DEVELOPMENT OF A NEW ELECTRO-PNEUMATIC TRANSDUCER

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ABSTRACT

Reading process is one of the most important problems facing blinds, as they can read only texts printed in BRAIL. That, for sure, shrinks the domains from which they could get information. In the last seven years, a serious study was performed in France aiming particularly for creating a new system consisting mainly of an optical element (camera) which can be passed over the ordinary printed letters to transform each of them into specific electric code. This last one, when gotten as an input to a special transducer, is transformed to give a pressure output acting upon a system of tinny plungers, which give at last tactile signals, readable by blinds. In this way any ordinary printed text can be available to be read if blinds demand for it without asking for help, whenever they want.

Hereafter, the main idea of the system is described altogether with the necessary preparatory studies that were important to be carried out before getting deeply into the system details. Being the most important element in the system, the electro-pneumatic transducer is also analysed with its measured characteristics and performance parameters.

1. INTRODUCTION

More than 70 % of information are nowadays published in printed texts or in books. This way of publication represents one of the most severe problems facing the blinds as they can not deal with it. That is why BRAIL letters, when firstly invented had represented a real revolution, since the blinds, thanks to BRAIL method, could get all the needed information independently by their fingers without asking for help from the others. Even with using BRAIL letters, the problem was not completely solved, because it is still necessary to print books at first in BRAIL, before becoming available to be read. In the last few years, a serious study was developed in the laboratories of (L'INSTITUT DE MECANNIQUE DES FLUIDES DE TOULOUSE) in France, mainly aiming for designing a new system by which the orcinary printed letters in the ordinary books could be transformec into a reasnable tactile signals applied on the blind fingers tips, to form at the end understandable words to the reader.

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Dr. C. FONADE altogether with the first author had founded the bases of the system in a series of patents, until they could finally present their last version of the system in which the second author had the opportunity to participate in performing the last group of experiments, in developing the mathematical model of the system, and in studying the effect of different operational & design parameters of the system performance.

2. PREPARATORY STUDIES

Before going deeply into the system details, it is important to study the human response against different exciters, in order to choose the optimum zones of excitation signals whatever was their form (audio, visual or tactile signals).

2.1. ELECTRO-TACTILE DISCRIMINATION OF TWO POINTS AS FUNCTION OF FREQUENCY, SITES OF HUMAN BODY, AND DIFFERENT STIMULATION CODES.

In 1977, M. SOLOMONOW & others /3/, had developed a very interesting study concerning the discrimination of two different point plungers exited electrically as function of frequency, they had also studied the response of different body sites to different stimulation codes. Their system was based on variation the frequency between two electrodes, aiming for finding out the limits of human sensation of two different points (LDTP).

This research has tried:

a- to find out the response of different sites of human body.

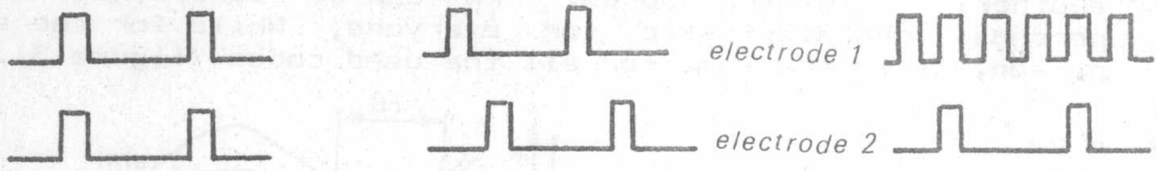
b- to get clear the differences of the right side organs sensibility with respect to the left side organs in the body.

c- to study the influence and response due to different excitation codes.

For answering all these questions, a basic test bench was constructed such that it consists of two coaxial electrodes made of inox steel, they are principally branched to a special stimulator capable to deliver negative pulses of current (0:40 A) during a limited period (10 sec : 10 msec) with a certain frequency (1 : 300 Hz). In addition, the signal output can be adjusted in order to give either local base excitation code (i.e. using signals arising from two identical electrodes, but the distance between them is stepwisely variable), time base excitation code (i.e. using two identical signals with a time delay of one with respect to the other), or frequency base excitation code (i.e. one electrode is always fed with a signal of frequency 5 Hz, while the other is fed with a signal of variable frequency (10:100 Hz).

