
C     COURBE MOYENNE
C-------------------------------------------------------------------------------
  960 IF(IMP(11).LE.0) GO TO 980
      CALL TRC9G8 (IT9,LPLAN,IT10,
     *            IMP(12),IPV1,RAM4,A,A,1,1.)
C-------------------------------------------------------------------------------
C                     CALCUL DES ANGLES D'EULER
C-------------------------------------------------------------------------------
  980 IF (IMP(13)+IMP(14)+IMP(15)+IMP(16)+IMP(17)+IMP(18)+IMP(19).EQ.0)
     * GO TO 1110
      CALL INTEG7 (1,EULER,EULER,PCSIN)
C-------------------------------------------------------------------------------
C                     TRACAGE DES ANGLES D'EULER
C-------------------------------------------------------------------------------
```

```
      IF (IMP(13).EQ.0) GO TO 1000
      CALL TRC9G8 (IT19,LROTZ,IT16,
     *             0,IPV3,ANGLE(1,1),ANGLE(2,1),ANGLE(3,1),9,DEGRAD)
      CALL TICOU8 (IPV3,0,0,1,LROTY,LROTX)
C-----------------------------------------------------------------------
C      REMPLISSAGE DE LA MATRICE D'EULER
C-----------------------------------------------------------------------
 1000 DO 1010 J=1,NPTM
 1010 CALL MEULER (ANGLE(1,J),3,ANGLE(2,J),2,ANGLE(3,J),1,
     *             PEUL(1,1,J),TRE)
C-----------------------------------------------------------------------
C        CALCUL DANS LE REPERE LABORATOIRE
C            DE LA VITESSE ANGULAIRE
C            DE L'ACCELERATION ANGULAIRE
C-----------------------------------------------------------------------
      DO 1020 J=1,NPTM
      DO 1020 I=1,4,3
 1020 CALL PRODMT (PEUL(1,1,J),ALPH(I,J),ANGLE(I+3,J),3,3,1,3,9,9)
C-----------------------------------------------------------------------
C         TRACAGE DE LA VITESSE ANGULAIRE / LABO
C-----------------------------------------------------------------------
      IF (IMP(14).EQ.0) GO TO 1030
      CALL TRC9G8 (IT20,LX,IT11,
     *             0,IPV3,ANGLE(4,1),ANGLE(5,1),ANGLE(6,1),9,1.)
      CALL TICOU8 (IPV3,0,0,1,LY,LZ)
C-----------------------------------------------------------------------
C         TRACAGE DE L'ACCELERATION ANGULAIRE / LABO
C-----------------------------------------------------------------------
 1030 IF(IMP(15).EQ.0) GO TO 1040
      CALL TRC9G8 (IT21,LX,IT12,
     *             0,IPV3,ANGLE(7,1),ANGLE(8,1),ANGLE(9,1),9,1.)
      CALL TICOU8 (IPV3,0,0,1,LY,LZ)
C-----------------------------------------------------------------------
C        CALCUL DANS LE REPERE LABORATOIRE
C            DE L'ACCELERATION LINEAIRE
C            DE LA VITESSE LINEAIRE
C            DE LA POSITION DU CDG
C-----------------------------------------------------------------------
 1040 IF (IMP(16)+IMP(17)+IMP(18)+IMP(19).EQ.0) GO TO 1110
      DO 1050 J=1,NPTM
 1050 CALL PRODMT (PEUL(1,1,J),ALPH(7,J),POSIT(7,J),3,3,1,3,9,9)
      IF (IMP(17)+IMP(18)+IMP(19).EQ.0) GO TO 1080
      DO 1060 I=1,3
      POSIT(I,1) = POSIN(I,3)
 1060 POSIT(I+3,1) = POSIN(I,4)
      DT = DELTAT/2.
      DO 1070 I=1,3
      K = I+3
      L = K+3
      DO 1070 J=2,NPTM
      M = J-1
      POSIT(K,J) = POSIT(K,M) + DT * (POSIT(L,M)+POSIT(L,J))
 1070 POSIT(I,J) = POSIT(I,M) + DELTAT * (POSIT(K,M)+
     *             DELTAT*(2*POSIT(L,M)+POSIT(L,J))/6.)
C-----------------------------------------------------------------------
C     TRACAGE DE L'ACCELERATION LINEAIRE / LABO
C-----------------------------------------------------------------------
 1080 IF(IMP(16).EQ.0) GO TO 1090
      CALL TRC9G8 (IT22,LX,IT10,
     *             0,IPV3,POSIT(7,1),POSIT(8,1),POSIT(9,1),9,GE)
      CALL TICOU8 (IPV3,0,0,1,LY,LZ)
C-----------------------------------------------------------------------
C     TRACAGE DE LA VITESSE LINEAIRE / LABO
C-----------------------------------------------------------------------
 1090 IF(IMP(17).EQ.0) GO TO 1100
      CALL TRC9G8 (IT23,LX,IT17,
     *             0,IPV3,POSIT(4,1),POSIT(5,1),POSIT(6,1),9,.001)
      CALL TICOU8 (IPV3,0,0,1,LY,LZ)
C-----------------------------------------------------------------------
C     TRACAGE DE LA POSITION DU CDG / LABO
C-----------------------------------------------------------------------
 1100 IF (IMP(18).EQ.0) GO TO 1110
      CALL TRC9G8 (IT24,LX,IT18,
     *             0,IPV3,POSIT(1,1),POSIT(2,1),POSIT(3,1),9,.001)
      CALL TICOU8 (IPV3,17,3,0,LY,LZ)
C-----------------------------------------------------------------------
C   VISUALISATION DE LA TETE
C-----------------------------------------------------------------------
 1110 IF (NBL.LT.0) GO TO 9999
      CALL TRAA (15.,-85.,2)
      CALL TRAA (0.,2.6,2)
      IF (IMP(19).GT.0) CALL TRATET
```

```
9900 IF (NBL.GT.0) CALL TRA001 (JBAND,1,LBUF,IBUF,NBL)
9999 STOP
     END
```

```
// EXEC PROC=COMPIL,NOM=CAP7
//COMP.SYSIN DD *
      SUBROUTINE CAP7 (NSUPCA,IMP)
      COMMON /ANAT/ XP(3,9), XO(3), DX(3,9), XGO(3), C(9,3), NV,
     *          RO1(3,3), RO2(3,3), RO3(3,3), ANG(3,3), R69(6,9), TRE(80)
      DIMENSION      RO(3,9)
      EQUIVALENCE    (RO,RO1)
C-----------------------------------------------------------------------
C     EMPLISSAGE DES MATRICES 'RO' DE COSINUS DIRECTEURS DES VOIES
C     PERMETTANT DE CORRIGER LES ANGLES DES CAPTEURS
C  09-11-81       NOUVEL ORDRE DES ANGLES D'EULER
C                 NOUVELLE CLASSIFICATION DES INDICES NSUPCA
C     NSUPCA = 1 : UTILISE LES ANGLES D'EULER SUIVANT ZYX
C     NSUPCA = 2 : UTILISE LES ANGLES PROJETES
C     NSUPCA = 3 : TOUTES LES COMPOSANTES SONT DEFINIES
C     NSUPCA = 4 : SUPPORT ETOILE SANS LES ANGLES
C     NSUPCA = 5 : SUPPORT ETOILE
C
C     UTILISATION 9 GAMMA VOIE PAR VOIE
C-----------------------------------------------------------------------
      R3 = SQRT(3.)
      GO TO (650,700,720,582,600), NSUPCA
C-----------------------------------------------------------------------
C CAS NSUPCA=4 : ON DONNE LES 3 COORD APPROXIM X,Y,Z DES 3 CAPTEURS,
C                MAIS PAS LES ANGLES
C-----------------------------------------------------------------------
C COORDONNEES CENTROIDE, MISES EN XO
 582  DO 584 I = 1,3
 584  XO (I) = (XP(I,1)+XP(I,4)+XP(I,7)) / 3.
C VECTEUR U1, DIRIGE DU CENTROIDE VERS LE CAPTEUR 1, MIS EN DX(1)
      DO 586 I = 1,3
 586  DX(I,1) = XP(I,1) - XO(I)
      CALL NRMVEC (DX)
C VECTEUR CAPT3 --> CAPT2, MIS EN DX(4)
      DO 588 I = 1,3
 588  DX(I,4) = XP(I,4) - XP(I,7)
C VECT K, PERP AU PLAN 1-2-3, MIS EN TRE
      CALL PRDVEC (DX,DX(1,4),TRE)
      CALL NRMVEC (TRE)
C VECT U2, U3, DIRIGES DU CENTROIDE VERS LES CAPTEURS 2 ET 3
      CALL PRDVEC (TRE,DX,DX(1,4))
      DO 590 I = 1,3
      DX (I,7) = -.5 * (DX(I,1) + DX(I,4) * R3)
 590  DX (I,4) = -.5 * (DX(I,1) - DX(I,4) * R3)
C      POSITIONS CORRIGEES DES 3 CAPTEURS
      DO 592 K = 1,3
      DO 592 I = 1,3
 592  XP (I,3*K-2) = XO (I) + .054 * DX (I,3*K-2)
C      VECTEURS I DES 3 CAPTEURS
      DO 594 K = 1,3
 594  CALL PRDVEC (TRE,DX(1,3*K-2),RO(1,3*K-2))
C      VECTEURS J DES 3 CAPTEURS
      DO 596 K = 1,3
      DO 596 I = 1,3
 596  RO (I,3*K-1) = .5 * (TRE(I) - R3 * DX(I,3*K-2))
C      VECTEURS K DES 3 CAPTEURS
      DO 598 K = 1,3
 598  CALL PRDVEC (RO(1,3*K-2),RO(1,3*K-1),RO(1,3*K))
      GO TO 615
C-----------------------------------------------------------------------
C CAS NSUPCA=5 : ON DONNE LES 3 COORD XYZ DU CAPTEUR 1 ET 3 ANGLES , QUI
C SONT DES RESULTATS DIRECTS DE MESURE, CONTRAIREMENT AUX ANGLES D'EULER
C A1 = (OY, PROJ AXE CAPT2-->CAPT3 DANS XOY) VU DE DESSUS
C A2 = (OZ, PROJ J1 DANS XOZ) VU DE DROITE
C A3 = (OZ, PROJ J1 DANS YOZ) VU DE L'ARRIERE
C-----------------------------------------------------------------------
C VECTEUR J1, MIS EN RO1(,2)
 600  RO1 (1,2) = -TAN (ANG(2,1))
      RO1 (2,2) =  TAN (ANG(3,1))
      RO1 (3,2) =  1.
      CALL NRMVEC (RO1(1,2))
C VECT PERP AU PLAN (C2C3,OZ)
      RO1 (1,3) = -COS (ANG(1,1))
      RO1 (2,3) = -SIN (ANG(1,1))
      RO1 (3,3) =  0.
C      VECT I1, MIS EN RO1(,1)
      CALL PRDVEC (RO1(1,2),RO1(1,3),RO1)
      CALL NRMVEC (RO1)
C VECT K1
      CALL PRDVEC (RO1,RO1(1,2),RO1(1,3))
C VECTEURS UNITAIRES, CENTROIDE --> CAPTEURS 1,2,3
      DO 604 I = 1,3
```

