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COMFORT IMPROVEMENT

OF HELICOPTER PASSENGER SEATS

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1. INTRODUCTION

Ergonomics groups the knowledge in physiology, psychology and related sciences applied to human work with the aim of a better adaptation of working methods, means and environment. Hence, it groups specialists of various origins such as health officers, physiologists, psychologists, engineers.

Ergonomics has the merit of having drawn the engineers' attention, not only on working problems, but also on the works products to adapt them to the users' requirements.

The study of seats, we have conducted, is a typical example of the ergonomic procedure. From statistics drawn up, particularly in the United States, and based on subjective reactions, it has been possible to determine and quantify the main factors affecting the passenger's sensibility to the comfort offered by a seat.

These factors may be classed in two main categories :

- Those related to the adaptation problems of the seat dimensions and shape to the anatomic and anthropometric features of the passengers.

- Those related to the transmission of vibrations through the seat.

They have guided our research for the design of seats which could improve the comfort of our helicopters.

2. ANALYSIS OF THE HUMAN BODY ANTHROPOMETRIC AND ANATOMIC FEATURES

By studying the dimensions of the various parts of the body and this over a large population, anthropometry allows the determination of human being models according to age, sex, generation and race.

Therefore, using these models, it is possible to design seats which are geometrically correct for the average stature of most of the human beings. To satisfy the whole population, it would be necessary to make adjustments which often are considered as being costly and complicated.

Anatomy shows that a child, at birth, has a spinal column which is straight in the lumbar region like that of the quadrupeds. When growing up, he stands up to walk, his spinal column bows rearward, in the lumbar region, as the sacrum, locked by the pelvis, cannot swing fully to the vertical. Hence, the trunk weight is supported by a column, which is curved due to the inclination of its bearing surface on the sacrum.

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Back aches, frequent when seated for long periods, have drawn the attention of medical experts. They have demonstrated that a seating position, with the back straight and perpendicular with the legs, causes a straightening of the spinal column in the lumbar region (figure 1). Due to this straightening there is an overpressure applied on the forward rim of intervertebra disks, causing their projection at the rear thus distending **ligaments** running along the spinal column and compressing the sciatic nerve.

A seating position with a slight rearward inclination, where the trunk and legs are at an angle of about 115 degrees, allows, with the help of an adequate lumbar support, the return of the spinal column to a nearly normal curve.

3. STUDY OF PARAMETERS TO BE CONSIDERED WHEN DESIGNING COMFORTABLE PASSENGER SEATS

A parametric study based on the conclusions of medical research work, anthropometric data, various statistical studies and the characteristics of various existing seats has allowed the definition, according to the space available, of the geometry of a comfortable seat for the medium size passenger (figure 2).

The significant parameters in the design of a comfortable seat have been classed statistically in their order of importance.

- 40 % for the basic function which is the support of the buttocks and shoulders.

- 20 % for the support of the lumbar region

- 15 % for the minimum "trunk/thigh" angle

- 3 % for the seat inclination

- 2 % for the forward and upper seat edges

A well-designed seat should maintain the trunk and leg muscles in a semi-relaxed position.

The body weight is transmitted through the buttocks, the thigh hind face and the spinal column dorso-lumbar region.

Dimensions of seat pan

The seat pan supports the buttocks and the thigh hind section.

From the statistics (figure 3), it appears that the percentage of unsatisfied passengers versus seat pan width varies according to a linear law.

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For an optimum width of 60 cm, it may be possible to adopt a width of 44 cm for "tourist" type seats and 50 cm for the V.I.P. type.

The seat pan depth, measured from the lumbar region support, should not exceed 40.6 cm. to avoid an uncomfortable bearing point under the knees. It is advisable to maintain approximately this value, the minimum not to be exceeded being 33 cm.

Also, the seat pan height should not be greater than 42 cm., as beyond this value the smaller passengers will not be able to rest their feet on the floor.

Contrarily to an impression too easily acquired, the cushion forward section should not provide a too firm support for the thigh soft parts which are not adapted to withstand a high pressure. The compression of nerves and blood vessels would lead quick to weariness of the legs.

Dimensions of seat back

The seat back should provide, through an enveloping shape, vertical and lateral support for the lumbar, sacral and dorsal regions.

It should form an angle of about 105 degrees with the seat pan to bring back the spinal column curve in a nearly normal position.

To have a better weight distribution in the dorsal and sacral regions, one would tend to increase the seat back inclination, but the passenger has to look forward and this position imposes on the cervical regions an attitude in hyperflexion which is to be avoided.

Except for fully reclining seats, it is obvious that a limited adjustment of the seat back inclination may bring an appreciable comfort improvement.

In the lumbar region, its width is the same as that of the seat pan, and may decrease to about 38 cm at the shoulder blade level.

The minimum seat back height may be limited to the lumbar region support, that is 33 cm, but may be extended, with advantage, to 71 cm to support the shoulders and even to 85 cm if it includes a head rest. In this case, the minimum width of the head rest should be 25 cm.

The lumbar region support should be located rather low to support the fourth and fifth lumbar vertebrae, while leaving the space for the sacrum and the buttocks, so that the spinal column may come freely in contact with the seat back. The sides of this support shall project to ensure a lateral contact improving the support when submitted to centrifugal forces.

