STATISTICAL CHARACTERIZATION AND MODELLING OF WAVY LIQUID FILMS IN VERTICAL TWO-PHASE FLOW

A Dissertation

Presented to

the Faculty of the Department of Chemical Engineering

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy in Chemical Engineering

---

by

Kuang-Juh Chu

August, 1973

ACKNOWLEDGEMENTS

The research project described in this thesis was carried with help from various persons and organization. The author would like to express his sincere gratitute to:

Dr. A. E. Dukler for his invaluable guidance and constant encouragement during the course of this study;

U. S. Department of Interior, Office of Saline Water, for their support under Grant no. 667;

Dr. M. G. Hubbard for his encouragement to take this research project;

Mr. W. N. Chen for his assistance in constructing the experimental apparatus, running the computer program, and plotting the graph;

Dr. A. J. Seriff for his valuable suggestion about the signal analysis;

Dr. P. Hutchinson for his valuable suggestion about the stochastic differential equation;

Dr. F. L. Worley Jr. for his valuable suggestion about the experimental apparatus;

Dr. R. L. Motard for his help in formulating the digilization procedures;

Dr. D. Webb for his valuable suggestion about the film thickness measurements;

Mr. Mike Smith for his designing and building the various electronic circuits;

Mr. Roy Priest for his careful machining of the experimental apparatus;

The Engineer System Simulation Laboratory and their staff for providing the computer facilities and debugging the computer program;

Mr. C. Y. Chang and Mr. Charles Huang for their assistance in preparing the graphs.

Finally, the author wishes to express deepest appreciation to his wife, Stella for her patience and encouragement throughout the project, and also for her careful punching of the data cards and typing the manuscript.

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ABSTRACT

The motion of a wavy liquid thin film falling under the action of gravity and of a co-current gas flow, was investigated in a 2" diameter channel for a wide range of liquid and gas flow rates. The Reynolds number for the liquid phase was varied from 200 to 7500 and for the gas phase, from 0 to 113000. Since the nature of all processes observed in such a system are "random", it was necessary to use statistical means to describe this random wave process.

By the use of a number of techniques for time series analysis, a broad range of information on the characteristics of the waves was extracted from the film thickness data. The existence of three distinct classes of waves was established from this analysis, each with their characteristic dimensions (amplitude, shape, base length and separation distance) and celerity. One type is the small waves moving on the substrate; a second is the large wave structure and a third type are small waves moving on these large waves. Detailed statistical data were developed including probability density and moments for the amplitude, location of maximum, minimum, separation time, base dimension, shape and celerity for each class. The variation of these statistical properties with liquid and gas rates and with location down the tube were established. Joint probability densities

for certain important properties were also obtained. In order to develop much of this information, several new techniques of extracting the relevant data from the signals had to be developed involving special processing of the time series analysis and detailed interpretation of the stochastic process, h(t).

A new technique for simultaneous measurement of local pressure and film thickness was developed. By measuring the spectral density of the wall pressure fluctuations and cross density between the pressure and film thickness definitive information on the gas-liquid interaction was obtained.

These data were used to determine the distribution of liquid flow between waves and substrate and, for the first time, it is possible to understand the local flows in a wavy system such as this. The data also permitted definitive tests of existing theories. All were shown to be inadequate for both large and small waves.

New theoretical approaches were developed to explain the process of wave motion. These included (1) introducing white noise perturbations into the equations of motion and (2) extending a theory originally proposed by Telles in which a shot noise model is assumed for the wave motion. In particular, this extension is shown to be the only theoretical description of wave motion that describes large wave behavior.

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CHAPTER I

INTRODUCTION

The flow of thin films of liquid over a solid surface with and without gas flow has been observed in numerous engineering processes in the field of petroleum, chemical, nuclear and power industries. The significance of film flow in the above processes lies in the fact that higher heat and mass transport rates are caused by the presence of the liquid interface itself.

The influence on the transport processes by this free liquid surface is due to the waves which are generated on the interface by response to external disturbances. Description of the free surface waves present as an important, difficult, and challenging problem in the field of applied mathematics and practical engineering. The classical wave theory occupied the efforts of many great mathematicians such as G. Green, G. Airy, G. Stokes, Lord Rayleigh etc., Their works are well presented in many books by Stoker (S-7), Lamb (L-1), and Kinsman (K-4). Usually their approaches describe the wave motion on the free surface as periodic. But in the real world one often discovers that the classical theory is inadequate for many wave phenomenon on the free liquid surface such as ocean waves and wavy flow in two-phase flow. Once Lord Rayleigh took a look at ocean waves and remarked "the basic law of the seaway is the apparent lack of any law".

An adequate theory of stochastic processes is a quite recent development carried out by a number of men. Among the most important contributors are Khintchine, Kolmogorov, Levy, Tukey, Rice, and Slutsky. This advanced mathematics first appeared in the field of turbulence and communication theory. Pierson (P-7) was the first oceanographer who applied the results developed for noise in electronic circuits to problems in ocean gravity waves. He brought together four major concepts which were necessary before the modern approach to wave could take form:

(a) The conviction that the problem of bringing law to the confusion of the ocean wave, in its essence, was a statistical problem.

(b) The realization that even under the new formulation the motion must still obey the classical equations (Navier Stokes equations).

(c) The identification of the energy spectrum as the ordering and governing principle in the apparent confusion.

(d) The conception that the space-time function describing a given sea state must have a certain multivariate probability structure.

Since Pierson's four concepts, one discovers a viewpoint from which the chaotic appearance of the ocean waves reveals a kind of order.

The existence of certain random aspects of the waves motion on falling film was discovered by Dukler (D-9), W'cks (W-4), Telles (T-2), and Webb (W-2). But the nature of this random process is still not well defined. Waves on the falling film present a more difficult problem than ocean waves for the following reasons:

(a) The waves of the falling film appear strongly non-Gaussian in nature which prevents one from using certain statistical transformation possible for ocean waves.

(b) The external force acting on the waves in the direction of propagation is not only due to the gas phase velocity but also due to the gravitational force.

(c) Since the waves appear on the very thin film the viscous forces also are important and the potential function can not be applied as in the ocean waves system.

(d) The velocity field is impossible to measure.

The purpose of this work is to study certain statistical properties associated with instantaneous film thickness and wave structure, to examine the question of the characteristics of this random wave system in search of a more fundamental basis on which to build stochastic models for the waves and to investigate analytically various approaches to obtain a more fundamental understanding of this complex wavy velocit; field.

CHAPTER II

PREVIOUS STUDIES

1. INTRODUCTION

A general review of the two-phase flow in conduits was published by Dukler and Wicks (D-7) in 1963, and a detailed survey of film flow in particular was presented by Fulford (F-1) in 1964. Recently a detailed discussion of modelling of the wavy gas-liquid interface was given by Dukler (D-3), and a comprehensive survey of annular two-phase flow was also given by Hewitt and Hall-Taylor (H-7). A detailed review and discussion of important theoretical progress and experimental measurements in vertical wavy falling film with and without gas flow will be given in the following section, particularly the publications after 1965.

2. THEORETICAL ANALYSIS

All the theoretical analysis for a falling film start with the equation of continuity and the equations of motion for a two dimensional system as follows:

$$u_x + v_y = 0 \qquad \text{(II-1)}$$

$$u_t + u u_x + v u_y = g - \frac{1}{\rho} p_x + \nu (u_{xx} + u_{yy}) \qquad \text{(II-2)}$$

$$v_t + u v_x + v v_y = - \frac{1}{\rho} p_y + \nu (v_{xx} + v_{yy}) \qquad \text{(II-3)}$$

Boundary conditions of this falling film system are: no slip condition at wall, normal stress and shear stress at interface, and the kinematic boundary condition. These boundary conditions are expressed in the following five equations:

$$u = 0 \qquad \text{at} \quad y = 0 \quad \text{--------} \quad (\text{II}-4)$$

$$v = 0 \qquad \text{at} \quad y = 0 \quad \text{--------} \quad (\text{II}-5)$$

$$p = 2\mu \left\{ \frac{u_x h_x^2 - (u_y + v_y) h_x + v_y}{(1 + h_x^2)} \right\} + \sigma \left\{ \frac{h_{xx}}{(1 + h_x^2)^{3/2}} \right\} \qquad \text{at} \quad y = h \quad \text{---} \quad (\text{II}-6)$$

$$2\,(v_y - u_x)\, h_x + (v_x + u_y)\,(1 - h_x^2) = 0 \qquad \text{at} \quad y = h \quad \text{---} \quad (\text{II}-7)$$

$$v = h_t + u h_x \qquad \text{at} \quad y = h \quad \text{---} \quad (\text{II}-8)$$

A complete solution of this set of nonlinear partial differential equations with nonlinear boundary conditions is impossible to obtain. Only partial information can be developed and this only when suitable simplifications are made.

2-1. SMOOTH FILM MODEL

The first two important theoretical studies of vertical film flow were done by Hopf (H-9) in 1910 and Nusselt (N-2) in 1928. They considered that the flow is a steady, uniform smooth film and is controlled by gravitational and viscous force only. The equations and the boundary conditions can be simplified by the above assumption as

$$\nu \frac{d^2 u}{dy^2} + g = 0 \qquad (\text{II}-9)$$

$$u = 0 \qquad \text{at } y = 0 \qquad (\text{II}-10)$$

$$\frac{du}{dy} = 0 \qquad \text{at } y = h \qquad (\text{II}-11)$$

The solution is the famous parabolic velocity distribution

$$u = \frac{g}{\nu}\left(hy - \frac{y^2}{2}\right) \qquad (\text{II}-12)$$

Since that work there are many extentions of this famous result for different geometry and by adding different correction terms. The most important and significant work in this smooth film approach was developed by Dukler (D-4, D-8). He considered a turbulent liquid film with and without interfacial shear due to the action of co-current gas flow. The basic equation was obtained by a force balance among gravitational force, viscous force, Reynolds stress and interface shear stress.

$$\frac{d}{dy}\left\{(\mu + \varepsilon_1 \rho_L)\frac{du}{dy}\right\} - \frac{\partial p}{\partial x} + (\rho_L - \rho_G)\, g = 0 \qquad (\text{II}-13)$$

The numerical solution of this equation was presented in terms of two parameters: the liquid Reynolds number and a dimensionless pressure drop parameter. The approach was also extended by Dukler (D-5, D-6) in a heat transfer design problem.

The main defect of this type of approach arises from the fact that the film is not smooth at all except near the region of entrance and very small liquid flow rates. Experimental evidence shows that the transport rate is controlled by the rough surface due to the waves. Recently, Wicks (W-4) extended Dukler's turbulent smooth film model by introducing a discontinuity in the stress at the gas-liquid interface to take care of the effect of interactions between the gas flow and the surface wave. To accomplish that, he assumed that one can neglect the effect of the wave disturbance in the continuous liquid phase below the waves and the gas phase. The studies by Worley (W-5) would tend to indicate that this assumption is valid on the gas phase, but on the liquid phase there might persist a significant effect all the way to the wall.

2-2. WAVY FLOW BY STABILITY CONSIDERATION

The first series of rigorous formulations of the stability of a liquid film flowing down an inclined plane were presented by Yih (Y-1, Y-2) and Benjamin (B-3). Their basic approach can be stated as below:

(a) The primary flow obeys the Nusselt equations (II-9), (II-10) and (II-11)

(b) A sinusoidal disturbance on the velocity field and pressure is assumed, and the form of disturbance is expressed by means of a Fourier series

$$\psi' = \phi_1(y) \exp\{i N_W (x - ct)\} \quad ------ \quad (II-14)$$

$$p' = \phi_2(y) \exp\{i N_W (x - ct)\} \quad ------ \quad (II-15)$$

(c) Assuming the disturbances are small, the equations (II-1) through (II-8) can be linearized and simplified. The well-known Orr-Sommerfeld equations results.

$$\phi_1'''' - 2N_W^2 \phi_1'' + N_W^4 \phi_1 = i N_W Re \{(U - C)(\phi_1'' - N_W^2 \phi_1) - U''\phi_1\} \quad -- \quad (II-16)$$

where N_W is a dimensionless wave number

C is a complex wave velocity

Their results can be summarized by the statement that the flow is unstable for all Reynolds numbers. The wave velocity is obtained as three times the average velocity calculated from Nussels equations. This analytical solution for infinitesimal disturbances has done much to improve an understanding of the instability of this flow, but their results are limited to flows of low Reynolds number or very low Weber number and therefore are not of great practical interest.

The direct numerical integrations of the Orr-Summerfeld Equation by Whitaker (W-3), permitted extension of results to higher Reynolds numbers. Anshus and Goren (A-3) obtained an approximate solutions by replacing the x directions velocity by its values at the free surface, and their results agreed well with that of Whitaker. Recently, Anshus (A-1) solved the Asymptotic Solution of the Orr-Summerfeld Equation, and Krantz and Goren (K-7) used a polynominal equation in y for the velocity profile to integrate the equation of motions and reduced the differential equations to the algebraic equation for the wave number N_w. All these three results predict that the wave velocity and the wave length is a function of Reynolds number, and the dimensionless wave velocity $(c/\bar{u})$ is always less than or equal to three.

The above linear stability theory can only predict the initial growth of an unstable infinitesimal disturbance breaking down once the disturbance becomes too large. To take account of initially finite disturbance and to predict equilibrium amplitude when disturbance grows to finite size, a nonlinear stability theory was developed. In 1965, Anshus (A-2) applied Stuart's (S-8) and Watson's (W-1) nonlinear stability theory of parallel flow to derive a amplitude equation for the case of falling film. The usual form of amplitude equation is

$$\frac{dA^2}{dt} = k_1 A^2 + k_2 A^4 \qquad (II-17)$$

where k_1 and k_2 are functions of wave number N_W, wave velocity C and Reynolds number Re. The equilibrium amplitude of the wave was obtained directly by letting $\frac{dA^2}{dt} = 0$. Recently Lin (L-4, L-5, L-6) has applied the amplitude expansion technique proposed by Reynolds and Potter (R-1), who extended and modified the method of Stuart and Watson, to study the nonlinear stability of a falling film. His results show that the wave velocity of long waves increase with the amplitude. But for the waves with relatively short wave length, the wave velocity decreases as the amplitudes increase. A result particularly important to this study is the discovery that the solution is able to give a wave profile and to predict a wave velocity greater than three times the average film velocity.

In parallel to the above work which applies Stuart and Watson's method, Mei (M-2) and Benny (B-4) presented another approach to treat nonlinear waves on thin films. Their approach is a systematic direct expansion of equations of motions and boundary conditions by a suitable dimensionless small parameter. However, the effect of surface tension is neglected in their nonlinear analysis, and consequently they were unable to obtain a finite equilibrium amplitude. Nakaya and Takaki (N-1) used similar expansions as Mei and retained the surface tension term. A equilibrium amplitude was then obtained. This clearly indicated that surface tension does have a stabilizing effect on finite-amplitude waves. Recently Gjevik (G-2) extended Benney's method to include the effect of surface tension. His results is similar to Lin's prediction. Krantz and Goren (K-6) also used Benney's expansion method to show that equilibrium amplitude for most highly amplified waves is a function of a single dimensionless group $G = Re\,We^{1/2}$ the asymptotic solution of equilibrium amplitude for the case of $G \ll 1$ and $G \gg 1$ was solved by Javdani and Goren (J-1).

2-3. WAVY FLOW BY INTEGRAL METHODS

Three approaches which have been followed in the search for periodic solutions of the integral momentum equations to characterize the wavy interface will be briefly discussed in this section.

(i) Kapitza's method

This approach was first suggested by Kapitza (K-2). The main idea of his approach can be summarized as follows:

(a) The x-direction equation (II-2) is integrated over the film thickness, and P_x term is evaluated from boundary condition (II-6) which introduces the surface tension force with equations.

(b) Assuming the profile of the free surface moves without changing in form with a constant wave velocity, it is possible to integrate the kinematic boundary condition (II-8) and to relate the instantaneous film thickness and instantaneous velocity to the mean film thickness and mean velocity as

$$h\,(c-\bar{u}) = h_o\,(c-u_o) \qquad \text{(II-18)}$$

(c) By assuming the velocity profile to be everywhere parabolic, scaled by the instantaneous film thickness (which is related to the mean film thickness by $h = h_o(1+\eta)$), the partial differential equation obtained from (a) can be reduced to a ordinary differential equation in terms of η .

The solution is obtained by seaking the condition at which a steady periodic solution exists. The linear theory of Kapitza which considers only the first harmonic in the η expansion, predicts the wave velocity and the wave length. Kapitza's nonlinear theory retains two harmonics but produce an unknow wave amplitude which is dependent on mean film thickness $\bar{h}_o$. A minimization principle which has yet to be validated, was used to minimize $\bar{h}_o$. This nonlinear theory gives not only the wave velocity and the wave length but also the wave amplitude.

There have been numerous studies based on the modification of Kapitza's method. Among those the most significant extension on no gas flow are Shkadov (S-2), Lee (L-2), Byatt-Smith (B-9), Rushton and Davies (R-3), Gollan and Sideman (G-3), Massot, Irari, and Lightfoot (M-1), and Levich (L-3). The extension for the case where the free surface was exposed to the shear due to a gas flow was also done by Semenov (S-1) and Wicks (W-4). The solution obtained from this integral method agree reasonably well with that of stability method. However this method is simpler.

(ii) Ruckenstein's method

In 1968, an interesting work was done by Berbente and Ruckenstein (B-9). They used the Kapitza's type equations. As in the procedure of Kapitza, a velocity distribution is assumed, but in their case the velocity is described by a power series in y up to the 6th degree, the coefficient of each term depending on a single variable x'

$$\frac{U}{U_o} = \frac{3}{2} \sum_{n=0}^{6} a_n \left(\frac{\bar{h}-y}{\bar{h}_o}\right)^n \qquad (\text{II}-19)$$

$$\frac{V}{u_0} = \frac{3}{2} \sum_{n=0}^{6} b_n \left(\frac{\eta - y}{\eta_0} \right)^6 \quad \text{--------- (II-20)}$$

, where $\quad a_n = a_n(x')$

$$b_n = b_n(x')$$

$$x' = x - ct$$

The velocity is no longer parabolic and local accelerations in the waves can be accommodated. Substituting ~~of~~ these relations for velocity into the equations of motion and the continuity equation, a set of nonlinear differential equations in terms of η , a_n and b_n are obtained. By making the Fourier series expansion and linearization, the equations are reduced to a set of algebraic equations. The absence of one relationship makes a closed form solution impossible. A correlation between amplitude and a dimensionless group was made on Kapitza's data to make up one more relationship. The solution are close to Shkadov's results.

(iii) Dressler's method

A discontinous type solution for roll waves which is widely used in open channel flow, was first proposed by Dressler (D-2) in nearly horizontal channels and was modified by Brock (B-7) to include small channel angles. The approach is to apply the integral momentum equation to give the shape of the back of the single wave and a shock condition to the front. Recently Miya, Woodmansee, and

Hanratty (M-3) extended this roll waves model to the case where waves driven by the interfacial shear caused by gas flow in horizontal channel. The applicability of this roll wave model to vertical falling films have been explored in this laboratory.

2.4. STATISTICAL MODELS OF WAVY FLOW

Statistical models have been developed for gravity waves on the ocean under the condition of inviscid flow by Kampe' de Ferriet (K-1), Tick (T-4), Phillips (P-6) and Hasselmann (H-2). But the only random wave model for a falling film was done by Telles (T-2, T-3). Telles assumed that the separation distance of waves is a shot noise processes and a single wave can be represented by the Gram-Charlier series. The theory of shot noise processes which was developed by Rice (R-2), enables him to extract the Gram-Charlier coefficients from statistical data of film thickness such as moments. The equation of motion for an isolated wave represented by Gram-Charlier series was solved by quasi-linearization. The results give the liquid velocity profile and wave velocity for this isolated wave.

Telles's method is not a rigorous statistical approach. However it gives us a promising method to handle such a difficult phenomenon.

3. EXPERIMENTAL MEASUREMENTS

In the early stage of falling film study the experimental work was concentrated on measuring the mean film thickness. The experimental determination of parameters charactering the interfacial wavy structure is extremely difficult especially in the region far from the entrance or at high liquid flow rates. This is clearly indicated by the fact that the number of systematic experimental studies published in last ten years is much less than that of theoretical investigations. Some of the experimental investigations published are either qualitative or unreliable. Since the waves are moving at least in the two dimensions, x and t , it is ideal to have a measuring system which can simutaneously record the instantaneous film thickness at multiple position along the test tube. In order to reach the above goal, only the method of light absorption and conductivity probe are suitable at present time.

The following discussion will be based only on the important recent experimental investigation by Greenberg (G-4), Charvonia (C-1), Stainthorp, Allen and Batt (S-3 , S-4 , S-5), Portalski and Clegg (P-10 , P-11), Tailby and Portalski (T-1), Hewitt et al (H-1 , G-1 , H-2 , H-7), Webb (W-2), Wicks (W-4), and Telles and

Dukler (T-3). Table II-1 gives the outline of the experimental techniques used in these studies.

TABLE II-1

PREVIOUS EXPERIMENTAL TECHNIQUES

Investigator	Measuring Probe	Test Section	no. of Probes	Gas Effect Re_G	Liquid Effect Re_L	Length Effect
Greenberg and Charvonia	light absorption	2.5"I.D. tube 2.38' length	1	$5x10^4$-$3x10^4$	17-1780	---
Stainthorp Allen and Batt	light absorption	1.36"I.D. tube 2.49' length	1 and 2	$5x10^3$-$4.6x10^4$	20-200	2"-12"
Portalski Allen and Clegg	light absorption	21"wide 7'length	1	---	10-700	4"-10"
Wicks, Telles and Dukler	conductivity probe	6"wide 18'length	2	$2.7x10^4$-$5.7x10^4$	1000-5000	---
Hewitt and Webb	conductivity probe	1.5"I.D. tube 50'length	2	$3.5x10^4$ $8.2x10^4$	400-4200	6'-50'

3-1. FILM PROPERTIES

Measurements considering the film as a random process is a relatively recent development. Mean film thickness was measured in all of the studies described in Table II-1. The first important statistical measurement of film thickness was done by Charvonia. He used analog methods to construct a type of wave frequency - amplitude spectrum (in terms of standard statistical terminology this was a form of probability density function of the film thickness). Useful information was not obtained, however because of lack of other wave structure measurement and the difficulty in assigning the statistical meaning to such curves. Wicks used a similar technique to obtain the probability distribution function of film thickness. The probability distribution function is an integral function of the probability density function. It naturally contains less information. The spectral density and cross spectral density of film thickness were first measured by Telles using a wave form analyzer. Unfortunately the recording voltage which was used to obtain the spectral function is a nonlinear function of film thickness. Hence only part of the useful information can be extracted. Webb (W-2) recently repeated Wicks and Telles's measurement in a circular tube.

3-2. WAVE PROPERTIES

The characteristic of a fluctuation disturbance, or wave is described by Stainthorp et al (S-3, S-5) and Portalski et al (P-10, T-1) in terms of wave amplitude, wave velocity, wave length and wave frequency. Only the mean value of those quantities based on the arithmetic average of observation of less than 100 waves was presented. The statistical error in those mean value measurement is large. The first accurate measurement on wave velocity was from the phase spectrum by Telles. The same principle was applied by Webb using cross correlation. The only statistical function describing the variation in wave velocity was obtained by Webb. A method was used to obtain the probability density function of the wave velocity by measuring the time displacement of corresponding waves on a wave trace. It is doubtless that the result suffers a large error due to the difficulty of identifying the wave at two positions along the time. Lack of statistical description of the wave is obvious. Since the wave on the falling film is an unsymmetrical non sinusoidal type, using only the above four quantities to describe the wave is unsuitable and incomplete.

CHAPTER III

DESCRIPTION OF THE EXPERIMENTAL EQUIPMENTS AND TECHNIQUES

1. INTRODUCTION

The equipment used in this study was designed primarily to measure the interfacial structure of water-air film flow under the following considerations:

(a) The flow channel should be sufficiently long to permit fully developed wavy flow to occur over an appreciable length of test section.

(b) The cross section of the flow channel should be symmetrical in order to avoid corner effect which occurred in Wicks' (W- 4) and Telles' (T- 3) study due to their use of a rectangular channel.

(c) The inside wall of the test section should be sufficiently smooth and uniform to prevent disturbing the wave structure.

(d) Multiple measuring stations along the length and multiple probes along the periphery must be available to allow for a study of wave structure along the length and the periphery.

(e) The entire test section should be substantially free from external vibration.

In an attempt to satisfy these conditions, the following flow system was constructed.

2. GENERAL FLOW SYSTEM

The flow system consisted of a 14 ft long test section, a [illegible] ft long air-water injection section, a 2 ft long air-water separation section and four measuring stations. The whole system was mounted between two 3/4 inch plywood sheets on a 25 ft by 5 ft by 2 ft unistrut structure. A complete schematic flow diagram of the apparatus is given in Fig. III-1. The detailed structure of each section is described as follow:

2-1. LIQUID-GAS INLET SYSTEM

The liquid-gas inlet system consisted of a 12 inch long by 8 inch I. D. cylindrical tank to hold a constant level of water. Water flows down into a vertical 2 inch I. D. 1/4 inch wall pipe which is set inside the cylinder. Air is injected from the top of the cylinder into the 2 inch water outlet pipe by a 2.00 inch I. D. 1/4 inch wall pipe with a smooth knife outside edge, which can be adjusted to maintain a suitable gap to allow the water smoothly flowing down the pipe without forming a jet. A small tubing is also connected from the air inlet to the cylinder to equalize the pressure. A detailed sketch of the system

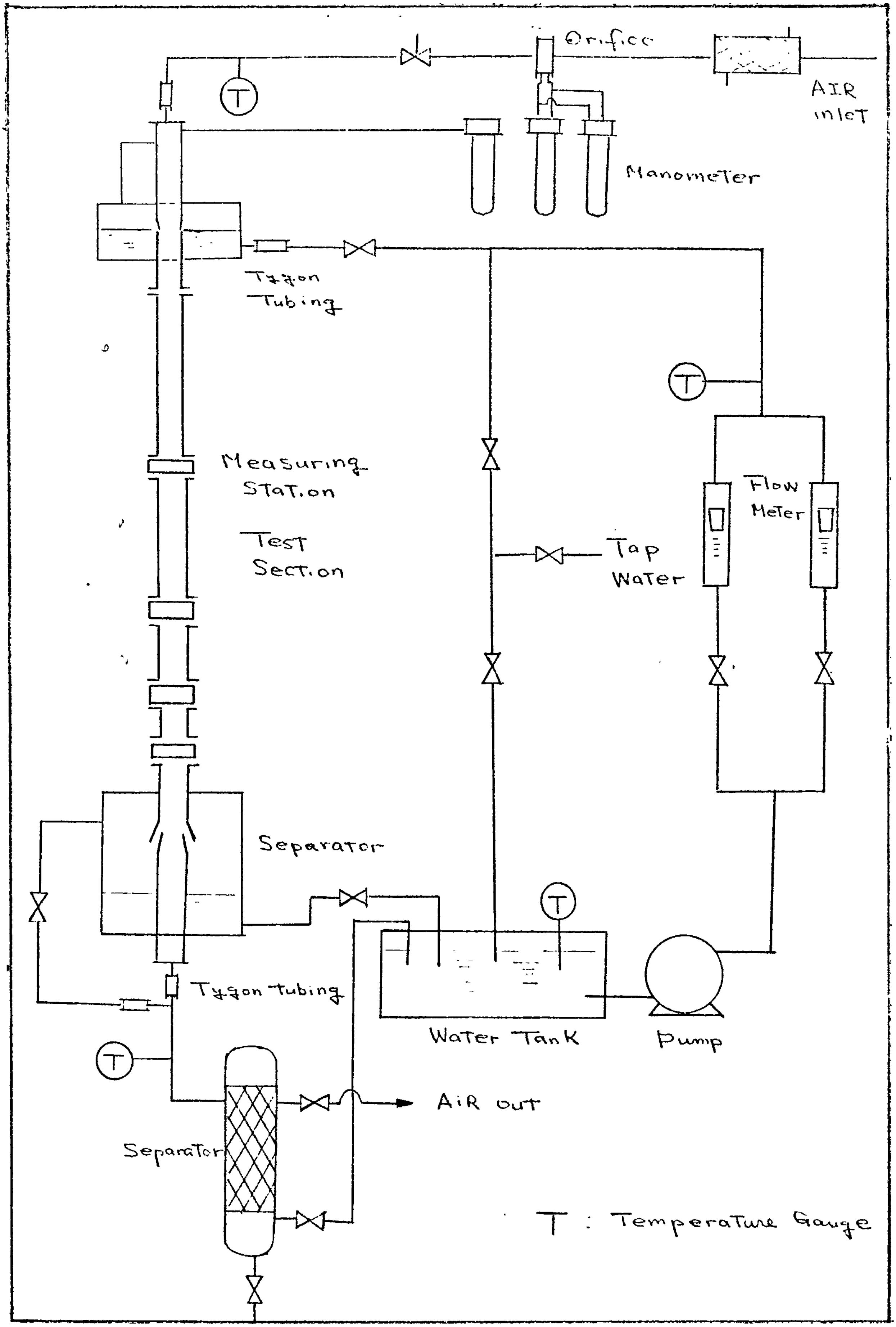


Fig. III-1. GENERAL FLOW SYSTEM

is shown in Fig. III-2. All the connections from this inlet system to the main air line and water line are flexible tygon tubing so that it can be adjusted to be perfectly horizontal and also insulate the test section from external vibration. This system was constructed of Plexiglass.

2-2. LIQUID-GAS SEPARATION SYSTEM

The liquid-gas separation system consisted of two units . First is an annular slot removal unit to separate water in the film flow from the central air flow. Second is a commercial Peerless Vane type line separation to remove the water entrainment in the air. A detailed description of the annular slot removal device is given in Fig. III-3. This device consisted of 1 ft x 1 ft x 1 1/2 ft Plexiglass box which maintained a constant level of water by a valve. Connection pipe from the test section was expanded from 2" I. D. to 5" I. D. inside the box to allow the film flow spread to the box. The gas core was removed by a 1.75 inch I. D. Plexiglass inside the box with a 2 inch I. D. circular knife edge section on the top which can be traversed into the expansion section. All connections from this device were also tygon tubing. The Peerless Vane type line separation have extremely low pressure drop from 2" - 6" of water and 100% removal of all entrained droplets 8 - 10 microns and larger.

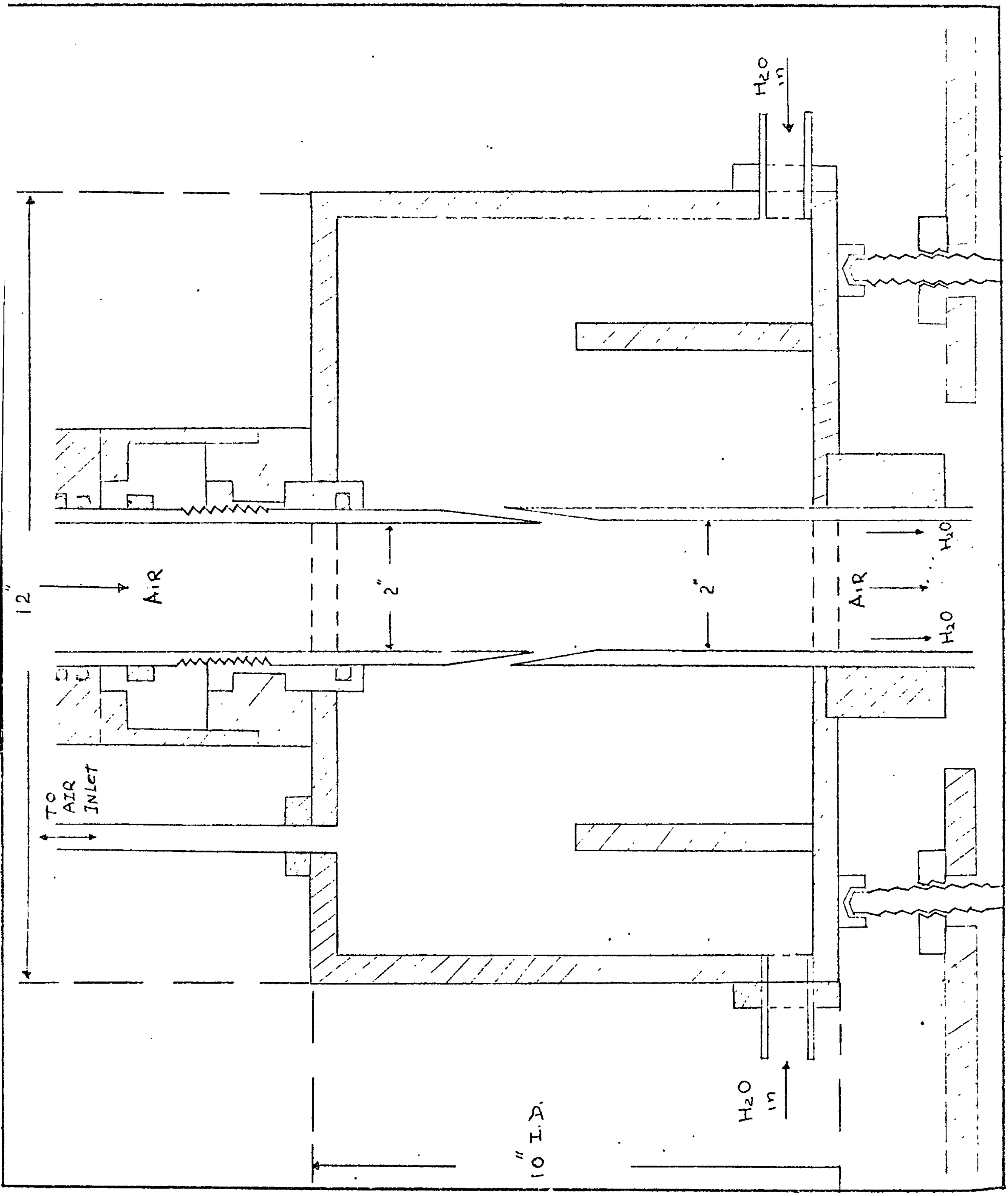


Fig. III-2. LIQUID-GAS INLET DEVICE

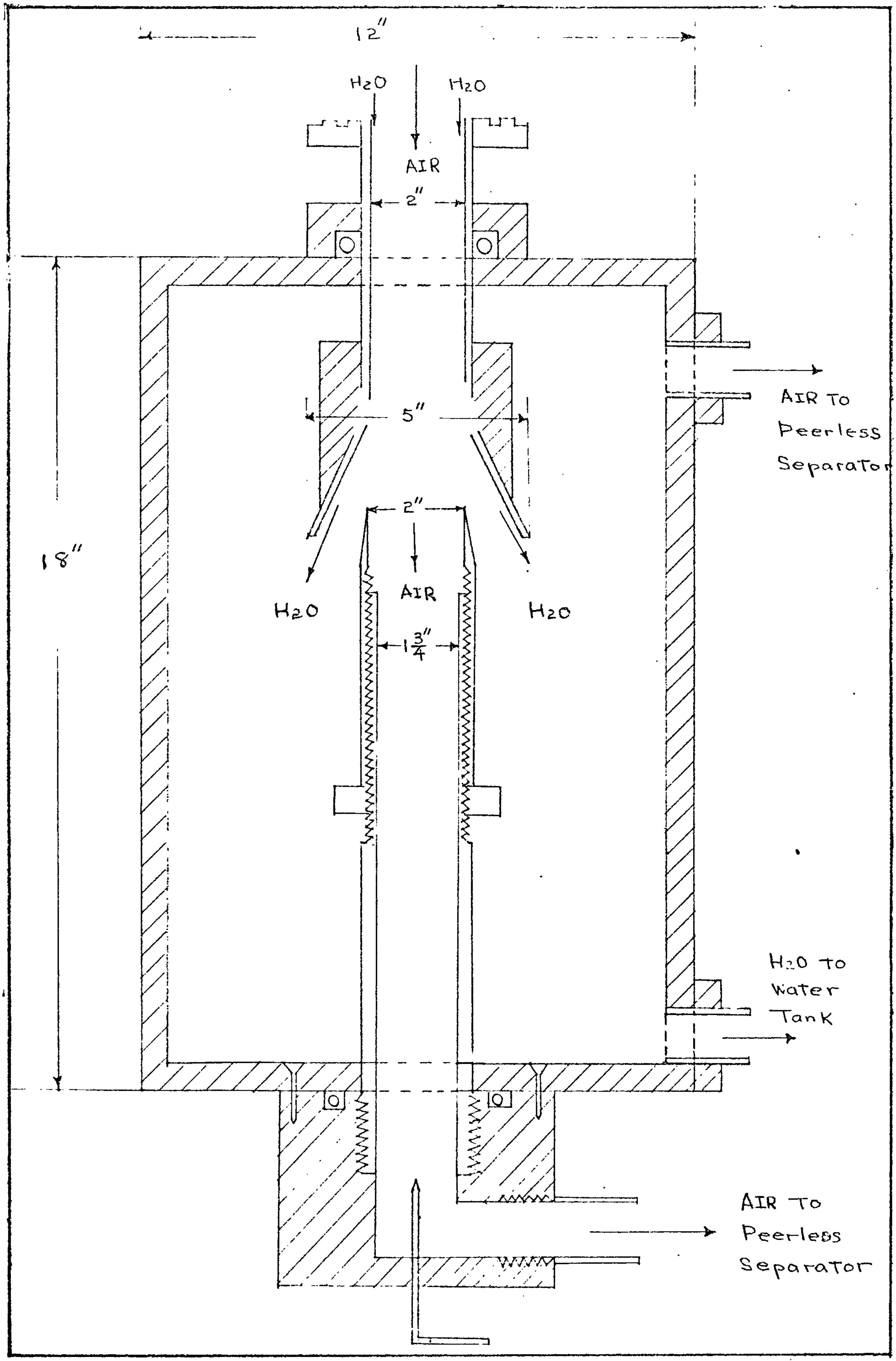


Fig. III-3. LIQUID-GAS SEPARATION DEVICE

2-3. TEST SECTION

The test section consisted of 4 lengths of 2" I. D. Plexiglass pipe with lengths of 1 ft, 2 ft, 4 ft, and 6 ft. A typical 2' section is shown in Fig. III-4. Each section was constructed from a number of 1 ft long pipes which were individually machined to have exactly 2" I. D. and 2.45" O. D. with error less than 0.001" and two flanges with an interlocking "O" ring. Sepcial care was taken on the flanges to match the measuring block housing to the adjacent test section. A special supporting ring for the test section was also designed to support the weight of the test section and to keep a perfect alignment of the test section with the vertical. Fig. III-5 shows one of the supporting ring..

2-4. FILM THICKNESS MEASUREMENT STATION

There are four measuring stations, each housed between two adjacent test sections. Therefore the separation distance between the measuring stations were 13.936 inch, 25.936 inch and 49.936 inch. Each individual measurement station consisted of four pairs of conductivity probes for film thickness and four pressure channels to the pressure transducer adapter. A detailed sketch of this system is given in Fig. III-6. The design of the probe housing was such that four film thickness probe pairs

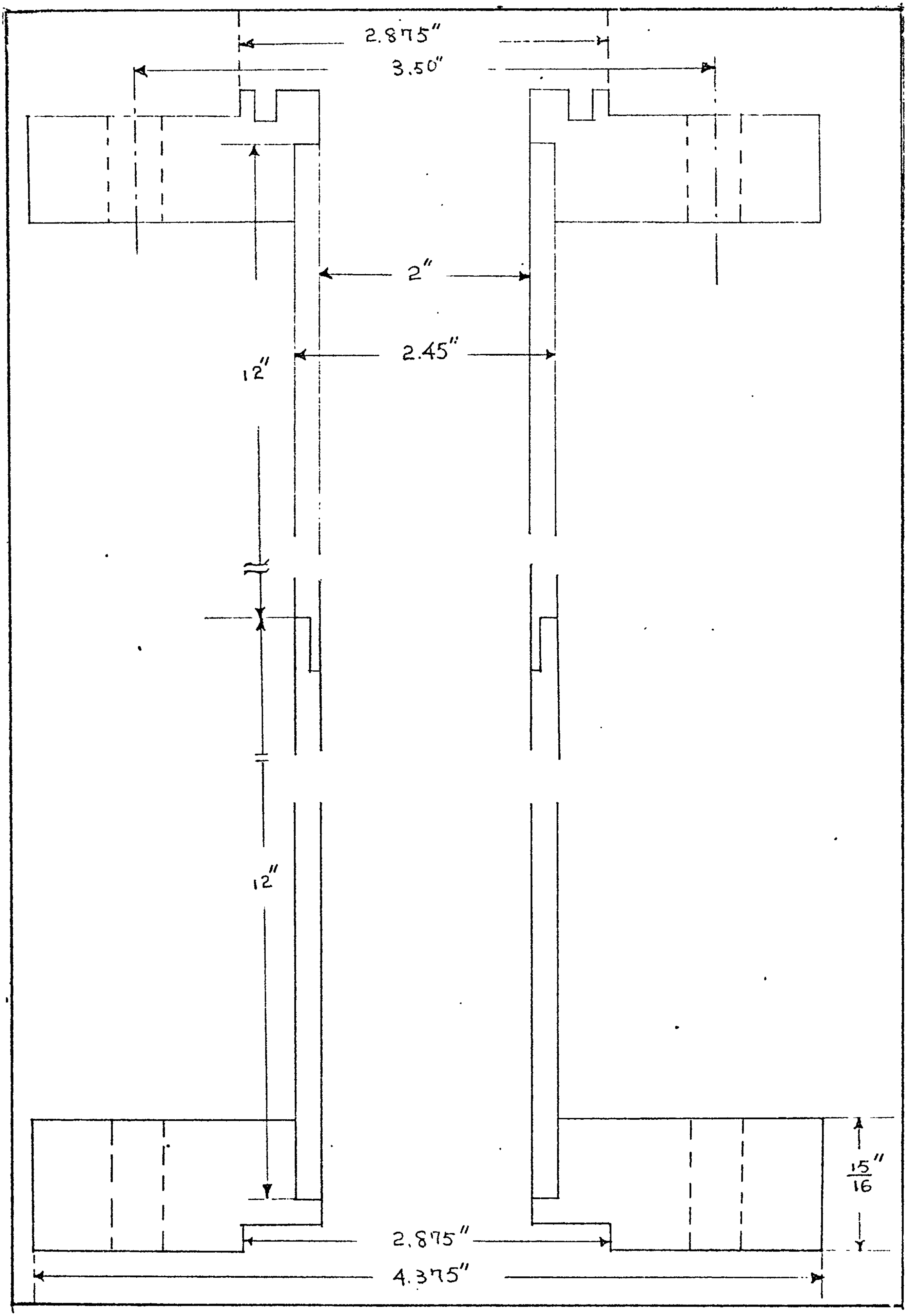


Fig. III-4. TWO FEET TEST SECTION

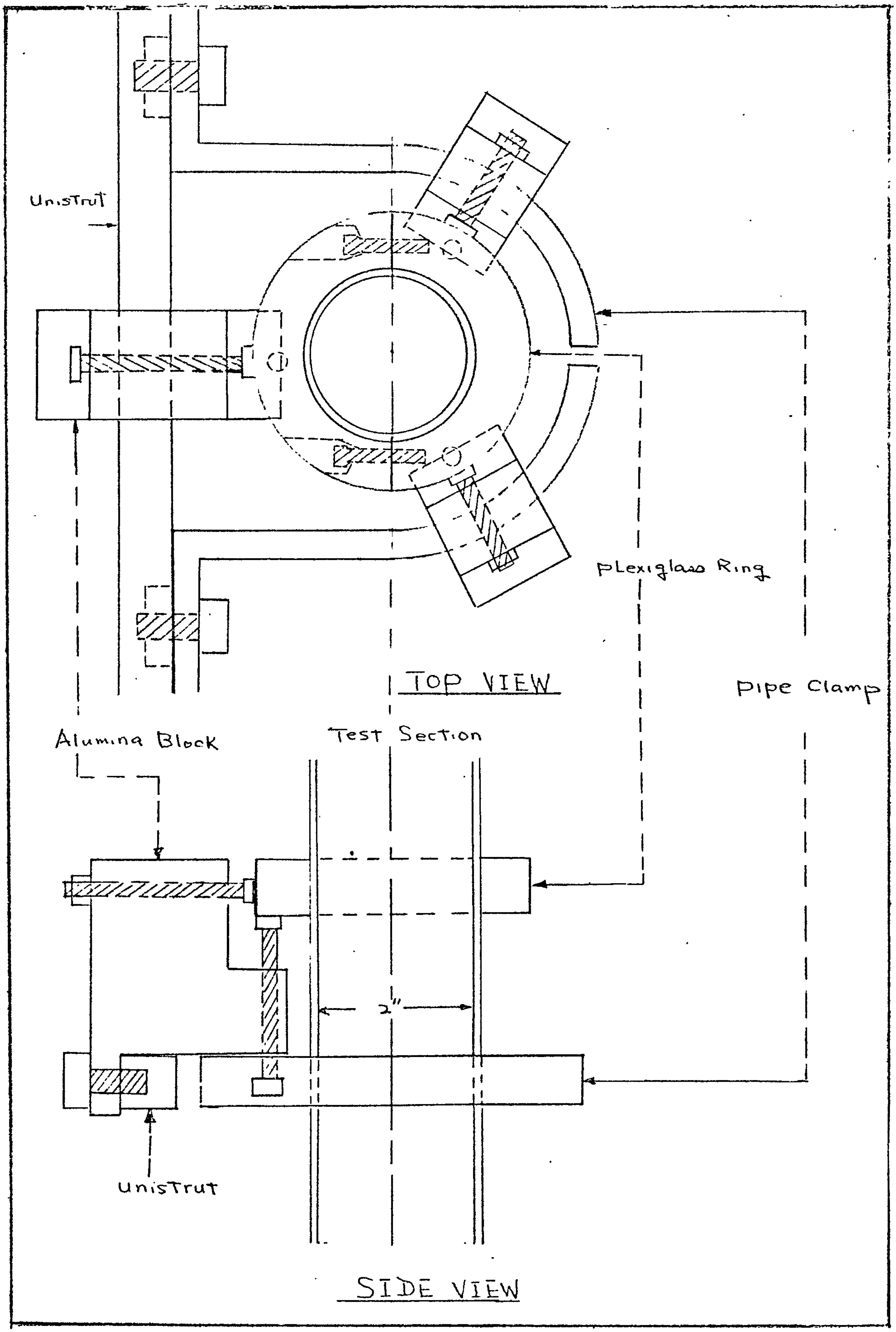


Fig. III-5. SUPPORT OF TEST SECTION

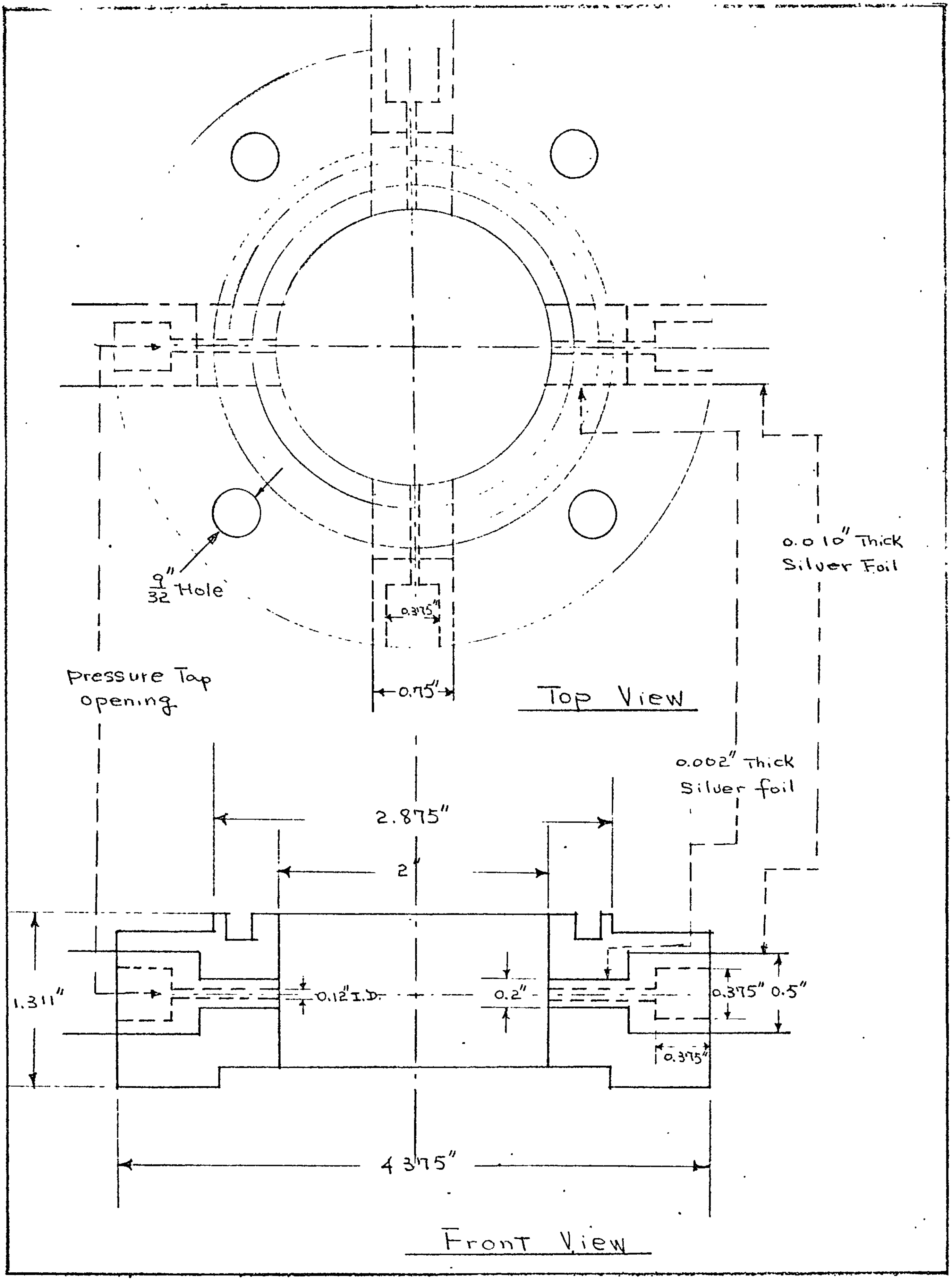


Fig. III-6. MEASURING STATION

were arranged perpendicularly to each other around the periphery of the flow tube. The associated pressure tapping was situated between the components of the probe pairs.

The film thickness conductivity probes were of a similar geometry to that used extensively in this laboratory by Wicks (W-4), Telles (T-2) and in England by Webb (W-2) for the study of film thickness. The electrodes were made of silver foil, 0.002" in thickness, and were cast into an Aralite housing. The silver foil electrode pairs were 0.2 inch apart and parallel and their width being 3/4 inch. The main feature of the design of the probe housing was the pressure and film thickness were measured at a single point.

3. EXPERIMENTAL TECHNIQUE

The purpose of the following paragraph is to discuss all the electronic equipment used in this study, various calibration methods applied for different measurements and the form of data stored for the statistical analysis.

3-1. INSTANTANEOUS FILM THICKNESS

The method of measuring instantaneous film thickness is based on the fact that the conductance of a liquid film depends on the liquid film thickness and the specific conductivity of the liquid. This method has been discussed and analyzed in detail by Wicks (W-4) and Webb (W-2). The system used in this study has similar probe as Wicks (W-4), Telles (T-2), and Webb (W-2), but includes a different calibration system and a new design of four channel simultaneous conductivity monitoring circuits. For convenience the method used here is described under the following sub-headings:

(i) Conductivity Probe

The silver electrodes used as a conductivity probe in this study showed a unstable reading of conductivity for a constant liquid film thickness. This phenomenon also happened in Webb's (W-2) study. This difficulty was overcome by platinizing a thin layer of platinum black onto the silver probe surface. Platinizing solution was obtained from Leeds and Northrup Co. (L & N part Std. 1192-3). An auxiliary chemically pure platinum is also needed for platinization. The platinization procedure is briefly described as follow:

(a) Immerse the silver conductivity probe and the auxiliary platinum electrode in the platinizing solution.

(b) Connect the negative terminal of a 3 V. battery to both leadwire of the conductivity cell, and then connect the positive terminal of the battery to the auxiliary electrode for approximate 30 second.

(c) During the platinizing operation, stir the solution gently.

A detailed procedure of platinization is given in Leeds & Northrup's Directions for used in their electrolytic conductivity cell.

(ii) Calibration of the Conductivity Probe

As mentioned above, the thickness of liquid film is related to the conductance of the liquid film. The conductance of the liquid film will vary with the specific conductivity of the liquid which is a function of temperature and salinity. Therefore in order to avoid making a calibration curve for various temperatures and salinity, calibrations were carried out for liquid film thickness vs. cell constant which is independent of temperature and salinity. The definition of cell constant for a conductivity probe at given film thickness is

$$K_{cc} = \frac{L_{m\ell}}{A_{mea}} \qquad \text{(III-1)}$$

where K_{cc} = value of cell constant in cm^{-1}.

$L_{m\ell}$ = mean length of the conducting path between the cell electrodes

Amea = mean effective cross-sectional area of the conducting path between the electrodes

The factors $L_{m\ell}$ and A_{mea} take into consideration not only physical dimensions but also the shape of vessel in which the electrodes are mounted and the nature of electrode surface. Therefore the values of $L_{m\ell}$ and A_{mea} can not be easily measured by machanical means, but the value of K_{cc} can be readily determined by an auxiliary standard conductivity cell with a known K_{cc} value as reference cell. Since the measured conductance of electrolyte from a conductivity cell can be described as the following equation:

$$K_{cc} = \frac{G_s}{G_m} \qquad \text{(III-2)}$$

where G_s = specific conductance of electrolyte in mhos/cm at solution temperature

G_m = measured conductance of electrolyte in mhos

Applied equation (III-2) to a standard reference cell, we can determine the specific conductance of the liquid G_s. Then applied the same equation on the unknown cell we can determine the cell constant by equation (III-3)

$$K_{ccu} = \frac{G_{ms}}{G_{mu}} K_{ccs} \qquad \text{(III-3)}$$

where K_{ccu} = unknown cell constant

K_{ccs} = cell constant of a standard conductivity cell

G_{mu} = measured conductance of electrolyte from unknown cell

G_{ms} = measured conductance of electrolyte from standard conductivity cell

The main features of this calibration system is given in Fig. III-7. A series of plugs of various diameters used to set up film of different thickness is given in Table III-1. Water was continuously pumped through the calibration block in order to eliminate air bubbles during the measurement of the conductance. Special care was also taken in housing the plug and the conductivity probe to reduce the error.

TABLE III-1

Probe Calibration Plugs

Plug No.	Diameter (inch)	Film Thickness (inch)	Plug No.	Diameter (inch)	Film Thickness (inch)
1	1.990	0.005	10	1.701	0.1495
2	1.980	0.010	11	1.651	0.1745
3	1.9694	0.0153	12	1.600	0.2000
4	1.951	0.0245	13	1.5504	0.2248
5	1.93	0.035	14	1.4504	0.2748
6	1.901	0.0495	15	1.400	0.300
7	1.8504	0.0748	16	1.301	0.3495
8	1.8014	0.0993	17	1.201	0.3995
9	1.751	0.1245	18	1.00	0.500

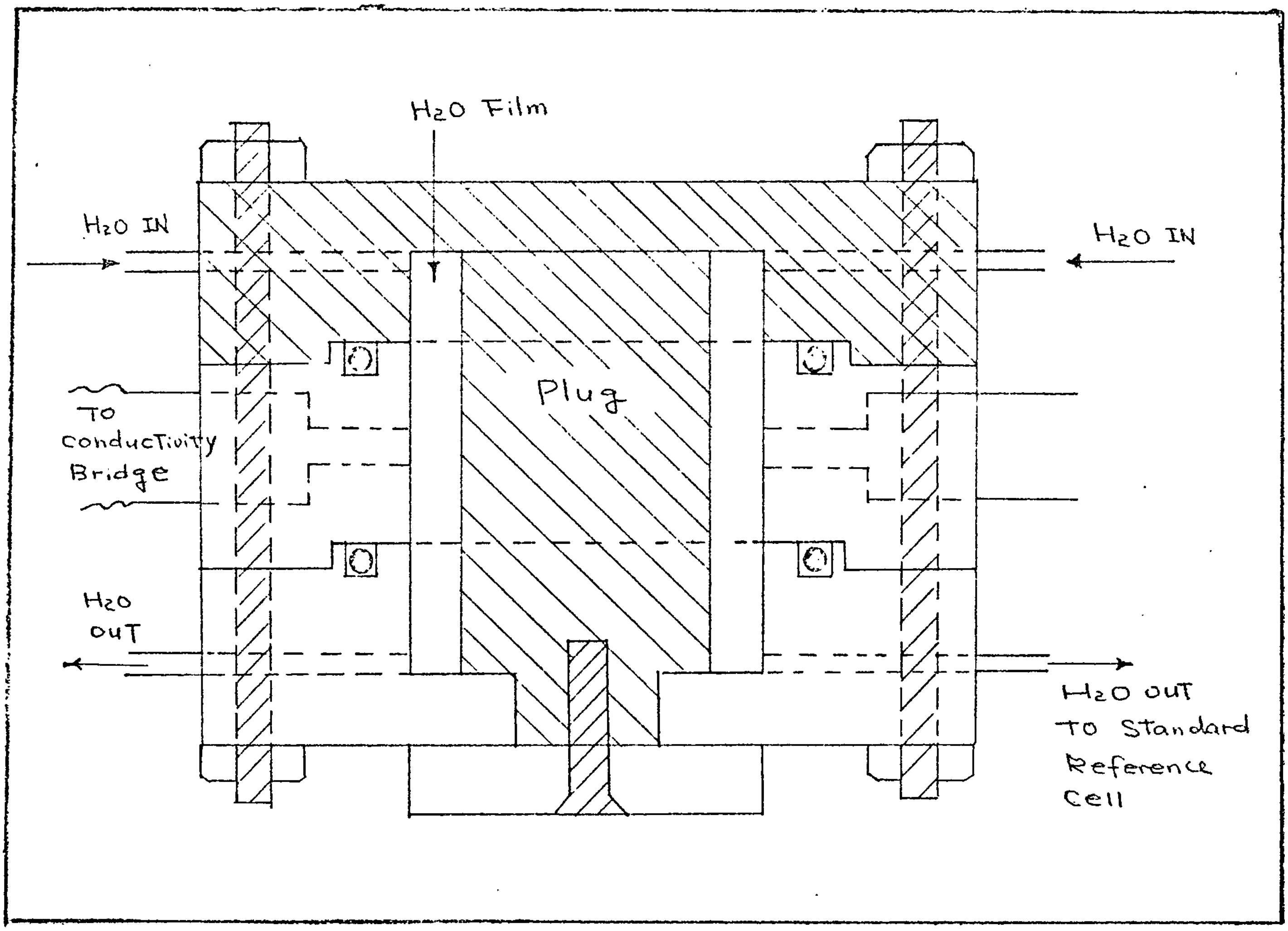


Fig. III-7. CALIBRATION SYSTEM

The procedure of the calibration method can be described as the following steps:

(a) Set up a known film thickness by the plug at the conductivity probe to be calibrated.

(b) Record the conductance from the conductivity probe by a Leeds & Northrup's Conductivity Bridge.

(c) Measure the conductance from a standard Leeds & Northrup's Conductivity Cell with cell constant $K_{cc} = 0.1$ in the same liquid.

(d) Calculate the cell constant for the given film thickness by equation (III-3).

(e) Rotate the plug and repeat the above processes. After several rotation, the average cell constant were used for the given film thickness.

(f) Set up another film thickness by changing another plug and repeat the above procedures.

The final calibration curve K_{cc} vs. film thickness for conductivity probe is given in Fig. III-8.

(iii) Conductivity Monitoring Circuit

In the design of the conductivity monitoring circuit, an A. C. voltage with 1 KC frequency and constant amplitude was applied to the electrodes. Then the signal from the conductivity probe will also be an A. C. signal with 1 KC frequency and amplitude varying with the liquid film thick-

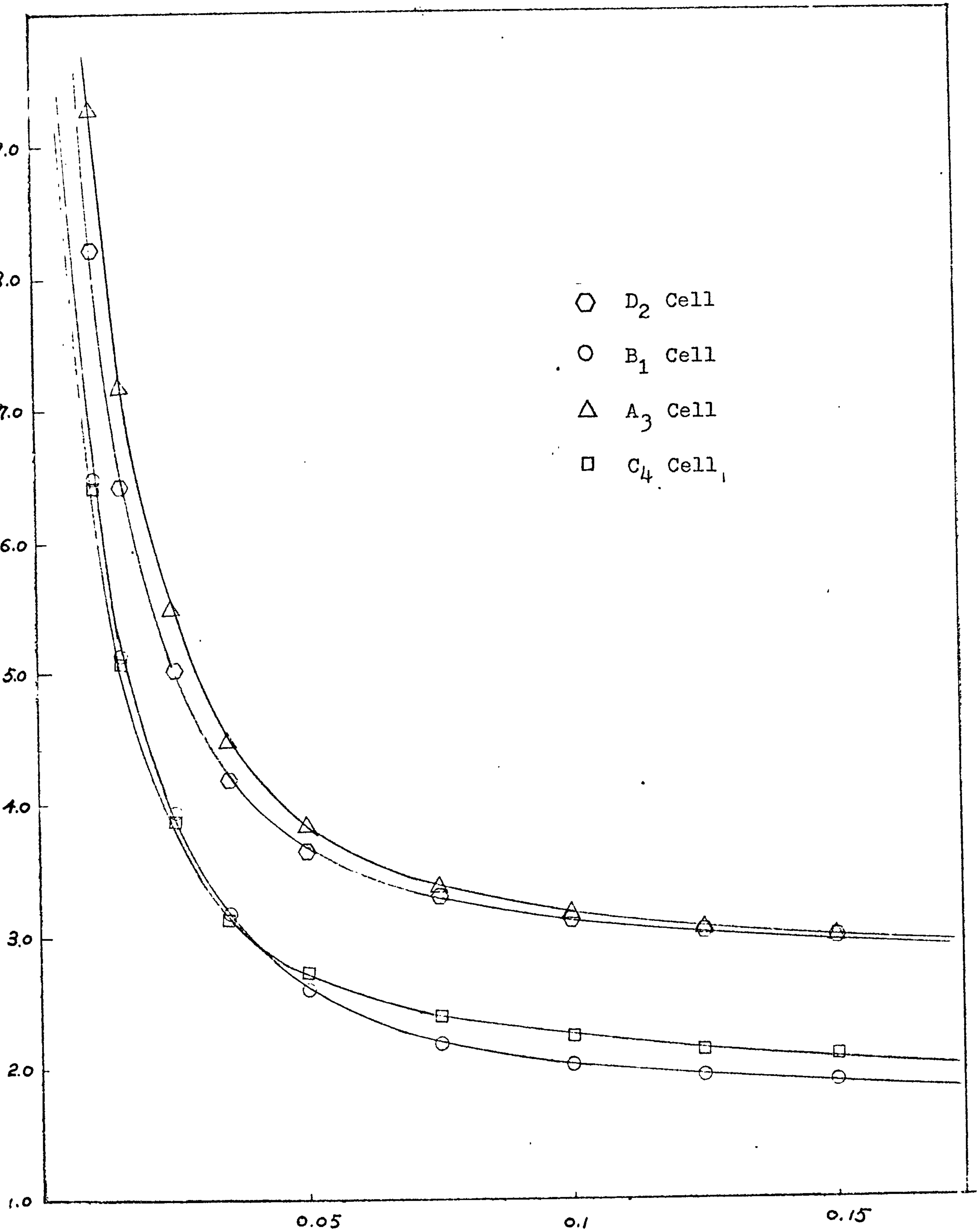


Fig. III-8. CALIBRATION CURVE

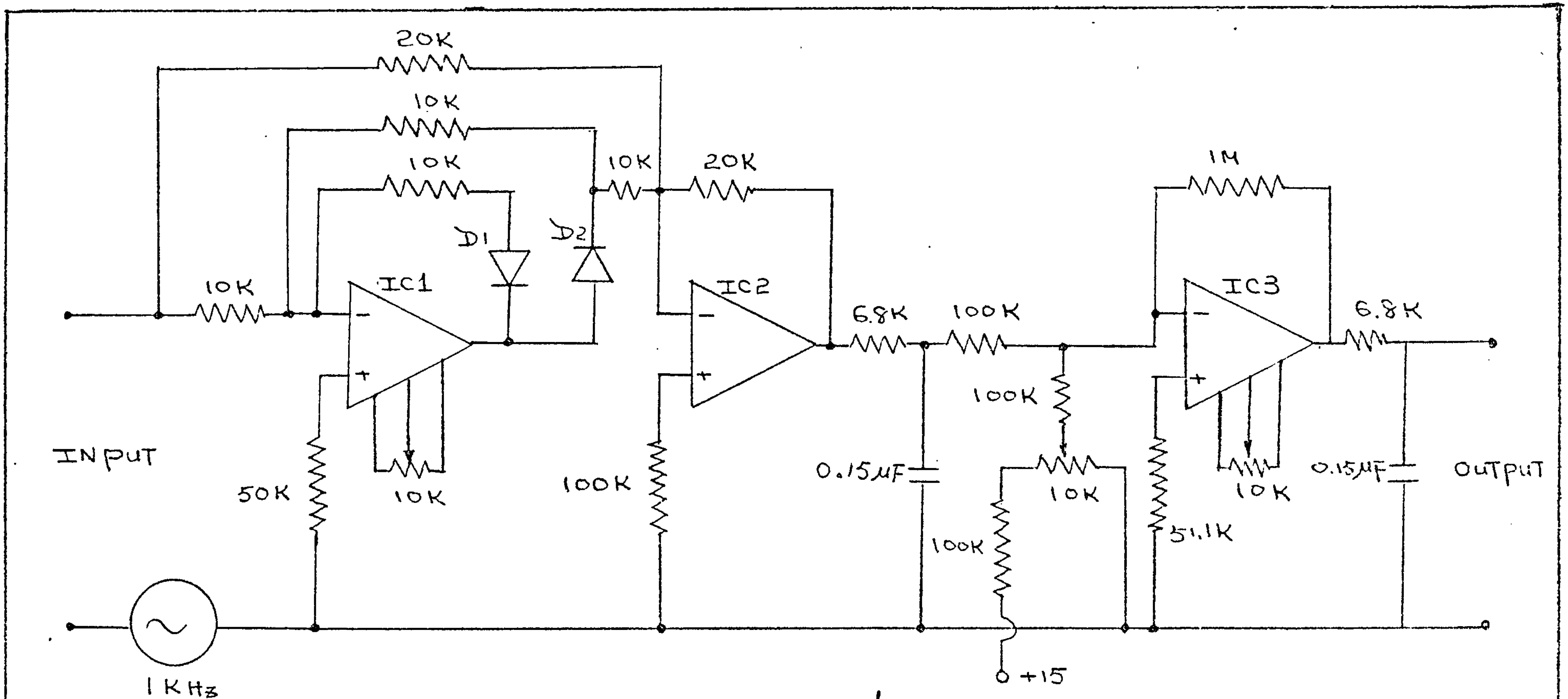
ness. The above 1 KC signal becomes a D. C. signal after passing through a linear full wave rectifier and two 1 KC low pass filters. The detailed circuit diagram is shown in Fig. III-9, and the function of this circuit will be illustrated in Fig. III-10. The above 1 KC osicillator can be set at any amplitude $\leqslant$ 12.00 A. C. voltage and a offset was also used to set D. C. output. The main characteristics of this circuit system are output D. C. voltage from +1.2v$\sim$ -1.2v corresponding with the variation of the resistance 4 KΩ $\sim$300kΩ. (conductance 3.7×10^{-6} mhos $\sim$ 2.50×10^{-4} mhos) and a frequency response around 100 K Hz.

