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ACQUISITION AND ANALYSIS OF DATA TO CHARACTERIZE DYNAMIC ACTIONS IN HYDRAULIC ENERGY DISSIPATORS

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SUMMARY

The characteristics of three-dimensionality, anisotropy and non homogeneity of turbulence, that are present in the flow of hydraulic energy dissipators prevent an analytical study of this problem. In this case hydraulic modelling is the fundamental tool for studying the pressure field in those structures.

The practical difficulties in this kind of studies, like detection, recording and analysis of pressures, instrumentation checking and scale effects, among others, prevent us from obtaining better knowledge of the problem.

This paper suggests a solution for those practical difficulties, through an experimental and numerical methodology.

The Experimental Methodology enables presssures to be recorded at different points of the structure in study and the Numerical Methodology enables us to correctly acquire and analyse the pressure field. This analysis is performed in the time domain and frequency domain.

The first results of the application of this methodology in the case of free falling jet at arc dams into a plunge pool, are presented.

1.- INTRODUCTION

The phenomena associated with macroturbulent pressure fluctuations can be responsible for differential pressures, fatigue phenomena due to alternating loads, resonance phenomena when the frequency adjusts to the structure's eigen-frequency and intermittent cavitation phenomena.

The number of examples of deterioration around the world [ICOLD (1987), (1983)] shows the lack of knowledge in this field, and this is probably due to the practical difficulties posed by the detection, recording and analysis of the random variables (velocities and pressures).

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This work offers an experimental and numerical method, designed, calibrated and contrasted for the study of the pressure field in various types of hydraulic energy dissipators. The work was done at the Hydraulic Laboratory of the Civil Engineering School of the Polytechnical University of Catalonia - Spain.

This methodology is used from two points of view:

- As a fundamental tool in the study of hydraulic models of specific prototypes.
- In a line of research to improve our hydraulic and structural knowledge of energy dissipators.

2.- BASIS OF THE METHODOLOGY

The methodology is based on the physical modelling of the studied structure and on recording the instantaneous pressures at different points, using piezoresistive pressure transducers.

Pressures are detected and recorded in accordance with the Sampling Theorem of System Theory; so, the sampling frequency, has to be at least double the frequency to be detected; to avoid the overlapping of high frequencies on low frequencies, called the "aliasing phenomenon". [OPPENHEIM A.V. and SCHAFER R.W. (1975), TRETTER S. (1976)].

The recorded pressures are analysed through the Random Variables Theory because the studied phenomenon is assumed to be a Stochastic, Stationary and Ergodic Process - [STANISIC M. (1985), ASH R.B. and GARDNER M.F. (1975), PAPOULIS A. (1965)].

The methodology is supported by a software package that consists of 2 data acquisition programs and 5 data treatment programs.

3.- EXPERIMENTAL METHODOLOGY

It is an automated data acquisition system (Fig.1), whose fundamental parts are: the hydraulic model, the pressure transducers, a data acquisition card that transforms the analog signal to a digital one, and the computer that controls the tests. The signal recorded in the tests is stored on diskettes, to be transferred later to a larger computer where it will be treated.

The pressure transducers are a very important part to be considered in the experimental methodology, because they are the basic elements that determine pressure records; therefore their functioning has to be checked to guarantee the reliability of the experimental result. Fig. 2, shows the calibration device schematically.

3.1. Static Calibration

It consists of recording the pressure levels of a water column and it's corresponding voltage values, measured by the transducer. It is performed at different heights, while filling and emptying the water tube.

The results are plotted and their regression equations are determined. A linear response in every transducer makes its use easier and guarantees low hysteresis. In fact it is important to require this characteristic when selecting a transducer. Fig. 3, shows a typical static calibration curve.