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Also, arm rests constitute a good lateral support, they should be locatec at 21.6 cm above the seat pan and have a width of at least 4.5 cm.

Cushion

The comfort offered by the cushions depends on the shape, thickness, stiffness of foam used and facing material quality.

Thick and soft cushions are to be avoided, the passenger sinks into them and cannot change easily his position. Research conducted in medical laboratories has shown that a polyurethane foam cushion, 5 cm thick, is comfortable for a period of 20 hours of continuous seating if the seat shape is anatomically correct. To increase the comfortable feeling, a thickness of 8 cm may be adopted.

The cushion facing material should allow heat exchange.

Therefore, synthetic materials, simili leather type, should be avoided and, it is preferable to use cloth and velvet which are well aerated and have a better friction coefficient retaining better the passenger in place. Some nylon fabrics, having an appearance similar to velvet, offer a good comfort with, besides an easier maintenance.

General arrangement of seat

The arrangement of the seats is characterized by the distance between ea row or pitch. This dimension defines the space reserved to the legs and the space between the knees and the previous seat back·Statistics (fig. 3) show that a 28 cm space between two seats of normal height usually satisfy all passengers. Below 24 cm, there are more unsatisfied people. Comfort increases when the lower sections of the seats are clear, thus allowing stretching or folding of legs.

Finally, to prevent the passenger from slipping forward due to the nose down configuration of the helicopter in forward flight, it is necessary to tilt the seat slightly rearwards by about 7 degrees.

When the height of the cabin does not allow such position, while reducing the seat pan height, it is necessary to tilt the seat rearwards and to provide more space so that the passenger can stretch his legs and have a foot-rest giving a foot/shin-bone angle of 90°.

By parametric study, it has been possible, in the case of the medium size passenger, to define the relationship between the different variables characterizing the seat arrangement with respect to the space available (fig. 2) to achieve a good comfort :

- β angle of the seat pan with respect to the horizontal

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- α angle of the seat back with respect to the seat pan

- h height of the seat reference "R" with respect to the floor.

- H height of the passenger when seated, except clearance

- l abscissa of the seat reference "R" with respect to the rear point of the heels

- L passenger's overall height* from the rear of his heel to the back of his head

The origin "O" corresponds to the back of the passenger's foot, with legs stretched. Therefore, dimension "L" must be increased by the foot length to obtain the overall dimension. Reference R is located at the trunk/thigh joint.

For instance, in a cabin which is 131.5 cm high, it would be possible to define a comfortable seat, having a seat pan with a 6° tilt, a "seat pan/back rest" of 105°, and a passenger's trunk/thigh joint located 50 cm above the floor and 63 cm aft of the heels. The back of the passenger's head shall be at 85 cm from the back of the heels.

A seat with characteristics very different from those above will be uncomfortable.

4. STUDY OF VIBRATION TRANSMISSION THROUGH THE SEAT

The helicopter is subjected to oscillations of various amplitude and frequency, in the vertical and horizontal planes as well as in roll and pitch. These are transmitted to the passenger through the seat which is an elastic system. As the human body is also an elastic system having weight, stiffness and shock absorbing characteristics, the response to motions to which it is subjected, depends on :

- the weariness

- the musculature

- the attention

- various individual factors

Because of their own impedance, some parts of the body are in resonance at frequencies above 3 cps and according to their amplitude, the vibrations can become unbearable especially between 3 and 15 Hertz.

* Read length

.../...

The vibrations generate micro-traumatisms on the body :

- Distortions of the movements and reflexes
- Seasickness
- Troubles of the locomotor system
- Loss of equilibrium

The metabolic processes concerning the food assimilation and the muscular activity can be affected. So, the weariness, a reduction of the working capacity and of the attention can be the result of excessive vibrations

Therefore it is essential to design seats which can absorb vibrations. However, considering the complexity of the "human body/seat" dynamic model it is only by an experimental analysis that it is possible to study conveniently the seat transfer ability.

A test has been carried out to study the influence of the various parameters upon the vertical transfer of the "passenger seat" system ; this test has been performed on a vibrating platform ; using three accelerometers positioned on the floor for the input reference, at the "passenger seat cushion" interface and against the sternum at the thorax height, the various accelerations have been recorded at the 3 levels and compared.

The measurements have been made on two types of seats with persons of three different weights, and cushions of four densities within a range of frequencies between 2 and 30 cps, in increments of .1 cps and with three input accelerations, (0.05 g , 0.1 g and 0.25 g) the response rates which are very low at the high frequencies, beyond 15 cps, lessen quickly at lower frequencies especially at the thorax level with a resonance zone of about 4 cps.

It can be noted that :

- the foam having a specific weight equal to 40 kg/m3 give better results (fig. 4).
- the heaviest passengers are subjected to a more uniform damping which is better in the resonance area and poorer beyond this area (fig. 5).
- a change of back-rest modifies slightly the vertical response of the passenger (fig. 6).
- the stiffness of the seat affects strongly the response of the assembly (fig. 6).
- the vibration damping becomes more efficient when the acceleration level increases (fig. 7).

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Conclusion

For the purpose of improving the helicopter transport quality, an ergonomic research task conducted in the field of passenger seats has shown that the total comfort of a seat was depending on its geometry and its ability to attenuate vibrations.