Every measurement of the previous codes was performed as follows:

a- The distance between the centres of the two electrodes is adjusted from 20 : 25 mm; in order to be sure that the two electrodes signals are distinguished separately.



a. local base code   b. time base code   c. frequency base code

fig. 1. THE THREE APPLIED CODES

b- Slight pressure must be applied on the two electrodes, to guarantee a sufficient degree of contact with the skin.

c- The first electrode is regulated to give higher and higher power slowly up till the pain limit, then decreased gradually to attain the limit of minimum comfort.

d- The same procedure must be repeated with the other electrode.

e- One of the two electrodes is moved to approach the other gradually up till they reach the minimum distance at which the subject under test can still distinguish two separate signals. (limit of discrimination of two different points: LDTP).

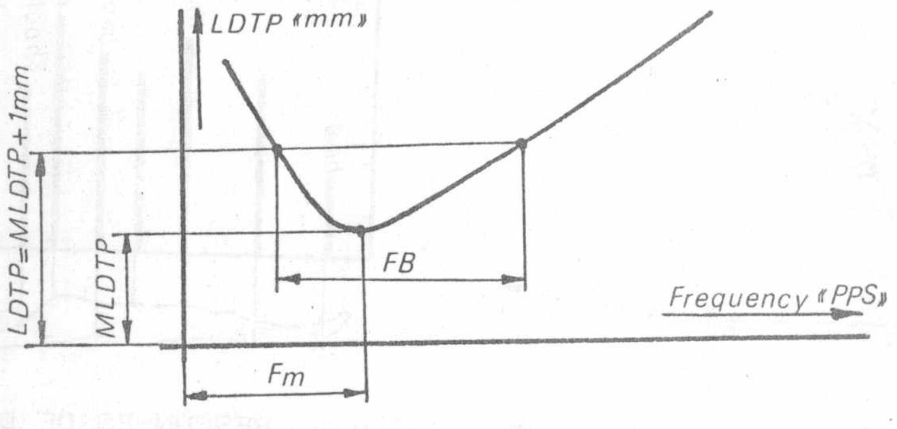


fig. 2. TYPICAL HUMAN RESPONSE AS FUNCTION OF FREQUENCY

In general, for the three different stimulation codes, the limit of dis- crimination of two different points has the behaviour shown in figure (2), on which, the following parameters as:

MLDTP: minimum limit of discrimination of two different points.
Fm : frequency corresponding to the previous mentioned minmum.
FB : frequency band width for which LDTP is less than MLDTP+1mm.

As a conclusion from the experimental results, note that:

a- LDTP vary as function of frequency in the frequency band

(0:100 pulse/sec.) for all different codes.

b- Every person has his own "Fm" which differs from one to another. In other words, "Fm" can be considered as a personal characteristic for everyone, While for the same person, it is the same for all the used codes (figure 3).