3.2. Noise Treatment

It has been found that the slops of the linear response obtained by the static calibration of the pressure transducers (nominal sensitivity), are practically the same as the values given by the manufacturer and they are essentially constant during their whole useful life; the ordinates to the origin of these curves, have a random variation, due to the noise conditions present each day, therefore it is necessary to obtain this value in each test run [see CASTILLO (1989)].

3.3. Dynamic Calibration

The dynamic calibration finds the transfer functions of the pressure transducers. The transfer function defines the kind of response (in the frequency domain) of the pressure transducers to the dynamic stimuli, and, therefore, up to what frequency the dynamic information obtained in the tests is reliable.

The transfer function of a system is defined as the Fourier Transform of the response to the impulse [(KOOPMANS L.H. (1974), OPPENHEIM and SCHAFER (1975)].

To obtain the impulse function, we use the same equipment as in the static calibration (Fig. 2) so, we try to obtain a (jump/fall) function by opening the electrovalve, producing a unitary pressure increment by communicating vessels. So the derivative of the jump function gives us the impulse function we wanted.

The electrovalve opening time conditions the kind of response obtained in laboratory. So the response obtained can be considered as a "jump function", for opening times smaller or equal to the sampling period; otherwise, we will obtain a "ramp function" [see CASTILLO (1989)].

Fig. 4, shows a transfer function of one of the pressure transducers, which indicates that the transducer's dynamic response is reliable up to 25 Hz. For higher values it would be necessary to correct the transference functions, using an inverse filter.

4.- NUMERICAL METHODOLOGY

This is based on a Probabilistic Model and enables us to analyse the Pressure Field in Time and Frequency Domain.

4.1. Time domain analysis

From the pressure records, we obtain maximum, minimum and mean pressure fluctuation values.

Maximum amplitudes, maximum semiamplitudes (both above and below the mean pressure), time and spatial correlations are found and the pressure wave form is characterised through the Probability Distribution and the Probability Density Functions.

4.2. Frequency domain analysis

This is done through frequency decomposition by conventional techniques of Spectral Analysis (Discrete Finite Fourier Transform and the implementation of the Fast Fourier Transform Algorithm).

This frequency analysis is performed for the Univariate and Multivariate cases, by obtaining its spectral estimation, through the Periodogram Method.

4.2.1. Univariate Spectral Density

This determines the frequency distribution of the cuadratic pressure fluctuations. Therefore, we are able to analyse the resonance phenomena by possible couplings of dominant frequency bands of pressure fluctuations, with the structure's eigen-frequency.

4.2.2. Multivariate Spectral Density

By means of "coherence and phase" functions, we are able to measure the degree of linear association and the mean phase-shift in a frequency, of the pressure records, measured at different points.

The "coherence" measures the degree of correlation and the "phase" determines the average phase-shift between actions at the analyzed points.

Therefore from this analysis we will define the actions and vibration modes of the studied structure.

5.-METHODOLOGY APPLICATION TO FREE SPILLING IN ARC DAMS. RESULTS

A first application of the methodology has been made to free spilling in arc dams, using the hydraulic model of "Llosa del Cavall" Dam, that gives a constant falling height of 1.72m. A methacrylate plunge pool was constructed, at whose bottom where installed the piezometers and the pressure transducers.

Three flows were analysed (Q=3, 6 y 8 l/s) with 8 heights of water cushions (h=0,4,6,12,16,20 y 25 cm.). From the five measure points, 110 records of instantaneous pressures, were obtained.

Each pressure record contents 2400 data, obtained with a frequency of 20 samples per second and a test time of 120 seconds. Fig. 5, shows the five measuring points at the basin's bottom. The impact point or stagnation point defines the coordinates origin (x,y).

Fig. 6, shows the mean pressures calculated for the three tested flows, with a water cushion height of h=0.25 m for different recording times from 30 sec. to 120 s. These results confirm the stationary hypothesis, assumed in the analysis and information treatment.