```
      DX(I,1) = .5 * (RO1(I,3) - R3 * RO1(I,2))
      DX(I,4) =  .5 * (RO1(I,1)*R3 - DX(I,1))
 604  DX(I,7) = -.5 * (RO1(I,1)*R3 + DX(I,1))
C POSITION DES CAPT 2 ET 3
      DO 606 K = 2,3
      DO 606 I = 1,3
 606  XP(I,3*K-2) = XP(I,1) + .054 * (DX(I,3*K-2)-DX(I,1))
C VECT PERP AU PLAN 1-2-3
      CALL PRDVEC (DX,RO1,XO)
C VECTEURS I,J,K DES CAPTEURS 2 ET 3
      DO 610 K = 2,3
      CALL PRDVEC (XO,DX(1,3*K-2),RO(1,3*K-2))
      DO 610 I = 1,3
      RO (I,3*K-1) = .5 * (XO(I)-R3*DX(I,3*K-2))
 610  RO (I,3*K  ) = .5 * (XO(I)*R3+DX(I,3*K-2))
 615  IF (IMP.GT.0) PRINT 6261, ((XP(I,3*K-2),K=1,7,3),I=1,3)
 6261 FORMAT ('OPOSITIONS (RE)CALCULEES DES CAPTEURS'/' EN X :',3F12.7/
     * ' EN Y :',3F12.7/' EN Z :',3F12.7/)
      GO TO 720
C-----------------------------------------------------------------------
C CAS NSUPCA=1 : LES POSITIONS DES CAPTEURS NE SONT PAS MODIFIEES,
C                LES COMPOSANTES SCALAIRES DES VOIES SONT CALCULEES
C                D'APRES LES ANGLES D'EULER DES CAPTEURS
C-----------------------------------------------------------------------
 650  DO 690 K = 1,3
 690  CALL MEULER (ANG(1,K),3,ANG(2,K),2,ANG(3,K),1,RO(1,3*K-2),IRE)
      GO TO 720
C-----------------------------------------------------------------------
C CAS NSUPCA=2 : ON DONNE LES POSITIONS DES CAPTEURS QUI NE SERONT
C                PAS MODIFIEES - ON DONNE DES ANGLES PROJETES :
C
C     A1 = (OY, J DU CAPTEUR) VU DE DESSUS   (ROT OZ)
C     A2 = (OZ, K DU CAPTEUR) VU DE GAUCHE   (ROT OY)
C     A3 = (OZ, K DU CAPTEUR) VU DE DOS      (ROT OX)
C-----------------------------------------------------------------------
 700  DO 710 I=1,3
      I3 = 3*I
      I2 = I3 - 1
      I1 = I2 - 1
C...RECHERCHE DU VECTEUR K MIS DANS RO( ,I3)............................
      RO(1,I3) = -TAN(ANG(2,I))
      RO(2,I3) =  TAN(ANG(3,I))
      RO(3,I3) =  1.
      CALL NRMVEC (RO(1,I3))
C...RECHERCHE DU VECTEUR ORTHOGONAL AU PLAN (J,OZ), MIS DANS RO( ,I1)...
      RO(1,I1) = COS(ANG(1,I1))
      RO(2,I1) = SIN(ANG(1,I1))
      RO(3,I1) = 0.
C...RECHERCHE DU VECTEUR J MIS DANS RO( ,I2)............................
      CALL PRDVEC (RO(1,I3),RO(1,I1),RO(1,I2))
      CALL NRMVEC (RO(1,I2))
C...RECHERCHE DU VECTEUR I MIS DANS RO( ,I1)............................
 710  CALL PRDVEC (RO(1,I2),RO(1,I3),RO(1,I1))
C-----------------------------------------------------------------------
C CAS NSUPCA=3 : ON DONNE AVEC PRECISION LES POSITIONS DES CAPTEURS,
C                ET TOUTES LES COMPOSANTES DES VOIES
C-----------------------------------------------------------------------
 720  DO 730 I=1,3
      DO 730 K=1,7,3
      DO 730 J=1,2
 730  XP(I,K+J) = XP(I,K)
      CALL TRANSP(RO,C,3,9,3,9)
      RETURN
      END
```

```
      SUBROUTINE CAPISO (NSUPCA, ANG, RO)
      DIMENSION  ANG(3), RO(3,3), TRE(80)
C-----------------------------------------------------------------------
C     CAPISO REMPLIT LA MATRICE DES COSINUS DIRECTEURS POUR UN
C     CAPTEUR ISOLE - APPELE PAR PREPSG - GIRON - 24-12-1981
C-----------------------------------------------------------------------
      IF (NSUPCA.EQ.1) GO TO 10
C-----------------------------------------------------------------------
C CAS NSUPCA=2 : LES POSITIONS DES CAPTEURS NE SONT PAS MODIFIEES,
C                LES COMPOSANTES SCALAIRES DES VOIES SONT CALCULEES
C                D'APRES LES ANGLES D'EULER DES CAPTEURS
C-----------------------------------------------------------------------
      CALL MEULER (ANG(1),3,ANG(2),2,ANG(3),1,RO(1,1),TRE)
      ANG(1) = ATAN2(-RO(1,2),RO(2,2))
      ANG(2) = ATAN2( RO(1,3),RO(3,3))
      ANG(3) = ATAN2(-RO(2,3),RO(3,3))
      GO TO 9999
C-----------------------------------------------------------------------
C CAS NSUPCA=1 : ON DONNE LES POSITIONS DES CAPTEURS QUI NE SERONT
C                PAS MODIFIEES - ON DONNE DES ANGLES PROJETES :
C
C    A1 = (OY, J DU CAPTEUR) VU DE DESSUS   (ROT OZ)
C    A2 = (OZ, K DU CAPTEUR) VU DE GAUCHE   (ROT OY)
C    A3 = (OZ, K DU CAPTEUR) VU DE FACE     (ROT OX)
C-----------------------------------------------------------------------
C   RECHERCHE DU VECTEUR K MIS DANS RO( ,3)
C
 10   RO(1,3) =  TAN(ANG(2))
      RO(2,3) = -TAN(ANG(3))
      RO(3,3) =  1.
      CALL NRMVEC (RO(1,3))
C
C   RECHERCHE DU VECTEUR ORTHOGONAL AU PLAN (J,OZ), MIS DANS RO( ,1)
C
      RO(1,1) = COS(ANG(1))
      RO(2,1) = SIN(ANG(1))
      RO(3,1) = 0.
C
C   RECHERCHE DU VECTEUR J MIS DANS RO( ,2)
C
      CALL PRDVEC (RO(1,3),RO(1,1),RO(1,2))
      CALL NRMVEC (RO(1,2))
C
C   RECHERCHE DU VECTEUR I MIS DANS RO( ,1)
C
      CALL PRDVEC (RO(1,2),RO(1,3),RO(1,1))
C
 9999 RETURN
      END
```

```
      SUBROUTINE ETOILE (NSUPCA, RO, ANG, XP)
      DIMENSION XP(3,3), XO(3), DX(3,3), RO(3,9), ANG(3,3), TRE(80)
C-----------------------------------------------------------------------
C  SOUS-PROGRAMME PERMETTANT DE REMPLIR LES MATRICES DE COSINUS
C  DIRECTEURS POUR LE MONTAGE ETOILE
C                                          PREP9G 14-06-83
C-----------------------------------------------------------------------
      R3 = SQRT(3.)
      GOTO (90,85,5), NSUPCA
C-----------------------------------------------------------------------
C CAS NSUPCA=3 : ON DONNE LES 3 COORD APPROXIM X,Y,Z DES 3 CAPTEURS,
C                MAIS PAS LES ANGLES
C-----------------------------------------------------------------------
C COORDONNEES CENTROIDE, MISES EN XO
 5    DO 10 I = 1,3
 10   XO(I) = (XP(I,1)+XP(I,2)+XP(I,3)) / 3.
C VECTEUR U1, DIRIGE DU CENTROIDE VERS LE CAPTEUR 1, MIS EN DX(1)
      DO 20 I = 1,3
 20   DX(I,1) = XP(I,1) - XO(I)
      CALL NRMVEC (DX)
C VECTEUR CAPT3 --> CAPT2, MIS EN DX(2)
      DO 30 I = 1,3
 30   DX(I,2) = XP(I,2) - XP(I,3)
C VECT K, PERP AU PLAN 1-2-3, MIS EN TRE
      CALL PRDVEC (DX,DX(1,2),TRE)
      CALL NRMVEC (TRE)
C VECT U2, U3, DIRIGES DU CENTROIDE VERS LES CAPTEURS 2 ET 3
      CALL PRDVEC (TRE,DX,DX(1,2))
      DO 40 I = 1,3
      DX (I,3) = -.5 * (DX(I,1) + DX(I,2) * R3)
 40   DX (I,2) = -.5 * (DX(I,1) - DX(I,2) * R3)
C POSITIONS CORRIGEES DES 3 CAPTEURS
      DO 50 K = 1,3
      DO 50 I = 1,3
 50   XP (I,K) = XO(I) + .054 * DX (I,K)
C VECTEURS J DES 3 CAPTEURS
      DO 60 K = 1,3
 60   CALL PRDVEC (DX(1,K),TRE,RO(1,3*K-1))
C VECTEURS K DES 3 CAPTEURS
      DO 70 K = 1,3
      DO 70 I = 1,3
 70   RO (I,3*K) = .5 * (TRE(I) - R3 * DX(I,K))
C VECTEURS I DES 3 CAPTEURS
      DO 80 K = 1,3
 80   CALL PRDVEC (RO(1,3*K-1),RO(1,3*K),RO(1,3*K-2))
      GO TO 120
C-----------------------------------------------------------------------
C CAS NSUPCA=2 : ON DONNE LES 3 COORD XYZ DU CAPTEUR 1 ET 3 ANGLES
C                D'EULER AUTOUR DE Z,Y,X
C-----------------------------------------------------------------------
 85   CALL MEULER (ANG(1,1),3,ANG(2,1),2,ANG(3,1),1,RO,TRE)
      GO TO 95
C-----------------------------------------------------------------------
C CAS NSUPCA=1 : ON DONNE LES 3 COORD XYZ DU CAPTEUR 1 ET 3 ANGLES , QUI
C SONT DES RESULTATS DIRECTS DE MESURE, CONTRAIREMENT AUX ANGLES D'EULER
C A1 = (OY, PROJ AXE CAPT2-->CAPT3 DANS XOY) VU DE DESSUS
C A2 = (OZ, PROJ K DANS XOZ) VU DE GAUCHE
C A3 = (OZ. PROJ K DANS YOZ) VU DE FACE
C-----------------------------------------------------------------------
C VECTEUR K1, MIS EN RO(,3)
 90   RO (1,3) = TAN (ANG(2,1))
      RO (2,3) = -TAN (ANG(3,1))
      RO (3,3) =  1.
      CALL NRMVEC (RO(1,3))
C VECT PERP AU PLAN (C2C3,OZ)
      RO (1,1) = COS (ANG(1,1))
      RO (2,1) = SIN (ANG(1,1))
      RO (3,1) =  0.
C VECT J1, MIS EN RO(,2)
      CALL PRDVEC (RO(1,3),RO,RO(1,2))
      CALL NRMVEC (RO(1,2))
C VECT I1
      CALL PRDVEC (RO(1,2),RO(1,3),RO)
C VECTEURS UNITAIRES, CENTROIDE --> CAPTEURS 1,2,3
 95   DO 100 I = 1,3
      DX(I,1) = -.5 * (RO(I,1) + R3 * RO(I,3))
      DX(I,2) = -.5 * (RO(I,2) * R3 + DX(I,1))
 100  DX(I,3) =  .5 * (RO(I,2) * R3 - DX(I,1))
C POSITION DES CAPT 2 ET 3
      DO 110 K = 2,3
      DO 110 I = 1,3
 110  XP(I,K) = XP(I,1) + .054 * (DX(I,K)-DX(I,1))
```