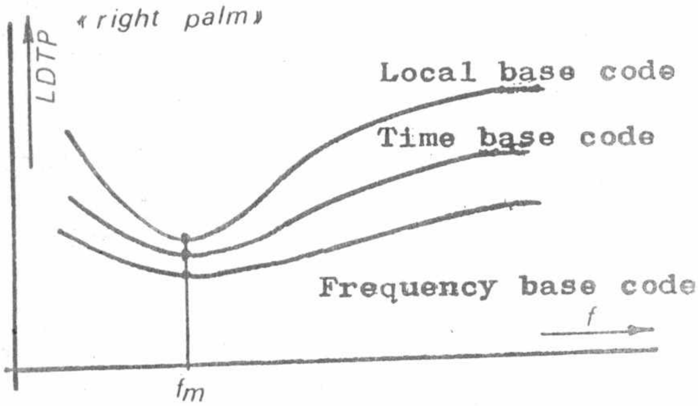


fig.3. (LDTP-f)FOR THE SAME PERSON WITH DIFFERENT CODES

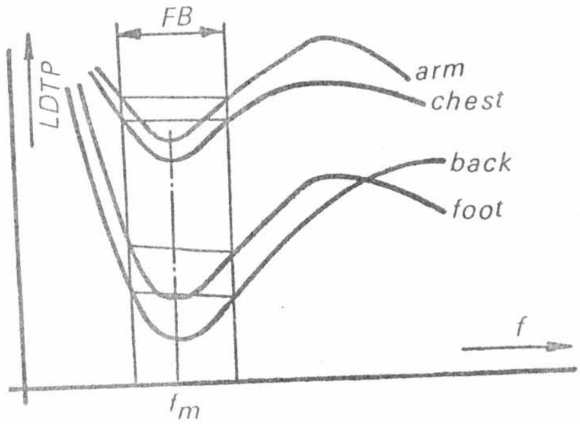


fig.4.(LDTP-f) FORTHE SAME PERSON & SEVERAL BODY SITES.

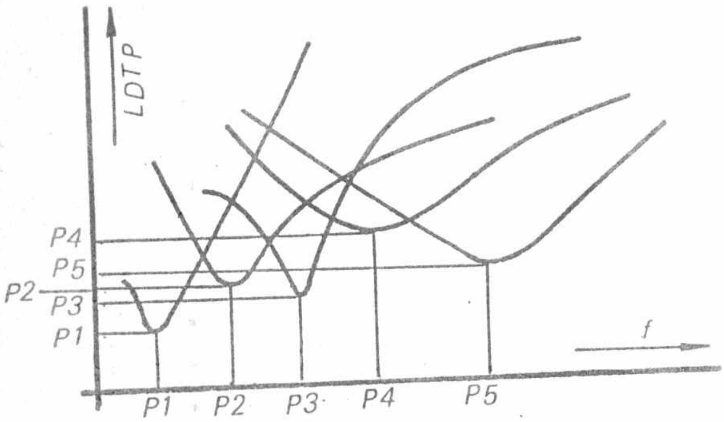


fig.5. (LDTP-f) FOR THE SAME ORGAN & DIFFERENT 5 PERSONS

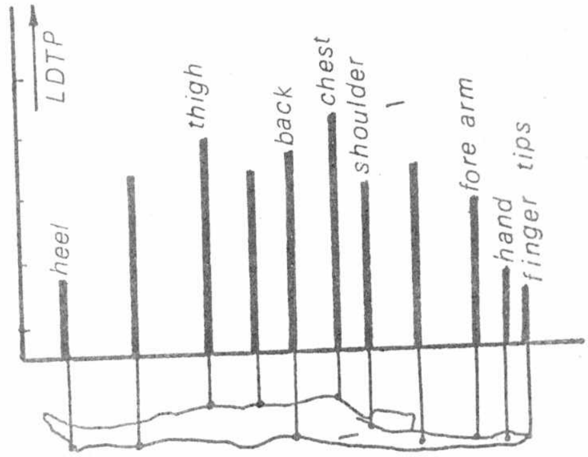


fig.6. RESPONSES OF DIFFERENT BODY SITES OF THE SAME PERSON

c- MLDTP varies from one body site to another, while "Fm" remains the same for all body sites of the same person (figure 4).

d- MLDTP corresponding to certain body site varies widely for different persons (figure 5).

e- On the human body, it is found that the terminal parts (such as: fingers tips, heels,...etc.) are the most sensible over all, the sensibility decreases when moving towards the trunk (figure 6).

f- The dominant side of body shows less (LDTP) if compared with the nondominant side; while it is easier to distinguish LDTP in this later one.

g- "FB" may vary from person to another, but it remains constant for all body sites of the same person (figure 4); "FB" has its least value for the dominant site if compared to the non-dominant one (figure 7).

h- LDTP is improved when applying the time base excitation code if compared with the local base excitation code, but it gives its best results when applying the frequency base excitation code (figure 3).

i- It is remarked that the most comfortable frequency for any body is Fm.