A parametric study based on medical research work, anthropometric data and statistics has allowed the definition of the geometry for an anatomically correct passenger seat, according to the space available, and the corresponding comfort level.

The study of vibration transmission has been initiated on an experimental basis and has revealed some very disagreeable resonance at low frequencies.

The resonance phenomenon may be attenuated by "seat structure/cushion" and "seat/floor" elastic links. However, it should be noted that low frequency excitations close to the rotor nominal speed are met on poorly rigged helicopters only.

The application of this research work has enabled us to achieve an appreciable improvement on our most recent helicopters, such as the "ECUREUIL"

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SHAPES OF SPINAL COLUMN IN THE LUMBAR REGION

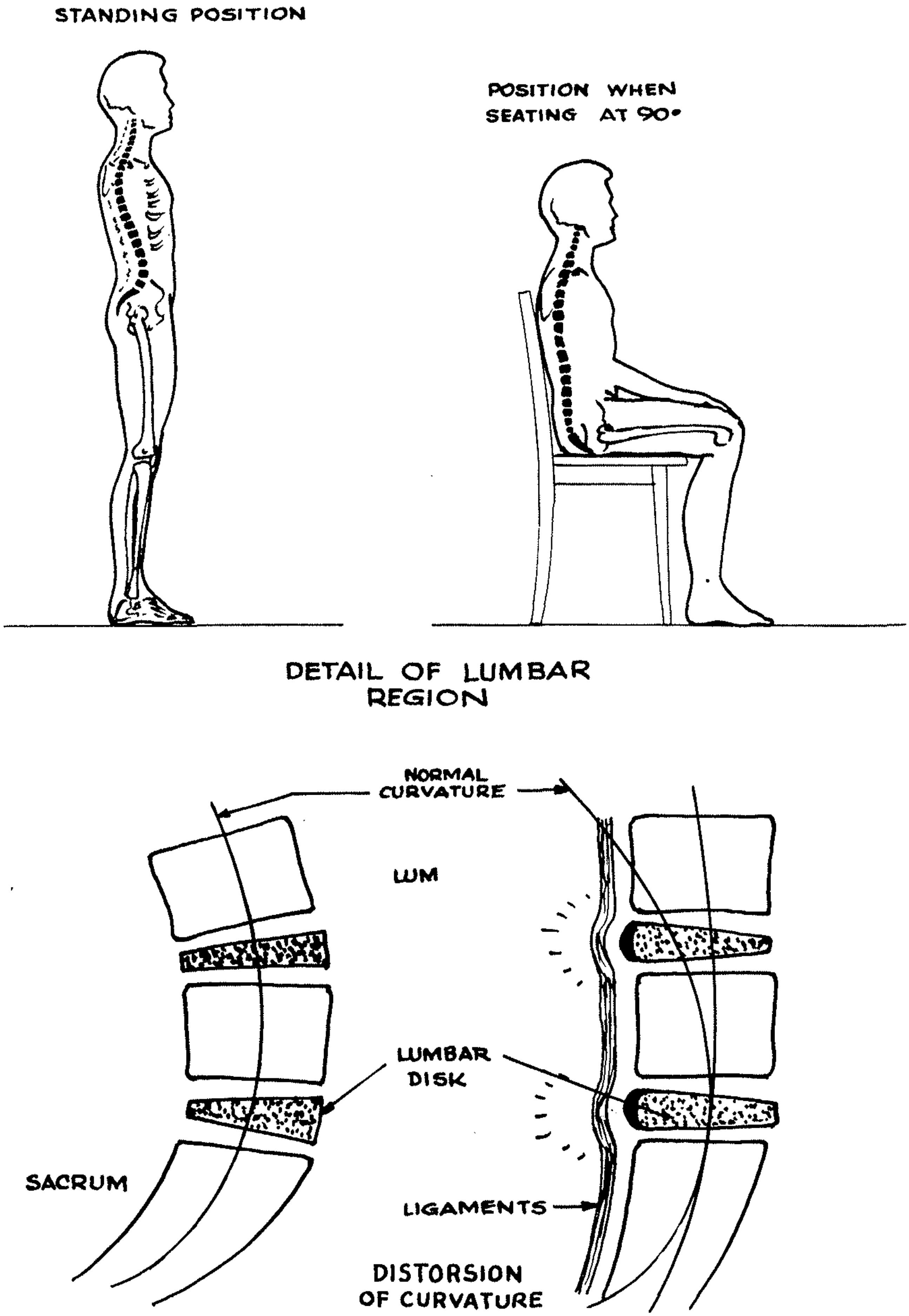
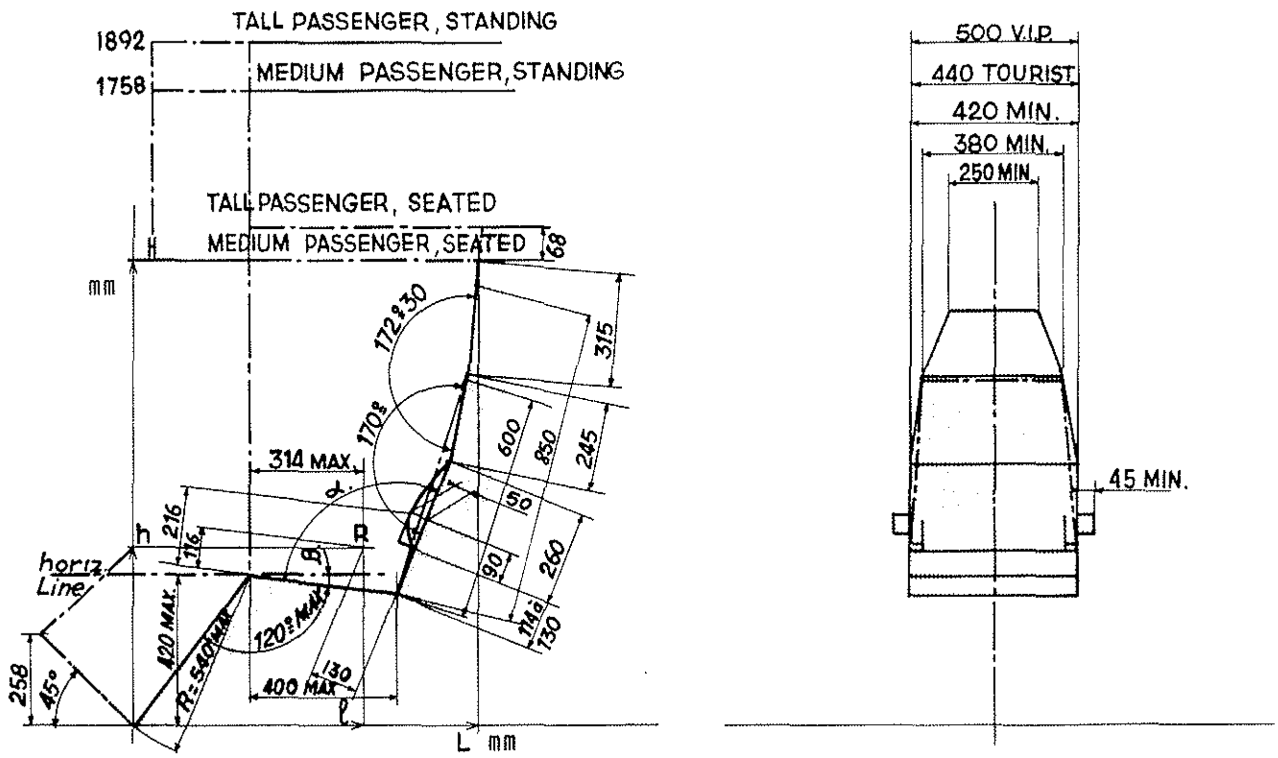