```
C VECT PERP AU PLAN 1-2-3
      CALL PRDVEC (RO(1,2),DX,XO)
C VECTEURS I,J,K DES CAPTEURS 2 ET 3
      DO 130 K = 2,3
      CALL PRDVEC (DX(1,K),XO,RO(1,3*K-1))
      DO 130 I = 1,3
      RO (I,3*K) = .5 * (XO(I)-R3*DX(I,K))
 130  RO (I,3*K-2) = -.5 * (XO(I)*R3+DX(I,K))
 120  TYPE 140, ((XP(I,K),K=1,3),I=1,3)
 140  FORMAT ('0POSITIONS (RE)CALCULEES DES CAPTEURS'/' EN X :',3F12.7/
     * ' EN Y :',3F12.7/' EN Z :',3F12.7/)
      DO 150 K=1,3
      I = 3*K-3
      ANG(1,K) = ATAN2 (-RO(1,I+2),RO(2,I+2))
      ANG(2,K) = ATAN2 ( RO(1,I+3),RO(3,I+3))
 150  ANG(3,K) = ATAN2 (-RO(2,I+3),RO(3,I+3))
      RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=FCTRK8
//COMP.SYSIN DD *
      SUBROUTINE FCTRK8 (Y,DERY,II,KR)
C-----------------------------------------------------------------------
C   CALCUL DE 'DERY' (ACCEL ANGUL) A CHAQUE INSTANT
C   POUR INTEGRATION PAR RUNGE-KUTTA
C   APPELLE 'MATPRV' ET 'PRODMT'
C   INTEGRATION 9 GAMMA VOIE PAR VOIE
C   DONNEES BRUTES ENTREES DANS GAMA
C                                                        17-12-81
C-----------------------------------------------------------------------
      COMMON /TAB/ RAM(2005,9), GAM(2001,9), GAMA(9,2001), ALPH(9,2001),
     *            DELTAT, NPIM
      COMMON /ANAT/ XPC(3,7), XPV(3,9), XC(3), DX(3,9), XGQ(3), C(9,3),
     *     NV, RO1(3,3), RO2(3,3), RO3(3,3), ANG(3,3), R69(6,9), TRE(80)
      DIMENSION Y(3),DERY(6), V(9), ALP(9)
C-----------------------------------------------------------------------
C   CALCUL DE L'ACCELERATION LUE, PAR INTERPOLATION ENTRE LES DONNEES
C-----------------------------------------------------------------------
      IF (KR.GE.1) GO TO 20
      DO 10 J=1,NV
 10   ALP(J) = 0.5 * (GAMA(J,II-1) + GAMA(J,II))
      GO TO 40
 20   DO 30 J=1,NV
 30   ALP(J) = GAMA(J,II)
C-----------------------------------------------------------------------
C EMPLISSAGE DE LA MATRICE DE PRODUIT VECTORIEL VITESSE ANGULAIRE OMEGA
C LE CARRE DE LA MATRICE OMEGA (RO1) EST MIS DANS RO2
C-----------------------------------------------------------------------
 40   CALL MATPRV (RO1,3,Y(1),Y(2),Y(3))
      CALL PRODMT (RO1,RO1,RO2,3,3,3,3,3,3)
C-----------------------------------------------------------------------
C   CALCUL DU VECTEUR V = OMEGA * OMEGA * POSITIONS CAPTEURS - ACCEL LUES
C-----------------------------------------------------------------------
      DO 80 I = 1,NV
      CALL PRODMT (RO2,DX(1,I),RO1,3,3,1,3,3,3)
      CALL PRODMT (C(I,1),RO1,V(I),1,3,1,9,3,9)
 80   V(I) = V(I) - ALP(I)
C-----------------------------------------------------------------------
C   CALCUL DE DERY
C-----------------------------------------------------------------------
      CALL PRODMT (R69,V,DERY,6,NV,1,6,9,6)
      RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=HPCG2
//COMP.SYSIN DD *
      SUBROUTINE HPCG2 (PRMT,Y,DERY,NDIM,IHLF,SFCT2,AUX)
C-----------------------------------------------------------------------
C   SOUS PROGRAMME DE CALCUL DES VITESSE ET ACCELERATION ANGULAIRES
C-----------------------------------------------------------------------
      DIMENSION PRMT(1),Y(1),DERY(1),AUX(16,1),L(11)
      DO 301 I=1,11
301   L(I)=0
      KI=0
      KM=0
      II=1
      II1=0
      N=1
      IHLF=0
      X=PRMT(1)
      H=PRMT(3)
      PRMT(5)=0.
      DO 1 I=1,NDIM
      AUX(16,I)=0.
      AUX(15,I)=DERY(I)
1     AUX(1,I)=Y(I)
      IF(H*(PRMT(2)-X))3,2,4
2     IHLF=12
      GO TO 4
3     IHLF=13
4     KK=1
      CALL SFCT2 (X,Y,DERY,L,II,II1,KI,KM)
      IF(PRMT(5))6,5,6
5     CONTINUE
      IF(IHLF)7,7,6
6     RETURN
7     DO 8 I=1,NDIM
8     AUX(8,I)=DERY(I)
      ISW=1
      GO TO 100
9     X=X+H
      KI=KI-1
      L(II)=L(II)+1
      DO 10 I=1,NDIM
10    AUX (2,I)=Y(I)
11    IHLF=IHLF+1
      X=X-H
      KI=KI+1
      L(II)=L(II)-1
      DO 12 I=1,NDIM
12    AUX(4,I)=AUX(2,I)
      II=II+1
      H=0.5*H
      KM=KM+1
      KI=KI*2
      N=1
      ISW=2
      GO TO 100
13    X=X+H
      KI=KI-1
      L(II)=L(II)+1
      CALL SFCT2 (X,Y,DERY,L,II,II1,KI,KM)
      N=2
      DO 14 I=1,NDIM
      AUX(2,I)=Y(I)
14    AUX(9,I)=DERY(I)
      ISW=3
      GO TO 100
15    DELT=0.
      DO 16 I=1,NDIM
16    DELT=DELT+AUX(15,I)*ABS(Y(I)-AUX(4,I))
      DELT=.06666666666666667*DELT
      IF(DELT-PRMT(4))19,19,17
17    IF(IHLF-10)11,18,18
18    IHLF=11
      X=X+H
      KI=KI-1
      L(II)=L(II)+1
      GO TO 4
19    X=X+H
      KI=KI-1
      L(II)=L(II)+1
      CALL SFCT2 (X,Y,DERY,L,II,II1,KI,KM)
      DO 20 I=1,NDIM
      AUX(3,I)=Y(I)
20    AUX(10,I)=DERY(I)
```

```
      N=3
      ISW=4
      GO TO 100
21    N=1
      L(II)=L(II)+1
      X=X+H
      KI=KI-1
      CALL SFCT2 (X,Y,DERY,L,II,II1,KI,KM)
      DO 302 I=1,11
302   L(I)=0
      X=PRMT(1)
      KI=2**KM
      DO 22 I=1,NDIM
      AUX(11,I)=DERY(I)
22    Y(I)=AUX(1,I)+H*(.375*AUX(8,I)+.79166666666666667*AUX(9,I)
     1-.20833333333333333*AUX(10,I)+.041666666666666667*DERY(I))
23    X=X+H
      KI=KI-1
      L(II)=L(II)+1
      N=N+1
      IF(KI) 403,403,404
403   KI=2**KM
404   CONTINUE
      IF(KM-2) 400,401,401
401   CALL SFCT2(X,Y,DERY,L,II,II1,KI,KM)
      GO TO 402
 400  CALL SFCT2 (X,Y,DERY,L,II,II1,2,KM)
402   IF(PRMT(5)) 6,24,6
24    IF(N-4)25,200,200
25    DO 26 I=1,NDIM
      AUX(N,I)=Y(I)
26    AUX(N+7,I)=DERY(I)
      IF(N-3)27,29,200
27    DO 28 I=1,NDIM
      DELT=AUX(9,I)+AUX(9,I)
      DELT=DELT+DELT
28    Y(I)=AUX(1,I)+.33333333333333333*H*(AUX(8,I)+DELT+AUX(10,I))
      GO TO 23
29    DO 30 I=1,NDIM
      DELT=AUX(9,I)+AUX(10,I)
      DELT=DELT+DELT+DELT
30    Y(I)=AUX(1,I)+0.375*H*(AUX(8,I)+DELT+AUX(11,I))
      GO TO 23
100   DO 101 I=1,NDIM
      Z=H*AUX(N+7,I)
      AUX(5,I)=Z
101   Y(I)=AUX(N,I)+.4*Z
      II1=1
      Z=X+.4*H
      CALL SFCT2 (Z,Y,DERY,L,II,II1,KI,KM)
      II1=0
      DO 102 I=1,NDIM
      Z=H*DERY(I)
      AUX(6,I)=Z
102   Y(I)=AUX(N,I)+.29697760924775360*AUX(5,I)+.15875964497103583*Z
      Z=X+.45573725421878943*H
      II1=2
      CALL SFCT2 (Z,Y,DERY,L,II,II1,KI,KM)
      II1=0
      DO 103 I=1,NDIM
      Z=H*DERY(I)
      AUX(7,I)=Z
103   Y(I)=AUX(N,I)+.21810038822592047*AUX(5,I)-3.0509651486929308*
     1AUX(6,I)+Z*3.8328647604670103
      L(II)=L(II)+1
      Z=X+H
      CALL SFCT2 (Z,Y,DERY,L,II,II1,KI,KM)
      L(II)=L(II)-1
      DO 104 I=1,NDIM
104   Y(I)=AUX(N,I)+.17476028226269037*AUX(5,I)-.55148066287873294*
     1AUX(6,I)+1.2055355993965235*AUX(7,I)+.17118478121951903*H*DERY
     2(I)
      GOTO(9,13,15,21),ISW
200   ISTEP=3
201   IF(N-8)204,202,204
202   DO 203 N=2,7
      DO 203 I=1,NDIM
      AUX(N-1,I)=AUX(N,I)
203   AUX(N+6,I)=AUX(N+7,I)
      N=7
204   N=N+1
      DO 205 I=1,NDIM
```