(iv) Calibration of the Conductivity Monitoring Circuit

The calibration of the conductivity monitoring circuit was done by a standard decade resistor box. Fig. III-11 shows several calibration curves for different A. C. amplitudes from oscillator.

(v) Data Recording and Storage

The final four channel D.C. voltage signals which proportion to the liquid film thickness were recorded on a 7 track Ampex tape recorder with speed of 3 3/4 inch per second. Then the D. C. voltage signals were reproduced on IBM 360-44 Analog - to - Digital converter and went through the above two calibration curves with the aid of the specific conductivity of the water. The D. C. voltage



IC1, IC2, and IC3 are integrated circuit (FAIRCHILD 7741393)

D1 and D2 are diode (FD 300)

Fig. III-9. CONDUCTIVITY MONITORING CIRCUIT DIAGRAM

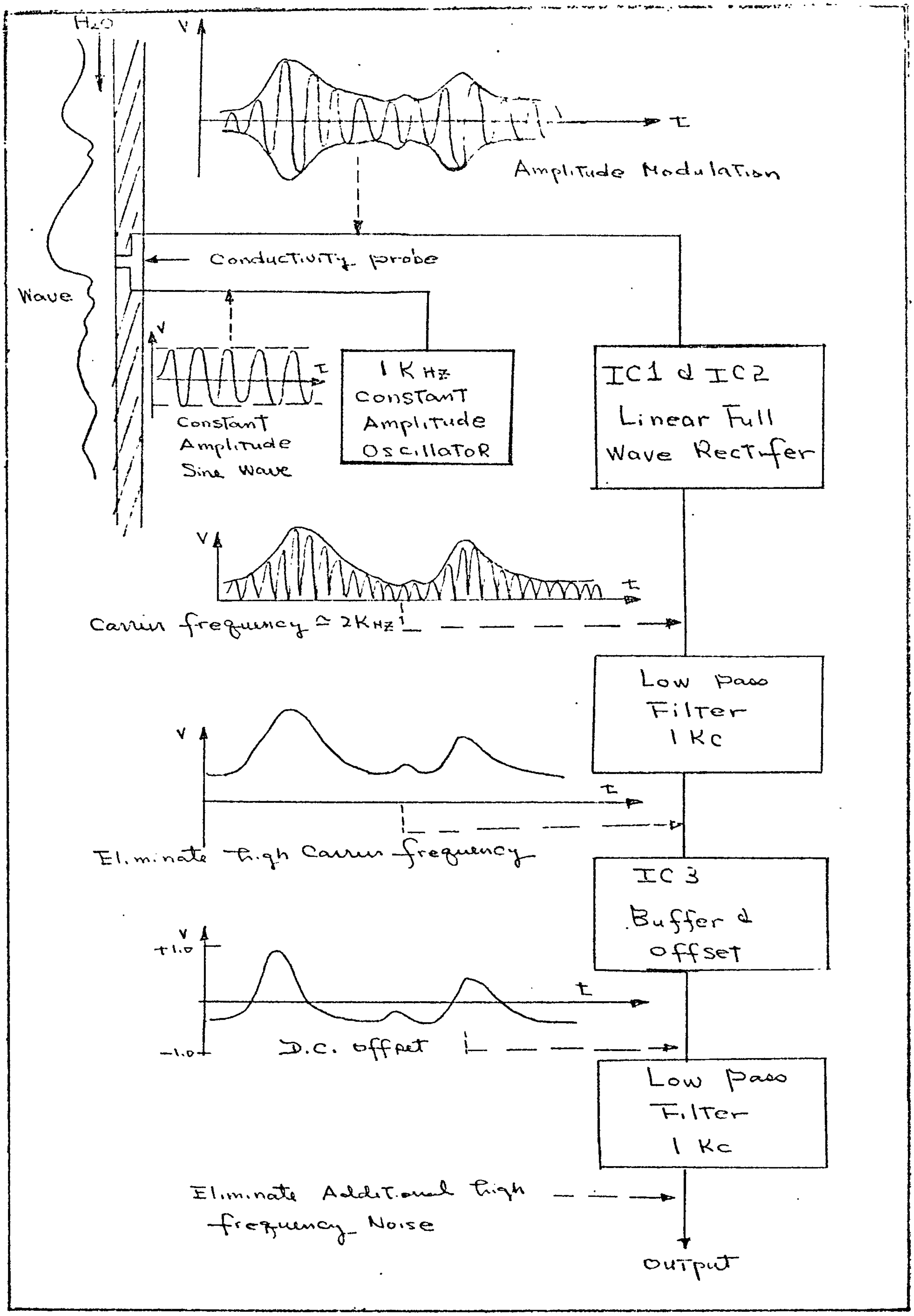


Fig. III-10. FUNCTION OF THE CONDUCTIVITY MONITORING CIRCUIT

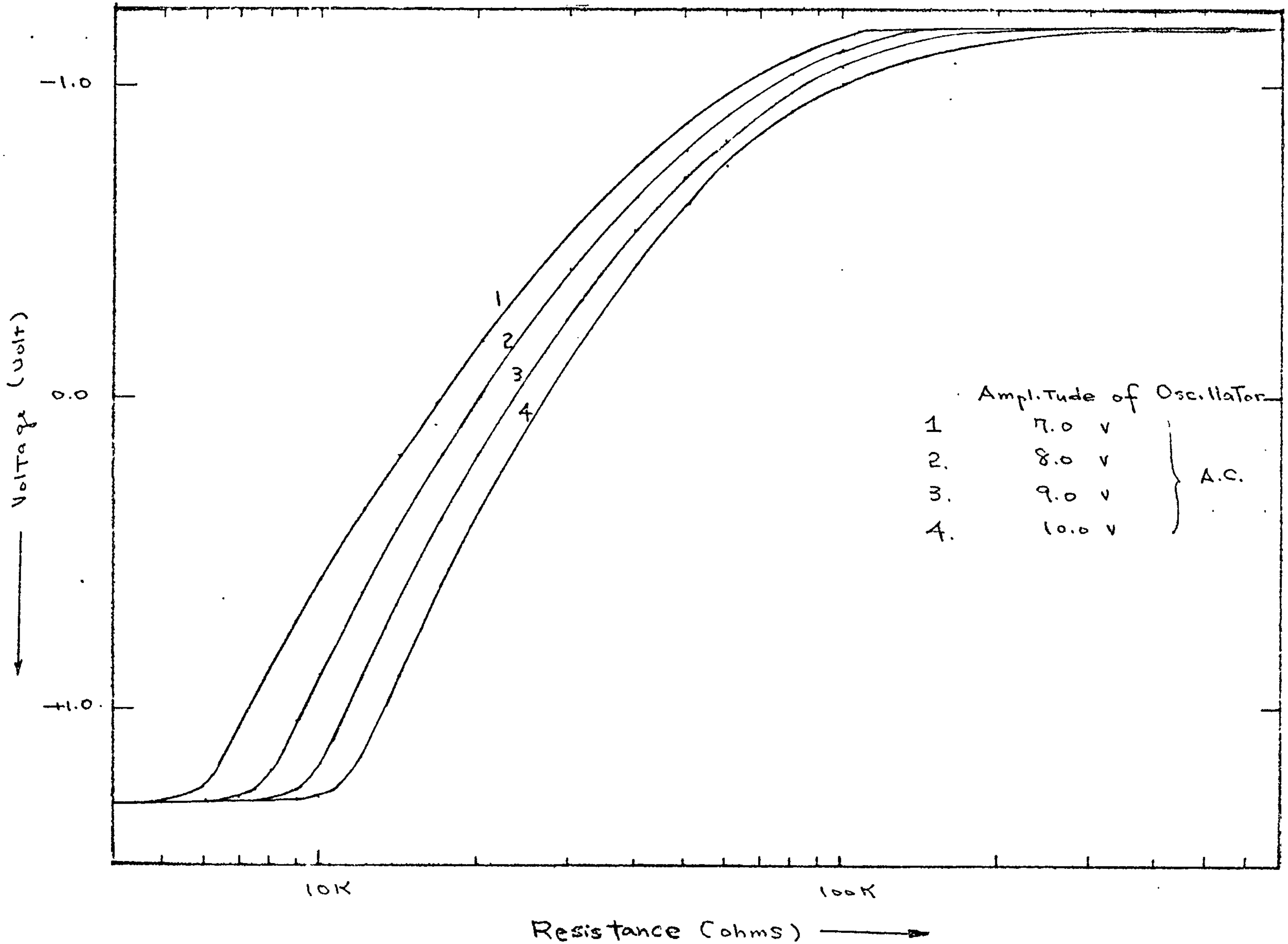


Fig. III-11. CALIBRATION CURVE OF THE CONDUCTIVITY MONITORING SYSTEM signal was transfered into the actual film thickness in digital form and was stored in magnetic tape. The detailed procedure is shown in Fig.III-12. The Hybrid Computer program to perform the above task is given in Appendix A.

3-2. INSTANTANEOUS PRESSURE FLUCTUATION AND PRESSURES DROP

The purpose of measuring the instantaneous pressure is to detect the pressure fluctuations that occurs as a result of local variations of film thickness. Only the studies by Telles (T-2) and Webb (W-2) have tried to make such measurements. Both fail to produce useful information concerning the pressure fluctuation actually due to the local wave motion.

There are two main difficulties in making such a measurement. First is the pressure of large sound wave type of fluctuations generated from outside of the flow system especially at the outlet. These fluctuations interfere with the observed pressure. Second, the pressure transducer used for such measurement needs to satisfy two requirements; high resolution at low absolute pressure and high frequency response. Low-pressure transducers usually have very low frequency response.

The sound wave type of pressure fluctuation was reduced to the minimum by using special tubing to insulate

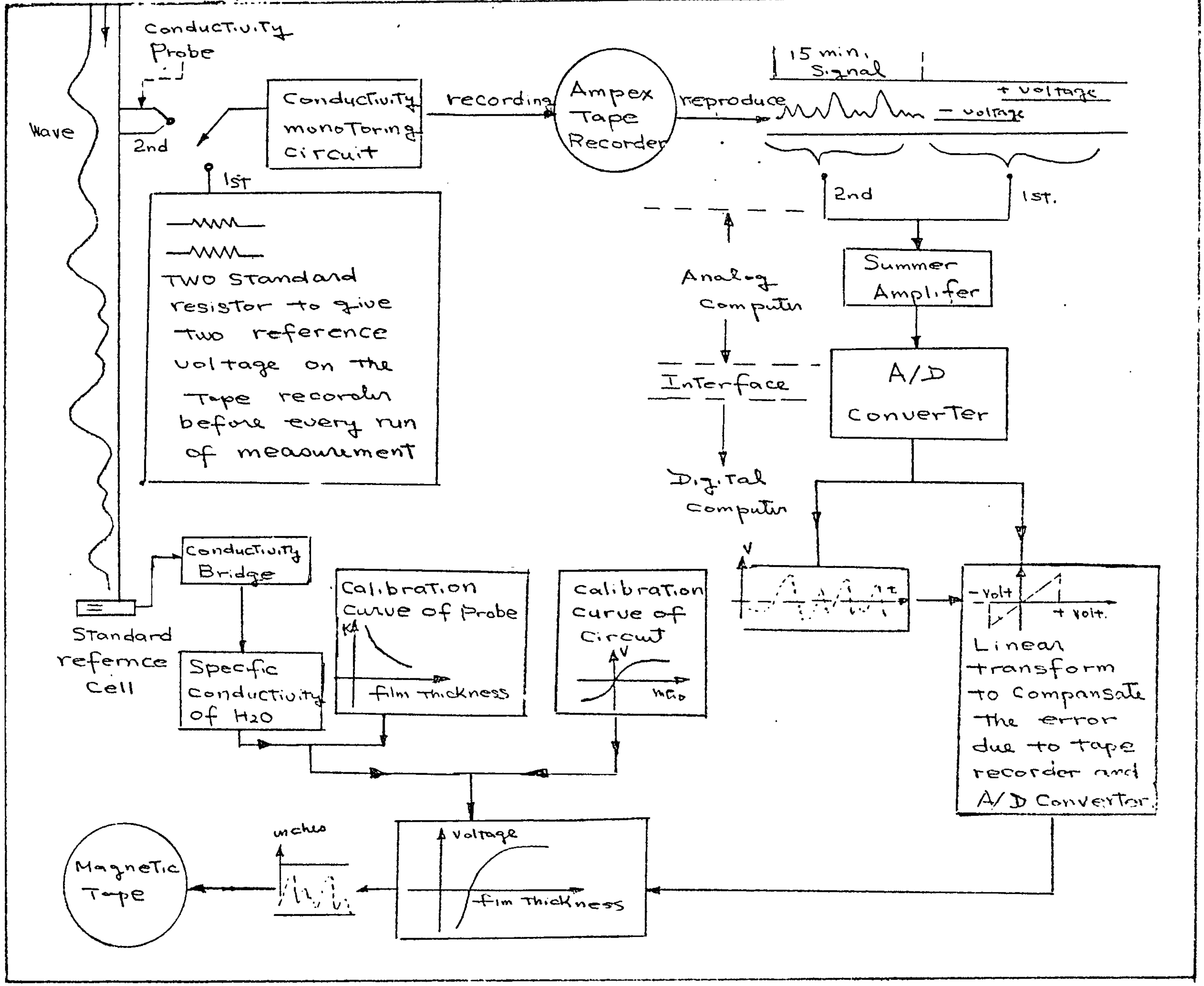


Fig. III-12. PROCEDURE OF THE DATA RECORDING AND STORAGE the external system from the main flow channel. Outlet pulsations were eliminated by keeping a constant level of water in the liquid-gas separation tank as mentioned in Section 2. The pressure transducer found to be suitable was a DISA pu2a low pressure transducer of the capacitive type. The pressure to be measured acts on a diaphragm which forms one plate of a capacitor. As a result the capacitance varies with the pressure. The main characteristics of this pressure transducer for different thickness of diaphragms used in this study are given in Table III-2.

TABLE III-2

CHARACTERISTICS OF PRESSURE TRANSDUCER

Diaphragm Thickness, mm	0.12	0.14	0.16	0.20
Pressure Range, psi	0.85	1.42	2.13	4.27
Diaphragm Resonance Water 20 °c KHz	1.4	1.7	2.1	2.9
Channel Resonance Water 20°c KHz	0.083	0.11	0.13	0.18
Damping Ratio Water 20°c		0.01		

Several auxiliary units: tuning plug, Oscillator and Reactance converter, from DISA were also used in order to transfer the response from the pressure transducer to a D. C. voltage variation. The functions of all these units and of the Resonant circuit for pressure transducer are shown in Fig. III-13. The pressure transducer was calibrated with each diaphragm with a manometer under static pressure conditions in the flow channel.

Recording and storage system for the instantaneous pressure data were the same as that for the instantaneous film thickness except in the case of pressure measurement the calibration curve is simply a single linear curve.

The data of pressure drop was obtained by taking the difference of the mean value of time average pressure at two different positions.

3-3. ENTRAINMENT MEASUREMENT

The liquid phase and the air phase were separated by the annular slot removal unit which was described in section 2-2. Then the liquid content in the air phase was extracted from the air by a Peerless Vane type separator. The water was timed as it flowed into a graduated cylinder.

3-4. FLOW METER

Two Safequard Rotameters were used to measure the liquid flow rates. The Rotameters were calibrated by a

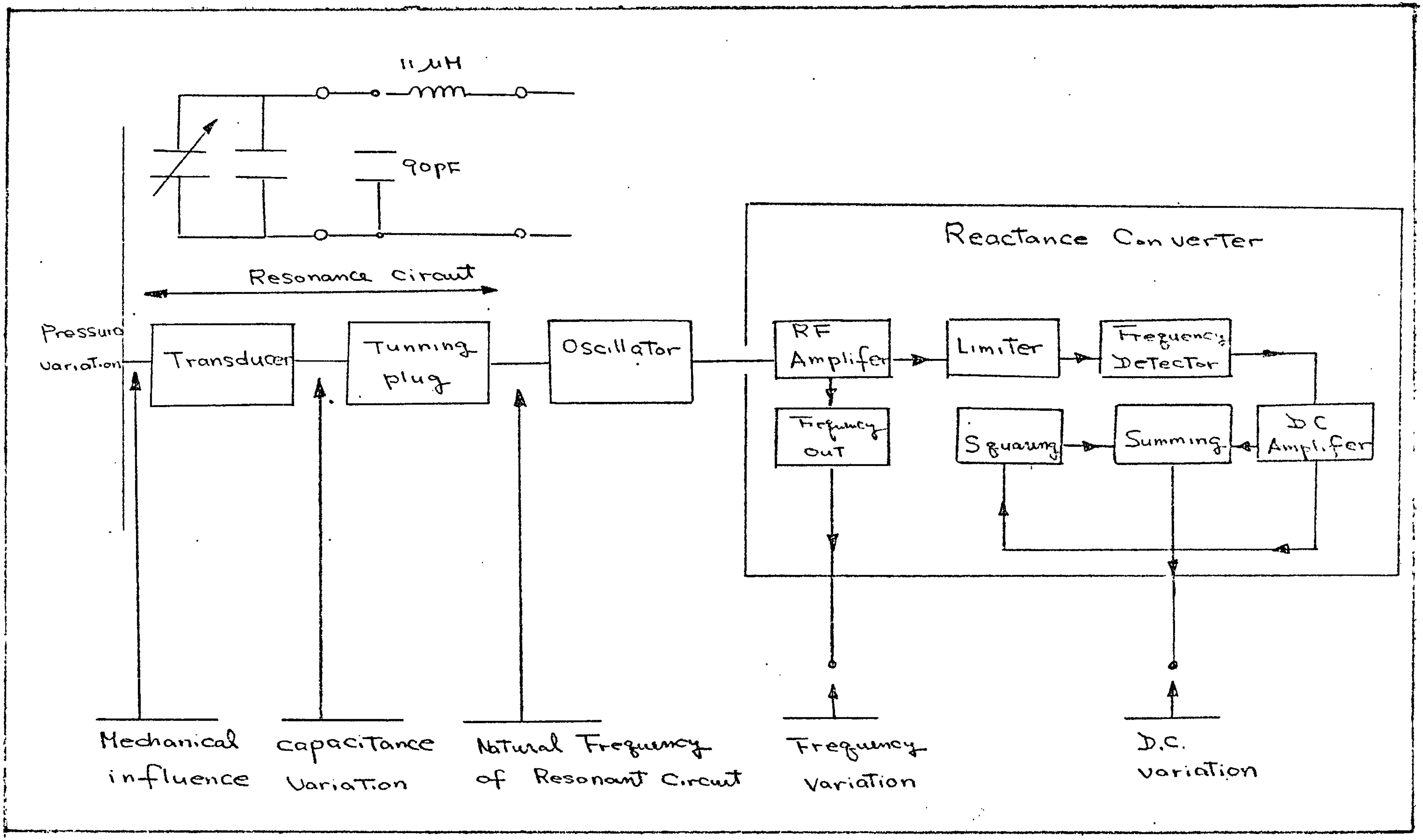


Fig. III-13. FUNCTION OF PRESSURE TRANSDUCER AND AUXILIARY UNITS weighting tank and a stop watch. The air flow rate was measured by using an orifice runs and manometer. The above orifice plates were carefully calibrated by a Rockwell low pressure flow prover.

Errors due to the measuring technique for each measured quantity described in this chapter will be discussed carefully in Appendex B.

CHAPTER IV

EXPERIMENTAL DATA: ENTRAINMENT, PRESSURE, PRESSURE DROP AND FILM THICKNESS

1. INTRODUCTION

In this chapter the experimental data is presented in a summarized form. The original data are filed in data books at Chemical Engineering Department of the University of Houston. Methods of data processing associated with statistical data are also described in this chapter.

The experimental data which describe some overall features of the system are the following:

(a) Entrainment rate

(b) Pressure drop

(c) Central moments of film thickness

(d) Probability density functions of film thickness

(e) Spectral density and cross-spectral density functions of film thickness

(f) Phase spectra of film thickness

(g) Auto covariance and cross-covariance functions of film thickness

(h) Spectra of wall pressure fluctuation and cross-spectra between pressure and film thickness

The matrix of operating conditions consisted of five air flow rates and ten water flow rates. Data were collected at four film thickness measuring stations and two pressure measuring stations. These conditions are tabulated in Table IV-1. Table IV-2, Table IV-3, and Table IV-4.

TABLE IV-1

AIR FLOW RATE AND AIR REYNOLDS NO.

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
Re_G	0.0	4,214	62,650	92,860	113,550

TABLE IV-2

WATER FLOW RATE AND WATER REYNOLDS NO.

(R_{eL} including entrainment rate)

W_G(lb/sec)	0.016	0.028	0.044	0.08	0.126
Re_{LG} ?,	211	367	572	1,016	1,605
W_L(lb/sec)	0.18	0.24	0.35	0.47	0.585
Re_L	2,299	3,151	4,572	6,109	7,560

TABLE IV-3

FILM THICKNESS MEASURING STATIONS AND LOCATIONS

CELL NO.	C_4	A_3	B_1	D_2
DISTANCE FROM INLET (ft)	6.2	10.4	12.5	13.7

TABLE IV-4

PRESSURE MEASURING STATIONS AND POSITIONS

PRESSURE TRANSDUCER NO.	P_2	P_1
DISTANCE FROM INLET (ft)	12.5	13.7

2. ENTRAINMENT

The method of entrainment measurements described in the last chapter offered some difficulties in the low flow rate region because it was difficult to adjust slot gap for the low flow rate. Moeck (M-4), Hewitt (H-8) and Webb (W-2) have discussed the relative advantage of different methods. There is no very satisfactory measuring method available at present due to large fluctuations in the amplitude of the waves. In this study the width of slot gap was adjusted by the maximum film thickness as measured from probability density function. Because of the uncertainty, liquid entrainment rates should be considered as approximate values. The mass rate of entrainment is shown in Fig. IV-1. The result shows an increase of entrainment rate with both gas and liquid flow rates.

3. PRESSURE DROP

Pressure gradient measurements are shown in Fig. IV-2, plotted versus air flow rate at various value of water flow

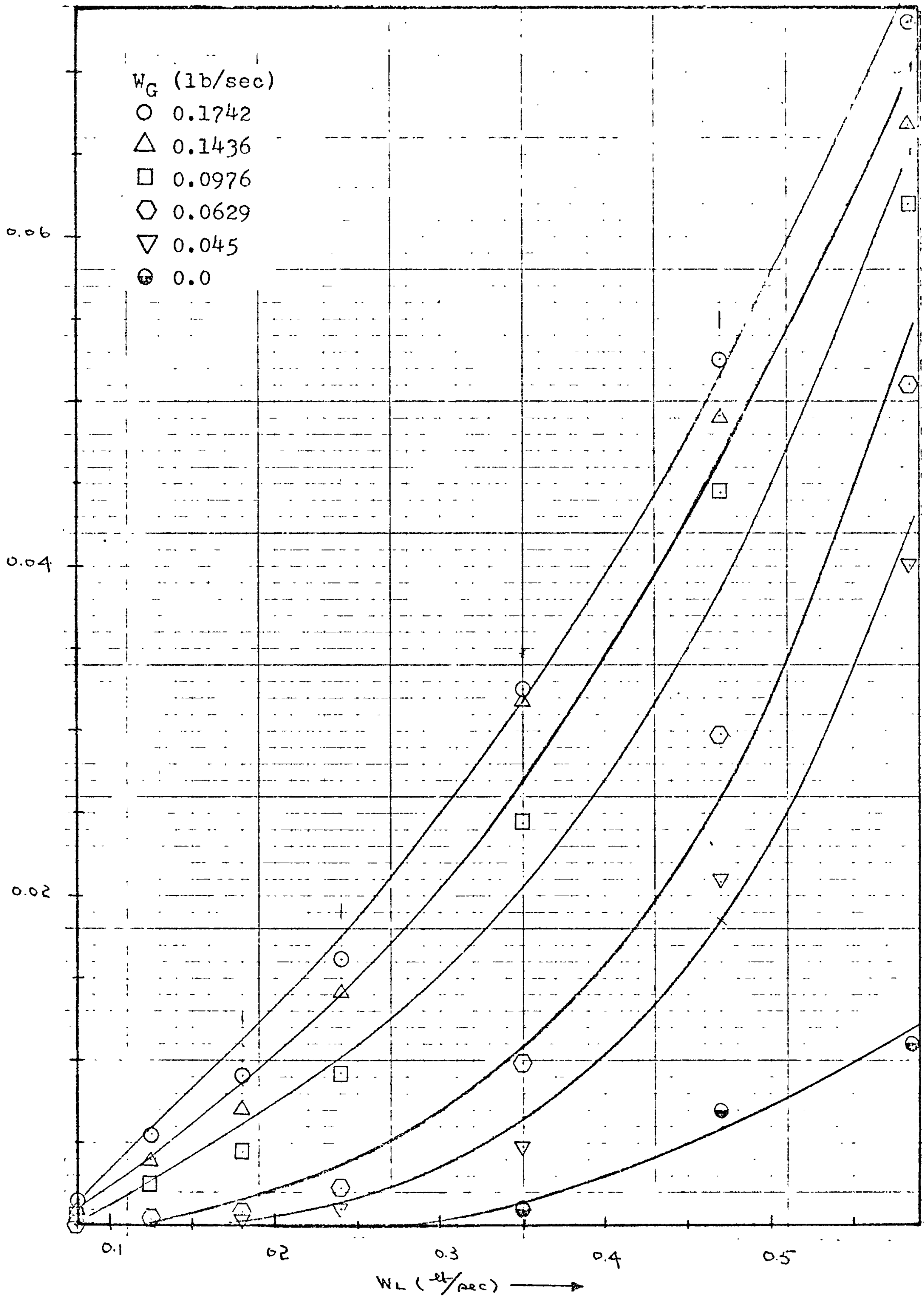


Fig. IV-1. ENTRAINMENT

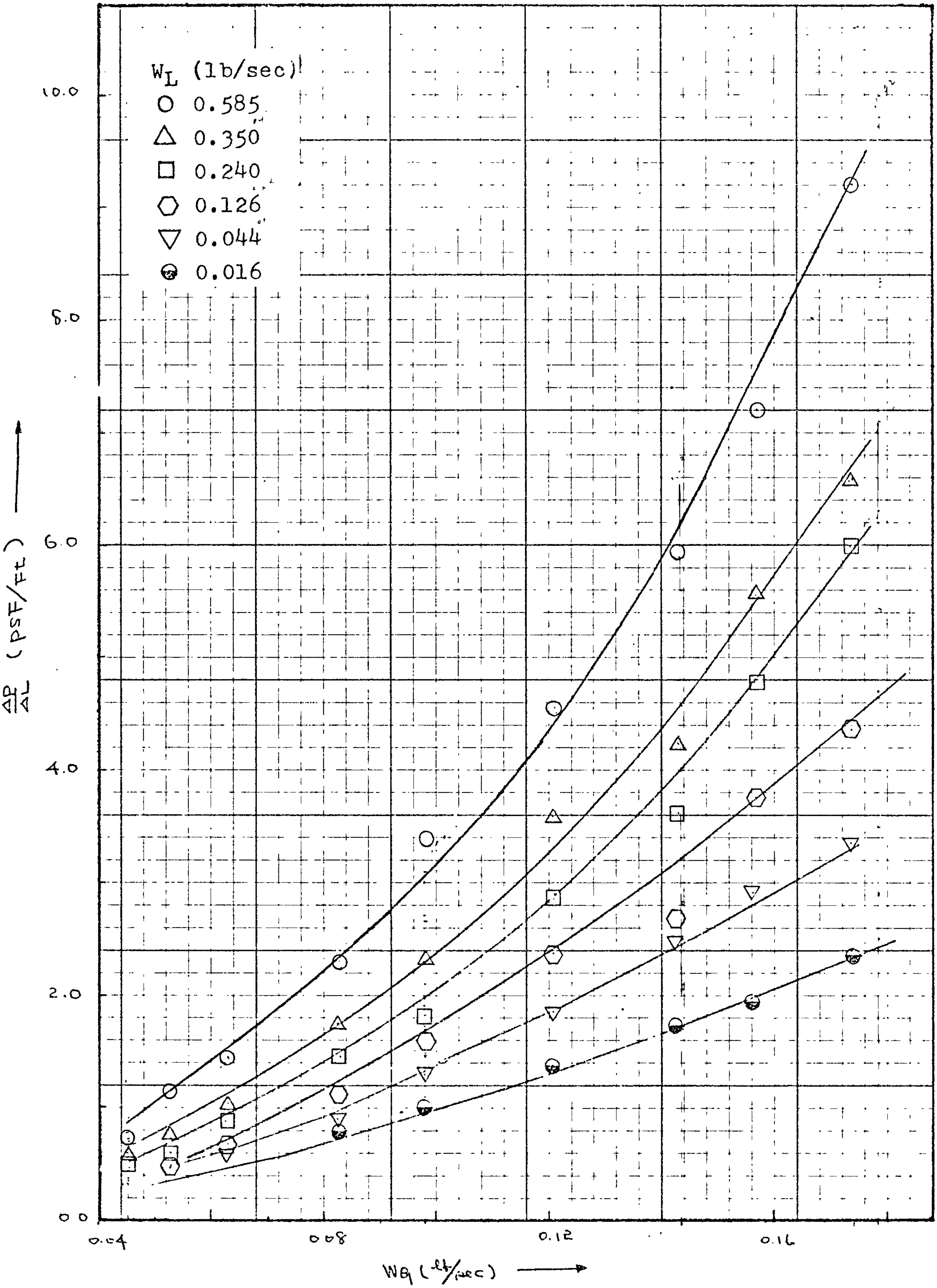


Fig. IV-2. PRESSURE DROP

rate. The results show a trend typical of all two-phase pressure drop measurements. As either the liquid or gas rate increases, they cause increased pressure gradient. The results also are in a good agreement with data of Chien and Ibele (C-3) who studied the flow in a 2" diameter tube.

4. MOMENT AND PROBABILITY DENSITY ANALYSIS OF FILM THICKNESS

In this section the method of computing moments and probability density by digital means is described briefly. Moments and probability density of film thickness are shown in graphical form.

4-1. MOMENT AND PROBABILITY FUNCTION ANALYSIS

The definition of the first four central moments and probability functions of film thickness $\hat{h}(t)$ are given in the following equations:

$$\tilde{F}(h) = \tilde{P}\{\hat{h}(t) \leq h\} \quad \text{(IV-1)}$$

$$\tilde{f}(h) = \frac{d\tilde{F}}{dh} \quad \text{(IV-2)}$$

$$\langle h(t) \rangle = \int_{-\infty}^{+\infty} h \tilde{f}(h)\, dh \quad \text{(IV-3)}$$

$$\tilde{C}_2 = \langle \{h(t) - \langle h(t) \rangle\}^2 \rangle$$

$$= \int_{-\infty}^{+\infty} \{h(t) - \langle h(t) \rangle\}^2 \tilde{f}(h)\, dh \quad \text{(IV-4)}$$

$$\tilde{C}_3 = \langle \{ \hat{h}(t) - \langle \hat{h}(t) \rangle \}^3 \rangle$$
$$= \int_{-\infty}^{+\infty} \{ \hat{h}(t) - \langle \hat{h}(t) \rangle \}^3 \tilde{f}(\hat{h})\, d\hat{h} \quad \text{---- (IV-5)}$$

$$\tilde{C}_4 = \langle \{ \hat{h}(t) - \langle \hat{h}(t) \rangle \}^4 \rangle$$
$$= \int_{-\infty}^{+\infty} \{ \hat{h}(t) - \langle \hat{h}(t) \rangle \}^4 \tilde{f}(\hat{h})\, d\hat{h} \quad \text{---- (IV-6)}$$

where $\tilde{F}$ is the probability distribution function

$\tilde{f}$ is the probability density function

$\langle h(t) \rangle$ is the mean of film thickness h(t)

$\tilde{C}_2$, $\tilde{C}_3$, $\tilde{C}_4$ are second, third, fourth central moments

$\wedge$ is a random variable

$\langle\ \rangle$ is an expected value

$\sim$ represents statistical quantities

$\tilde{P}$ is the probability of the event

The digital computer algorithm for calculating the mean and the second, third, and fourth central moments is as follows:

$$\langle \hat{h}(t) \rangle = \frac{1}{n} \sum_{i=1}^{n} \hat{h}_i \quad \text{-------- (IV-7)}$$

$$\tilde{C}_2 = \frac{1}{n} \sum_{i=1}^{n} \hat{h}_i'^2 \quad \text{-------- (IV-8)}$$

$$\tilde{C}_3 = \frac{1}{n} \sum_{i=1}^{n} \hat{h}_i'^3 \quad \text{-------- (IV-9)}$$

$$\tilde{C}_4 = \frac{1}{n}\sum_{i=1}^{n} h_i'^4 \quad \text{--------} \quad (IV\text{-}10)$$

where $\quad h_i = h(\tau_0 + (i-1)\Delta\tau) \qquad i = 1, \cdots, n$

τ_0 is arbitrary time.

$\Delta\tau$ is sampling interval.

$h_i' = h_i - \langle h(t)\rangle \qquad i = 1, \cdots, n$

An estimate of probability function can be obtained from the following procedure:

(a) Select a probability interval

$$\Delta h = \frac{h_a - h_b}{K} \quad \text{--------} \quad (IV\text{-}11)$$

where $\quad h_a$ and h_b are such that $h_a < h(t) \leq h_b$.

K is the number of probability intervals.

(b) Scan the data h_i, $i=1, \cdots, n$ through the K class of probability intervals to find

$$N_j = \{\text{No. of } h_i \text{ Such that } d_{j-1} < x \leq d_j\} \quad j=1,\cdots,K \;\text{--}\; (IV\text{-}12)$$

where $\quad d_j = h_a + j\Delta h \qquad , \quad j = 1, \cdots, K$

(c) Then the probability density and distribution will be obtained by the following equations:

$$\tilde{f}_j = \left(\frac{N_j}{n}\right)\frac{1}{\Delta h} \qquad j = 1, \cdots, K \quad \text{------} \quad (IV\text{-}13)$$

$$\tilde{F}_j = \frac{1}{n}\sum_{i=1}^{j} N_i \qquad j = 1, \cdots, K \quad \text{-------} \quad (IV\text{-}14)$$

The actual calculation variables were selected as follows:

sampling frequency = 500 samples per sec

record length = 10 sec (5000 samples) per computer run

no. of runs per calculation = 20

probability interval

0.001 in. for $h(t) \leqslant 0.05$ in.

0.005 in. for 0.05 in. $< h(t) \leqslant 0.1$ in.

0.025 in. for 0.1 in. $< h(t) \leqslant 0.2$ in.

0.05 in. for 0.2 in. $< h(t) \leqslant 0.4$ in.

The computer programs to calculate the above quantities are given in Appendix A, and the statistical errors of estimation are given in Appendix B.

4-2. MOMENTS OF FILM THICKNESS

The mean film thickness measured at the D_2 and B_1 cells in this work are compared with results given by Telles (T-2) and Webb (W-2) in Fig. IV-3. The results show good agreement.

The mean film thickness $\langle h(t) \rangle$, the second, third and fourth central moments $\widetilde{C}_2$, $\widetilde{C}_3$, $\widetilde{C}_4$ at D_2 cell are plotted in Fig. IV-4, Fig. IV-5, Fig. IV-6 and Fig. IV-7.

The data shows the mean film thickness and the central moments are monotonically increasing functions of liquid rate and decreasing functions of gas rate except at low gas rate. The unusual type of data at low gas rate are also shown in Telles' and Webb's work. The data also shows a value of $\widetilde{C}_3$ which is significant compared with $\widetilde{C}_2$ and $\widetilde{C}_4$. This implies a strong non normal probability distribution for film thickness. The numerical values of

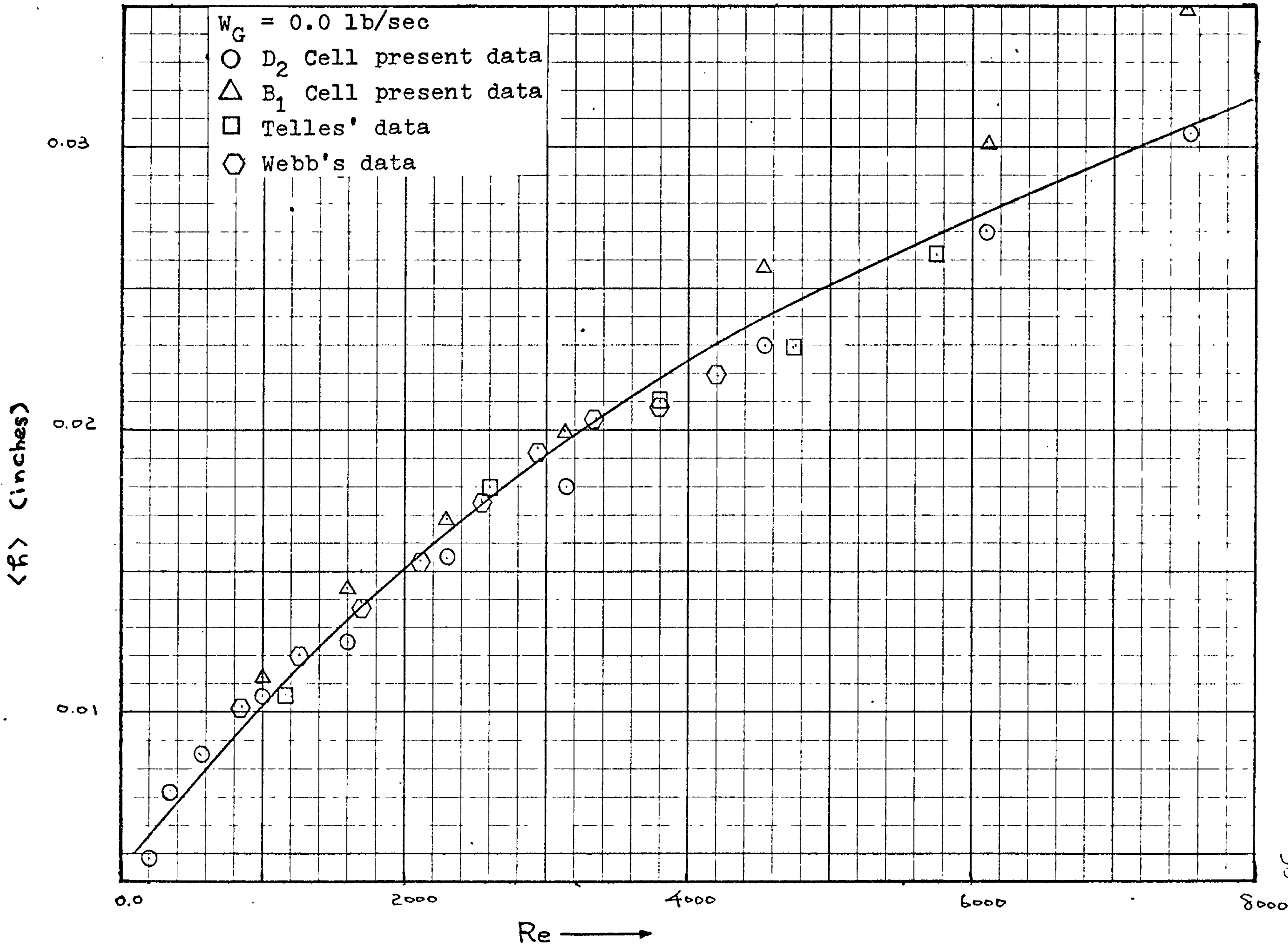


Fig. IV-3. COMPARISON OF MEAN FILM THICKNESS

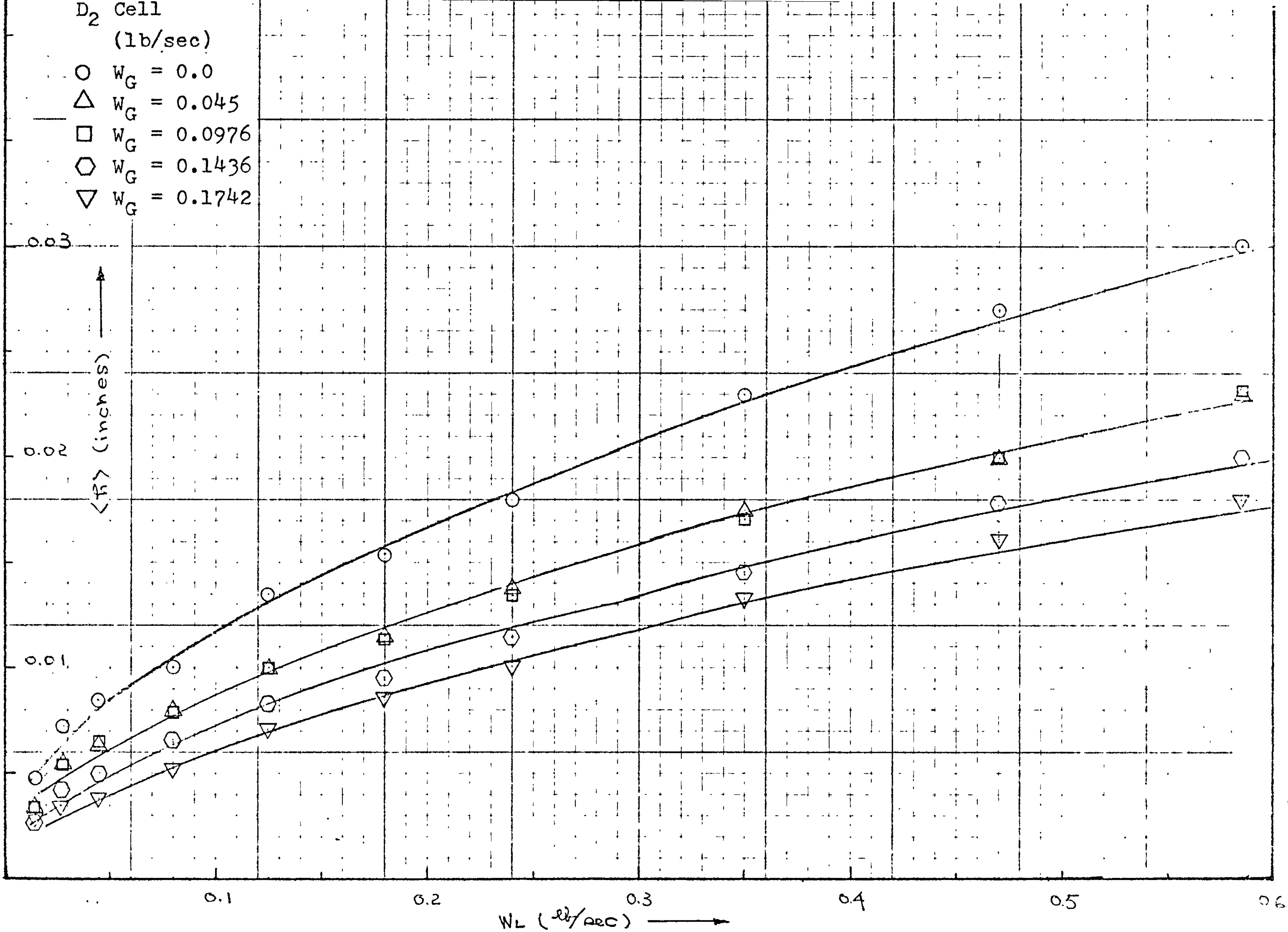


Fig. IV-4. MEAN FILM THICKNESS

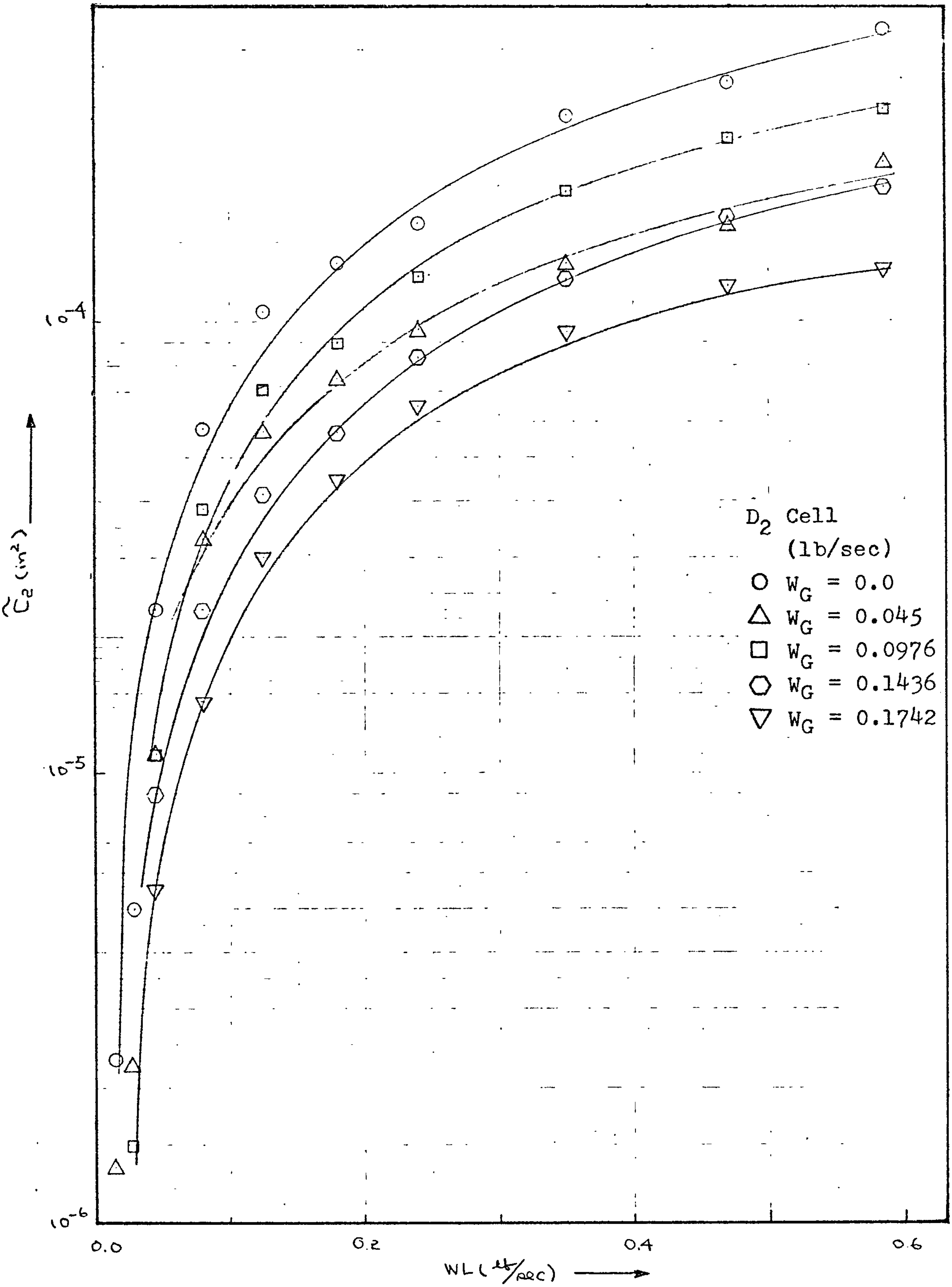


Fig. IV-5. SECOND CENTRAL MOMENT OF FILM THICKNESS

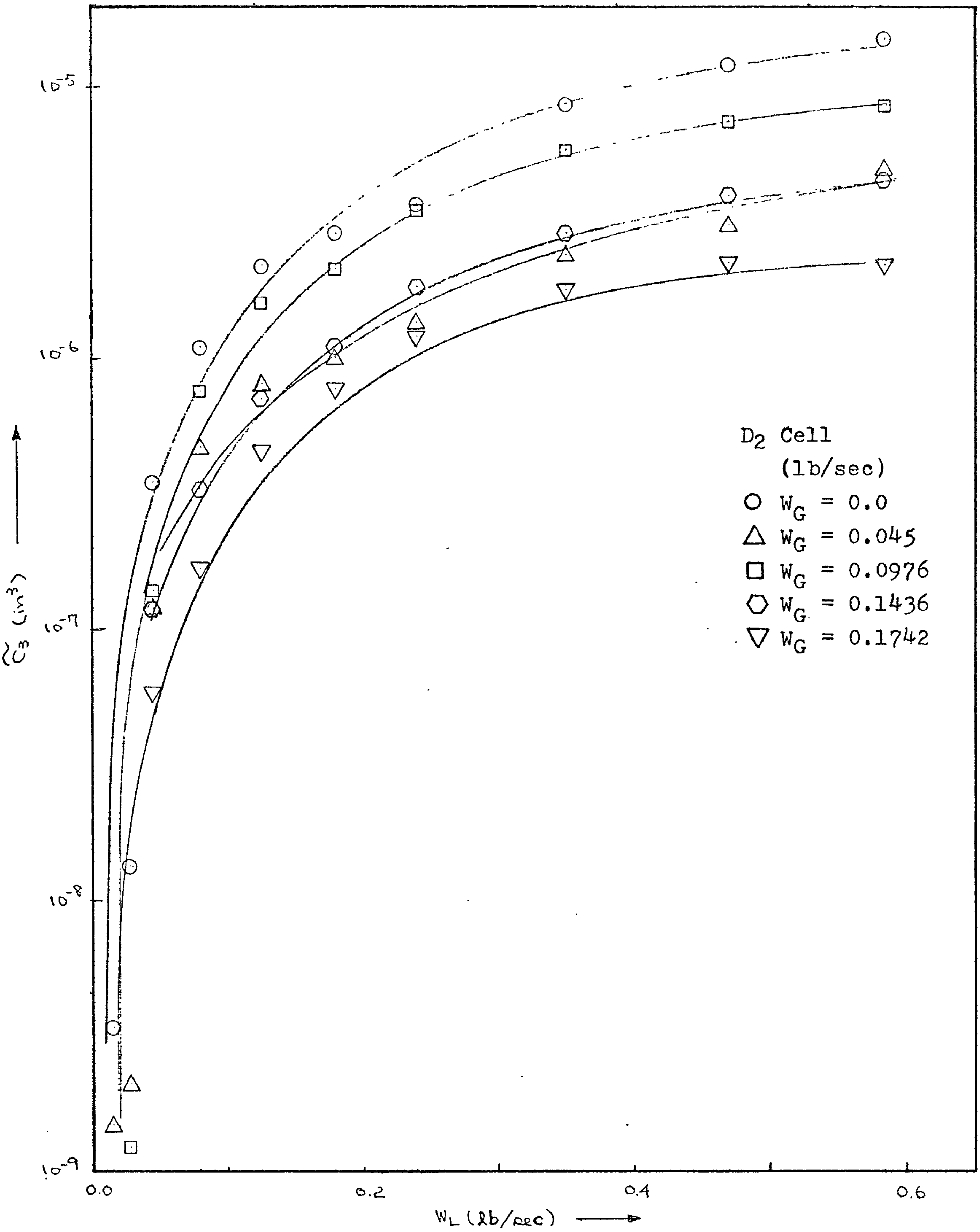


Fig. IV-6. THIRD CENTRAL MOMENT OF FILM THICKNESS

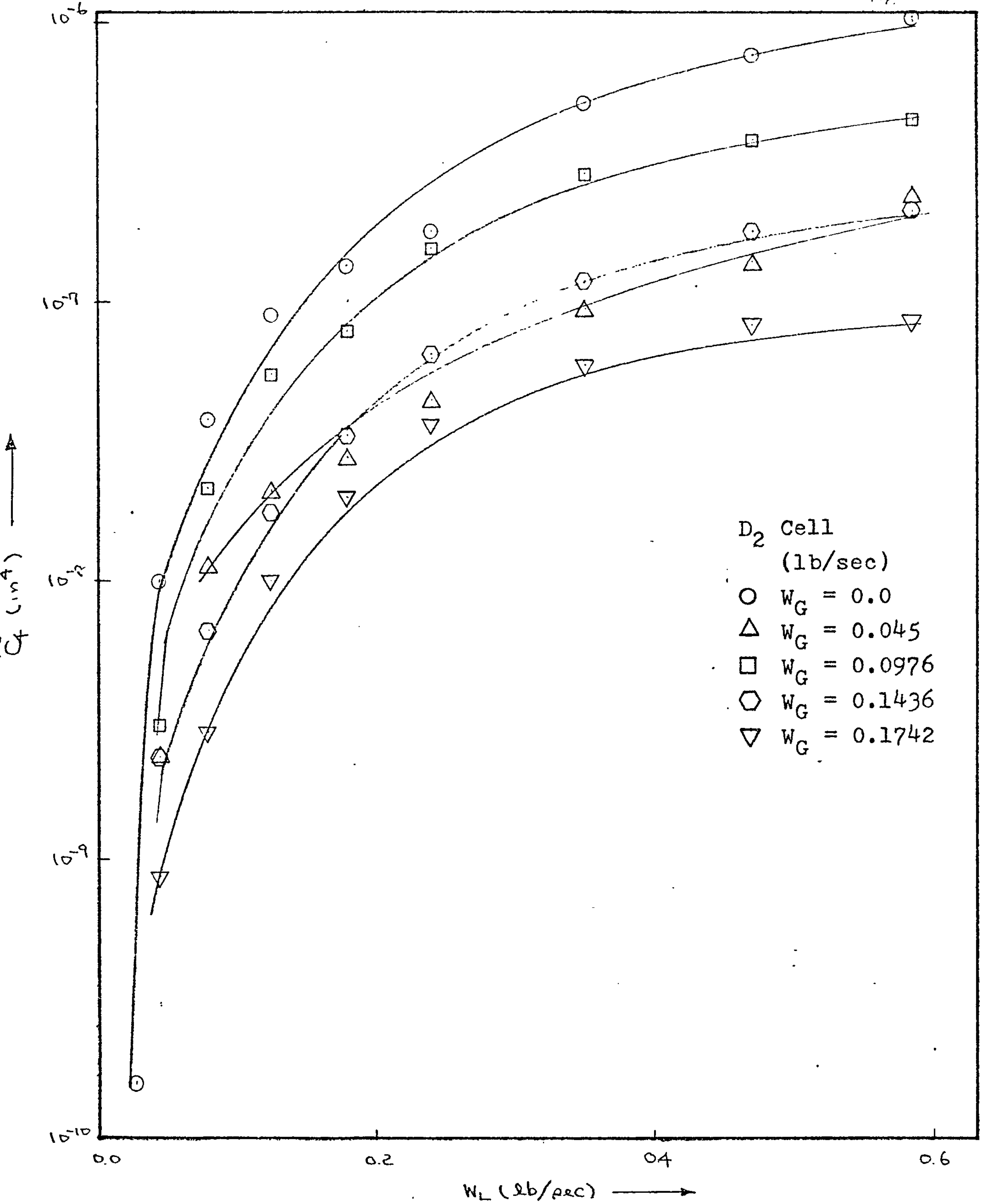


Fig. IV-7. FOURTH CENTRAL MOMENT OF FILM THICKNESS of $\langle h(t)\rangle$, $\widetilde{C}_2$, $\widetilde{C}_3$, $\widetilde{C}_4$ including the measurements made at B_1, A_3 and C_4 cells are tabulated in Appendix C.

4-3. PROBABILITY FUNCTION OF FILM THICKNESS

The probability density of film thickness $h(t)$ are presented in Fig. IV-8 through Fig. IV-12, and the numerical values are tabulated in Appendix C. Direct measurement of this quantity has never before been reported. The probability distribution functions of $h(t)$, which contain less information on the wave structure are filed in the data books. In these figures the following phenomema are observed:

(a) A very large maximum is always present which has a value below the expected value of film thickness, $\langle h(t)\rangle$.

(b) In the neighborhood of this maximum the distribution is very narrow.

(c) The probability density in the region $\hat{h} > \langle \hat{h}(t)\rangle$ is spread over a wide range and its slope is small.

(d) The maximum peak values increase with gas flow rate and decrease with liquid flow rate. The spread of the curve shows a reverse effect.

These observations are of extreme importance in the interpretation of the results, which follow in subsequent section.