FIGURE 1

GEOMETRY OF THE ANATOMICALLY CORRECT PASSENGER SEAT



———.———.——— UTILITY TYPE SEAT, WITHOUT HEAD REST

——————— AIRPLANE TYPE SEAT, WITH HEAD REST

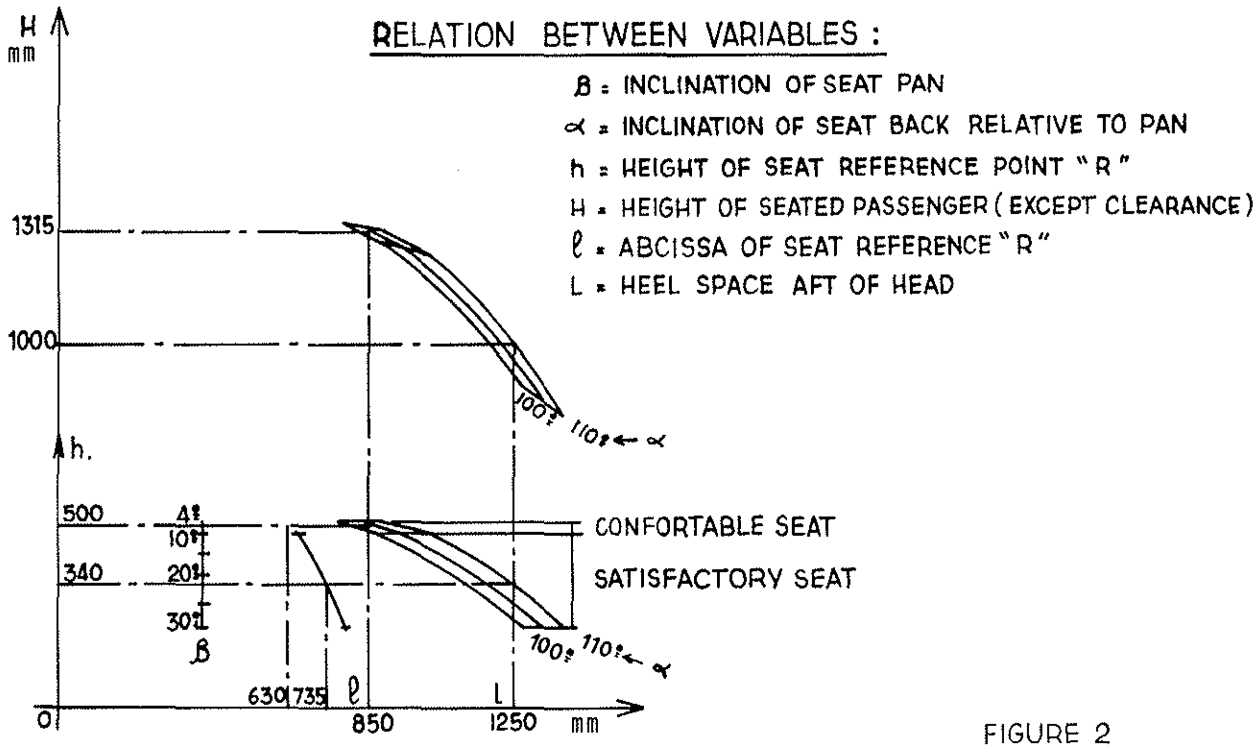
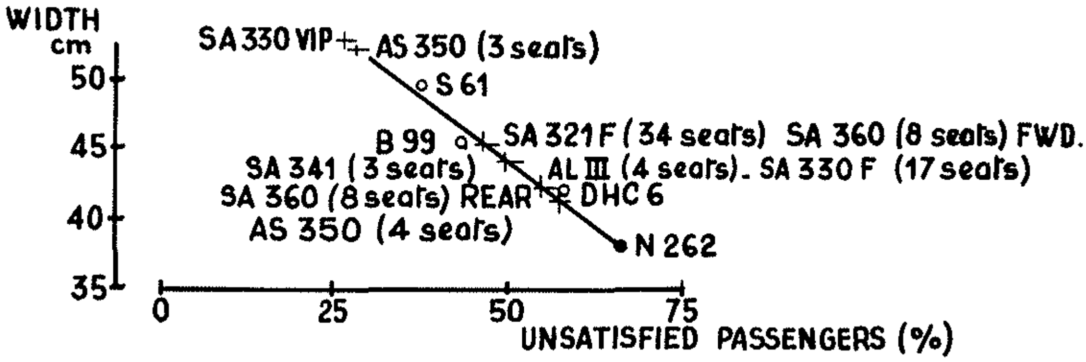