```
      AUX(N-1,I)=Y(I)
205   AUX(N+6,I)=DERY(I)
      L(II)=L(II)+1
      X=X+H
206   ISTEP=ISTEP+1
      DO 207 I=1,NDIM
      DELT=AUX(N-4,I)+1.333333333333333*H*(AUX(N+6,I)+AUX(N+6,I)-
     1AUX(N+5,I)+AUX(N+4,I)+AUX(N+4,I))
      Y(I)=DELT-.9256198347107438*AUX(16,I)
207   AUX(16,I)=DELT
      CALL SFCT2 (X,Y,DERY,L,II,II1,KI,KM)
      DO 208 I=1,NDIM
      DELT=.125*(9.*AUX(N-1,I)-AUX(N-3,I)+3.*H*(DERY(I)+AUX(N+6,I)
     1+AUX(N+6,I)-AUX(N+5,I)))
      AUX(16,I)=AUX(16,I)-DELT
208   Y(I)=DELT+.07438016528925620*AUX(16,I)
      DELT=0.
      DO 209 I=1,NDIM
209   DELT=DELT+AUX(15,I)*ABS(AUX(16,I))
      IF(DELT-PRMT(4))210,222,222
210   CONTINUE
      KI=KI-1
      CALL SFCT2 (X,Y,DERY,L,II,II1,KI,KM)
      IF(PRMT(5))212,211,212
211   IF(IHLF-11)213,212,212
212   RETURN
213   IF(H*(X-PRMT(2)))214,212,212
214   IF(ABS(X-PRMT(2))-.1*ABS(H))212,215,215
215   IF(DELT-.02*PRMT(4))216,216,201
216   IF(IHLF)201,201,217
217   IF(N-7)201,218,218
218   IF(ISTEP-4)201,219,219
219   IMOD=ISTEP/2
      IF(ISTEP-IMOD-IMOD)201,220,201
220   H=H+H
      KI=KI/2
      KM=KM-1
      II=II-1
      IHLF=IHLF-1
      ISTEP=0
      DO 221 I=1,NDIM
      AUX(N-1,I)=AUX(N-2,I)
      AUX(N-1,I)=AUX(N-4,I)
      AUX(N-3,I)=AUX(N-6,I)
      AUX(N+6,I)=AUX(N+5,I)
      AUX(N+5,I)=AUX(N+3,I)
      AUX(N+4,I)=AUX(N+1,I)
      DELT=AUX(N+6,I)+AUX(N+5,I)
      DELT=DELT+DELT+DELT
221   AUX(16,I)=8.962962962962963*(Y(I)-AUX(N-3,I))
     1-3.361111111111111*H*(DERY(I)+DELT+AUX(N+4,I))
      GOTO 201
222   IHLF=IHLF+1
      IF(IHLF-10)223,223,210
223   H=.5*H
      KI=KI*2
      KM=KM+1
      II=II+1
      ISTEP=0
      DO 224 I=1,NDIM
      Y(I)=.00390625*(80.*AUX(N-1,I)+135.*AUX(N-2,I)+40.*AUX(N-3,I)
     1+AUX(N-4,I))-.1171875*(AUX(N+6,I)-6.*AUX(N+5,I)-AUX(N+4,I))*H
      AUX(N-4,I)=.00390625*(12.*AUX(N-1,I)+135.*AUX(N-2,I)+
     1108.*AUX(N-3,I)+AUX(N-4,I))-.0234375*
     2(AUX(N+6,I)+18.*AUX(N+5,I)-9.*AUX(N+4,I))*H
      AUX(N-3,I)=AUX(N-2,I)
224   AUX(N+4,I)=AUX(N+5,I)
      L(II)=L(II)-1
      X=X-H
      L(II)=L(II)-2
      DELT=X-(H+H)
      CALL SFCT2 (DELT,Y,DERY,L,II,II1,KI,KM)
      DO 225 I=1,NDIM
      AUX(N-2,I)=Y(I)
      AUX(N+5,I)=DERY(I)
225   Y(I)=AUX(N-4,I)
      L(II)=L(II)-2
      DELT=DELT-(H+H)
      CALL SFCT2 (DELT,Y,DERY,L,II,II1,KI,KM)
      L(II)=L(II)+4
      DO 226 I=1,NDIM
      DELT=AUX(N+5,I)+AUX(N+4,I)
```

```
      DELT=DELT+DELT+DELT
      AUX(16,I)=8.962962962962963*(AUX(N-1,I)-Y(I))
     1-3.361111111111111*H*(AUX(N+6,I)+DELT+DERY(I))
  226 AUX(N+3,I)=DERY(I)
      GC TO 206
      END
```

```
// EXEC PROC=COMPIL,NOM=INTEG7
//COMP.SYSIN DD *
      SUBROUTINE INTEG7 (KI,SFCT1,SFCT2,POSIN)
C-----------------------------------------------------------------------
C     SOUS-PROGRAMME D'INTEGRATION POUR 9 GAMMA VOIE PAR VOIE
C           KI = 1   => PAR PREDICTOR-CORRECTOR, EN UTILISANT SFCT1
C           KI = 2   => PAR RUNGE-KUTTA,         EN UTILISANT SFCT2
C   27-11-1981
C-----------------------------------------------------------------------
      COMMON /TAB/ RAM(2005,9), GAM(2001,9), GAMA(9,2001), ALPH(9,2001),
     *             DELTAT, NPTM
      DIMENSION Y(3), DERY(6), P(3), Q(3), PRMT(5), AUX(16,3), POSIN(3)
      EXTERNAL SFCT1, SFCT2
C-----------------------------------------------------------------------
      GO TO (10,30), KI
 10   PRMT (1) = 0.
      PRMT (2) = DELTAT * (NPTM-1)
      PRMT (3) = DELTAT
      PRMT (4) = 0.1
      DO 20 I = 1,3
      Y(I) = POSIN(I)
 20   DERY(I) = 1./3.
      CALL HPCG2 (PRMT,Y,DERY,3,IHLF,SFCT1,AUX)
      GO TO 9999
C-----------------------------------------------------------------------
C................. INITIALISATION   RUNGE-KUTTA ........................
 30   DO 40 I = 1,3
      Y (I) = POSIN(I)
 40   Q (I) = 0.
      CALL SFCT2 (Y, DERY, 1, 1 )
      DO 45 I = 1,3
 45   ALPH (I  ,1) = Y    (I)
      DO 48 I = 1,6
 48   ALPH (I+3,1) = DERY (I)
C.........................   INTEGRATION   ............................
      DO 100 J = 2,NPTM
C
      DO 50 I = 1,3
      P (I) = DERY (I) * DELTAT
      Y (I) = Y (I) + .5D0 * P (I)
 50   Q (I) = P (I)
      CALL SFCT2 (Y,DERY,J,0)
C
      DO 60 I = 1,3
      P (I) = DERY (I) * DELTAT
      Y (I) = Y (I) + .5D0 * P (I) - .5D0 * Q (I)
 60   Q (I) = Q (I) / 6.D0
      CALL SFCT2 (Y,DERY,J,0)
C
      DO 70 I = 1,3
      P (I) = DERY (I) * DELTAT - .5D0 * P (I)
      Y (I) = Y (I) + P (I)
 70   Q (I) = Q (I) - P (I)
      CALL SFCT2 (Y,DERY,J,1)
C
      DO 80 I = 1,3
      P (I) = DERY (I) * DELTAT + 2.D0 * P (I)
 80   Y (I) = Y (I) + Q (I) + P (I)  / 6.D0
      CALL SFCT2 (Y,DERY,J,1)
      DO 90 I = 1,3
 90   ALPH (I  ,J) = Y    (I)
      DO 95 I = 1,6
 95   ALPH (I+3,J) = DERY (I)
 100  CONTINUE
 9999 RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=INVMA3
//COMP.SYSIN DD *
      SUBROUTINE INVMA3 (A,B,D)
      DIMENSION  A(3,3), B(3,3)
      INTEGER*2  I,J, I2,I3, J2,J3, M(4)/2,3,1,2/
C-----------------------------------------------------------------------
C ENTREE : LA MATRICE A (3*3)
C SORTIE : LA MATRICE B (3*3), INVERSE DE A ( DOIT ETRE DISTINCTE DE A )
C              LE DETERMINANT D DE A - SI D EST NUL, B N'EST PAS CALCULEE
C-----------------------------------------------------------------------
C
C TRANSPOSEE DES COFACTEURS
C
      DO 10 I = 1,3
      I2 = M(I)
      I3 = M(I+1)
      DO 10 J = 1,3
      J2 = M(J)
      J3 = M(J+1)
   10 B(J,I) = A(I2,J2) * A(I3,J3) - A(I3,J2) * A(I2,J3)
C
C CALCUL DU DETERMINANT
C
      D = 0.
      DO 20 I = 1,3
   20 D = D + A(I,1) * B(1,I)
      IF (D.EQ.0.) GO TO 100
C
C MATRICE FINALE
C
      DO 30 I = 1,3
      DO 30 J = 1,3
   30 B(I,J) = B(I,J) / D
C
  100 RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=MATPRV
//COMP.SYSIN DD *
      SUBROUTINE MATPRV (A,LA,X,Y,Z)
      DIMENSION  A(LA,1)
      INTEGER*2  I
C-----------------------------------------------------------------------
C REMPLIT UNE MATRICE DE PRODUIT VECTORIEL   0    -Z    Y
C                                            Z     0   -X
C                                           -Y     X    0
C-----------------------------------------------------------------------
      DO 1 I = 1,3
 1    A (I,I) = 0.00
      A (3,2) = X
      A (2,3) =-X
      A (1,3) = Y
      A (3,1) =-Y
      A (2,1) = Z
      A (1,2) =-Z
      RETURN
      END
```

```
C// EXEC PROC=COMPIL,NOM=MEULER
C//COMP.SYSIN DD *
      SUBROUTINE MEULER (EUL1,N1,EUL2,N2,EUL3,N3,P,T)
      DIMENSION P(3,3),T(3,6)
C-----------------------------------------------------------------------
C                CE S-P REMPLIT LA MATRICE DE PASSAGE P DU REPERE
C         DE BASE (LABO) AU REPERE FINAL
C
C                         X LABO = (P) * X FINAL
C
C          P EST LE PRODUIT DE TROIS MOUVEMENTS DE ROTATION
C                SUCCESSIFS
C                   - D'ANGLE RESPECTIF EUL1,EUL2,EUL3
C                   - AUTOUR D'AXES DONNES PAR N1,N2,N3
C
C                         AXE X SI N = 1
C                         AXE Y SI N = 2
C                         AXE Z SI N = 3
C
C          T ZONE DE TRAVAIL
C
C-----------------------------------------------------------------------
      CALL MATRO3(P,EUL1,N1)
      CALL MATRO3(T,EUL2,N2)
      CALL PRODMT(P,T,T(1,4),3,3,3,3,3,3)
      CALL MATRO3(T,EUL3,N3)
      CALL PRODMT(T(1,4),T,P,3,3,3,3,3,3)
      RETURN
      END
```