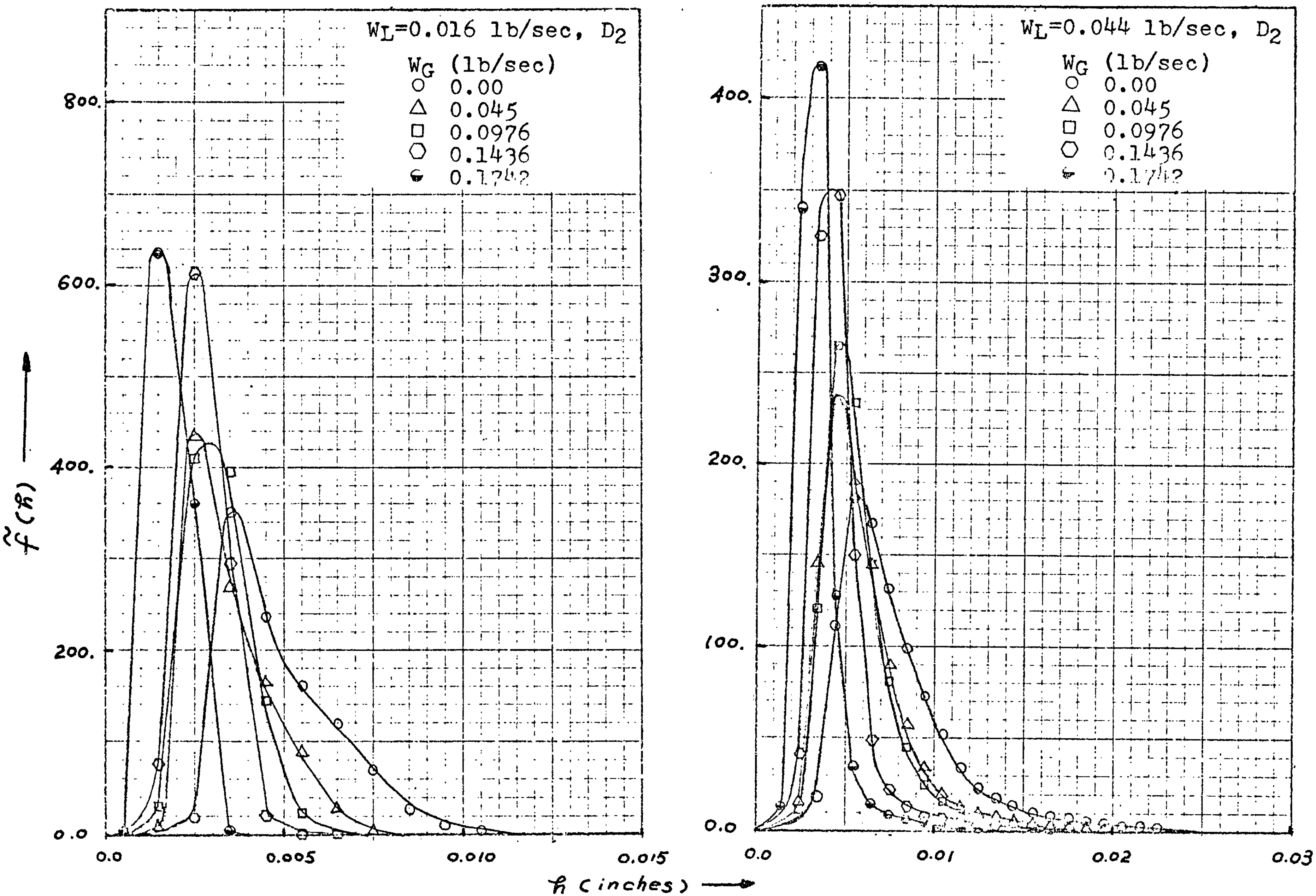


Fig. IV-8. PROBABILITY DENSITIES OF FILM THICKNESS

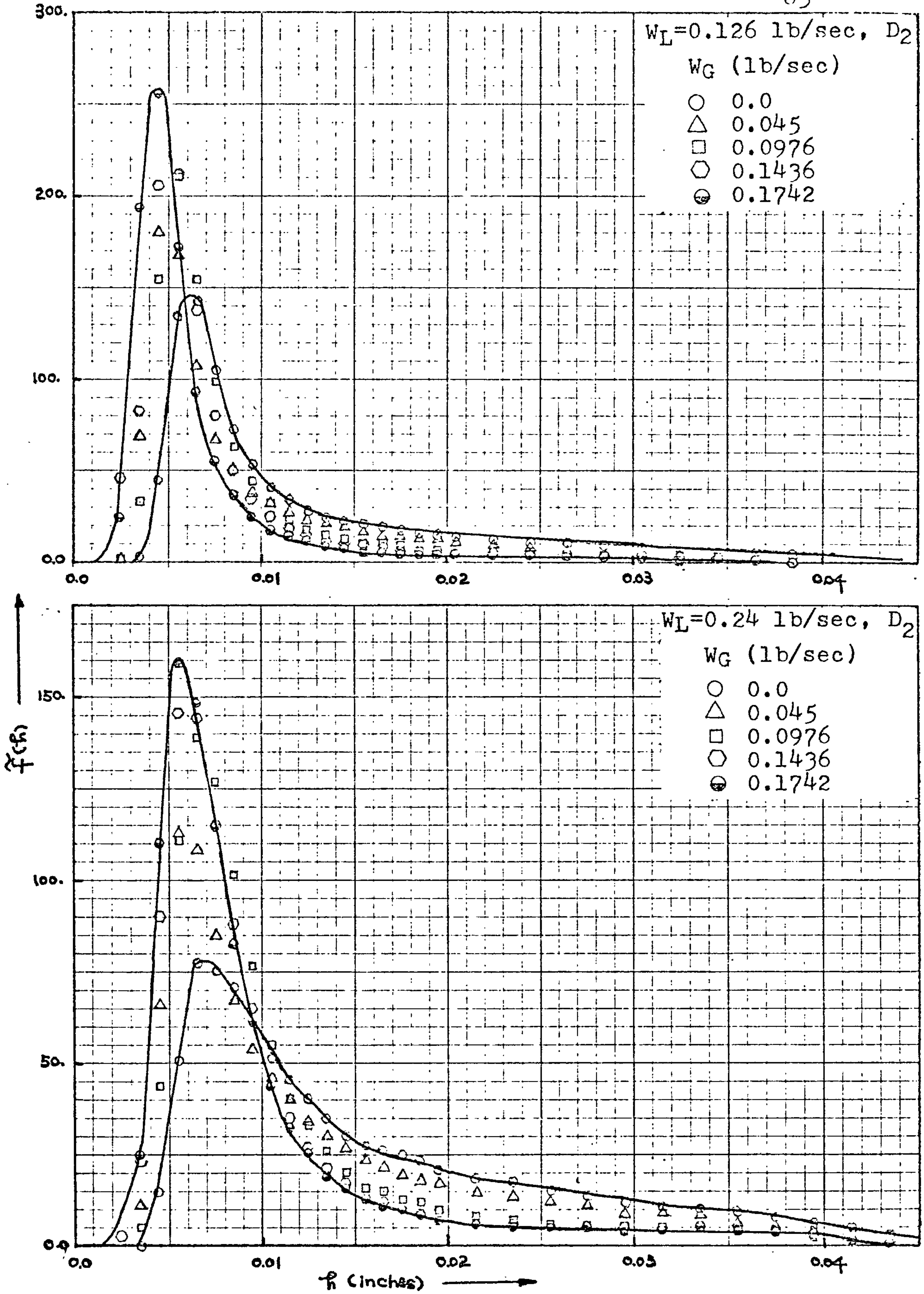


Fig. IV-9. PROBABILITY DENSITIES OF FILM THICKNESS

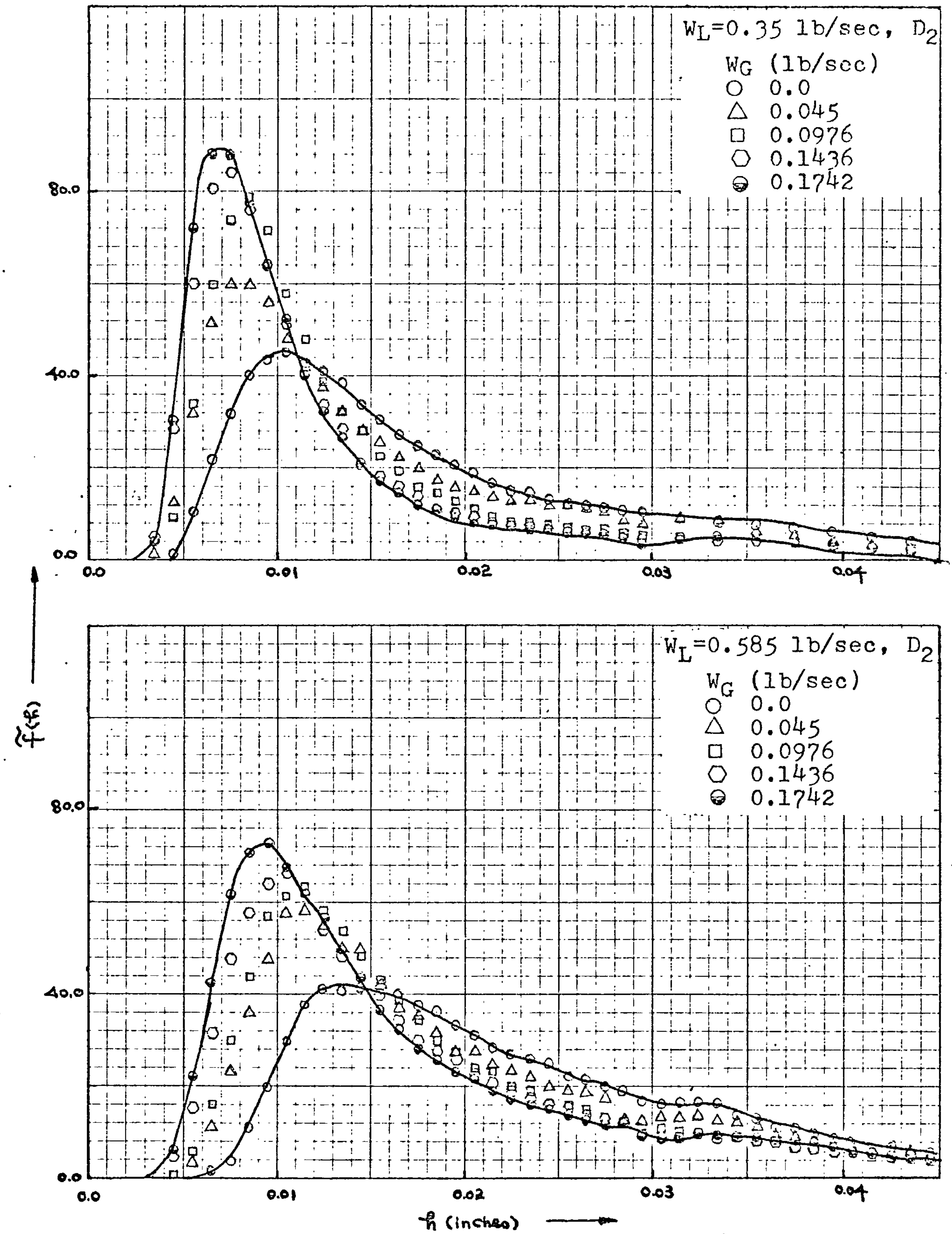


Fig. IV-10. PROBABILITY DENSITIES OF FILM THICKNESS

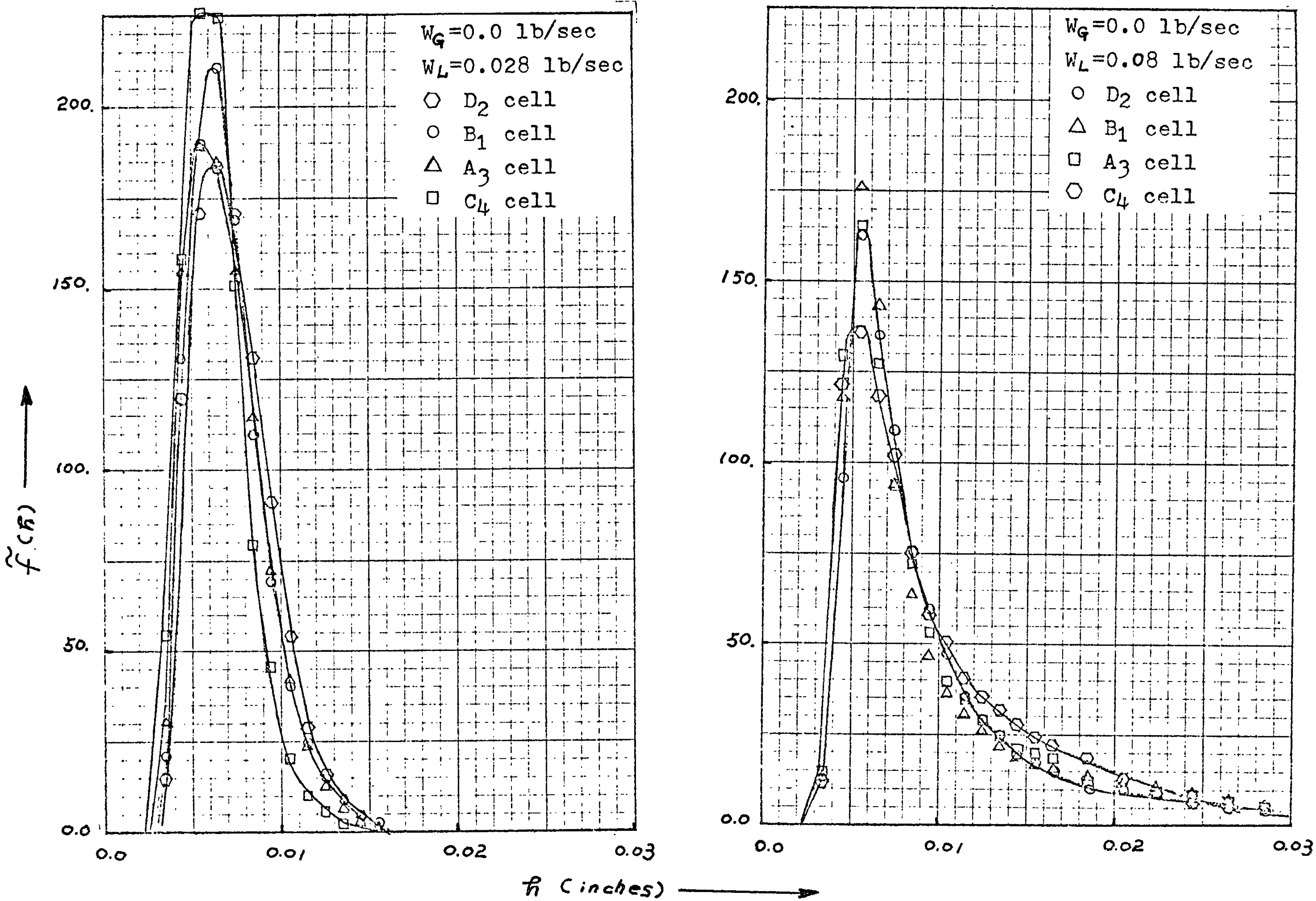


Fig. IV-11. PROBABILITY DENSITIES OF FILM THICKNESS

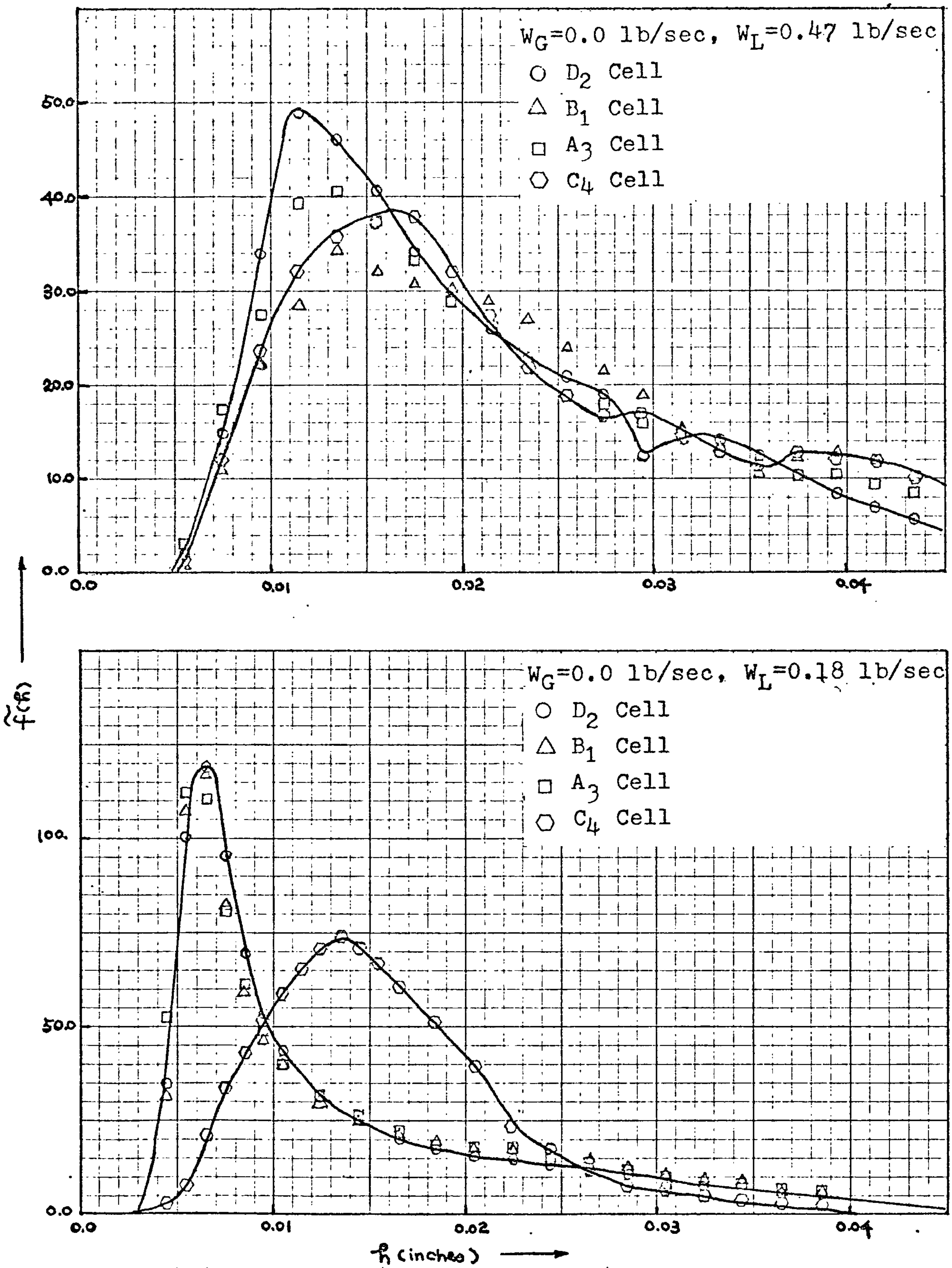


Fig. IV-12. PROBABILITY DENSITIES OF FILM THICKNESS

5. SPECTRAL AND CORRELATION ANALYSIS OF FILM THICKNESS

Spectral and correlation analyses are widely used to study time series. Geophysicists, in particular, have extracted much useful information about ocean waves with this powerful tool. There are only two previous studies of this nature for vertical wavy flow; those by Telles (T-2) and Webb (W-2). Both investigators analyzed the voltage signal which is a nonlinear function of the actual film thickness. This shortcoming is corrected in this study.

5-1. SPECTRAL AND CORRELATION ANALYSIS

Assuming the film thickness $h_1(t)$ and $h_2(t)$ are stationary processes, the definition of spectral density and correlation functions are given as follows:

$$\tilde{R}_{11}(\tau) = \langle \hat{h}_1(t+\tau)\,\hat{h}_1(t) \rangle \quad \text{--------- (IV-15)}$$

$$\tilde{R}_{12}(\tau) = \langle \hat{h}_1(t+\tau)\,\hat{h}_2(t) \rangle \quad \text{-------- (IV-16)}$$

$$\tilde{S}'_{11}(f) = \int_{-\infty}^{+\infty} e^{-i2\pi f\tau}\,\tilde{R}_{11}(\tau)\,d\tau \quad \text{------ (IV-17)}$$

$$\tilde{S}'_{12}(f) = \int_{-\infty}^{+\infty} e^{-i2\pi f\tau}\,\tilde{R}_{12}(\tau)\,d\tau \quad \text{----- (IV-18)}$$

where $h_1(t)$ is the film thickness time series at position 1

$h_2(t)$ is the film thickness time series at position 2

$\tilde{R}_{11}(\tau)$ is autocorrelation function of $\hat{h}_1(t)$

$\tilde{R}_{12}(\tau)$ is cross correlation function of $\hat{h}_1(t)$ and $\hat{h}_2(t)$

$\tilde{S}_{11}(f)$ is power spectrum function of $\hat{h}_1(t)$

$\tilde{S}_{12}(f)$ is cross power spectrum function of $\hat{h}_1(t)$ and $\hat{h}_2(t)$

Since $h_1(t)$ and $h_2(t)$ contain a D.C. level, the power spectrum density function will show a strong Delta function type of peak at zero frequency, therefore it is desirable to operate on the mean free quantities $h_1'(t)$ and $h_2'(t)$

$$\tilde{C}_{11}(\tau) = \langle \hat{h}_1'(t+\tau)\,\hat{h}_1'(t)\rangle \quad \text{--------- (IV-19)}$$

$$\tilde{C}_{12}(\tau) = \langle \hat{h}_1'(t+\tau)\,\hat{h}_2'(t)\rangle \quad \text{--------- (IV-20)}$$

$$\tilde{S}_{11}(f) = \int_{-\infty}^{+\infty} e^{-i2\pi f\tau}\,\tilde{C}_{11}(\tau)\,d\tau \quad \text{------- (IV-21)}$$

$$\tilde{S}_{12}(f) = \int_{-\infty}^{+\infty} e^{-i2\pi f\tau}\,\tilde{C}_{12}(\tau)\,d\tau \quad \text{------- (IV-22)}$$

where $h_1'(t) = h_1(t) - \langle h_1(t)\rangle$

$h_2'(t) = h_2(t) - \langle h_2(t)\rangle$

$\tilde{C}_{11}(\tau)$ is called auto-covariance function

$\tilde{C}_{12}(\tau)$ is called cross-covariance function

The important properties which were used in the actual computation are given as follows:

(a) $$\tilde{C}(\tau) = \int_{-\infty}^{+\infty} \tilde{S}(f)\,e^{i2\pi f\tau}\,df \quad \text{------ (IV-23)}$$

(b) $$\int_{-\infty}^{+\infty} \tilde{S}_{11}(f)\,df = \tilde{C}_{11}(0) = \tilde{C}_2 \geq \tilde{C}_{11}(\tau) \quad \text{--- (IV-24)}$$

(c) if $h(t)$ is real, then $C_{11}(\tau)$ is real and even, therefore $S_{11}(f)$ is also real and even

(d) $S_{12}(f)$ is complex, hence $C_{12}(\tau)$ is not necessary a symmetrical function

The detailed derivation of those properties are given in Papoulis (P-1 , P-2).

Since $S_{12}(f)$ is complex, we can further define

$$\tilde{S}_{12}(f) = \tilde{\Lambda}(f) + i\,\tilde{Q}(f) \qquad \text{(IV-25)}$$

$$\tilde{S}_A(f) = (\tilde{\Lambda}^2(f) + \tilde{Q}^2(f))^{1/2} \qquad \text{(IV-26)}$$

$$\tilde{\theta}(f) = \tan^{-1}\frac{\tilde{Q}(f)}{\tilde{\Lambda}(f)} \qquad \text{(IV-27)}$$

where $\tilde{\Lambda}(f)$ is called co-spectrum

$\tilde{Q}(f)$ is called quadrature spectrum

$\tilde{S}_A(f)$ is amplitude spectrum

$\tilde{\theta}(f)$ is phase spectrum

It is very reasonable to assume the processes of film thickness is ergodic (time averages equal to ensemble averages).

This assumption allows us to evaluate the correlation and spectral function by the following time average equations:

$$\tilde{C}_{11}(\tau) = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{+T} h_1'(t+\tau)\,h_1'(t)\,dt \qquad \text{(IV-28)}$$

$$\tilde{C}_{12}(\tau) = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{+T} h_1'(t+\tau)\,h_2'(t)\,dt \qquad \text{(IV-29)}$$

$$\tilde{S}_{11}(f) = \lim_{T\to\infty}\frac{1}{2T}\left|\int_{-T}^{+T} h_1'(t)\,e^{-i2\pi f t}\,dt\right|^2 \qquad \text{(IV-30)}$$

$$\tilde{S}_{12}(f) = \lim_{T\to\infty} \frac{1}{2T} \left\{ \int_{-T}^{+T} h_1'(t) e^{-i2\pi f t} dt \right\} \left\{ \int_{-T}^{+T} h_2'(t) e^{-i2\pi f t} dt \right\}^{*} \quad \text{--- (IV-31)}$$

where * is the complex conjugate

The proof of those four equations equivalent to equations (IV-19), (IV-20), (IV-21), and (IV-22) is given in Papoulis (P-1).

Since the powerful tool of Fast Fourier Transform is available, the calculation of the above quantities can be rapidly executed on the digital computer. $\tilde{C}_{11}(\tau)$ and $\tilde{C}_{12}(\tau)$ are calculated by equation (IV-23) using the Fourier Transform of the spectrum. The digital calculation parameters for this work were chosen as follows:

sampling frequency = 250 samples per sec

sample length = 2048 samples per run

no. of repeated runs per condition = 20

no. of points averaged in the frequency domain = 4

The computer program for estimating power spectrum and correlation is given in Appendix A. Statistical errors are analyzed in Appendix B.

5-2. SPECTRA AND CROSS-SPECTRA OF FILM THICKNESS

All the spectral data presented in this study are normalized value which is $\tilde{S}_{11}(f)/\tilde{C}_2^{(1)}$ for auto spectrum and $\tilde{S}_{12}(f)/\left\{\tilde{C}_2^{(1)} \tilde{C}_2^{(2)}\right\}^{1/2}$ for cross spectrum. $C_2^{(1)}$ and $C_2^{(2)}$ are the second central moments of $h_1(t)$ and $h_2(t)$,

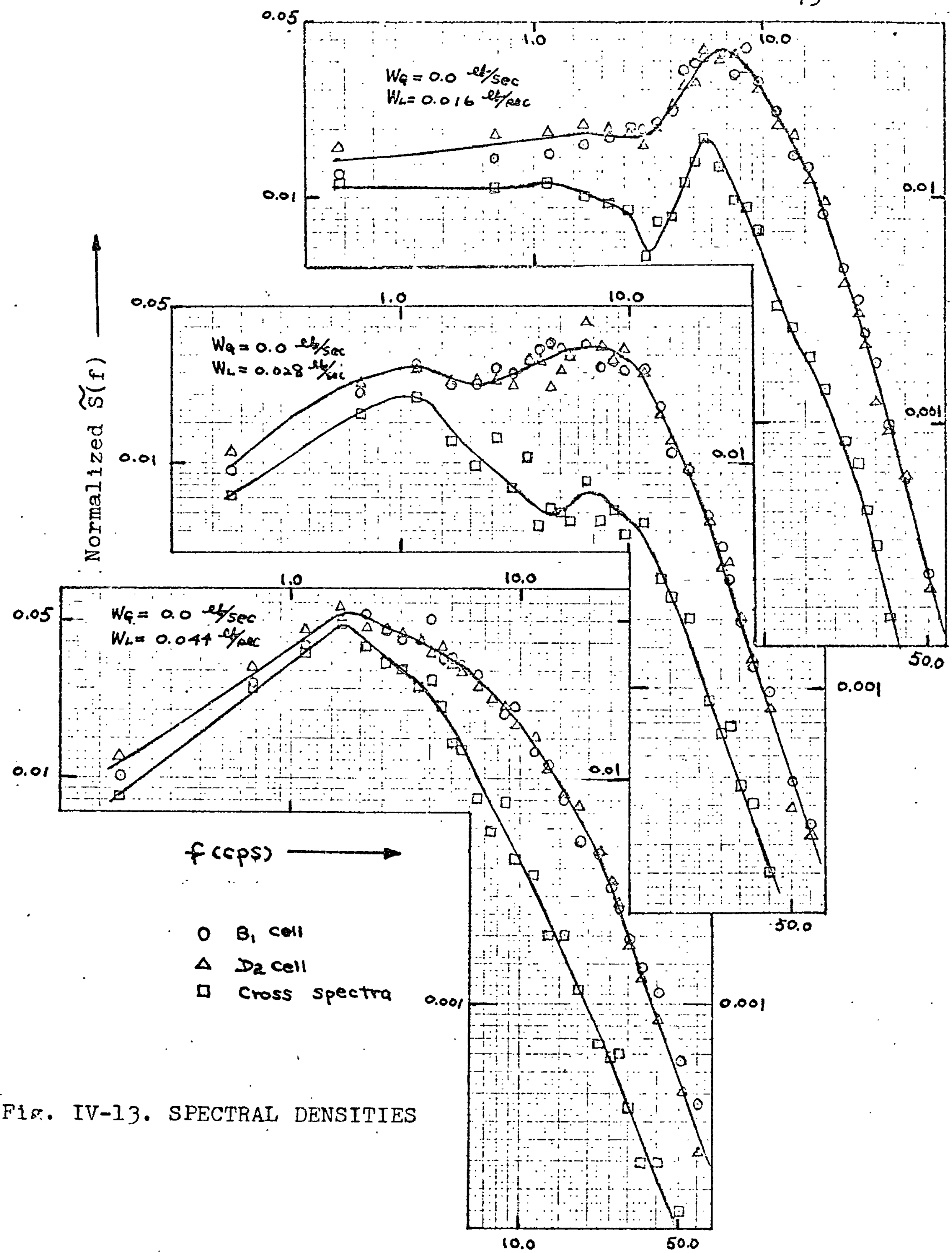


Fig. IV-13. SPECTRAL DENSITIES

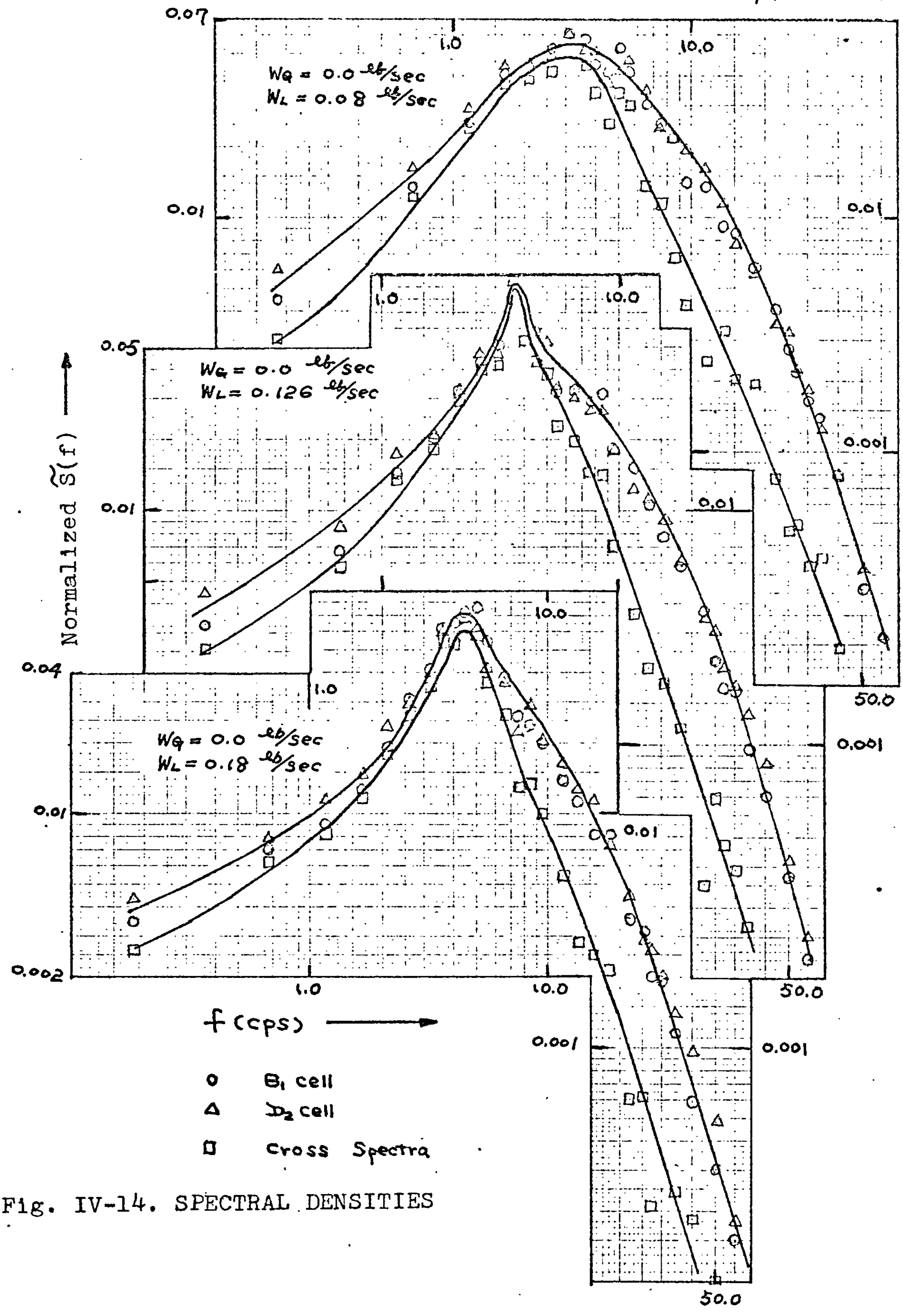


Fig. IV-14. SPECTRAL DENSITIES

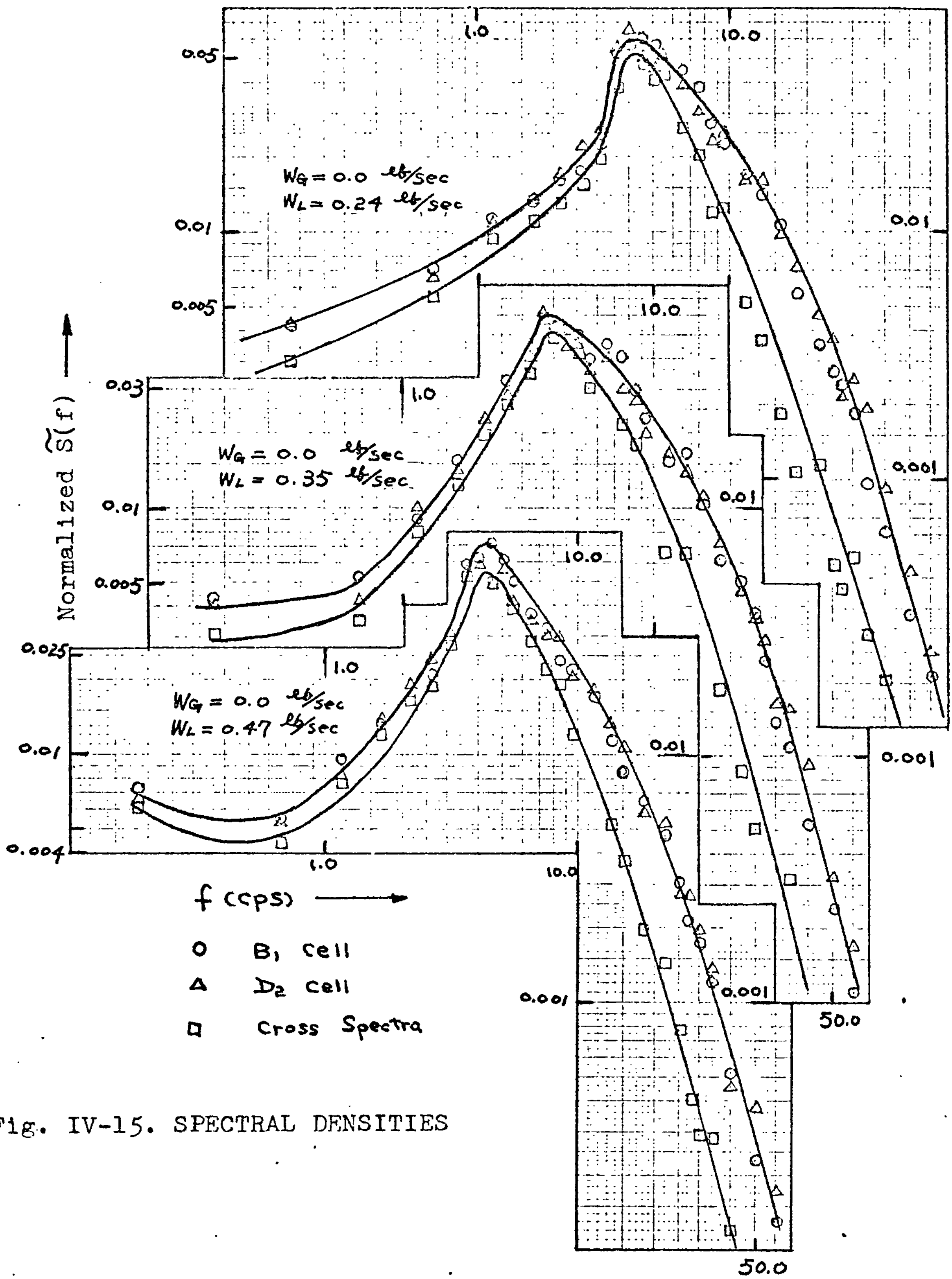


Fig. IV-15. SPECTRAL DENSITIES

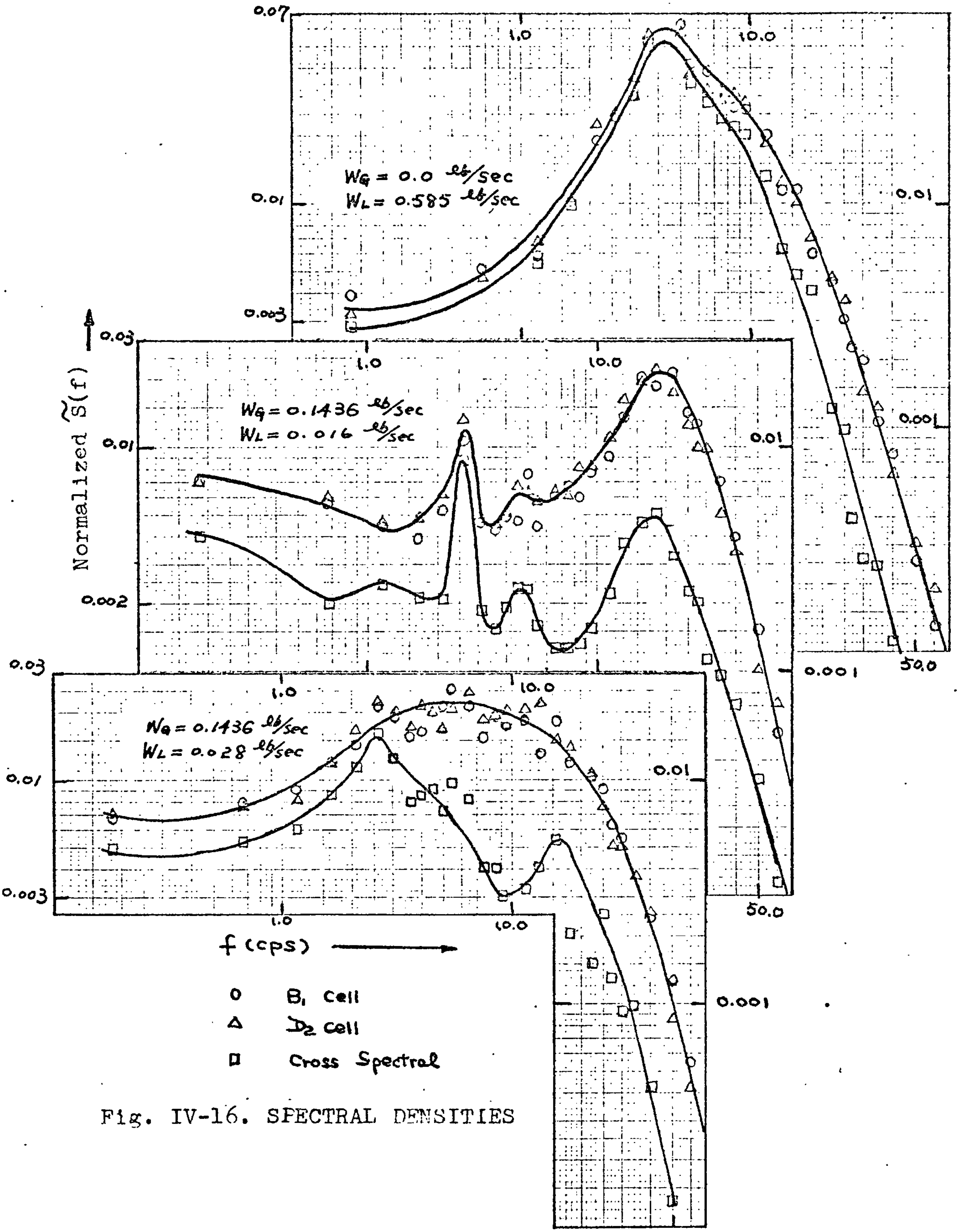


Fig. IV-16. SPECTRAL DENSITIES

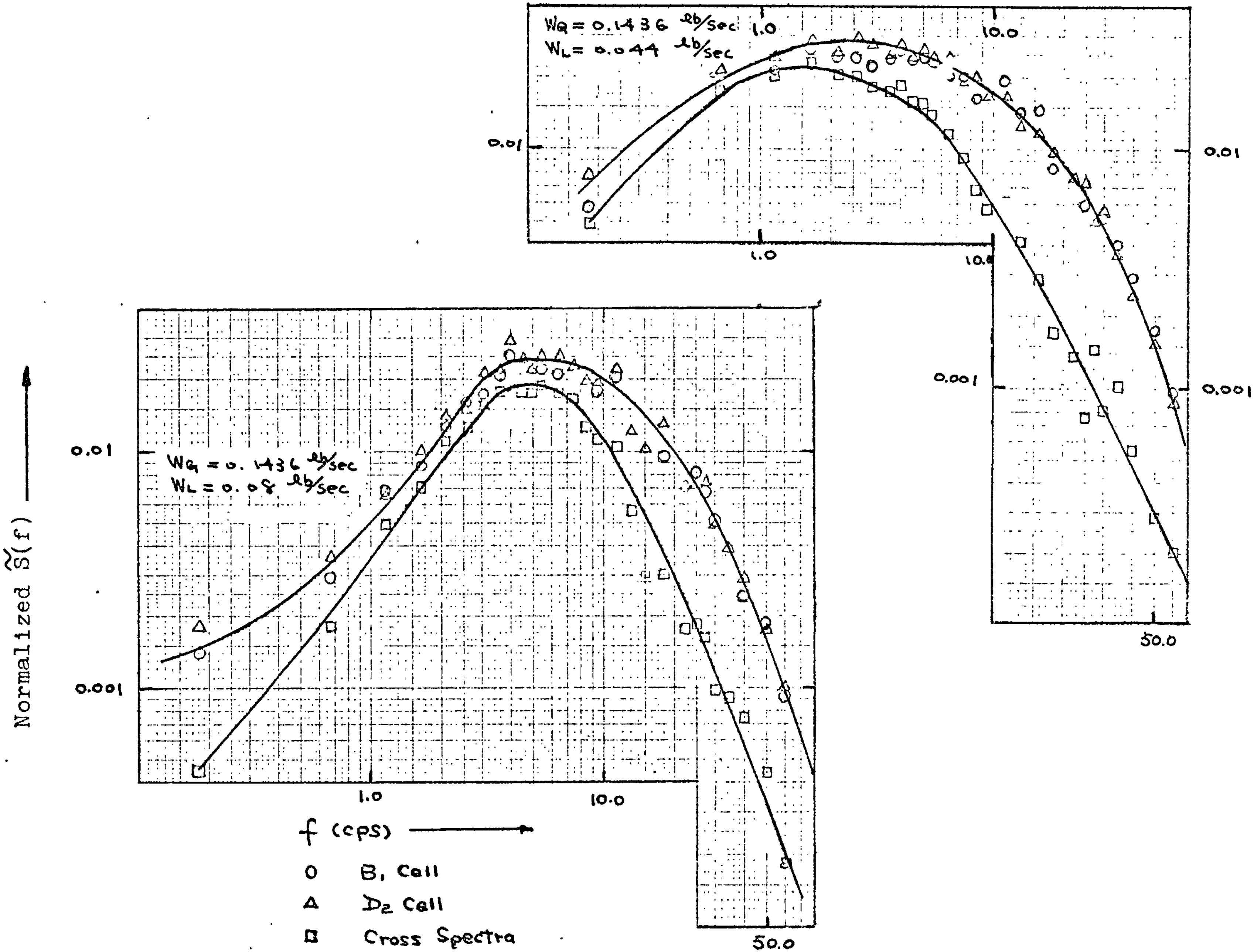


Fig. IV-17. SPECTRAL DENSITIES

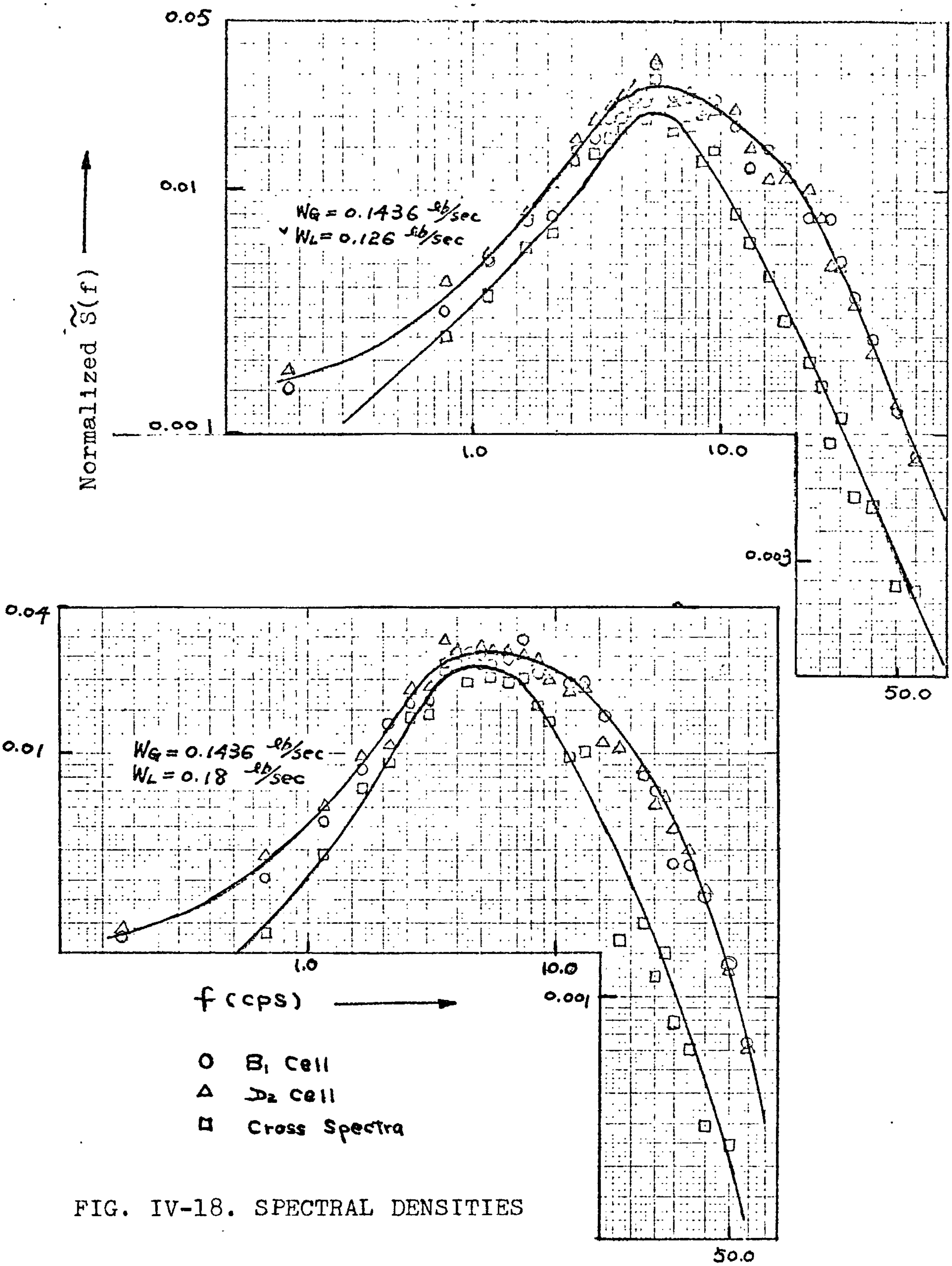


FIG. IV-18. SPECTRAL DENSITIES

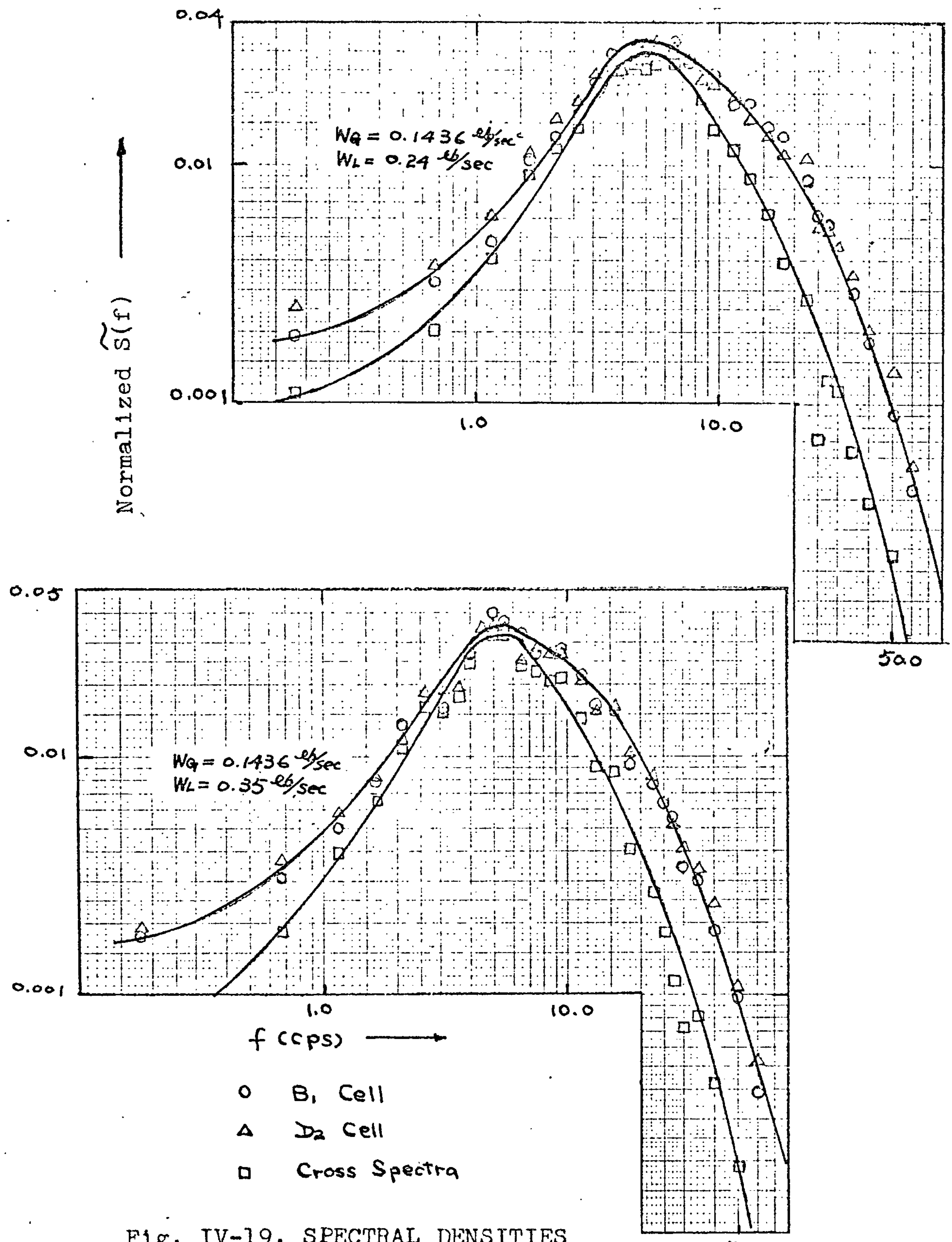


Fig. IV-19. SPECTRAL DENSITIES

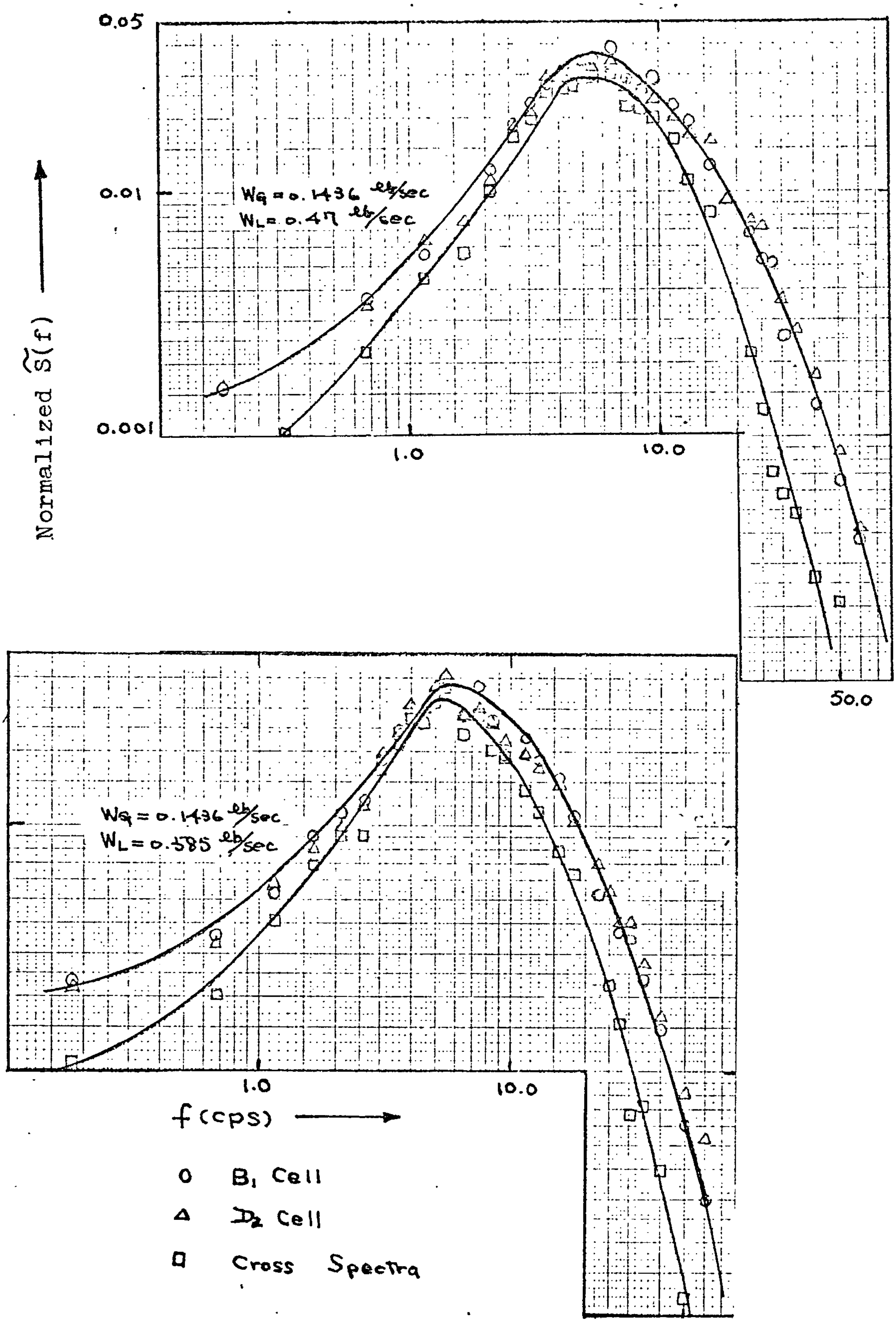


FIG. IV-20. SPECTRAL DENSITIES

which are given in Appendix C. The spectral densities of film thickness measured at B_1 and at D_2 and the amplitude spectral densities between them are plotted in Fig. IV-13 through Fig. IV-20. The phase spectra between B_1 and D_2 are shown in Fig. IV-21 through Fig. IV-23. The tables of these numerical values are in Appendix C. A few typical examples of the spectral density of film thickness at A_3 and at C_4 are plotted in Fig. VI-24 through Fig. IV-25. The complete data sets are in the data books.

One can observe the following facts from those spectral data.

(a) In most of the conditions the spectra shows a maximum value at a frequency which is called modal frequency f_m.

(b) The modal frequency increases with the gas rate and liquid rate except at the low liquid rates.

(c) For the liquid rate below 0.044 lb/sec there is suggestion of a double peak structure especially in cross amplitude spectrum. The low frequency peak increases with the liquid rate while the high frequency peak indicates the reverse effect.

(d) The increase of gas rate tends to increase the spread of the spectral curves in the neighborhood of the modal peak, and the increase of liquid rate gives the reverse

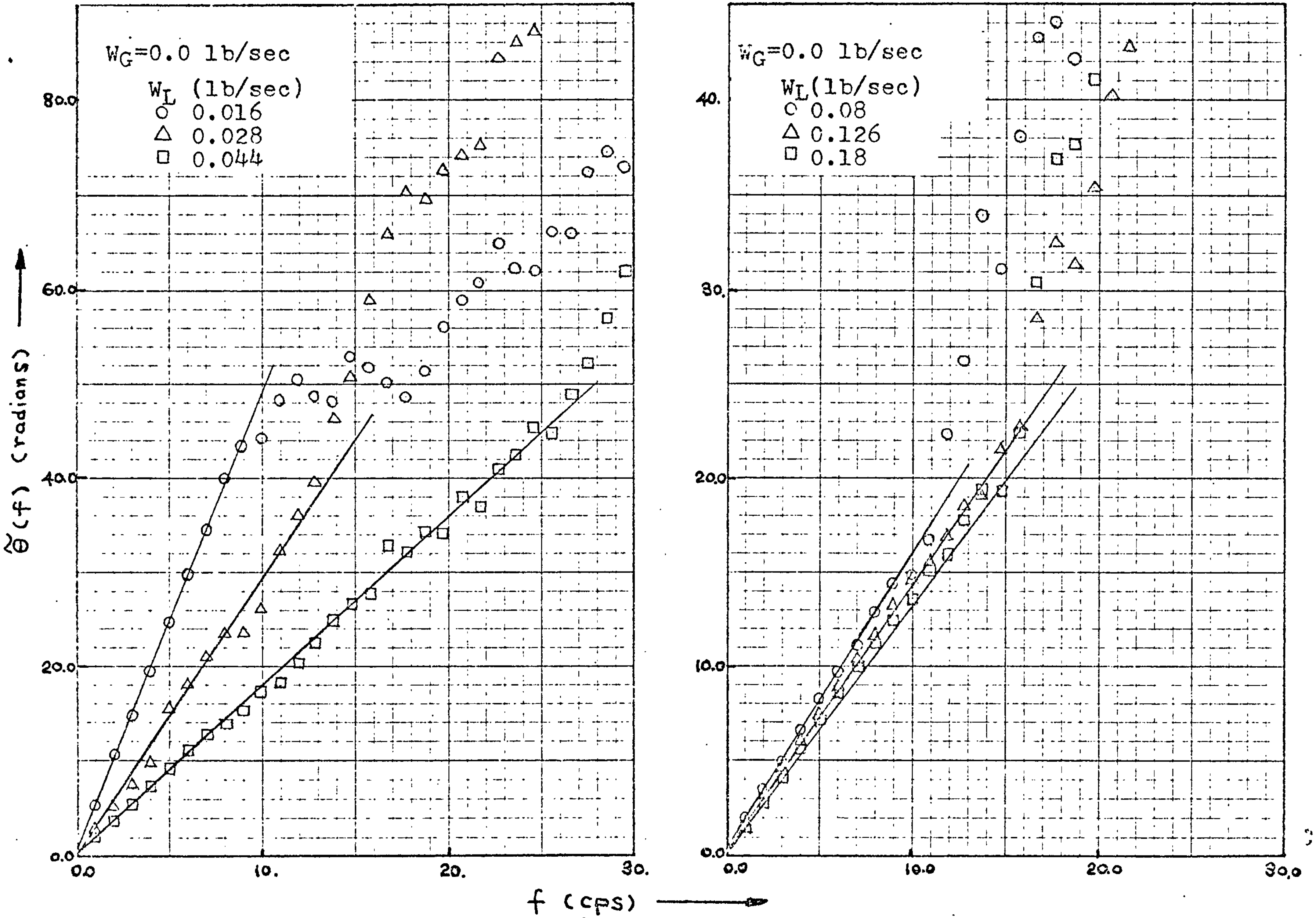


Fig. IV-21. PHASE SPECTRA

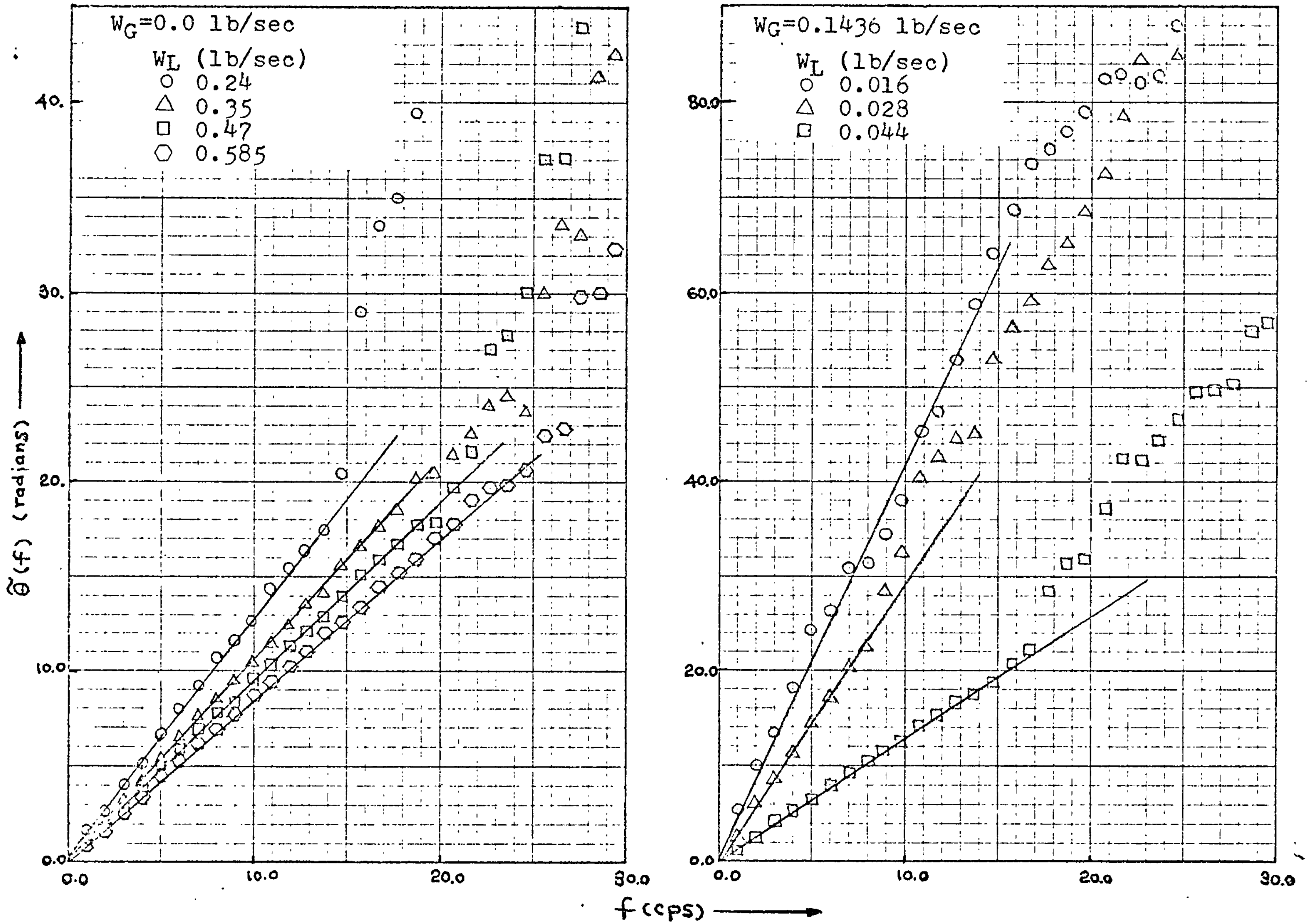


Fig. IV-22. PHASE SPECTRA

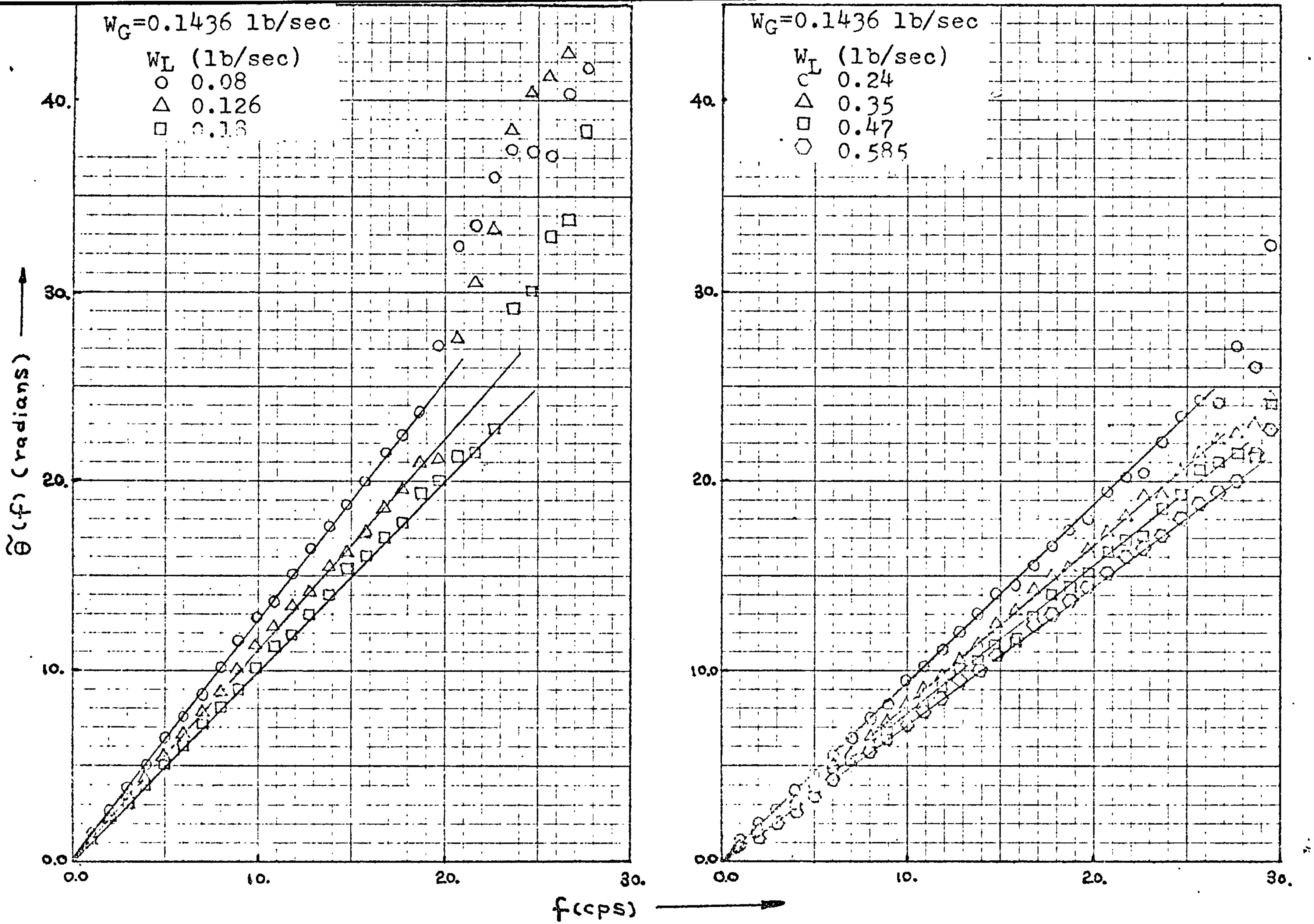


Fig. IV-23. PHASE SPECTRA

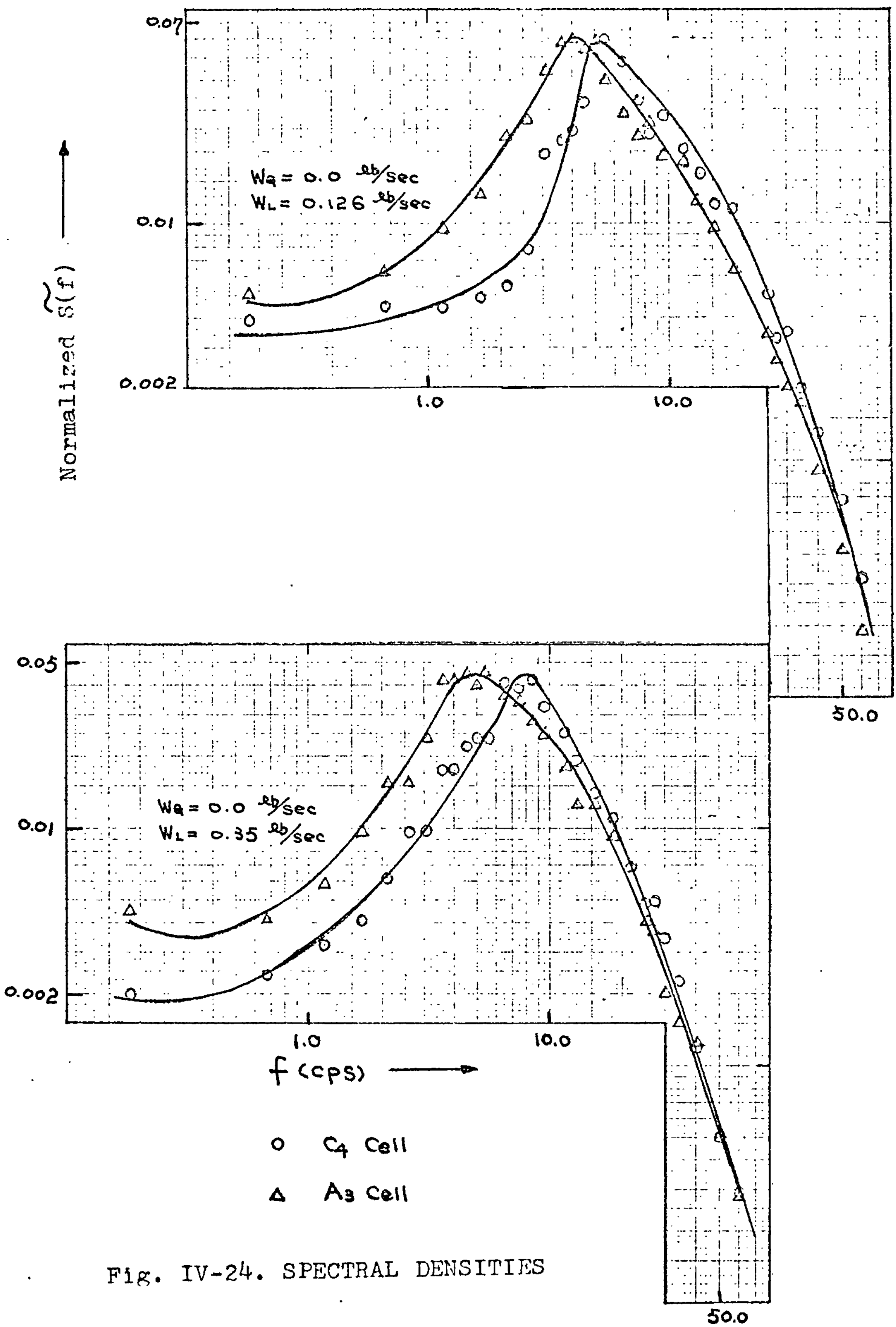


Fig. IV-24. SPECTRAL DENSITIES

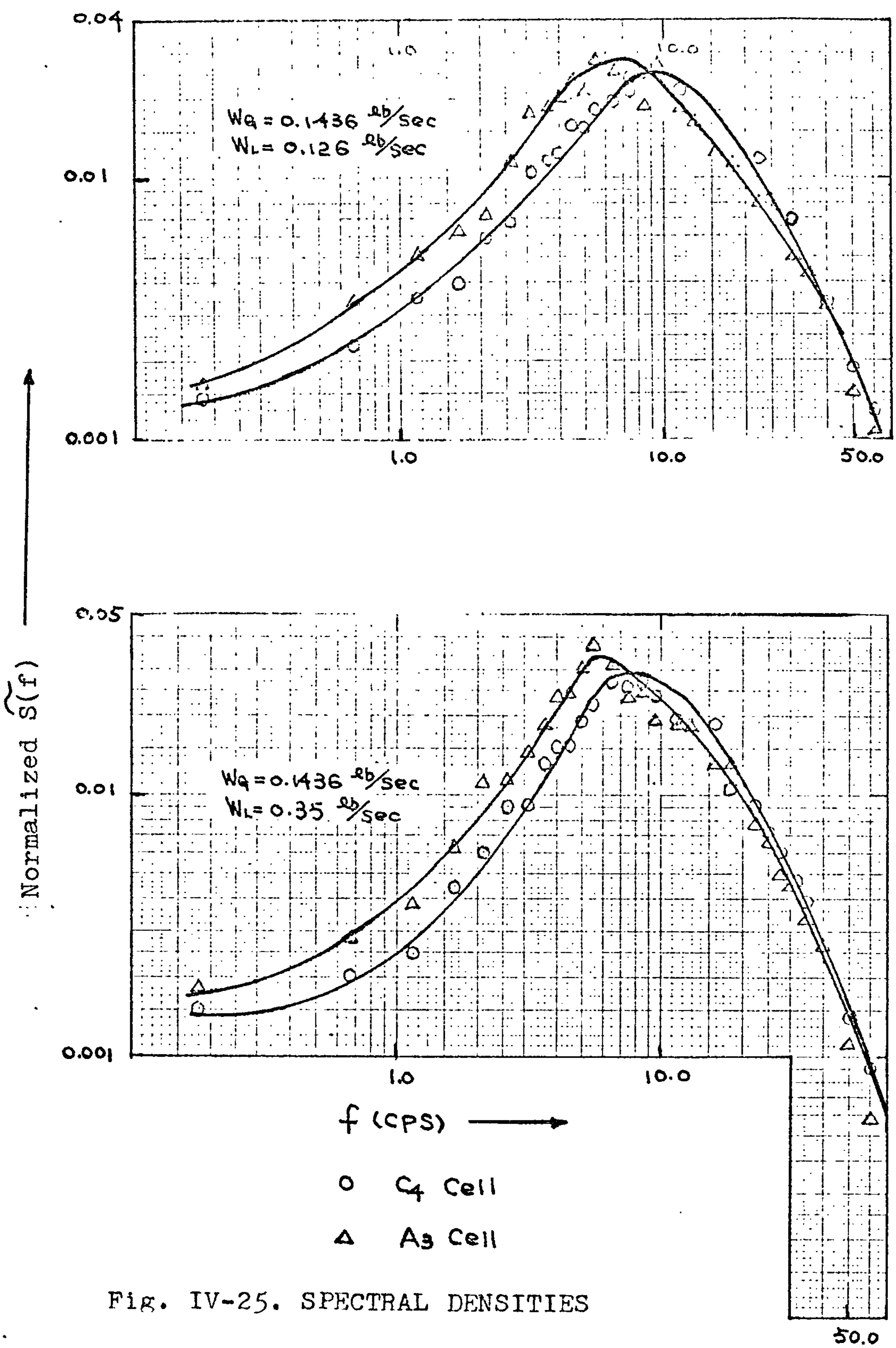


Fig. IV-25. SPECTRAL DENSITIES

effect.