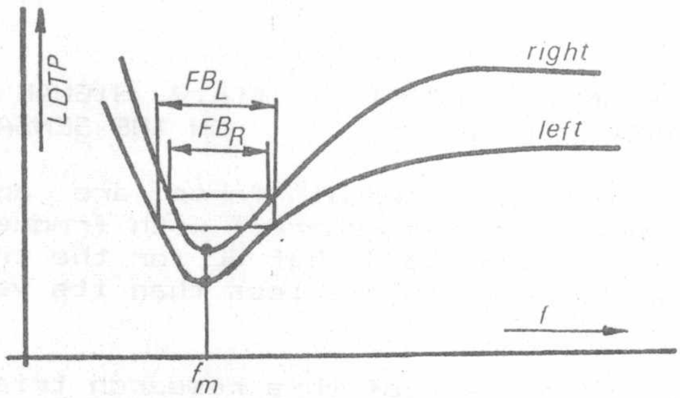


fig.7. (LDTPf) FOR RIGHT & LEFT HANDS OF THE SAME PERSON

2.2. VIBRO-TACTILE STIMULATION USING ELECTRICAL & MECHANICAL STIMULANTS /4/

This research tries to create a new vibro-tactile stimulants, and to find out the sensation properties of the human skin when exposed to vibration whether electrical or mechanical.

1. The research starts by determination of the effect of the contacter dimensions on the sensation limit, by using 30:70 Hz signals (SIN function) when applied on different persons. The contacter diameter varies from 0.5:10 mm. The average amplitude of vibration of this contacter is taken in the two directions of increasing and decreasing this amplitude. That average amplitude is considered as the sensation limit (SL). The shown results in figure (8) indicate that (SL) decreases when increasing the contacter area, but the inclination of curves remains approximately the same. It is also observed that they are approximately horizontal, independent of the frequency when the contacter diameter is less than 0.5 mm. In addition, they indicate that for contacter diameters varying from 10 mm to 0.5 mm, there is a difference in amplitude of 20 dB when the frequency is 200 Hz.

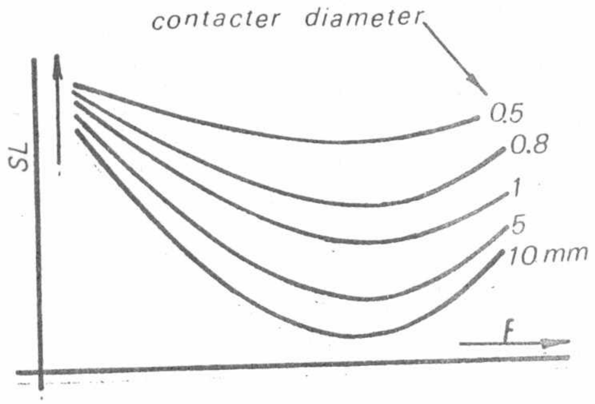


fig.8. CONTACTER DIAMETER EFFECT ON THE SENSATION LIMIT

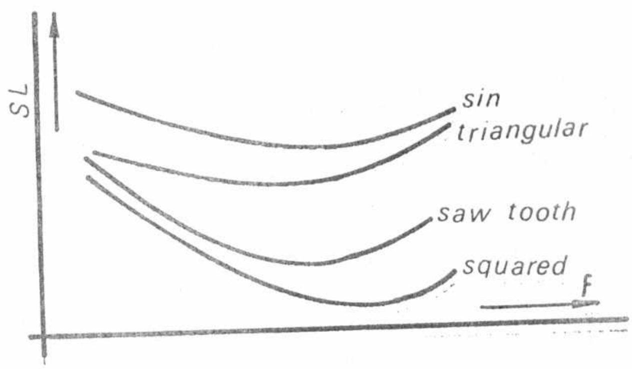


fig.9. SIGNAL FORM EFFECT ON THE SENSATION LIMIT

2. Secondly , different signal forms are applied (SIN, triangular, saw tooth and squared) with frequency from 30 to 300 Hz. It was found that SL for the triangular, saw tooth and squared signals are less than its value when using SIN signals.

3. Finally, the third part of this research tries to compare the vibro-tactile stimulation if using electro-mechanical stimulants with the case using only electrical stimulants. This was performed by placing two electrodes of Ag-Ag.Cl, on two points on the finger, then trying to find the best duration time of signal application. It was found that the optimal pulses are those of duration time 0.5 msec. When using longer period pulses, one would have a burning like sensation. Contrarily, with shorter period signals, picking like sensation is most probable.