```
C// EXEC PROC=COMPIL,NOM=NRMVEC
C//COMP.SYSIN DD *
      SUBROUTINE NRMVEC (V)
      REAL*4      V(3), D
      INTEGER*2   I
C-----------------------------------------------------------------------
C  CE S-P NORME LE VECTEUR V (LE REMPLACE PAR UN VECTEUR UNITAIRE
C                              DE MEMES DIRECTION ET SENS)
C-----------------------------------------------------------------------
      D = SQRT (V(1)*V(1)+V(2)*V(2)+V(3)*V(3))
      DO 1 I = 1,3
 1    V(I) = V(I) / D
      RETURN
      END
```

```
C// EXEC PROC=COMPIL,NOM=PRDVEC
C//COMP.SYSIN DD *
      SUBROUTINE PRDVEC (A,B,C)
      REAL*4      A(3), B(3), C(3)
C-----------------------------------------------------------------------
C  CE S-P EFFECTUE LE PRODUIT VECTORIEL DE A PAR B
C  LE RESULTAT EST MIS DANS C
C-----------------------------------------------------------------------
      C(1) = A(2)*B(3) - A(3)*B(2)
      C(2) = A(3)*B(1) - A(1)*B(3)
      C(3) = A(1)*B(2) - A(2)*B(1)
      RETURN
      END
```

```
C// EXEC PROC=COMPIL,NOM=PRODMT
C//COMP.SYSIN DD *
      SUBROUTINE PRODMT (A,B,C,L,M,N,LA,LB,LC)
      DIMENSION  A(LA,1), B(LB,1), C(LC,1)
      INTEGER*2  I, J, K, M2
C-----------------------------------------------------------------------------------
C  EFFECTUE LE PRODUIT MATRICIEL DE  A  (L LIGNES, M COLONNES)
C                                PAR  B  (M LIGNES, N COLONNES)
C          LE RESULTAT EST MIS DANS  C  (L LIGNES, N COLONNES)
C-----------------------------------------------------------------------------------
      IF (M-3) 10,70,30
 10   DO 20 I = 1,N
      DO 20 J = 1,L
      C (J,I) = 0.
      DO 20 K = 1,M
 20   C (J,I) = C (J,I) + A (J,K) * B (K,I)
      GO TO 1000
 30   M2 = M - 1
      DO 60 I = 1,N
      DO 50 J = 1,L
      D     =      A(J,1)*B(1,I)
      DO 40 K = 2,M2
 40   D     = D + A(J,K)*B(K,I)
 50   C(J,I) = D + A(J,M)*B(M,I)
 60   CONTINUE
      GO TO 1000
 70   DO 90 I = 1,N
      DO 80 J = 1,L
 80   C(J,I) = A(J,1)*B(1,I) + A(J,2)*B(2,I) + A(J,3)*B(3,I)
 90   CONTINUE
 1000 RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=SFCT8
//COMP.SYSIN DD *
      SUBROUTINE SFCT8 (X,Y,DERY,L,II,II1,KI,KM)
C-----------------------------------------------------------------------
C    'SFCT8', APPELE PAR 'SCAL8', VIA 'HPCG2'
C    TRAITEMENT DU PROBLEME '9 GAMMA', EN UTILISANT DES VOIES SEPAREES
C    CALCUL DE 'DERY' (ACCEL ANGUL) A CHAGUE INSTANT
C    APPELLE 'MATPRV' ET 'PRODMT'
C    LES DONNEES BRUTES SONT MISES DANS GAMA
C                                                        17-12-81
C-----------------------------------------------------------------------
      COMMON /TAB/ RAM(2005,9), GAM(2001,9), GAMA(9,2001), ALPH(9,2001),
     *              DELTAT, NPTM
      COMMON /ANAT/ XPC(3,7), XPV(3,9), XC(3), DX(3,9), XGO(3), C(9,3),
     *       NV, RO1(3,3), RO2(3,3), RO3(3,3), ANG(3,3), R69(6,9), TRE(80)
      DIMENSION Y(3),DERY(6),FTRI(6,6),PRMT(5),AUX(16,3),R(9,6)
      DIMENSION V(9),ALP(9),L(11)
      DATA I4/0/
C-----------------------------------------------------------------------
C  CALCUL DE L'ACCELERATION LUE, PAR INTERPOLATION ENTRE LES DONNEES
C-----------------------------------------------------------------------
      CALL TERPOL (L,II,II1,KI,KM,DELTAT,GAMA,9,ALP,NV)
C-----------------------------------------------------------------------
C EMPLISSAGE DE LA MATRICE DE PRODUIT VECTORIEL VITESSE ANGULAIRE OMEGA
C LE CARRE DE LA MATRICE OMEGA (RO1) EST MIS DANS RO2
C-----------------------------------------------------------------------
      CALL MATPRV (RO1,3,Y(1),Y(2),Y(3))
      CALL PRODMT (RO1,RO1,RO2,3,3,3,3,3,3)
C-----------------------------------------------------------------------
C  CALCUL DU VECTEUR V = OMEGA * OMEGA * POSITIONS CAPTEURS - ACCEL LUES
C-----------------------------------------------------------------------
      DO 80 I = 1,NV
      CALL PRODMT (RO2,DX(1,I),RO1,3,3,1,3,3,3)
      CALL PRODMT (C(I,1),RO1,V(I),1,3,1,9,3,9)
 80   V(I) = V(I) - ALP(I)
C-----------------------------------------------------------------------
C  CALCUL DE DERY
C-----------------------------------------------------------------------
      CALL PRODMT (R69,V,DERY,6,NV,1,6,9,6)
C-----------------------------------------------------------------------
C  EMPLISSAGE EVENTUEL DE ALPH
C-----------------------------------------------------------------------
      IF (KI.GT.0) GO TO 1000
      KI=2**KM
      I4=I4+1
      DO 90 I=1,3
      ALPH(I,I4)   = Y(I)
      ALPH(I+3,I4) = DERY(I)
 90   ALPH(I+6,I4) = DERY(I+3)
 1000 RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=SCAL8
//COMP.SYSIN DD *
      SUBROUTINE SCAL8 (IMP4, IMP16, PCSIN, IREF)
C-----------------------------------------------------------------------
C SCAL8 - RESOLUTION 9 GAMMA VOIE PAR VOIE
C  CALCUL DES ACCELERATIONS ANGULAIRES ET DES VITESSES ANGULAIRES
C  PERMET LE CHOIX DU POINT DE REFERENCE, PAR IREF
C  LES DONNEES BRUTES SONT PLACEES DANS GAMA
C-----------------------------------------------------------------------
      EXTERNAL SFCT8, FCTRK8
      COMMON /TAB/ RAM(2005,9), GAM(2001,9), GAMA(9,2001), ALPH(9,2001),
     *              DELTAT, NPTM
      COMMON /ANAT/ XPC(3,7), XPV(3,9), XC(3), DX(3,9), XGO(3), C(9,3),
     *     NV, RO1(3,3), RO2(3,3), RO3(3,3), ANG(3,3), R69(6,9), TRE(80)
      DIMENSION Y(3),DERY(6),RTRI(6,6),PRMT(5),AUX(16,3),R(9,6),
     *          RT(6,9), PCSIN(1)
C-----------------------------------------------------------------------
C  COORDONNEES DU POINT DE REFERENCE
C-----------------------------------------------------------------------
      K = IREF + 3
      GO TO (10,15,20), K
C-----------------------------------------------------------------------
C   IREF > 0  ==> REF : CAPTEUR IREF
C-----------------------------------------------------------------------
      DO 5 I = 1,3
 5    XC(I) = XPC(I,IREF)
      GO TO 25
C-----------------------------------------------------------------------
C   IREF = -2  ==> REF : BARYCENTRE DES MASSES SISMIQUES DES NV VOIES
C-----------------------------------------------------------------------
 10   DO 13 I = 1,3
      XC(I) = 0.
      DO 12 K = 1,NV
 12   XC(I) = XO(I) + XPV(I,K)
 13   XC(I) = XO(I) / NV
      GO TO 25
C-----------------------------------------------------------------------
C   IREF = -1  ==> REF : CENTRE DE GRAVITE
C-----------------------------------------------------------------------
 15   DO 17 I =1,3
 17   XC(I) = XGO(I)
      GO TO 25
C-----------------------------------------------------------------------
C   IREF = 0  ==> REF : ORIGINE DU REPERE ANATOMIQUE
C-----------------------------------------------------------------------
 20   DO 22 I = 1,3
 22   XC(I) = 0.
C-----------------------------------------------------------------------
C   EMPLISSAGE DE DX = COORD DES CAPTEURS / POINT DE REFERENCE
C-----------------------------------------------------------------------
 25   DO 30 I = 1,NV
      DO 30 J = 1,3
 30   DX(J,I) = XPV(J,I) - XC(J)
      IF(IMP16.EQ.1) PRINT 1100, (XC(J),(XPV(J,I),I=1,9),J=1,3),
     *                           ((DX(J,I),I=1,9),J=1,3)
 1100 FORMAT('0XO',50X,'XPV'/3(1X,F12.5,10X,9F12.5/),15X,
     *            ' DX'/3(23X,9F12.5/))
C-----------------------------------------------------------------------
C  CONSTRUCTION DE R
C-----------------------------------------------------------------------
      DO 40 I = 1,NV
      CALL MATPRV (RO1,3,DX(1,I),DX(2,I),DX(3,I))
      CALL PRODMT (C(I,1),RO1,R(I,1),1,3,3,9,3,9)
      DO 40 J = 1,3
 40   R (I,J+3) = - C (I,J)
      IF (IMP16.EQ.1) PRINT 1111, ((R(J,I),I=1,6),J=1,9)
 1111 FORMAT ('0MATRICE R'/9(1X,6F12.5/))
C-----------------------------------------------------------------------
C  CALCUL DE RT
C-----------------------------------------------------------------------
      CALL TRANSP (R,RT,NV,6,9,6)
      IF (IMP16.EQ.1) PRINT 1122, ((RT(J,I),I=1,9),J=1,6)
 1122 FORMAT ('0MATRICE RT, TRANSPOSEE DE R'/6(1X,9F12.5/))
C-----------------------------------------------------------------------
C     CALCUL DE RTR
C-----------------------------------------------------------------------
      CALL PRODMT (RT,R,RTRI,6,NV,6,6,9,6)
      DO 50 I=1,6
      DO 50 J=1,6
      IF (ABS(RTRI(I,J)).LE.1.E-6) RTRI(I,J)=0.0
  50  CONTINUE
      IF (IMP16.EQ.1) PRINT 1133, ((RTRI(J,I),I=1,6),J=1,6)
```