(e) On the low frequency side, the cross amplitude spectrum is almost identical with the auto spectral density from each of the two cells. As the frequency increases the cross amplitude spectrum will increase the departure from the auto spectra.

(d) The phase spectra shows a straight line in the low frequenc'' range. In the higher range the slope of the phase spectra gives a higher value than that of low frequency range.

5-3. CORRELATION FUNCTION OF FILM THICKNESS

The correlation contains the same information as the spectral function in another form. But some of the information is easier to extract in this time domain than from an analysis in the frequency domain. The auto-covariance and cross-covariance functions of film thickness at D_2 and at B_1, which are normalized by second central moment as the spectra, are plotted in Fig. IV-27 through Fig. IV-34. Since the auto-covariance function is symmetrical about $\tau = 0$, and the main lobe of the cross-covariance function is located at $\tau_1 > 0$ and unsymmetrical about τ_1 as given in Fig. IV-26 (a), it is convenient to present the auto-covariance function $\widetilde{C}(\tau)$ for $\tau \geq 0$ and the cross-covariance function $\widetilde{C_{12}}(\tau)$ by shifting time coordinate as $\widetilde{C_{12}}(\tau' + \tau_1)$, then folding $\widetilde{C_{12}}(\tau' + \tau_1)$ for $\tau' + \tau_1 \leq 0$ to

$\zeta' + \zeta_1 \geq 0$ as shown in Fig. IV-26(b). Those values are also tabulated in Appendix C. Those functions of film thickness at A_3 and at C_4 are filed in the data books.

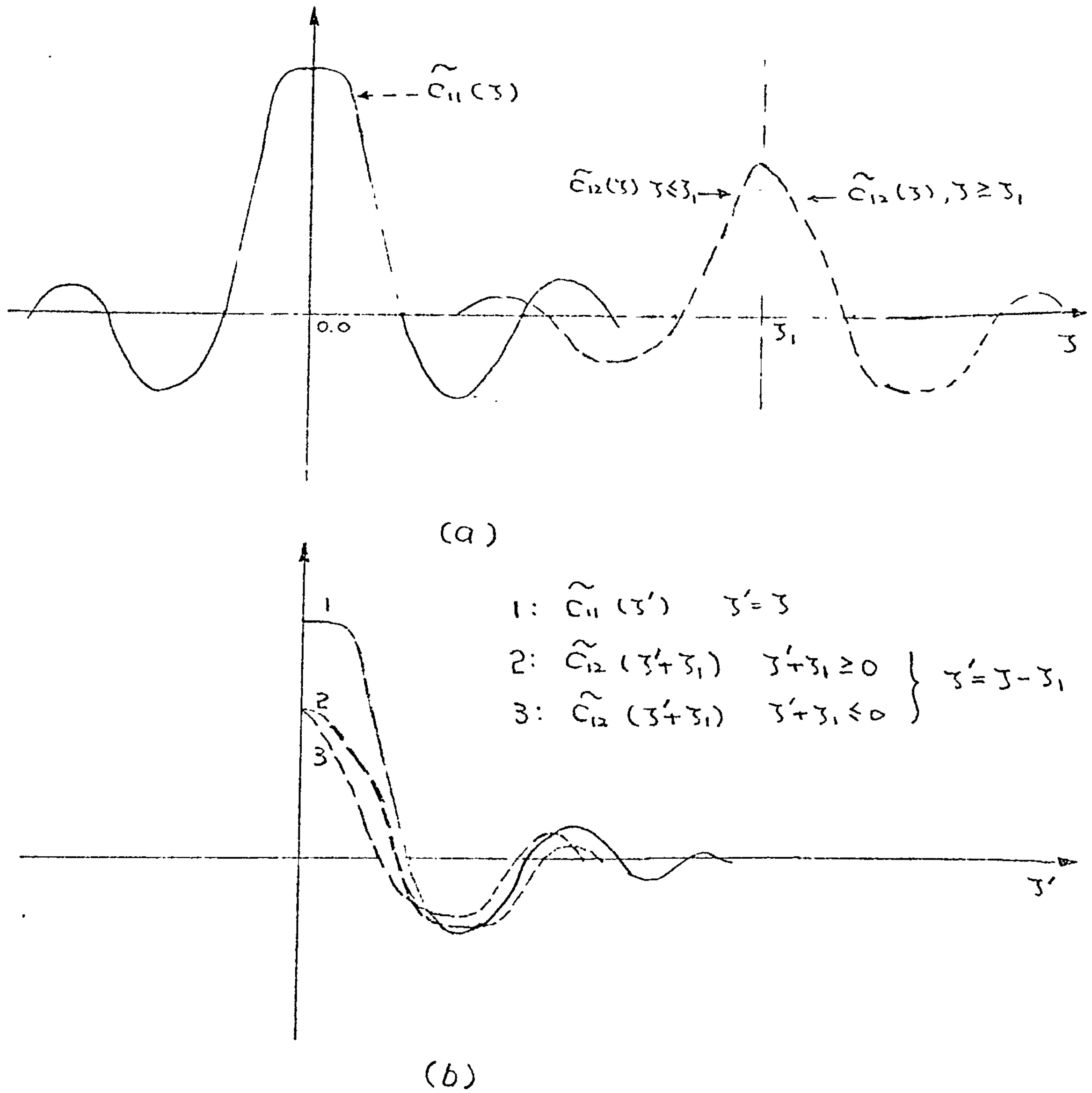


Fig. IV-26. REPRESENTATION OF COVARIANCE FUNCTION

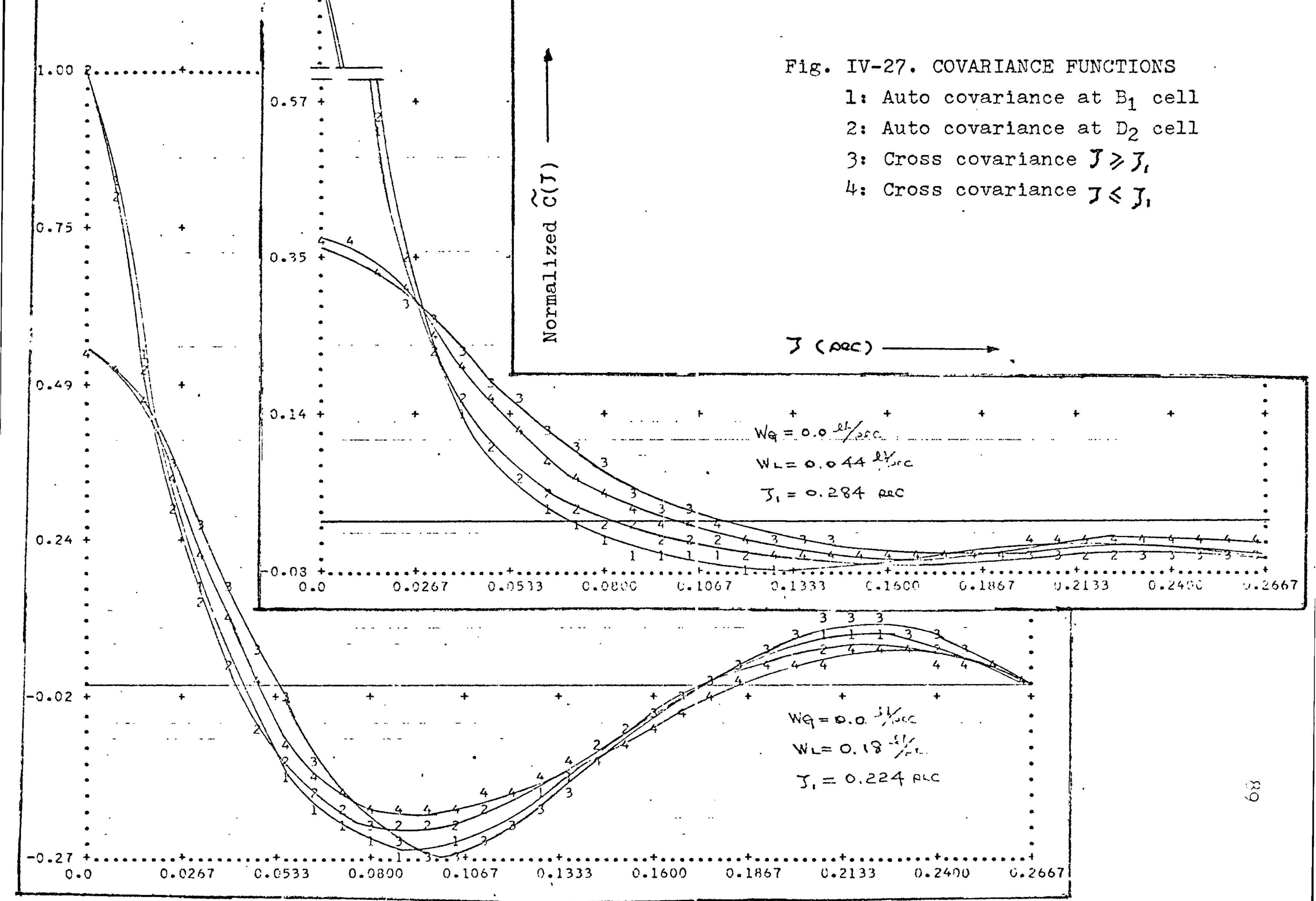


Fig. IV-27. COVARIANCE FUNCTIONS

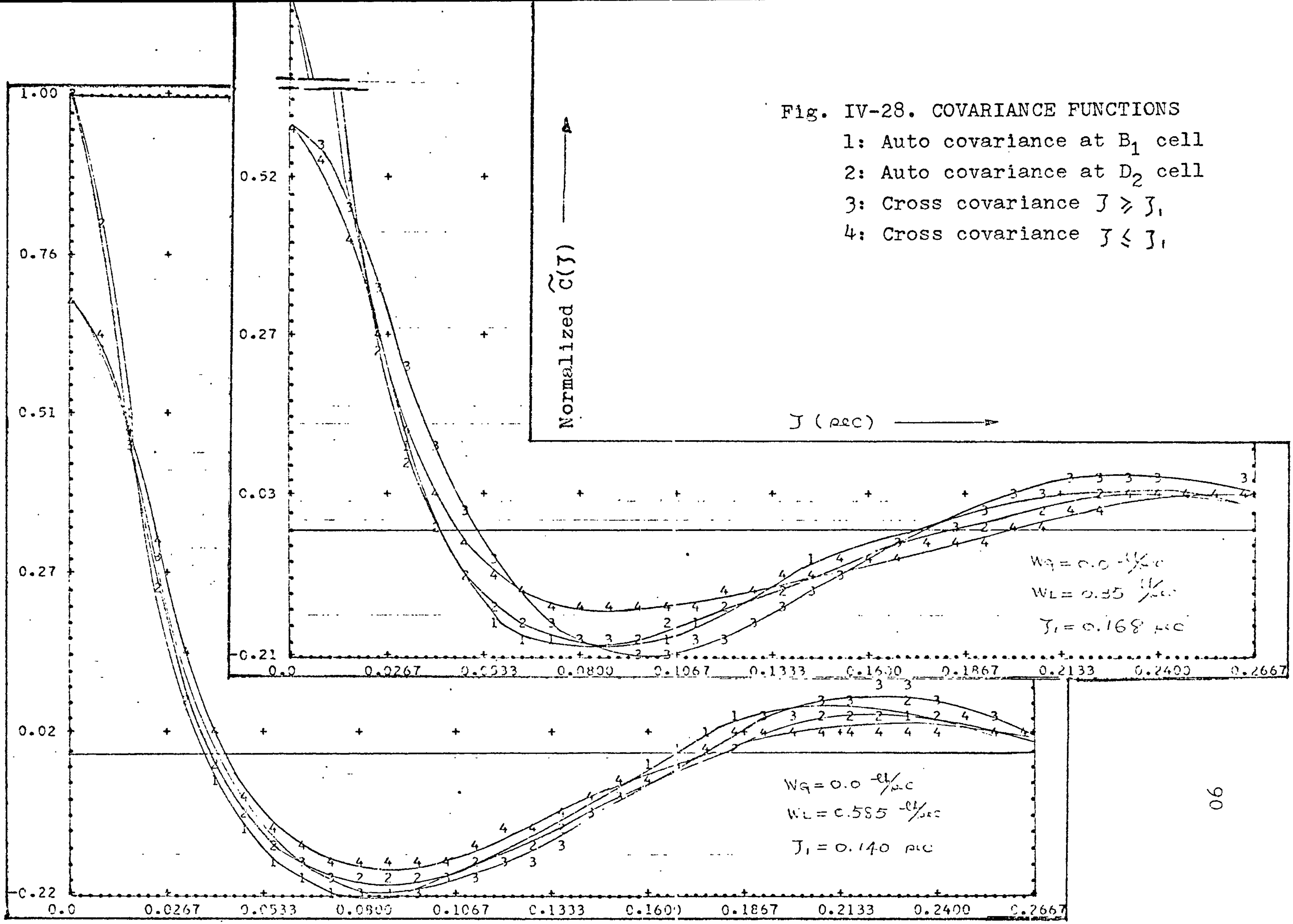


Fig. IV-28. COVARIANCE FUNCTIONS

1: Auto covariance at B_1 cell

2: Auto covariance at D_2 cell

3: Cross covariance $\tau \geq \tau_1$

4: Cross covariance $\tau \leq \tau_1$

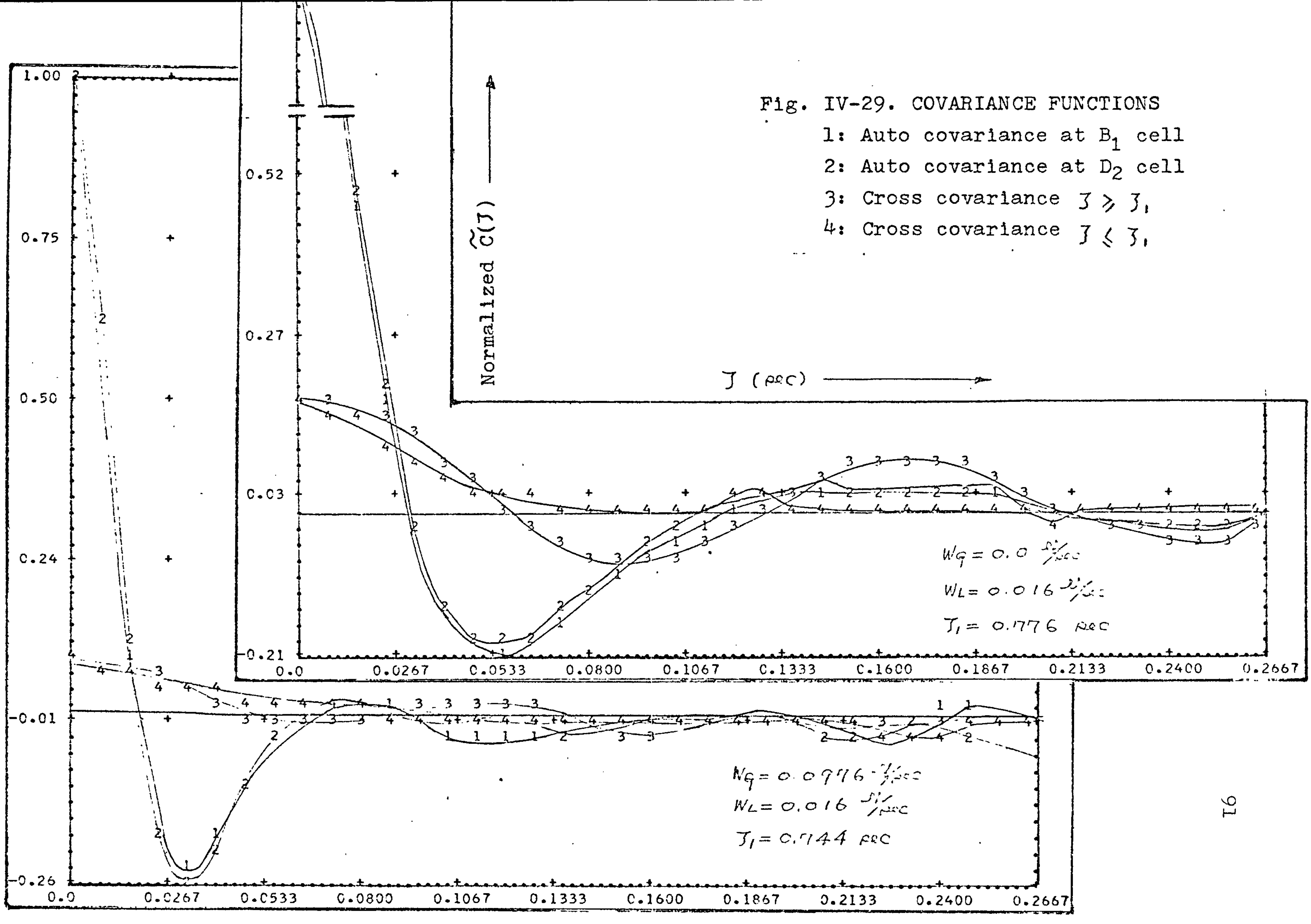


Fig. IV-29. COVARIANCE FUNCTIONS
1: Auto covariance at B_1 cell
2: Auto covariance at D_2 cell
3: Cross covariance $\mathfrak{J} \geqslant \mathfrak{J}_1$
4: Cross covariance $\mathfrak{J} \leqslant \mathfrak{J}_1$

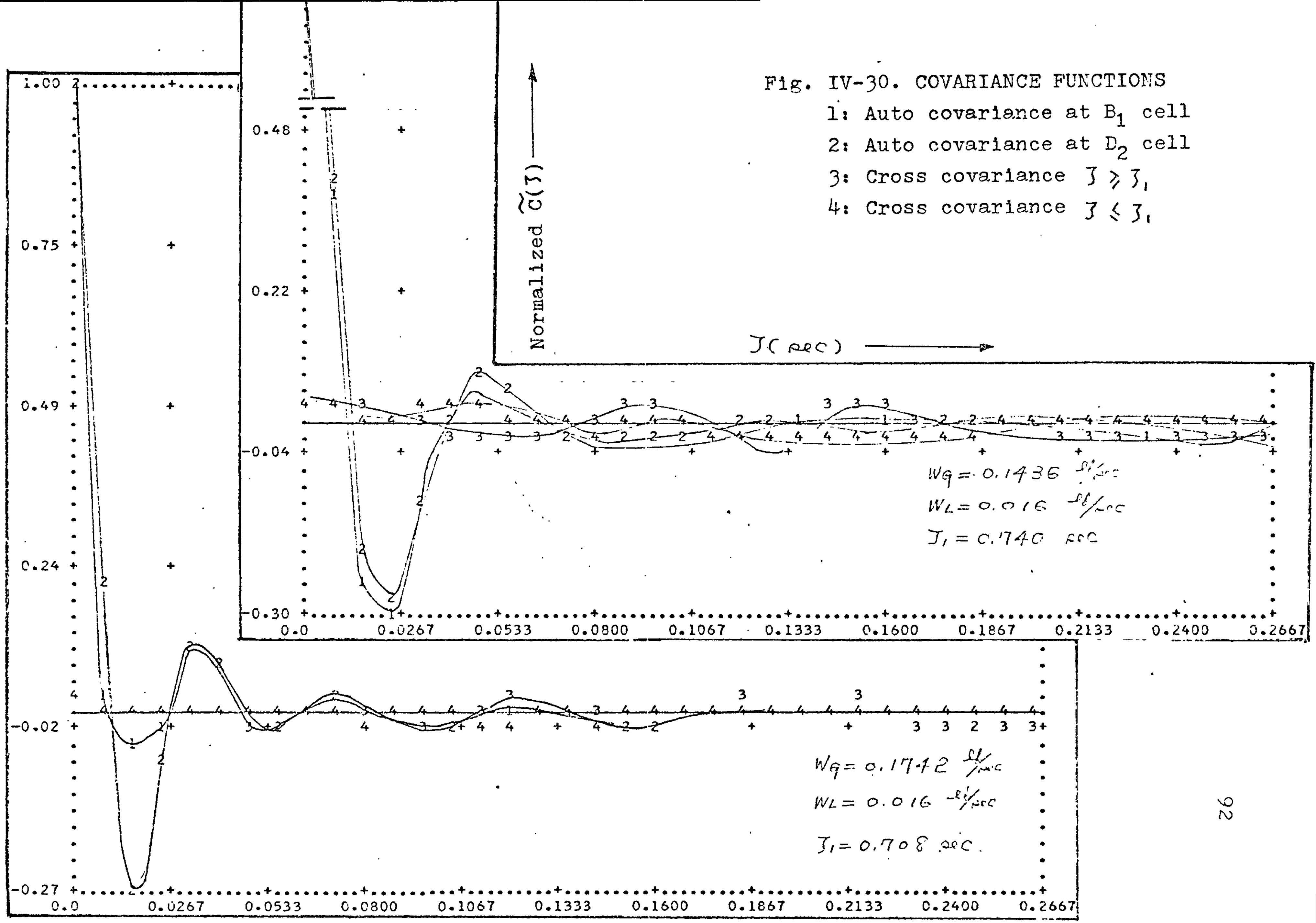


Fig. IV-30. COVARIANCE FUNCTIONS

1: Auto covariance at B_1 cell

2: Auto covariance at D_2 cell

3: Cross covariance $\mathfrak{Z} \geq \mathfrak{Z}_1$

4: Cross covariance $\mathfrak{Z} \leq \mathfrak{Z}_1$

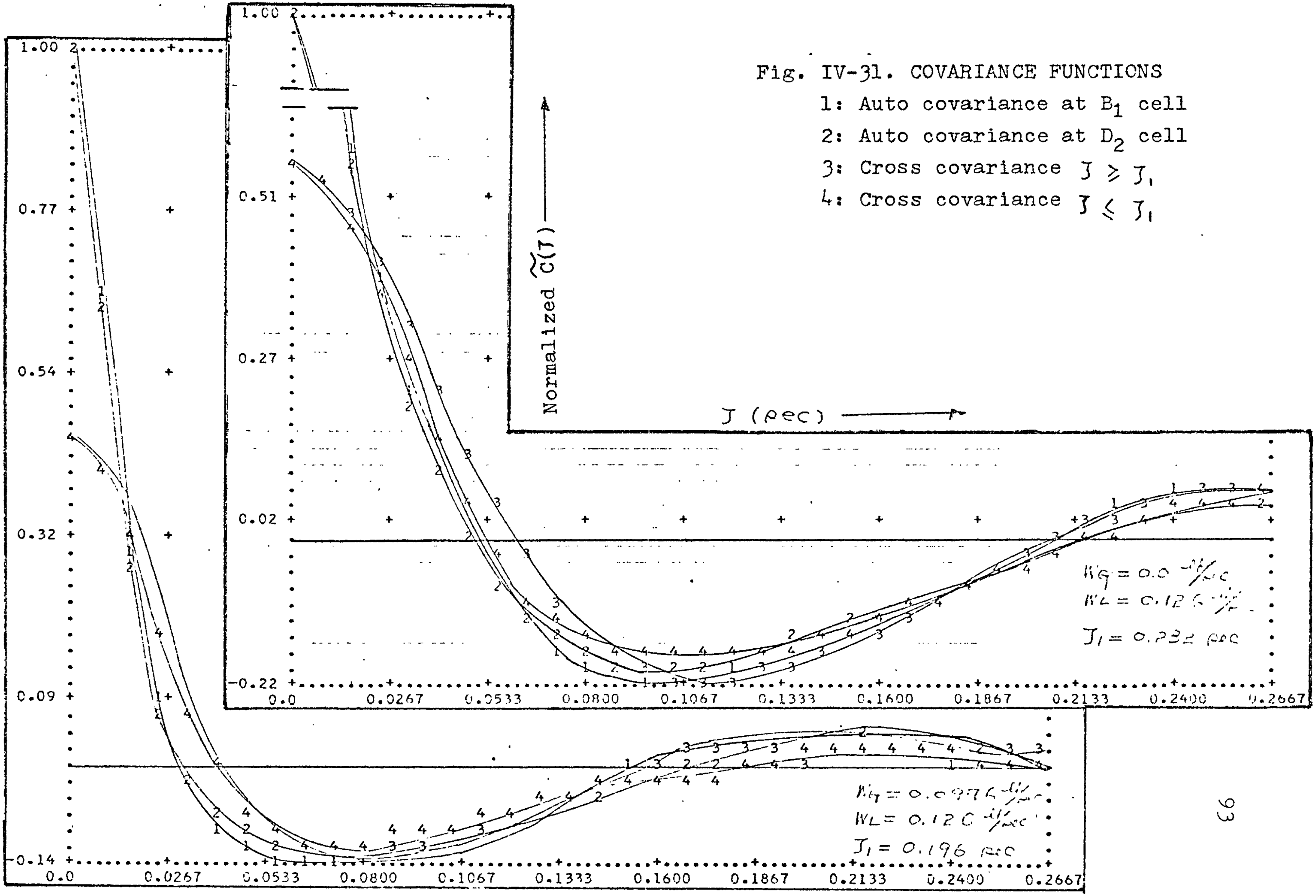


Fig. IV-31. COVARIANCE FUNCTIONS

1: Auto covariance at B_1 cell

2: Auto covariance at D_2 cell

3: Cross covariance $\tau \geq \tau_1$

4: Cross covariance $\tau \leq \tau_1$

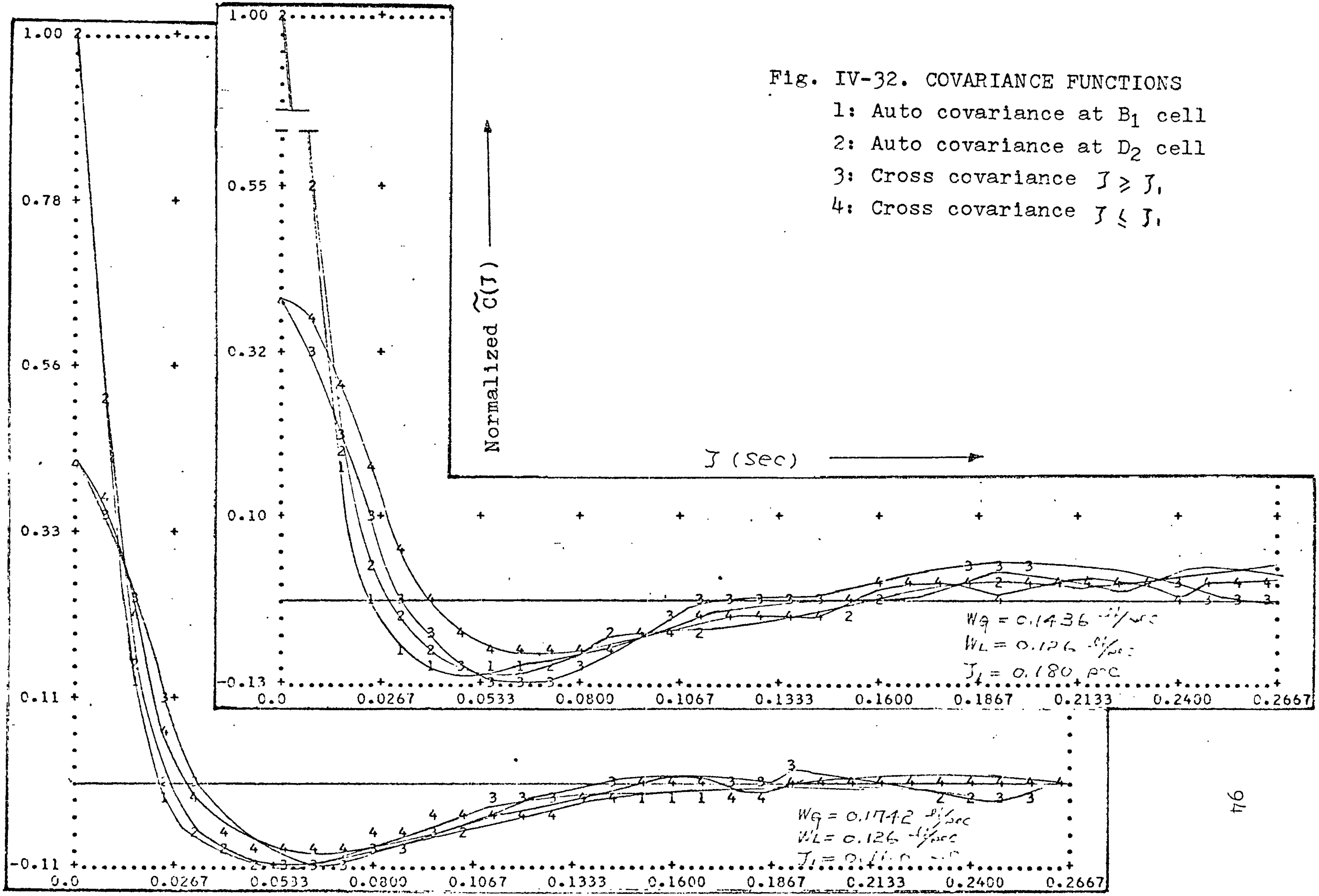


Fig. IV-32. COVARIANCE FUNCTIONS

1: Auto covariance at B_1 cell

2: Auto covariance at D_2 cell

3: Cross covariance $\tau \geq \tau_1$

4: Cross covariance $\tau \leq \tau_1$

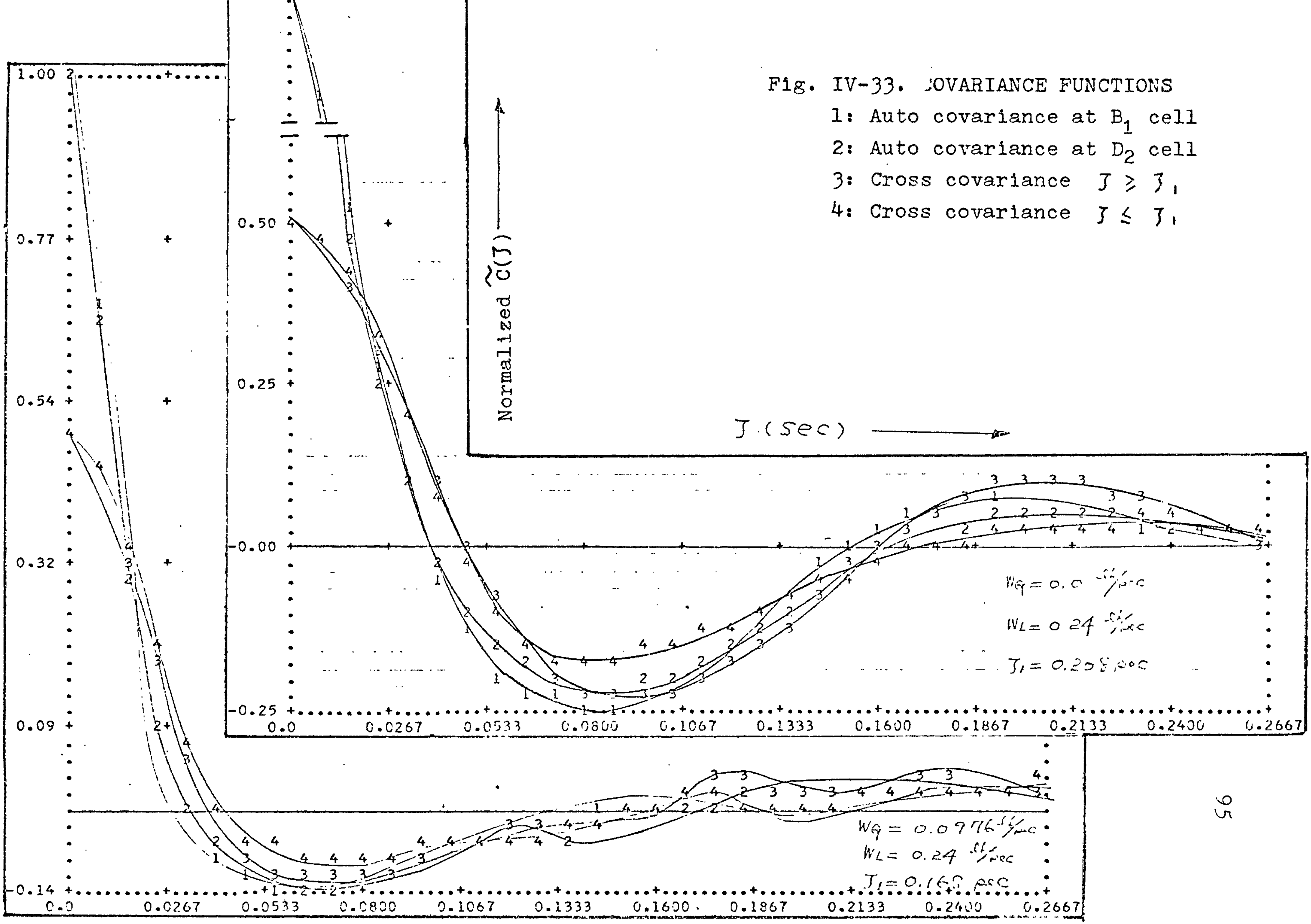


Fig. IV-33. COVARIANCE FUNCTIONS

1: Auto covariance at B_1 cell

2: Auto covariance at D_2 cell

3: Cross covariance $\tau \geq \tau_1$

4: Cross covariance $\tau \leq \tau_1$

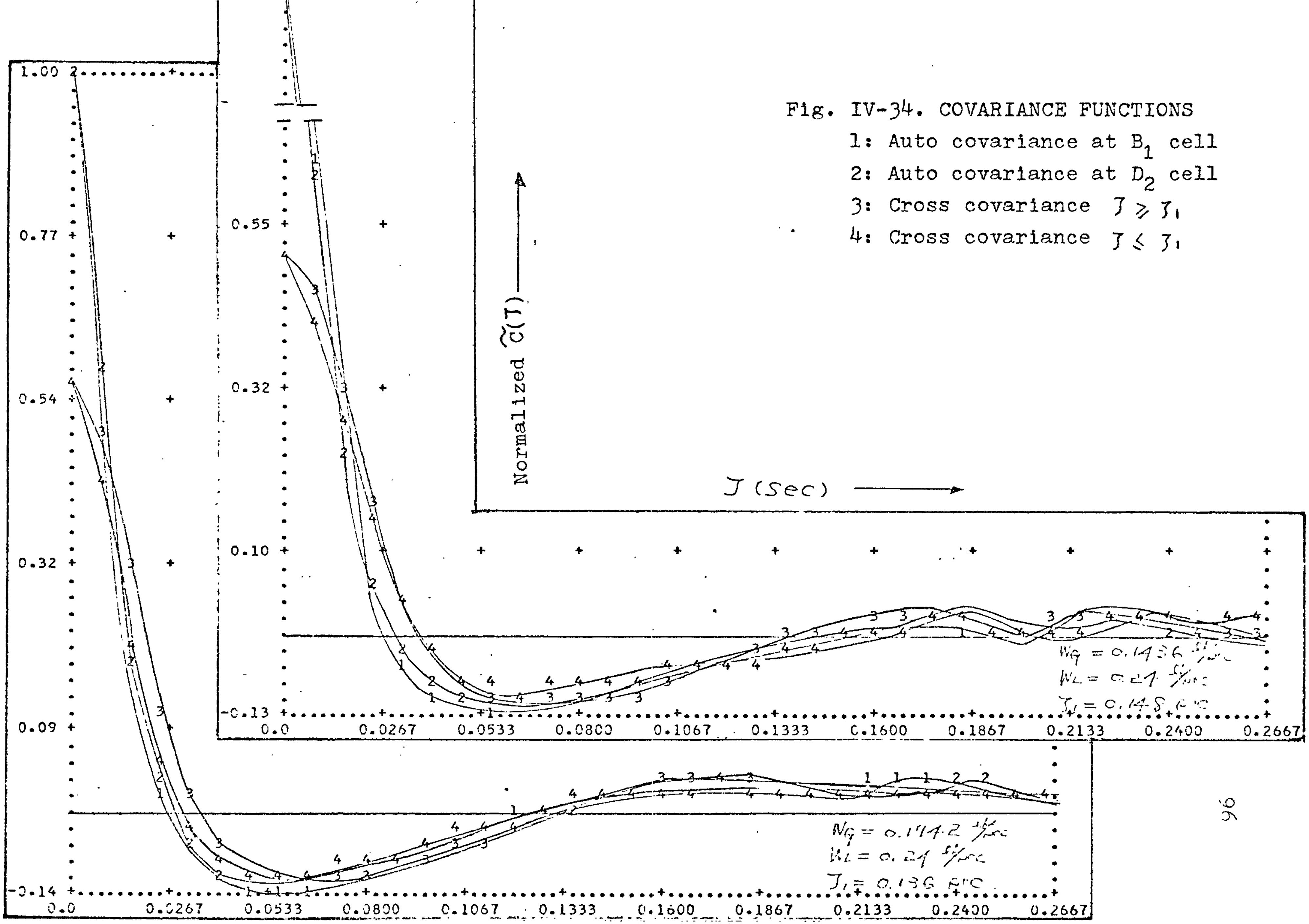


Fig. IV-34. COVARIANCE FUNCTIONS

1: Auto covariance at B_1 cell

2: Auto covariance at D_2 cell

3: Cross covariance $\tau \geq \tau_1$

4: Cross covariance $\tau \leq \tau_1$

Observing from those function, one can see the following facts:

(a) Time lag from origin to secondary peak of the auto-covariance,which is related to the period of the periodical process, first increases with liquid rate than decreases with the liquid rate. There is a transition region around W_L=0.044 which shows a very small secondary peak.

(b) The amplitude of the main peak of cross-covariance $\tilde{C}_{12}(\tau_1)$ increases with liquid flow rate. Its shape is almost identical with that of auto-covariance except in the neighborhood of zero time lag and small liquid rates. This suggests that the shape of the individual large wave is almost unchanged from B_1 to D_2 station except in the region of small liquid rates, and the shape of small wave changes from B_1 to D_2 station.

(c) Cross-covariance $\tilde{C}_{12}(\tau)$ shows some unsymmetrical properties around $\tau = \tau_1$ at which $\tilde{C}_{12}(\tau_1)$ is maximum as shown in previous Fig. IV- 26 (a). This might suggest that a secondary wave moving with different wave velocity exists.

(d) The time lag value τ_1 which is the travel time between two stations for a large wave increases with liquid rate and decreases with gas rate.

(e) The location of the minimum value of auto-covariance, which is related to the width of the large wave, increases and then decreases with the liquid rate.

The detailed discussion of the physical meaning of the above covariance functions will be given later.

6. SPECTRA OF WALL PRESSURE FLUCTUATION AND CROSS - SPECTRA OF WALL PRESSURE AND FILM THICKNESS.

The auto spectral and cross spectral density of wall pressure fluctuations around the mean are calculated in the same way as for film thickness. These results, all normalized by the total power or cross power, are plotted in Fig. IV-35 through Fig. IV-40 along with the film amplitude spectrum. The numerical value and the correlation functions are filed in data book. A vertical line appears on some pairs of data points of the pressure and cross spectrum. This indicates that a strong narrow spectral peak appears at a frequency between these two data points. These spectral spikes are attributed to the low frequency vibration of the system. With the spikes removed the pressure spectral density is similar to that of Telles' measurement and shows a multiple peak structure. A weak correspondence between pressure and film thickness can be observed but a strong correspondence of certain feature of the cross spectrum and film thickness does exist. The most important

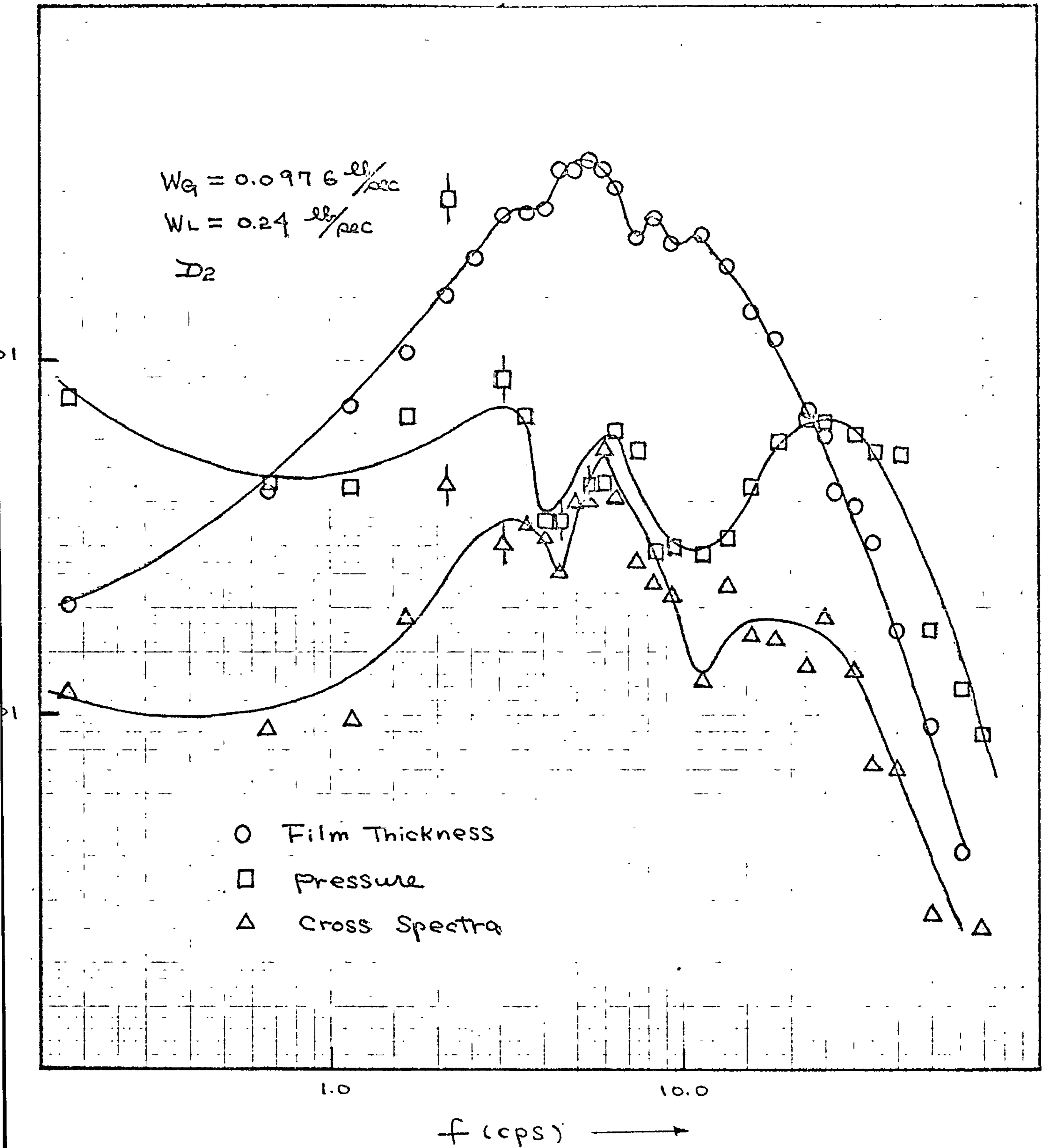


Fig. IV-35. SPECTRA OF PRESSURE FLUCTUATIONS

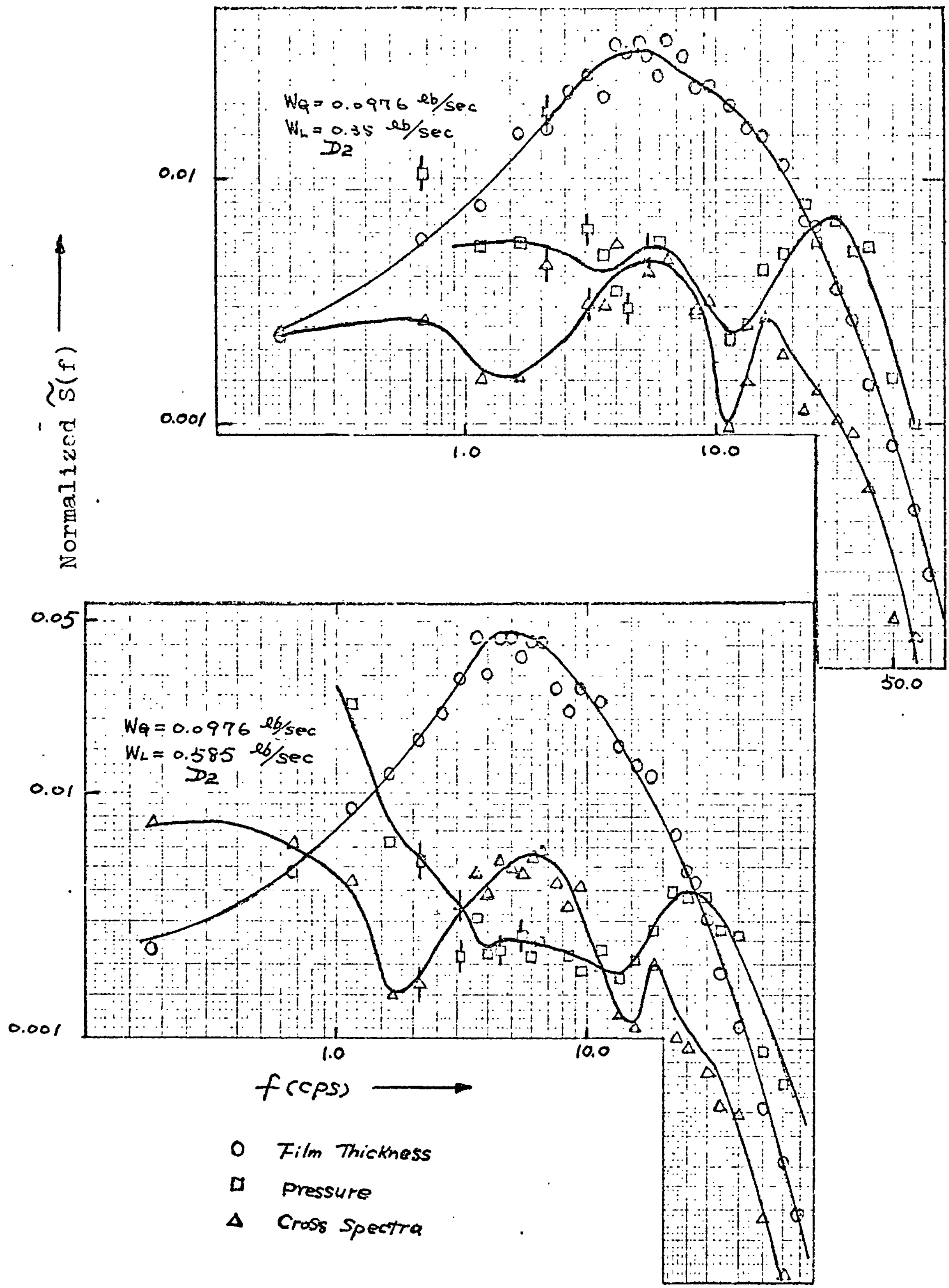


Fig. IV-36. SPECTRA OF PRESSURE FLUCTUATIONS

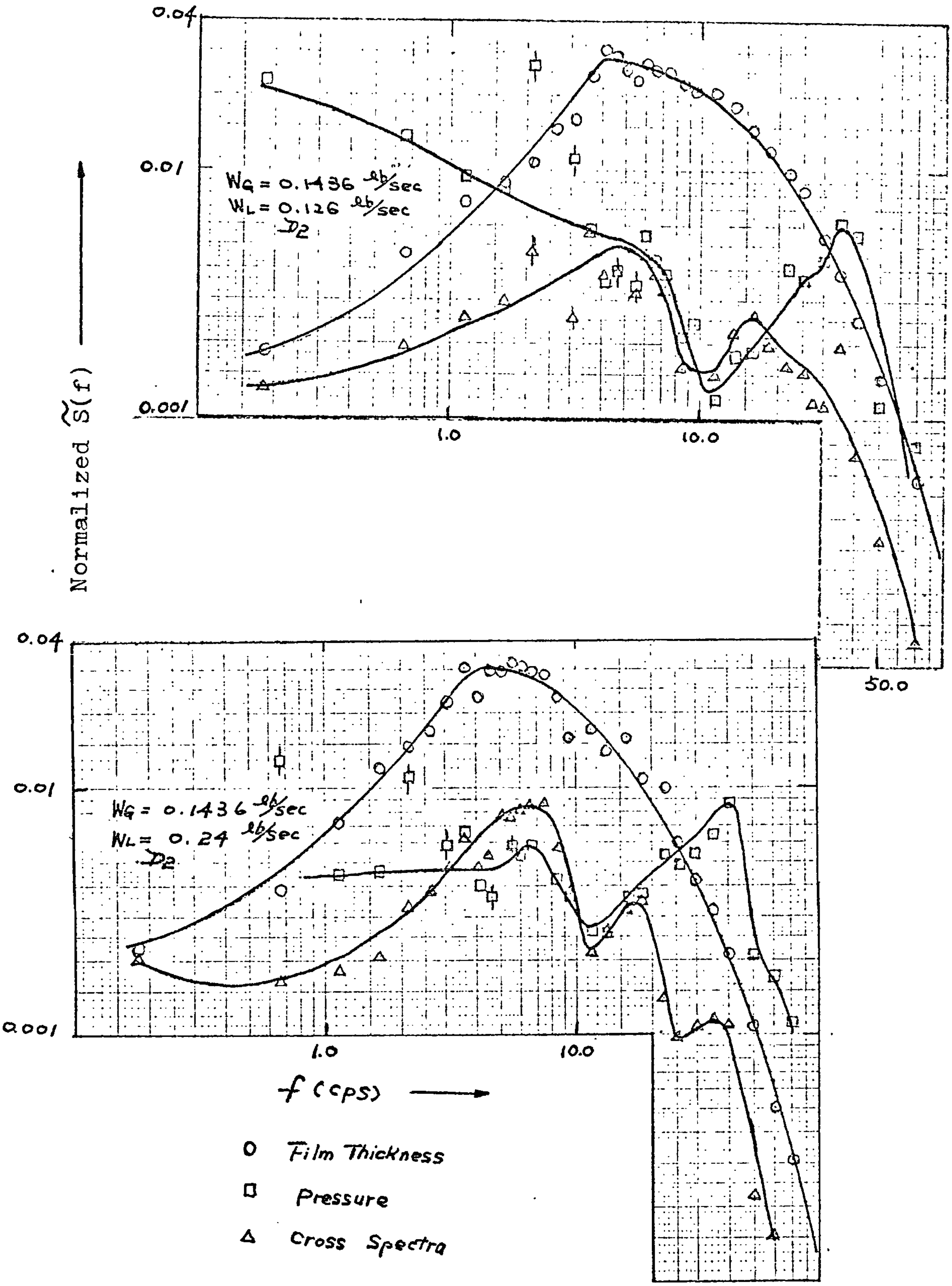


Fig. IV-37. SPECTRA OF PRESSURE FLUCTUATIONS

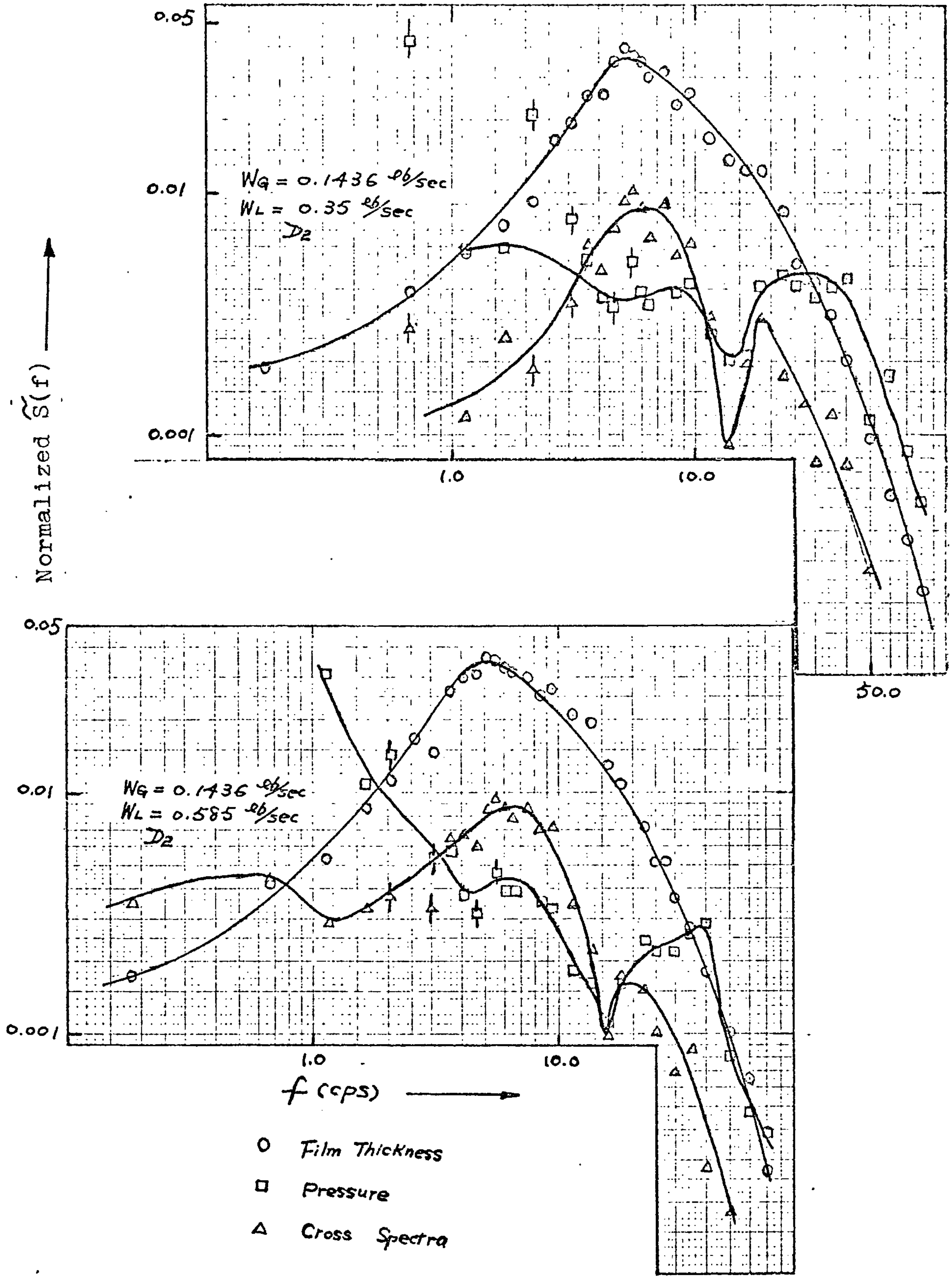


Fig. IV-38. SPECTRA OF PRESSURE FLUCTUATIONS

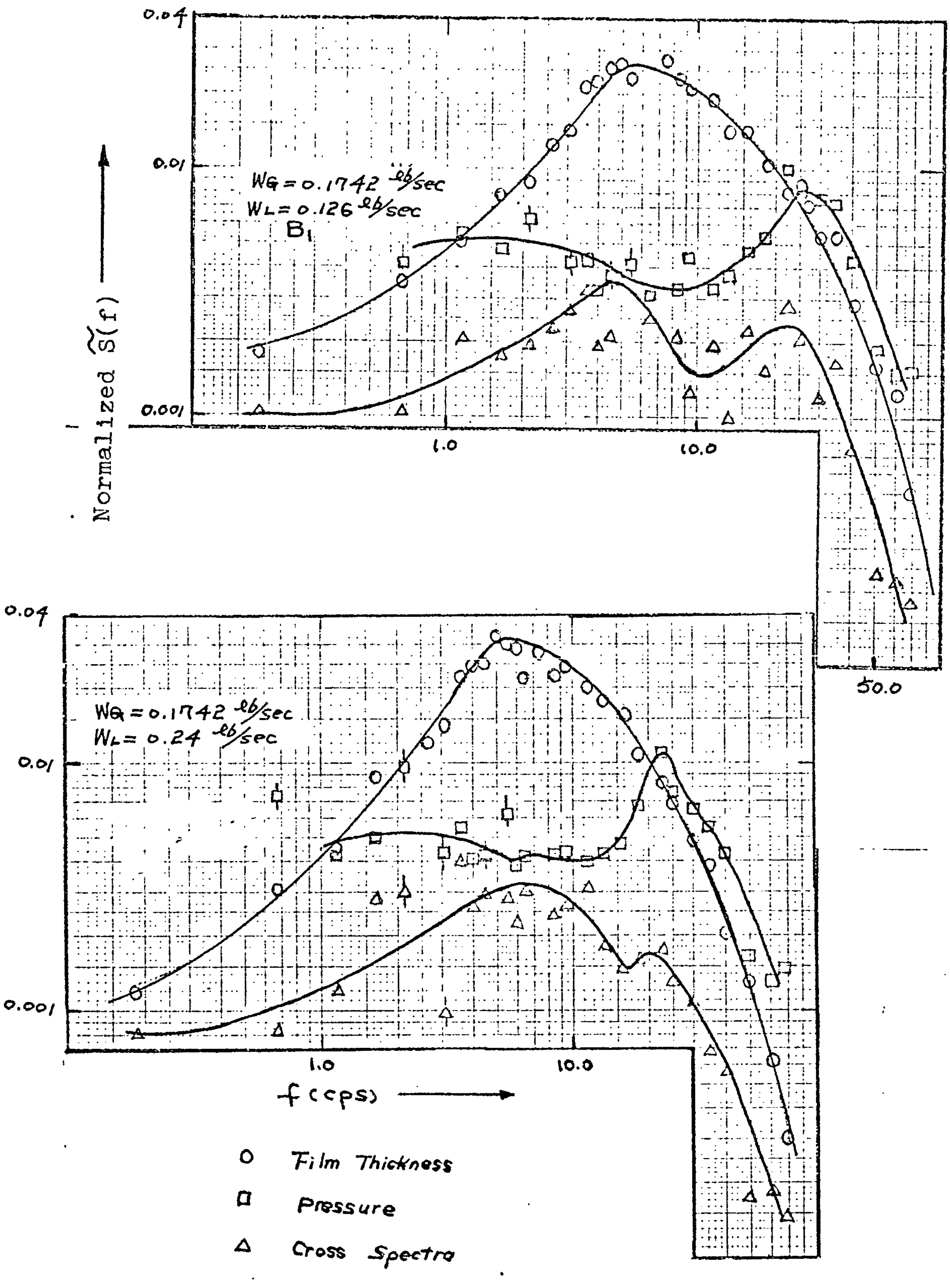


Fig. IV-39. SPECTRA OF PRESSURE FLUCTUATIONS

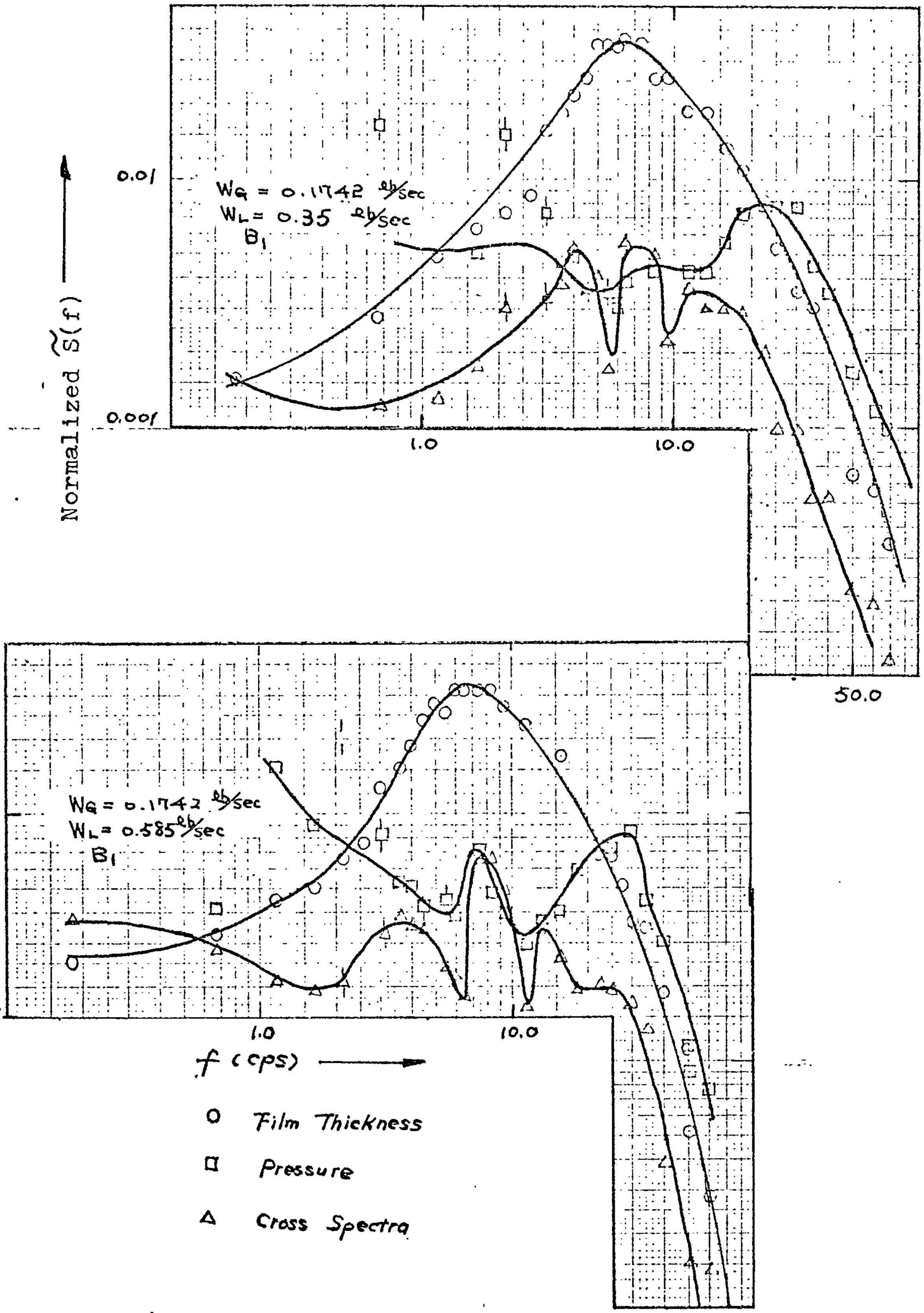


Fig. IV-40. SPECTRA OF PRESSURE FLUCTUATIONS

fact is that there exists a two peak structures in the cross-spectral density function and the main lobe of the cross-spectra corresponds very well to the spectra of film thickness.

