EUROPEAN COAL AND STEEL COMMUNITY

Community Ergonomic Research

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Technical Report N° 16

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AN ERGONOMIC EVALUATION OF SEVERAL MODIFIED PNEUMATIC HAMMERS

Source : Ergonomic Team of the Italian Steel Industry
Project N° 2 (FIAT)

Authors : Prof. Dr L. CROSETTI, Dr E. CASALONE, Prof. E. MEDA

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The aim of this research project was to make an ergonomic study of pneumatic hammers in the metallurgical industry. Pneumatic hammers are still widely used in steelworks and foundries : in steelworks they are employed to remove flaws from billets, demolish and rebuild furnaces and for various masonry and roadway maintenance operations; in iron and steel foundries they are used to clean castings.

In an attempt to reduce or eliminate the effects of the vibrations caused by impact of the striker on the chisel and the resulting reaction on the handle of the pneumatic hammer, a damping sleeve was designed and built; with appropriate modifications it could be applied to ordinary hammers.

The benefits which could be obtained with the new type of hammer - in terms of both human work and production - were then studied on the basis of objective data, by comparison with a normal hammer.

Procedure and techniques used in the study

The study was conducted in a factory environment (with the cooperation of skilled workers) as the conditions would otherwise inevitably have been somewhat artificial, and differed from the actual working environment.

It was proposed above all to study the characteristics of the vibrations, not only at the level of the instrument but also of the different parts of the human limb, by determining the amplitude, frequency and acceleration of the vibrations.

The quantity of work done by the test subjects using the two types of hammer was then determined : for this purpose the energy expenditure was quantified by measuring the subjects' respiration and collecting the air expired during the work. For this purpose a breathing mask, a spirometer and plastic bags of the Douglas type were used.

The expired air was collected under mercury and analysed in the Haldane-Margaria apparatus to determine the oxygen and carbon dioxide concentration; the effectiveness of this technique was checked by a simultaneous examination of the samples in the oxygen analizer.

As the ventilation and composition of the expired air were known, it was possible to determine, by calculating the difference, the quantity of oxygen consumed and carbon dioxide produced; this enabled the "net outlay" to be determined from the total outlay by subtracting the outlay due to the subject's posture. Measurement of the carbon dioxide production and the calculation relating to the respiratory quotient enabled the caloric power of the consumed oxygen to be evaluated more accurately and the "net outlay" to be determined in calories.

The technique outlined above required training and patient cooperation by the test subjects who had to accustom themselves to the mask and try not to vary their respiratory activity as any such variation might have invalidated the composition of the expired air; this delicate matter required several training sessions for each individual before beginning the actual experiments.

The metal to be cleaned consisted of a billet of standardized material, milled in the shape of a parallelepiped of constant dimensions (width about half a centimetre, length equal to that of the billet) so that the mechanical work to be performed by the hammer chisel remained as constant as possible. One parallelepiped was used with the normal pneumatic hammer and the other with the modified hammer. An index of the mechanical work performed by the two hammers was provided by the weight of the material cleaned in a given unit of time.

The noise level of the hammers was then studied by means of a phonometer and a recording taken on paper.

Finally an incidental factor which does not seem to have been considered in previous research was studied : possible changes in the tactile sensitivity of the hands of workers using pneumatic hammers for several years. While other research has examined the vascular characteristics, the roughness of the skin and the influence of chronic traumatism on the articulations of the upper limb, the stage of tactile sensitivity - which is particularly high in the case of the hand - has not been analysed.

Use of an esthesiometer enabled this parameter to be studied, and an attempt was made to determine the "tactile discrimination" with a Weber compass; this part of the research was conducted on the hands of workers who had been operating pneumatic hammers for several years - a comparison being made between the right and left hands - and also by the same method on the hands of subjects who had not been exposed to the same chronic stresses.

Study of hammer vibrations

The first part of the research consisted in studying the vibrations produced by the pneumatic hammer used for cleaning purposes; these vibrations were recorded on the body of the hammer itself.

Four different hammers were considered :

- the first was of the normal type, referred to in the research as hammer No. 1;

- the second, modified hammer was given the reference No. 2. Here the modification consisted simply in inserting a layer of damping plastic material between the chisel housing and the body of the hammer; it is, however, felt that this modification cannot be applied under practical conditions because of the difficulty in fixing the layer of plastic material firmly;

- the third, modified hammer was given the reference No. 3. In this case the modification consisted in fitting on the hammer body a damping bush into which the chisel is inserted. This bush is fixed to the hammer by balls held in a suitable flexible steel ring; the inside surface is lined with vulcanised rubber applied between two cylindrical steel cable sections. The chisel is then fixed, with its base in the shape of a hexagonal parallelepiped, by other balls held in another flexible steel ring;

- the fourth, modified hammer, referred to as hammer No. 4, is the same as No. 3 but with further modifications. In this case the damping bush is not fixed by ball bearings but screwed into the hammer body; the chisel base is in the shape of a hexagonal truncated pyramid instead of a parallelepiped, as this was found to reduce the possibility of vibration on the seating. The rubber was of two different types, i.e. soft and more rigid, to determine which type was more suitable.

The following control apparatus and instruments were used :

1) Dynamometric footboard : this consists of a mobile carriage mounted on ball bearings and onnected through a spring to a fixed base; the operator stands on the carriage and, as he thrusts the pneumatic

hammer against the workpiece to be cleaned, applies backward pressure with his feet on the carriage; the position of this carriage is checked by two micro-switches which actuate first one and then a second indicator light, thus showing the level of effort applied to the carriage and hence the forward thrust impacted by the operator to the pneumatic hammer. The thrust required to actuate the first light is about 11 kg, with carriage travel of 5 mm; to actuate the second light a thrust of 17 kg is needed with total carriage travel of 27 mm. For the carriage to be displaced through half its travel, i. e. 14 mm, a thrust of about 15 kg is needed and the effort sustained by the operator is 15 kg + 4 and 2 kg.

This apparatus was used to ensure that the hammer operator exerted a constant - and at all times comparable - forward thrust on the hammer (the operator always worked with only one light actuated);

2) Three KISTLER Model 808 A piezo-electric accelerometers were applied to the hammer body; these units were connected to three power amplifiers of the same make; the entire system was then connected to a multi-channel recorder - practically inertia-free in the analysis frequency range - operating with photo-sensitive paper (VISICORDER Model 1508, manufactured by HONEYWELL).

The accelerometers were applied to the hammer body in such a way that one of them detected longitudinal acceleration, the second vertical acceleration and the third transverse acceleration.

The recorder timer interval was 0.1 sec., the paper speed 1500 mm/sec; 1 mm of the paper with its millimetre scale corresponded to 1 g.

The following values were recorded :

Hammer No. 1 - frequency 45 hz : only the low frequencies were calculated here : i.e. those which are presumably felt by the human limb.

Total acceleration (positive and negative) in g

longitudinal 80
vertical 63
transverse 68

Hammer No. 2 - frequency 40 hz.

Total acceleration (positive and negative) in g :

longitudinal 50
vertical 51
transverse 49

Hammer No. 3 - frequency 38 hz.

Total acceleration (positive and negative) in g :

longitudinal 30
vertical 22
transverse 36

Hammer No. 4 - frequency 40 hz.

Soft damping bush :

Total acceleration (positive and negative) in g :

longitudinal 40
vertical 30
transverse 30/35

Harder damping bush :

Total acceleration (positive and negative) in g :

longitudinal 40
vertical 20
transverse 50.

A first brief comment which may be made on the data of the four recordings is that the three modified hammers filter vibrations to a greater extent than the normal hammer. Of these three hammers the best recordings seem to be those of hammers 3 and 4.

Study of vibrations transmitted to the limbs

To determine how vibrations are transmitted to the upper limbs of the operator, the equipment described above in connexion with the hammers was again used, i.e. the dynamometric footboard, the accelerometers (arranged on the limb so as to detect longitudinal, vertical and transverse acceleration respectively) and the photosensitive paper recorder.

However, whereas no problems arose in conducting the experiments on the hammers, in this case there was the difficulty of fixing the accelerometers on the limb in such a way as to obtain proper adhesion and detect the vibrations satisfactorily.

In order to work without cuts, the best system was to fix the units tightly on the skin of the osseous projections of the wrist, elbow and shoulder with adhesive tape. The system proved satisfactory on the wrist and elbow, but less so on the muscular masses tended to damp the vibrations transmitted by the bones of the scapulo-humeral articulation to the accelerometers.

This is probably one of the reasons why hammer vibrations appeared to be practically zero at the shoulder in all the experiments.

Here again the recorder timing interval was 0.1 s, the calibration 1g/mm and the paper speed 1500 mm/s.

Examination of the data obtained gives the following information :

Hammer No. 1 (unmodified) :

frequency at all the articulations 40 hz, except for the left shoulder where it cannot be calculated because of the characteristics of the plotted recording. This is the recording with the highest peaks and maximum value at the left wrist. While the right elbow is still affected by vibrations which seem scarcely reduced by the right wrist, few vibrations reach the left elbow.

This phenomenon can perhaps be understood by considering the position of the operator's upper limbs.

In fact for a right-handed subject as in this instance, the right hand grips the hammer handle and pushes it forwards : the vibrations can therefore be transmitted easily from the wrist to the elbow, especially as during the effort, the wrist, held in a straight line with the forearm, and the elbow, held at a very wide angle (almost fully extended), do little to dampen the vibrations they receive.

On the other hand, the left hand which simply guides the movement of the chisel, rests - without exerting much pressure - on the hammer body with the axis of the wrist at right angles to the axis of the instrument and the elbow at an angle of almost ninety degrees. The wrist and elbow are therefore better able to filter the vibrations they receive.

The phenomenon observed with this hammer is repeated to varying degrees with the others.

Hammer No. 2 (modified) :

frequency at the two wrists and right elbow 40 hz; the frequency cannot be calculated at the left elbow and at the two shoulders.

With this hammer, the highest peaks are again observed at the left wrist.

Hammer No. 3 (modified) :

frequency 42-44 hz at the two wrists and right elbow;the frequency cannot be calculated at the left elbow and at the two shoulders.

The highest vibrations are noted here at the right wrist.

Hammer No. 4 (modified) :

frequency 42 hz at the two wrists and at the right elbow; the frequency cannot be calculated at the left elbow and at both shoulders. The highest peaks are recorded at the right wrist.

Comparison of the values in g, shown in the table, for the four hammers indicates a significant difference between the values for the unmodified hammer No. 1 and the other three modified hammers.

Of the three modified hammers, No. 4 undoubtedly gives the best results.

VALUE IN g. OF VIBRATIONS TRANSMITTED BY THE FOUR HAMMERS TO THE UPPER LIMBS

Hammer No. 1 (unmodified)	right wrist	right elbow	right shoulder
- long.	26	20	8
- total vert. g.	20	8	4
- transv.	16	12	0
	left wrist	left elbow	left shoulder
- long.	50	5	0
- total vert. g.	28	0	0
- transv.	32	0	0
Hammer No. 2 (modified)	right wrist	right elbow	right shoulder
- long.	16	12	6
- total vert. g.	12	12	0
- transv.	12	9	0
	left wrist	left elbow	left shoulder
- long.	9	6	0
- total vert. g.	25	5	0
- transv.	17	0	0
Hammer No. 3 (modified)	right wrist	right elbow	right shoulder
- long.	16	15	0
- total vert. g.	26	13	0
- transv.	26	13	0
	left wrist	left elbow	left shoulder
- long.	15	4	5
- total vert. g.	20	0	0
- transv.	15	0	0
Hammer No. 4 (modified)	right wrist	right elbow	right shoulder
- long.	9	5	0
- total vert. g.	5	4	1
- transv.	10	7	0
	left wrist	left elbow	left shoulder
- long.	0	0	0
- total vert. g.	1	1	1
- transv.	7	0	0

Energy outlay during use of hammers

The outlay in human energy during use of the pneumatic hammers described above was studied.

A first analysis was made of the postural outlay of two workers, who were experienced in cleaning operations (F.G. : weight = 70.0 kg; height 1.59 m; age = 50; P.P. : weight = 70.5 kg; height = 1.59 m; age = 50). After a first attempt at cleaning with the billet at the level of a normal table, this position was abandoned because the two workers were accustomed to cleaning the billet at a height of about 30-40 cm above the ground. All subsequent experiments were conducted with this arrangement which presupposes a standing posture with forward inclination of the torso by about 70° and slight bending of the knees. The average outlay in this position was 1.57 and 1.72 calories/min. respectively. Assuming an outlay of 1 calory for the upright position, the 'cost' of this posture was 0.57 and 0.72 cal./min.

In a second series of experiments the worker stood on the dynamometric footboard described above, modified so that a variation in thrust of ± 2 kg was indicated by a light signal.

The chisel was inserted in a solid block of steel so that there was no progress or cleaning.

This was done mainly with a view to determining whether the various vibrations of the different hammers had any influence on energy outlay. The results obtained are shown in Table I below and concern the test subject F.G.

TABLE I

Hammer	V_{EO2} l/min	R	Eq.Cal.O_2/l	Gross calories/min
1) (	0.4695	0.760	4.751	2.23
4)	0.4445	0.808	4.809	2.15
1) (	0.3930	0.880	4.899	1.92
2)	0.4140	0.890	4.911	2.03
1) (	0.3949	0.740	4.727	1.86
3)	0.3910	0.810	4.813	1.88

In each pair of experiments, unmodified hammer No. 1 was used for comparison with hammer No. 2, 3 or 4; since in the case of subject F.G. the postural outlay is 0.57 cal/min, the net outlay is obtained by subtracting the value of 0.57 from each value in the "gross calories/min." column. It is apparent that even after subtracting this constant value the O2 consumption does not vary and neither does the energy outlay in the two experimental conditions, namely during use of the normal hammer in comparison with the modified hammers.

To solve one of the problems set in this research, namely to determine the outlay in human energy during use of modified pneumatic hammers, the oxygen consumption was measured during cleaning work on a parallelepiped with length 100 cm x 0.7 x 0.5 in C 21 R steel. The feed pressure to the hammer was maintained constant as were the chisel characteristics.

To maintain a constant hammer inclination, an attempt was made to provide the hammer with a mechanical support, with adjustable inclination, so that the operator had only to apply thrust to the support; the difficulty of working under these conditions, due to elimination of the operations to which the staff are accustomed, made it necessary to abandon this technique.

For the practical outlay measurements, the sample of expired air was taken in the manner described above; the experiment lasted for 3-4 minutes and the sample of expired air was taken in the last two minutes.

In each experiment the normal hammer (No. 1) was used and then the modified hammer (No. 2 - 3 - 4).

The results obtained are shown in Tables II and III.

Tables II and III cover a total of 11 experiments in which the consumption of oxygen (VO_2 l/min) is indicated in litres per minute and the corresponding respiratory quotient with the letter R.

The energy outlay is indicated in calories/min., representing the gross value; to obtain the net value it is sufficient to subtract for F.G. 0.57 and for P.P. 0.72 calories/min; these values are due to posture maintenance. In the last column under the indication weight/min, the weight in g. of material cleaned in one minute is shown.

Examination of the energy outlay values obtained in tables II and III shows that the difference between energy outlay during use of the normal pneumatic hammer (No. 1) and a modified hammer (2-3 or 4) is practically zero in most cases.

In fact in experiments 2, 3, 4, 5, 6, 8, 9 and 10 the outlay in energy is identical for the two hammers when the work - taking the weight of the cleaned material as the index - is also identical.

In some experiments, however, the outlay in energy is rather higher when the modified pneumatic hammer is used, e.g. in experiment No. 1 where the increase in outlay is 11% for a 20% increase in material, and in experiment No. 7 where the increase in outlay is 19% while the rise in weight of the cleaned material is 14%; in experiment 11 on the other hand, the maximum increase in cleaned material, i.e. 27%, is obtained with the modified hammer, while the increase in energy outlay is barely 8%. These experiments all have in common an increase in the energy outlay during use of the modified hammers; this increase always corresponds to an increase in the weight of cleaned material. The fact that there is not an exact correspondence between the increase in energy outlay and the rise in weight of cleaned material is easy to explain as a very slight displacement of the horizontal progression line of the tool is sufficient to give a clear difference in weight.

In conclusion, analysis of the results in Tables II and III shows that in practice there are no appreciable difference in outlay depending on which hammer is used, despite the fact that the damping system for the modified hammers is highly efficient, both from the physical and from the human angles.