```
 1133 FORMAT ('OMATRICE RTR, PRODUIT DE RT ET R'/6(1X,6F12.5/))
C-------------------------------------------------------------------
C  INVERSION DE RTR
C-------------------------------------------------------------------
      CALL INVMAT (RTRI,6,6,TRE,IR)
      IF (IMP16.EQ.1) PRINT 1144, ((RTRI(J,I),I=1,6),J=1,6)
 1144 FORMAT ('OMATRICE RTRI, INVERSE DE RTR'/6(1X,6F14.3/))
C-------------------------------------------------------------------
C   IMPRESSION SUPPLEMENTAIRE PROVISOIRE
C-------------------------------------------------------------------
      IF (IMP16.LE.0) GO TO 60
      CALL PRODMT (RT,R,TRE,6,NV,6,6,9,6)
      CALL  PRODMT (RTRI,TRE,R,6,6,6,6,6,9)
      PRINT 1150, ((R(J,I),I=1,6),J=1,6)
 1150 FORMAT ('OMATRICE UNITE ? RTRI*(RT*R))'/6(1X,6F11.6/))
C-------------------------------------------------------------------
C  CALCUL DE R69
C-------------------------------------------------------------------
   60 CALL PRODMT (RTRI,RT,R69,6,6,NV,6,6,6)
      IF (IMP16.EQ.1) PRINT 1155, ((R69(J,I),I=1,9),J=1,6)
 1155 FORMAT ('OMATRICE R69, MATRICE FINALE,',
     *' PRODUIT DE RTRI ET RT'/6(1X,9F14.3/))
C-------------------------------------------------------------------
      CALL INTEG7 (IMP4,SFCT8,FCTRK8,FCSIN)
      RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=SIHIC9
//COMP.SYSIN DD *
      SUBROUTINE SIHIC9 (IPV,G1,G2,G3,NDIMG,G4,NPT,DT,NPRINT,V,ECH,IH)
C***************************  SIHIC9  *************************************
C* SOUS-PROGRAMME DE CALCUL D'INDICES DE SEVERITE ET DU H.I.C.            *
C* DERIVE DU PROGRAMME PRINCIPAL 'SIHIC' QUI FAIT PARTIE DE 'PRAKIMOD'    *
C* 9  GAMMA VOIE PAR VOIE : G92010                                         *
C* IPV : INDICE DE PRESENCE DES VOIES                          15-01-82   *
C* IH  : INDIQUE LA NATURE DES VALEURS G1,G2,G3                            *
C*       1 ==> ACC LIN, 2 ==> ACC ANG, 3  ==> VIT ANG                      *
C* POUR LES CALCULS DE DUREES DE DEPASSEMENT, LES VALEURS SONT DIVISEES*
C* PAR DES COEFFICIENTS, DE FACON A RAMENER LES MAXI A MOINS DE 300      *
C*************************************************************************
      DIMENSION G1(NDIMG,1), G2(NDIMG,1), G3(NDIMG,1), G4(1), V(1),
     *          IPV(3), AG(4),PG(4),SI(4), IDIZ (10),
     *          NGM(4),NGA(4),NGP(4),TS(300,4),AM(4),IAM(4),E(4),EC(4)
      REAL*8    ELM(4), ACC(2,3)
      DATA ELM /'LONGIT', 'TRANSV', 'VERTIC', 'RESULT'/,
     *     ACC /'ACCELERA','TIONS','ACCEL. A','NGUL.','VITESSES',' ANG.'/
C-------------------------------------------------------------------------
      G4 (1) = 0.
      DO 10 K=1,4
      AM  (K) = 0.
      NGM (K) = 0
      NGP (K) = 0
      SI  (K) = 0.
      PG  (K) = 0.
      DO 10 I = 1,300
10    TS (I,K) = 0.
      PT=0.
      V(1)=0.
C-------------------------------------------------------------------------
C RECHERCHE DES MAXI, INTEGRATION DES GAMMA ET GAMMA**2.5
C-------------------------------------------------------------------------
      DO 20 J = 1,3
 20   AG(J)   = 0.
      DO 45 I=2,NPT
      IF (IPV(1).NE.0) AG(1) = ABS ( G1 (1,I) ) / ECH
      IF (IPV(2).NE.0) AG(2) = ABS ( G2 (1,I) ) / ECH
      IF (IPV(3).NE.0) AG(3) = ABS ( G3 (1,I) ) / ECH
      AG(4) = SQRT (AG(1)*AG(1)+AG(2)*AG(2)+AG(3)*AG(3))
      G4 (I) = AG (4)
      DO 40 K = 1,4
      IF (AG(K).LE.AM(K)) GO TO 40
      IAM(K)=I
      AM(K) = AG(K)
40    CONTINUE
      IF (IH.GT.1) GO TO 45
      V(I) = V(I-1) + .5 * (AG(4)+PG(4)) * DT
      CALL INDSEV (DT,PG,AG,SI)
      IF (NPRINT.GE.3) WRITE (6,1300) I,T,AG,SI,V(I)
 1300 FORMAT (1X,I5,F8.5,8F7.2,F7.3)
      DO 45 K = 1,4
      PG(K) = AG(K)
  45  CONTINUE
C-------------------------------------------------------------------------
C  MISE A L'ECHELLE, PUIS CALCUL DES DUREES DE DEPASSEMENT
C-------------------------------------------------------------------------
      DO 47 K = 1,4
      IF (K.LE.3.AND.IPV(K).LE.0) GO TO 47
      E(K) = AMAX1(AM(K)/300., .0001)
      CALL NORMEC (E(K))
      EC(K) = E(K) * ECH
  47  CONTINUE
      DO 160 I=2,NPT
      T = FLOAT (I-1) * DT
      IF (IPV(1).NE.0) AG(1) = ABS ( G1 (1,I) ) / EC(1)
      IF (IPV(2).NE.0) AG(2) = ABS ( G2 (1,I) ) / EC(2)
      IF (IPV(3).NE.0) AG(3) = ABS ( G3 (1,I) ) / EC(3)
      AG(4) = G4(I) / E(4)
      DO 120 K=1,4
      IF (K.LE.3.AND.IPV(K).LE.0) GO TO 120
      NGA(K) = INT(AG(K))
      IF (NGA(K)-NGP(K)) 80,120,50
50    IF (NGA(K).GT.NGM(K)) NGM(K) = NGA(K)
      IF (AG(K)-PG(K).LT..1E-5) GO TO 70
      II = NGP(K)+1
      IJ = NGA(K)
      IF (II.GT.IJ) GO TO 110
      DO 60 J = II,IJ
      TS(J,K) = TS(J,K) - PT - DT*(FLOAT(J)-PG(K))/(AG(K)-PG(K))
60    CONTINUE
```

```
      GC TC 110
70    TS(NGA(K),K) = TS(NGA(K),K) - PT
      GO TO 110
80    IF (PG(K)-AG(K).LT..1E-5) GO TC 100
      II = NGA(K)+1
      IJ = NGP(K)
      IF (II.GT.IJ) GO TO 110
      DC 90 J = II,IJ
 90   TS(J,K) = TS(J,K) + PT + DT*(FLCAT(J)-PG(K))/(AG(K)-PG(K))
      GC TO 110
100   TS(NGP(K),K) = TS(NGP(K),K) + T
110   NGP(K) = NGA(K)
 120  PG(K) = AG(K)
160   PT=T
C-----------------------------------------------------------------------
C     ECRITURE DES GAMMA MAXI
C-----------------------------------------------------------------------
      DC 230 K = 1,4
      IF (K.LE.3.AND.IPV(K).LE.0) GC TC 230
      IF (NGA(K).LE.0) GC TC 220
      II = NGA(K)
      DC 200 J = 1,II
200   TS (J,K) = TS (J,K) + T
220   DC 230 J = 1,300
      TS (J,K) = TS (J,K) * 1000.
 230  CCNTINUE
      WRITE (6,9001) (ACC(J,IH),J=1,2)
 9001 FCRMAT  (///27X,30(1H-)/27X,1HI,28X,1HI/27X,'I  ',A8,A7,'MAX',
     *'IMALES  I'/27X,1HI,28X,1HI/27X,30(1H-))
      DC 250 K = 1,4
      TT = FLCAT(IAM(K)-1) * DT * 1000.
 250  IF (K.EG.4.CR.IPV(K).NE.0) WRITE (6,8001) ELM(K), AM(K), TT
 8001 FCRMAT (1H0,60X,'EN',2X,A8,17X,'VALEUR MAXI =',F11.2/
     * 65X,6(1H*),4X,'OBTENUE A L''INSTANT (MSEC) =',F11.2)
C-----------------------------------------------------------------------
C    ECRITURE DES S.I.
C-----------------------------------------------------------------------
      IF (IH.NE.1) GO TO 300
      WRITE (6,9002)
 9002 FCRMAT (//23X,37(1H-)/23X,1HI,35X,1HI/
     * 23X,'I  INDICES  DE  SEVERITE  (G.S.I.)  I'/23X,1HI,35X,1HI/23X,
     * 37(1H-))
      DC 260 K=1,4
 260  IF (K.EG.4.CR.IPV(K).NE.0) WRITE (6,7001) ELM(K), SI(K)
 7001 FCRMAT (1H0,58X,'S.I.',2X,A8,29X,'=',F11.2/65X,6(1H*))
C-----------------------------------------------------------------------
C DUREES DE DEPASSEMENT DE SEUILS ET CALCUL GAMMA 3MS
C-----------------------------------------------------------------------
 300  WRITE (6,6000) (ACC(I,IH),I=1,2)
 6000 FCRMAT  (//20X,42(1H-)/20X ,1HI,40X,1HI/20X,1HI,11X,'NIVEAUX   DEP
     *ASSES',11X,1HI/20X,'I  PAR  LES',A10,A7,
     * 'RESULTANTES  I'/20X,1HI,5X,'PENDANT  UNE  DUREE  DE  3 MS',6X,
     * 1HI/20X,1HI,40X,1HI/20X,42(1H-))
      DC 550 K = 1,4
      DC 500 I=2,10
500   IDIZ(I) = (I-1)*30 * E(K) + .5
      IF (NPRINT.LE.1) GO TC 520
      WRITE (6,6001) (ACC(I,IH),I=1,2), ELM(K), (IDIZ(I),I=2,10)
 6001 FCRMAT (1H0/3X,'DUREES (MS) DE DEPASSEMENT DE SEUILS DEFINIS ',
     *'D(E)',A9,A5,28X,A8/94X,6(1H*)/10X,1H+,10X,'0 *',9(I10,' *'))
      DC 510 I=10,30,10
      II = I * E(K) + .5
 510  WRITE (6,6002) II,(TS(J*30+I-30,K),J=1,10)
 6002 FCRMAT (1X,I10,'*',10F12.3)
520   DC 530 J=1,300
      IF (TS(J,K).LT.3.) GC TC 540
530   CCNTINUE
540   IF (J.LE.1) GC TO 550
      IF (TS(J,K).GE..001) GC TC 542
      TT = ( J-1 + (TS(J-1,K)-3.) * (AM(K)/E(K)-J) / TS(J-1,K) ) * E(K)
      GC TO 545
 542  TT = ( J - (3.-TS(J,K)) / (TS(J-1,K)-TS(J,K)) ) * E(K)
 545  WRITE (6,6005) ELM(K), TT
 6005 FCRMAT (1H0,81X,'VALEUR 3 MS ',A8,'=',F11.2/82X,12('-'),6('*'))
550   CCNTINUE
      IF (IH.NE.1) GO TC 9999
      WRITE (6,5001)
 5001 FCRMAT (1H0//33X,18(1H-)/33X,'I',16X,'I'/33X,'I',3X,'H.  I.  C.',
     * 3X,'I'/33X,'I',16X,'I'/33X,18(1H-))
C-----------------------------------------------------------------------
C    CALCUL DU HIC
C-----------------------------------------------------------------------
```