CHAPTER V

EXPERIMENTAL DATA: WAVE STRUCTURE

1. INTRODUCTION

This chapter discusses the methods used to process the time series analysis of film thickness to obtain the statistics of the wave motion and presents the basic data to illustrate trends. Full data was filed in the data book. The numerical values of the data used in this chapter appear in Appendix D. An interpretation of these data is undertaken in Chapter VI. All previous measurements which have been reported on wave properties treat waves on falling films as sinusoidal, and such a wave can be completely specified by three parameters: wave amplitude A, and two of the three parameters wave length, λ, wave period, T, and wave velocity, C. But it is now clear that sinusoidal waves never occur on a falling film. The technique used in all previous measurements to obtain sinusoidal wave parameters involved measurements from either photographs or instantaneous trace of film thickness. The results involve large uncertainties. Some typical wave traces obtained in this study are shown in Fig. V-1 and Fig V-2. One can observe the following phenomena:

(a) There are approximately three type of waves: large waves, small wave trains which sit on the substrate,

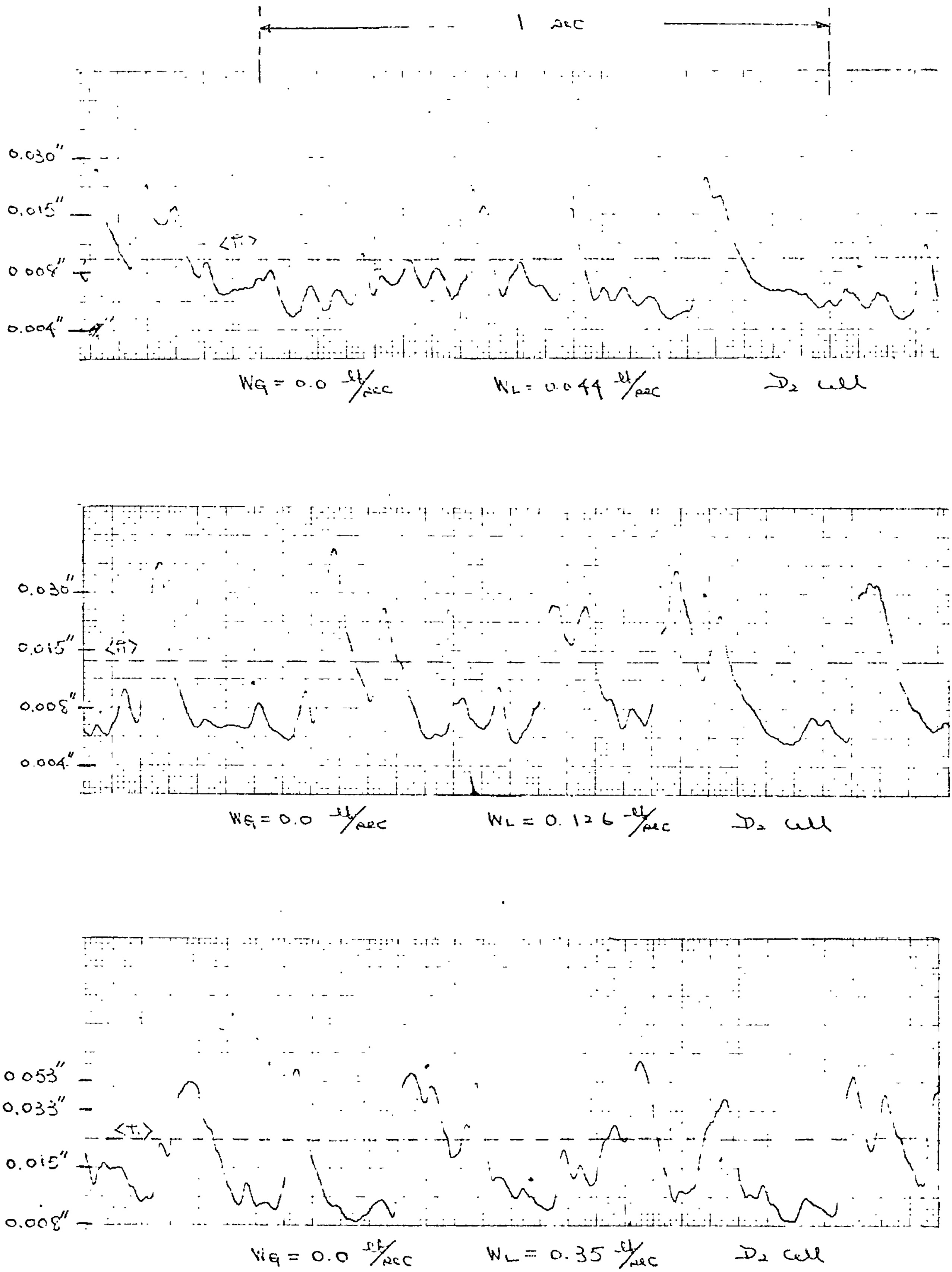


Fig. V-1. TIME TRACES OF WAVE PROFILES

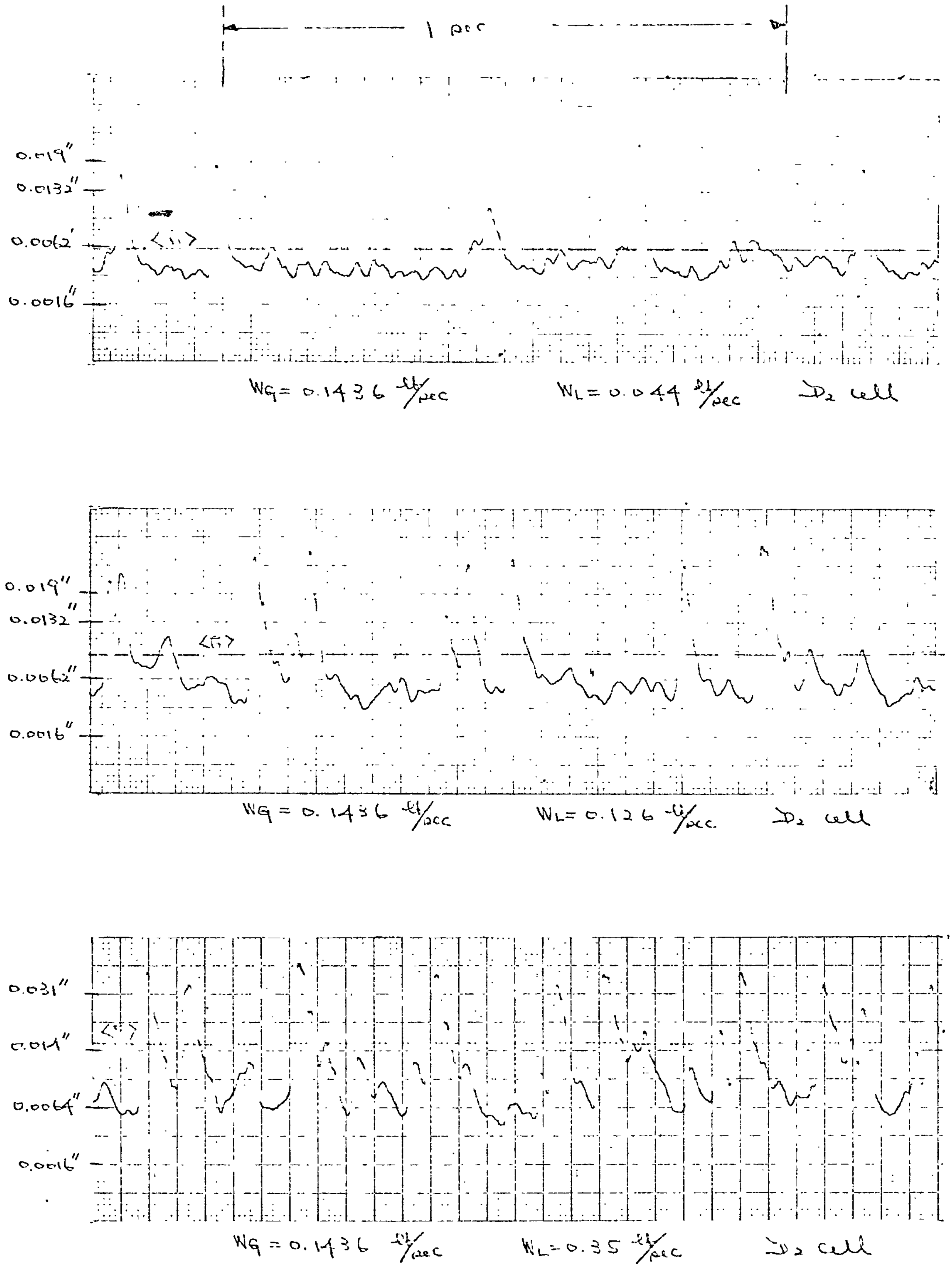


Fig. V-2. TIME TRACES OF WAVE PROFILES

small waves which ride on the large waves.

(b) The wave front is steeper than the wave back.

(c) There is a random nature associated with the wave amplitude and the wave separation between two waves.

In the following section the waves are considered as non-symmetrical and measured in terms of two groups of parameters: one set measured in the time scale to characterize the base dimensiones of the wave and one set measured in length scale to characterize amplitude. A length scale for the base can be obtained as soon as the wave velocity, C, is known and this will be discussed in the next chapter. Since the waves on a falling film are both non sinusoidal and non-periodic, the statistical properties of the wave parameters must be obtained to adequately describe the waves. These data and their development from the time series analysis of film thickness are discusses here.

2. METHOD OF ANALYSIS OF WAVE STRUCTURE

It is the objective of the data processing scheme to extract the statistics of seven parameters describing the random waves: wave amplitude, A, time for passage of base of the wave, T_{bs}, time between successive waves, T_{sep}, time for passage of wave front, T_{fn}, time for passage of back of the wave, T_{bk}, the film thickness at the minimum of the wave, h_{min}, and the film thickness at the maximum of the wave, h_{max}. These terms are defined in the sketch in Fig. V-3. Noting that because the minimum film thickness in front and in back of a waves are not necessary the same, the definition of wave

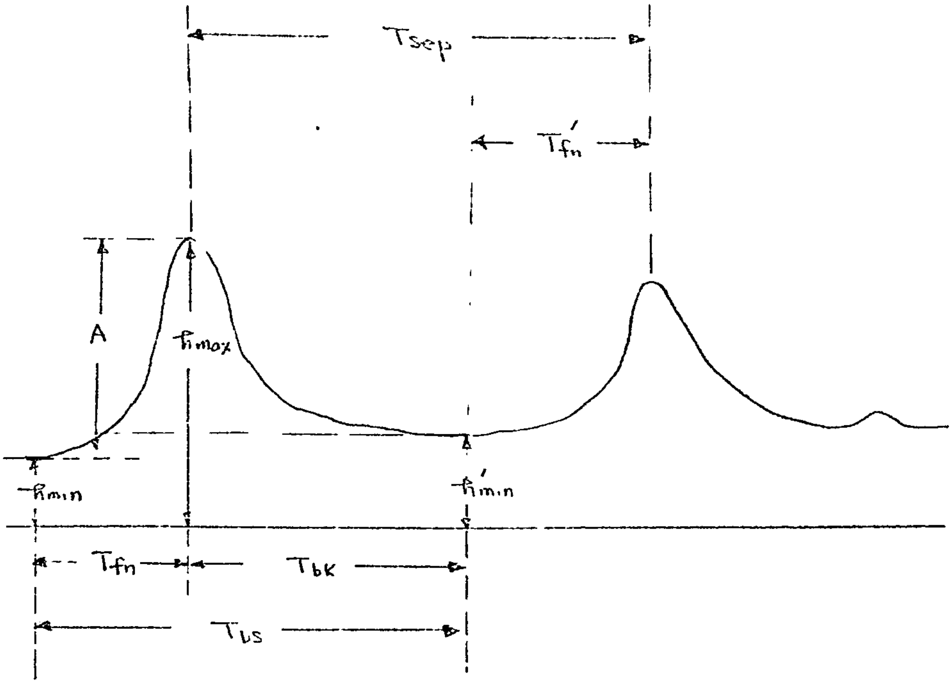


Fig. V-3 WAVE PARAMETERS

amplitude is arbitrarily defined as:

$$A = h_{max} - \frac{(h_{min} + h'_{min})}{2} \quad \text{---} \quad (V-1)$$

The relation among the time scale parameters can be described by

$$T_{bs} = T_{fn} + T_{bk} \quad \text{----------------} \quad (V-2)$$

$$T_{sep} = T_{fn} + T'_{fn} \quad \text{---------------} \quad (V-3)$$

In the subsequent section, it is convenient to call the above seven parameters as, A the wave amplitude, h_{max} the wave maximum, h_{min} the wave minimum, T_{sep} the wave separation, T_{bs} the wave base, T_{fn} the wave front, and T_{bk} the wave back.

The existence of a small and a separate large wave is discussed above. Because the physics controlling each of these typesare likely to be quite different, it is important to calculate the statistics of each type separately so that models can be built for each class of wave. In order to reach this goal using the digital computer, it is necessary to establish the creteria for identifying small and large waves. The word, "large waves", implies that one see a large fluctuation about the undisturbed level or mean values. Hence it is natural to use a change across the mean film thickness to identify the presence of a large wave. These types of waves are identified with the following creteria (see Fig. V-4)

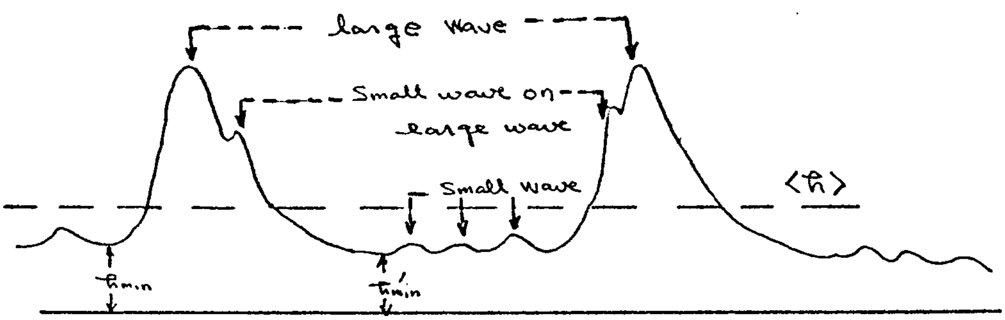


Fig. V-4 IDENTIFICATION OF WAVES

(a) A large wave exists if an excursion in film thickness is found such that $h_{max} > \langle h \rangle$ and $h_{min}, h'_{min} < \langle h \rangle$

(b) A small wave exists on the substrate if for that excursion, $h_{max}, h_{min}, h'_{min} < \langle h \rangle$

(c) A small wave exists on large wave if $h_{max} > \langle h \rangle$ and (i) $h_{min} > \langle h \rangle$, $h'_{min} < \langle h \rangle$

(ii) $h_{min} < \langle h \rangle$, $h'_{min} > \langle h \rangle$

or (iii) $h_{min} > \langle h \rangle$, $h'_{min} > \langle h \rangle$

where h_{min} is wave minimum at front

h'_{min} is wave minumum at back

The calculation of the statistical properties of the above seven parameters are illustrated by the following steps:

(a) Given a time series of film thickness

$h_{(t)} = h_i \quad i=1,---, n$ with time interval Δt

(b) Search for relative maximum and minimum of film thickness by

$h_{min}^{(j)} = h_i$, if $h_{i-1} > h_i < h_{i+1}$

$h_{max}^{(j)} = h_k$, if $h_{k-1} < h_k > h_{k+1}$

$h_{min}^{(j+1)} = h_\ell$, if $h_{\ell-1} > h_\ell < h_{\ell-1}$

where $i < k < \ell$

and calculate the time interval between successive h_{min} and h_{max} by

$T_{fn}^{(j)} = (k-i)\Delta t$

$T_{bk}^{(j)} = (\ell-k)\Delta t$

(c) Repeat the above process to form a sequence

$h_{min}^{(j)}, T_{fn}^{(j)}, h_{max}^{(j)}, T_{bk}^{(j)}, \quad j=1,----,m$

(d) Separate the above sequence into three subsequences by the above criteria given in Fig. V-4 as:

$h_{min}^{(j_1)}, T_{fn}^{(j_1)}, h_{max}^{(j_1)}, T_{bk}^{(j_1)}, j_1= 1,--- m_1$ for small wave

$h_{min}^{(j_2)}, T_{fn}^{(j_2)}, h_{max}^{(j_2)}, T_{bk}^{(j_2)}, j_2=1.--- m_2$ for small wave on large wave

$h_{min}^{(j_3)}, T_{fn}^{(j_3)}, h_{max}^{(j_3)}, T_{bk}^{(j_3)}, j_3=1,---,m_3$ for large wave

(e) Calculate $A^{(j_i)}, T_{bs}^{(j_i)}, T_{sep}^{(j_i)}$ for $j_i=1,---,m_i$ and $i=1,2,3$ by equation (V-1), (V-2) and (V-3). for $i=3$, if there are small waves on substrate between two sucessive large waves then equation (V-3) will be modified as

$$T_{sep}^{(j_3)} = T_{fn}^{(j_3)} + T_{fn}^{(j_3+1)} + \sum_{j_1=\ell}^{k} T_{bs}^{(j_1)}$$

(f) Calculate mean, variance and histogram of the above seven paramters $A^{(j_i)}$, $h_{max}^{(j_i)}$, $h_{min}^{(j_i)}$ $T_{bs}^{(j_i)}$, $T_{sep}^{(j_i)}$, $T_{fn}^{(j_i)}$ and $T_{bk}^{(j_i)}$ for $i=1,2,3$ by the method given in the previous Chapter IV

The computer program to do the above calculation is given in Appendix A.

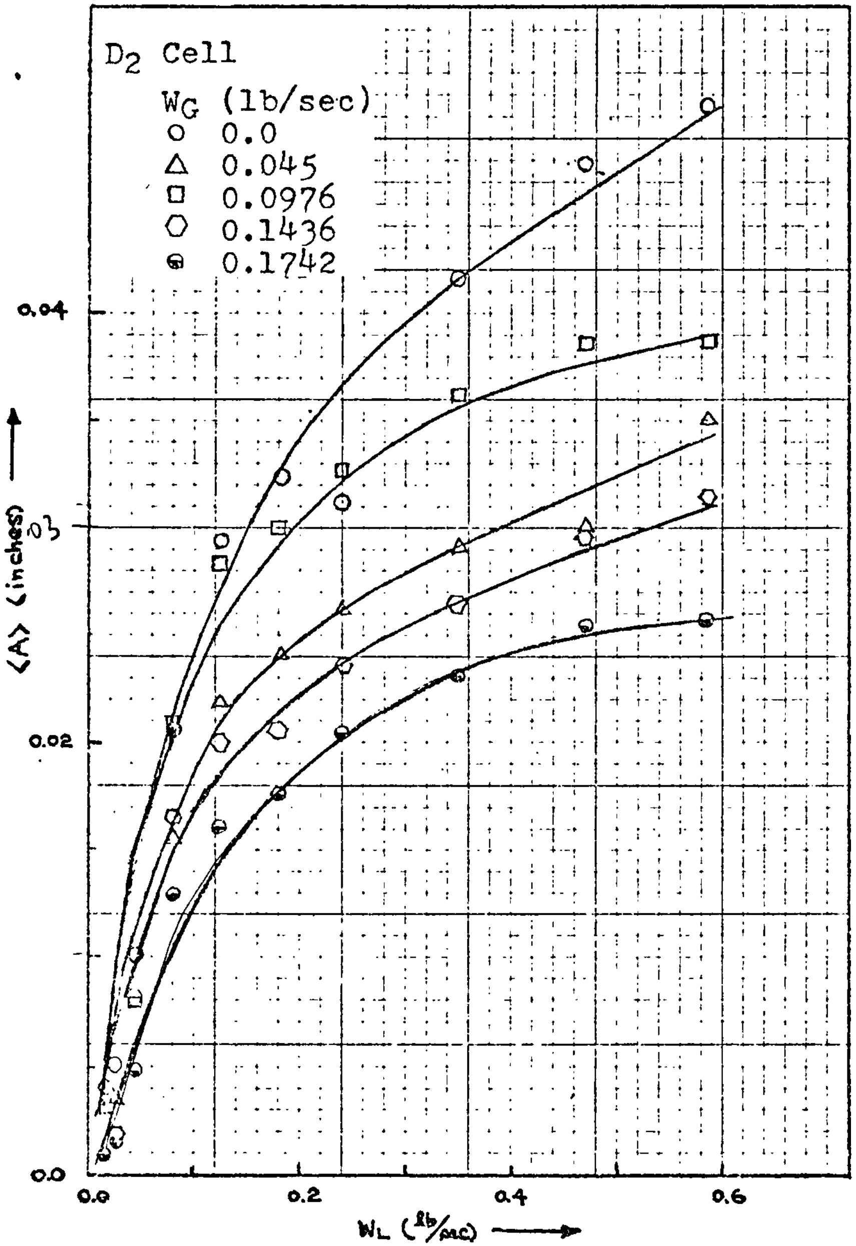
3. STATISTICS OF THE LARGE WAVES

The statistics of the large waves measured at D_2 cell will be presented in graphical form. These statistics are discussed in the following three categories:

3-1 AMPLITUDE DOMAIN

In the amplitude domain, the mean and standard deviation of wave amplitude, wave maximum, and wave minimum of the large waves are given in Fig. V-5, Fig. V-6 and Fig. V-7. The trend of these data indicated that the value of these parameters related to amplitude (A, h_{max}, h_{min}) increase with liquid flow rate and decrease with gas flow rate except the condition at W_G= 0.045 lb/sec. The standard deviation of wave amplitude $\tilde{\sigma}_{amp}$ is roughly equal to the standard deviation of wave maximum $\tilde{\sigma}_{max}$ and the standard deviation of wave minimum $\tilde{\sigma}_{min}$ is much smaller than either of these. This suggests that the substrate height is quite constant. So variation in amplitude must be directly equivalent to variation in wave maximum h_{max}.

The histogram of the above three wave parameters have been calculated. The histogram of wave minimum of the large waves has a narrow band distribution which can be well described by its mean and standard deviation. The histogram of wave maximum of the large waves corresponds well to that of wave amplitude. Hence only the histogram of wave



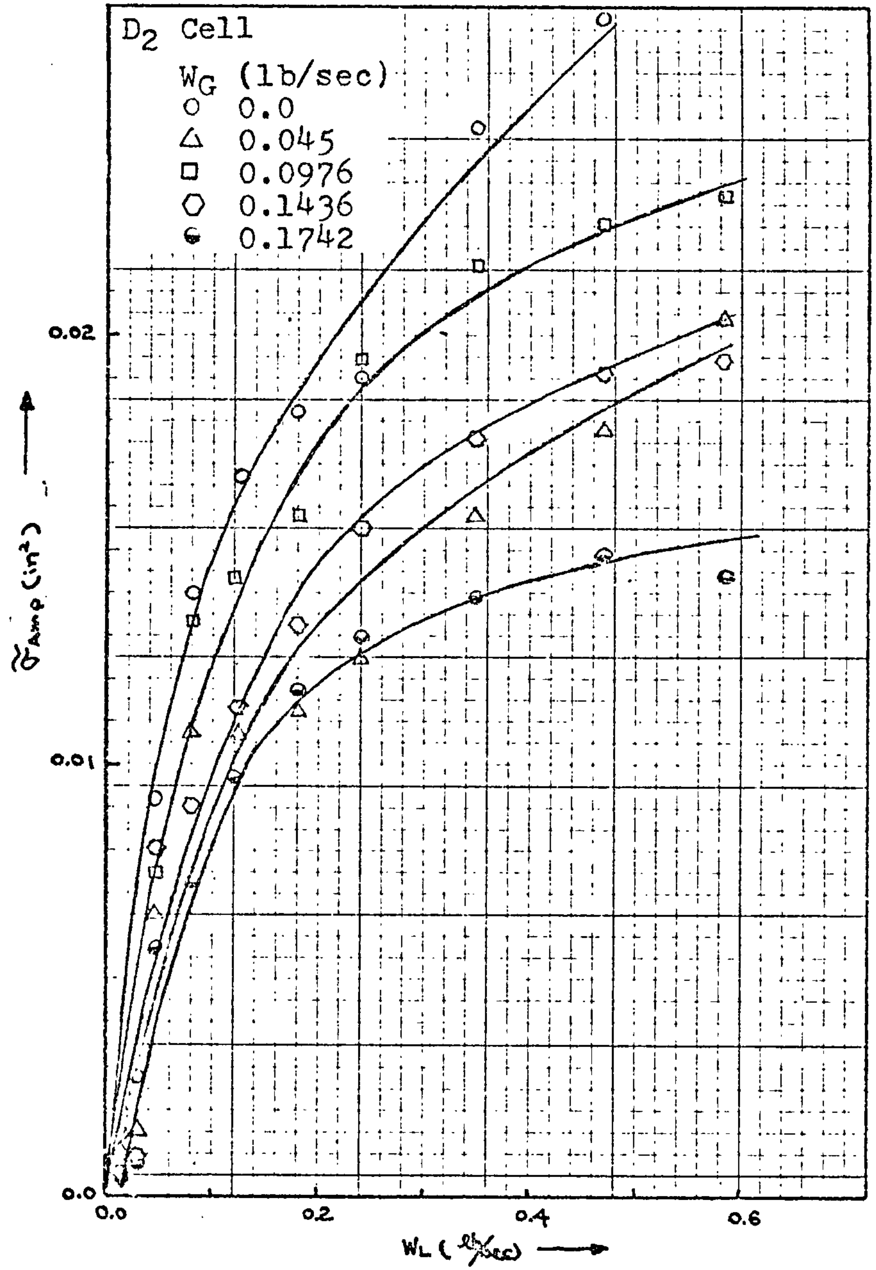


Fig. V-5. THE MEAN AND STANDARD DEVIATION OF WAVE AMPLITUDE OF THE LARGE WAVE

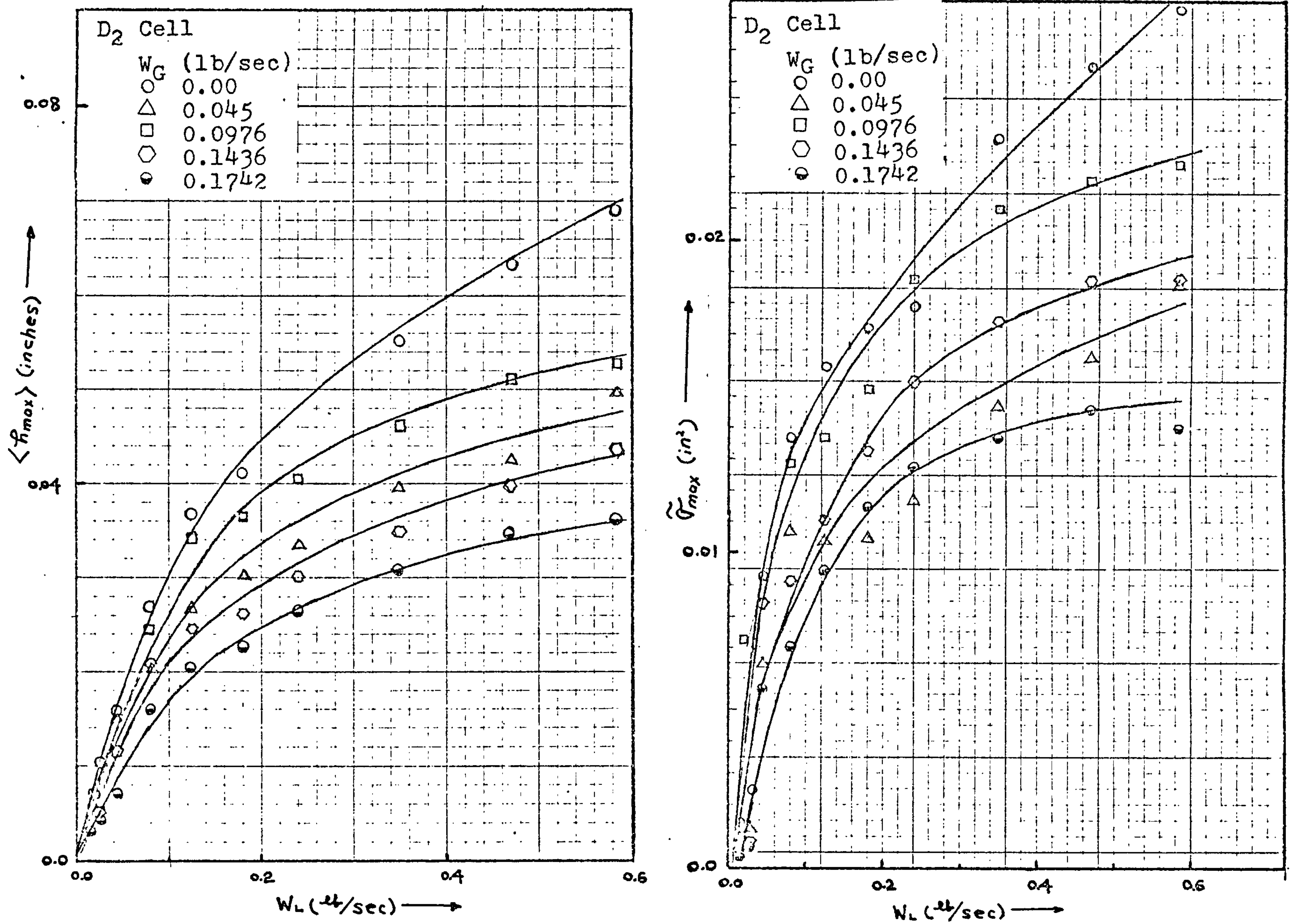


FIG. V-6. THE MEAN AND STANDARD DEVIATION OF WAVE MAXIMUM OF THE LARGE WAVES

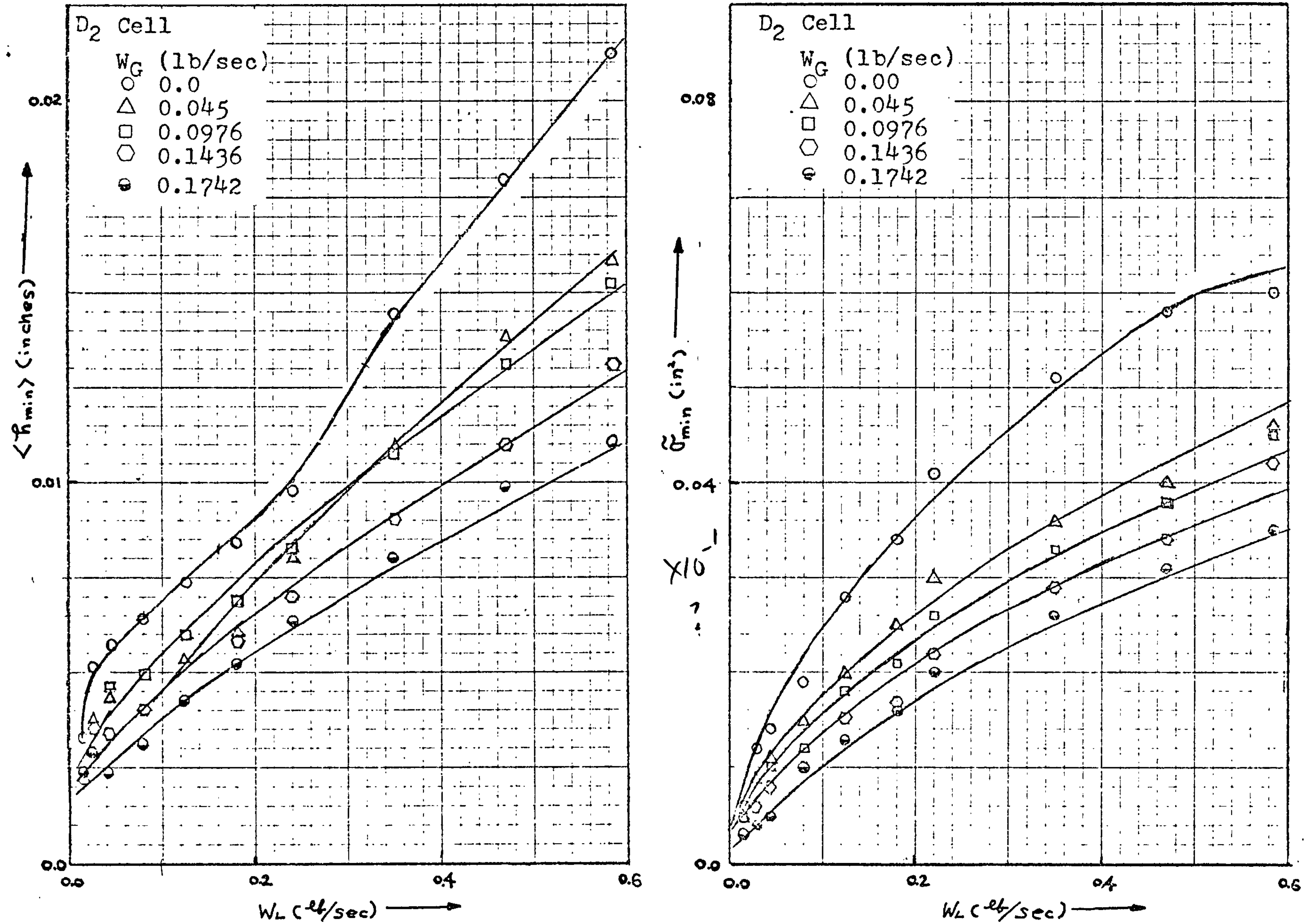


FIG. V-7. THE MEAN AND STANDARD DEVIATION OF WAVE MINIMUM OF THE LARGE WAVES amplitude of the large wave is shown in Fig. V-8 through Fig. V-12. In these graphs, N_L is the total number of the large waves used in the histogram. The general features of these curves for the large wave are as follows: At low liquid rates the amplitude histogram shows a single peak; At intermedate rates there are two very well defined peaks and at still higher rate three characteristic wave size are indicated by three peaks at the histogram. Thus there appears to be three characteristics type of large waves at higher flow rates.

3-2 Time Domain

In the time domain, the mean and standard deviation of wave base and wave separation of the large waves are given in Fig. V-13 and Fig. V-14. The wave front and the wave back are related to the wave base by equation (V-2). The ratio of $\langle T_{bk}\rangle / \langle T_{fn}\rangle$ and the wave frequency which is related to the time scale by equation (V-4), are shown in Fig. V-15.

$$f_\ell = \frac{1}{\langle T_{sep}\rangle} \qquad \text{(V-4)}$$

Where f_ℓ is the wave frequency of the large waves.

The trend of the wave base and the wave separation of the large waves show that the values increase with liquid flow rate up to $W_L \simeq 0.08$ lb/sec then decrease with liquid flow rate. At all liquid rates increasing the gas rate causes these

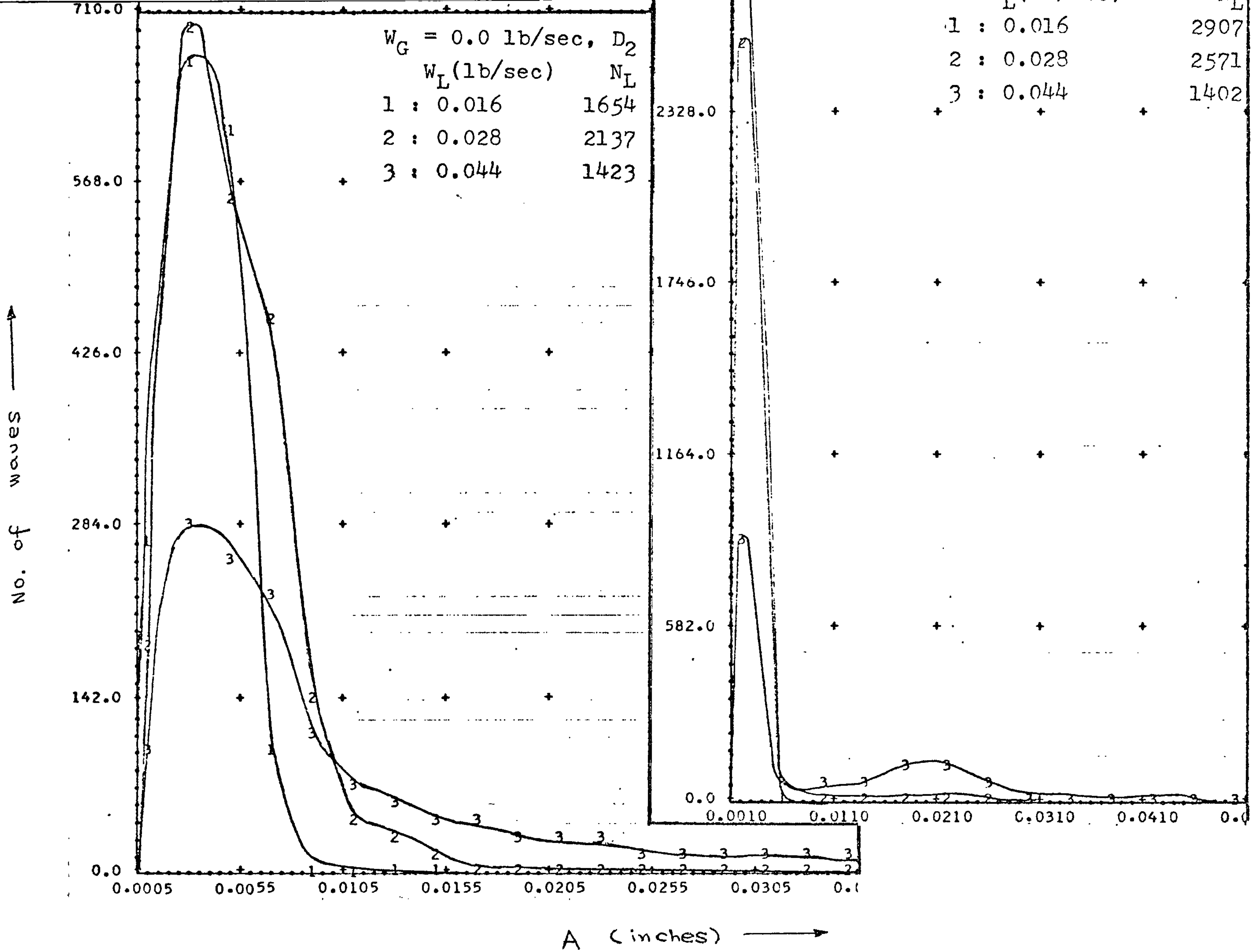


FIG. V-8. HISTOGRAM OF WAVE AMPLITUDE OF THE LARGE WAVES

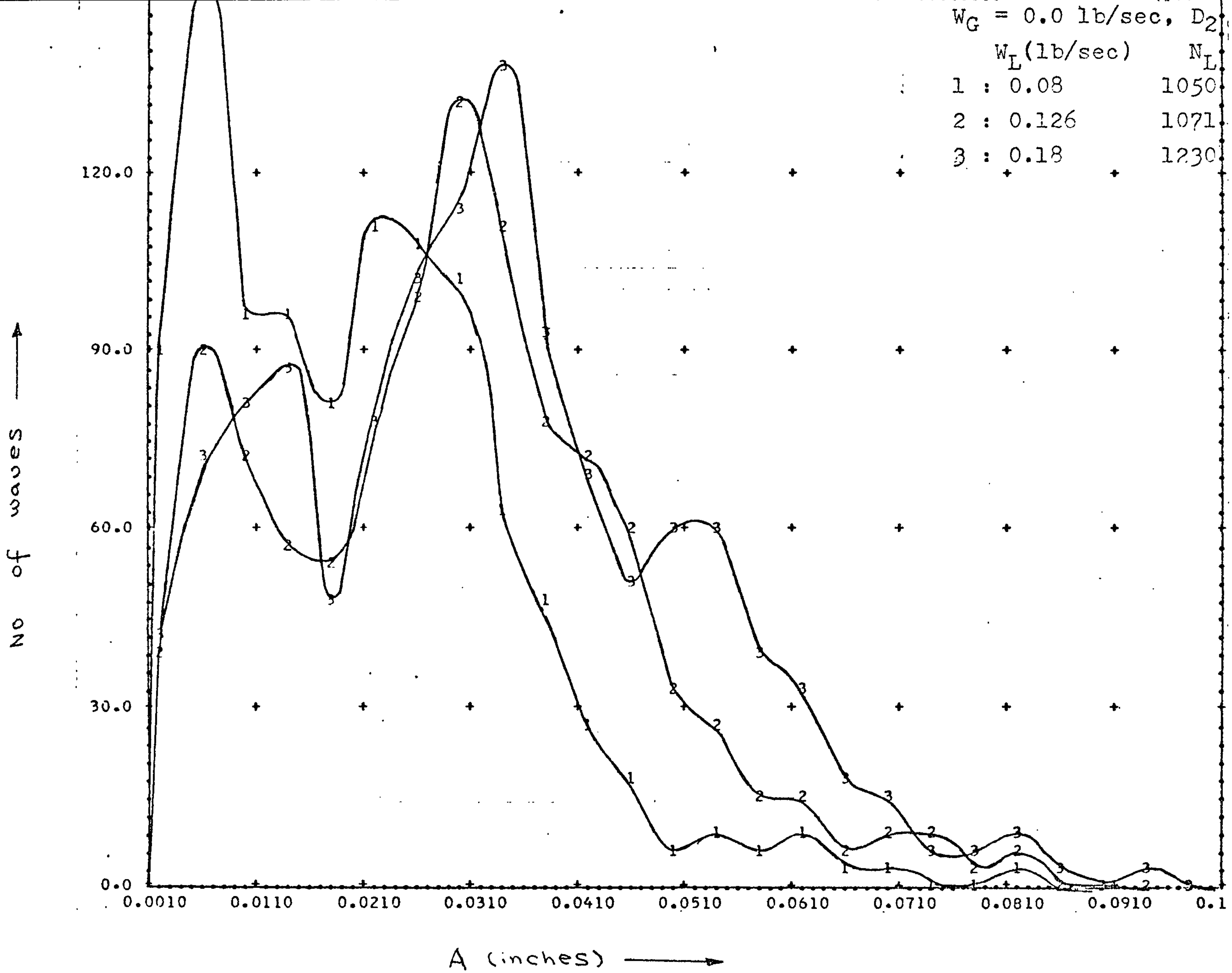


FIG. V-9. HISTOGRAM OF WAVE AMPLITUDE OF THE LARGE WAVES

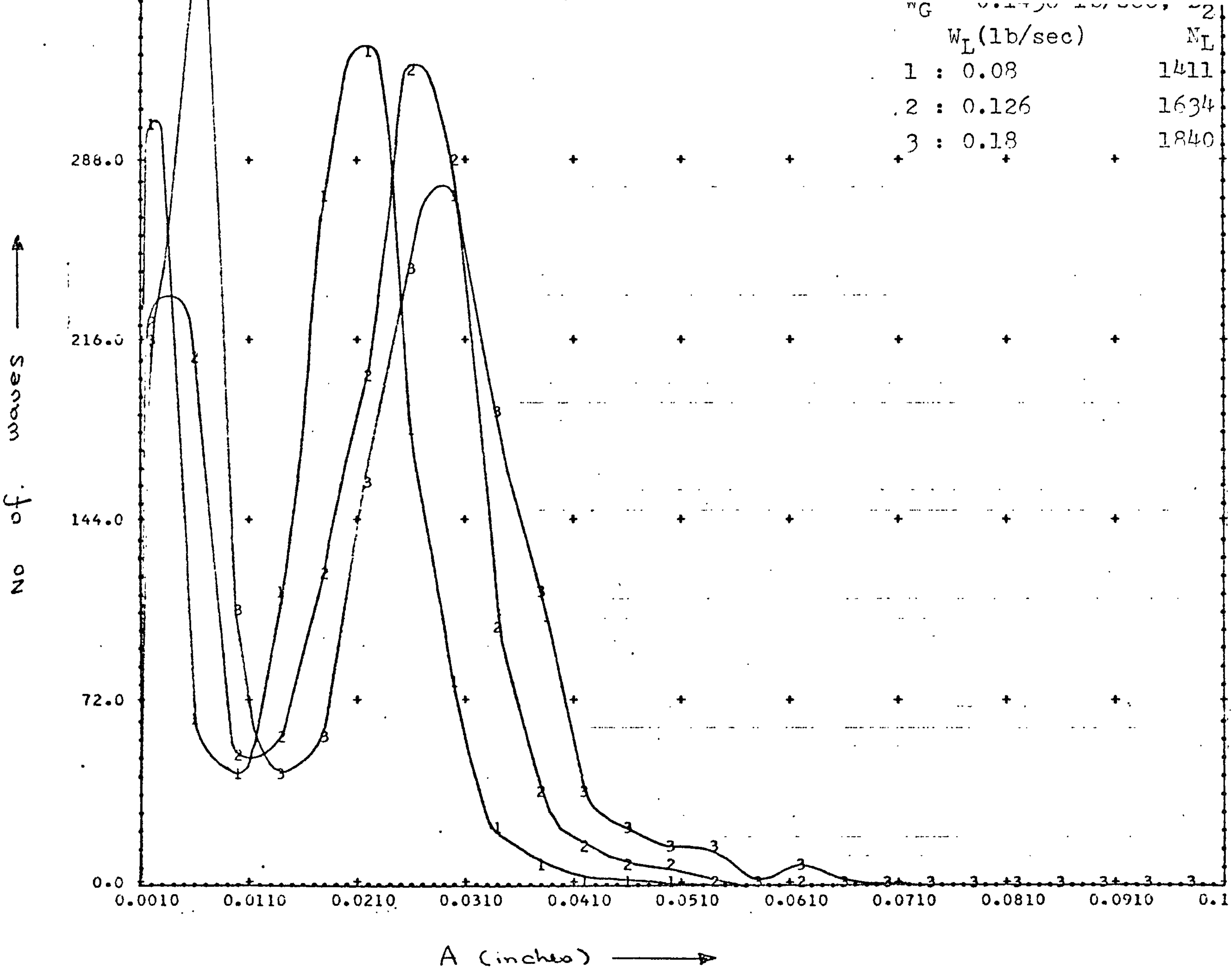


FIG. V-10. HISTOGRAM OF WAVE AMPLITUDE OF THE LARGE WAVES

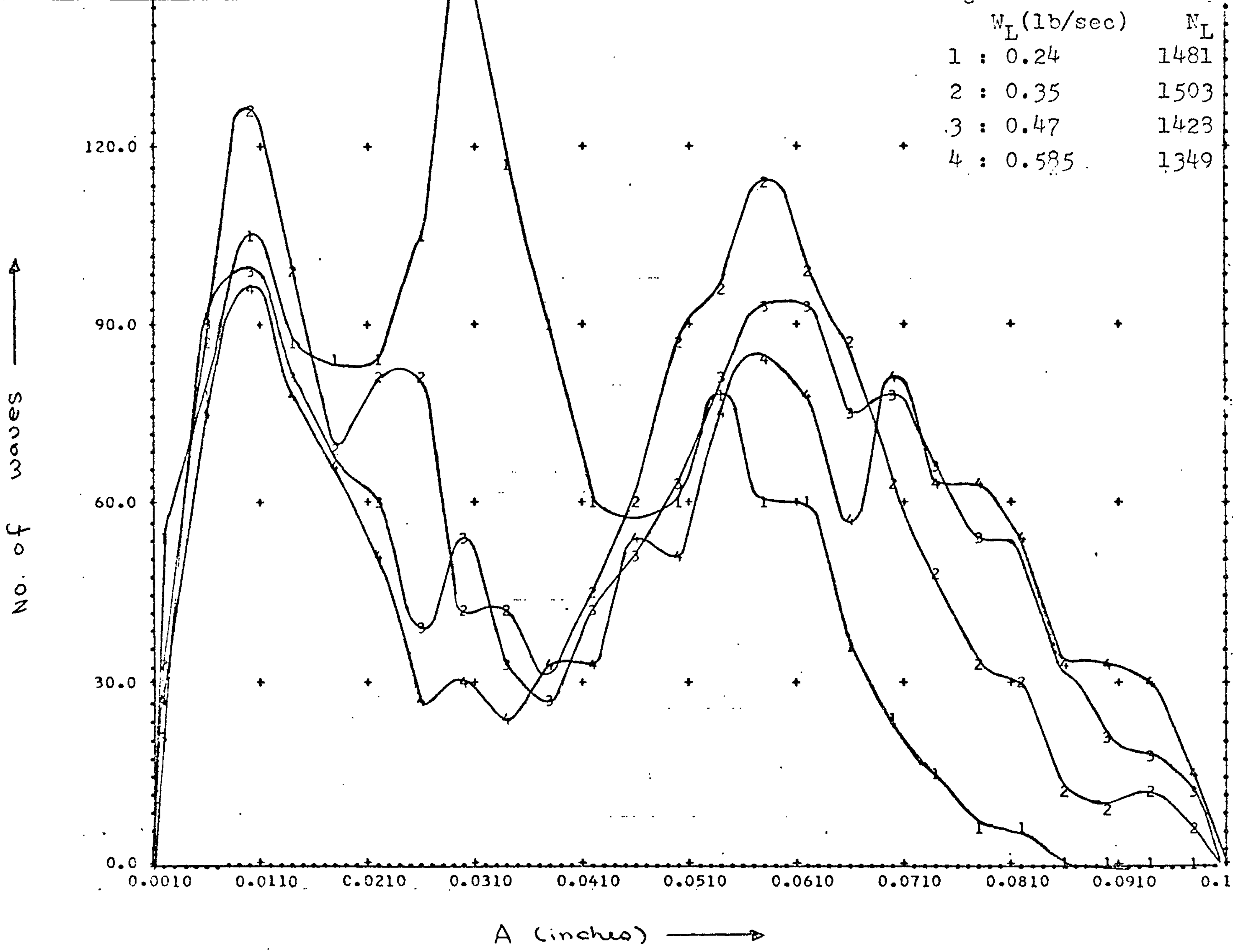


FIG. V-11. HISTOGRAM OF WAVE AMPLITUDE OF THE LARGE WAVES

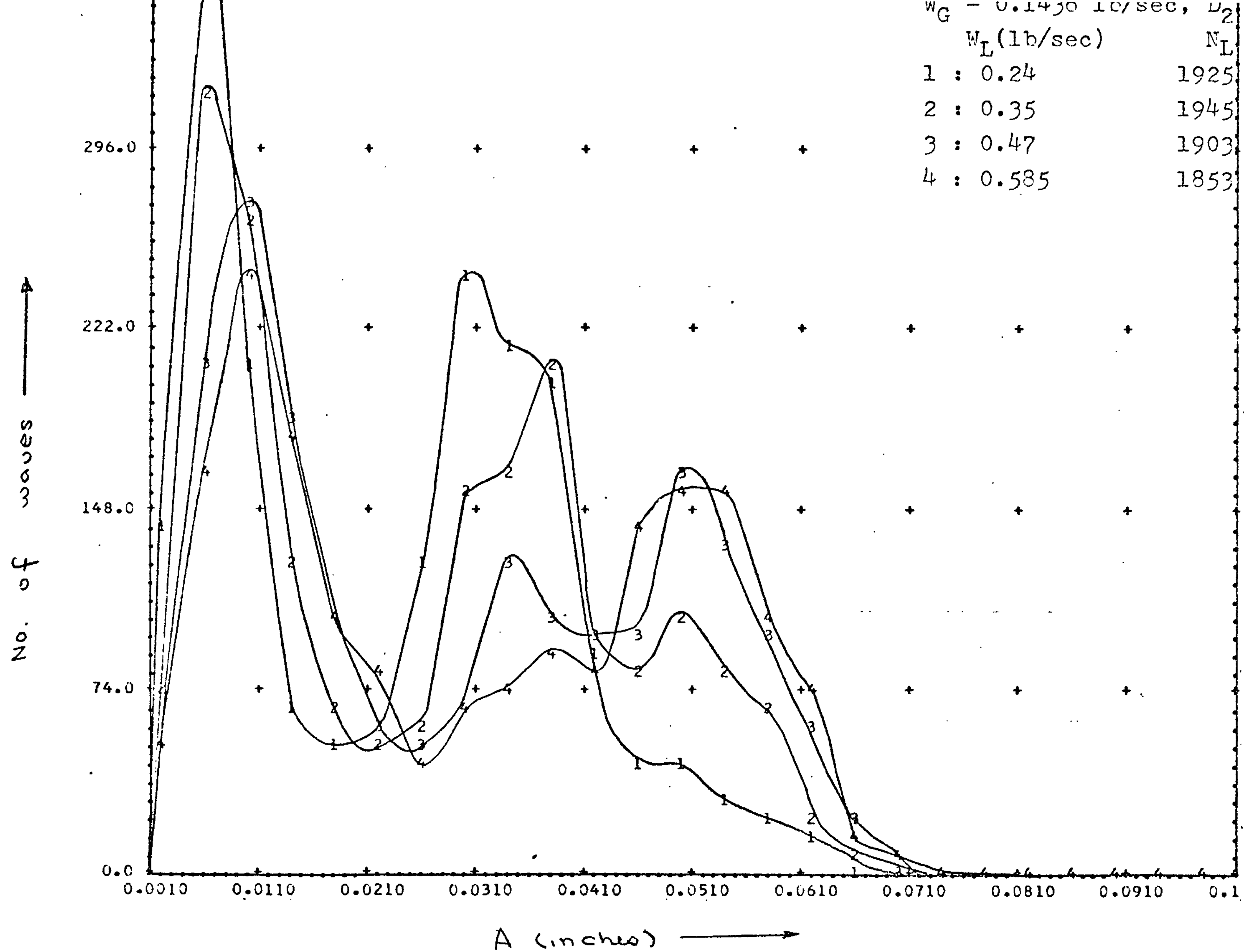


FIG. V-12. HISTOGRAM OF WAVE AMPLITUDE OF THE LARGE WAVES

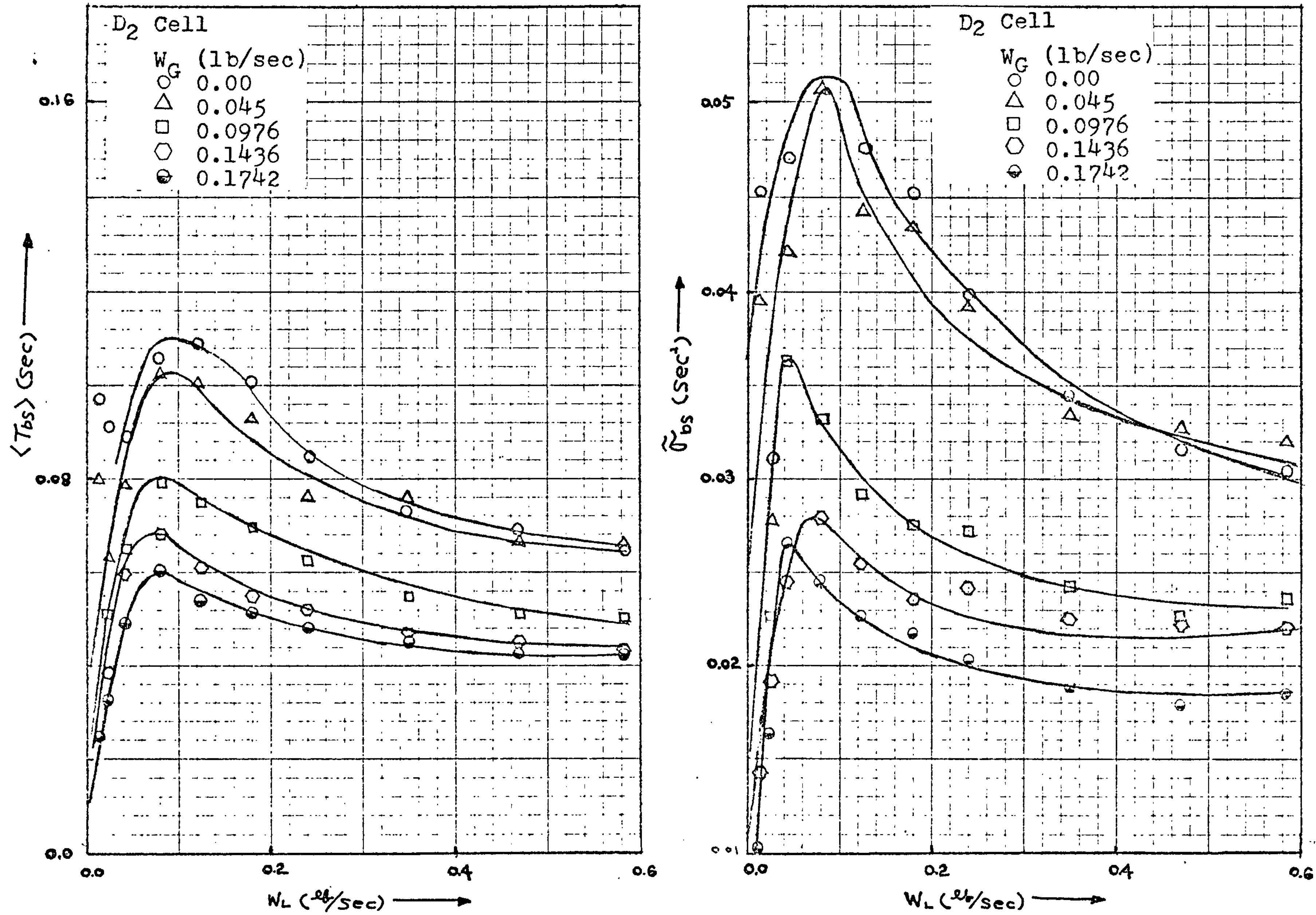


FIG. V-13. THE MEAN AND STANDARD DEVIATION OF WAVE BASE OF THE LARGE WAVES

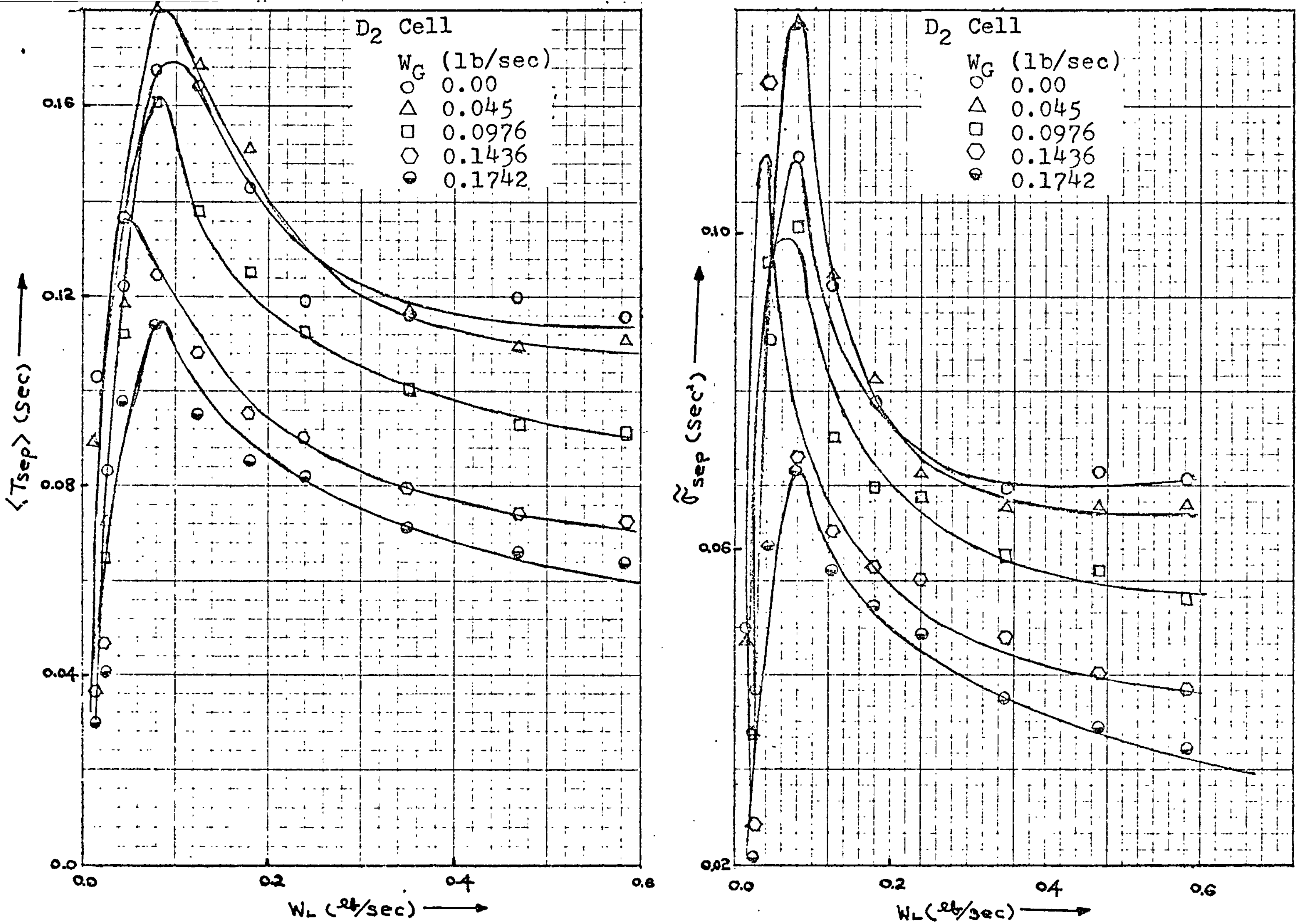


FIG. V-14. THE MEAN AND STANDARD DEVIATION OF WAVE SEPARATION OF THE LARGE WAVES

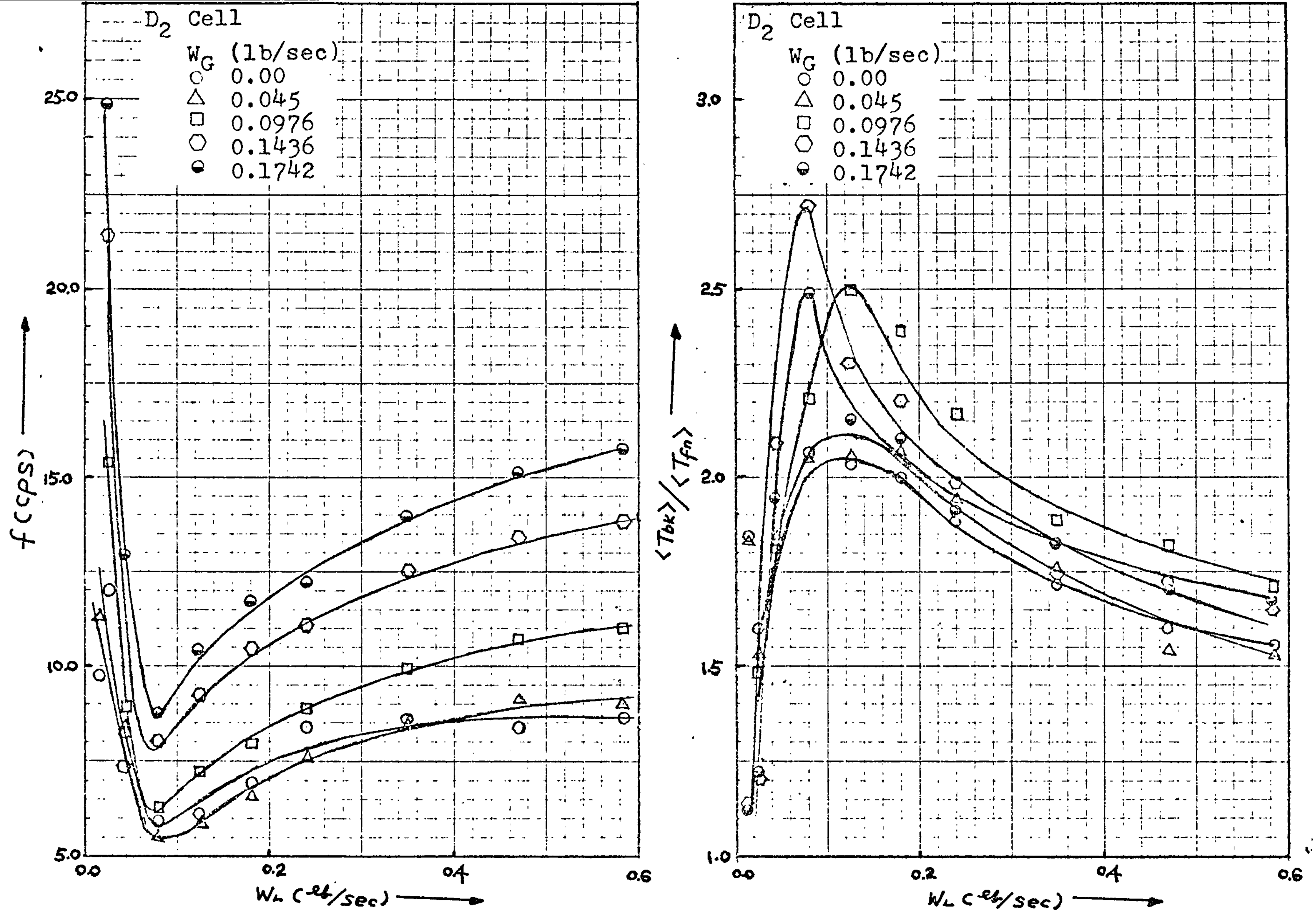


FIG. V-15. THE WAVE FREQUENCY AND $\langle T_{bk}\rangle / \langle T_{fn}\rangle$ OF THE LARGE WAVES parameters to decrease. This suggests an important transition at $W_L \simeq 0.08$ lb/sec and the observation is substantiated by other measurements. The effect of the liquid flow rate on the ratio of $\langle T_{bk} \rangle / \langle T_{fn} \rangle$ is similar and also shows a transition at $W_L \simeq 0.08$ lb/sec, but the effect of the gas flow rate is different. The value of $\langle T_{bk} \rangle / \langle T_{fn} \rangle$ first increases then decreases with gas flow rate. The most important feature of the ratio of $\langle T_{bk} \rangle / \langle T_{fn} \rangle$ is that the large wave rapidly become non-symmetrical as the liquid flow rate increase above very small values.