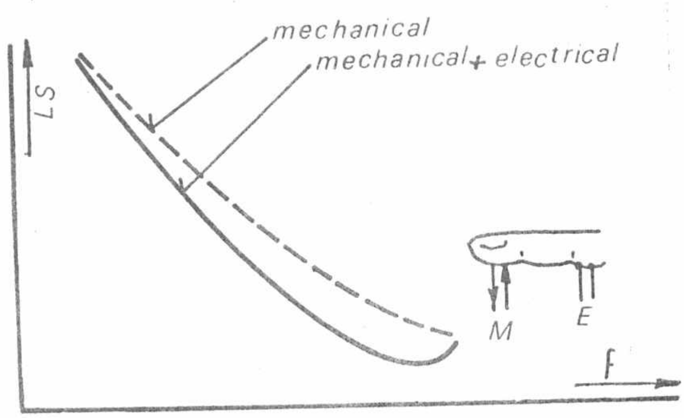


fig.10. INDEX TIP SENSATION WHEN USING DIFFERENT STIMULANTS

At last, a mechanical vibrator was added, in order to find out the effect of the two stimulants. It was noticed that the sensibility to vibration obtained by electro-mechanical stimulants is less than that obtained by only mechanical stimulants by 0.1 mm at 200 Hz.

All these experiments were repeated with changing the position of application but always on the finger, and it was found that the most sensible part of the finger is the tip of index.

3. NEW DESIGN OF A SPECIAL CONVERTOR SERVING BLINDS FOR READING

Coming now to the most important point of this study concerning a new design of reading system serving blinds, which represents the main aim of the project DELTA. carried out in France (1980 and the years after) in laboratories of "L'INSTITUT NATIONALE POLYTECHNIQUE DE TOULOUSE". The principal construction of the system is schematically shown in figure (11).

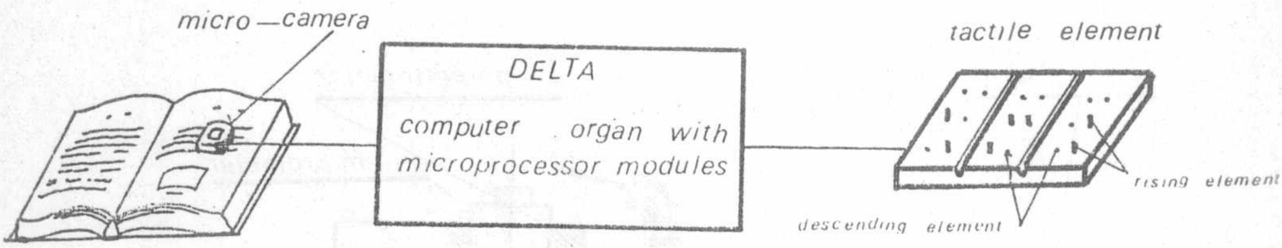


fig.11. SCHEMATIC DIAGRAM OF THE STYSTEM

Tactile reading, page by page, much interests the blinds, as it can be done using the two hands and not only one finger which gives the ability to read only a group of 12 or 24 characters. Instead, the surface of tactile zone allows reading of much higher number of characters (1024 characters).

The procedure can be schematically presented as shown in fig.12

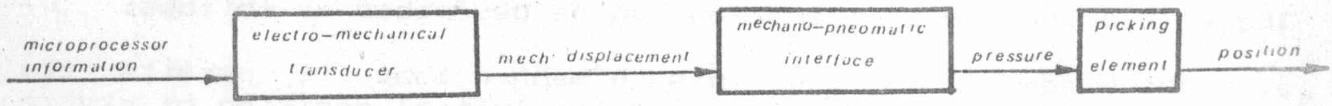


fig.12. BLOCK DIAGRAM REPRESENTING THE SYSTEM

The transducer role is to convert to the form of mechanical displacement, an electric signal corresponding to the generated code by a microprocessor. This signal can be continuous or modulated (with any carrying frequency, whatever it is).

For different conditions of erection, energy consumption and price of different elements (magnetic, thermic or piezoelectric) necessary for the electro-mechanical transformation phase, two solutions are suggested, to use:

a. either heated bi-blades (thermocouple principle).

b. or vibrating piezoelectric blades.

The two solutions were tested and proved high reliability.