Noise level

The noise level of the four hammers was then measured during cleaning work on the steel billets described above.

A phonometer and paper recorder manufactured by Bruel & Kjaer were used; the instruments were placed at 0.80 m above the ground and at a distance of 0.60 m from the hammer.

The results obtained show that the noise level does not vary significantly from one hammer to another, ranging from a minimum of 103 to a maximum of 106 dBC.

Threshold and tactile discrimination

The work was completed by a study of the tactile sensitivity of the skin of the hands where the traumatic action of the pneumatic hammer is certainly most intense.

For this purpose 20 test subjects were selected who had been working for several years in a foundry on cleaning operations involving the daily use of a pneumatic hammer : one of these subjects had been performing work of this kind for 4 years - the minimum figure - while the maximum was 17 years; the figures for the other subjects were between these two extremes. The threshold of tactile sensitivity and tactile discrimination was determined for all these persons (all the subjects were men, aged between 29 and 52).

The tactile sensitivity threshold was examined using an esthesiometer of the Von Frei type. Although the principle and design were basically as described by Von Frei, in practice the camel-hair or horse-hair was replaced by a segment of fishing-line with a diameter of 0.1 mm and different lengths so as to obtain a flexural load of 3 to 12 g/mm^2 (3; 4.5; 5; 6.6; 9; 12 grams). Each segment of line was inserted and sealed in a small metal tube, inserted in turn in a handle for ease of use.

Beginning with the esthesiometer with the minimum flexural load, the minimum pressure value capable of inducing a tactile sensation in the subject with his eyes closed was sought : the threshold was sought on the fleshy part of the fingertips, on the thenar and hypothenar eminence on the palmar side, on the skin in the vicinity of the ungual furrow of the dorsal side of the hand and on the thenar and hypothenar eminence on the reverse side; these values were measured on both the right and left hands (see drawing attached to each table). For control purposes, the same measurements were made on 19 subjects, once again all males, between 20 and 55 years old who normally performed office work.

The tactile discrimination threshold was determined with a suitably modified gauge similar to the Weber compass. The two arms of the gauge terminated in a point and were applied to the skin of the subject, the distance being recorded in mm and fractions of a mm. The minimum distance between the two points at which the subject, with his eyes closed, still had the sensation of a double tactile stimulus was taken as the "threshold of tactile discrimination" and measured in mm and hundredths of mm.

This threshold was determined only for the fleshy part of the 2nd and 3rd fingertips, for the thenar and hypothenar eminence on the palmar side; on the dorsal side it was limited to the skin of the 2nd and 3rd fingers in the vicinity of the ungual furrow and on the reverse part of the thenar and hypothenar eminence. Once again both hands of the same 20 workers were examined and for control purposes on the sale 19 office staff.

Statistical analysis of the results (see tables) and comparison with the values for the control subjects show that in the case of the workers engaged in cleaning operations with a pneumatic hammer the threshold of tactile stimulation was always higher than in the control group; the difference was between a minimum of 1 g/mm^2 and a maximum of 2.35 g/mm^2.

All the differences encountered were quite significant; the probability, determined with Student's t factor, was in the order of 1% in a few cases but generally 1 ^{o}/oo. The behaviour was identical for both right and left hands and for the palmar and dorsal regions.

The values for tactile discrimination of the fingers of both right and left hands, on the dorsal and palmar sides, are always higher on the cleaning workers and the differences recorded are always significant ($P > 1^{o}/oo$). On the other hand for the thenar and hypothenar eminence of both hands the differences do not appear significant.

It may therefore be concluded that the threshold of tactile stimulation of the skin of the hands of cleaning workers is always higher - to a statistically significant extent - than in the case of the control subjects.

Tactile discrimination, on the fingers, is also less sensitive for the cleaning workers and this function is therefore less delicate in comparison with the control subjects.

SUMMARY

Piezo-electric accelerometers were used to study vibrations on the body of four pneumatic cleaning hammers; three of these hammers were of a modified type. Vibrations transmitted from the hammer to the operator's wrist, elbow and shoulder were recorded by the same system. The maximum vibration damping effect was obtained with hammer No. 4.

Consideration of the energy outlay during use of the different types of modified hammer did not reveal appreciable differences in oxygen consumption than when the unmodified hammer is used.

Significant differences in noise level were not recorded between the four hammers.

Analysis of the "tactile threshold" on the skin of the hands of cleaning workers who had used pneumatic hammers for several years revealed higher average values than for subjects used to office work and the difference between the two sets of figures was statistically significant.

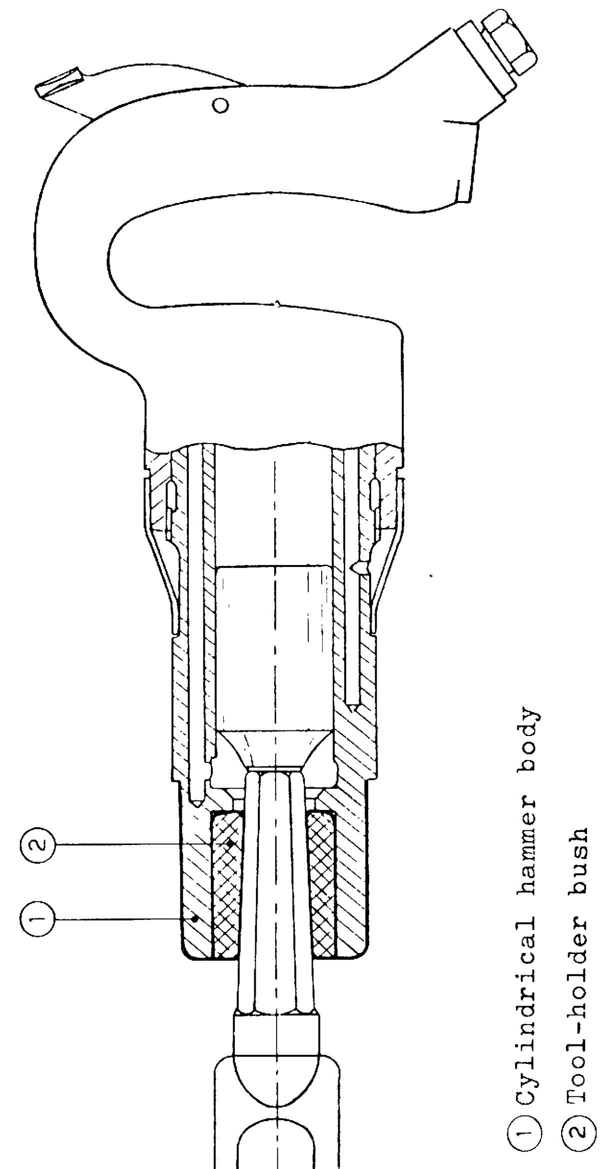
"Tactile discrimination" is also less sensitive in the case of cleaning workers; once again the difference is statistically significant.

A N N E X E S

HAMMER No. 1

Mod. 5576

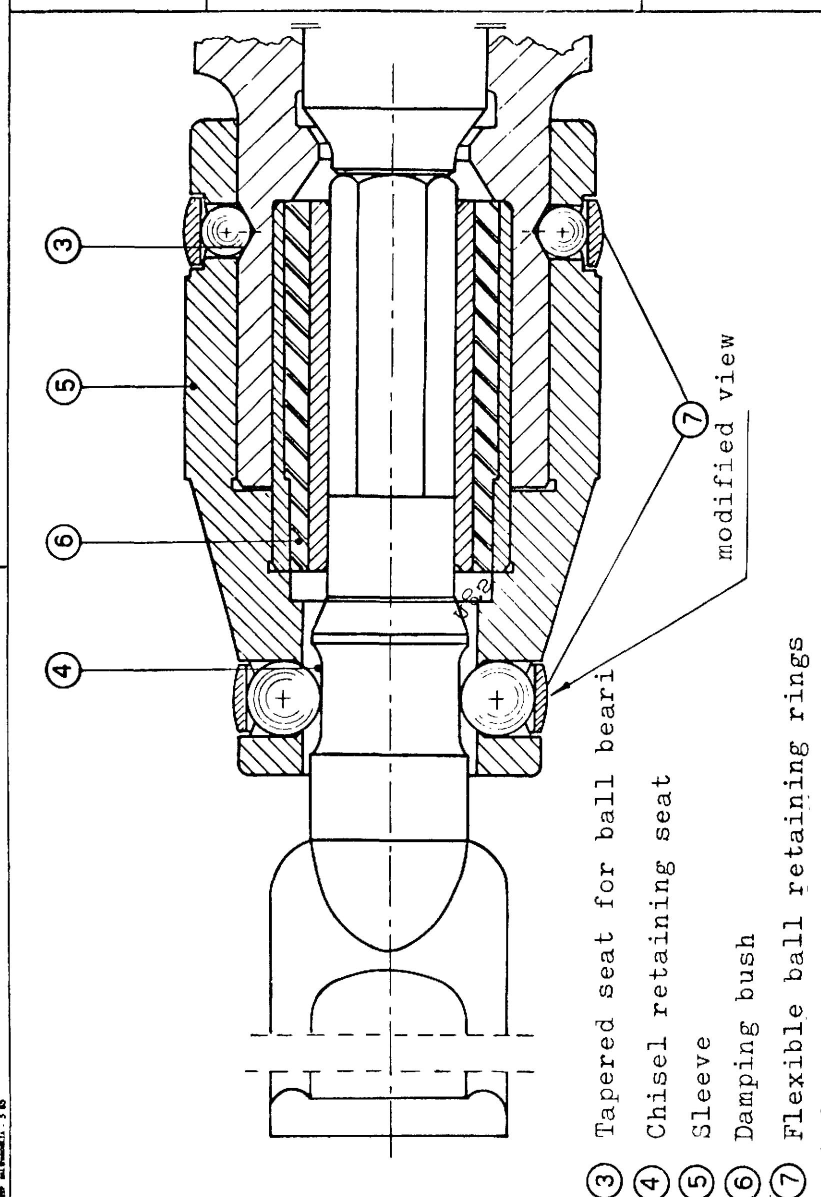
FIAT DIVISIONE SERV. di PRODUZIONE Servizio Lavoro	Diagram of normal pneumatic hammer	Annex 1



HAMMER No. 3

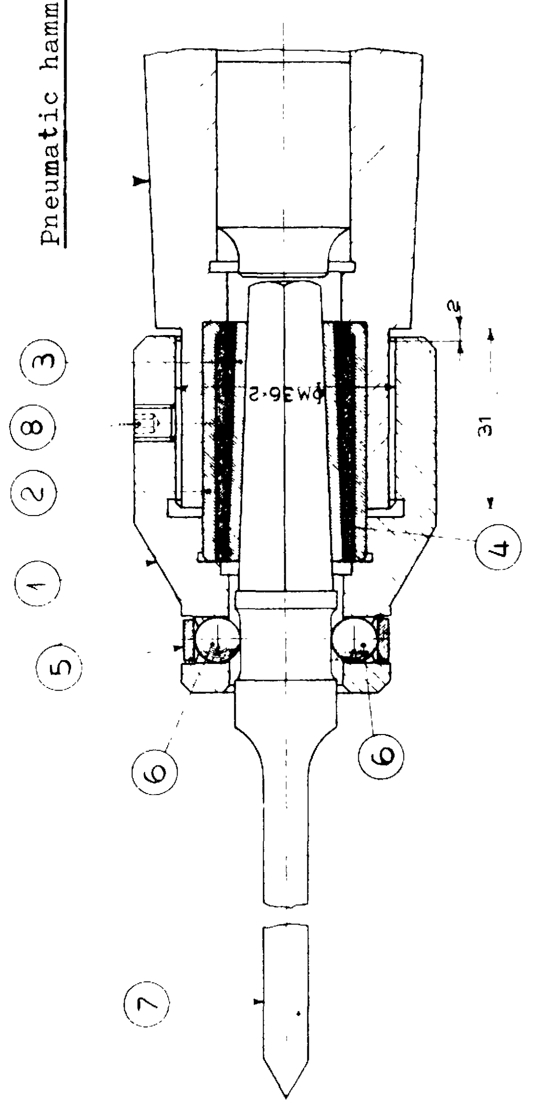
Mod. 5576

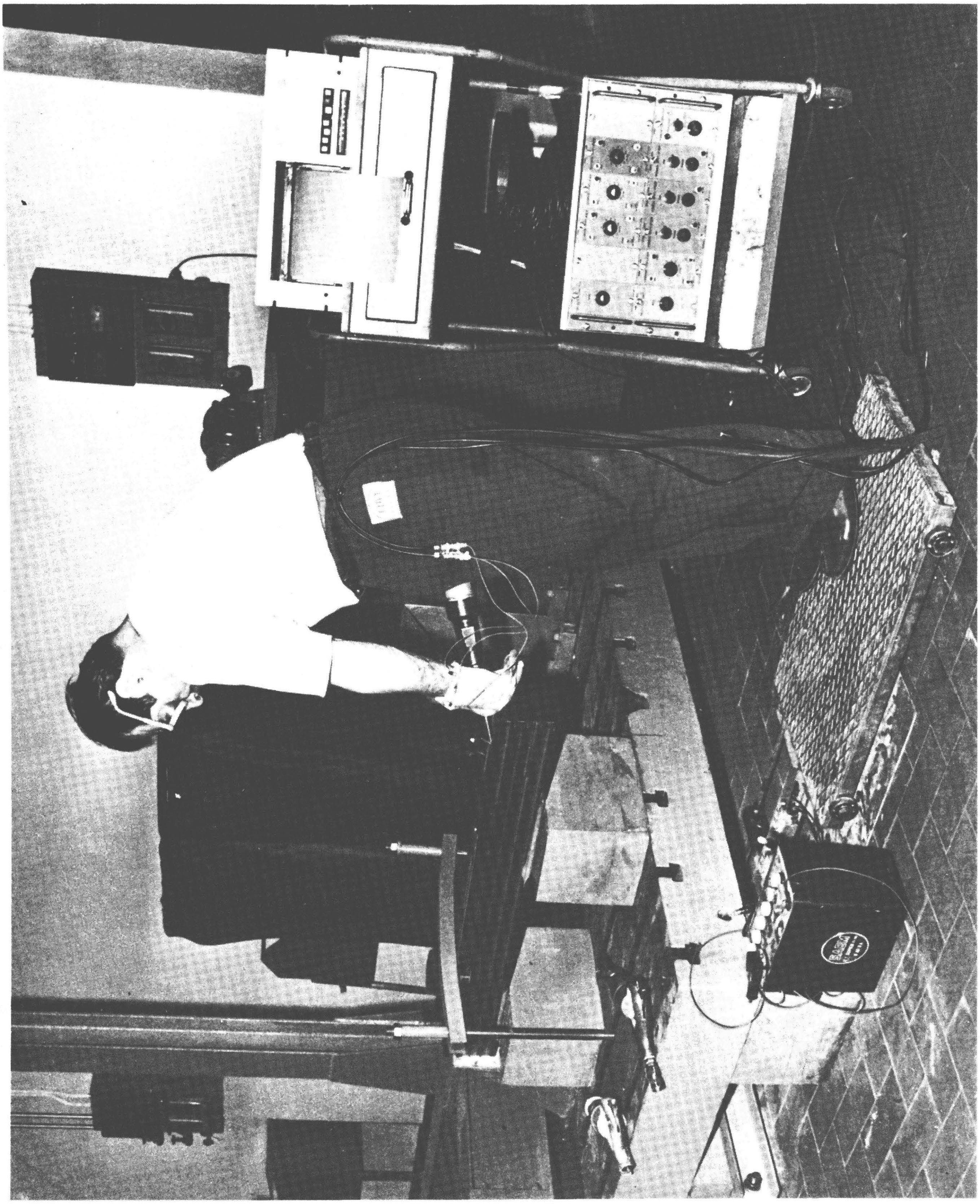
DIVISIONE SERV. di PRODUZIONE Servizio Lavoro	Damping sleeve on pneumatic chisel hammer	Annex 2



HAMMER No. 4

Pneumatic hammer FIAP-MS4





Timer 0.1 sec.   Paper speed : 1500 mm/sec.