FIGURE 2

ORIGIN "O" = BACK OF FOOT

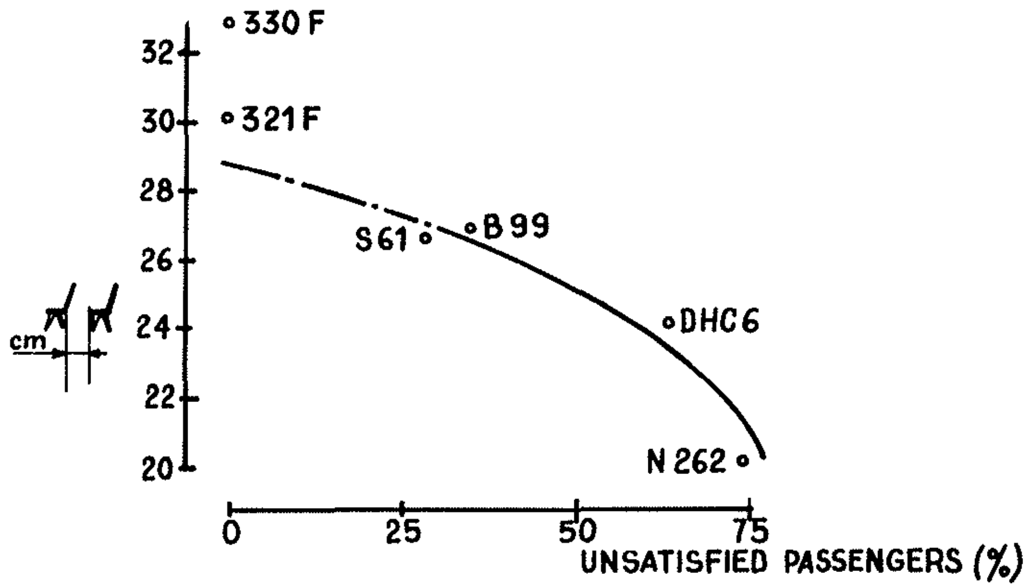
NOTE : FOR SMALL VALUES OF β, INCLINE SEAT REARWARD OF A VALUE CORRESPONDING TO THE AIRCRAFT ATTITUDE IN CRUISING FLIGHT

PERCENTAGE OF UNSATISFIED PASSENGERS ACCORDING TO SEAT WIDTH



DE HAVILLAND DHC 6 (19 SEATS)
NORD 262 (26 SEATS)
BEECH 99 (13 SEATS)
SIKORSKY S 61 (26 SEATS)

PERCENTAGE OF UNSATISFIED PASSENGERS ACCORDING TO SEAT PITCH



DE HAVILLAND DHC 6 (19 SEATS)
NORD 262 (26 SEATS)
BEECH 99 (13 SEATS)
SIKORSKY S 61 (26 SEATS)