Typical plots of a test run are shown in Fig. 7, where we can observe that the sampling frequency has been high enough to register the phenomenon. Observe the alternating pressure and its continuous falling below zero at point T4, such as the differential pressure between points T2 y T4.

Fig. 8, presents the mean dynamic pressure P_s obtained in this work for the stagnation point and compares it with the expression proposed by COLA R. (1966). We can say that the mean dynamic pressure at the stagnation point can fit a single curve, in function of the parameter h/B thus it is independent of the spilling flow, because its whole effect is integrated in the thickness of jet B.

The values obtained from the expression proposed by Cola are higher than those obtained in this work, because Cola doesn't consider the jet aeration effect when falling freely in the atmosphere nor the entrainment of air which occurs when the jet enters the cushion.

This conclusion can be applied to the maximum and minimum dynamic pressures, maximum amplitudes of pressure and semiamplitudes above and below the mean pressure [CASTILLO (1989), (1990)].

The fluctuation pressures for the stagnation point are analysed through the "mean square fluctuation pressure" P_f that is adimensionalized with regard to the "mean square fluctuation pressure", corresponding to the direct impact case on null cushion P_{f0}, in terms of the parameter h/B, as shown in Figs. 9 and 10. Also we show the results proposed by LENCASTRE (1961). We can say that from this results, a functional relation is established through the family of curves which depends on the spilling flow, and therefore the jet B thickness doesn't contain the whole effect, in contrast with Lencanstre's conclusions.

An important fact, indicated by Lencastre and now verified, is that the maximum pressure fluctuations don't appear in the direct impact case (h=0), but for low heights of water cushion. This phenomenon can be explained by the null or small effect of small cushions in the energy dissipation, and by the advantage that a certain water cushion thickness gives for developing turbulence. These maximum pressure fluctuations are produced for values of [$4 \leq h/B \leq 8$].

The present study reveals our poor knowledge of the pressure fluctuations dissipation and the turbulence indices in terms of the water cushion height.

Therefore in accordance with the values obtained in our tests, and other authors' results, we show some first results.

Fig. 11, shows the Density and Probability Distribution Functions of the instantaneous pressures, recorded at the stagnation point for different heights of water cushion, observing that they approach a Normal Type Distribution when a greater height of water cushion exists.

Fig. 12(a) shows the Univariate Spectral Densities for the direct impact case (h=0) and Fig. 12(b) shows the maxima of the Spectral Densities for every test flow at the stagnation point. We came to the conclusion that the energy associated with the pressure fluctuations is negligible for frequencies over 0,3 Hz.

Besides, it is confirmed again that the maximum pressure fluctuations appear with low heights of water cushions and not for the direct impact case.

Fig. 13 shows the maximum coherence and the phases corresponding to the pressure fluctuations for the flow Q=3 l/s and water cushion heights h=4, 12 and 20 cm. It is observed that maximum coherences are under 0,10 Hz, in all the analysed cases.

The greatest coherence belongs to the pairing of points down-stream and to the right of the stagnation point, with a water cushion height of 20 cm.

The corresponding phase is 0°; this indicates that the pressure fluctuations at these points appear at the same time and in the same direction. The complete analysis of the coherences and phases for each flow and water cushions height, between the measuring points at the basin's bottom, can be found in CASTILLO (1989).

The evolution of the coherences in terms of h/B for the Q=3 l/s is shown in Fig. 14. We observe that the pressures at the points coupled with the stagnation point have a low coherence; this indicates the independence between actions. Meanwhile for points which do not pair with the stagnation point, the pressures have higher coherence, which implies a considerable synchronization of the pressure fluctuations. It may be interesting to consider this in the dynamic calculation of the structure.

At the Hydraulic Laboratory of the Polytechnical University of Catalonia a substructure has been constructed to make tests with falling heights of 7m and a flow range up to 300 l/s which, together with this methodology, will enable us to advance in the knowledge of this type of structures.