The histogram of the wave base for the large waves are plotted in Fig. V-16 through Fig V-18. These curves appear to have a single peak unsymmetrical distribution. Considering the fact that we observe several characteristic wave amplitudes, the fact that all these waves have the only one characteristic base time seems remarkable. The histogram of the wave separation of the large waves are shown in Fig. V-19, Fig. V-20 and Fig. V-21. They appear to be of a multiple peak structure with the modal value of the largest peak being independent of liquid rate for each gas rate.

3-3. JOINT HISTOGRAM

In the previous two sections, the detailed structure of the wave parameters of the large waves were explored. Naturally, the next equation is, "what is the statistical

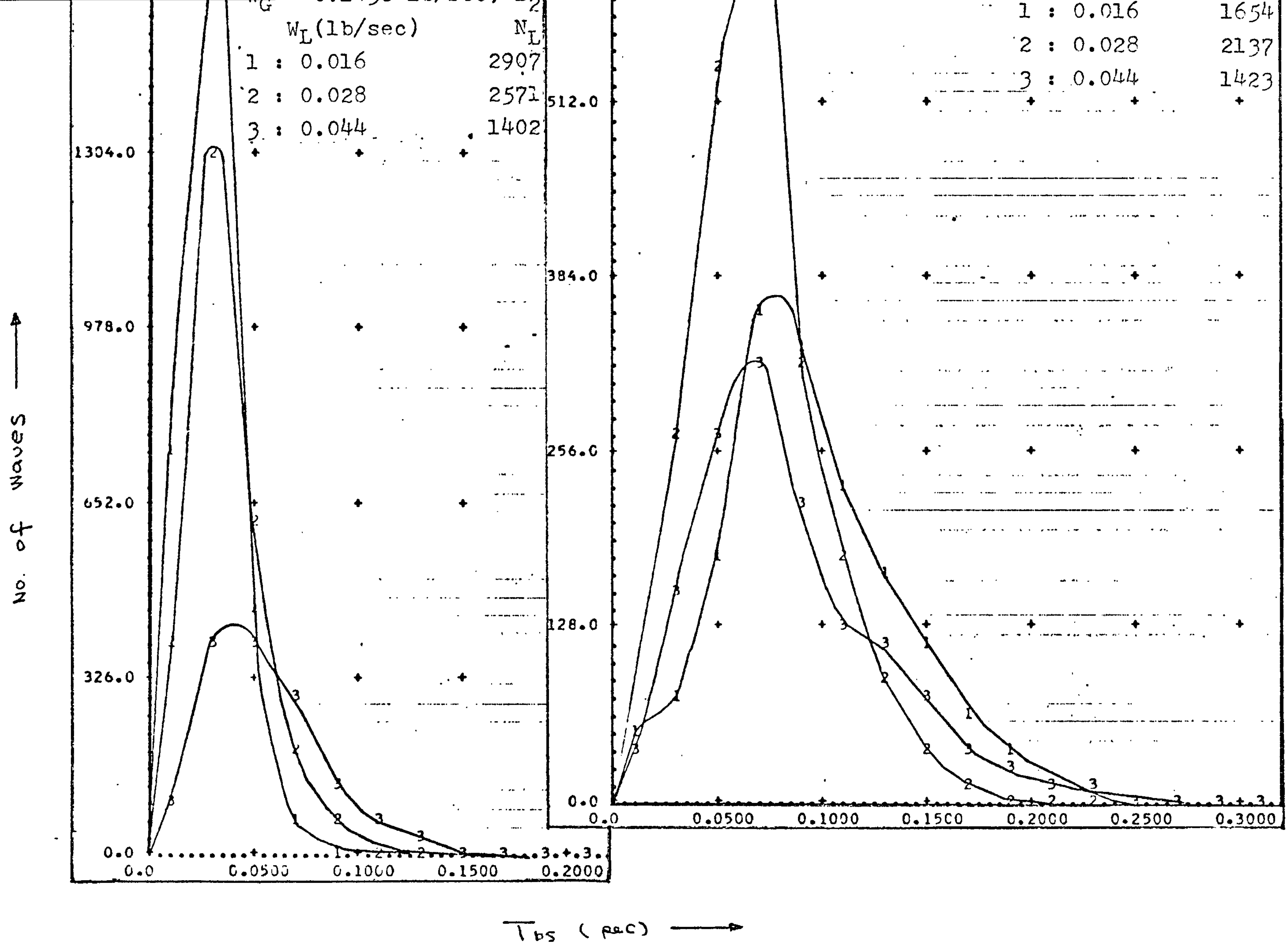


FIG. V-16. HISTOGRAM OF WAVE BASE OF THE LAPGE WAVES

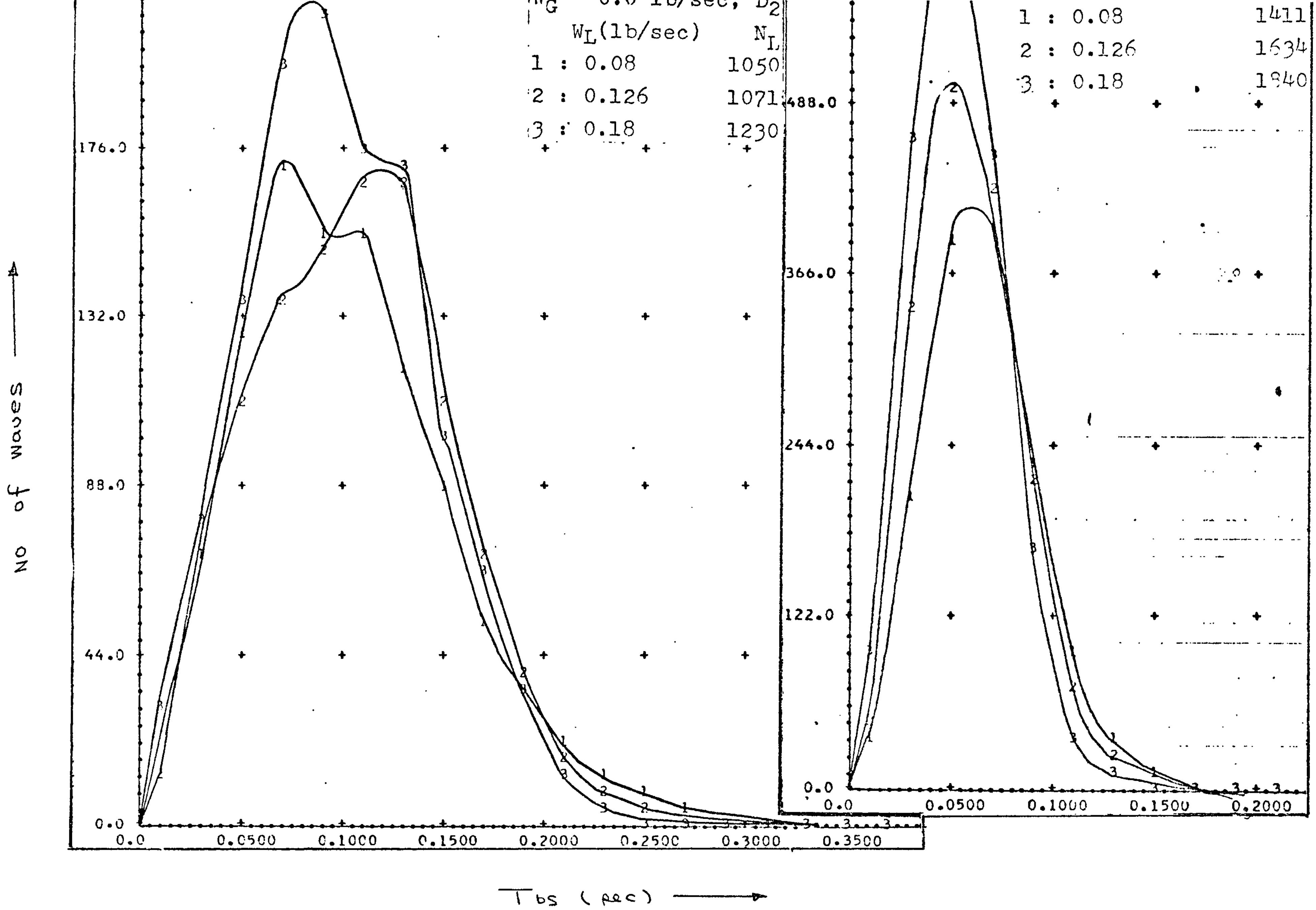


FIG. V-17. HISTOGRAM OF WAVE BASE OF THE LARGE WAVES

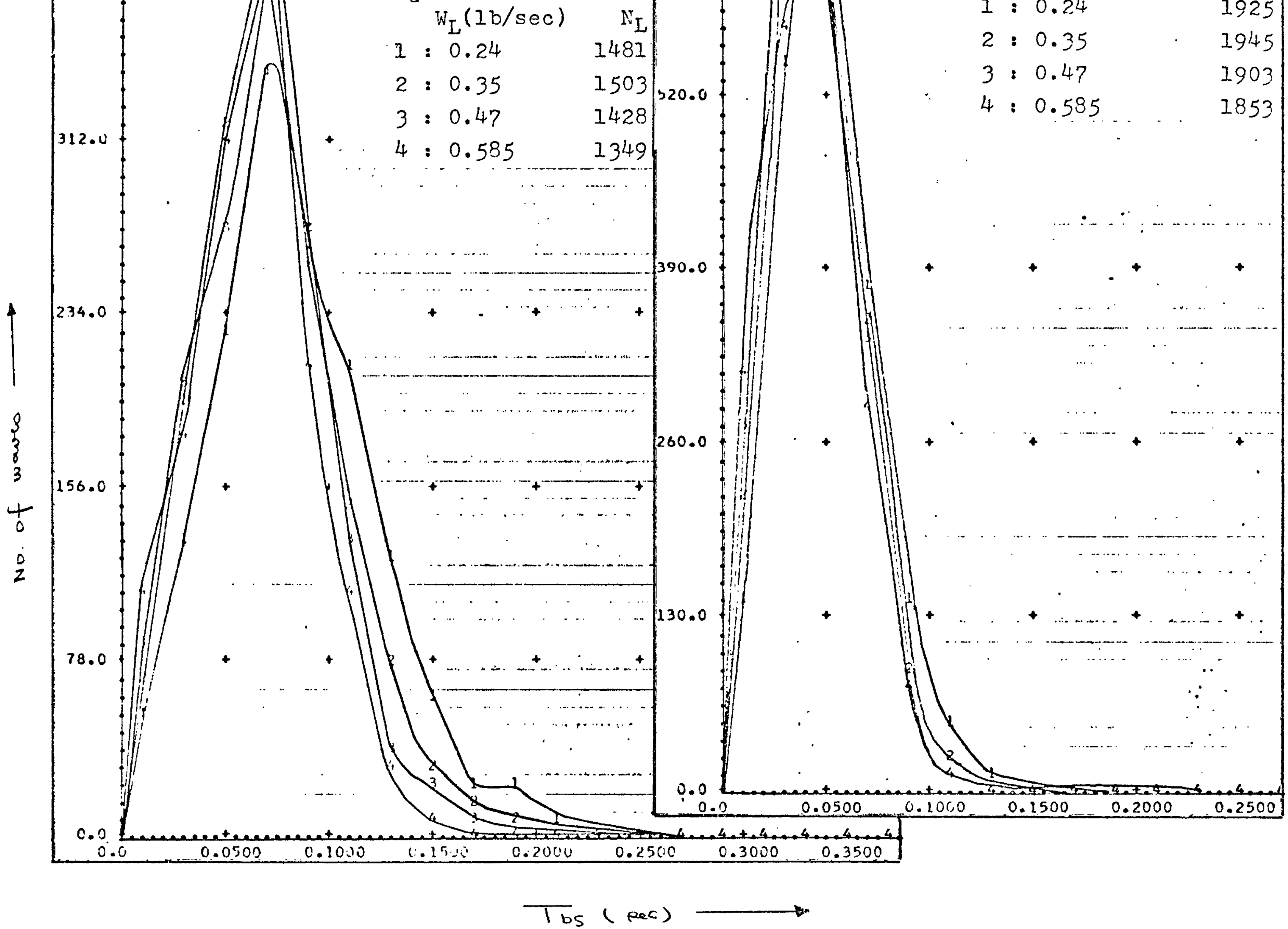


FIG. V-18. HISTOGRAM OF WAVE BASE OF THE LARGE WAVES

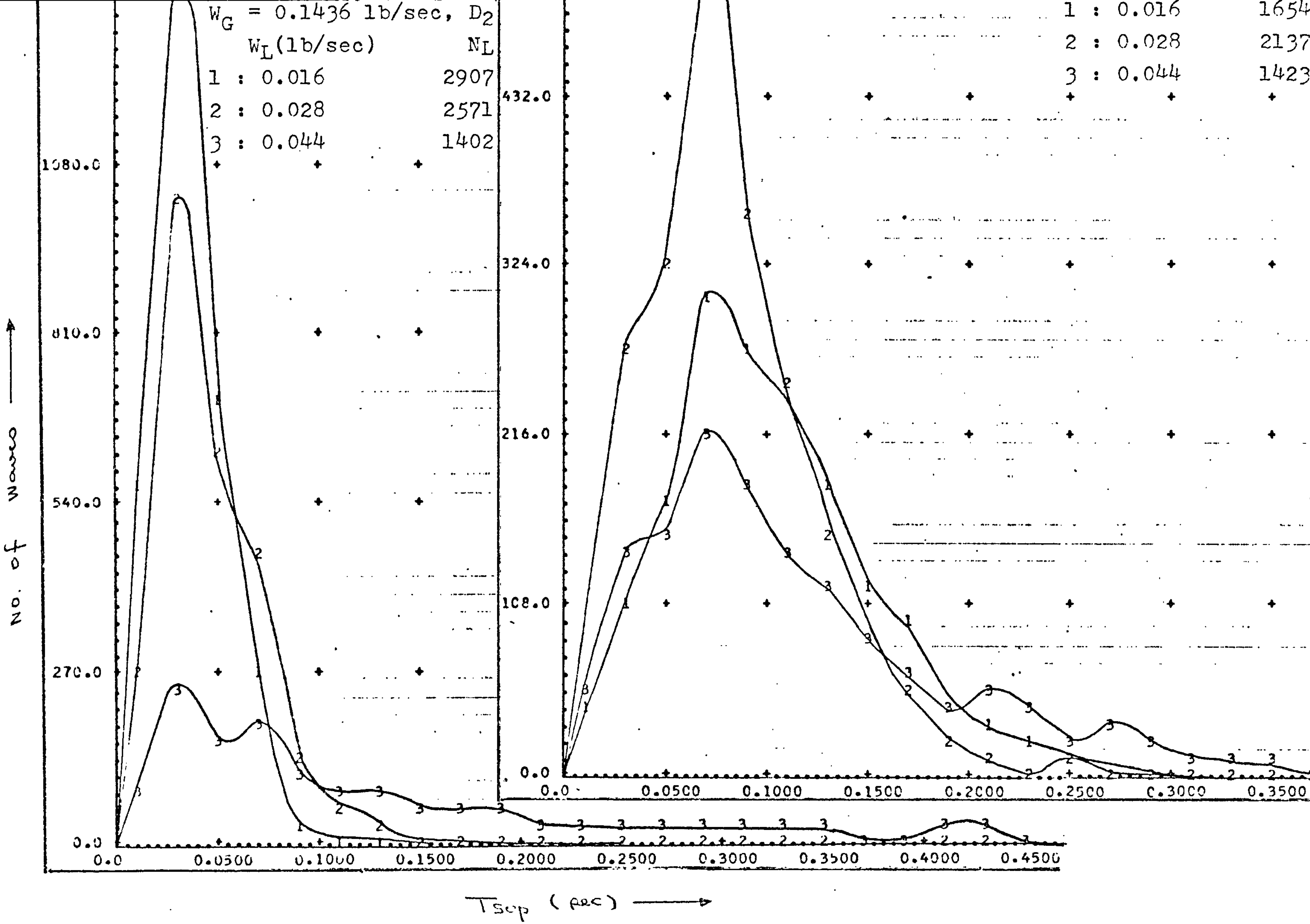


FIG. V-19. HISTOGRAM OF WAVE SEPARATION OF THE LARGE WAVES

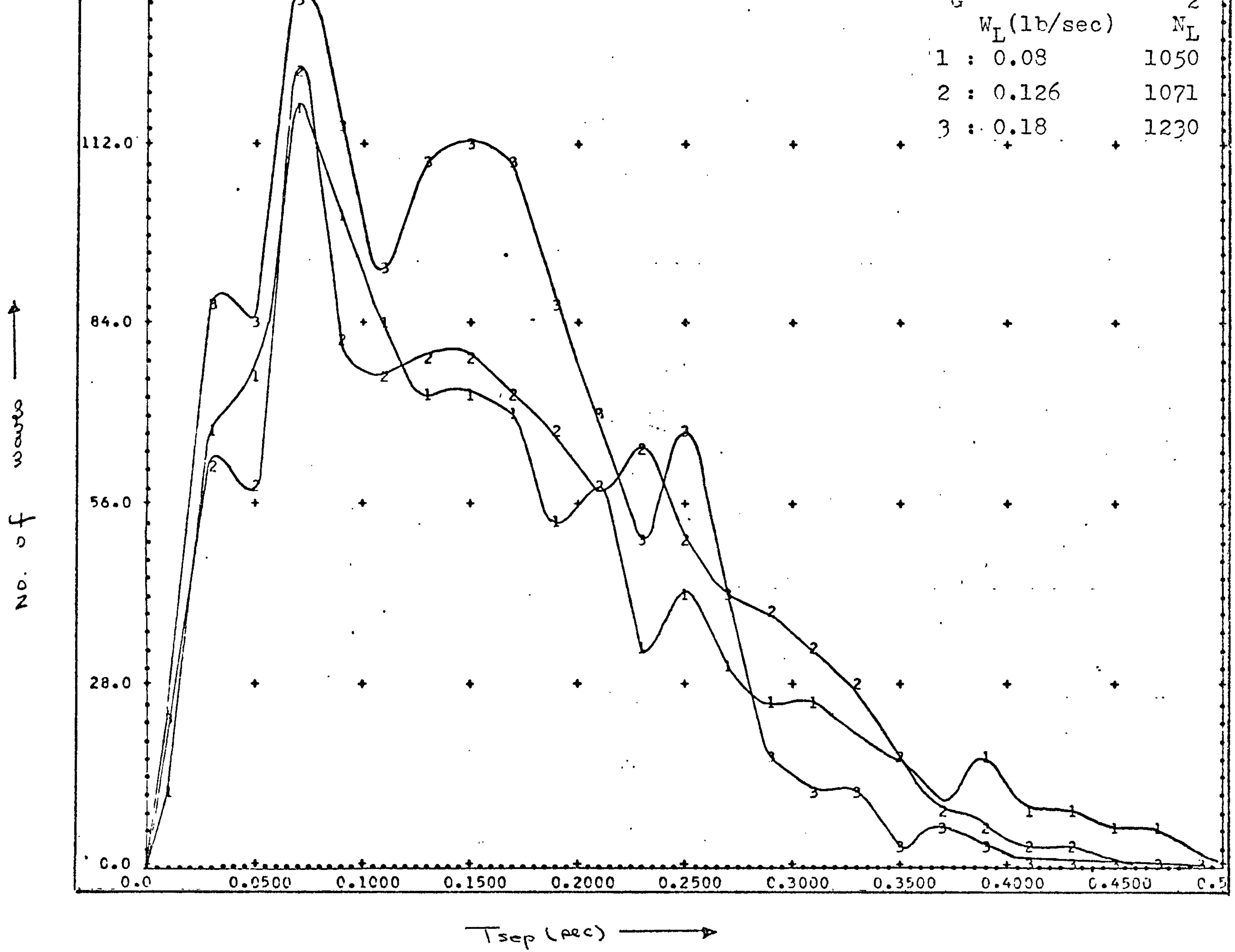


FIG. V-20 (a) HISTOGRAM OF WAVE SEPARATION OF THE LARGE WAVES

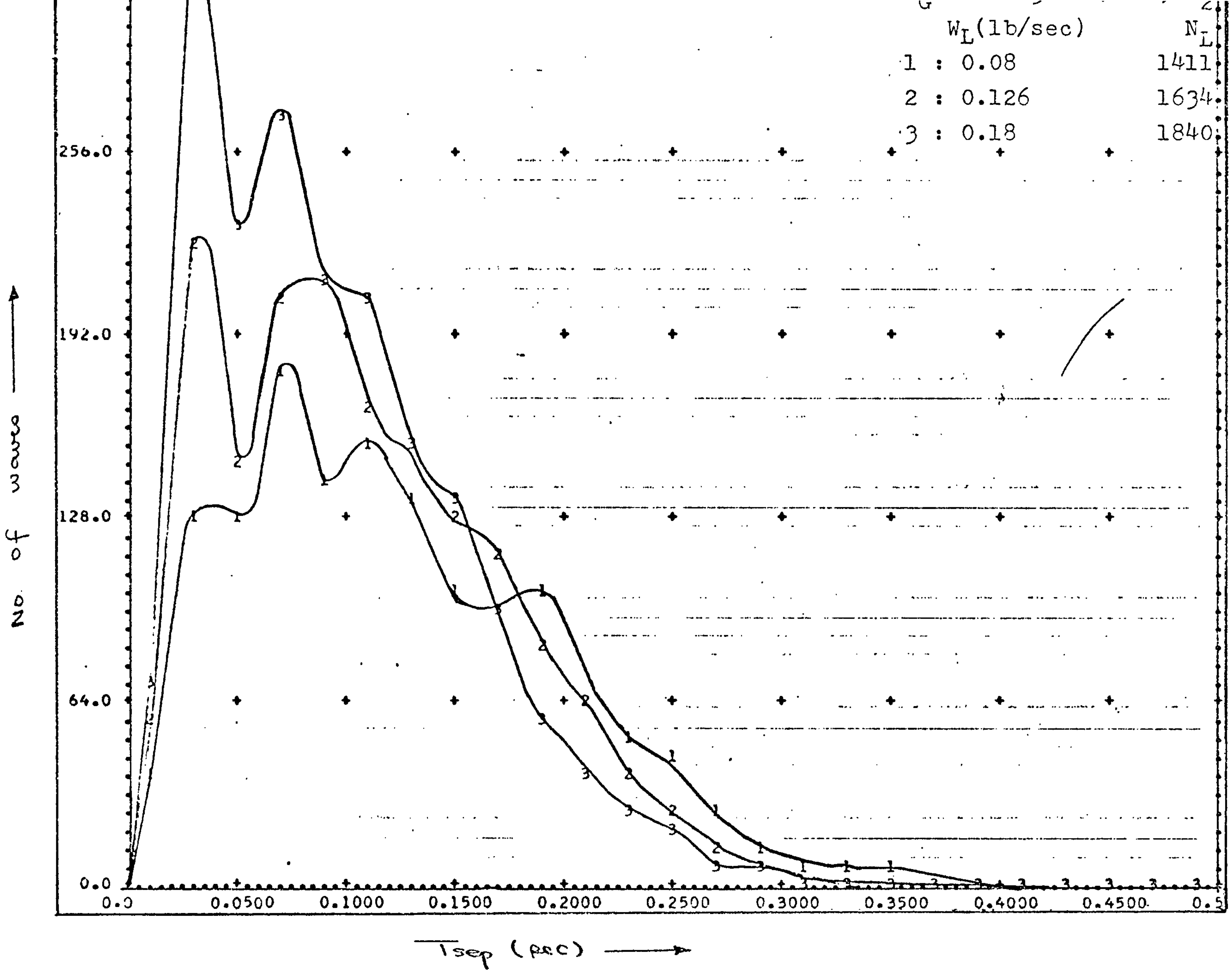


FIG. V-20 (b) HISTOGRAM OF WAVE SEPARATION OF THE LARGE WAVES

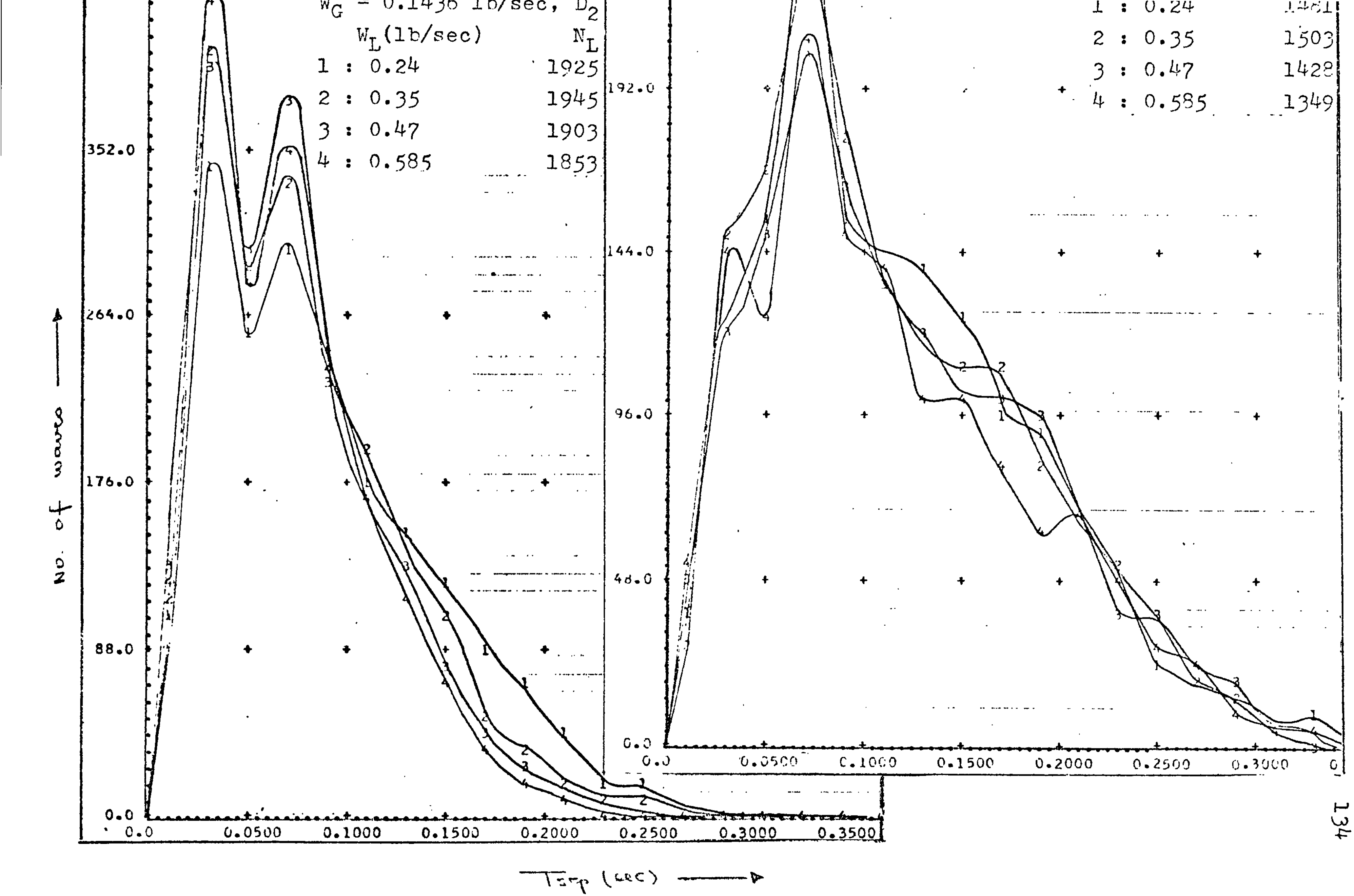


FIG. V-21. HISTOGRAM OF WAVE SEPARATION OF THE LARGE WAVES relation between them for the large waves?" In the time domain, a large wave separation is usually associated with large wave base, wave front, and wave back, since they are related by equation V-2 and V-3. In the amplitude domain, the minimum, h_m, of a large wave possesses a very narrow distribution. Hence the wave maximum and the wave amplitude are approximately related by equation V-1 with a constant wave minimum. Therefore the only unknown relationship is the joint statistical properties between the wave parameter in the time and amplitude domains. The wave separation and the wave maximum of large wave are used to study their joint histogram. The definition of joint histogram is given as:

$$\tilde{H}(h_{max}, T_{sep}) = N_L \cdot \tilde{P}\left\{h_{max}^{(1)} < \hat{h}_{max} \leq h_{max}^{(2)}, T_{sep}^{(1)} < \hat{T}_{sep} \leq T_{sep}^{(2)}\right\} \quad \text{---} \quad (\text{V-5})$$

where
$$h_{max}^{(1)} = h_{max} - \frac{\Delta h_{max}}{2}$$
$$h_{max}^{(2)} = h_{max} + \frac{\Delta h_{max}}{2}$$
$$T_{sep}^{(1)} = T_{sep} - \frac{\Delta T_{sep}}{2}$$
$$T_{sep}^{(2)} = T_{sep} + \frac{\Delta T_{sep}}{2}$$

Δh_{max} is the probability interval for wave maximum

ΔT_{sep} is the probability interval for wave separation

N_L is the total number of the large waves

The full result is tabulated in Appendix D. The numbers appearing in the table in Appendix D are the number of waves in that corresponding probability interval. In this section, the typical joint histogram of the wave maximum and the wave separation are presented in the form of the probability of the wave separation at various wave maximum as in Fig. V-22. The data show that the modal of the wave separation given a wave maximum, h_{max}, is approximately proportional to that given wave maximum. The above implies that the smaller wave maximum is associated with the smaller wave separation and the large wave maximum is associated with the large wave separation. They also show multiple modal values in these two dimensional domains.

4. STATISTICS OF SMALL WAVES ON SUBSTRATE

In this section, the statistics of the small waves on the substrate are presented in a similar way as the large waves.

4-1. AMPLITUDE DOMAIN

The mean value and standard deviation of wave amplitude, wave maximum, and wave minimum of the small waves are given in Fig. V-23 through Fig. V-25. The general trend of these data is similar to the large waves. But the order of $\langle A \rangle$ and $\langle h_{max} \rangle$ of the small waves is smaller. Aside from difference in order of $\langle A \rangle$ and $\langle h_{max} \rangle$, small and large waves differ

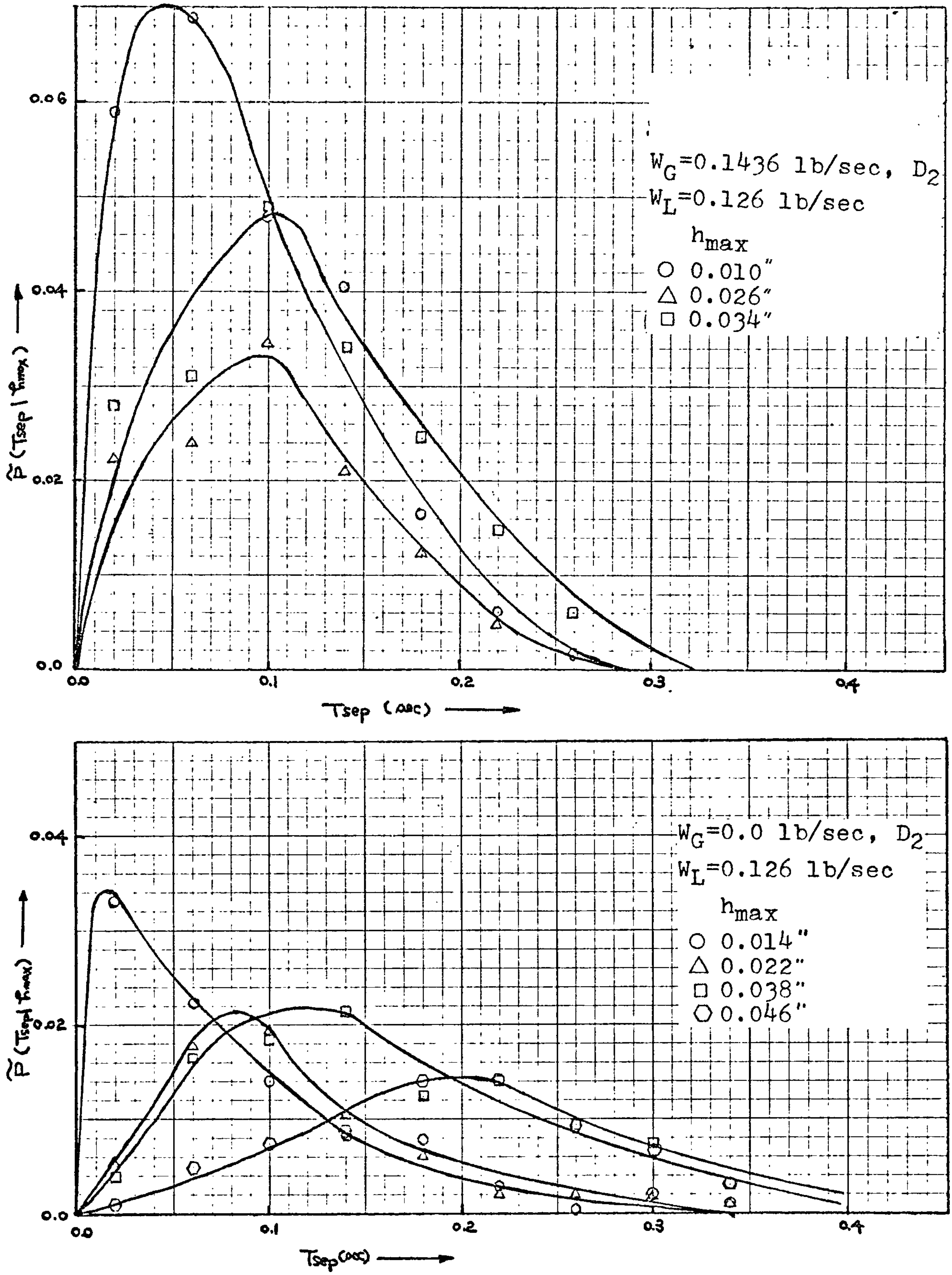


FIG. V-22. JOINT PROBABILITY OF WAVE SEPARATION AND WAVE MAXIMUM OF THE LARGE WAVES

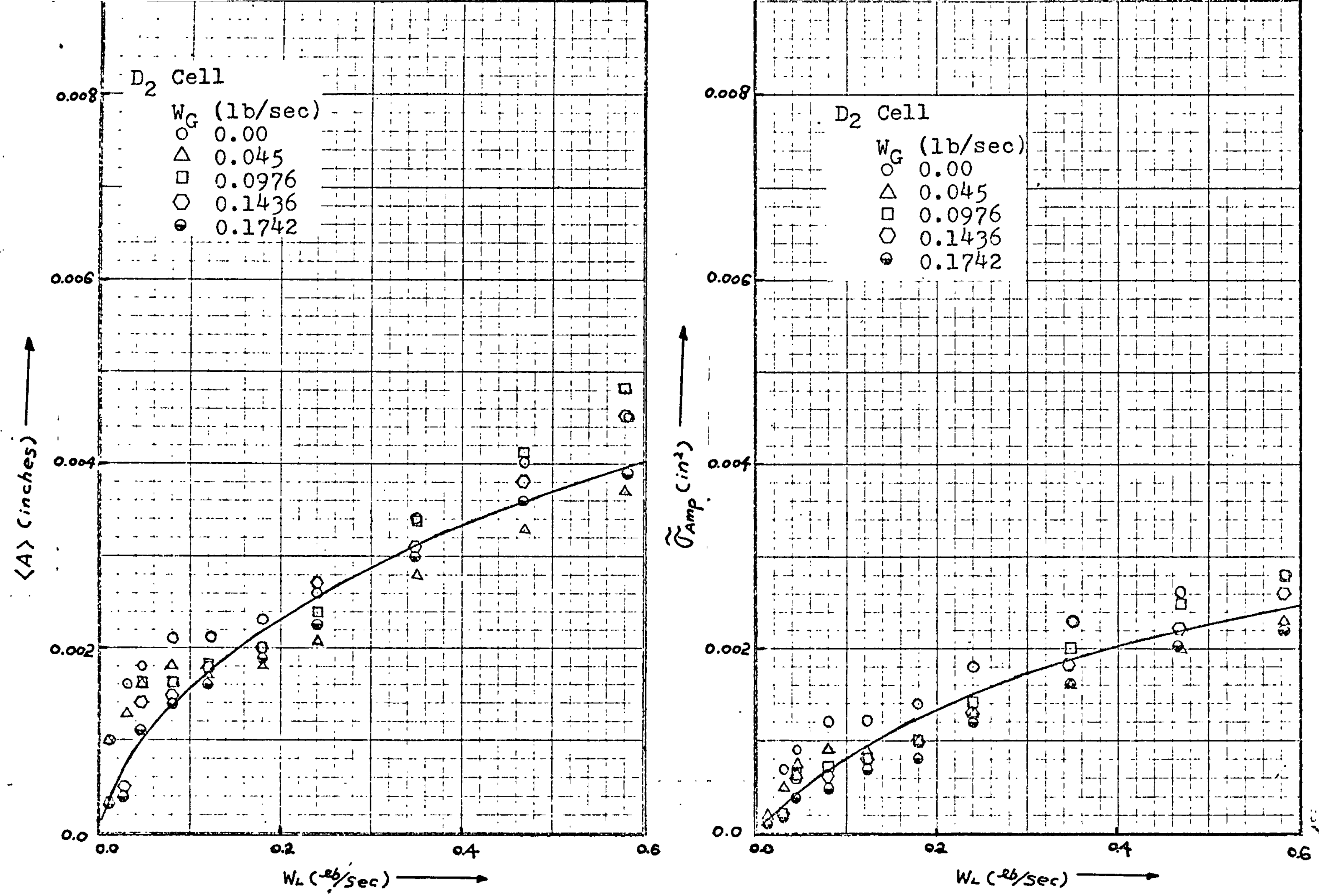


FIG. V-23. THE MEAN AND STANDARD DEVIATION OF WAVE AMPLITUDE OF THE SMALL WAVES

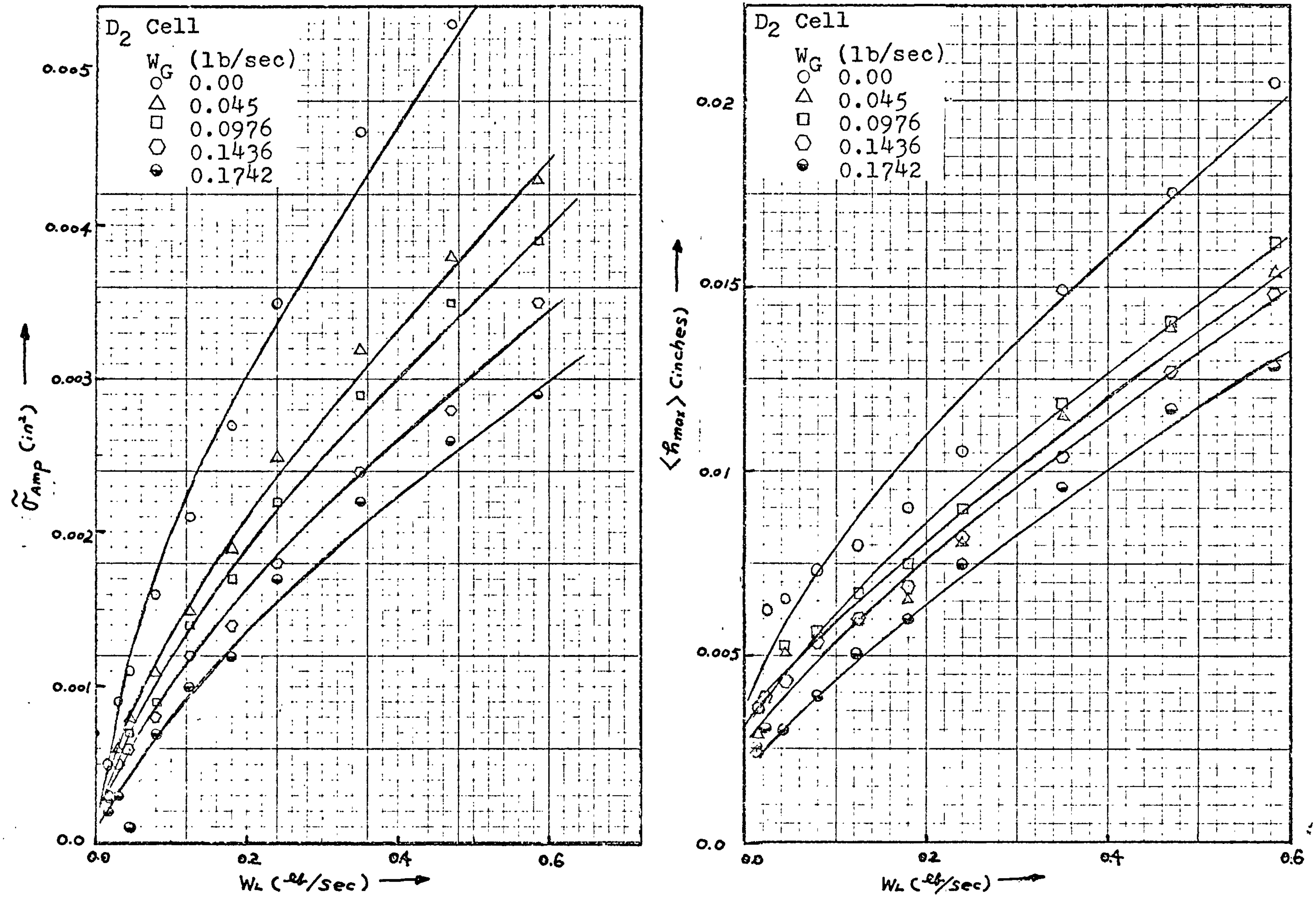


FIG. V-24. THE MEAN AND STANDARD DEVIATION OF WAVE MAXIMUM OF THE SMALL WAVES

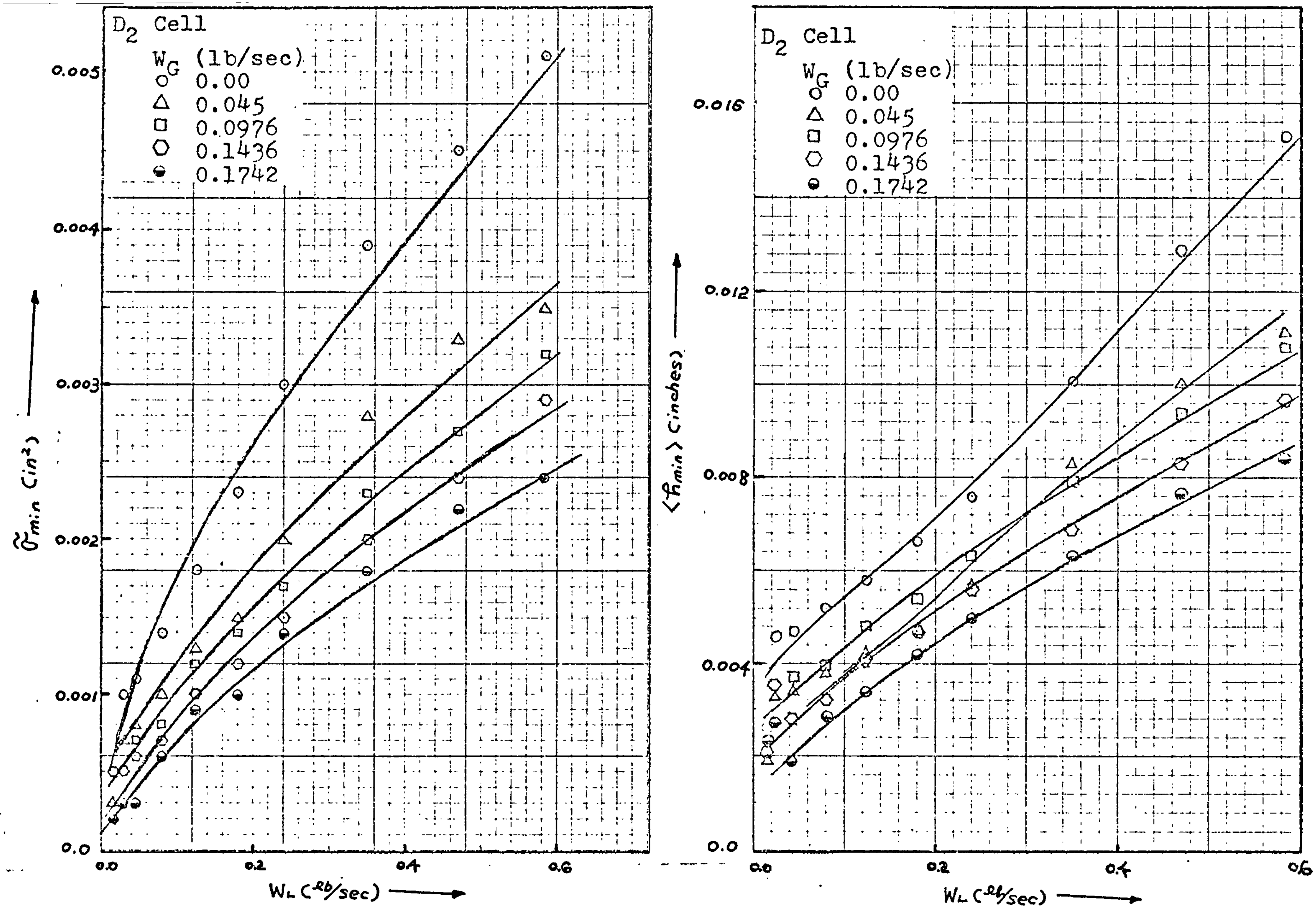


FIG. V-25. THE MEAN AND STANDARD DEVIATION OF WAVE MINIMUM OF THE SMALL WAVES in an important way as indicated by the values of $\tilde{\sigma}$. For the small waves, the standard deviation of wave maximum, $\tilde{\sigma}_{max}$, is about equal to the standard deviation of wave minimum, $\tilde{\sigma}_{min}$, and the standard deviation of wave amplitudes $\tilde{\sigma}_{Amp}$ is much smaller than $\tilde{\sigma}_{max}$ and $\tilde{\sigma}_{min}$. This suggests that the small waves are very uniform in size and that any variations in h_{min} is reflected immediately in a variation of h_{max}.

The histogram of wave amplitude of the small waves are given in Fig. V-26 and Fig. V-27. The general features of these data show that a single narrow peak characterizes the distribution for small waves on the substrate for all liquid and gas rates.

4-2. TIME DOMAIN

The mean value and standard deviation of wave base for the small waves are plotted in Fig.V-28. The wave frequency of the small waves is given as:

$$f_s = \frac{1}{\langle T_{bs} \rangle} \qquad \text{------} \qquad (V-6)$$

The data of the wave frequency f_s and the ratio of $\langle T_{bk} \rangle / \langle T_{bs} \rangle$ is shown in Fig. V-29. The trend of these data is similar to that of the large wave except the peak value of the ratio $\langle T_{bk} \rangle / \langle T_{bs} \rangle$ occurs at W_L=0.35 lb/sec. The histogram of wave base of the small waves is also shown in Fig. V-30 and Fig. V-31. They show

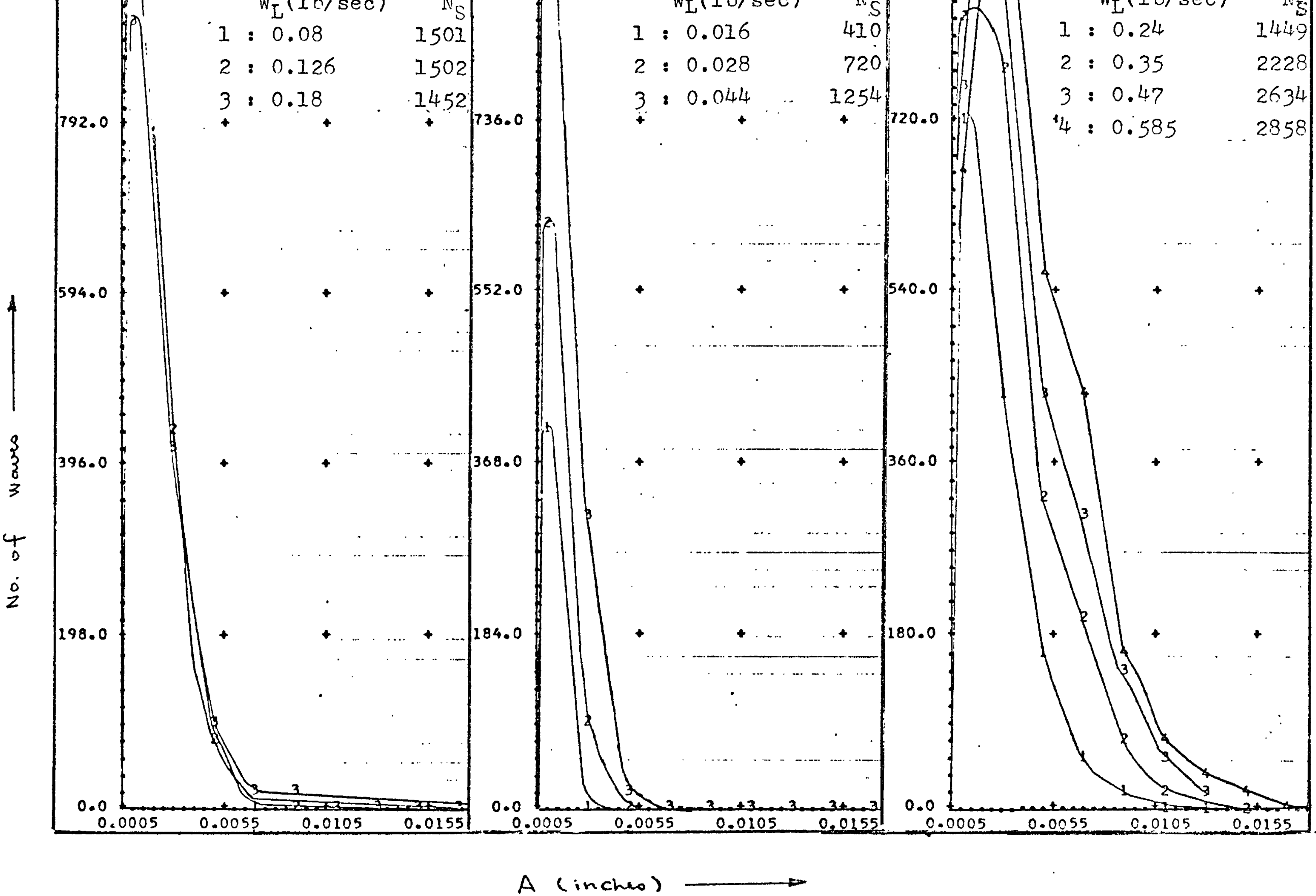


FIG. V-26. HISTOGRAM OF WAVE AMPLITUDE OF THE SMALL WAVES

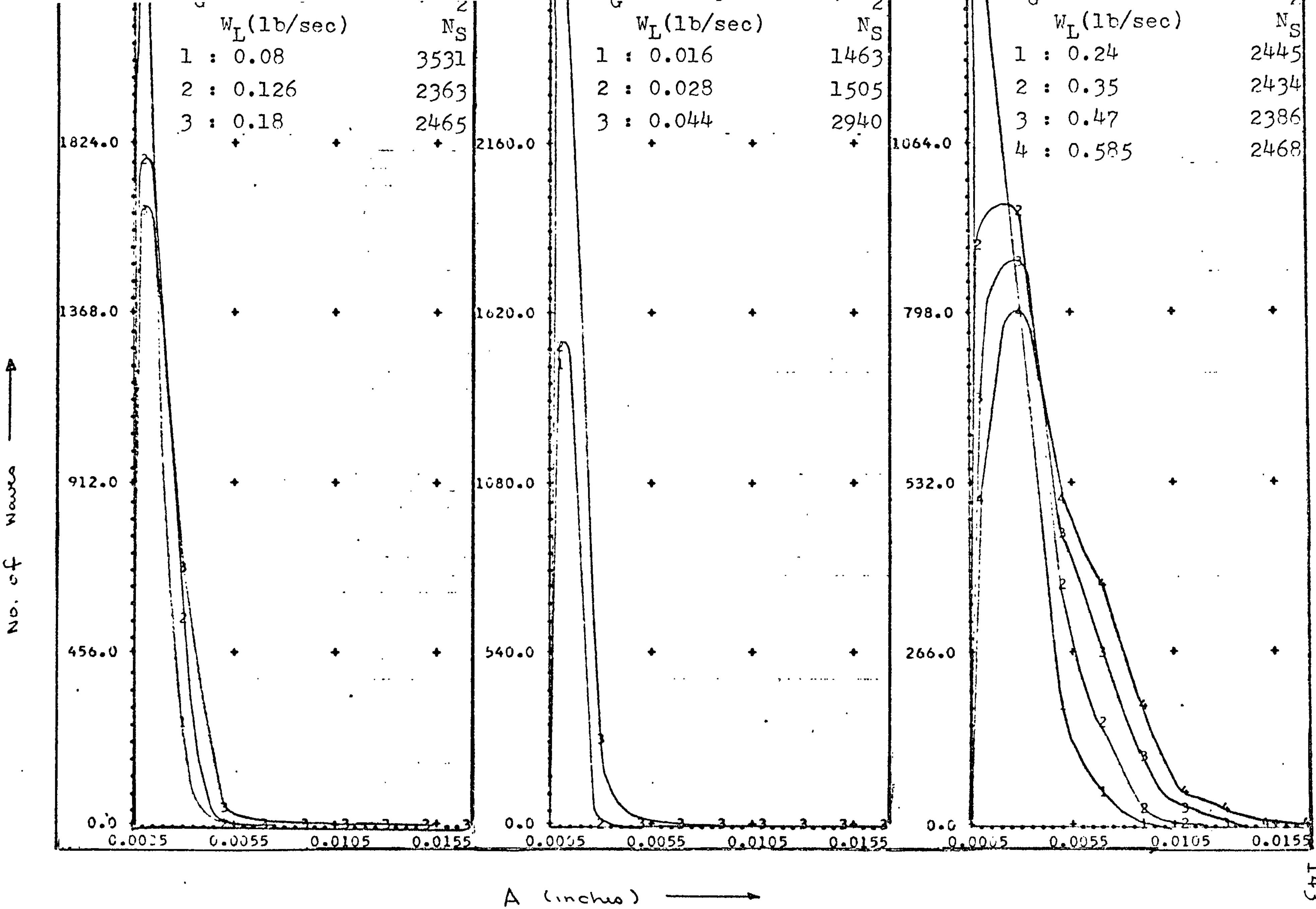


FIG. V-27. HISTOGRAM OF WAVE AMPLITUDE OF THE SMALL WAVE

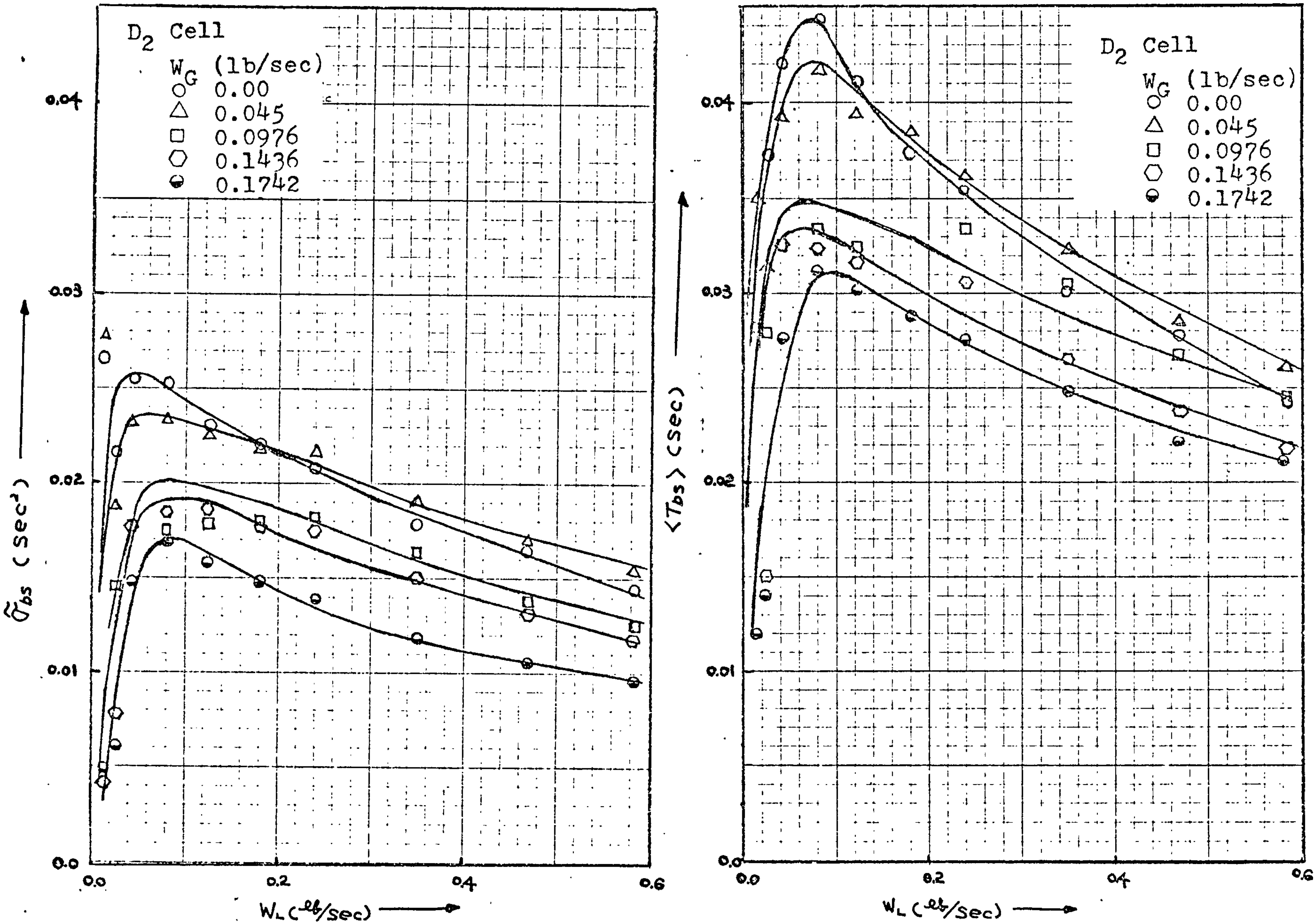


FIG. V-28. THE MEAN AND STANDARD DEVIATION OF WAVE BASE OF THE SMALL WAVES

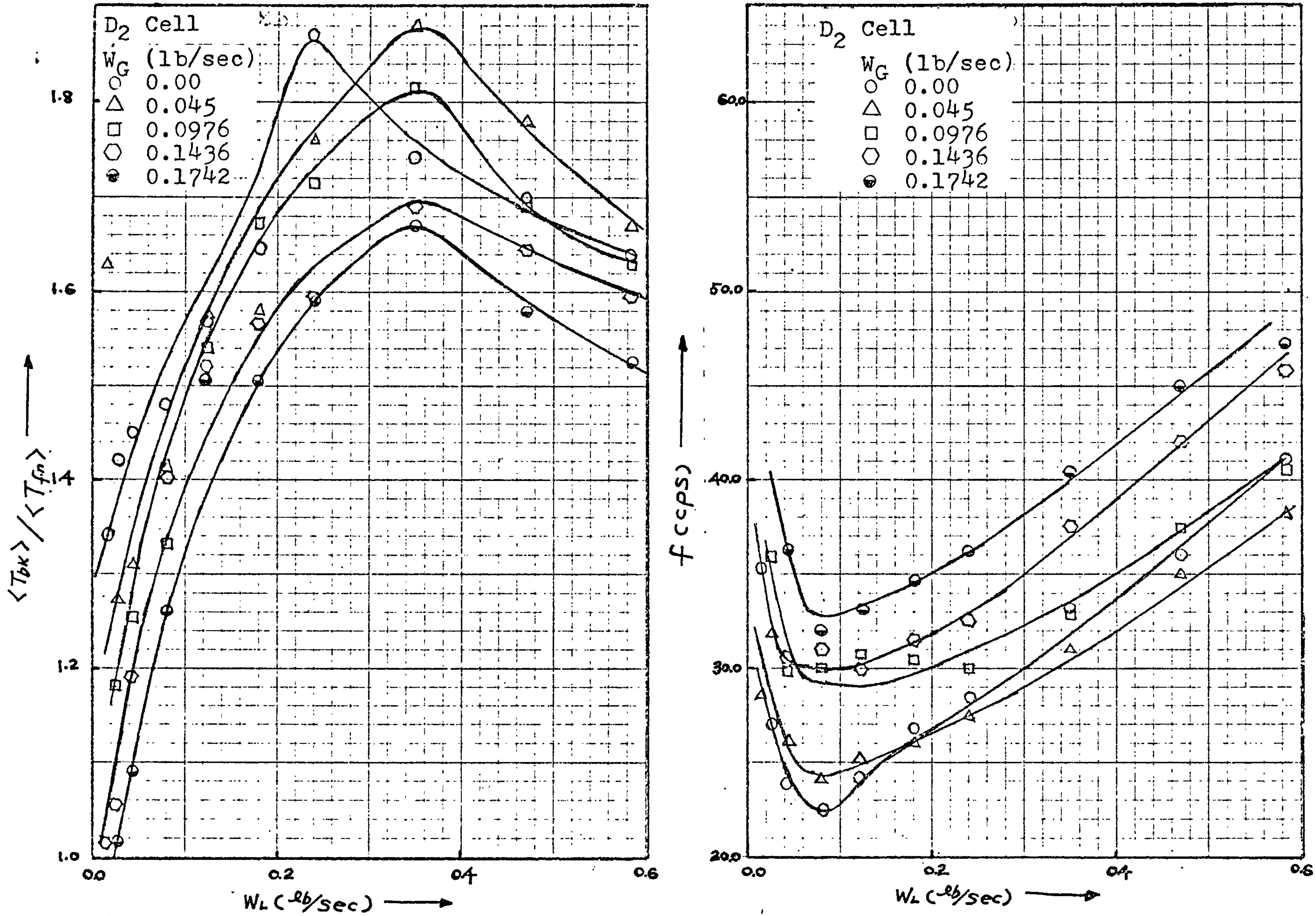


FIG. V-29. THE WAVE FREQUENCY AND $\langle T_{bk} \rangle / \langle T_{fn} \rangle$ OF THE SMALL WAVES

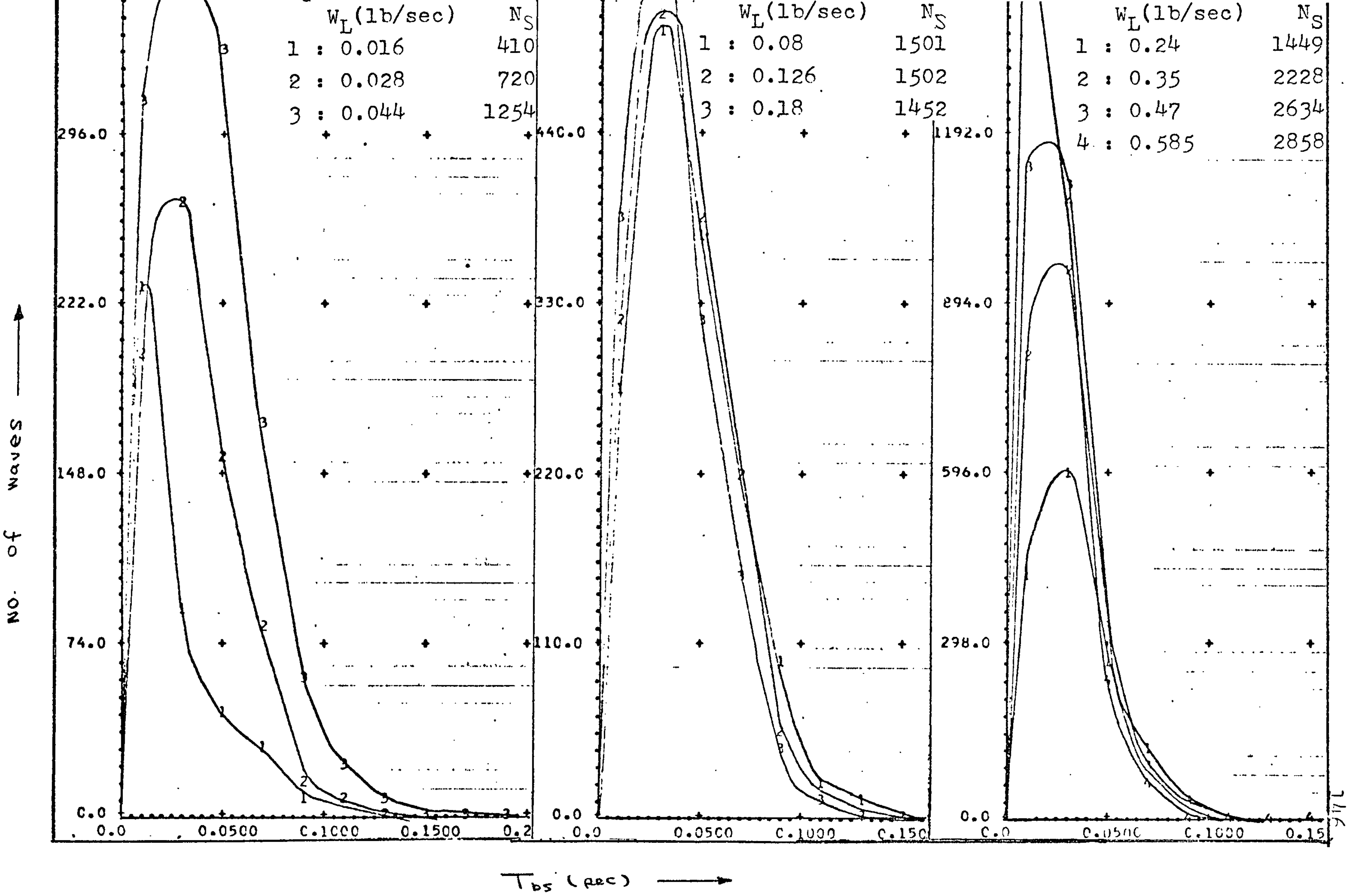


FIG. V-30. HISTOGRAM OF WAVE BASE OF THE SMALL WAVES

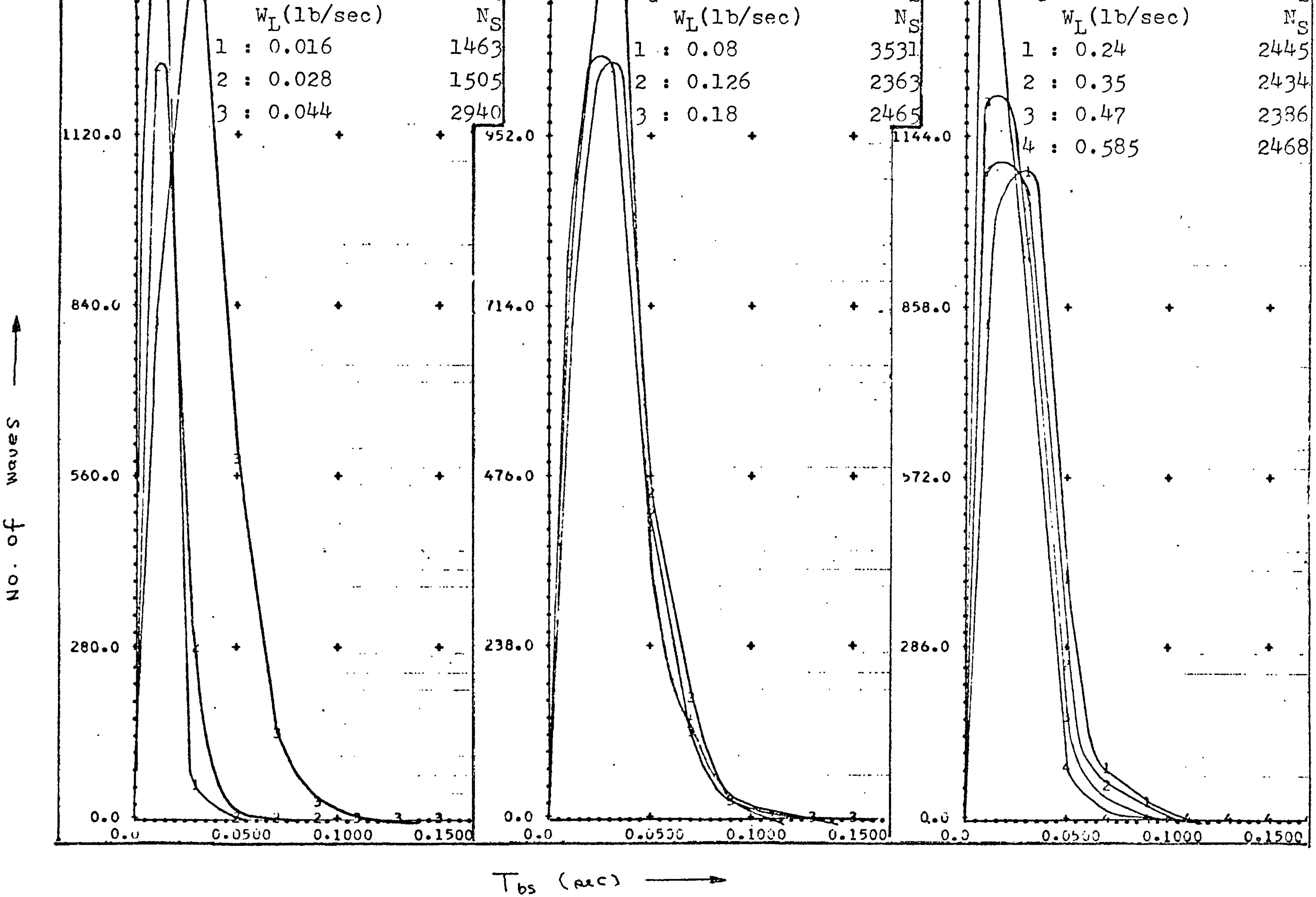


FIG. V-31. HISTOGRAM OF WAVE BASE OF THE SMALL WAVES a usual single narrow peak distribution for all liquid and gas rates.