transv. 1 g/mm

vert. 1 g/mm

long. 1 g/mm

HAMMER No. 1

HAMMER No. 2

Long. 1 g/mm

Vert. 1 g/mm

Transv. 1 g/mm

Timer : 0,1 s

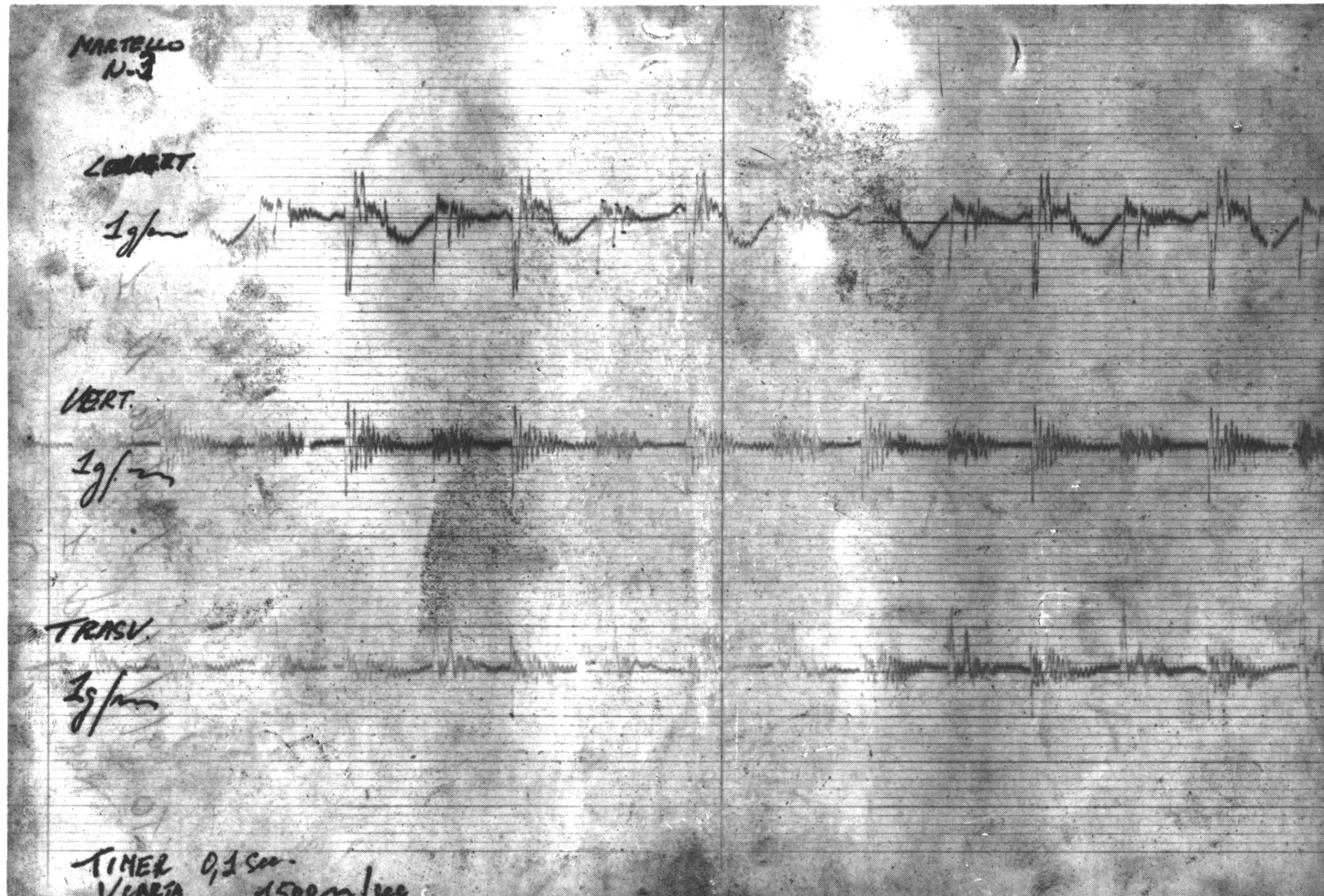
Paper speed : 1 500 mm/s

HAMMER No. 3

Long. 1 g/mm

vert. 1 g/mm

transv. 1 g/mm

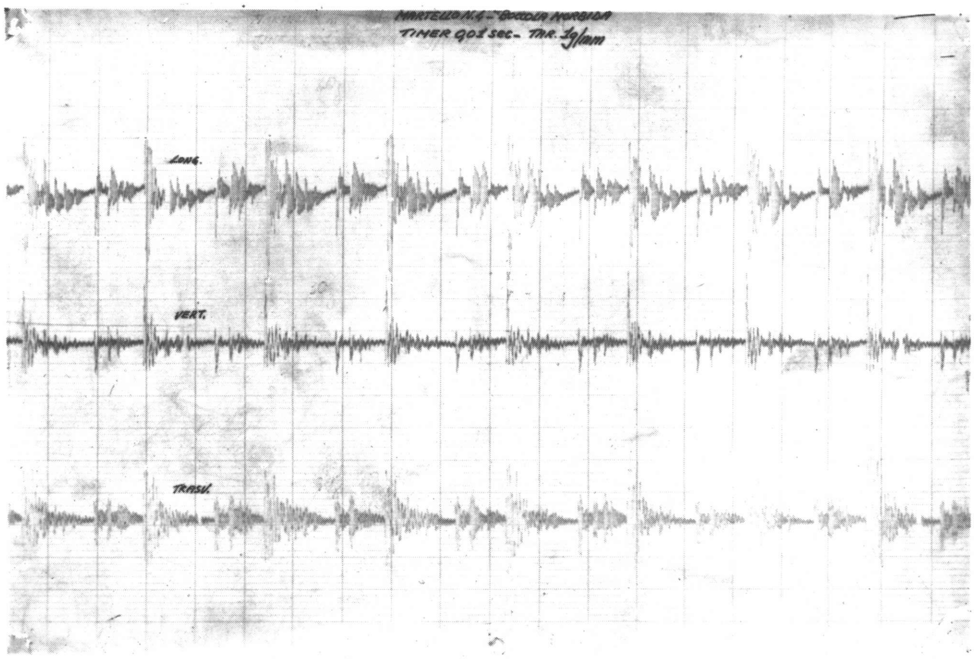


Timer : 0,1 s

Paper speed : 1 500 mm/s

HAMMER No. 4 - Soft bush

Timer 0.1 sec. - Cal. 1 g/m



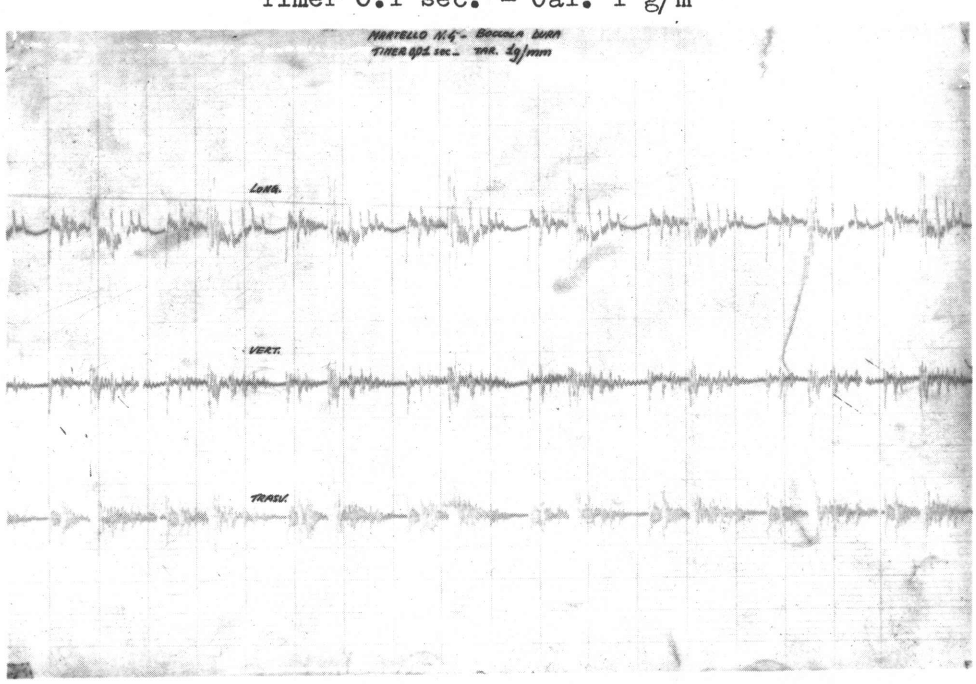
Long.

vert.

transv.

HAMMER No. 4 - Hard bush

Timer 0.1 sec. - Cal. 1 g/m



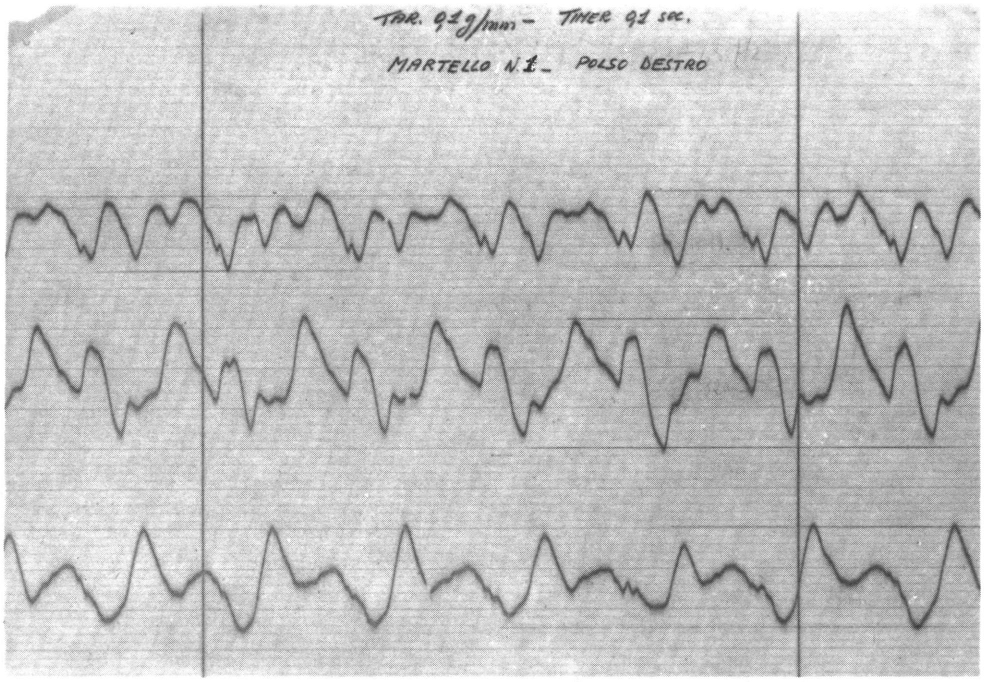
Long.

vert.

transv.

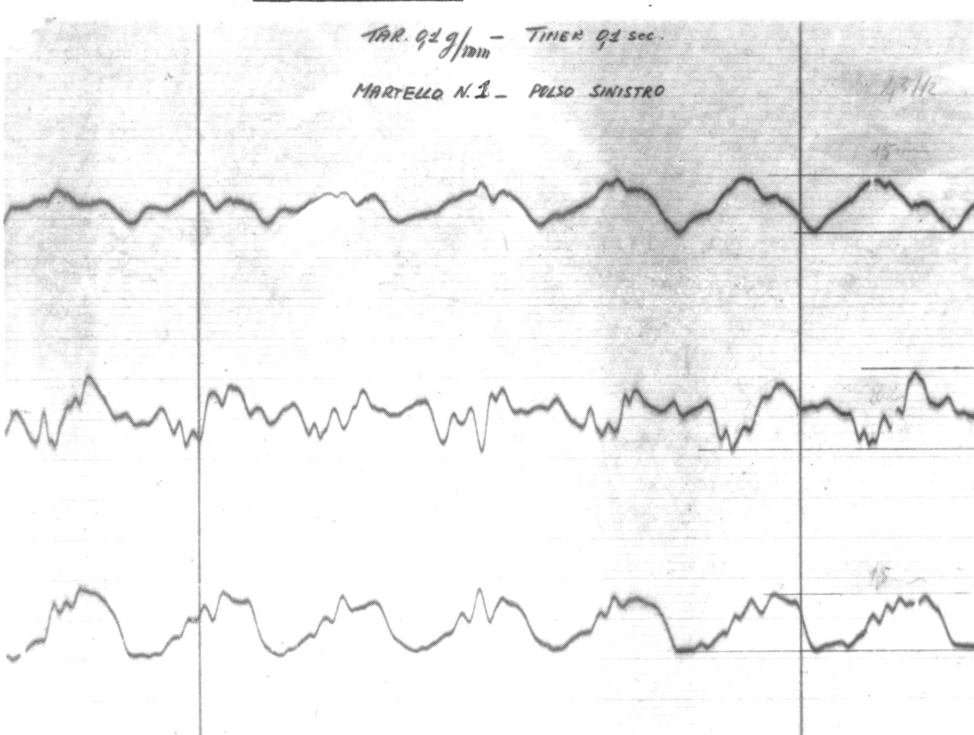
Cal. 1 g/mm - Timer 0.1 sec.

HAMMER No. 1 - right wrist



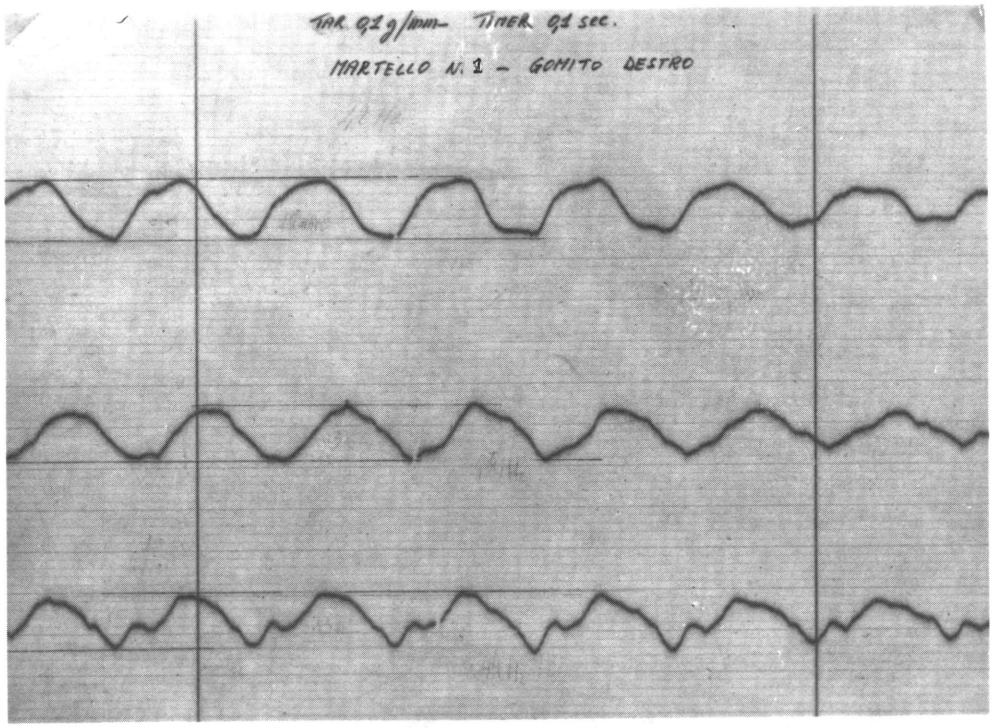
Cal. 1 g/mm - Timer 0.1 sec.