ACKNOWLEDGEMENT

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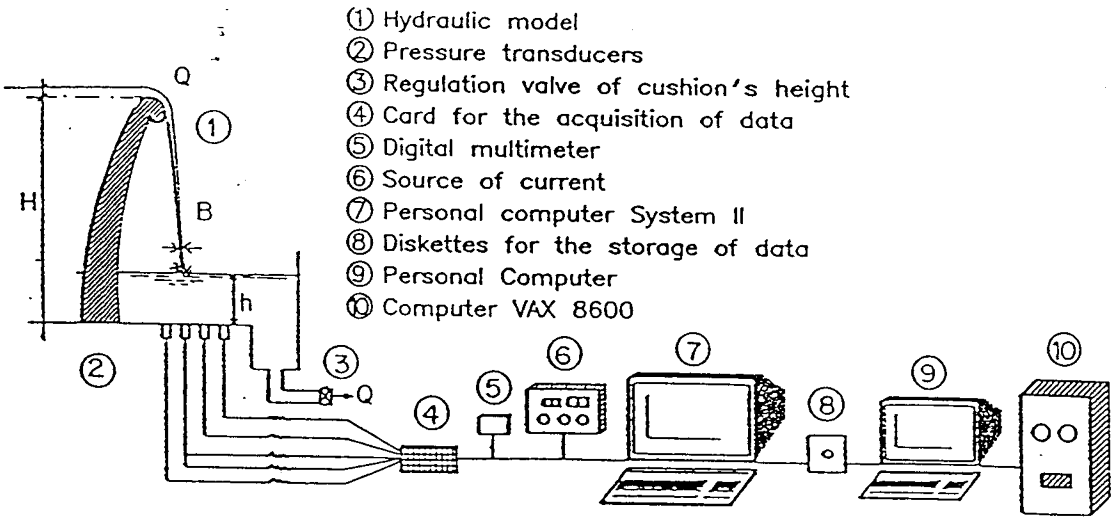
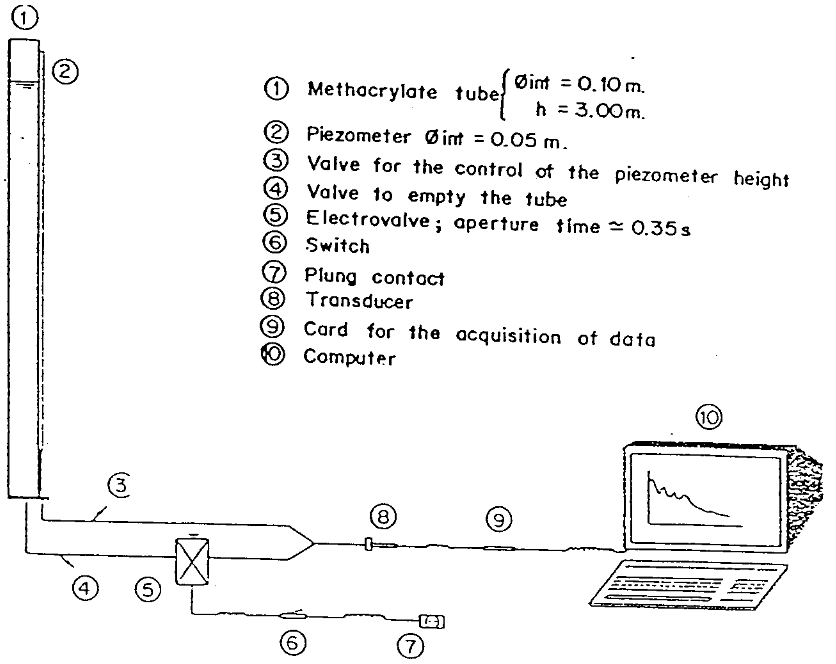