5. STATISTICS OF SMALL WAVES ON LARGE WAVES

Based on the above mentioned criteria in Section 2 small waves on large waves will include not only the small waves riding on the large waves but also some of the large waves travelling very close to each other. Only the data on the wave amplitude and the wave base will be used in this section to illustrate the general features of this type of waves.

5-1. AMPLITUDE DOMAIN

The mean value and standard deviation of wave amplitude of the small waves on large waves is given in Fig. V-32. The trend of these data shows a similar effect of gas and liquid flow rates as the large waves and the small waves. The order of magnitude of these data is between that of the large waves and the small waves. The histogram of wave amplitude of the small waves on large wave is shown in Fig. V-33 through Fig. V-35. These curves shows a single or a double peak on the main lobe and with a smaller side lobe.

5-2. TIME DOMAIN

The mean value and standard deviation of wave base of the small waves on large wave is shown in Fig. V-37. The

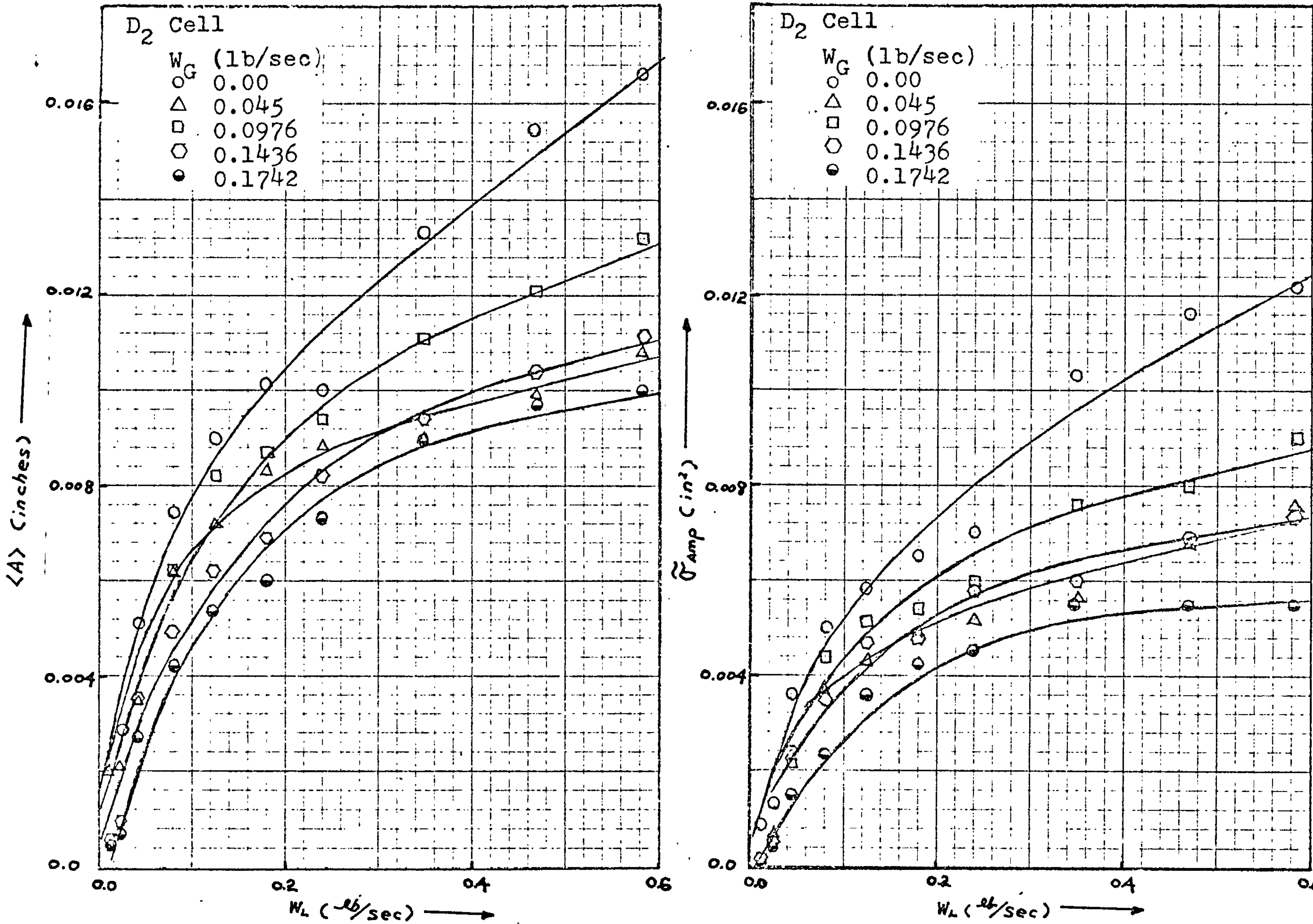


FIG. V-32. THE MEAN AND STANDARD DEVIATION OF WAVE AMPLITUDE OF THE SMALL WAVES ON LARGE WAVES

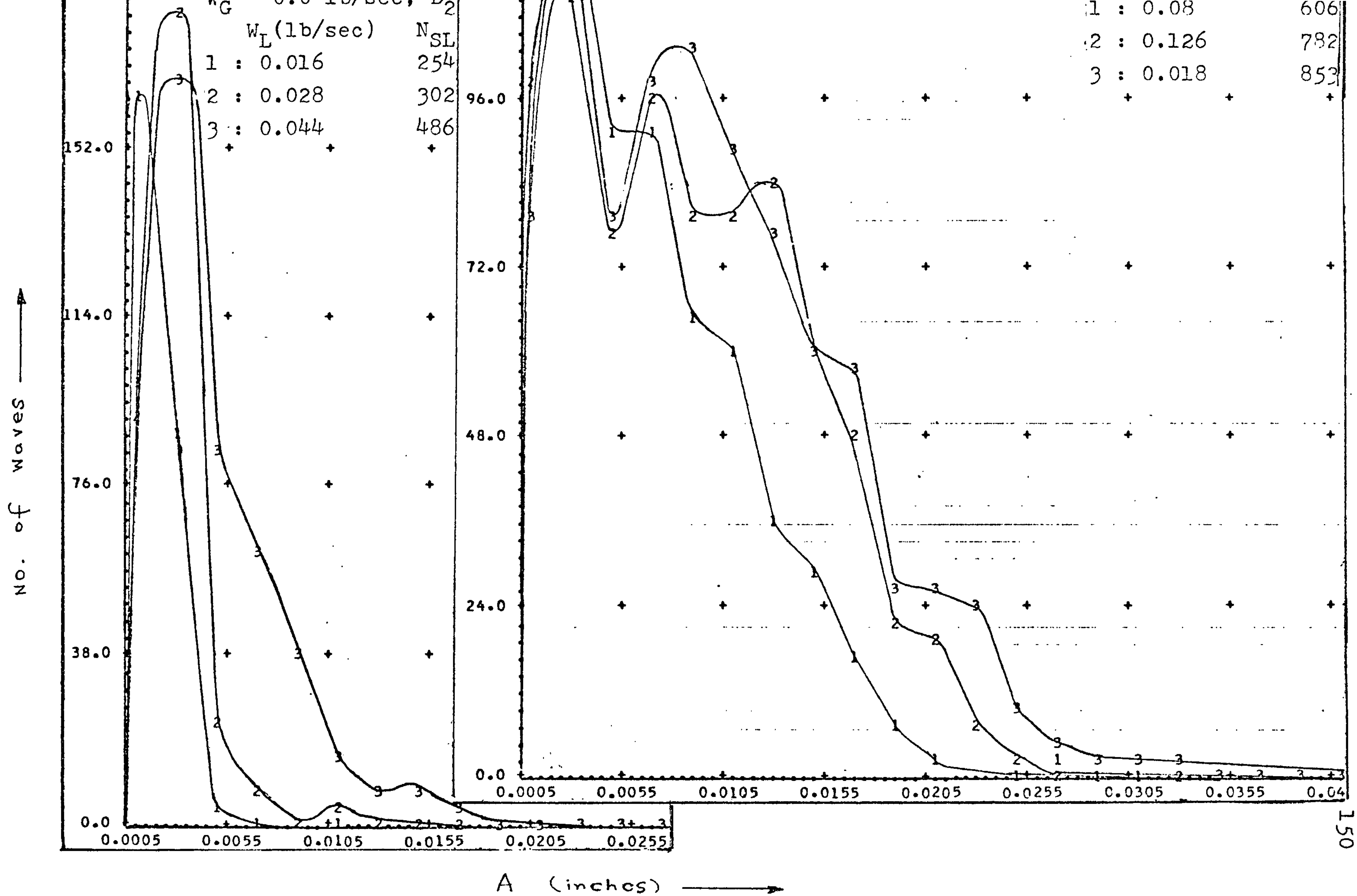


FIG. V-33. HISTOGRAM OF WAVE AMPLITUDE OF THE SMALL WAVES ON LARGE WAVES

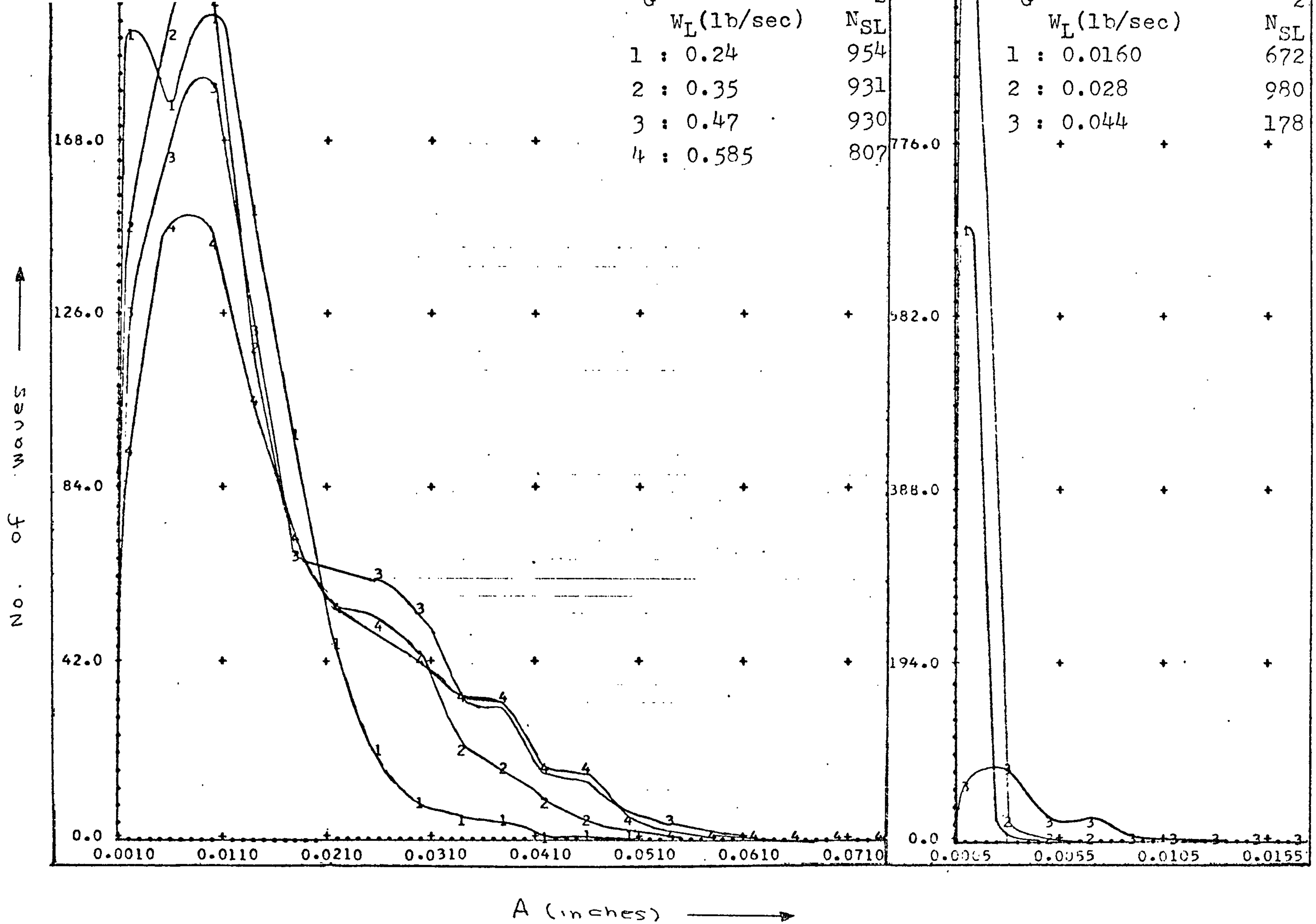


FIG. V-34. HISTOGRAM OF WAVE AMPLITUDE OF THE SMALL WAVES ON LARGE WAVES

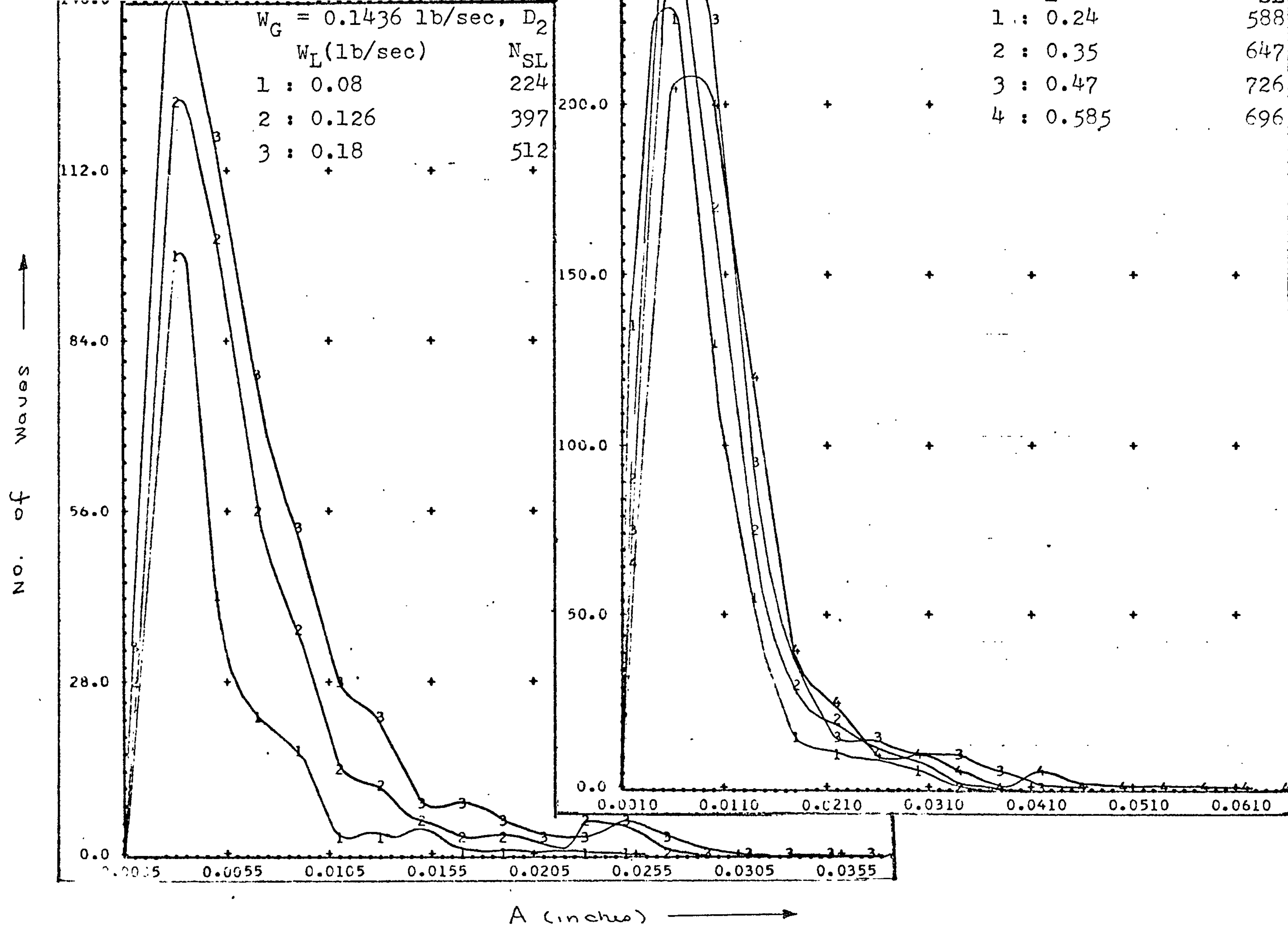


FIG. V-35. HISTOGRAM OF WAVE AMPLITUDE OF THE SMALL WAVES ON LARGE WAVES

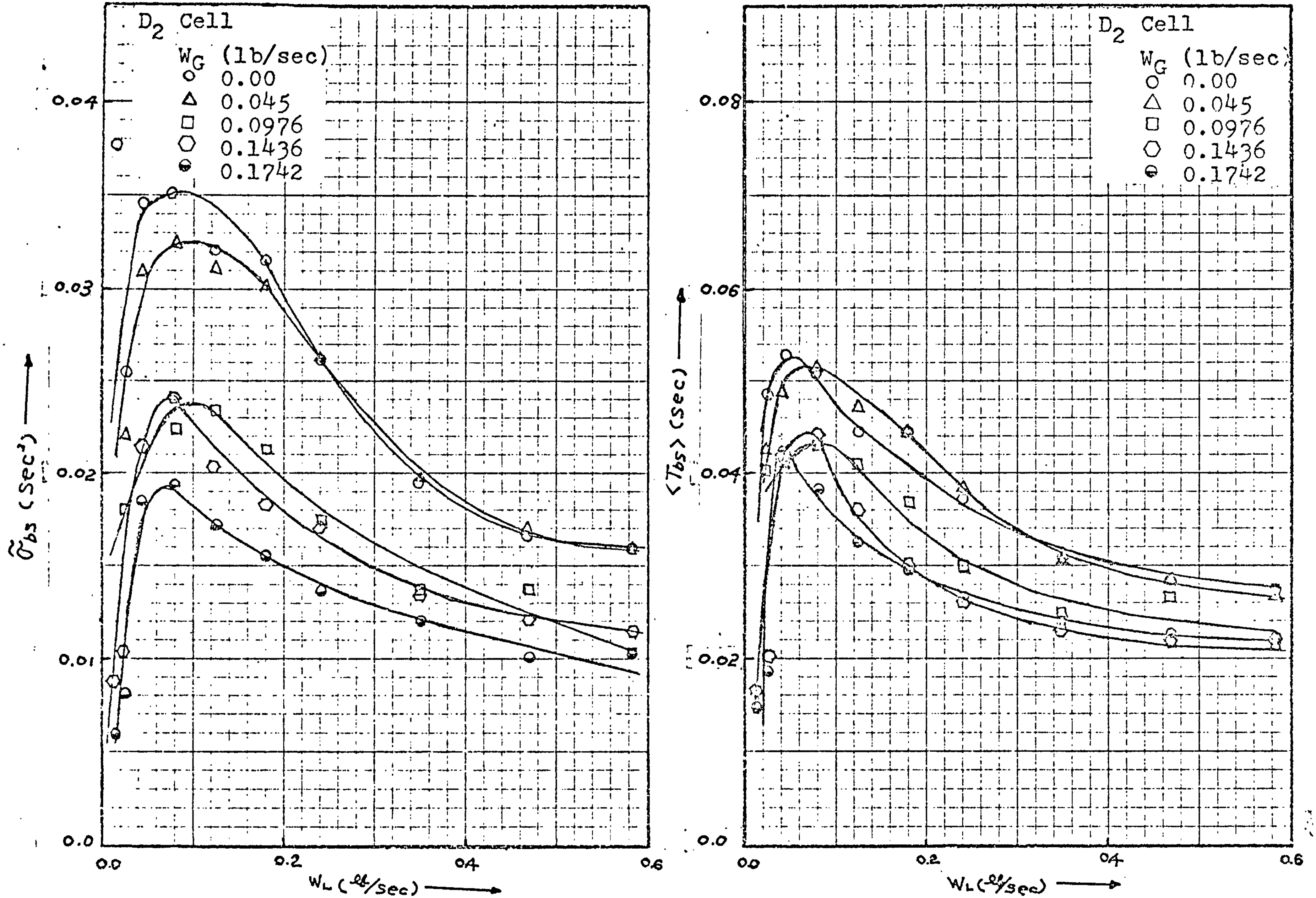


FIG. V-36. THE MEAN AND STANDARD DEVIATION OF WAVE BASE OF THE SMALL WAVES ON LARGE WAVES trend of these data is similar to that of the large waves and the small waves, and their order of magnitude is between the two of them. The histogram of wave base of the small wave on large wave is a usual single narrow peak distribution and will not be shown here.

CHAPTER VI

INTERPRETATION OF EXPERIMENTAL DATA AND SPECULATIONS ON THE PROCESS OF WAVE MOTION

1. INTRODUCTION

The statistical data presented in the last two chapters give only part of the useful information available. The structure of the processes can not be completely described from the time series data without special processing. In this chapter, further information is extracted from the data by various techniques using assumptions and speculations about the processes. Hopefully a more complete description of the structure of the processes can thus be defined.

2. WAVE VELOCITY AND WAVE LENGTH

One of the most important wave parameter which is not directly obtainable from the time series analysis is the wave velocity. In this section, this parameter will be obtained for both the large and small waves by various methods. Webb (W-2) measured a probability density function for the wave velocity. Telles (T-2) obtained a linear phase spectrum which implies a constant wave velocity. There is an obvious conflict in the results between these two reports. This paradox is examined here.

2-1. WAVE VELOCITY AND WAVE LENGTH OF LARGE WAVES

Telles assumed that film thickness time series measured at two position are two stationary stochastic processes such that

$$\hbar_1'(t) = \hbar'(t - \frac{x}{c}) \qquad \text{at } x = 0 \text{ -------- } (VI-1)$$

$$\hbar_2'(t) = \hbar'(t - \frac{x}{c}) \qquad \text{at } x = \ell \text{ -------- } (VI-2)$$

where ℓ is separation distance between two positions.
Then from equations (IV-20) and (IV-21), one can obtain

$$\begin{aligned} \tilde{C}_{12}(\tau) &= \langle \hat{\hbar}'(t+\tau)\, \hat{\hbar}'(t - \frac{\ell}{c}) \rangle \\ &= \tilde{C}_{11}(\tau + \frac{\ell}{c}) \text{ ------------- } (VI-3) \end{aligned}$$

$$\begin{aligned} \tilde{S}_{12}(f) &= \int_{-\infty}^{+\infty} e^{-i2\pi f\tau}\, \tilde{C}_{11}(\tau + \frac{\ell}{c})\, d\tau \\ &= e^{+i2\pi f\frac{\ell}{c}}\, \tilde{S}_{11}(f) \text{ ------- } (VI-4) \end{aligned}$$

Comparing the above equation (VI-4) with equation (IV-25), it is clear that

$$\tilde{\Lambda}(f) = \cos 2\pi f \frac{\ell}{c}\, \tilde{S}_{11}(f) \text{ ---- } (VI-5)$$

$$\tilde{Q}(f) = \sin 2\pi f \frac{\ell}{c}\, \tilde{S}_{11}(f) \text{ ---- } (VI-6)$$

The phase spectrum from equation (IV-27) becomes

$$\tilde{\theta}(f) = 2\pi f \frac{\ell}{c} \text{ --------- } (VI-7)$$

The equation implies that the slope of phase spectrum is equal to the ratio of separation distance and wave velocity. The wave velocity, C, can also be obtained from cross covariance as Webb showed. One important property of auto-covariance is shown in equation (IV-24)

$$\tilde{C}_{11}(0) \geq \tilde{C}_{11}(\tau) \qquad \text{for all } \tau$$

From equation (IV-24) and equation (VI-3), one obtains

$$\tilde{C}_{12}\left(-\frac{\ell}{c}\right) \geq \tilde{C}_{12}(\tau) \qquad \text{for all } \tau \text{ --- (VI-7)}$$

The meaning of equation (VI-7) is that the maximum of cross-covariance is at the time lag $\tau = -\frac{\ell}{c}$. Therefore the wave velocity can be directly obtained from the location of the maximum of the cross-covariance.

The wave velocity was obtained from both the phase spectrum and the cross-covariance for a gas flow rate, W_G=0.0 lb/sec. These are compared with Telles' and Webb's data in Fig. VI-1 and show good agreement. Although both methods are equivalent, the method of cross-covariance depends on locating a single maximum point. Hence if the time lag interval is large or the separation distance between two measuring stations is large the method is subject to large error. The wave velocity for all gas flow rates and liquid flow rates is given in Fig. VI-2. These data show the usual trend of increasing velocity with both gas and liquid rates. The wave length of large wave which is defined by $\langle \lambda \rangle = C \langle T_{sep} \rangle$ was calculated and plotted in Fig. VI-3.

2-2. NONLINEARITY OF PHASE SPECTRA

In the present study, the data of phase spectra as given in Chapter IV show a departure from the constant slope above a frequency of about 10 cps. This did not appear

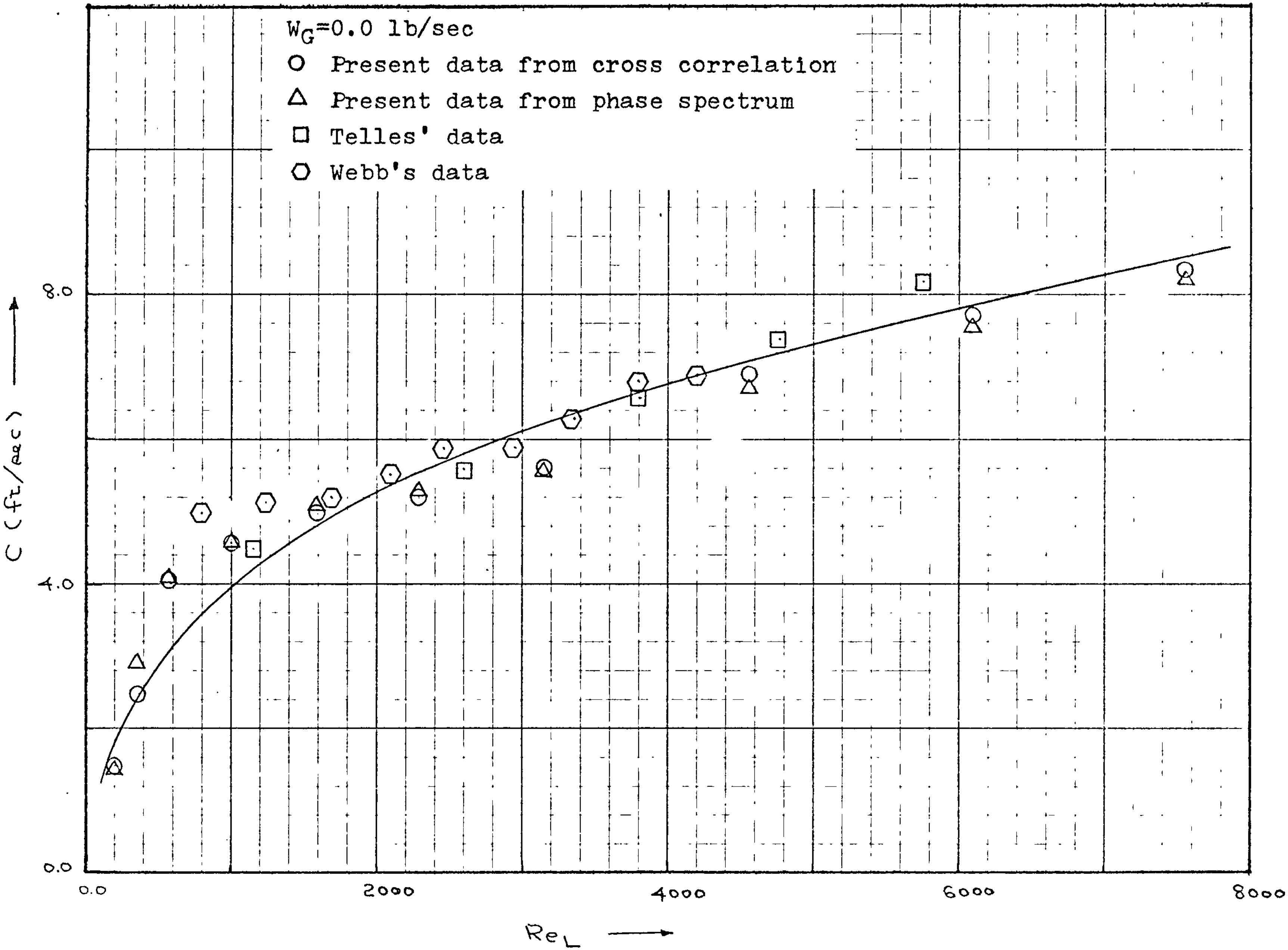


Fig. VI-1. COMPARISON OF WAVE VELOCITY

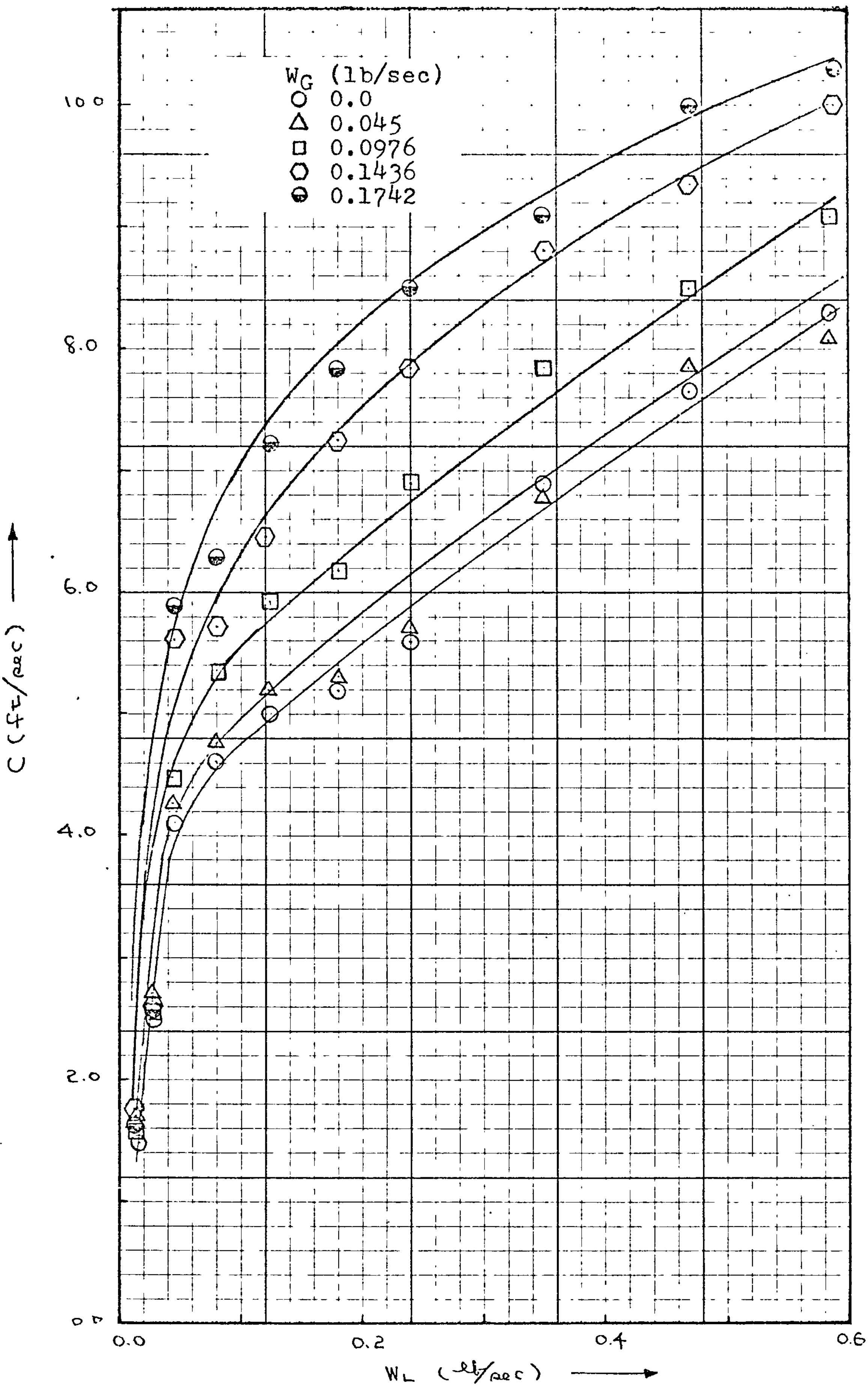


Fig. VI-2. WAVE VELOCITY

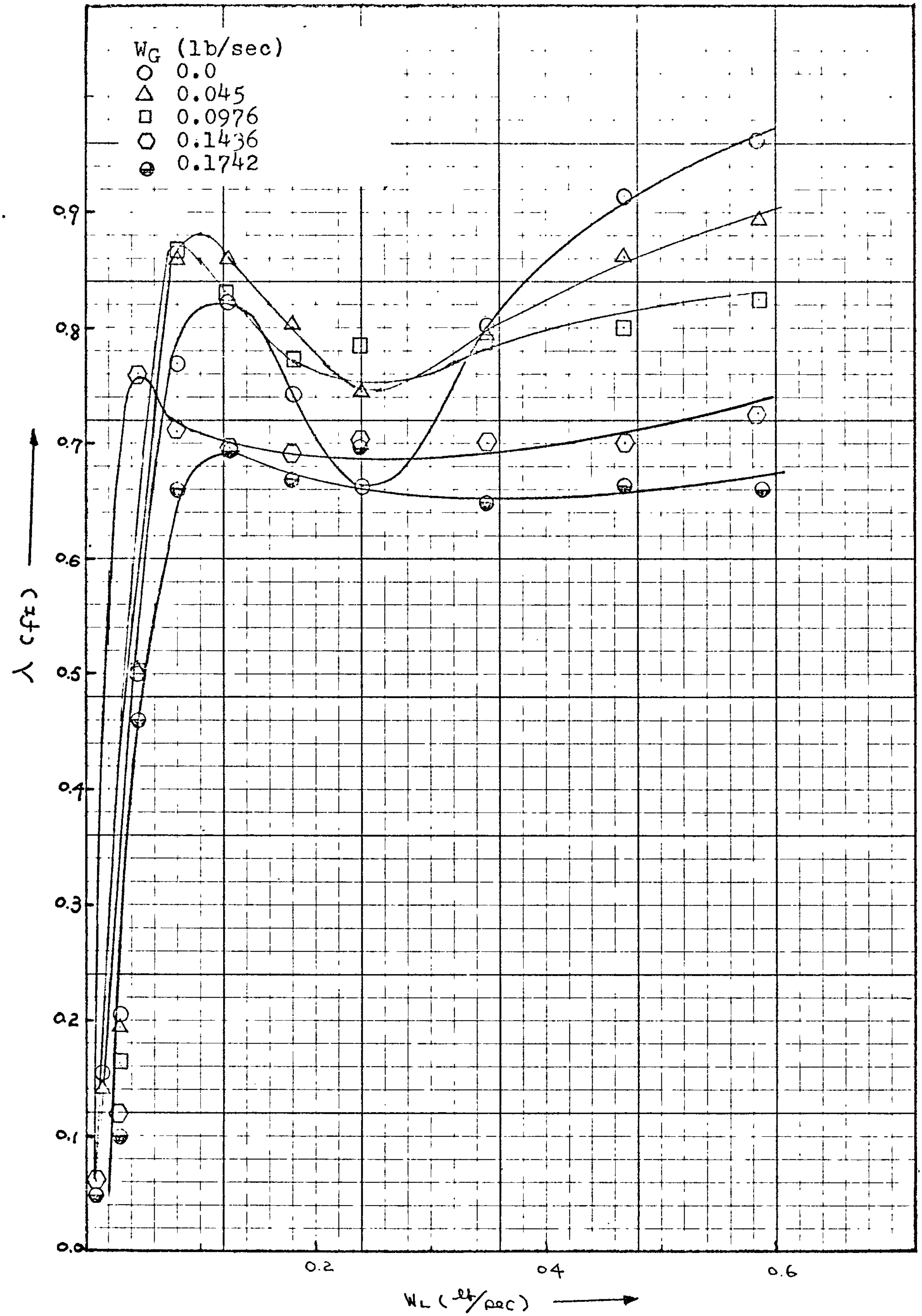


Fig. VI-3. WAVE LENGTH OF THE LARGE WAVES in Telles' data. But if his data is carefully reexamined, one would find that he only presented the data possessing a constant slope and neglected the data above that region. In this section, we will discuss the possible reason for this phenomena. One reasonable assumption is that the process $\hat{h}(t)$ contains two components, $\hat{h}_A(t)$ and $\hat{h}_B(t)$. $\hat{h}_A(t)$ is moving at constant velocity C, i.e. $\hat{h}_A(t) = \hat{h}_A(t)\left(\frac{-x}{c} + t\right)$ while $\hat{h}_B(t)$ is a unknown process. We further assume $\hat{h}_A$ can be approximated by a fourier sine series. Then at two measuring locations, 1 and 2, the observed signals would be

$$\hat{h}_1(t) = \hat{h}_A\left(t - \frac{x}{c}\right) + \hat{h}_B(t) \quad \text{at } x = 0 \text{ ---(VI-8)}$$

$$\hat{h}_2(t) = \hat{h}_A\left(t - \frac{x}{c}\right) + \hat{h}_B(t) \quad \text{at } x = \ell \text{ ---(VI-9)}$$

$$h_A\left(t - \frac{x}{c}\right) = \sum_{j=1}^{n} \hat{a}_j \operatorname{Sin} \frac{2}{T_j}\left(t - \frac{x}{c}\right) \quad \text{------(VI-10)}$$

while $T_j = jT_1$

Now assume $\hat{h}_A(t)$ and $\hat{h}_B(t)$ are uncorrelated, and $h_A(t)$ and $\hat{h}_B(t)$ have zero mean.

Then the cross spectrum is

$$\tilde{S}_{12}(\omega) = \sum_{j=1}^{n} \frac{a_j^2}{2}\pi \cos j\omega_1 \frac{\ell}{c}\,\delta(j\omega_1 - \omega) + i\sum_{j=1}^{n} \frac{a_j^2}{2}\pi \operatorname{Sin} j\omega_1\frac{\ell}{c}(j\omega_1 - \omega)$$

$$+ \tilde{S}_{BB}(\omega) \text{ ---------- (VI-11)}$$

where ω is angular frequency

δ is Delta function

$$\omega_1 = \frac{2\pi}{T_1}$$

$$\omega_j = \frac{2\pi}{T_j} = j\omega_1$$

Suppose the real and imaginary part of $\widetilde{S}_{BB}(\omega)$ are also represented by the delta function as

$$\widetilde{S}_{BB}(\omega) = \sum_{j=1}^{n} b_j^2\, \delta(j\omega_1 - \omega) + i \sum_{j=1}^{n} c_j^2\, \delta(j\omega_1 - \omega) \quad \text{----} \quad (\text{VI}-12)$$

then

$$\widetilde{S}_{12}(\omega) = \sum_{j=1}^{n} \left\{ \frac{a_j^2}{2}\pi \cos j\omega_1 \frac{l}{c} + b_j^2 \right\} \delta(j\omega_1 - \omega)$$
$$+\, i \sum_{j=1}^{n} \left\{ \frac{a_j^2}{2}\pi \sin j\omega_1 \frac{l}{c} + c_j^2 \right\} \delta(j\omega_1 - \omega) \quad \text{---} \quad (\text{VI}-13)$$

Hence the phase spectrum is

$$\widetilde{\theta}_{12}(\omega) = \tan^{-1} \frac{\sum_{j=1}^{n} \left\{ \frac{a_j^2}{2}\pi \cos j\omega_1 \frac{l}{c} + b_j^2 \right\} \delta(j\omega_1 - \omega)}{\sum_{j=1}^{n} \left\{ \frac{a_j^2}{2}\pi \sin j\omega_1 \frac{l}{c} + C_j^2 \right\} \delta(j\omega_1 - \omega)} \quad \text{---} \quad (\text{VI}-14)$$

Equation (VI-14) indicates that the phase spectrum will be affected by the energy contained in the unknown processes b_j^2 and c_j^2.

Suppose

(a) $\omega = 0 \sim n_1\omega_1 \qquad n_1 < n$

$$\frac{a_i^2}{2}\pi \gg b_i^2 , \quad \frac{a_i^2}{2}\pi \gg C_i^2$$

and

$$j\omega_1 \frac{l}{c} \neq m\frac{\pi}{2} \qquad m = 1, 2, \cdots$$

then

$$\widetilde{\theta}_{12}(\omega) \simeq j\omega_1 \frac{l}{c} \qquad j = 1, \cdots, n_1 \quad \text{----} \quad (\text{VI}-15)$$

(b) $\omega = (n_1+1)\,\omega_1 \sim n_2\,\omega_1 \qquad n_2 < n$

$$\frac{a_i^2}{2}\pi \simeq b_i^2 \qquad \frac{a_i^2}{2}\pi \simeq c_i^2$$

then $\widetilde{\Theta}_{12}$ will not be on the same slope.

(c) $\omega = (n_2+1)\,\omega_1 \sim n\omega_1$

$$\frac{a_i^2}{2}\pi << b_i^2 \;, \quad \frac{a_i^2}{2}\pi << c_i^2$$

then

$$\widetilde{\Theta}_{12}(j\omega_1) = \tan^{-1}\left(\frac{b_j^2}{c_j^2}\right) \qquad j = n_2+1, \cdots, n \quad \text{--- (VI-16)}$$

This implies that the phase is controlled by the unknown process. The above result is illustrated in Fig. VI-4. This is precisely the appearance of all the phase angle data.

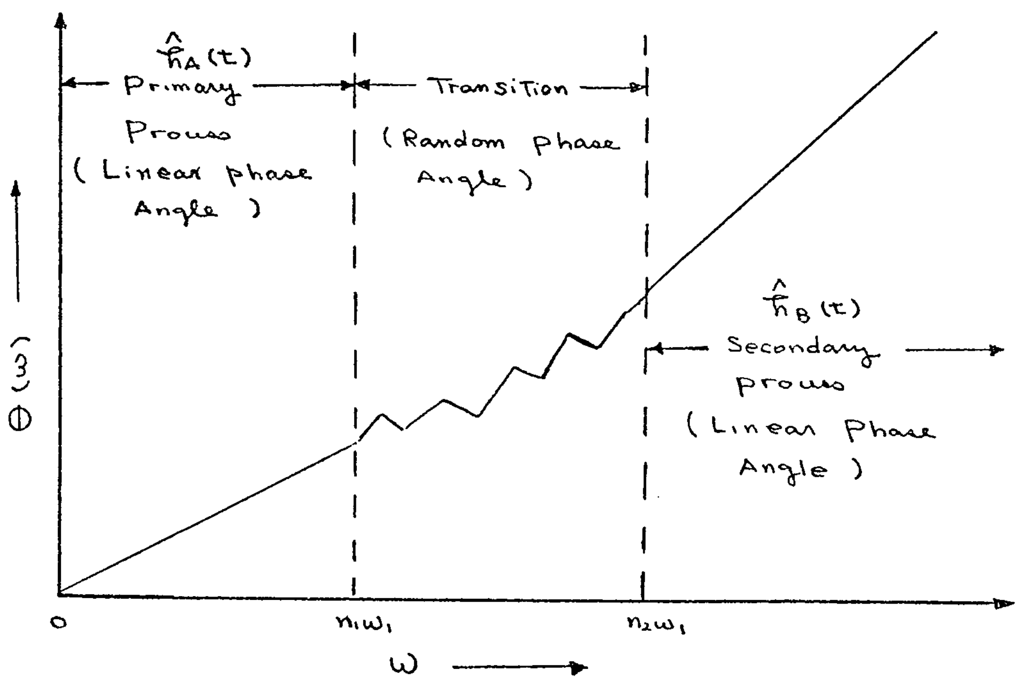


FIG. VI-4 PHASE SPECTRUM

2-3. SECONDARY LARGE WAVE VELOCITY

From the above analysis, it is clear that the non-linearity of the phase spectrum is due to the processes containing a component which is not moving at the primary wave velocity C. The next step is to find the component which is moving at a velocity C', different from C and determine its value. Numerous techniques to obtain the wave velocity for different components have been pointed out by Seriff (S-9). One of the most powerful methods is the two dimensional spectrum which is used by geophysicists and oceanographers. In the present study, only four unequal spacing probe were employed. This is too few measurements to apply two dimensional Fourier Transform techniques. The method used in this section involves the subtraction of two signals measured at the two stations.

Consider that the process $\hat{h}_B$ in equations (VI-8) and (VI-9) is moving at velocity C', then

$$\hat{h}_1(t) = \hat{h}_A(t) + \hat{h}_B(t) \quad \text{at } x = 0 \quad --- \quad (\text{VI}-17)$$

$$\hat{h}_2(t) = \hat{h}_A(t-\tau_1) + \hat{h}_B(t-\tau_2) \quad \text{at } x = l \quad --- \quad (\text{VI}-18)$$

where $\tau_1 = \frac{l}{C}$ and $\tau_2 = \frac{l}{C'}$

The above two relations are shown schematically in Fig. VI-5.

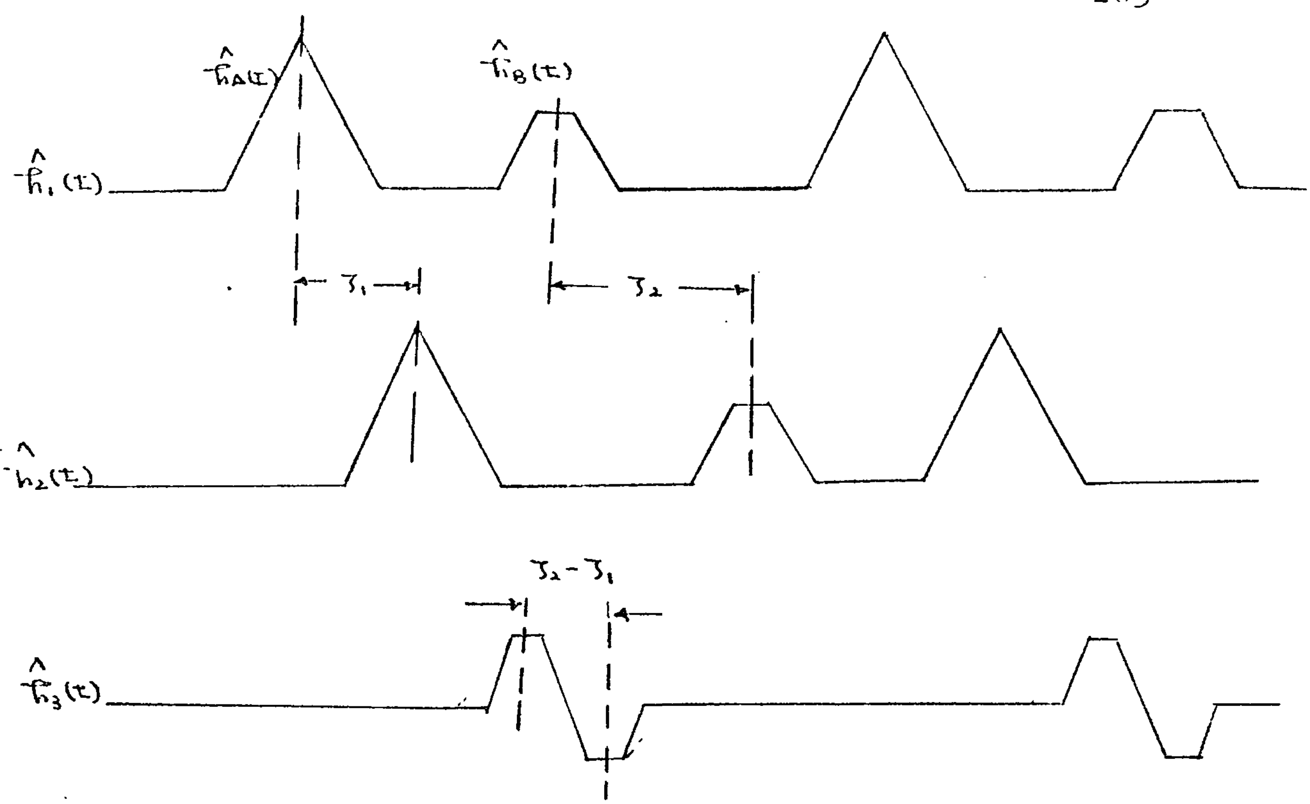


FIG. VI-5. SUBTRACTION OF TWO SIGNALS

Shift $\hat{h}_2(t)$ by time τ_1, then subtract two signals, we obtain a new signal $\hat{h}_3(t)$ as:

$$\begin{aligned}\hat{h}_3(t) &= \hat{h}_1(t) - \hat{h}_2(t + \tau_1) \\ &= \hat{h}_B(t) - h_B(t + \tau_1 - \tau_2) \quad \text{-----(VI-19)}\end{aligned}$$

The covariance of $\hat{h}_3(t)$ becomes

$$\begin{aligned}\tilde{C}_{33}(\tau) &= \langle \hat{h}_3(t+\tau)\, \hat{h}_3(t) \rangle \\ &= 2\,\tilde{C}_{BB}(\tau) - \tilde{C}_{BB}(\tau - \tau_1 + \tau_2) \\ &\quad - \tilde{C}_{BB}(\tau + \tau_1 - \tau_2) \quad \text{--(VI-20)}\end{aligned}$$

Equation (VI-20) shows that $\tilde{C}_{33}(\tau)$ has one positive peak at $\tau = 0$ and two negative peaks one at $\tau = \tau_1 - \tau_2$ and one at $\tau = \tau_2 - \tau_1$. Since τ_1 is a known quantity, from the location of negative peaks of $\tilde{C}_{33}(\tau)$ one can obtain

$$C' = \frac{\ell}{\tau' + \tau_1} \qquad \text{----------- (VI-21)}$$

where $\tau' = \tau_2 - \tau_1$ = location of negative peak .

The above discussion neglects the change in amplitude between $\hat{h}_1(t)$ and $\hat{h}_2(t)$. Actual data show this is not negligible. In order to compensate for this amplification factor, A_f, one considers

$$\hat{h}_2(t) = \frac{1}{A_f}\hat{h}_A(t-\tau_1) + \frac{1}{A_f}\hat{h}_B(t-\tau_2) \qquad \text{--- (VI-22)}$$

The amplification factor can be obtained from the covariance function $\tilde{C}_{11}(\tau)$, $\tilde{C}_{22}(\tau)$ and $\tilde{C}_{12}(\tau+\tau_1)$ by the following three equations:

$$\tilde{C}_{11}(\tau) = \tilde{C}_{AA}(\tau) + \tilde{C}_{BB}(\tau) \qquad \text{------(VI-23)}$$

$$\tilde{C}_{22}(\tau) = \frac{1}{A_f^2}\left(\tilde{C}_{AA}(\tau) + \tilde{C}_{BB}(\tau)\right) \text{--(VI-24)}$$

$$\tilde{C}_{12}(\tau+\tau_1) = \frac{1}{A_f}\left(\tilde{C}_{AA}(\tau) + \tilde{C}_{BB}(\tau+\tau_1-\tau_2)\right)$$

$$= \frac{1}{A_f}\left(\tilde{C}_{AA}(\tau) + \tilde{C}_{BB}(\tau)\right) \text{--(VI-25)}$$

From equation (VI-20), the spectral density of $\hat{h}_B(t)$ can also be obtained

$$\tilde{S}_{BB}(\omega) = \frac{1}{2}\,\frac{1}{1-\cos\omega|\tau_2-\tau_1|}\,\tilde{S}_{33}(\omega) \qquad \text{--- (VI-26)}$$

Since the subtraction process is not perfect, the $\tilde{C}_{33}(\tau)$ contains not only the information on $\hat{h}_B(t)$, but also the residues of $\hat{h}_A(t)$ and the component which is not moving at either C or C'. This effect can be found from the quantity $F_n \gg 0$.

$$F_n = \tilde{C}_{33}(0) - 2\,\tilde{C}_{33}(\tau_1-\tau_2) \qquad \text{------ (VI-27)}$$

In order to extract the power spectral density containing only $\hat{h}_B$, one modifies equation (VI-26) into

$$\widetilde{S}_{BB}(\omega) = \frac{1}{2}\,\frac{\widetilde{S}_{33}(\omega) - A_n(\omega)}{1 - \cos\omega|z_2 - z_1|} \qquad \text{(VI-28)}$$

$$A_n(\omega) = \frac{\pi F_n}{f_c} \qquad \text{(VI-29)}$$

where f_c is folding frequency of $\widetilde{S}_{33}(\omega)$

Equation (VI-29) implies that the noise component F_N is uniformly distributed in $\widetilde{S}_{33}(\omega)$ (white noise assumption). The calculated values of C' obtained from the above procedures are compared with the primary wave velocity in Table VI-1.

W_L(lb/sec)	C	C'	f_m	$f_m^{(B)}$	$S_{11}(f_m)$	$S_{BB}(f_m^{(B)})$
0.016	1.50	1.41	0.671	4.578	0.043	0.019
0.044	4.09	3.41	1.648	4.089	0.0546	0.0076
0.126	5.01	4.21	3.601	6.042	0.1013	0.0062
0.24	5.58	4.76	4.089	6.531	0.0619	0.01012
0.35	6.91	5.69	3.601	7.507	0.0649	0.00721
0.585	8.30	6.75	5.066	6.531	0.0642	0.00352

TABLE VI-1. PROPERTIES OF SECONDARY WAVES
$W_G = 0.0$ lb/sec

In Table VI-1, f_m, $f_m^{(B)}$ are the modal frequency of $\widetilde{S}_{11}(f)$ and $\widetilde{S}_{BB}(f)$ respectively. The corresponding slope of phase spectra for C' is also plotted in Fig. VI-6 with the actual data. From the frequency band of the corresponding slope of phase spectra for C', it is obvious that the wave velocity

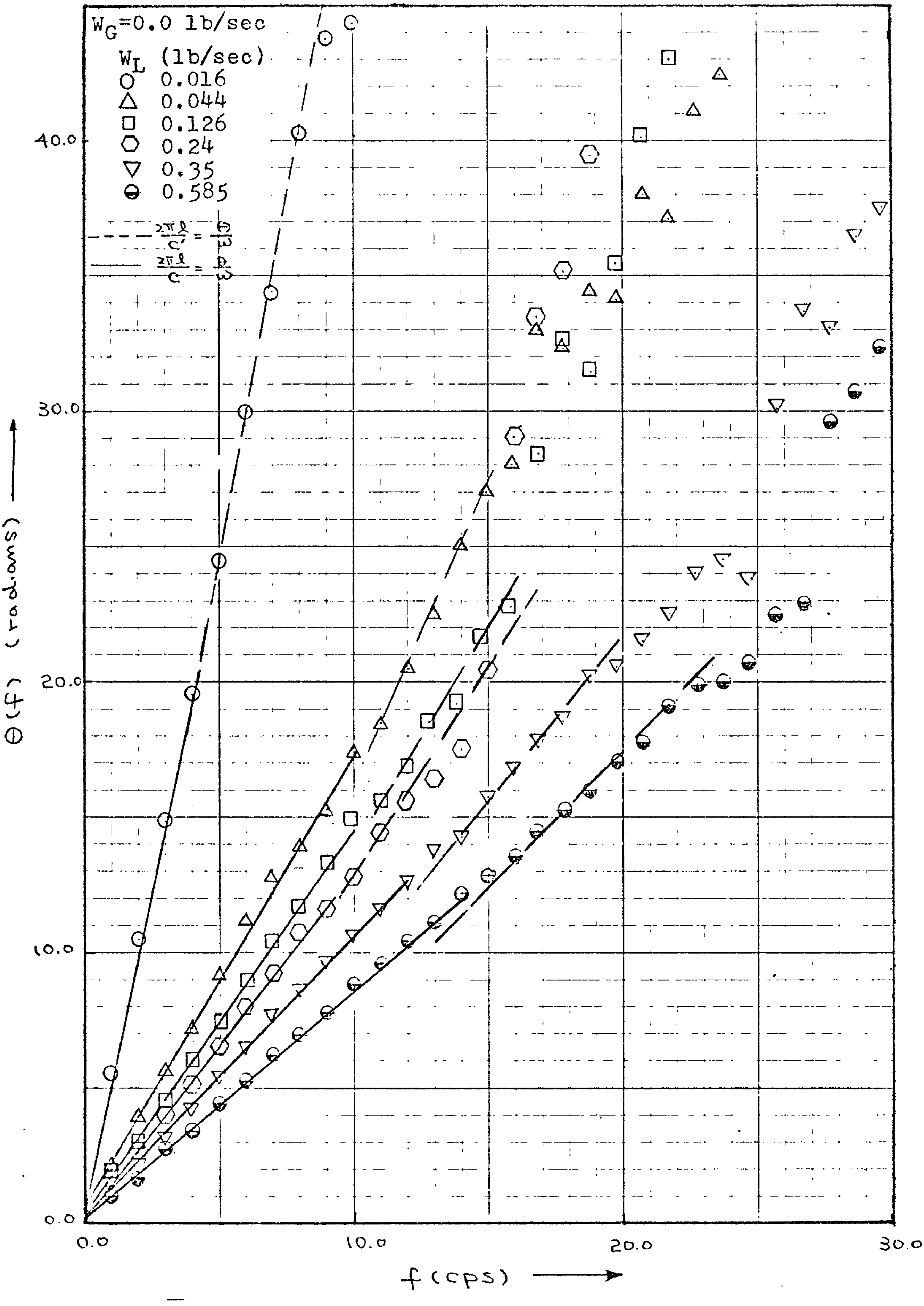


Fig. VI-6. COMPARISON OF C AND C' ON PHASE SPECTRA which has thus been obtained is for a secondary large wave.

2-4. WAVE VELOCITY AND WAVE LENGTH OF SMALL WAVES

One very important result of the previous section is that the local slope of the phase spectrum evaluated at certain frequency is related to the wave velocity of the wave having that frequency. This can also be derived analytically. Assuming $\hat{h}_B(t)$ in equation (VI-8) and (VI-9) to be represented by a Fourier sine series with a wave velocity C'.

$$\hat{h}_B\left(t-\frac{x}{C'}\right)=\sum_{j=k}^{m} b_j \sin\frac{2\pi}{T_j}\left(t-\frac{x}{C'}\right) \qquad (\text{VI-30})$$

where $1 \leq k < n < m$

then the equation (VI-14) becomes

$$\tilde{\Theta}_{12}(\omega)=\tan^{-1}\frac{\left\{\sum_{j=1}^{n}\frac{a_j^2}{2}\pi\sin j\omega_1\frac{l}{C}+\sum_{j=k}^{m}\frac{b_j^2}{2}\pi\sin j\omega_1\frac{l}{C'}\right\}\delta(j\omega_1-\omega)}{\left\{\sum_{j=1}^{n}\frac{a_j^2}{2}\pi\cos j\omega_1\frac{l}{C}+\sum_{j=k}^{m}\frac{b_j^2}{2}\pi\cos j\omega_1\frac{l}{C'}\right\}\delta(j\omega_1-\omega)} \qquad (\text{VI-31})$$

similarly the result will be

$$\tilde{\Theta}_{12}(\omega)=j\omega_1\frac{l}{C} \quad \text{for } j=1,\ldots,k-1 \qquad (\text{VI-32})$$

$$\tilde{\Theta}_{12}(\omega)=j\omega_1\frac{l}{C'} \quad \text{for } j=n+1,\ldots,m \qquad (\text{VI-33})$$

Based on the above result, one would ask whether a constant slope of phase spectrum can be found in the frequency range for small waves. If so, the wave velocity of small wave, C_s, can be extracted. The data of phase spectrum in the range of small wave frequencies shows another slope. But the data are inconsistent and fluctuate widely in this region. This is probably due to the fact that the primary velocity of the small and large waves are very different and the digitizing interval used for the small phase angle of the large waves is not suitable for the large phase angle associated with the small waves. A technique is available to eliminate the effect of the primary waves on the signals for the small waves at the two positions.

$$\hat{h}_1(t) = \sum_{j=1}^{n} a_j \sin \frac{2\pi}{T_j} t + \sum_{j=k}^{m} b_j \sin \frac{2\pi}{T_j} t \qquad \text{at } x = 0$$

$$\hat{h}_2(t) = \sum_{j=1}^{n} a_j \sin \frac{2\pi}{T_j}\left(t - \frac{\ell}{C}\right) + \sum_{j=k}^{m} b_j \sin \frac{2\pi}{T_j}\left(t - \frac{\ell}{C_s}\right) \qquad \text{at } x = \ell$$

Now shift $\hat{h}_2(t)$ by $\tau_1 = \frac{\ell}{C}$

$$\hat{h}_3(t) = \hat{h}_2(t+\tau_1) = \sum_{j=1}^{n} a_j \sin \frac{2\pi}{T_j}\left(t - \frac{\ell}{C} + \tau_1\right) + \sum_{j=k}^{m} b_j \sin \frac{2\pi}{T_j}\left(t - \frac{\ell}{C_s} + \tau_1\right) \qquad \text{---(VI-34)}$$

The phase spectrum will be

$$\tilde{\theta}_{13}(\omega) = \tan^{-1} \frac{\left\{ \sum_{j=1}^{n} \frac{a_j^2}{2} \pi \sin j\omega_1 \left(\frac{\ell}{C} - \tau_1\right) + \sum_{j=k}^{m} \frac{b_j^2}{2} \pi \sin j\omega_1 \left(\frac{\ell}{C_s} - \tau_1\right) \right\} \delta(j\omega_1 - \omega)}{\left\{ \sum_{j=1}^{n} \frac{a_j^2}{2} \pi \cos j\omega_1 \left(\frac{\ell}{C} - \tau_1\right) + \sum_{j=k}^{m} \frac{b_j^2}{2} \pi \cos j\omega_1 \left(\frac{\ell}{C_s} - \tau_1\right) \right\} \delta(j\omega_1 - \omega)} \qquad \text{---(VI-35)}$$

Since $\frac{\ell}{C} - \tau_1 = 0$ equation (VI-35) becomes

$$\tilde{\theta}_{13}(\omega) = \begin{cases} 0 & \text{for } j = 1, \cdots, k-1 \\ 0 & \text{if } a_j^2 \gg b_j^2 \text{ for } j = k, \cdots, n \\ j\omega_1\left(\frac{\ell}{C_s} - \tau_1\right) & \text{if } a_j^2 \ll b_j^2 \text{ for } j = k, \cdots, n \\ j\omega_1\left(\frac{\ell}{C_s} - \tau_1\right) & \text{for } j = n+1, \cdots, m \end{cases} \qquad \text{----(VI-36)}$$

A typical phase spectrum obtained by the above method is shown in Fig. VI-7. The wave velocity, C_s, is thus extracted from the above curve and the wave length λ calculated from $C_s \langle T_{bs} \rangle$. Results for the small waves are tabulated in Table VI-2.