HAMMER No. 1 - left wrist



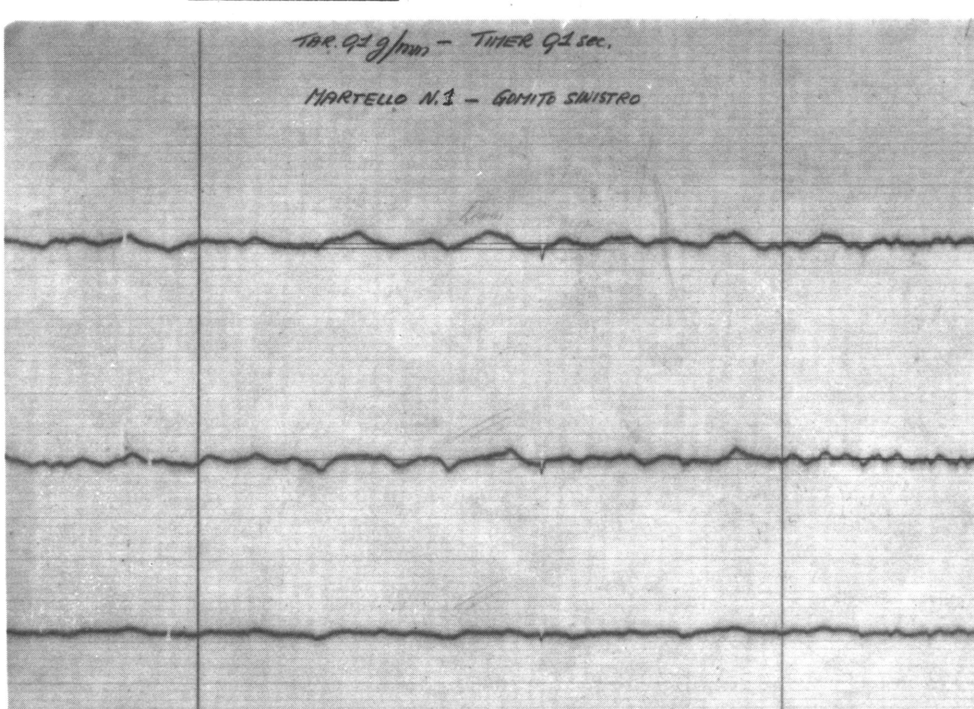
Cal. 1g/mm - Timer 0.1 sec.

<u>HAMMER No. 1</u> - right elbow



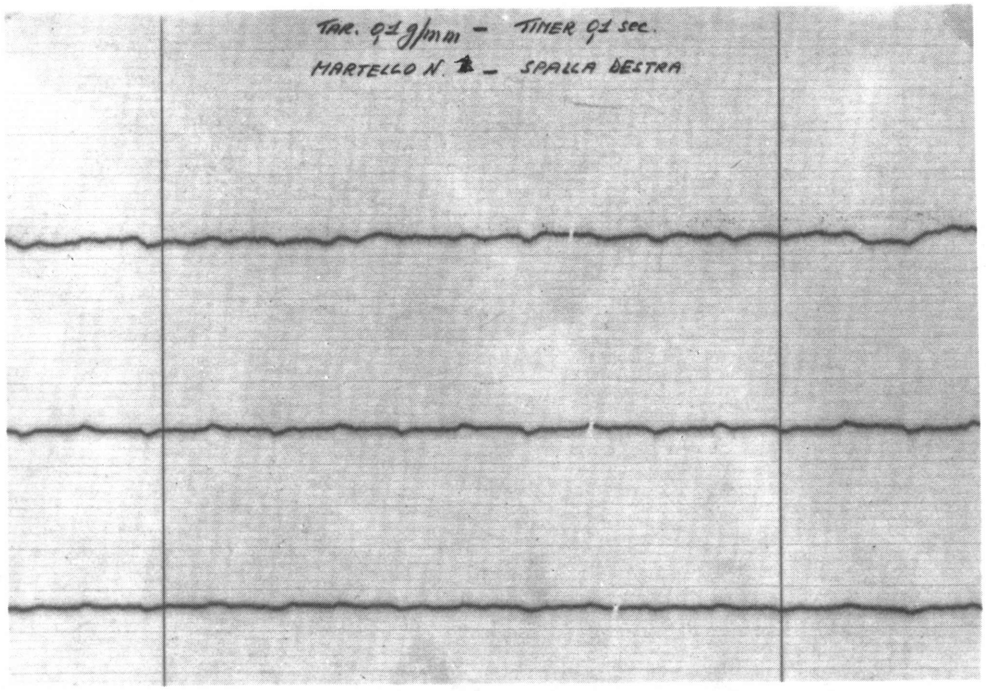
Cal. 1g/mm - Timer 0.1 sec.

<u>HAMMER No. 1</u> - left elbow



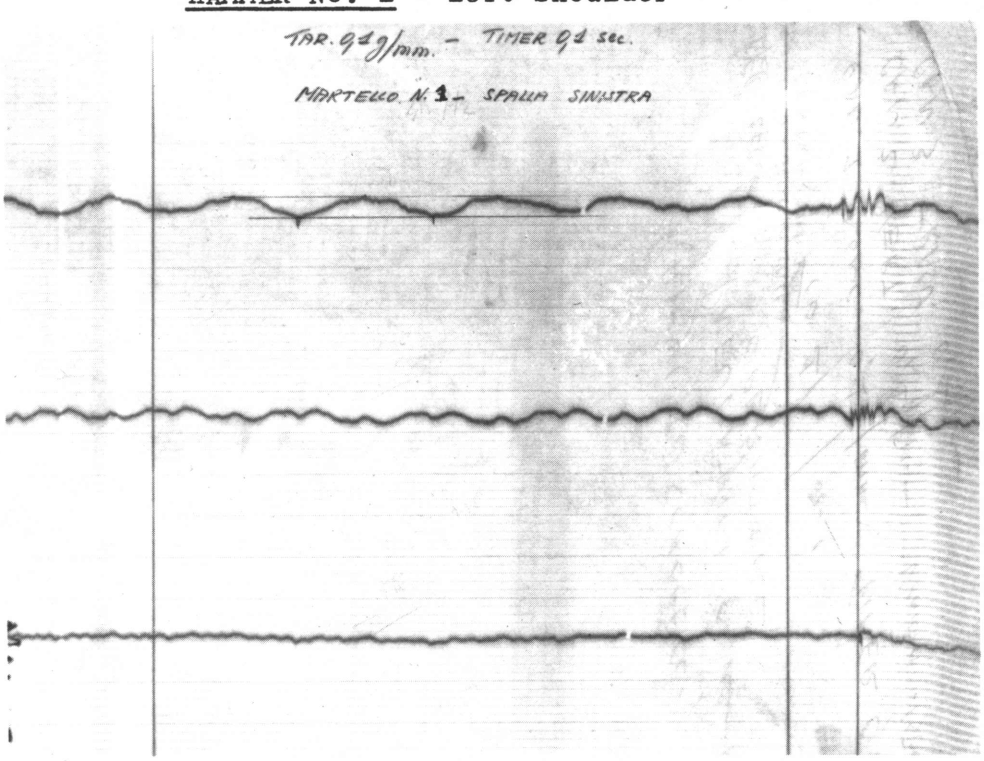
Cal. 1 g/mm - Timer 0.1 sec.

HAMMER No. 1 - right shoulder



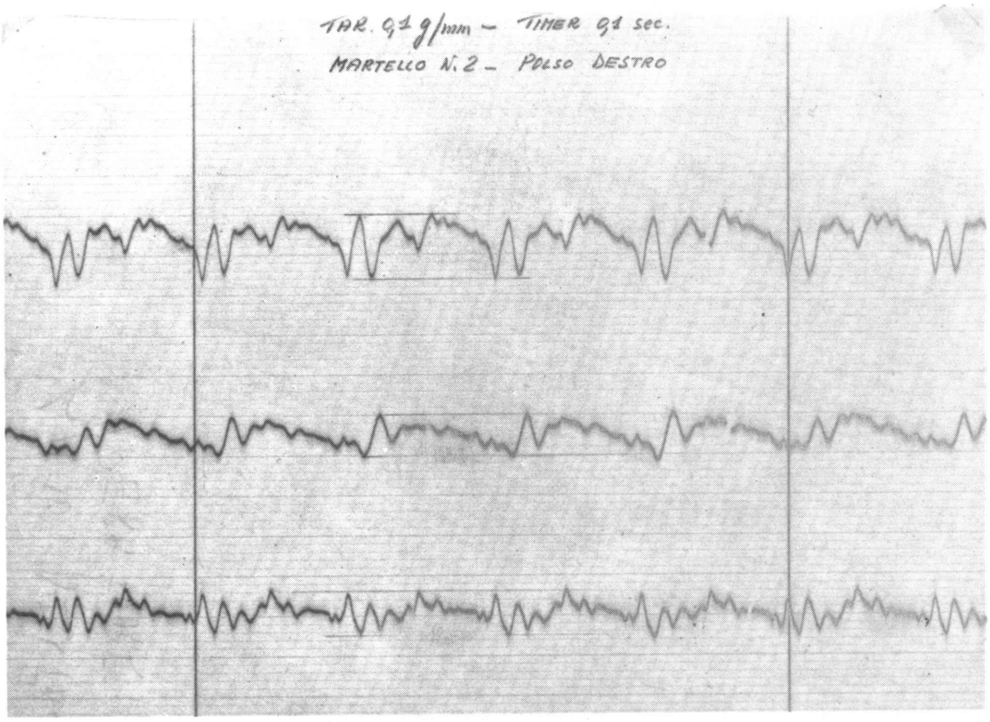
Cal. 1g/mm - Timer 0.1 sec.

HAMMER No. 1 - left shoulder



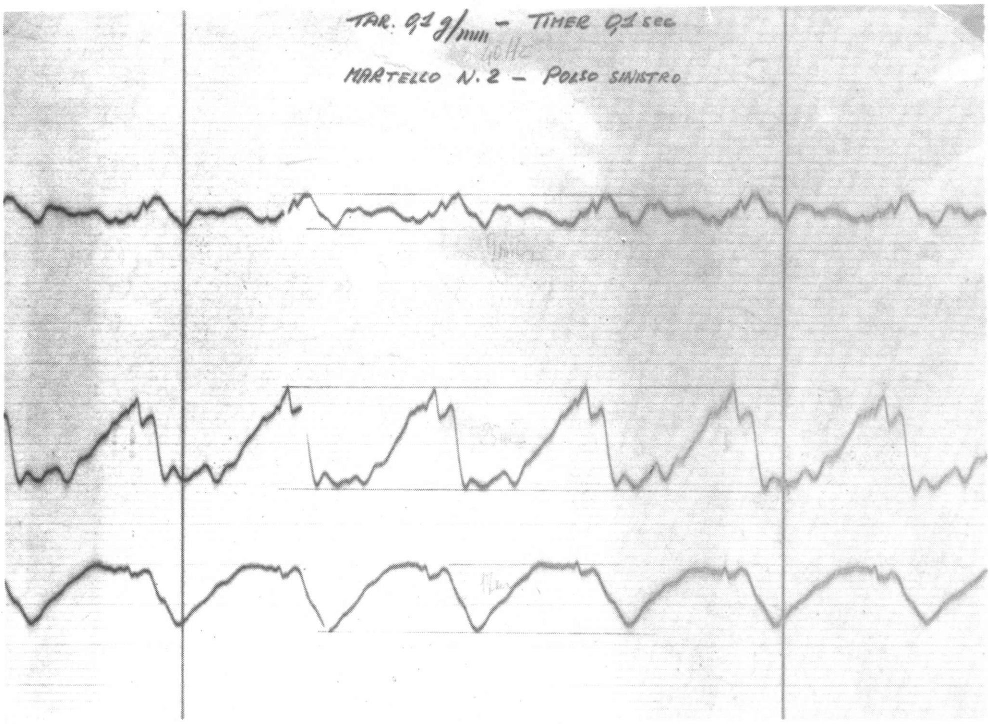
Cal. 1 g /mm - Timer 0.1 sec.

HAMMER No. 2 - Right wrist

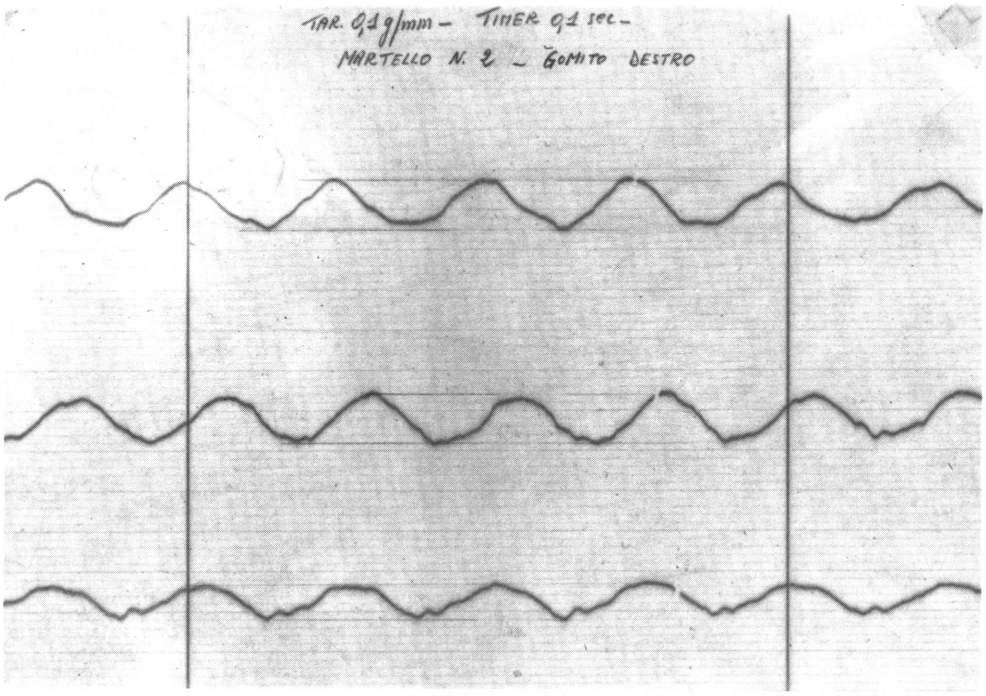


Cal. 1g/mm - Timer 0.1 sec.

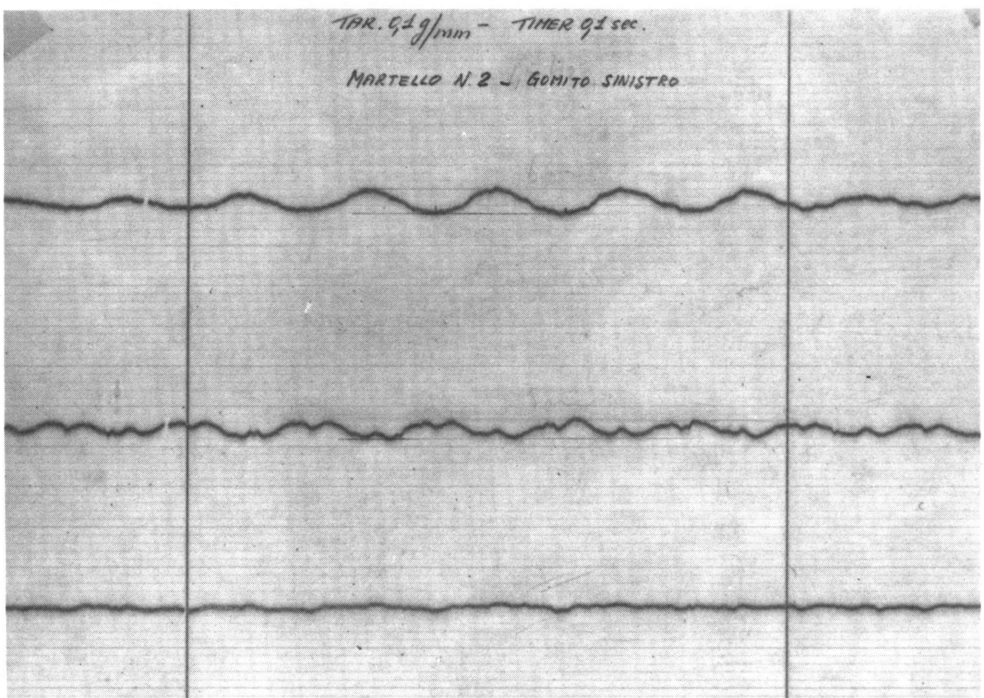
HAMMER No. 2 - Left wrist



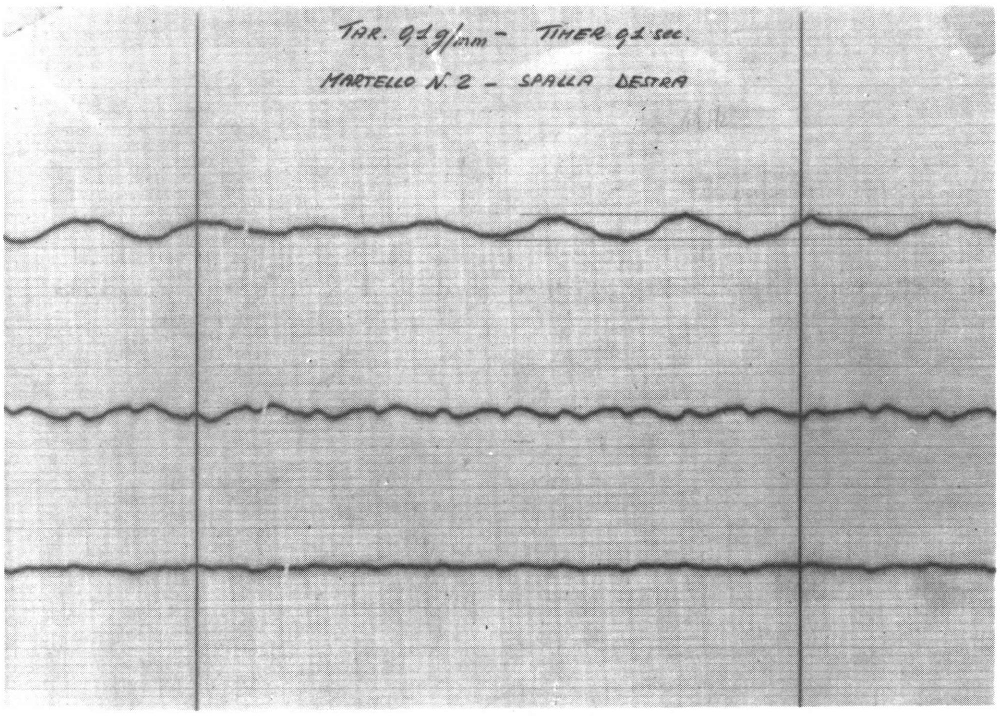
Cal. 1 g/mm - Timer 0.1 sec.
HAMMER No. 2 - right elbow