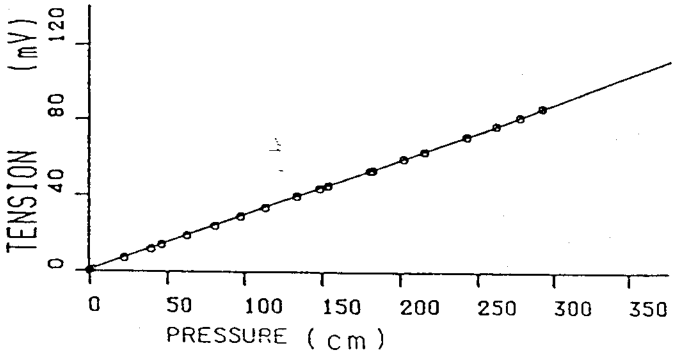
① Hydraulic model
② Pressure transducers
③ Regulation valve of cushion's height
④ Card for the acquisition of data
⑤ Digital multimeter
⑥ Source of current
⑦ Personal computer System II
⑧ Diskettes for the storage of data
⑨ Personal Computer
⑩ Computer VAX 8600

FIGURE 1



① Methacrylate tube $\begin{cases} Øint = 0.10\,m. \\ h = 3.00\,m. \end{cases}$
② Piezometer Øint = 0.05 m.
③ Valve for the control of the piezometer height
④ Valve to empty the tube
⑤ Electrovalve; aperture time ≃ 0.35 s
⑥ Switch
⑦ Plung contact
⑧ Transducer
⑨ Card for the acquisition of data
⑩ Computer

FIGURE 2



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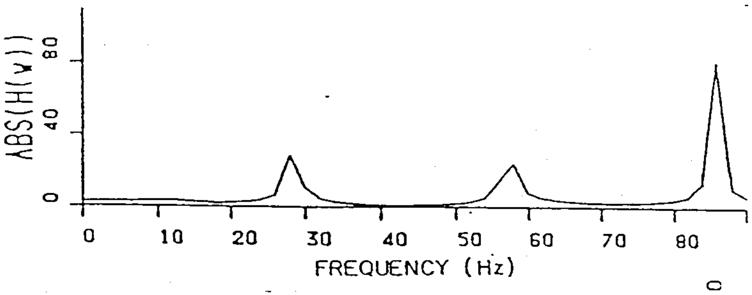

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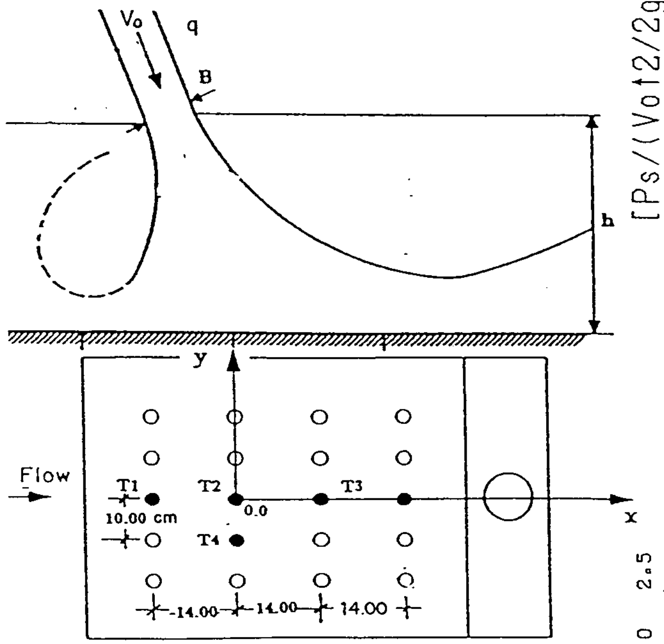
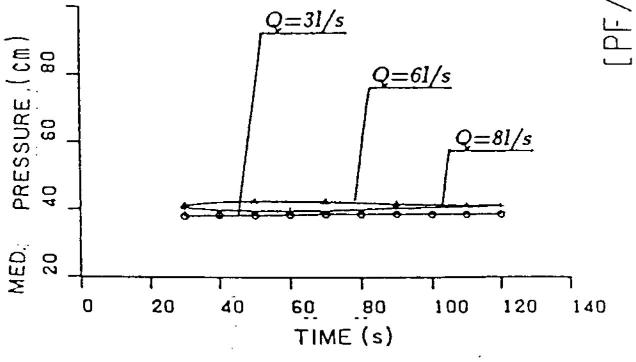