4. PROCEDURE OF CONVERSION OF AN ELECTRIC SIGNAL INTO PNEUMATIC OR HYDRAULIC ONE, USED TRANSDUCER IN THE SYSTEM

This research creates a new procedure of conversion of an electric signal into pneumatic or hydraulic one, only by using a pneumatic (or hydraulic) potentiometer (4) (figure 13), consisting of a fluidic capacitance (6) mounted at the feeding entrance (7), there is also a nozzle (9) providing a leakage flow (9a), as well as another pneumatic (or hydraulic) exit.

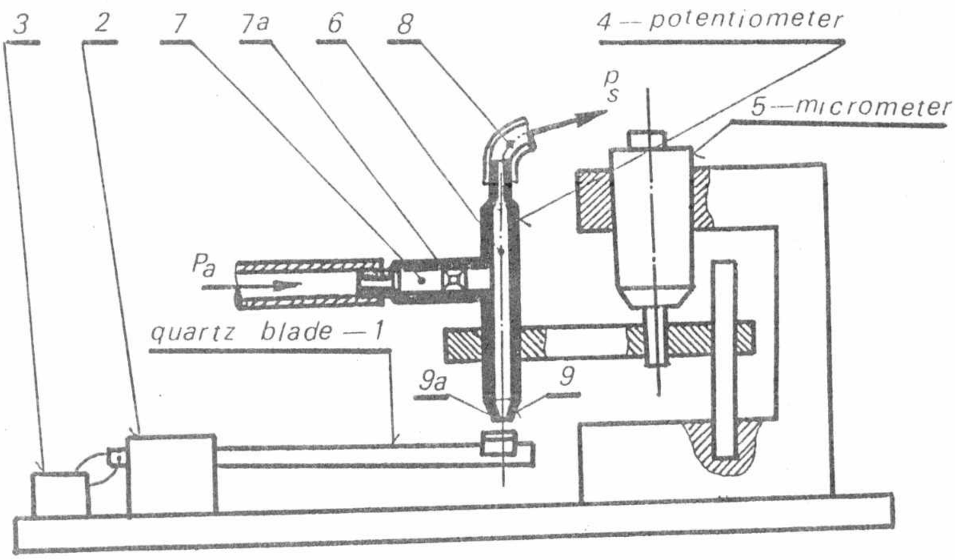


fig.13. SCHEMATIC DRAWING OF THE BASIC SYSTEM.

The main principle of operation can be described as follows:

a. the blade (1) is fixed in such manner that it permits its free part to vibrate around its initial position of static equilibrium in a lateral direction perpendicular to its axis.

b. blade (1) is displaced near to the pneumatic (hydraulic) potentiometer nozzle (9) in such a way that its free part is placed directly facing the nozzle to cover and uncover successively the leakage outlet (9a) during vibration around its initial equilibrium position.

c. applying the given electric signal on the blade (1) with suitable conditions such that the free portion of blade may vibrate with an amplitude directly function of the applied electric input. The leakage flow leaving the nozzle would be also affected.

d. At the outlet (8), a pneumatic (hydraulic) signal would be generated representing at every instant the initial electric input.

Blade (11) must be fixed in such a way that its free portion would vibrate in a horizontal plan approximately parallel to the plan of the nozzle opening (9a). It is adjusted such that it permits only a very small leakage flow, when the blade covers the nozzle completely.

When the blade starts to uncover the nozzle gradually in successive positions getting far more and more from its initial position, it regulates the leakage directly as function of the vibration amplitude of blade (figure 14.a).

Figure(14.b) represents another realization design in which the blade uncovers at first the nozzle opening atits initial position, and gradually masks the nozzle in successive positions getting farer more and more. In the two cases, the average pressure Ps can represent the behaviour of the electric signal input.