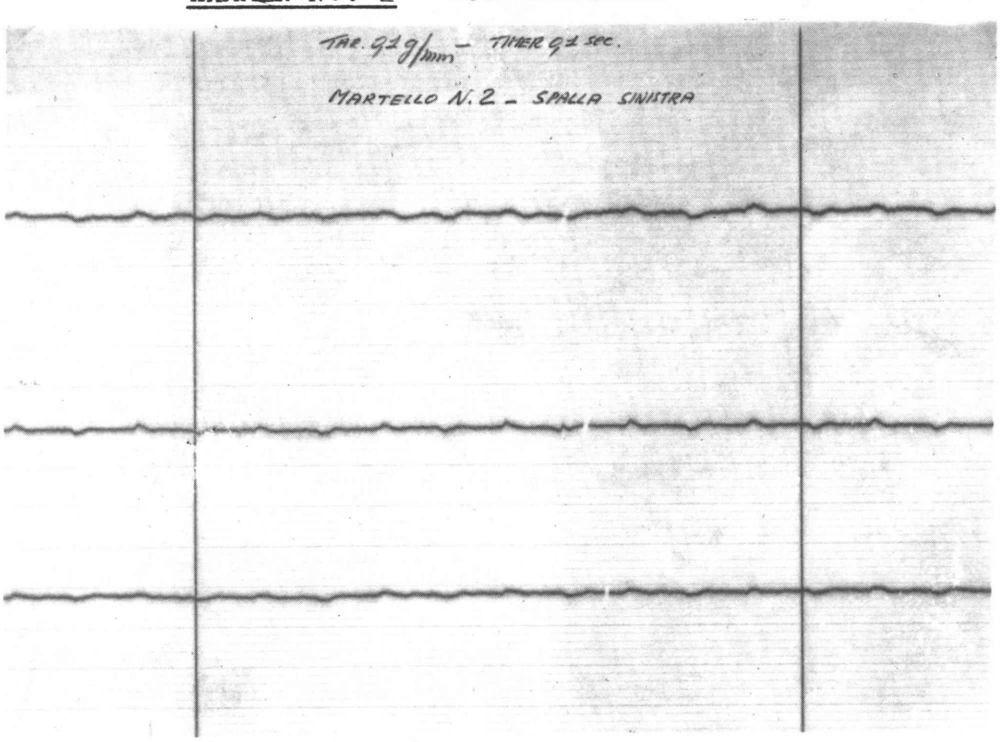
Cal. 1 g/mm - Timer 0.1 sec.
HAMMER No. 2 - left elbow



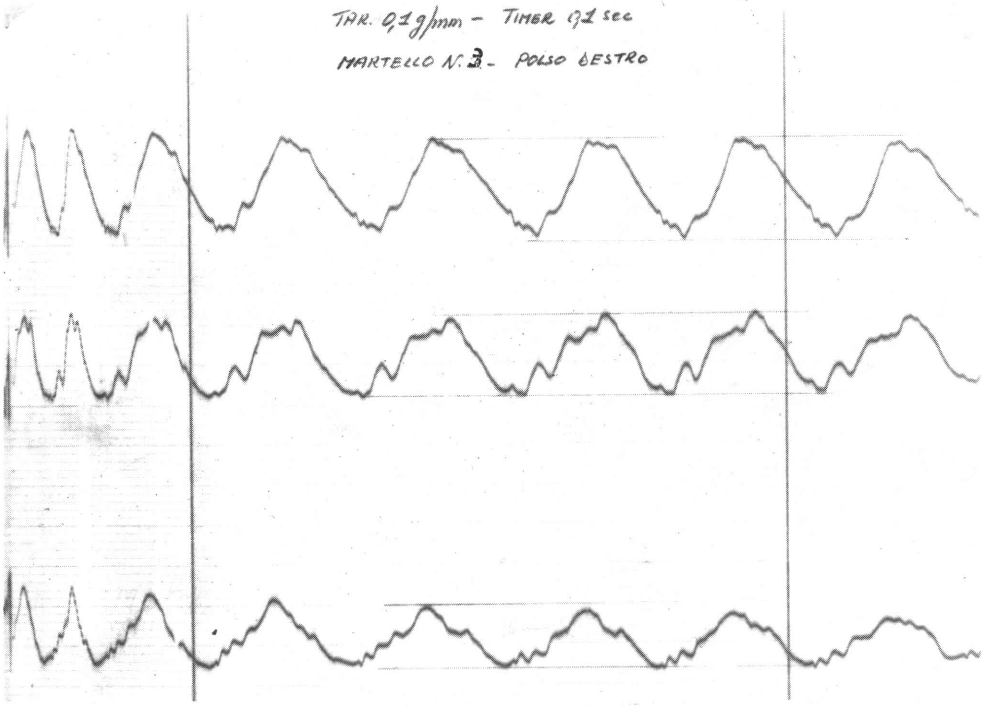
Cal. 1 g/mm - Timer 0.1 sec.
HAMMER No. 2 - right shoulder



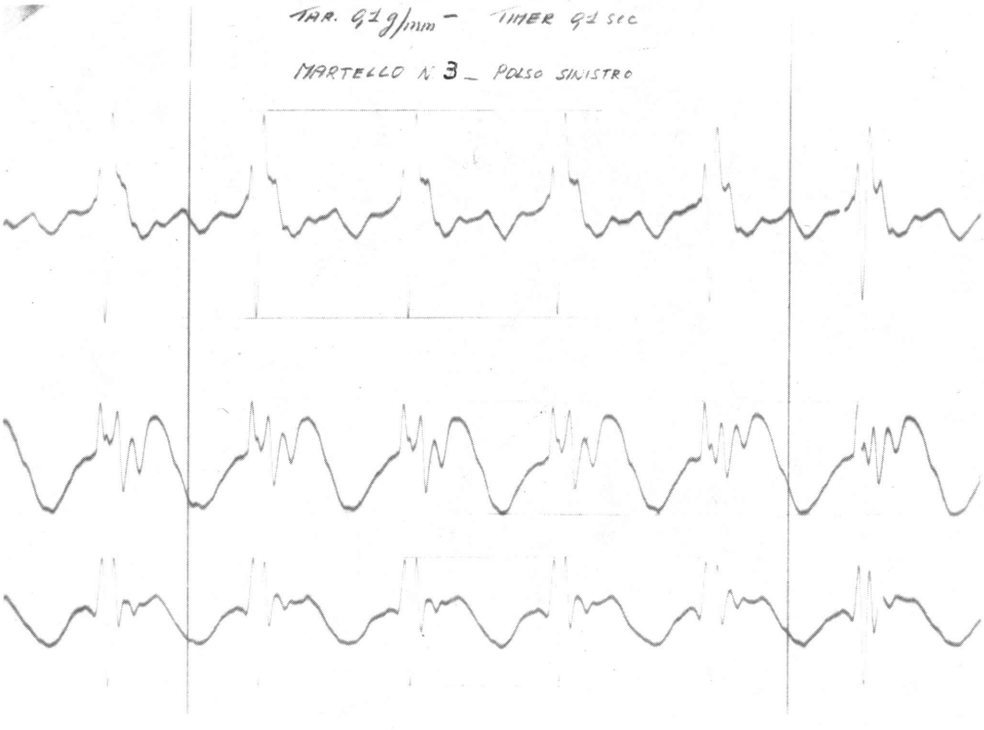
Cal. 1 g/mm - Timer 0.1 sec.
HAMMER No. 2 - left shoulder



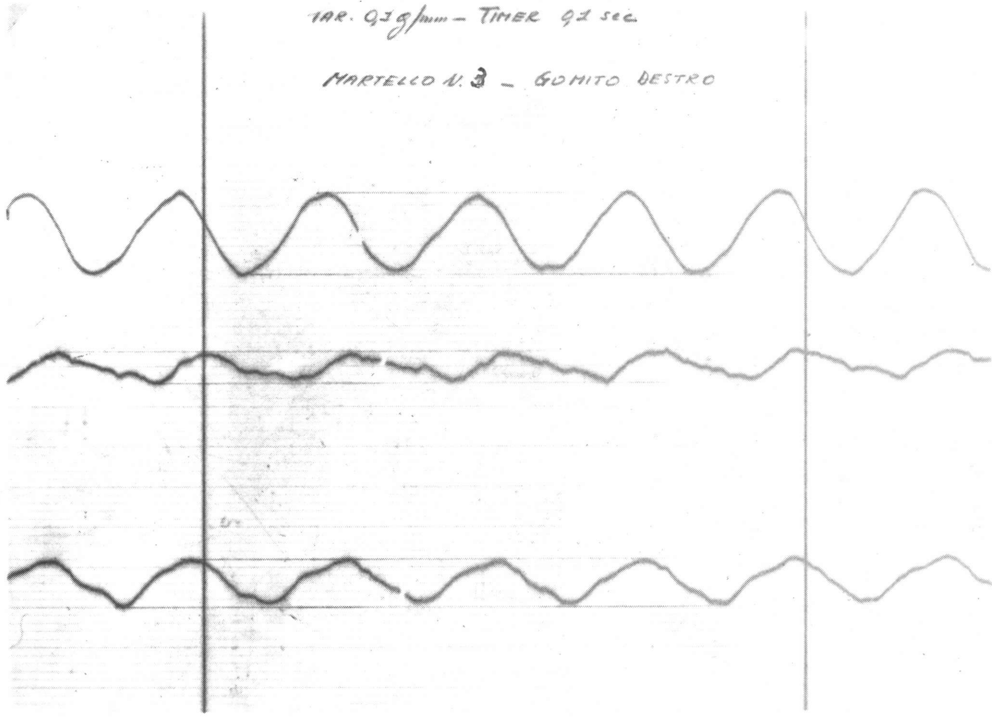
Cal. 1 g/mm - Timer 0.1 sec.
<u>HAMMER No. 3</u> - right wrist



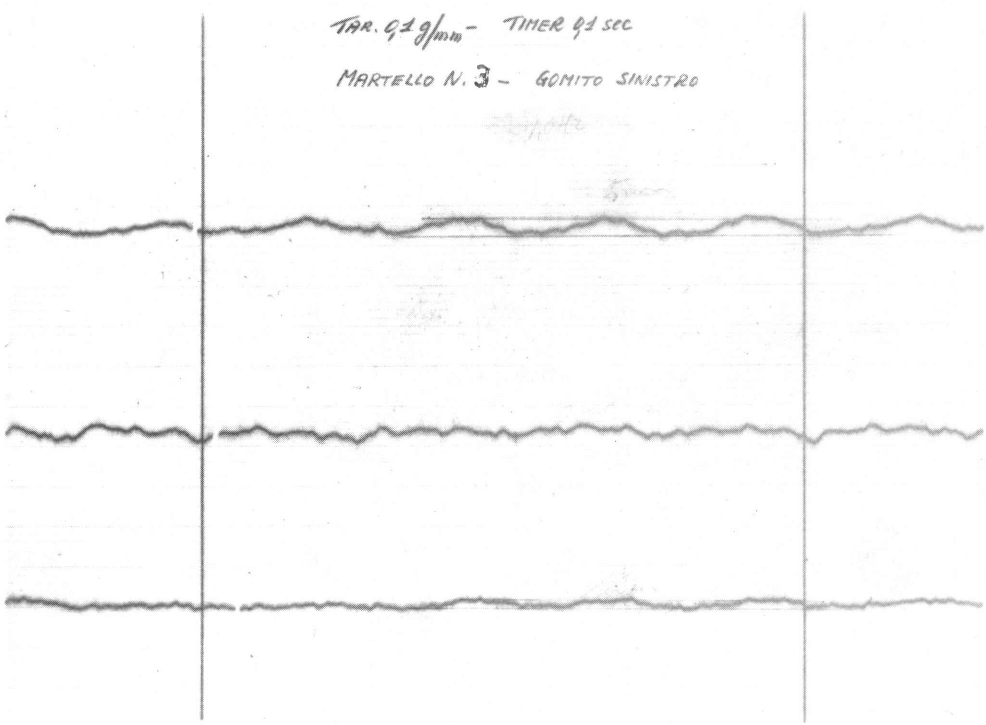
Cal. 1 g/mm - Timer 0.1 sec.
<u>HAMMER No. 3</u> - left wrist



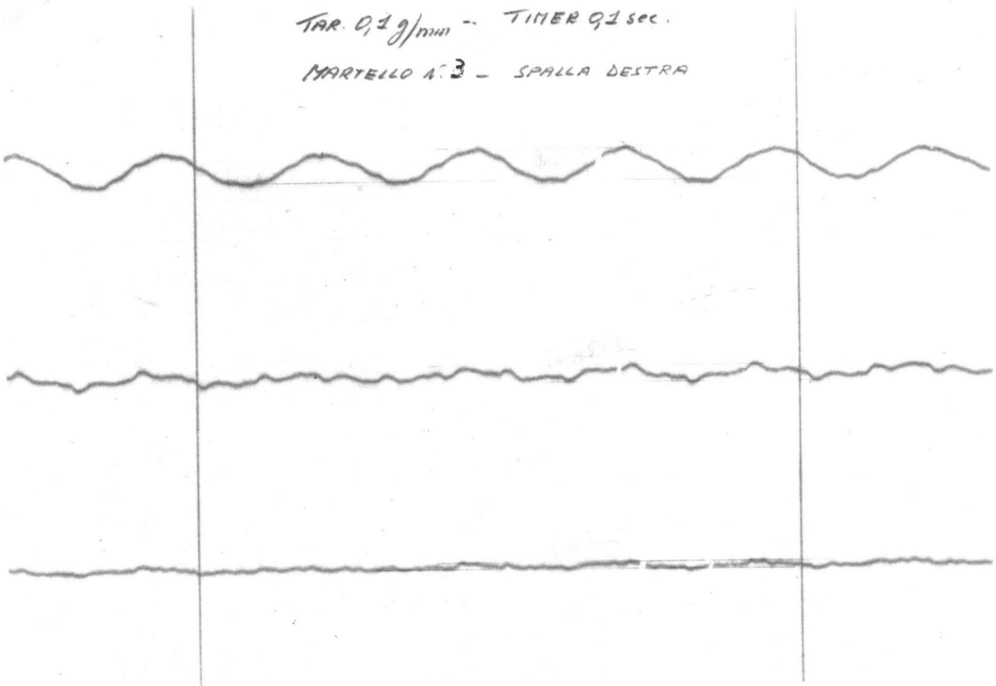
Cal. 1 g/mm - Timer 0.1 sec.
HAMMER No. 3 - right elbow