FIGURE 5



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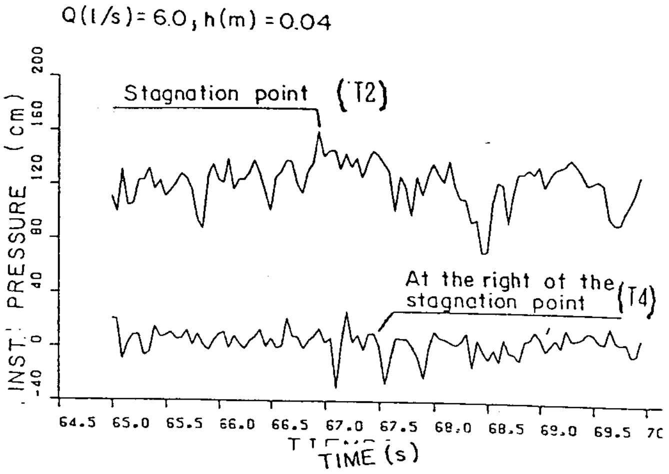

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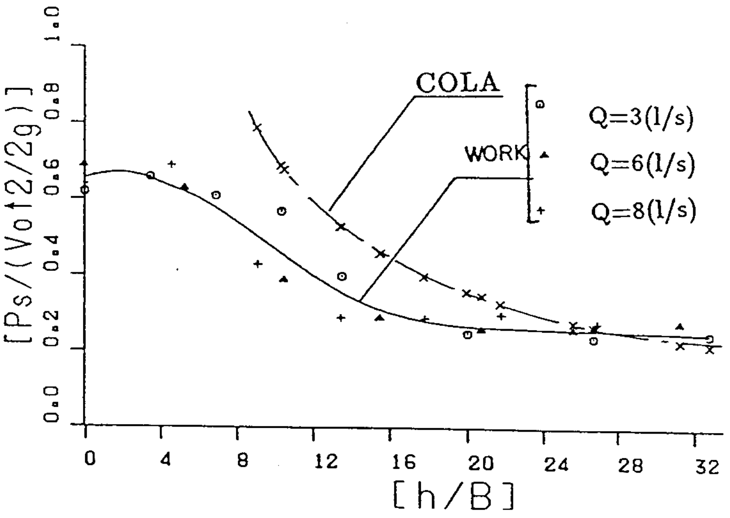