```
      CALL HICS9G (NPRINT,NPT,DT,G4,V)
      G4 (NPT+1) = SI (4)
 9999 RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=TICOU8
//COMP.SYSIN DD *
      SUBROUTINE TICOU8 (IPV,NP,I,J,LAB1,LAB2)
      DIMENSION LAB1(1),LAB2(1),IPV(3)
      INTEGER*2 I2(3)
      LOGICAL*1 L1(6)
      EQUIVALENCE (L1,I2)
      DATA I2 /'23','QR','YZ'/
C-----------------------------------------------------------------------
C        SI J = 0,
C   TRACE '23', 'QR' OU 'YZ' POUR I=1,2 OU 3, EN COULEURS 1 ET 2
C   DIMENSIONS: .5*.5  A LA POSITION NP*.25 / AXE MILIEU VERTICAL
C   TRACE EGALEMENT DEUX LABELS
C   IPV : INDICE DE PRESENCE DES VOIES              04-12-81
C-----------------------------------------------------------------------
      IF (IPV(2) + IPV(3).EQ.0) GO TO 9999
      CALL POSA (X,Y)
      IF (IPV(2).EQ.0) GO TO 10
      CALL PLUMA (1)
      IF (J.EQ.0) CALL PCARA (11.7,8.+.25*NP,2,L1(2*I-1),1,.5,.5,0.,-1.)
      CALL PCARA (X+10.1,Y+16.,0,LAB1,9,.2,.4,0.,-1.)
 10   IF (IPV(3).EQ.0) GO TO 20
      CALL PLUMA (2)
      IF (J.EQ.0) CALL PCARA (X+11.7,Y+7.5+.25*NP,0,L1(2*I),1,.5,.5,
     *               0.,-1.)
      CALL PCARA (X+9.5,Y+16.,0,LAB2,9,.2,.4,0.,-1.)
 20   CALL PLUMA (0)
      CALL TRAA (X,Y,0)
 9999 RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=TRC9G8
//COMP.SYSIN DD *
      SUBROUTINE TRC9G8 (ITIT,LABEL,IUNV,N1,IPV,VAL1,VAL2,VAL3,
     *                   NDVAL,ECH)
      COMMON /PLOT/ IPLOT,IGO,NBL,IDATE(2),NESSAI(2),NS(3,7),NEME,NHZ,
     *              DUREE,NPTS,DTT,NCAP,NOMCAP(140)
      DIMENSION  ITIT(1), LABEL(1), IUNV(1), IUH(4), NOH(3), NOV(2),
     *           VAL1(NDVAL,1), VAL2(NDVAL,1), VAL3(NDVAL,1), IPV(3)
      DATA   NOV/1,' '/,   NCH/5,'TEMP','S   '/,
     *       IUH/10,'1/10','0 DE',' S  '/
C-----------------------------------------------------------------------
C        TRACAGE DES COURBES POUR '9 GAMMA'
C        PROGRAMME G92011                                 26-02-82
C-----------------------------------------------------------------------
      C = DUREE + .05
      W = -C / 5.
      VS = 0.
      VI = 0.
      IF (IPV(1).EQ.0) GO TO 20
      DO 15 J = 1,NPTS
      VS = AMAX1 (VS,VAL1(1,J))
 15   VI = AMIN1 (VI,VAL1(1,J))
 20   IF (IPV(2).EQ.0) GO TO 30
      DO 25 J = 1,NPTS
      VS = AMAX1 (VS,VAL2(1,J))
 25   VI = AMIN1 (VI,VAL2(1,J))
 30   IF (IPV(3).EQ.0) GO TO 40
      DO 35 J = 1,NPTS
      VS = AMAX1 (VS,VAL3(1,J))
 35   VI = AMIN1 (VI,VAL3(1,J))
 40   VS = VS / ECH
      VI = VI / ECH
      DVV = AMAX1 ((VS-VI)/9.4, .1E-20)
 50   CALL NORMEC (DVV)
      XDH = AINT (3.-VI/DVV)
      XDH = AMAX1 (5.,XDH)
      XS  = XDH + VS/DVV
      IF (XS.LE.11.7) GO TO 60
      DVV = DVV * 1.1
      GO TO 50
 60   IF (XDH.LT.5.5 .AND. XS.LE.10.5) XDH = 6.
      VV = ( 9.-XDH) * DVV
      GA = 1. / (DVV*ECH)
      DVV = - DVV
      GB=-1250./DUREE
C-----------------------------------------------------------------------
      CALL TRA008 (13.,16.,0.,IPLOT,IGO,ITIT,LABEL,NBL,0.,6.4,IDATE,
     * NESSAI,1.5,14.,XDH,14.,2.,1.,7,10.5,NOV,IUNV,9.,15.5,-1.,VV,DVV,
     * 8,-1,14.,1.,12,1.1,NCH,IUH,XDH-.5,1.8,2.5,C,W,5,1)
      CALL PASNUM (NEME,NHZ,XDH)
      IF (IPV(1).NE.0) CALL CRB9G8(GA,GB,NPTS,VAL1,NDVAL,DTT,N1,0,XDH)
      IF (IPV(2).NE.0) CALL CRB9G8(GA,GB,NPTS,VAL2,NDVAL,DTT,N1,1,XDH)
      IF (IPV(3).NE.0) CALL CRB9G8(GA,GB,NPTS,VAL3,NDVAL,DTT,N1,2,XDH)
      CALL PLUMA (0)
      CALL POSA (C,W)
      DO 90 I = 1,NCAP
      CALL TRAA (C-XDH+.2+(NCAP-I)*.3,W+1.8,0)
      DO 80 K = 1,3
 80   CALL PCARA (0.,0.,2,NS(K,I),1,.2,.2,0.,-1.)
 90   CALL PCARA (0.,-.2,2,NOMCAP(20*I-19),9,.2,.2,0.,-1.)
      VV = NBL - .5
      CALL NOMBA (C-XDH+.1,W-14.2,0,VV,-1,.15,.15,0.,-1.)
      CALL TRAA  (C-XDH,W-14.,0)
      RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=TRATET
//COMP.SYSIN DD *
      SUBROUTINE TRATET
C-----------------------------------------------------------------------
C   TRACE UNE VISUALISATION DE LA TETE DU M.S. EN SORTIE DU PGM '9 GAMMA'
C   ---                           ---
C          ORDRE DES FACES : X- X+ Y- Y+ Z- Z+
C  XA    : COORDONNEES DES 8 SOMMETS DE LA TETE, DANS LE REPERE ANATOMIQUE
C  XL    : IDEM...                                             LABORATOIRE
C  XTIF  : COORDONNEES / REPERE FACE (DE 0. A 1. EN X ET Y),
C          DES EXTREMITES DES TRAITS D'IDENTIFICATION DES FACES
C  NLIF  : NOMBRE DE LIGNES D'IDENTIFICATION D'UNE FACE
C  IDLIF: INDICE DE DEBUT, DANS IDL, DE LA 1ERE SERIE DE LIGNES D'1 FACE
C  NTR   : NOMBRE DE TRAITS QUE CONTIENT CHAQUE LIGNE
C  IDL   : INDICE DE DEBUT DE CHAQUE LIGNE DANS XTIF
C  XMAX(I,J) : VALEUR MINI OU MAXI (I=1 OU 2) DE POSIT (POSITION TETE
C              /LABO), SELON X,Y,OU Z (J=1,2 OU 3)
C  OFB   : COORDONNEES BENSON DE L'ORIGINE D'UNE FACE (=CENTRE)
C  VUB   : 2 VECTEURS UNITAIRES DE LA FACE, SELON UNITES BENSON
C          ( ARETES 2,1 ET 2,3)
C  IAXB(I,J) : INDICE DES AXES LABO QUE L'ON TROUVE SELON X,Y,Z BENSON,
C              (I=1,2,3)(Z PERP A XOY), POUR LE GRAPHE J=1,2,3
C  ISAXB      : INDIQUE LES SIGNES DE CES MEMES AXES
C  XOB   : COORDONNEES BENSON DE L'ORIGINE DU GRAPHE EN COURS
C  IA ET IS : VALEURS DE IAXB ET ISAXB POUR LE GRAPHE EN COURS
C  IOS   : INDICE D'ORDRE DES SOMMETS, FACE PAR FACE, LES FACES ETANT VUES
C          DANS LE SENS OPPOSE AUX AXES X,Y,Z FRANCFORT
C  ECH   : ECHELLE = NB D'UNITES REELLES (M) PAR CM PAPIER BENSON
C-----------------------------------------------------------------------
      COMMON /TAB/ ANGLE(9,2005), POSIT(9,2001), PEUL(3,3,2001),
     *             ALPH(9,2001), DELTAT, NPTM
      COMMON /PLOT/ IPLOT,IGC,NBL,IDATE(2),NESSAI(2),NS(3,7),NEME,NH2,
     *              DUREE,NPTS,DTT,NCAR
      REAL*4        DX(6), XA(3,2,2,2), XL(3,2,2,2), XAE(3,8), XLE(3,8),
     *              XTIF(2,200), OFB(2), VUB(2,2), XOB(2), SB(2,4), X(2),
     *              XMAX(2,3)
      INTEGER*2     NLIF(6), IDLIF(6), IDL(120), IAXB(3,3), ISAXB(3,3),
     *              IOS(4,6), IA(3), IS(3), NTR(120), IFV(6)
      LOGICAL*1     LAX(3)
      EQUIVALENCE (XAE,XA), (XLE,XL)
      DATA          DX/-.1,.08,-.07,.07,-.12,.1/
      DATA      IOS/3,1,5,7, 4,2,6,8, 1,2,6,5, 3,4,8,7, 1,3,4,2, 5,7,8,6/
      DATA          IAXB/3,1,2, 3,2,1, 1,2,3/, ISAXB/1,1,1,1,-1,1,-1,-1,1/
      DATA          NLIF/5,9,7,7,1,3/, NTR/2,2,2,1,2, 1,1,1,1,1,2,1,1,1,
     *              1,2,8,3,2,1,1, 1,2,8,3,2,1,1, 8, 1,1,1/
      DATA XTIF/.5,.25, .4,.4, .25,.5,  -.25,.5, -.4,.4, -.5,.25,   -.5,
     *-.2,-.35,-.4,-.35,-.5, -.35,-.4,.35,-.4, .35,-.5,.35,-.4,.5,-.2,
     * .35,.5,.5,.25, .15,.1,.3,.1, .35,.2,.05,.2, -.15,.1,-.3,.1,
     * -.35,.5,-.5,.25, -.35,.2,-.05,.2,-.07,-.1, .2,-.25,-.2,-.25,
     * -.5,-.4,-.4,-.5, .4,-.5,.5,-.4,  .35,.5,.5,.25, -.5,.2,-.4,.4,-.3
     *,.5, -.1,.5,-.2,.1,-.1,.1,-.05,.15,.05,.15,.1,.05,0.,-.1,-.05,-.1,
     *-.07,-.05, -.06,.08,-.03,.12,.03,.12,.07,.05, 0.,-.1,.1,-.35,.4,-
     *.4, .5,-.2,.35,-.5, -.3,-.5,-.5,-.4, .35,.5,.5,.25, -.5,.2,-.4,.4,
     *-.3,.5, -.1,.5,-.2,.1,-.1,.1,-.05,.15,.05,.15,.1,.05,0.,-.1,-.05,-
     *.1,-.07,-.05, -.06,.08,-.03,.12,.03,.12,.07,.05, 0.,-.1,.1,-.35,.4
     *,-.4, .5,-.2,.35,-.5, -.3,-.5,-.5,-.4,
     * -.1,.1, .1,.1, .2,0., .2,-.2, .1,-.3, -.1,-.3, -.2,-.2,
     * -.2,0.,-.1,.1,  .5,.1,-.5,.1, -.5,-.35,-.35,-.5, .35,-.5,.5,-.35/
      DATA          LAX/'X','Y','Z'/
C-----------------------------------------------------------------------
C EMPLISSAGE DES COORD DES SOMMETS / ANAT
C-----------------------------------------------------------------------
      DO 10 K = 1,2
      DO 10 J = 1,2
      DO 10 I = 1,2
      XA (1,I,J,K) = DX (I)
      XA (2,I,J,K) = DX (2+J)
   10 XA (3,I,J,K) = DX (4+K)
C-----------------------------------------------------------------------
C BOUCLE SUR LES FACES, POUR EMPLIR IDLIF ET IDL
C IT = INDICE FINAL ACTUEL DES POINTS RECENSES, DANS XTIF
C ITF= INDICE FINAL DES LIGNES BRISEES RECENSEES, DANS IDL
C NT = NB DE LIGNES BRISEES DANS LA FACE ACTUELLE
C-----------------------------------------------------------------------
      IT = 0
      ITF= 0
      DO 20 I = 1,6
      NT = NLIF (I)
      IDLIF (I) = ITF + 1
      DO 20 J = 1,NT
      ITF = ITF + 1
      IDL (ITF) = IT + 1
```