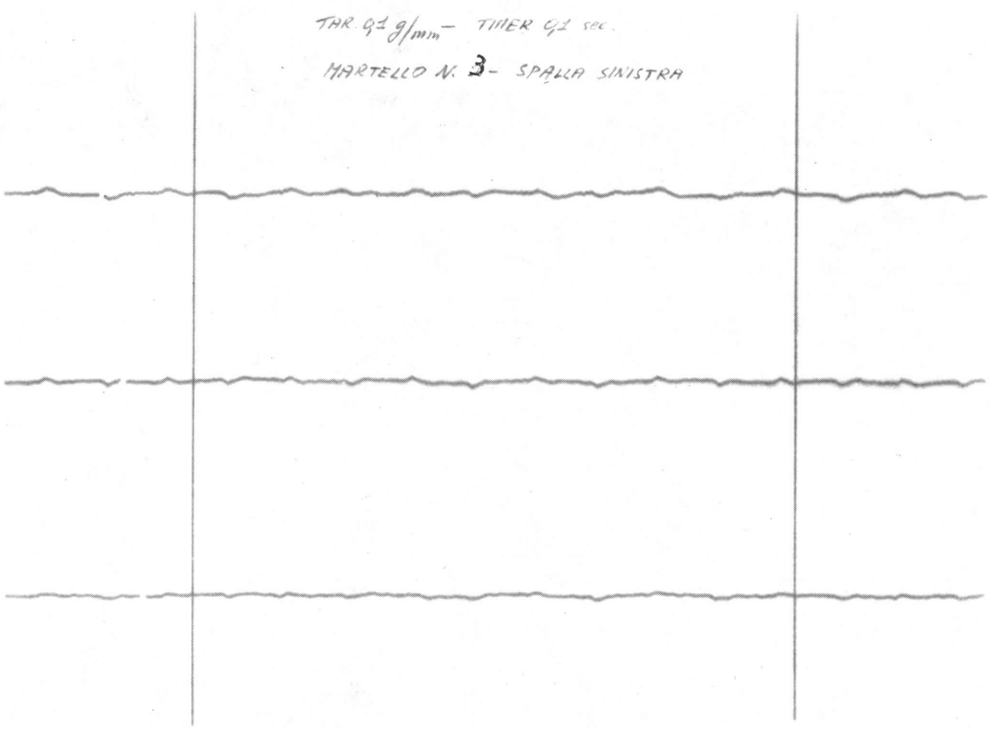
Cal. 1 g/mm - Timer 0.1 sec.
HAMMER No. 3 - left elbow



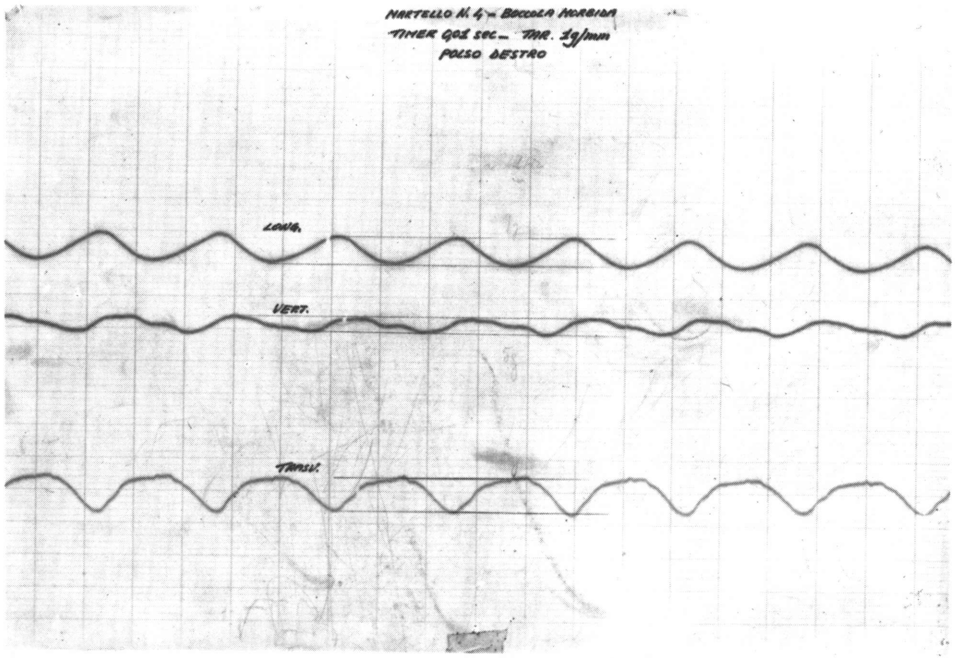
Cal. 1 g/mm - Timer 0.1 sec.
<u>HAMMER No. 3</u> - right shoulder



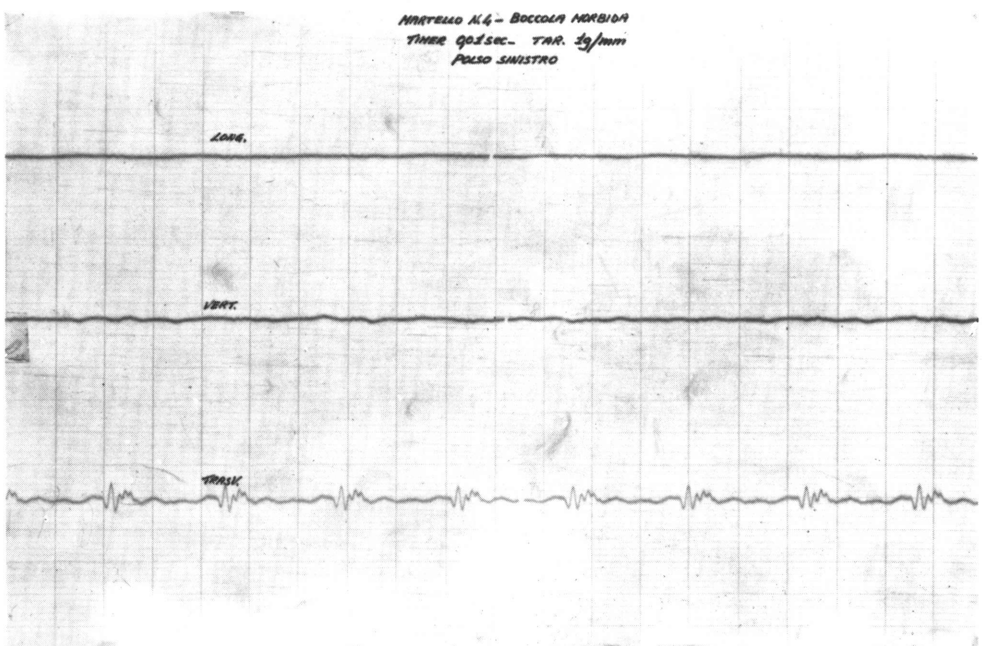
Cal. 1 g/mm - Timer 0.1 sec.
<u>HAMMER No. 3</u> - left shoulder



<u>HAMMER No. 4</u> - Soft damping bush
Timer 0.1 sec. - Cal. 1 g/mm
right wrist



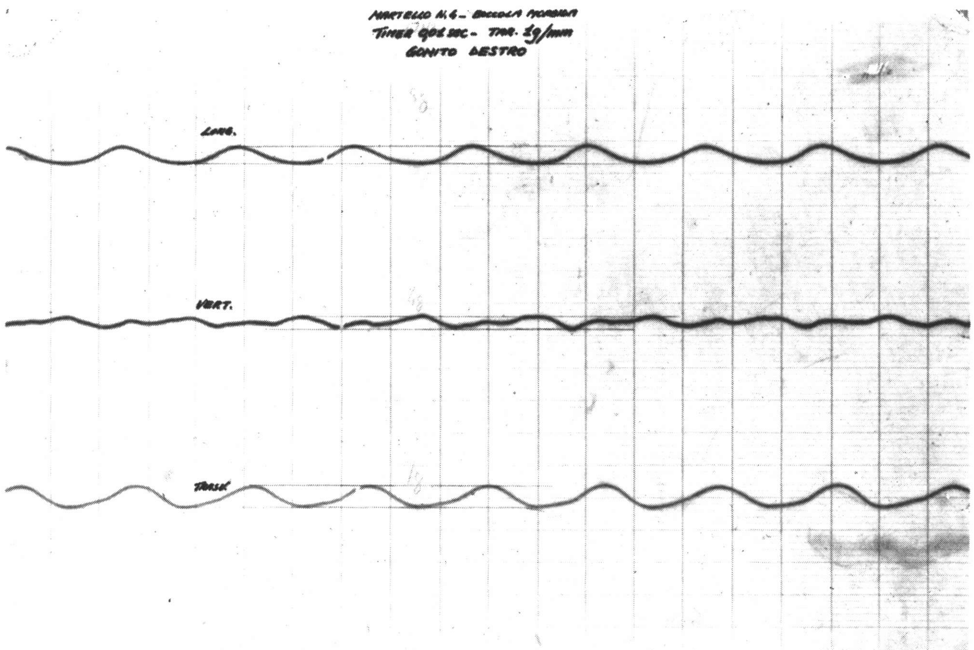
<u>HAMMER No. 4</u> - Soft damping bush
Timer 0.1 sec. - Cal. 1 g/mm
left wrist