FIGURE 8

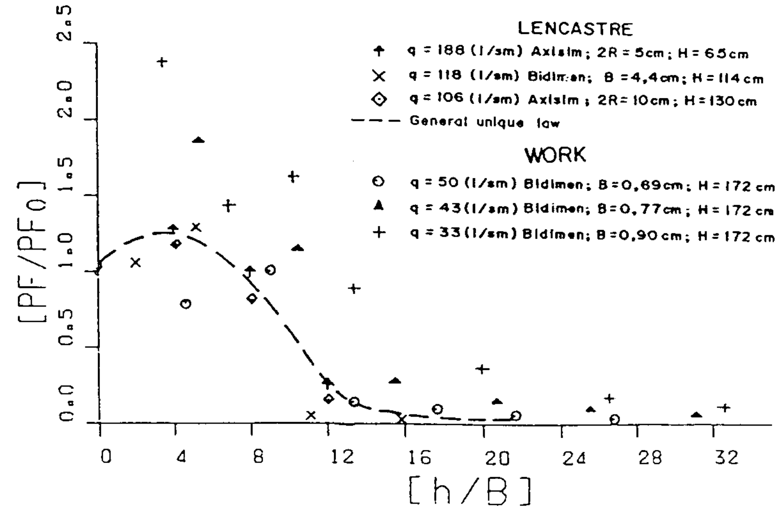
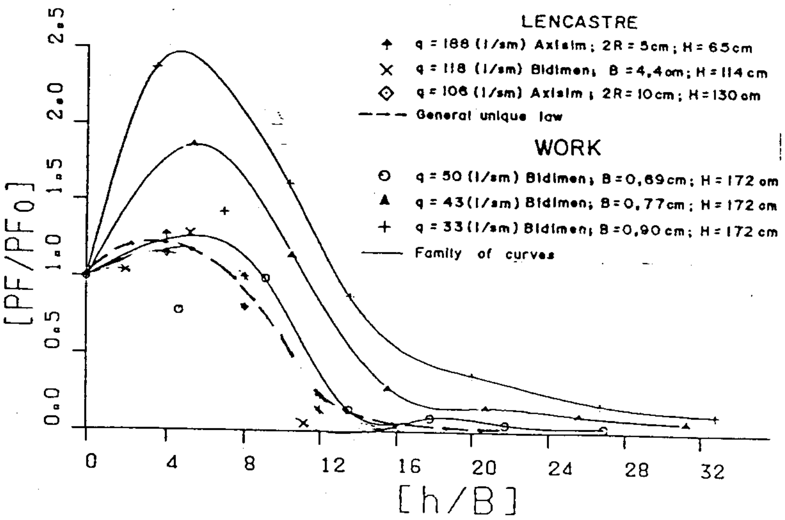


FIGURE 9



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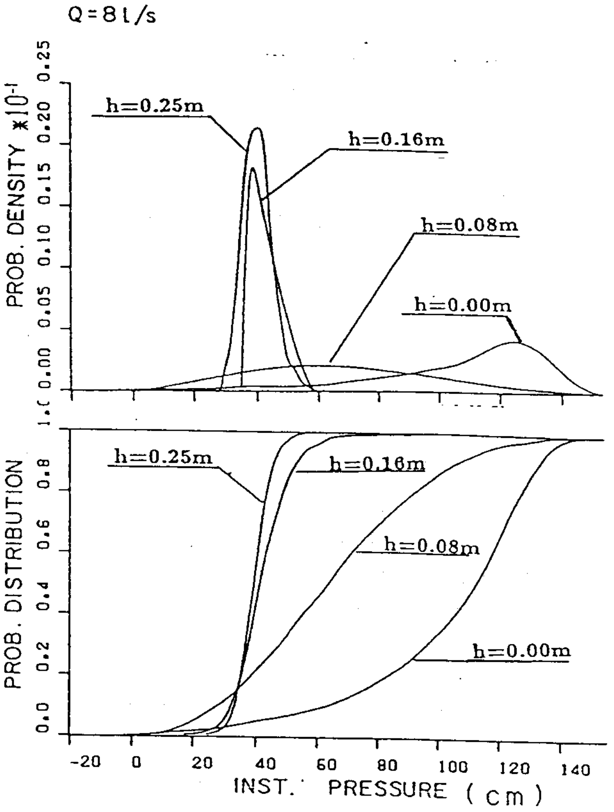