```
 20     IT = IT + NTR(ITF) + 1
C-----------------------------------------------------------------------
C RECHERCHE DES MINI ET MAXI DE POSITICN DU C.G. / LABO
C ELARGISSEMENT DE LA FENETRE
C POUR TENIR COMPTE DE L'ENCOMBREMENT DE LA TETE
C-----------------------------------------------------------------------
        IPT = (NPTM-1) / 50
        IPT = MAX0 ( IPT * 10 , 20 )
        DO 40 I = 1,3
        XMAX(1,I) = 0.
        XMAX(2,I) = 0.
        DO 30 J = 1,NPTM, IPT
        XMAX(1,I) = AMIN1( XMAX(1,I), POSIT(I,J) )
 30     XMAX(2,I) = AMAX1( XMAX(2,I), POSIT(I,J) )
        XMAX(1,I) = XMAX(1,I) - .15
 40     XMAX(2,I) = XMAX(2,I) + .15
        CALL POSA (XX,YY)
        CALL PNUMA (XX,YY,NBL,0.,0.)
C-----------------------------------------------------------------------
C BOUCLE SUR LES 3 GRAPHES
C-----------------------------------------------------------------------
C       DO 500 IGR = 1,3
        IGR = 0
  45    IGR = IGR + 1
        DO 50 I = 1,3
        IA(I) =  IAXB(I,IGR)
 50     IS(I) = ISAXB(I,IGR)
        ECH = AMAX1 (XMAX(2,IA(1))-XMAX(1,IA(1)),
     *               XMAX(2,IA(2))-XMAX(1,IA(2))) / 20.
C       CALL NORMEC (ECH)
        DO 60 I = 1,2
        L = (3-IS(I)) / 2
 60     XOB(I) = AINT ( -IS(I) * XMAX(L,IA(I)) / ECH + .99 )
        XOB(2) = XOB(2) + 25. * (IGR-1)
        CALL TCADRE (0.,20.,IGR*25.-25.,IGR*25.-5.,2,.02,.03)
        CALL POSA (XX,YY)
        CALL PNUMA (XX,YY,NBL,XX,YY)
C TRACAGE DU REPERE DU GRAPHE
        DO 70 I = 1,2
 70     X(I) = 10. - 9.5*IS(I)
        X(2) = X(2) + 25.*(IGR-1)
        DO 80 I = 1,2
        CALL TRAA (X(1),X(2),0)
        CALL TRAA ((2.-I)*IS(I), (I-1.)*IS(I), 3)
 80     CALL PCARA ((1-.5*I)*IS(I)-.25, (.5*I-.5)*IS(I)+.25, 2,
     *              LAX(IA(I)), 1, .5,.5, 0.,-1.)
C-----------------------------------------------------------------------
C BOUCLE SUR LES INSTANTS
C-----------------------------------------------------------------------
C       DO 500 J = 1,NPTM,20
        J = -19
  85    J = J + 20
        I = (J-1) / IPT
        IF (IPT*I.NE.J-1) GO TO 165
C SUR CHAQUE AXE TETE, QUELLE EST LA FACE VISIBLE ?
        DO 90 I = 1,3
        K = 2*I
        IFV (K) = 0
        IF (PEUL(IA(3),I,J)*IS(3).GT.0.) IFV (K) = 1
 90     IFV (K-1) = 1 - IFV (K)
C CALCUL DES COORD DES SOMMETS TETE / LABO
        DO 100 K = 1,8
        CALL PRODMT (PEUL(1,1,J),XAE(1,K),XLE(1,K),3,3,1,3,3,3)
        DO 100 L = 1,3
 100    XLE(L,K) = XLE(L,K) + POSIT (L,J)
C TRACAGE DES FACES
C       DO 160 I = 1,6
        I = 0
 105    I = I + 1
        IF (IFV(I).EQ.0) GO TO 160
        DO 110 K = 1,4
        DO 110 L = 1,2
 110    SB(L,K) = XOB(L) + IS(L) * XLE(IA(L),IOS(K,I)) / ECH
        DO 120 L = 1,2
        CFB(L) = .5 * (SB(L,1)+SB(L,3))
        DO 120 K = 1,2
 120    VLB(L,K) = SB(L,2*K-1) - SB(L,2)
C TRACAGE DES ARETES
        CALL TRAA (SB(1,4),SB(2,4),0)
        DO 130 K = 1,4
 130    CALL TRAA (SB(1,K),SB(2,K),1)
C TRACAGE DES TRAITS D'IDENTIFICATION
```

```
      NT = NLIF(I)
      IF (NT.LE.0) GO TO 160
      IT = IDLIF(I)
      DO 150 K = 1,NT
      I1 = IDL(IT+K-1)
      I2 = I1 + NTR(IT+K-1)
      IB = 0
      DO 150 L = I1,I2
      DO 140 M = 1,2
  140 X(M) = CFB(M) + XTIF(1,L) * VUB(M,1) + XTIF(2,L) * VUB(M,2)
      CALL TRAA (X(1),X(2),IB)
  150 IB = 1
C160  CONTINUE
  160 IF (I.LT.6) GO TO 105
C TRACAGE DU REPERE ANATOMIQUE
  165 DO 170 L = 1,2
      SB(L,4) = XCB(L) + IS(L) * POSIT(IA(L),J) / ECH
      DO 170 M = 1,3
  170 SB(L,M) = .05 * IS(L) * PEUL(IA(L),M,J) / ECH
      DO 180 K = 1,3
      CALL TRAA (SB(1,4),SB(2,4),0)
      CALL PLUMA (K-1)
      CALL TRAA (SB(1,K),SB(2,K),3)
  180 CALL TRAA (0.,0.,2)
      CALL PLUMA (0)
C500  CONTINUE
      IF (J+20.LE.NPTM) GO TO 85
      IF (IGR.LT.3) GO TO 45
      CALL TRAA (25.,0.,0)
      RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=TRANSP
//COMP.SYSIN DD *
      SUBROUTINE TRANSP (A,B,LI,LC,NL,NC)
      REAL*4      A(NL,1), B(NC,1)
      INTEGER*2   I,J
C-----------------------------------------------------------------------
C   TRANSPOSITION DE LA MATRICE 'A', COMPORTANT LI LIGNES ET LC COLONNES
C   LE RESULTAT EST MIS DANS  'B'
C-----------------------------------------------------------------------
      DO 1 I = 1,LC
      DO 1 J = 1,LI
    1 B(I,J) = A(J,I)
      RETURN
      END
```

```
// EXEC PROC=COMPIL,NOM=TERPOL
//COMP.SYSIN DD *
      SUBROUTINE TERPOL (L,II,II1,KI,KM,DELTAT,TAB,NDIMT,VECT,NDIMV)
      DIMENSION  L(11), TAB(NDIMT,1), VECT(NDIMV)
C-----------------------------------------------------------------------
C  DESTINE A SFCT6 OU SFCT7, EULER, PECG2
C  INTERPOLATION DES DONNEES CONTENUES DANS TAB
C                       LE RESULTAT EST MIS DANS VECT
C                                                            27-11-81
C-----------------------------------------------------------------------
      X1=0.0
      DO 10 I=1,11
 10   X1=X1+L(I)*(DELTAT/(2.**(I-1)))
      IF(II1-1) 40, 20, 30
 20   X1=X1+0.4*(DELTAT/(2.**(II-1)))
      GO TO 40
 30   X1=X1+.4557372542187894 3*(DELTAT/(2.**(II-1)))
 40   F=X1/DELTAT
      NABS = INT(F)
      H1=F-NABS
      IF (H1.LT. .999) GO TO 50
      NABS=NABS+1
      H1=0.0
 50   IXI=NABS+1
      IXI1=IXI+1
      DO 60 I=1,NDIMV
 60   VECT(I)=TAB(I,IXI)+H1*(TAB(I,IXI1)-TAB(I,IXI))
      RETURN
      END
```