FIGURE 3

VERTICAL RESPONSE RATE OF THE "SEAT / PASSENGER" SYSTEM FOR VARIOUS FOAM DENSITIES

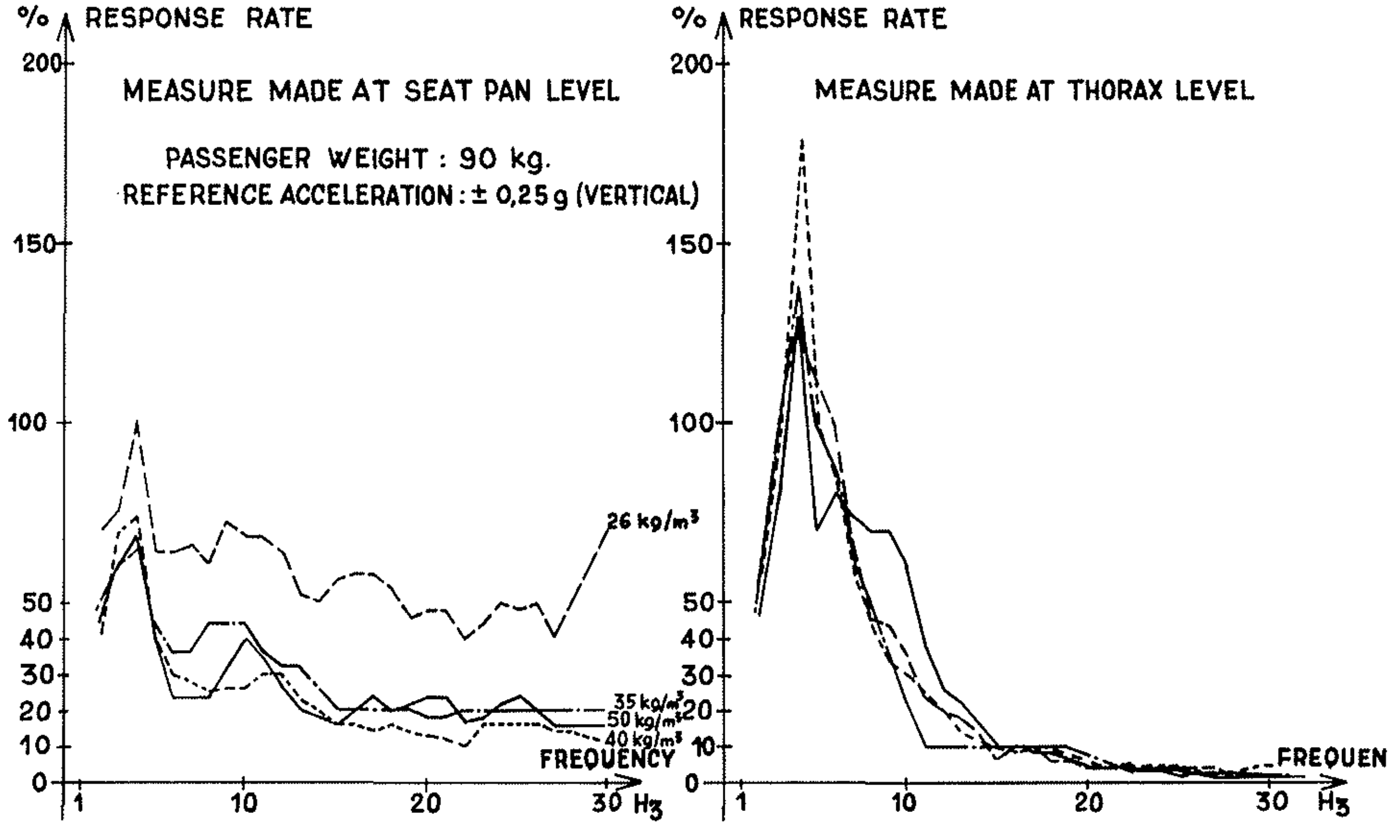


FIGURE 4