FIGURE 11

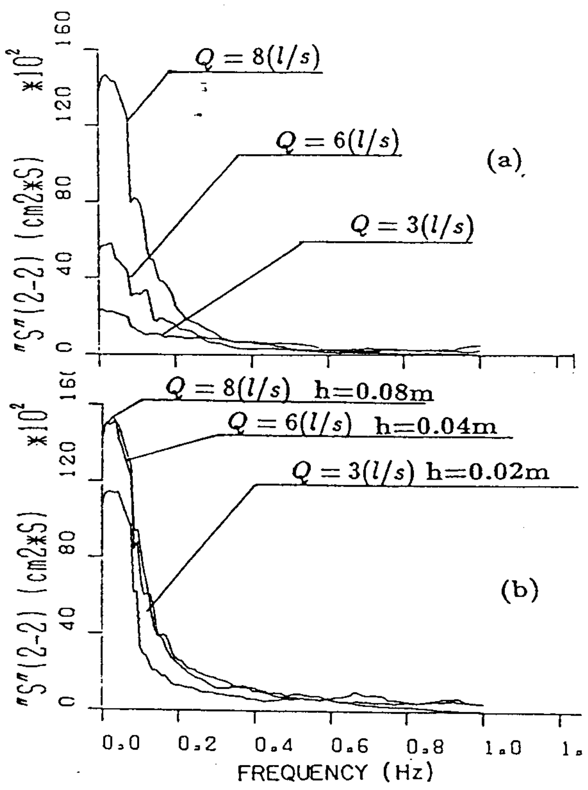

FIGURE 12

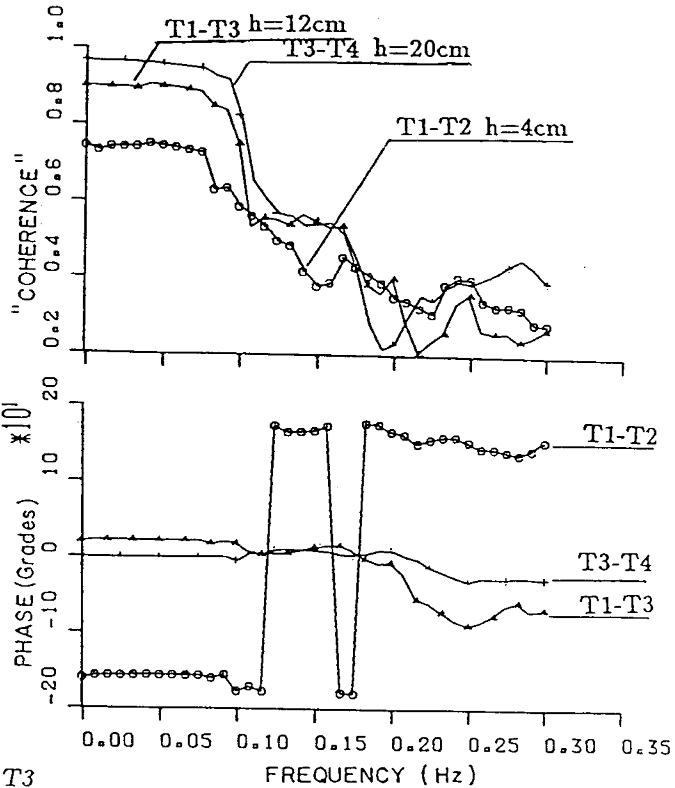

FIGURE 13

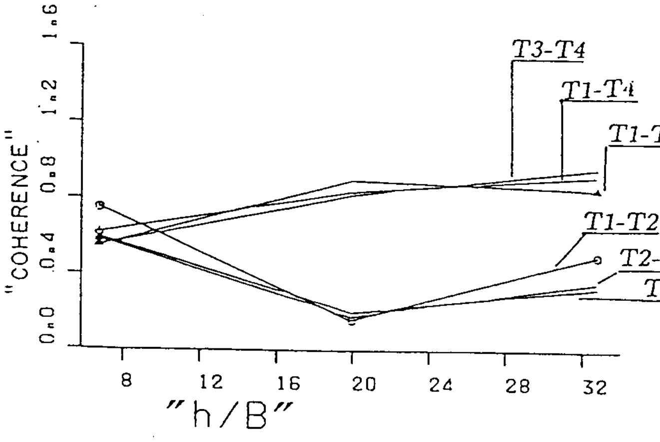

FIGURE 14