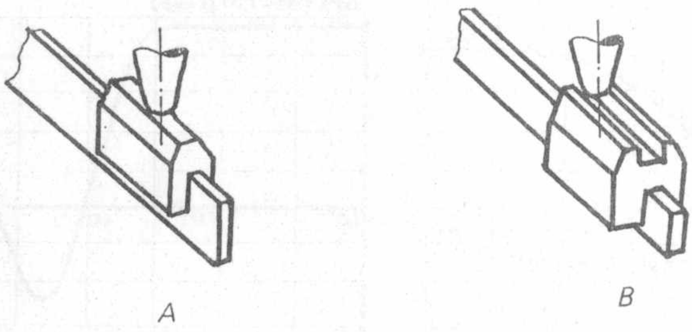


fig.14. TWO DIFFERENT DESIGNS FOR THE BLADE-NOZZLE SYSTEM

Thus, this procedure uses blade vibration in order to modulate the leakage through a nozzle, as function of this vibration. In such conditions, the developed average pressure inside the potentiometer is a true representative image of the electric input, without any distortion due to hysteresis, as this later parameter is eliminated by the rapid movements of blades around its static initial position.

This procedure can be also applied in cases using continuous electric currents, as they can be at first treated to obtain alternating currents of frequency near the resonance frequency of blade with amplitude representing the given continuous current.

As the alternating current is thus applied between the conducting faces of the piezoelectric blade, the amplitude of vibration of blade is directly function of the electric input with very good sensibility in the resonance zone of blade.

In addition, this procedure can be applied to convert an alternating current in order to obtain an outlet average pressure either function of the amplitude of the given current (if using constant frequency), or function of its frequency (if using constant amplitude). In the first case, the amplitude of variation is a direct function of the electric input.

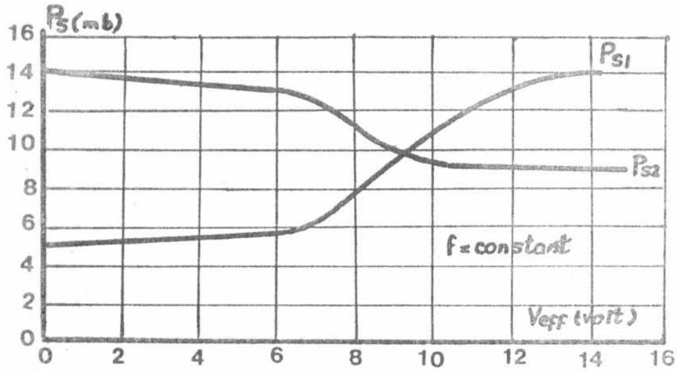


Fig. 15

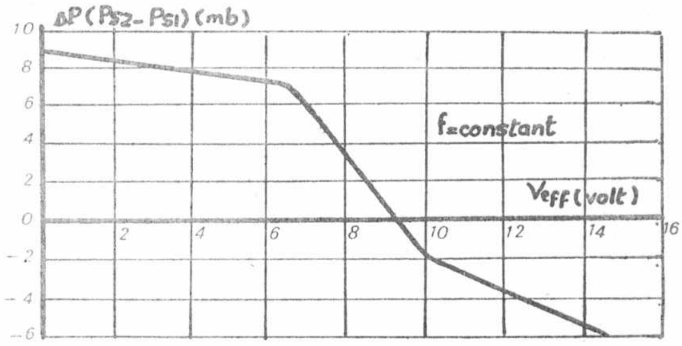


Fig. 16

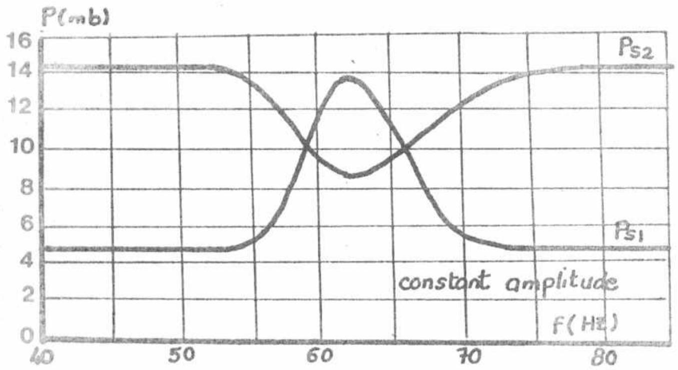


fig. 17

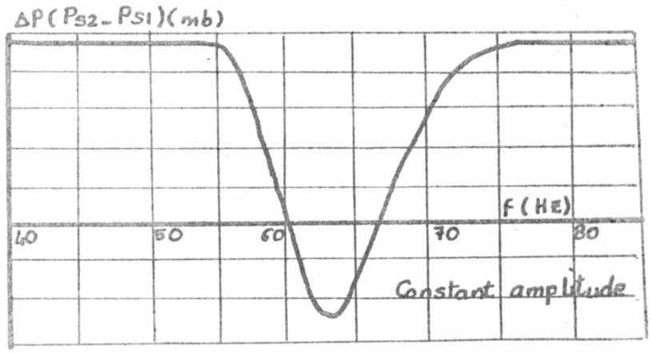


Fig. 18.