VERTICAL RESPONSE RATE OF THE "SEAT/PASSENGER" SYSTEM FOR VARIOUS PASSENGER WEIGHTS

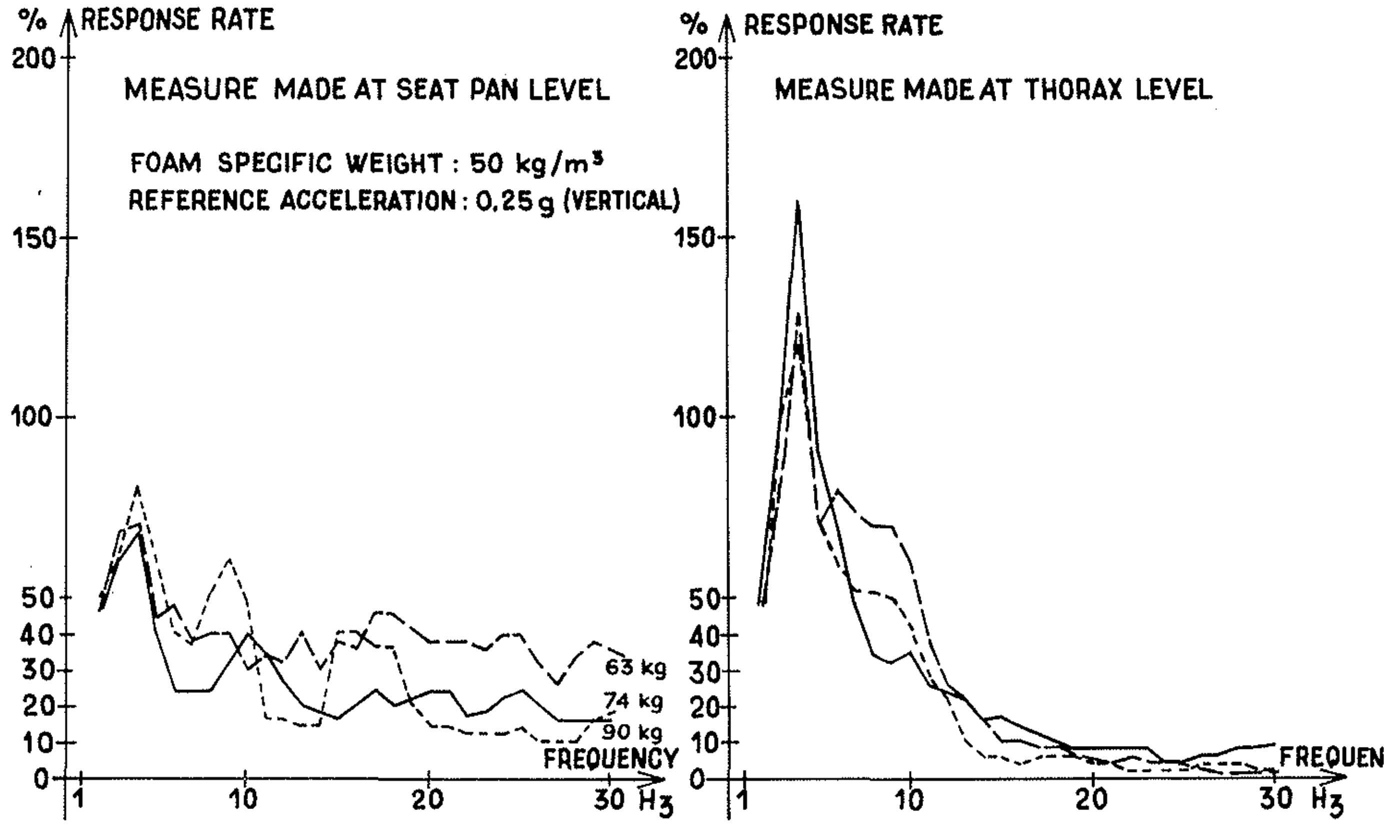
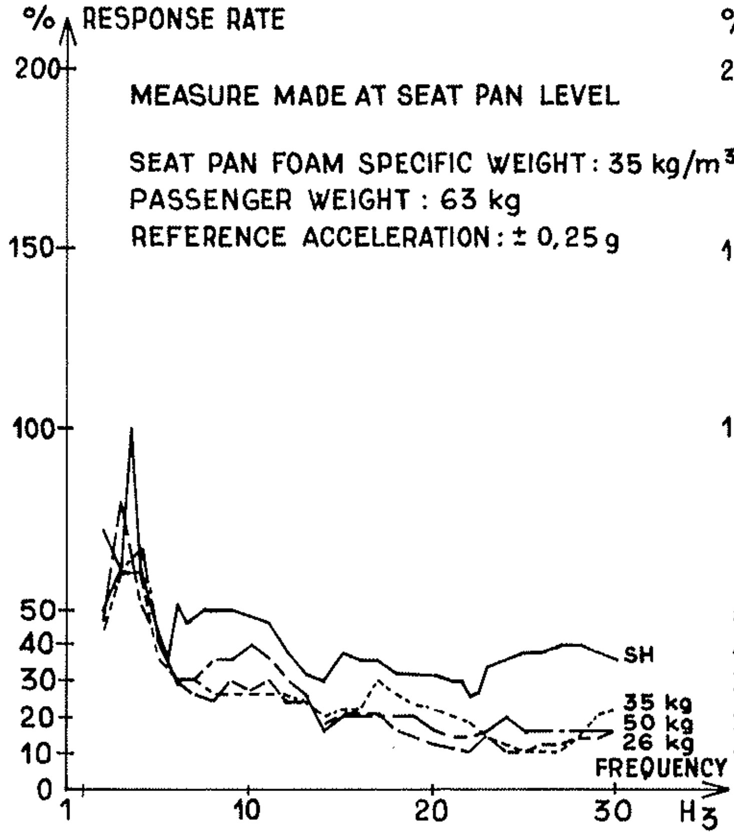