<u>HAMMER No. 4</u> - Soft damping bush

Timer 0.1 sec. - Cal. 1 g/mm

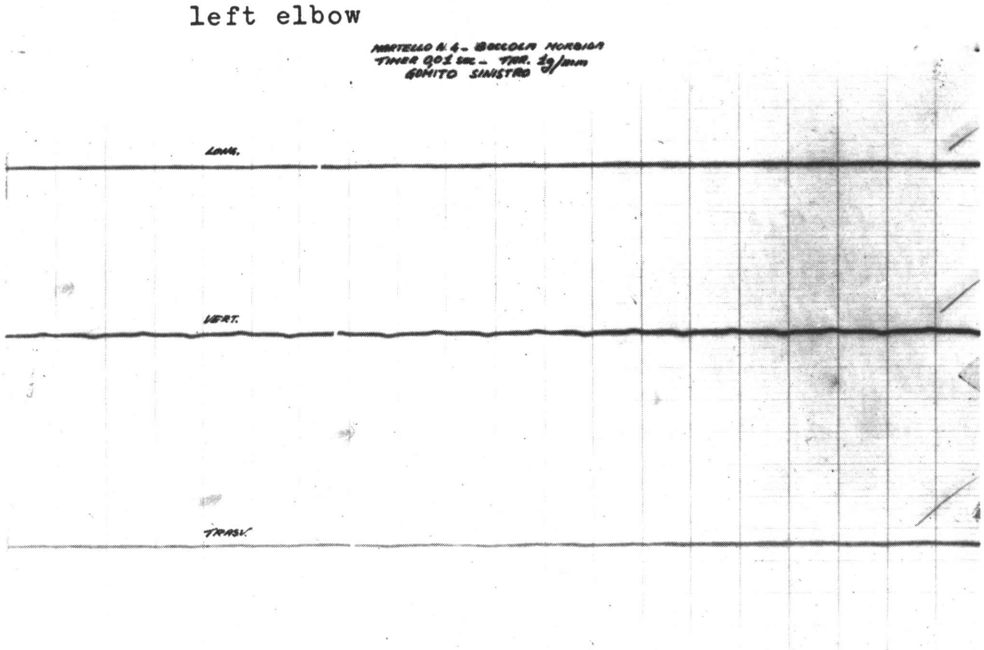
right elbow



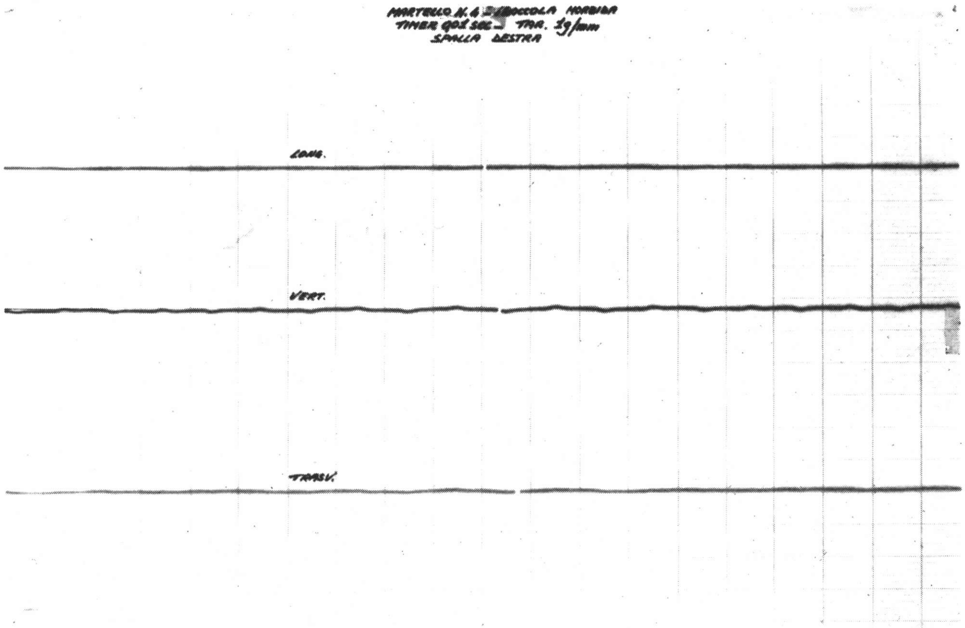
<u>HAMMER No. 4</u> - Soft damping bush

Timer 0.1 sec. - Cal. 1 g/mm

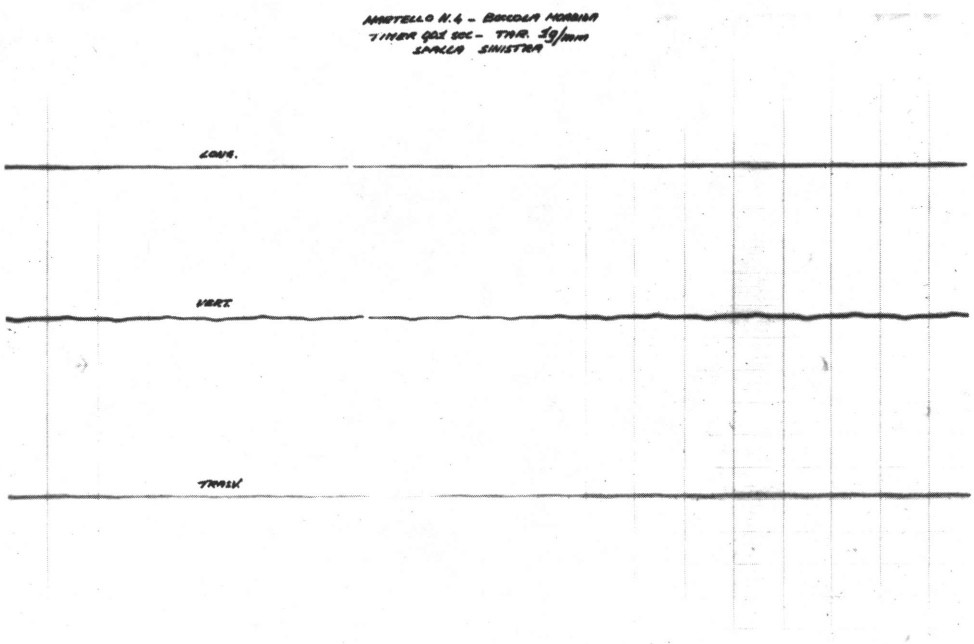
left elbow

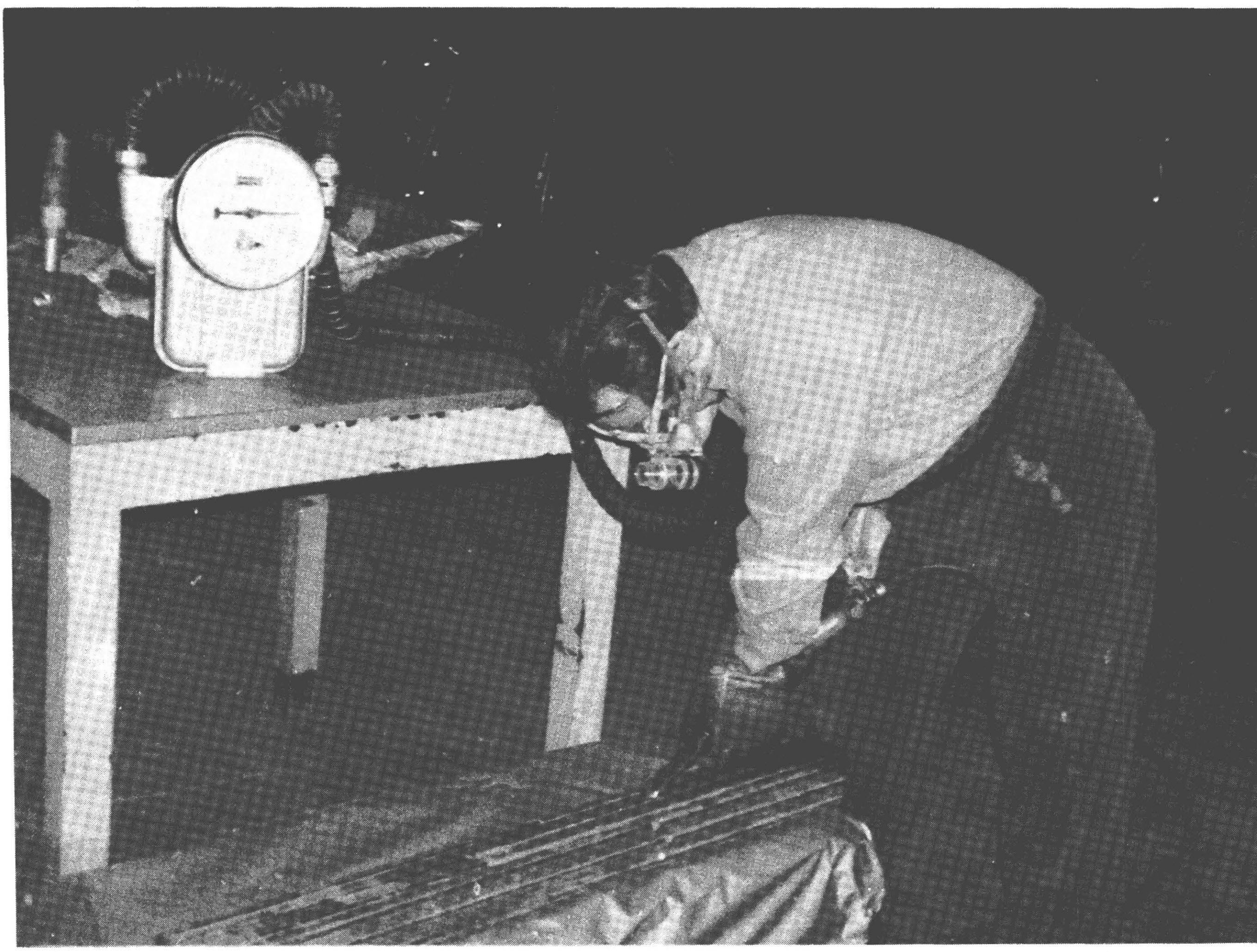


HAMMER No. 4 - Soft damping bush
Timer 0.1 sec. - Cal. 1 g/mm
right shoulder



HAMMER No. 4 - Soft damping bush
Timer 0.1 sec. - Cal. 1 g/mm
left shoulder





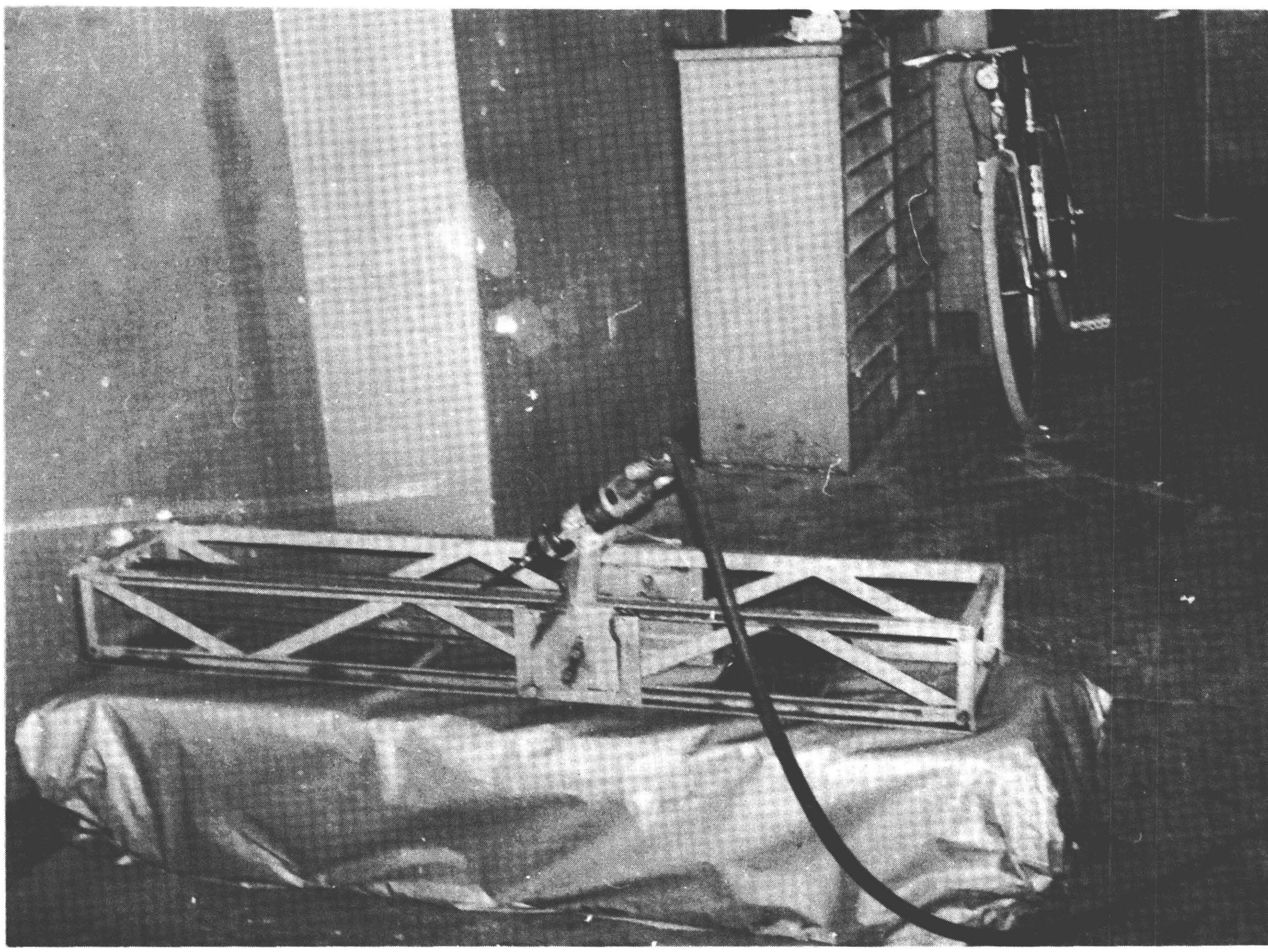


TABLE II

SUBJECT	HAMMER	VO_2 l/min.	R	Eq. Cal. O_2/l	Gross cal./min.	Weight g/min.
F.G	1)	0,4580	0,896	4,919	2,25	33,35
	3)	0,5126	0,848	4,858	2,49	40,17
	1)	0,4719	0,850	4,862	2,29	25,56
	4)	0,4915	0,840	4,850	2,38	28,28
	1)	0,6556	0,700	4,686	2,88	-
	3)	0,6106	0,780	4,776	2,91	-
	1)	0,4927	0,889	4,909	2,41	44,00
	4)	0,5183	0,804	4,805	2,49	44,56
	1)	0,5377	0,725	4,712	2,53	46,74
	3)	0,5307	0,773	4,770	2,53	48,93

TABLE III

SUBJECT	HAMMER	VO_2 l/min.	R	Eq.Cal. O_2/l	Gross cal./min.	Weight/min.
P.P.	1)	0,7075	0,820	4,825	3,41	-
	3)	0,7271	0,780	4,776	3,47	-
	1)	0,8033	0,832	4,840	3,88	41,60
	2)	0,9663	0,780	4,776	4,61	47,32
	1)	0,7311	0,934	4,969	3,63	45,77
	3)	0,7648	0,852	4,864	3,71	43,06
	1)	0,9630	0,878	4,895	4,71	40,01
	4)	1,0187	0,823	4,829	4,91	40,92
	1)	0,9331	0,878	4,895	4,56	31,66
	3)	0,9196	0,894	4,919	4,52	29,02
	1)	0,7732	0,836	4,838	3,74	36,60
	2)	0,8495	0,774	4,764	4,04	46,60

F.I.A.T. - MEDICAL DEPARTMENT
Industrial Hygiene Laboratory

Rec. No. 1 Date 30/1/73
Instrument : BRUEL & KJAER
Paper speed : 10 mm/sec
Pen speed : 250 mm/sec
Min. frequen. : 20 hz
Response corr. : RMS
Potentiometer : 50 db
Zero level : 60 db
Attenuation : .....db

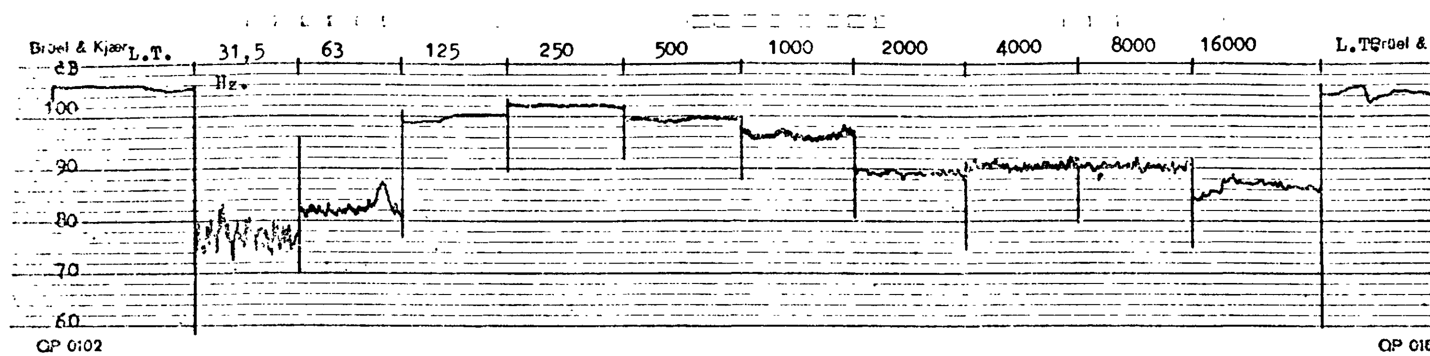
Sec. : FERRIERE Off. : .... Rep. : ....
Parameter measured : Noise level hammer No. 1 ....
....
....
....
....

Total level db

A	B	C	Lin.
			106

Sound spectrum

31.5 Hz	63	125	250	500	1000	2000	4000	8000	16000	Lin. db
77	82	100	102	100	96	89	90	90	87	105



F.I.A.T. - MEDICAL DEPARTMENT

Industrial Hygiene Laboratory

Rec. No. 2 Date 30/1/73

Instrument : BRUEL & KJAER

Paper speed : 10 mm/sec

Pen speed : 250 mm/sec

Min. frequen. : 20 hz

Response corr. : RMS

Potentiometer : 50 db

Zero level : 60 db

Attenuation : .....db

Sec.: FERRIERE Off. : .... Rep. : ....

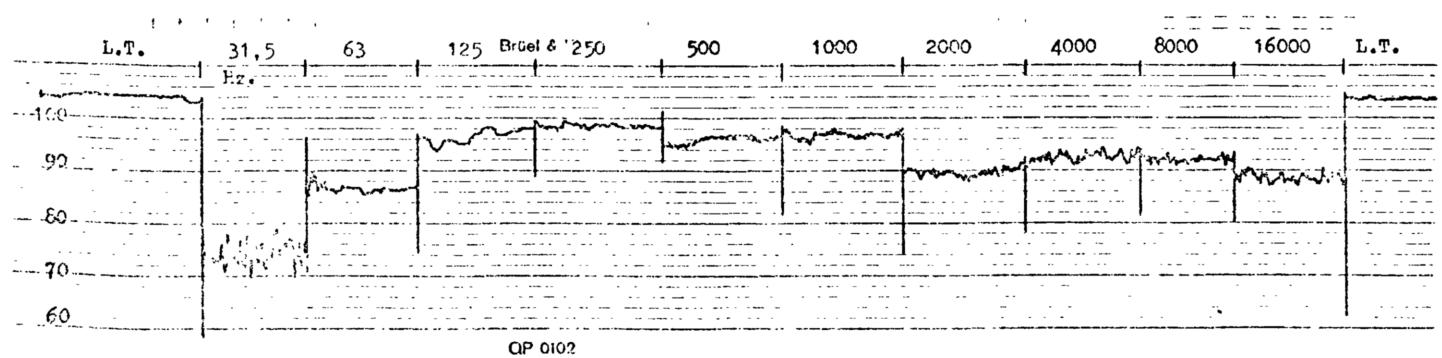
Parameter measured : Noise level hammer No. 2 ....

Total level db

A	B	C	Lin.
			104

Sound spectrum

31.5 Hz	63	125	250	500	1000	2000	4000	8000	16000	Lin. db
74	86	96	99	96	97	90	93	92	88	104



F.I.A.T. - MEDICAL DEPARTMENT
Industrial Hygiene Laboratory

Rec. No. 3 Date 30/1/73

Instrument : BRUEL & KJAER
Paper speed : 10 mm/sec.
Pen speed : 250 mm/sec.
Min. frequenc. : 20 hz
Response corr. : RMS
Potentiometer : 50 db
Zero level : 60 db
Attenuation : .....db

Sec.: FERRIERE Off. : .... Rep. : ....

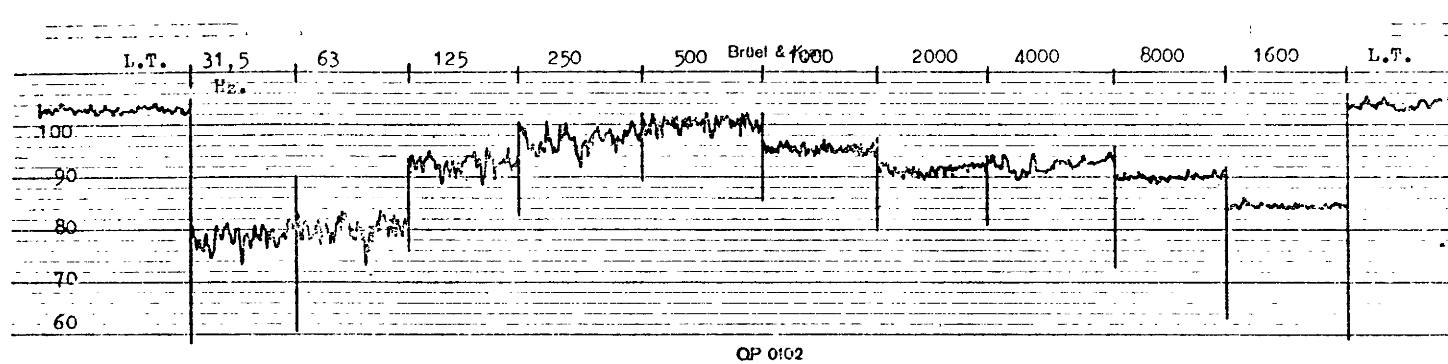
Parameter measured : Noise level hammer No. 3 ....

Total level db

A	B	C	Lin.
			103

Sound spectrum

31.5 Hz	63	125	250	500	1000	2000	4000	8000	16000	Lin. db
78	80	93	97	100	95	91	92	90	84	104



F.I.A.T. - MEDICAL DEPARTMENT

Industrial Hygiene Laboratory

Rec. No. 4 Date 30/1/73

Instrument : BRUEL & KJAER

Paper speed : 10 mm/sec.

Pen speed : 250 mm/sec.

Min. frequen. : 20 hz

Response corr. : RMS

Potentiometer : 50 db

Zero level : 60 db

Attenuation : .....db

Sec. : FERRIERE Off. : .... Rep. : ....