For the two designs (14A & 14B) if mounted on the same blade, the pressures inside the two potentiometers (P_{s1} : corresponding to design 14A and P_{s2} : corresponding to 14B) may respond in two different ways. The amplitude of variation passes by a maximum for a frequency corresponding to the resonance frequency of blade. This property is used to modulate the leakage discharge as function of frequency.

Figures (15) gives the characteristic curve of the mentioned convertor for the elements shown in figure (14), in case of conversion with constant frequency. While figure (16) shows the difference of both responses ($P_{s1}-P_2$) as function of the effective voltage.

At last, figures (17) and (18) give the characteristic curves in case of conversion with constant amplitude.

One of the main advantages of the studied convertor is the unnecessity of an additional auxiliary looping system, this simplifies the system construction, reduces its costs and eliminates any imprecision or any probable faults due to the mentioned auxiliary system.

Another advantage of this system, is to increase the sensibility of the realized conversion.

Furthermore, arranging the blade to vibrate in a parallel plan to the nozzle opening plan permits it to be so near that it can cover almost completely, or can uncover also almost completely the nozzle without risking any contact between them. Thus the average fluid consumption is reduced, in the same time, very high sensibility is obtained.

5. THE FINAL STAGE OF PRESSURE-DISPLACEMENT CONVERSION (THE TACTILE TERMINAL ELEMENT)

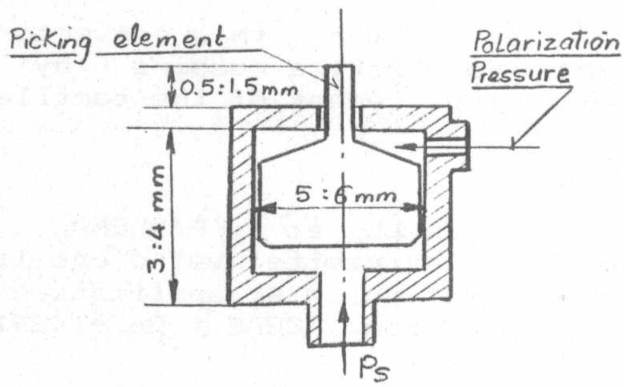


fig.19. PICKING ELEMENT DESIGN

When the electric input is exited, pressure in the outlet section pushes a small piston on top of which a tinny picking element is fixed (figure 19). When the input is cut off, the piston retracts under the effect of its natural weight, meanwhile if it is necessary, the higher chamber can be polarized by a constant pressure Pp.

6. COMMUTATION TIME OF TACTILE ELEMENT

To measure the time of rising or of descending of the picking element, a small target at it end was fixed. The displacement of both vibrating blade and the rising picking element were measured instantaneously one against the other.

For Ps (20 to 30 mbar) and Pp (5 to 9 mbar) the time of rising for the picking element does not exceed 0.45 sec., and the time of descending 0.25 sec.

These results, even with being satisfactory, can be improved by choosing different materials of blades. Also if associating with 6 potentiometers, and 6 picking elements, realization of any BRAIL character is possible.

7. CONCLUSION

This research explains the development of a new procedure for converting any electric signal into pneumatic one, and in particular the conversion into pneumatic pressure. In case of alternating current of constant frequency, the pressure would represent the variations in amplitude, while with a current of constant amplitude, it would represent the variations in frequency. It can also represent the amplitude of a d.c. signal.

The convertor can be also used as a pneumatic interface for electric circuits which deliver electric signals,while the output is required to be in mechanical form.

As an example of its application, this convertor can be used to realize a simple system for tactile reading (by translating an electric signal into a displacement of the tactile element).

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