FIGURE 5

VERTICAL RESPONSE RATE OF THE "SEAT/PASSENGER" SYSTEM FOR VARIOUS SEAT BACK RIGIDITY AND TWO SEAT SHAPES



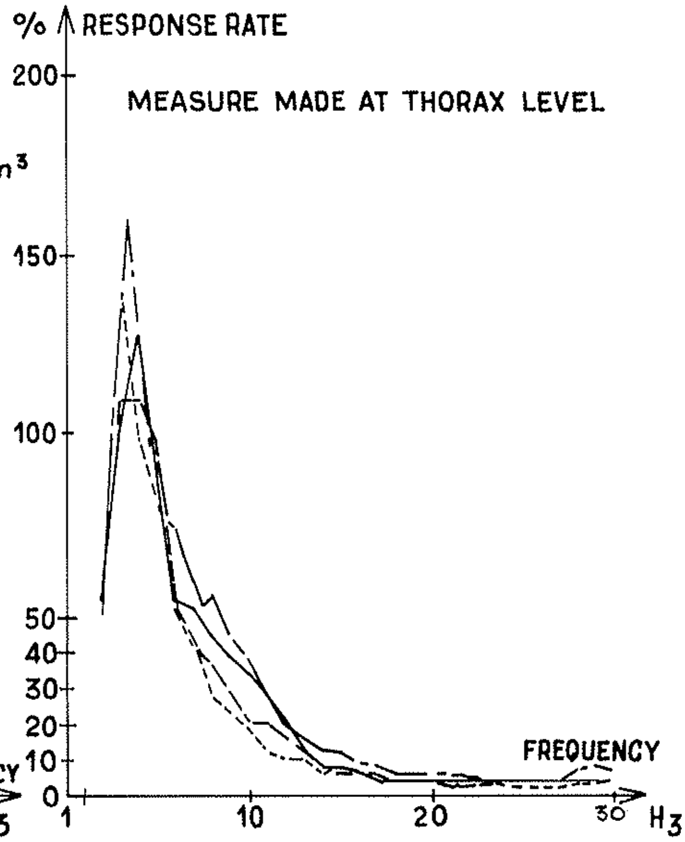
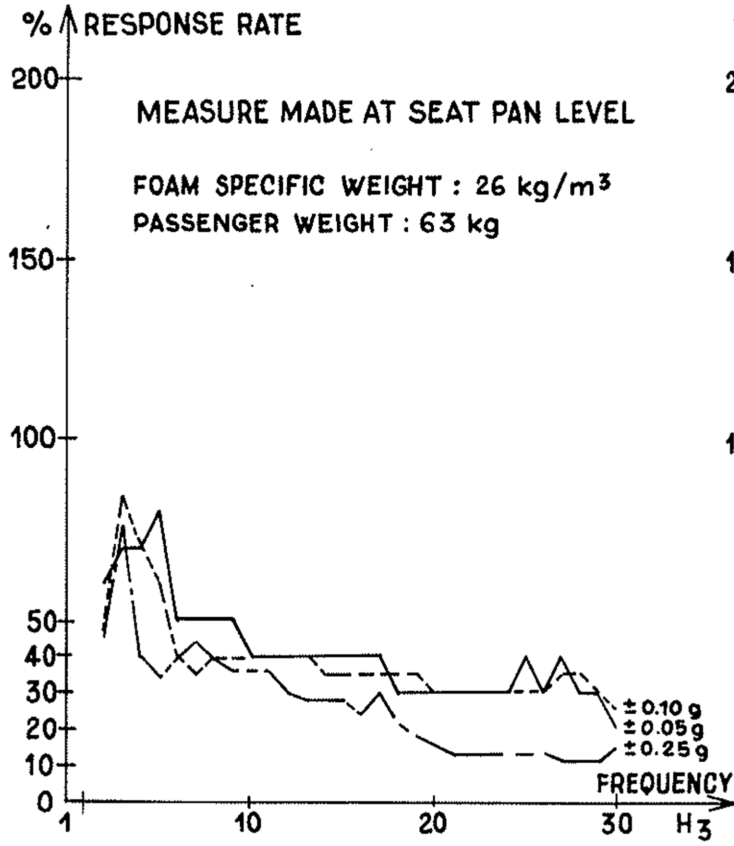


FIGURE 6

VERTICAL RESPONSE RATE OF THE "SEAT/PASSENGER" SYSTEM FOR VARIOUS EXCITATION LEVELS



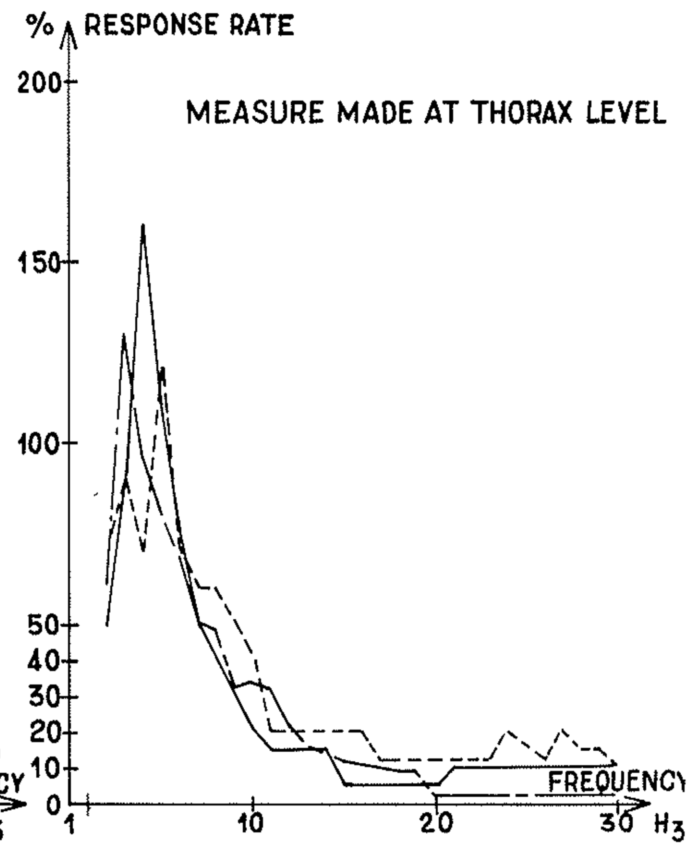


FIGURE 7