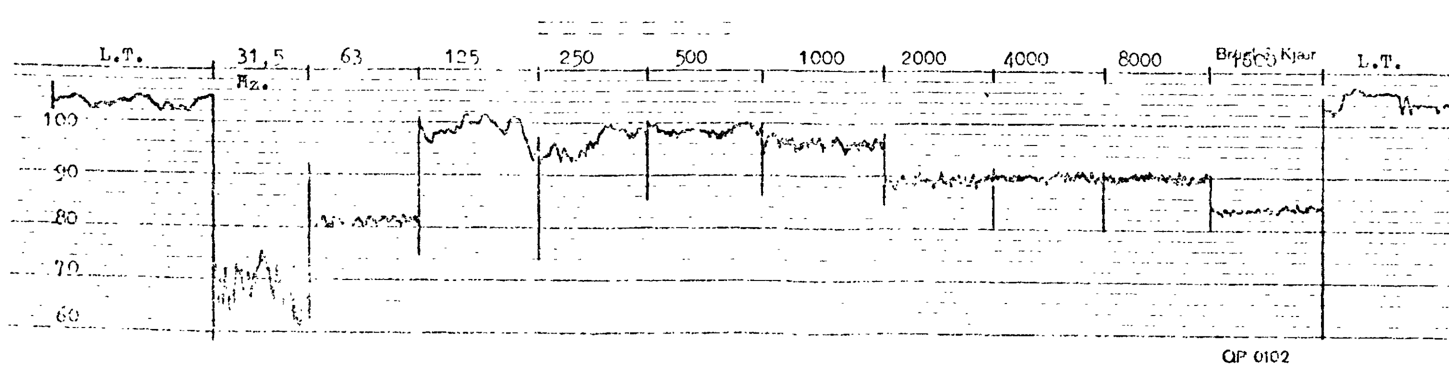
Parameter measured : Noise level hammer No. 4 ....

Total level db

A	B	C	Lin.
			103

Sound spectrum

31.5 Hz	63	125	250	500	1000	2000	4000	8000	16000	Lin. db
70	81	99	98	98	96	89	90	90	84	105



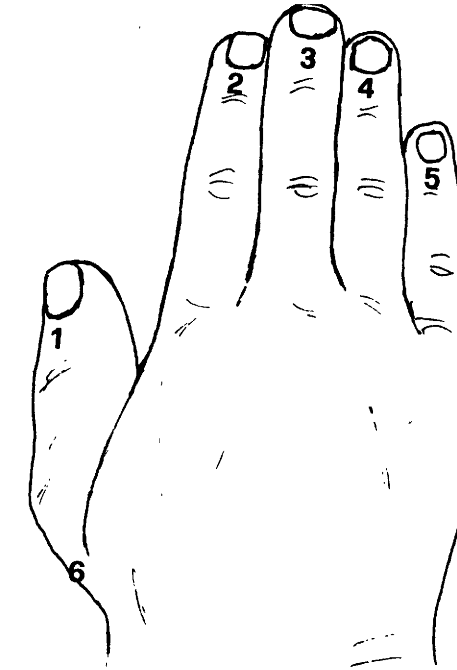
<u>TABLE IV</u> - Tactile stimulation threshold g/mm^2

RIGHT HAND - BACK

	1	2	3	4	5	6	7
average $\pm\sigma$ control grp	3,92 $\pm$ 0,83	3,88 $\pm$ 0,84	3,97 $\pm$ 0,90	4,18 $\pm$ 0,90	3,39 $\pm$ 0,67	4,15 $\pm$ 0,74	4,47 $\pm$ 0,84
average $\pm\sigma$ cleaning workers	5,00 $\pm$ 1,20	6,12 $\pm$ 1,61	6,00 $\pm$ 0,73	5,96 $\pm$ 1,74	5,24 $\pm$ 0,87	6,41 $\pm$ 2,11	6,31 $\pm$ 2,17
diff.	1,08	2,24	2,03	1,78	1,85	2,26	1,84
t	3,22	5,25	7,72	3,96	7,33	4,40	3,45
P	$>$ 0,01	$>$ 0,001	$>$ 0,001	$>$ 0,001	$>$ 0,001	$>$ 0,001	0,001

RIGHT HAND - PALM

	1	2	3	4	5	6	7
average $\pm\sigma$ control grp	4,47 $\pm$ 0,85	4,18 $\pm$ 0,97	4,13 $\pm$ 0,84	3,99 $\pm$ 0,83	3,97 $\pm$ 0,90	4,50 $\pm$ 0,91	4,63 $\pm$ 0,57
average $\pm\sigma$ cleaning workers	5,85 $\pm$ 1,67	5,47 1,82	5,59 0,93	5,17 0,97	5,30 0,98	6,92 2,27	6,28 1,56
diff.	1,38	1,26	1,46	1,25	1,33	2,42	1,65
t	3,21	2,65	5,10	4,26	4,36	4,32	4,33
P	$>$ 0,01	$\sim$ 0,01	$>$ 0,001	$>$ 0,001	$>$ 0,001	$>$ 0,001	$>$ 0,001



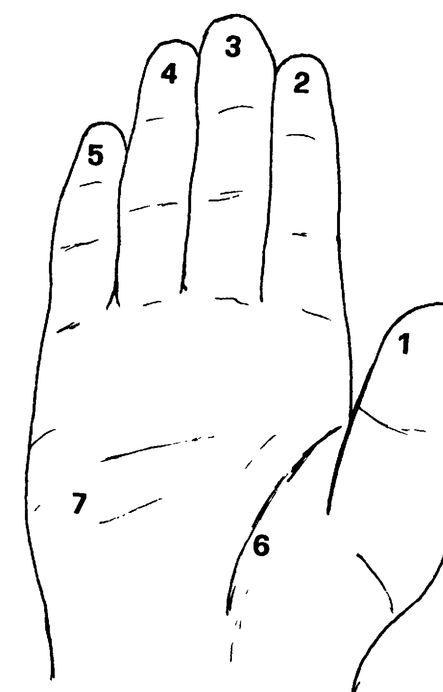


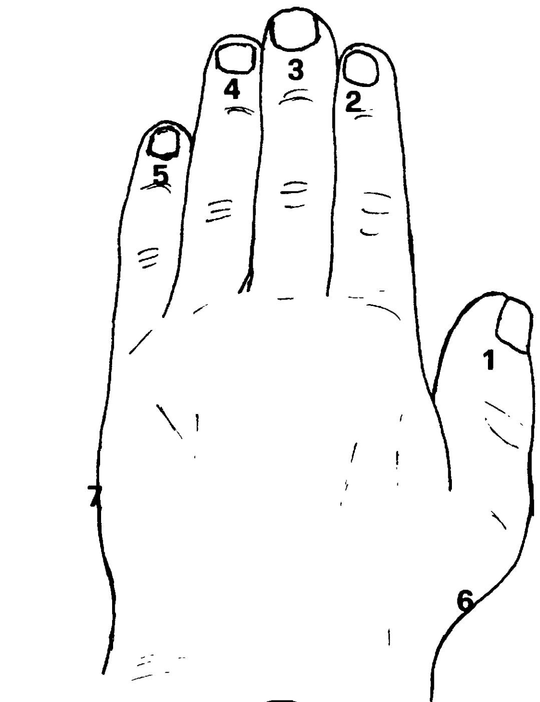
TABLE V - Tactile stimulation threshold

LEFT HAND - BACK

	1	2	3	4	5	6	7
average $\pm\sigma$ control gr.	3,71 $\pm$ 0,88	4,21 $\pm$ 0,80	4,10 $\pm$ 0,93	3,71 $\pm$ 0,76	3,47 $\pm$ 0,71	4,00 $\pm$ 0,81	4,44 $\pm$ 0,59
average $\pm\sigma$ cleaning workers	5,03 $\pm$ 0,97	5,26 $\pm$ 0,65	5,62 $\pm$ 1,07	5,46 $\pm$ 1,69	4,93 $\pm$ 0,98	5,84 $\pm$ 1,36	6,28 $\pm$ 1,32
diff.	1,32	1,05	1,52	1,75	1,46	1,84	1,84
t	4,71	4,77	4,90	4,37	5,61	5,41	5,93
P	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001

LEFT HAND - PALM

	1	2	3	4	5	6	7
average $\pm\sigma$ control gr.	4,32 $\pm$ 0,97	3,90 $\pm$ 0,99	3,83 $\pm$ 0,76	3,58 $\pm$ 0,75	3,94 $\pm$ 0,74	4,25 $\pm$ 0,57	4,55 $\pm$ 0,77
average $\pm\sigma$ cleaning workers	5,25 $\pm$ 0,99	5,31 $\pm$ 0,72	5,32 $\pm$ 0,80	5,10 $\pm$ 0,61	5,25 $\pm$ 0,84	6,60 $\pm$ 2,44	6,60 $\pm$ 4,16
diff.	0,93	1,41	1,49	1,52	1,31	2,35	2,05
t	2,92	5,10	5,82	6,87	5,09	3,99	4,16
P	> 0,01	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001



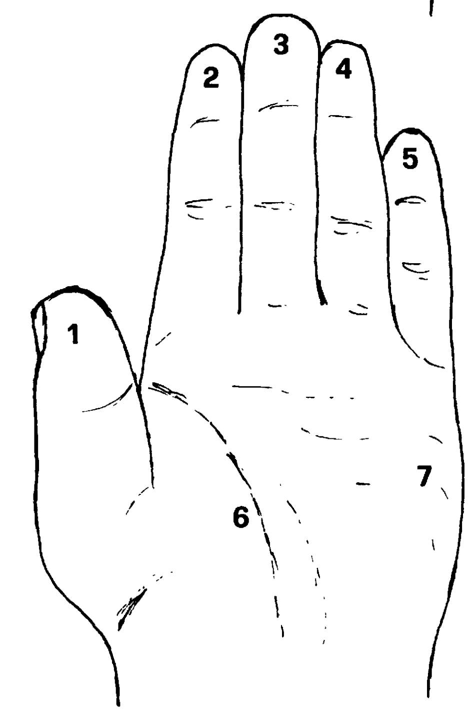
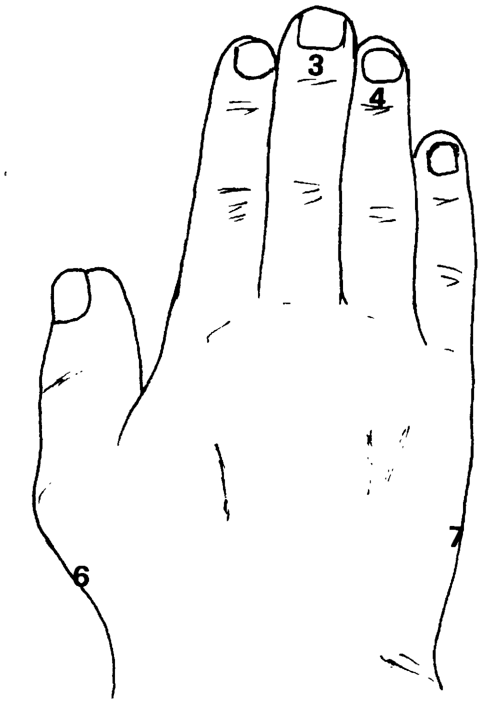


TABLE VI - Tactile discrimination - Right hand - Back

	3	4	6	7
Average $\pm\sigma$ Control gr.	3,00 $\pm$ 1,04	3,11 $\pm$ 0,93	10,98 $\pm$ 4,46	7,03 $\pm$ 3,47
Average $\pm\sigma$ Cleaning workers	5,11 $\pm$ 2,17	5,66 $\pm$ 2,45	11,42 $\pm$ 5,12	11,24 $\pm$ 7,29
diff.	2,11	2,55	0,44	4,21
t	3,83	4,23	0,28	2,28
P	> 0,001	> 0,001	~ 0,80	0,05-0,02

Right hand - palm

	3	4	6	7
Average $\pm\sigma$ Control gr.	2,31 $\pm$ 0,51	2,45 $\pm$ 0,57	9,55 $\pm$ 3,79	6,71 $\pm$ 2,71
Average $\pm\sigma$ Cleaning workers	3,61 $\pm$ 1,48	3,98 $\pm$ 1,08	10,81 $\pm$ 6,18	8,68 $\pm$ 4,55
Diff.	1,30	1,53	1,26	1,97
t	3,60	5,44	0,77	1,63
P	> 0,001	> 0,001	~ 0,50	~ 0,10



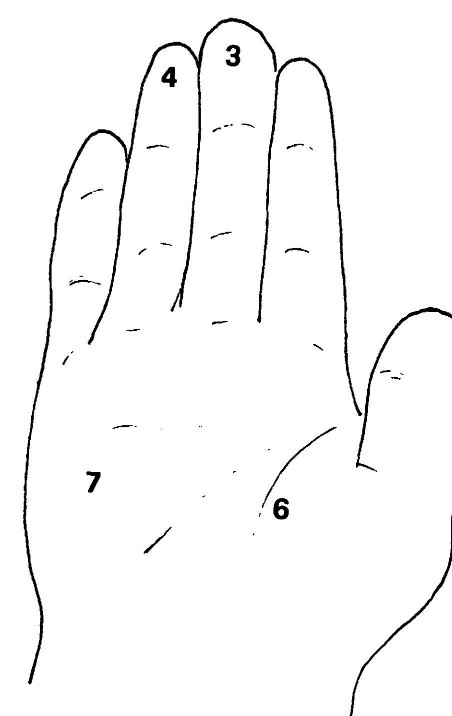
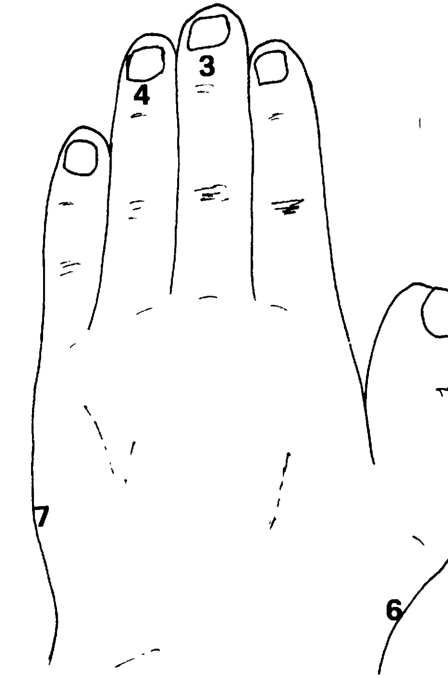


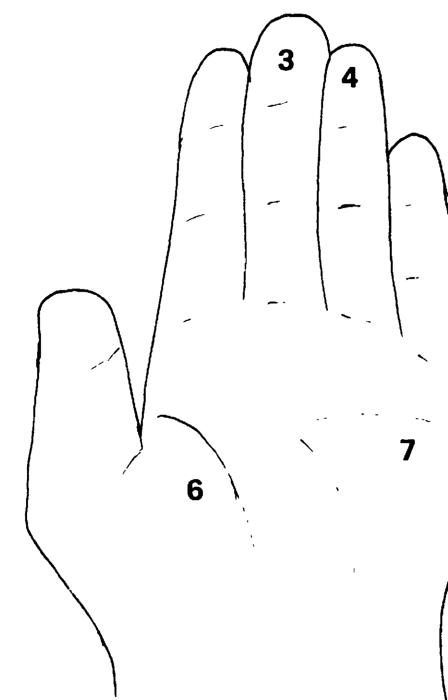
TABLE VII - Tactile discrimination - Left hand - Back

	3	4	6	7
Average $\pm \sigma$ Control gr.	3,14 $\pm$ 0,76	3,07 $\pm$ 1,10	10,45 $\pm$ 6,25	8,48 $\pm$ 5,51
Average $\pm \sigma$ Cleaning workers	5,17 $\pm$ 1,63	4,77 $\pm$ 1,76	10,92 $\pm$ 6,30	10,44 $\pm$ 6,29
diff.	2,03	1,70	0,47	1,96
t	5,20	3,77	0,24	1,07
P	> 0,001	> 0,001	~ 0,80	0,30



Left hand - palm

	3	4	6	7
Average $\pm \sigma$ Control gr.	2,68 $\pm$ 1,04	2,64 $\pm$ 1,06	10,97 $\pm$ 4,68	6,94 $\pm$ 3,10
Average $\pm \sigma$ Cleaning workers	3,54 $\pm$ 0,85	3,89 $\pm$ 1,27	9,95 $\pm$ 4,61	9,59 $\pm$ 4,68
diff.	0,86	1,25	1,02	2,58
t	2,96	3,47	0,71	2,09
P	0,01-0,001	~ 0,001	~ 0,50	0,05



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