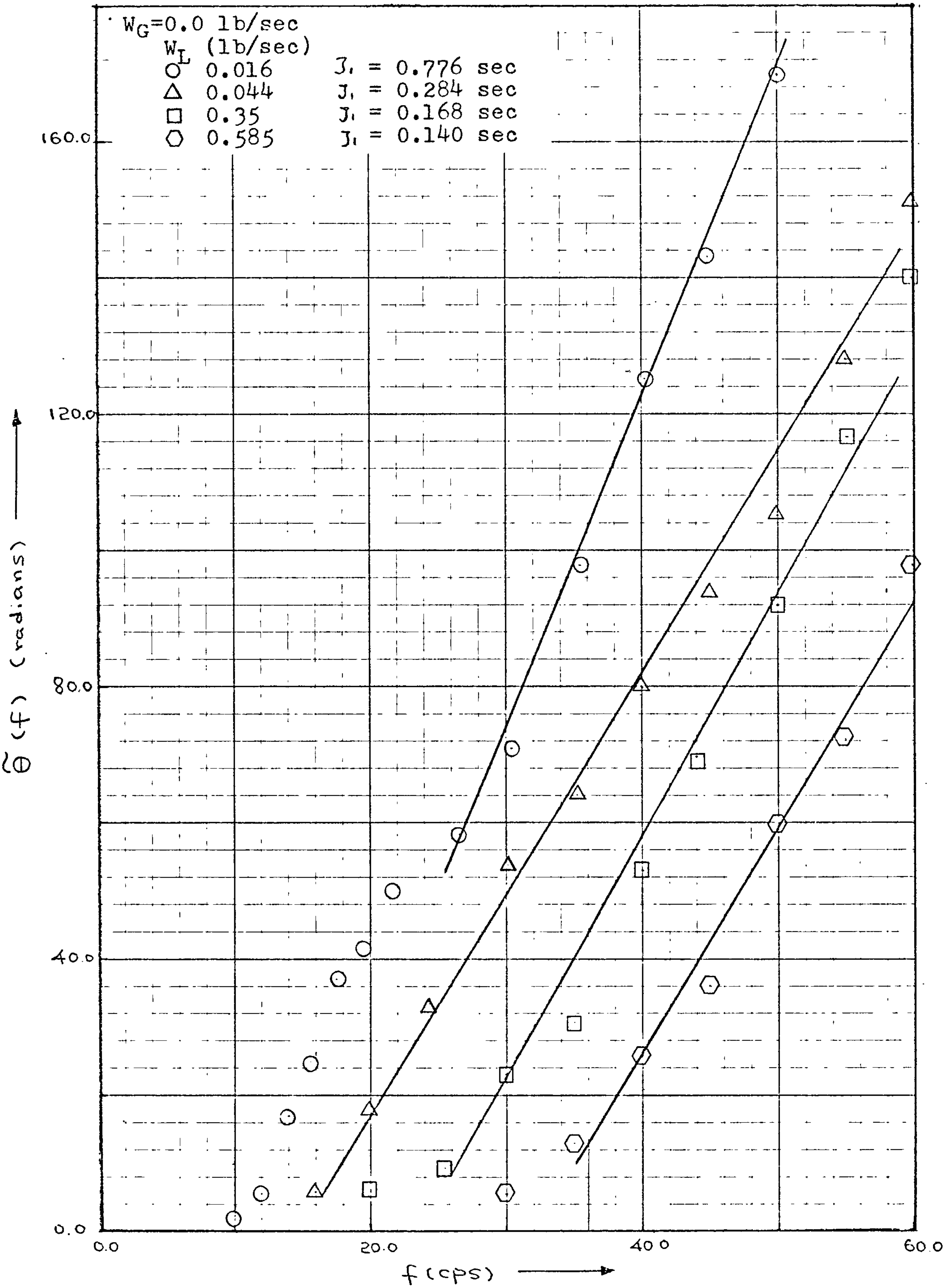


Fig. VI-7. PHASE SPECTRA

TABLE VI-2. WAVE VELOCITY AND WAVE LENGTH OF SMALL WAVES

W_L (lb/sec)	W_G = 0.0 lb/sec C_s (ft/sec)	λ (ft)	W_G = 0.1436 lb/sec C_s (ft/sec)	λ (ft)
0.016	0.74	0.0209	0.903	0.0107
0.028	1.19	0.0438	1.17	0.0175
0.044	1.39	0.0585	1.25	0.0408
0.08	1.405	0.0630	1.41	0.0455
0.126	1.410	0.0585	1.412	0.0470
0.18	1.46	0.0545	2.15	0.0680
0.24	1.63	0.0575	2.18	0.0667
0.35	2.02	0.0608	2.29	0.0610
0.47	2.10	0.0585	2.38	0.0567
0.585	2.39	0.0580	3.00	0.0655

3. SPECTRA AND CORRELATION OF FILM THICKNESS

In this section, the important properties of spectral density and correlation function of film thickness and its physical meaning will be explored. Telles considered a periodic sine wave process with random phase $a\mathrm{SIN}\,(2\pi f_m t + \hat{\theta})$ to study the power spectrum of film thickness. Since the spectral density of the above process is a Delta function, he concluded that the modal frequency is the most commonly found frequency of the waves. From this the average wave separation distance and time was calculated.

In this work the wave separation and the wave amplitude of large waves are shown to have a wide distribution. Thus, Telles' argument is not valid. One would expect a more general analysis could be done.

Consider h(t) a stochastic process as follow:

$$\hat{h}(t) = a \sin (2\pi \hat{f} t + \hat{\theta}) \quad \text{-------------} (\text{VI-37})$$

where $\hat{f}$, $\hat{\theta}$ are two independent random variables. $\hat{f}$ has a even probability density function, while $\hat{\theta}$ is a uniform distribution function.

The auto-correlation function and the spectral density function of this process will be

$$\tilde{R}(\tau) = \frac{a^2}{2} \int_{-\infty}^{+\infty} \tilde{f}(f) \cos 2\pi f \, df \quad \text{--------} (\text{VI-38})$$

$$\tilde{S}(f) = \frac{a^2}{2} \left\{ \tilde{f}(f) + \tilde{f}(-f) \right\} \quad \text{--------} (\text{VI-39})$$

Hence if the amplitude of the waves is the same, the modal frequency f_m is related to the modal value of the probability density function of wave frequency (or wave separation). The wave amplitude posesses a widely spread density function so it is necessary to consider this effect too. Consider $\hat{h}(t)$ as another stochastics process.

$$\hat{h}(t) = \sum_{j=1}^{n} \hat{a}_j \sin 2\pi f_j t \quad ---- \quad (\text{VI-40})$$

where $\hat{a}_j$ is an independent random variable associated a frequency f_j.

The result of this process is

$$\tilde{R}(\tau) = \sum_{j=1}^{n} \langle \hat{a}_j^2 \rangle \cos 2\pi f_j \tau \quad ----- \quad (\text{VI-41})$$

$$\tilde{S}(f) = \sum_{j=1}^{n} \langle \hat{a}_j^2 \rangle \left\{ \delta(f-f_j) + \delta(f+f_j) \right\} -- (\text{VI-42})$$

This result shows clearly that the maximum peak of S(f) will be located at f_m such that $\langle \hat{a}_m^2 \rangle \geq \langle \hat{a}_j^2 \rangle$ for $j = 1, ----, n$ and the secondary peak of R (τ) is at position τ_m such that $f_m \tau_m = 1$.

There are two special cases in the above equations (VI-38), (VI-39), (VI-41) and (VI-42).

(a) if $\tilde{f}(f) = \delta(f - f_k)$ and $\langle \hat{a}_k^2 \rangle >> \langle \hat{a}_j^2 \rangle$ for $j \neq k$

then

$$\tilde{R}(\tau) = a^2 \cos 2\pi f_k$$

$$\tilde{S}(f) = a^2 \delta(f - f_k) \quad f > 0$$

This is the case corresponding to Telles' consideration

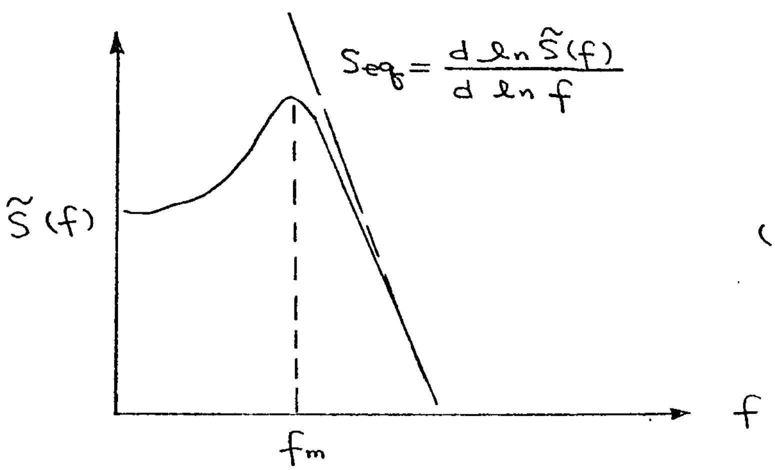
(b) if $\tilde{f}(f) = 1$ or $\langle \hat{a}_k^2 \rangle = \langle \hat{a}_j^2 \rangle$ for

$j, k = 1, \cdots, n$

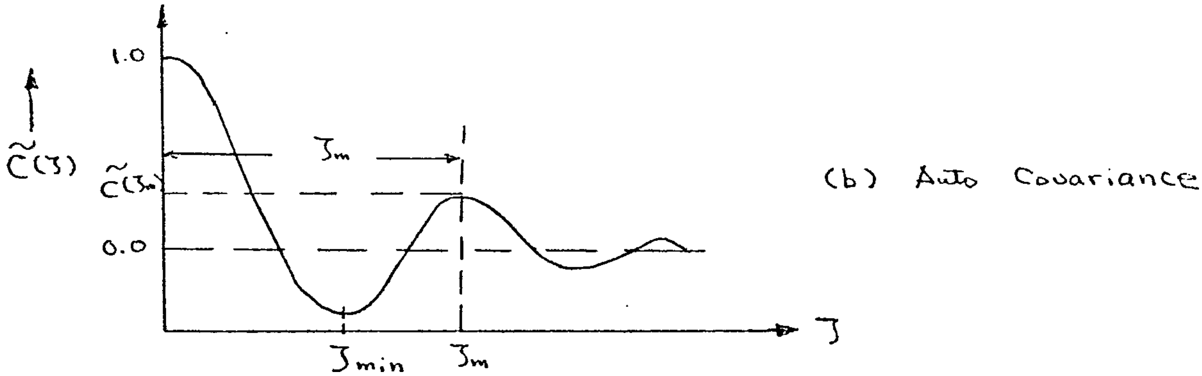
then $$\tilde{R}(\tau) = a^2 \delta(\tau)$$

$$\tilde{S}(f) = a^2$$

This result is a so called "white noise" process. The actual data for film thickness show that the result is somewhat between the above two special cases. Comparing with other wave data such as wind waves, the spectral density of film thickness shows a much wider spread with frequency, while the periodicity of the correlation is much weaker. In order to have more specific understanding of these statistical functions and their relation to the wave paramter, one would study the following quantities: f_m, τ_m, τ_{min}, $\tilde{C}(\tau_m)$, $\tilde{C}_{12}(\tau_1)$, and S_{eq} as shown in Fig. VI-8.



(a) Spectrum



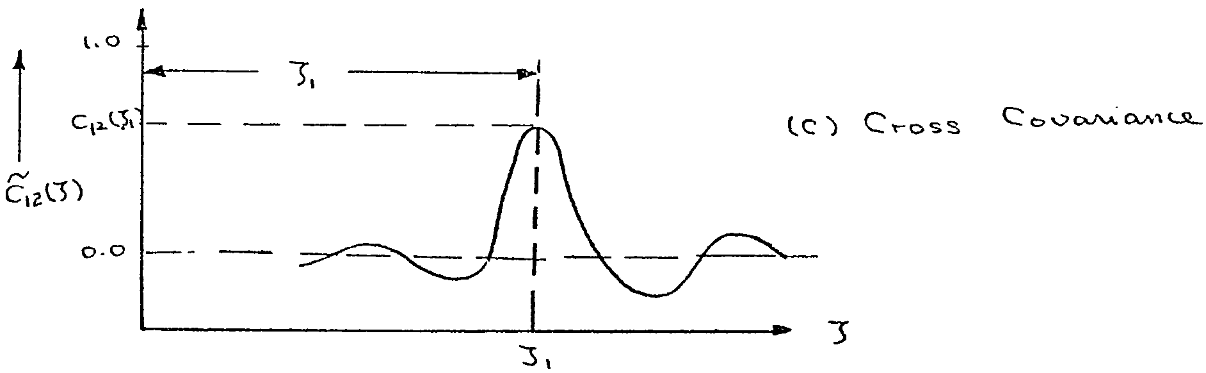


FIG. VI-8. PARAMETERS OF SPECTRUM AND COVARIANCE

3-1. MODAL FREQUENCY, MEAN PERIOD, AND MEAN BASE LENGTH

The modal frequency, f_m, defined above at condition W_G = 0.0 lb/sec is compared with the data of Telles and Webb in Fig. VI-9. The trend shows fair agreement. The modal frequency of spectrum and cross spectrum are usually the same. A double peak structure in cross spectrum and sometime also in auto spectrum appears in the range of small liquid flow rates. In the above figure, if the data suggest a

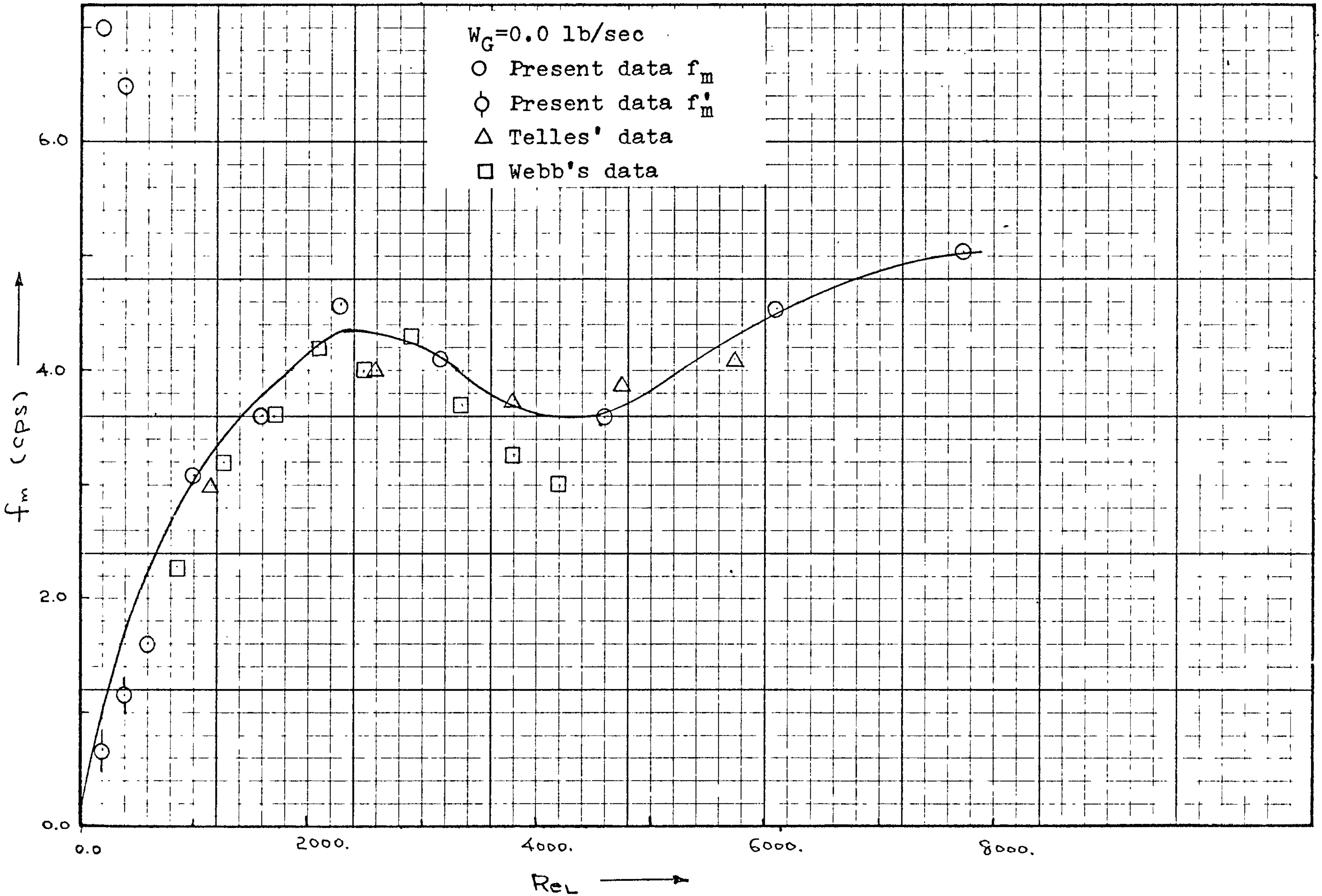


Fig. VI-9. MODAL FREQUENCY

double peak structure, the secondary peak will be represented by f'_m. As mentioned above, if the processes contain a periodic component strong enough to show a peak, then the correlation function $\widetilde{C}(\tau)$ will show a secondary peak at the mean period τ_m such that $f_m \tau_m = 1$. Therefore the data of $\frac{1}{\tau_m}$ and f_m should correspond. In Fig. VI-10, the data of $\frac{1}{\tau_m}$ and f_m vs. W_L are plotted for the gas flow rate $W_G = 0.0$ lb/sec and $W_G = 0.1436$ lb/sec. The relationship of $f_m \tau_m = 1$ is confirmed.

Since the modal frequency f_m or the mean period τ_m is related to not only the wave frequency but also the wave amplitude, it is necessary to find out what wave amplitude or wave maximum is associated with this modal frequency. The mean value of wave frequency, f_ℓ , for the large wave (defined in the previous chapter by $h_{max} > \langle h \rangle$) is much larger than the modal frequency, f_m, except at small flow rates. It is also impossible to find a wave separation, T_{sep}, to correspond to f_m in the joint histogram of T_{sep} vs. h_{max}. This is probably due to the fact that some of the large wave maximum, h_{max}, are not large enough to produce a positive component in the correlation at $\tau = T_{sep}$. Hence we need to discriminate some of the large waves having a smaller h_{max}. Redefine a new large wave separation T'_{sep} based on $h_{max} > 2\langle h \rangle$ as the following Fig. VI-11.

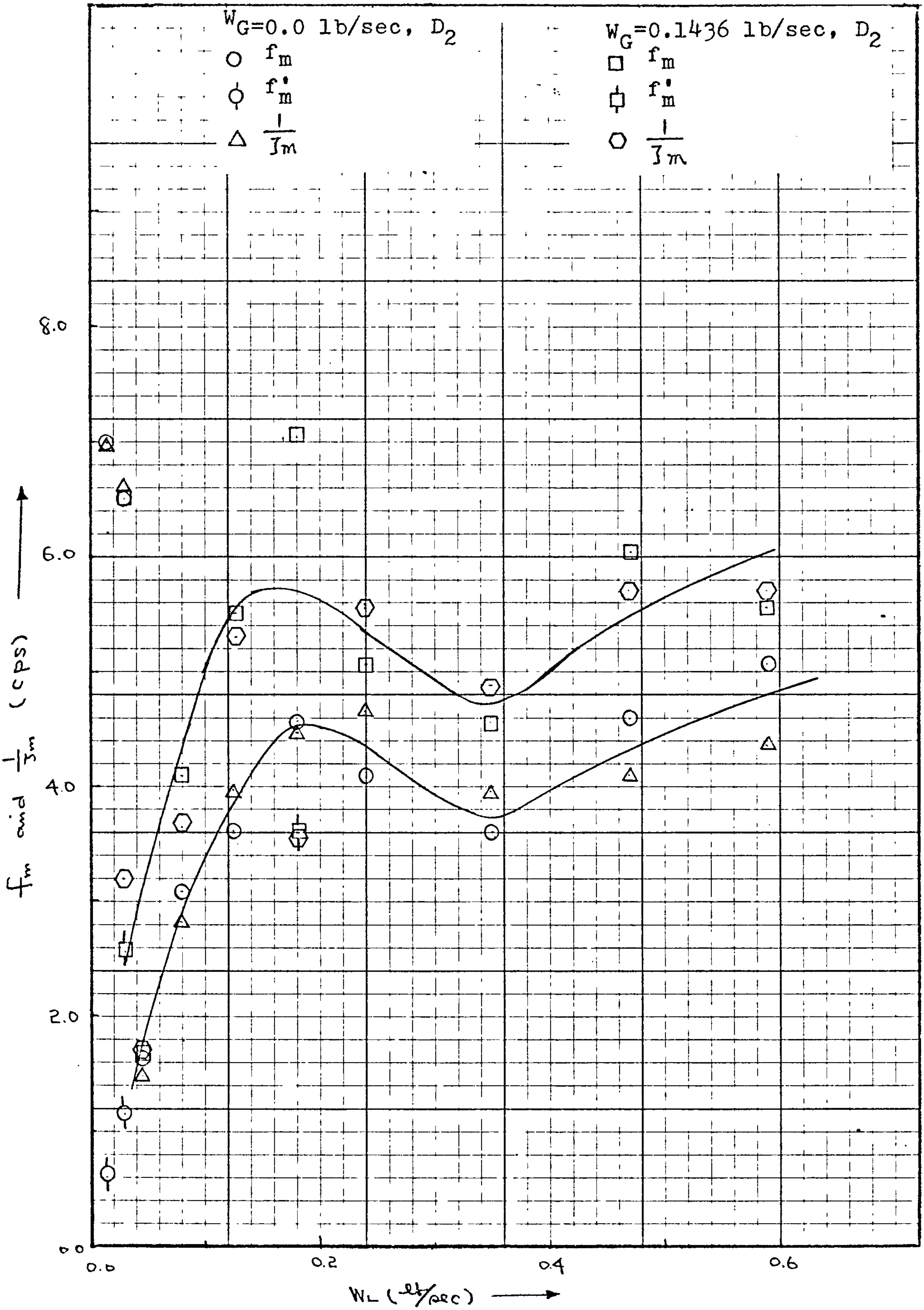


Fig. VI-10. MODAL FREQUENCY AND MEAN PERIOD

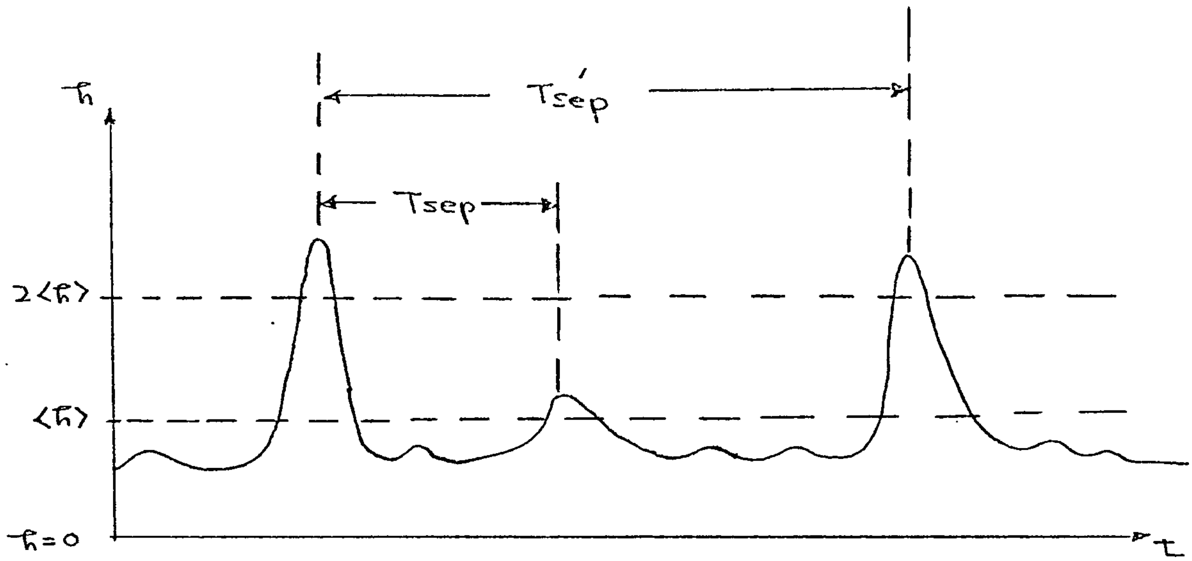


FIG. VI-11. NEW LARGE WAVE SEPARATION T'_{sep}

A typical joint probability of $h_{max} > 2\langle h \rangle$ and T'_{sep} is given in Fig. VI-12. The distributions show a single modal value with wide spread in the two dimensional domains. This indicate that the correlation function will have a weak periodical component at the modal value roughly equal to $\langle T'_{sep} \rangle$. The mean value of this new wave frequency $f'_{\ell} = \frac{1}{\langle T_{sep} \rangle}$ and f_{ℓ} vs. f_m is plotted in Fig. VI-13. The results of f'_{ℓ} show a fair agreement with f_m except the small liquid rates at which transition occurs. The value of f'_{ℓ} is a little higher than that of f_m in general. This

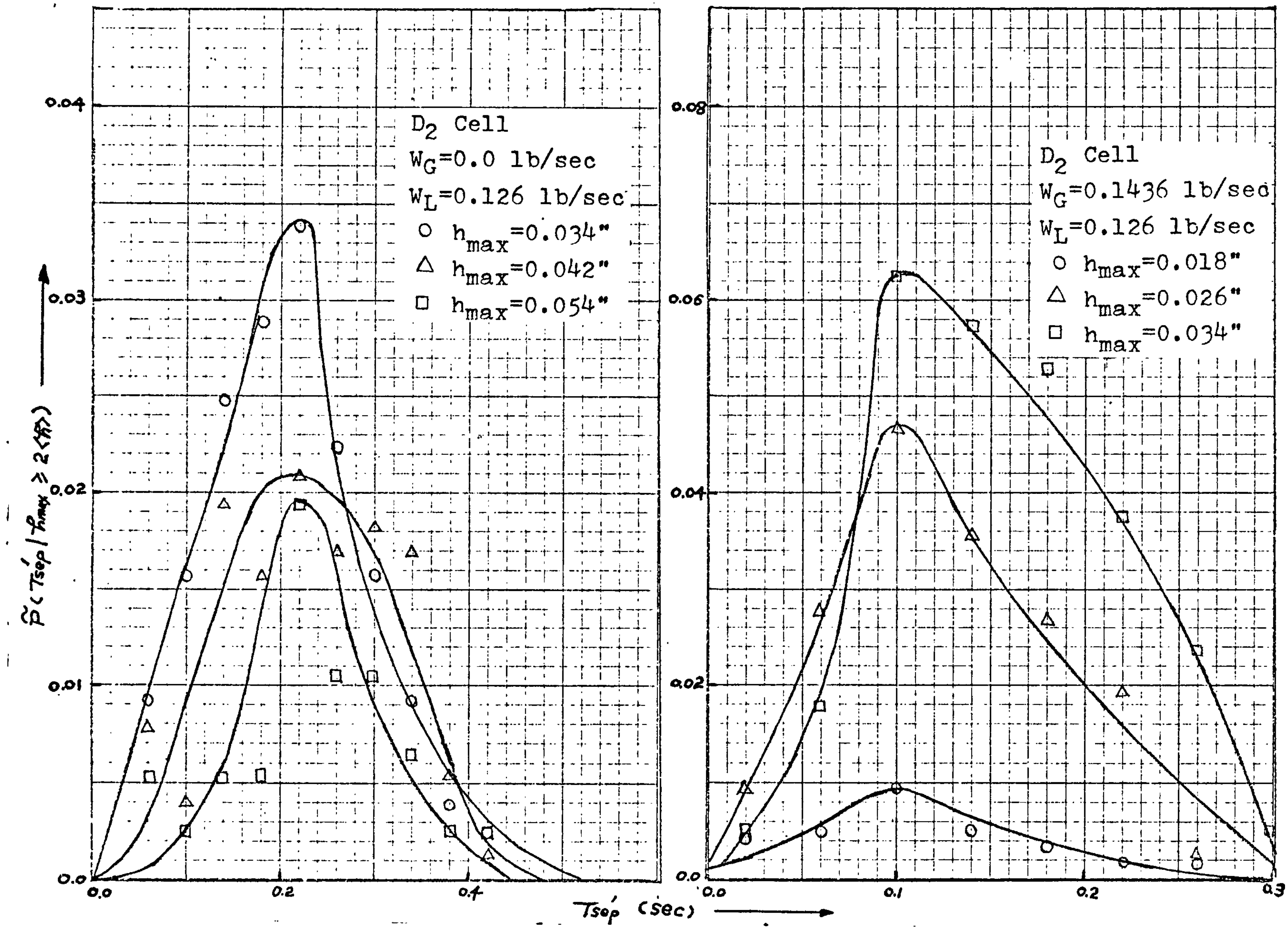


Fig. VI-12. JOINT PROBABILITY DENSITIES

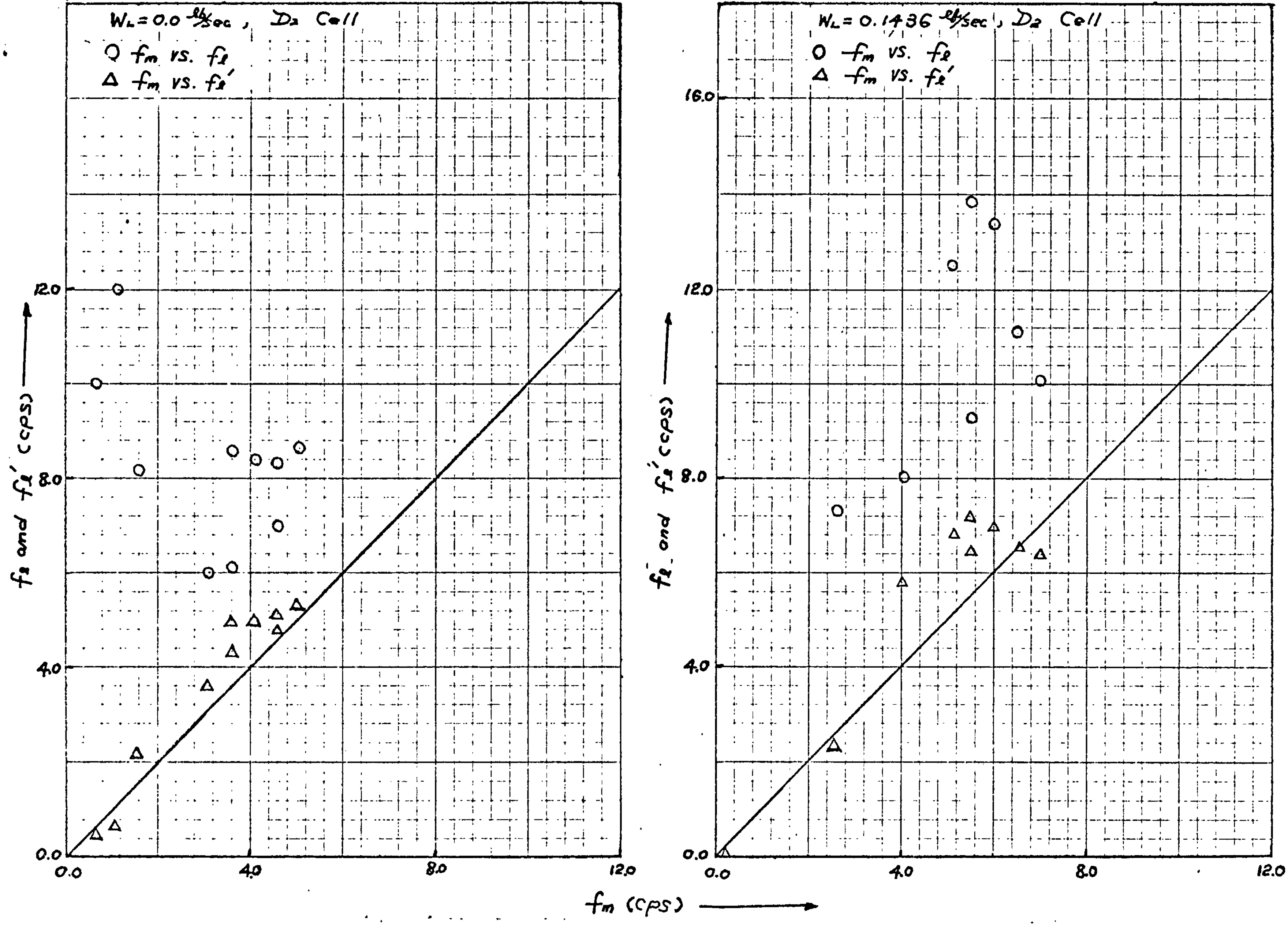


Fig. VI-13. MODAL FREQUENCY AND WAVE FREQUENCY is reasonable because the coupling of two large waves is treated as a large single wave in the actual calculating process of correlation function.

Another important quantity which can be extracted from the correlation function is the mean base time, τ_{min}. This mean base is well correlated with large wave base $\langle T_{bs} \rangle$ as shwon in Fig. VI-14. The reason is clear from the meaning of a correla'ion function. Some of the data have a large deviation. This is due to the difficulty in locating the minimum value of $\tilde{C}(\tau)$, when $\tilde{C}(\tau)$ had value near $\tilde{C}(\tau_{min})$.

The intensity of periodical component can be represented by $\tilde{C}(\tau_m)$. The value of $\tilde{C}(\tau_m)$ is usually in the range of $0.01 \sim 0.08$ which is very weak periodicity.

3-2. CROSS CORRELATION AND COHERENCY FUNCTION.

The cross covariance function of film thickness $\tilde{C}_{12}(\tau)$ which is presented as $\tilde{C}_{12}(\tau - \tau_1)$ in Chapter IV, is approximately the same as $\tilde{C}_{11}(\tau)$ and $\tilde{C}_{12}(\tau)$ except for the maximum value $\tilde{C}_{12}(\tau_1)$. This implies that the important features of the wave processes, $\hat{h}(t,x)$, between measuring stations, 1 and 2, are approximately unchanged. These features include, for example, the number of large waves, the relative wave maximum, the relative position of large waves etc. The cross covariance function shows an unsymmetrical shape about its maximum value, $\tilde{C}_{12}(\tau_1)$ as given in Chapter IV. This unsymmetrical properties can be

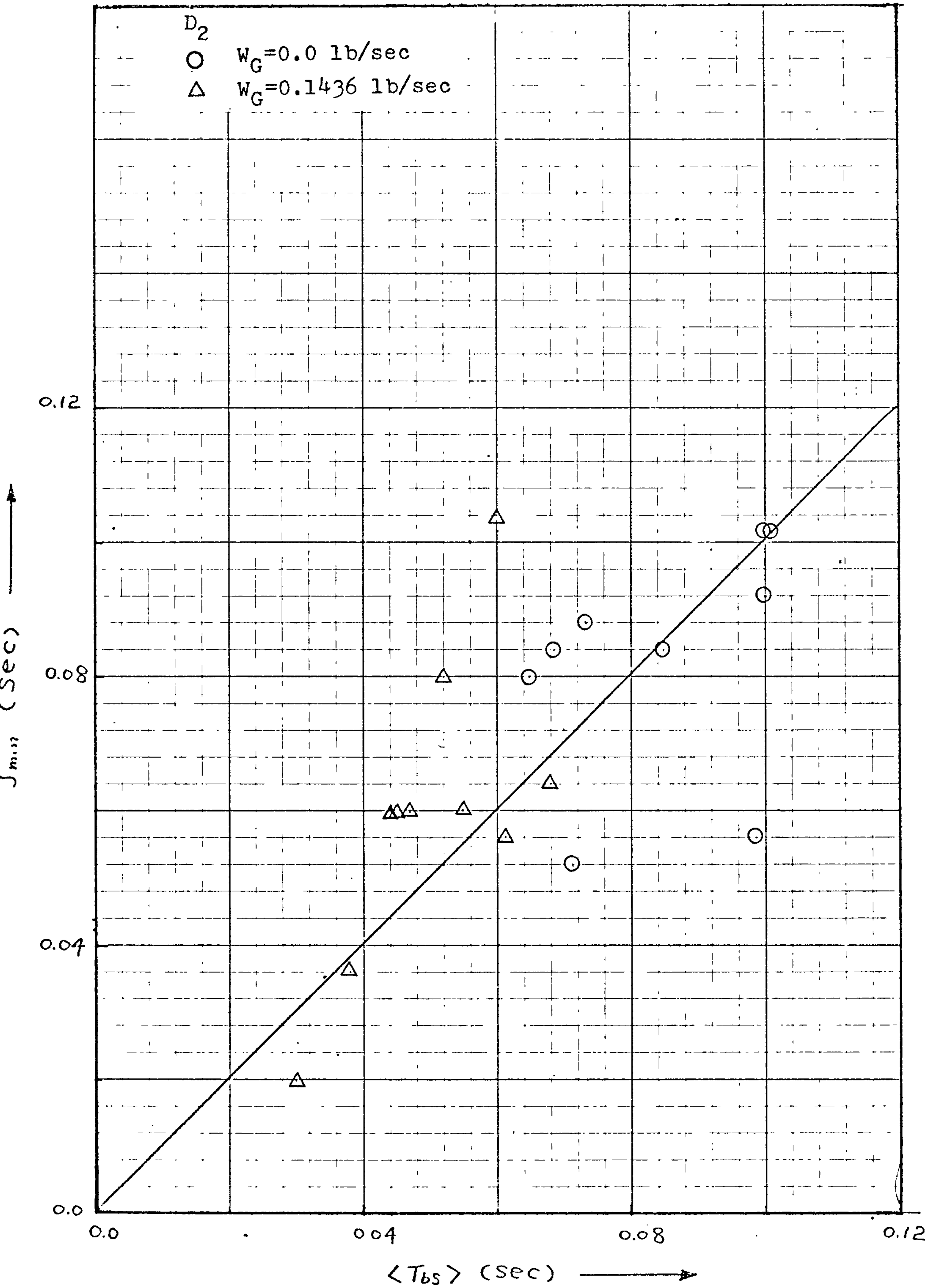


Fig. VI-14. MEAN BASE TIME AND WAVE BASE explained from the idea developed earlier that two distinct waves move with two different velocities given in equation VI-8), (VI-9), (VI-10), and (VI-30). Then the cross covariance of $\hat{h}_1(t)$ and $\hat{h}_2(t)$ will be

$$\tilde{C}_{12}(\tau) = \sum_{j=1}^{n} \frac{a_j^2}{2} \cos\omega_j(\tau - \frac{\ell}{c}) + \sum_{j=k}^{m} \frac{b_j^2}{2} \cos\omega_j(\tau - \frac{\ell}{c'}) \quad \text{(VI-43)}$$

$$\tilde{C}_A(\tau) = \sum_{j=1}^{n} \frac{a_j^2}{2} \cos\omega_j(\tau - \frac{\ell}{c}) \quad \text{(VI-44)}$$

$$\tilde{C}_B(\tau) = \sum_{j=k}^{m} \frac{b_j^2}{2} \cos\omega_j(\tau - \frac{\ell}{c'}) \quad \text{(VI-45)}$$

The above $\tilde{C}_A(\tau)$ and $\tilde{C}_B(\tau)$ are symmetrical about $\tau = \frac{\ell}{C}$ and $\tau = \frac{\ell}{C'}$ respectively. But the summation of these two is obvious not symmetrical about $\tau = \frac{\ell}{C}$. In studying the wave velocity, one knows that C' is smaller than C and b_j^2 is also smaller than a_j^2. Then the typical shape for $\tilde{C}_{12}(\tau)$ will be given as shown in Fig. VI-15.

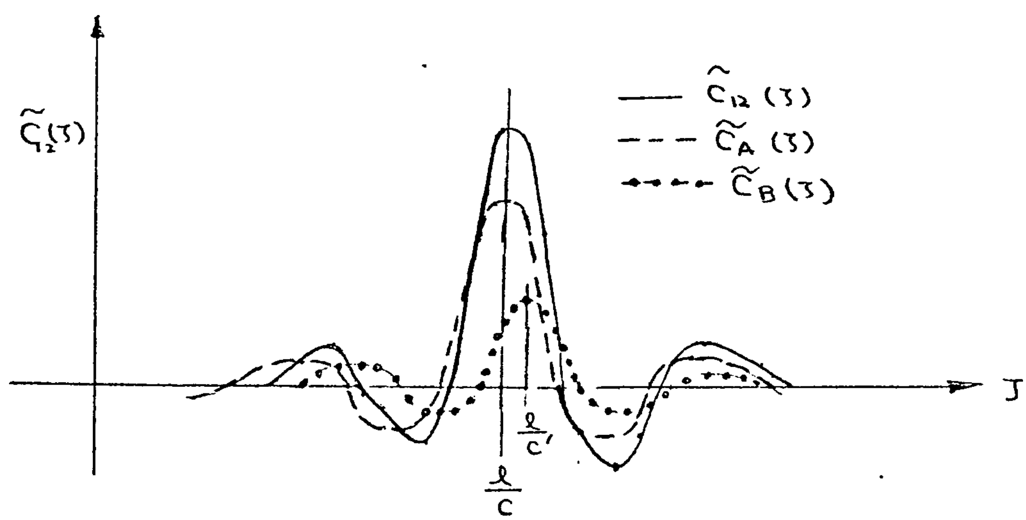
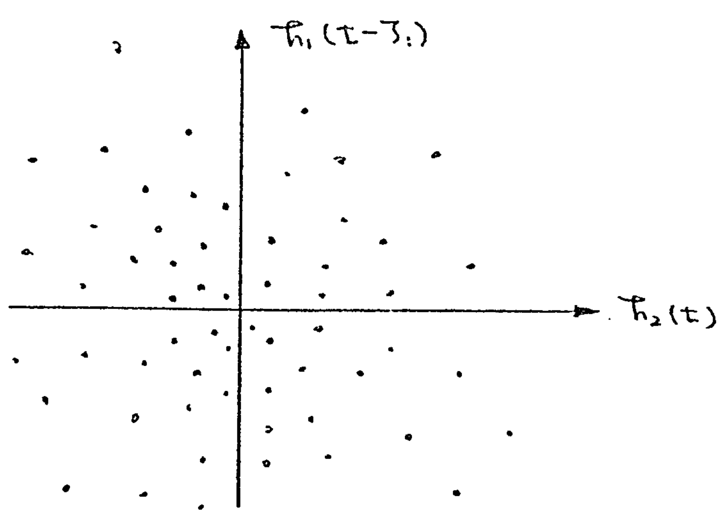
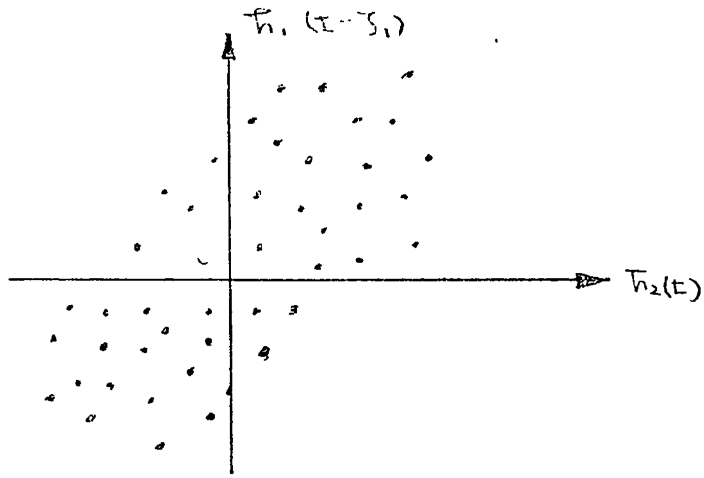


Fig. VI-15. UNSYMMETRICAL $\tilde{C}_{12}(\tau)$

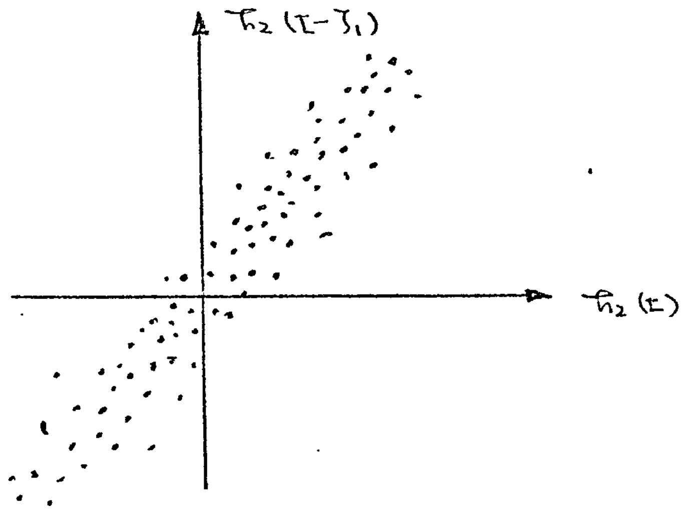
The reasons for the normalized maximum values of $\tilde{C}_{12}(\tau)$ at τ_1 being less than 1, might be the loss of identity of some of the small waves, small change in shape of some of the large waves, and different amplifications of different waves as they pass between the two measuring stations. Suppose $\hat{h}_1(t-\tau_1)$ and $\hat{h}_2(t)$ are normal processes if $\tilde{C}_{12}(\tau_1) = 0.0$, then given a value of $h_2(t_1)$, the value of $h_1(t_1-\tau_1)$ will be normally distributed as in Fig. VI-16. The value $\tilde{C}_{12}(\tau_1) = 0.5$ and $\tilde{C}_{12}(\tau_1) = 0.9$ are also given in the same figure. Hence given a larger value of $h_2(t)$ at $t = t_1$, the probability of having a larger value of $h_1(t_1 - \tau_1)$ is higher, if $\tilde{C}_{12}(\tau_1)$ is larger. Therefore the quantity $\tilde{C}_{12}(\tau_1)$ represents a measurement of the relative magnitude of $h_1(t - \tau_1)$ and $h_2(t)$.



(a) $\tilde{C}_{12}(\tau_1) = 0.0$



(b) $\tilde{C}_{12}(\tau_1) = 0.5$



(c) $\tilde{C}_{12}(\tau_1) = 0.9$

Fig. VI-16. SCATTER DIAGRAMS OF SAMPLES OF BIVARIATE NORMAL RANDOM VARIABLE

The experimental data of $\widetilde{C}_{12}(\tau_1)$ for conditions of various flow rates are given in Fig. VI-17. The data show an increasing value with liquid rates in general. The value of $\widetilde{C}_{12}(\tau_1)$ is around 0.5 - 0.7 for the high liquid rates. This suggests that the large waves move down stream without loss of identity and energy.

Another important paramter which can be obtained from the cross-spectral density function $\widetilde{S}_{12}(f)$ is called the coherency spectrum $\widetilde{K}_{12}(f)$ defined as follow:

$$\widetilde{K}_{12}(f) = \frac{|\widetilde{S}_{12}(f)|^2}{\widetilde{S}_{11}(f) \cdot \widetilde{S}_{22}(f)} \quad \text{--------} \quad (\text{VI}-46)$$

The physical meaning of this quantity as suggested by Jenkins (J- 2) and Box and Jenkins (B- 11), is like a correlation coefficient at each frequency f. Some of the coherency spectral density function are presented in Fig. VI-18. It is clearly indicated that the modal frequency of the spectrum does not correspond to the modal frequency of the coherency spectrum for the low liquid rates. This suggests that only the very low frequency wave components move down stream without losing their identity and energy for the low liquid rates.

3-3. THE EQUILIBRIUM RANGE OF SPECTRUM

An argument similar to Kolmogorov's analysis in turbulence was proposed by Phillips (P-4 , P-5) for the

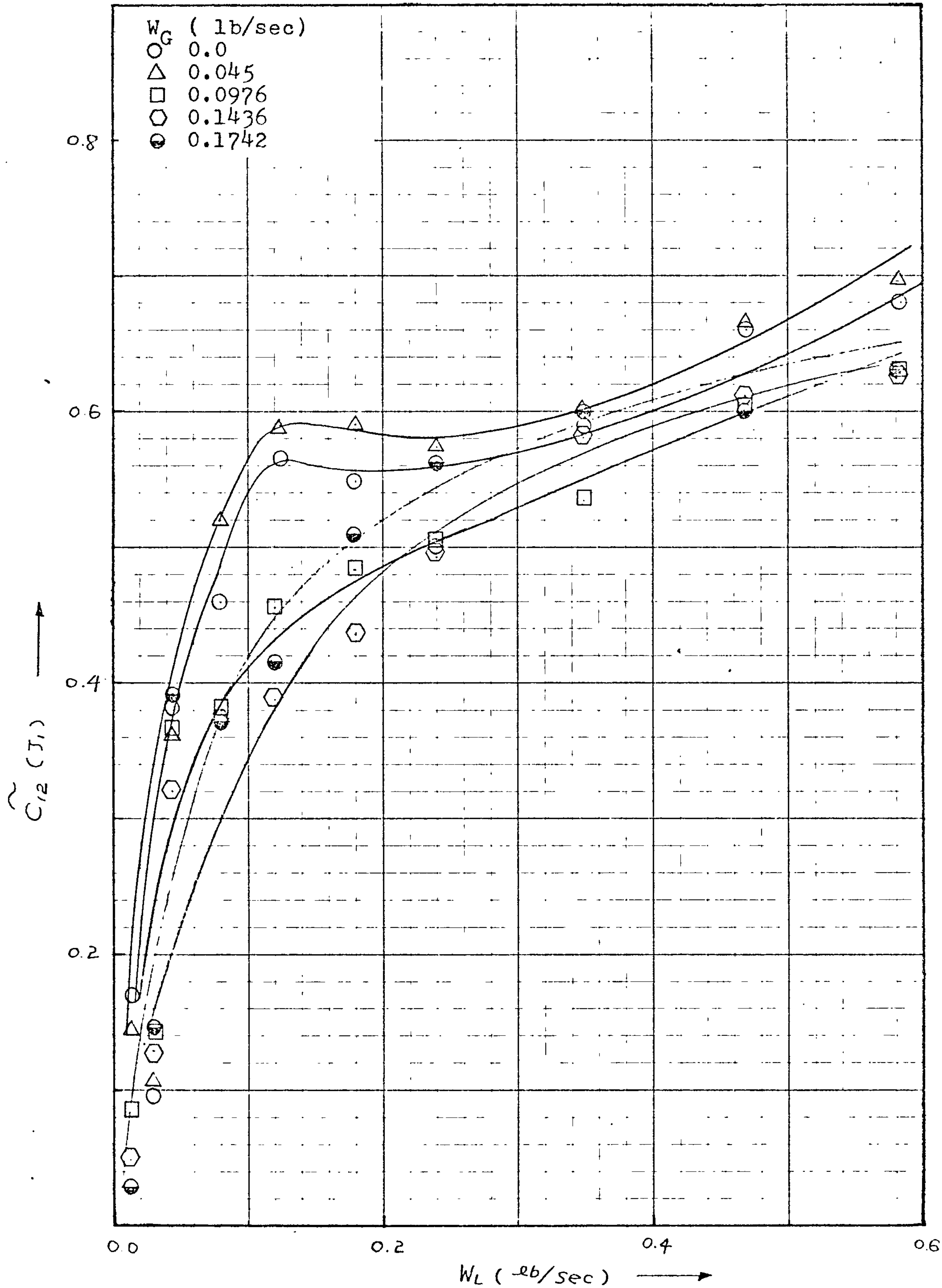


Fig. VI-17. CORRELATION COEFFICIENT AT ζ_1

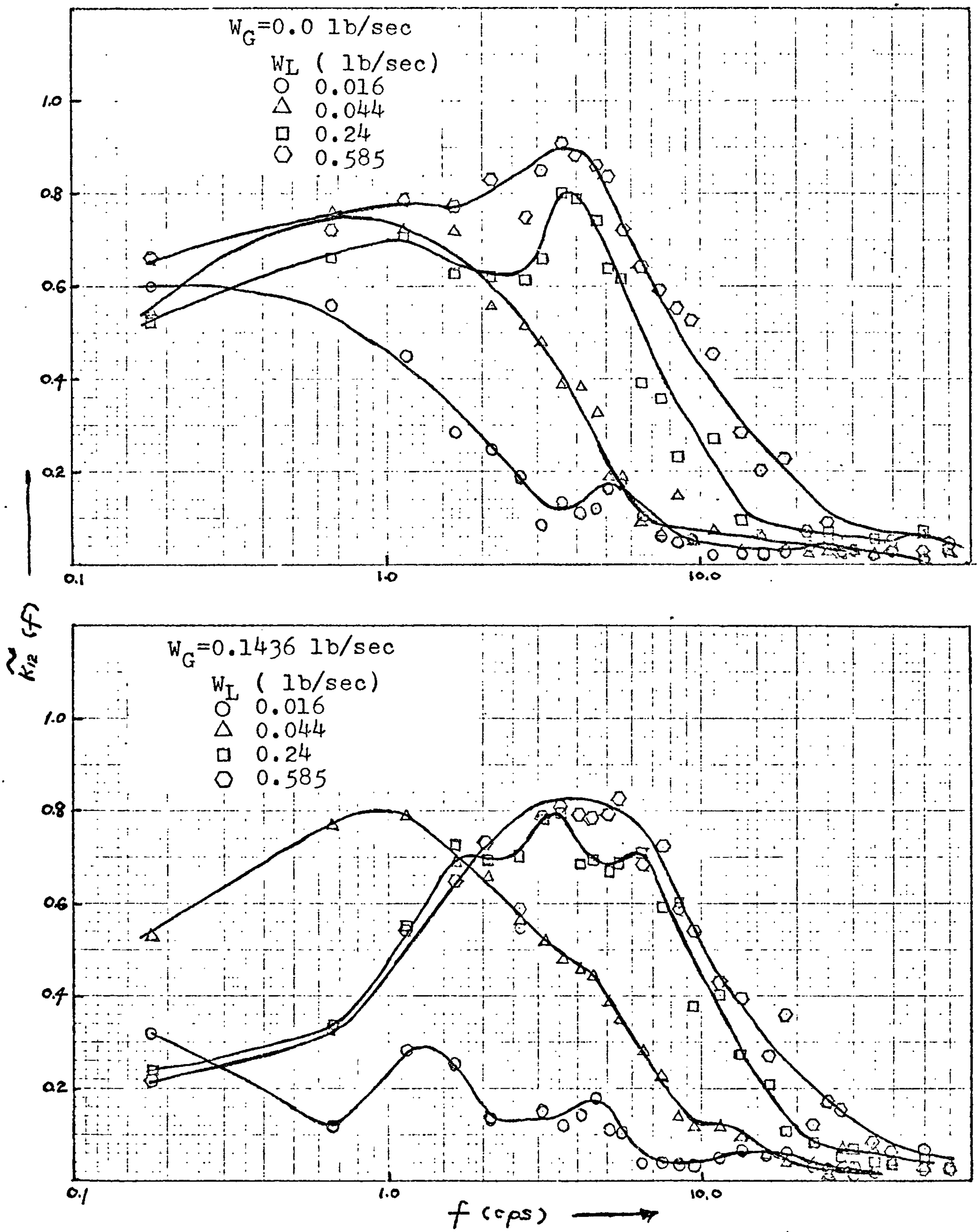


Fig. VI-18. COHERENCY SPECTRA

shape of a spectrum of ocean waves. However, the physical mechanism that maintains the equilibrium range in the wave spectrum is completely different from the mechanism found in turbulence. A well developed sea is covered by waves of all possible lengths shorter than some largest wave length, each one of which is in the state of breaking. Breaking occurs because local accelerations at the sharp crest of the wave exceed the acceleration of gravity and this process that controls the wave shape and thus the spectrum at high frequency. Consequently, the basic hypothesis of Phillips' work is that there exists an equilibrim range of large wave frequencies in the spectrum, determined entirely by the physical parameters (gravity) that govern the continuity of wave surface. Dimensional analysis shows that the equilibrium spectrum has the form

$$\tilde{S}(f) = \alpha_c \, g^2 f^{-5} \qquad \text{(VI-47)}$$

where α_c is a constant

There have been numerous efforts trying to verify the above equation by Burling (B-8), Kinsman (K-3), Hess, Hidy and Plate (H-4), Hidy and Plate (H-5 , H-6) and Plate (P-8 , P-9). Burling's data show a -5.5 power law. Kinsman's data give a -4.5 power law. While Hess, Hidy and Plate's measurements show a very good -5.0 power dependence at high frequencies. On the whole the validity of the equation (VI-47) appears to be well confirmed. However, some wave spectral data have been obtained showing the −5.0 rule at high frequencies without the appearance of white caps which represent the occurrance of breaking waves. Thus, the breaking process is probably not the only mechanism contributing to a limiting spectral shape. Equilibrium in the high frequency range may also be associated with the appearance of capillary waves. Hicks (H-13) has suggested that the spectrum for "pure" capillary waves, which should depend only on the kinematic surface tension and frequency, can be described as:

$$\tilde{S}(f) = \alpha_c' \, \gamma^{2/3} \, f^{-7/3} \qquad \text{(VI-48)}$$

where α_c' is a constant

$\gamma = \dfrac{\sigma}{\rho}$

σ is surface tension

ρ is density

However, no wind wave data have given direct verification for the above $-\dfrac{7}{3}$ power law. But the highest frequency of ocean wave spectrum is only about 13 cps, and the frequency range of capillary wave is usually around 10 cps - 100 cps.

In the present studies, the validity of the above two equations for the waves on the falling film will be examined. The data of spectrum slope S_{eq} was obtained from the log-log plots of spectra given in Chapter IV. Results are tabulated in Table VI-3.

TABLE VI-3. SLOPE OF FILM THICKNESS SPECTRA IN THE HIGH FREQUENCY RANGE.

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)			S_{eq}		
0.016	-2.94	-3.89	-4.28	-3.89	-----
0.028	-2.99	-3.60	-3.90	-4.00	-3.67
0.044	-2.77	-3.42	-3.30	-3.67	-3.74
0.08	-2.846	-3.36	-3.86	-3.73	-3.63
0.126	-2.855	-3.48	-3.62	-3.63	-3.67
0.18	-2.846	-3.69	-3.62	-3.89	-3.62
0.24	-2.840	-3.60	-3.80	-3.89	-3.77
0.35	-2.846	-3.69	-3.72	-3.65	-3.64
0.47	-2.846	-3.69	-3.52	-3.79	-3.64
0.585	-2.846	-3.69	-3.42	-3.72	-3.64

The above data for S_{eq} show approximately a -3.0 power law for no gas flow and a -4.0 power law for gas flow for all liquid flow rates. This result is between the rules described by the above two equations (VI-47) and (VI-48). The reasons for S_{eq} of falling films not following

Phillips' law or Hicks' law can be summarized as:

(a) The range of frequencies from which S_{eq} was obtained are about 15 cps - 80 cps in the present study. This is the range in which surface tension forces become important.

(b) The gravitational force acts along the direction of wave propagation. Therefore all sizes of waves are under the influence of gravity. Hence the gravitational force is also important for the capillary waves on the falling film.

One would therefore expect that the result would be some what between -5.0 power law and $-\frac{7}{3}$ power law. This is actually what is observed. Since both gravity and surface tension are important for the equilibrium subrange of spectrum, one would obtain the following equations by dimensional analysis

$$\tilde{S}(f) = \alpha_c'' g^{1/2} \gamma^{1/2} f^{-3} \quad \text{for no gas flow} \text{ --- } (\text{VI-49})$$

$$\tilde{S}(f) = \alpha_c''' g^{5/4} \gamma^{1/4} f^{-4} \quad \text{for no gas flow} \text{ --- } (\text{VI-50})$$

where α_c'' and α_c''' are constants.

4. PERIPHERY EFFECT.

The waves on the falling film are considered as a two dimensional motion in most of the theoretical analyses. The velocity of this two dimensional assumption will be tested in this section by the use of the correlation function. Consider two stationary processes $\hat{h}_1'(x, z_1, t)$ and $\hat{h}_2'(x, z_2, t)$ at same location x, but different peripheral positions z_1 and z_2. The auto-covariance and cross-covariance of $\hat{h}_1'$ and $\hat{h}_2'$ are

$$\tilde{C}_{11}(\tau) = \langle \hat{h}_1'(x, z_1, t+\tau)\, \hat{h}_1'(x, z_1, t) \rangle \quad \text{---- (VI-51)}$$

$$\tilde{C}_{22}(\tau) = \langle \hat{h}_2'(x, z_2, t+\tau)\, \hat{h}_2'(x, z_2, t) \rangle \quad \text{---- (VI-52)}$$

$$\tilde{C}_{12}(\tau) = \langle \hat{h}_1'(x, z_1, t+\tau)\, \hat{h}_2'(x, z_2, t) \rangle \quad \text{---- (VI-53)}$$

Suppose $\hat{h}_1$ and $\hat{h}_2$ are two-dimensional, i.e. independent of z direction, then

$$\hat{h}_1'(x, z_1, t) = \hat{h}_2'(x, z_2, t) = \hat{h}'(x, t) \quad \text{---- (VI-54)}$$

The relation of auto-covariance and cross-covariance becomes

$$\tilde{C}_{11}(\tau) = \tilde{C}_{22}(\tau) = \tilde{C}_{12}(\tau) \quad \text{—— —— (VI-55)}$$

Hence the two-dimensionality of the waves structure can be tested by equation (VI-55).

Four conductivity probes were inserted 90 degree apart around the periphery at each of two locations, B and D. B and D are separated by 1.161 ft. The sketch in Fig. VI-19 identifies particular probe at these two locations.

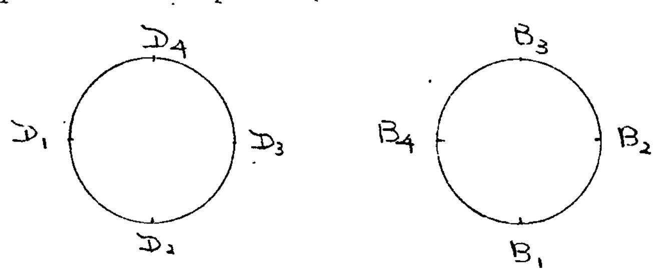


Fig. VI-19. CONFIGURATION OF THE CONDUCTIVITY PROBE

D_2 and B_1 cells are on the same vertical line. The data of $\widetilde{C}_{11}(\tau)$, $\widetilde{C}_{22}(\tau)$, and $\widetilde{C}_{12}(\tau)$ are given in Figs. VI-20 and VI-21. The results can be summarized as :

(a) Cross-covariance $\widetilde{C}_{12}(\tau)$ is approximately same as auto-covariance $\widetilde{C}_{11}(\tau)$ and $\widetilde{C}_{22}(\tau)$ except in the neighborhood of $\tau = 0$. This implies that the relative wave structure are two-dimensional, i. e. The waves are approximately a ring wave.

(b) The difference between cross-covariance and auto-covariance is probably due to the fact that the small waves are loosing their identity and the shape of the large waves are not identical around the periphery. Hence the large waves are approximately two dimensional and the small waves are probably three dimensional.

(c) A small time shift exists at the peak of $\widetilde{C}_{12}(\tau)$, and $\widetilde{C}_{12}(0)$ of D_2, D_4 pair is smaller than that of D_2, D_1 pair. The above fact shows that a very weak three-dimensionality also exists for the large waves.

On the whole, the two dimensional assumption for the large waves is a good approximation. The wave around the periphery can be clearly demonstrated in Fig. VI-22.

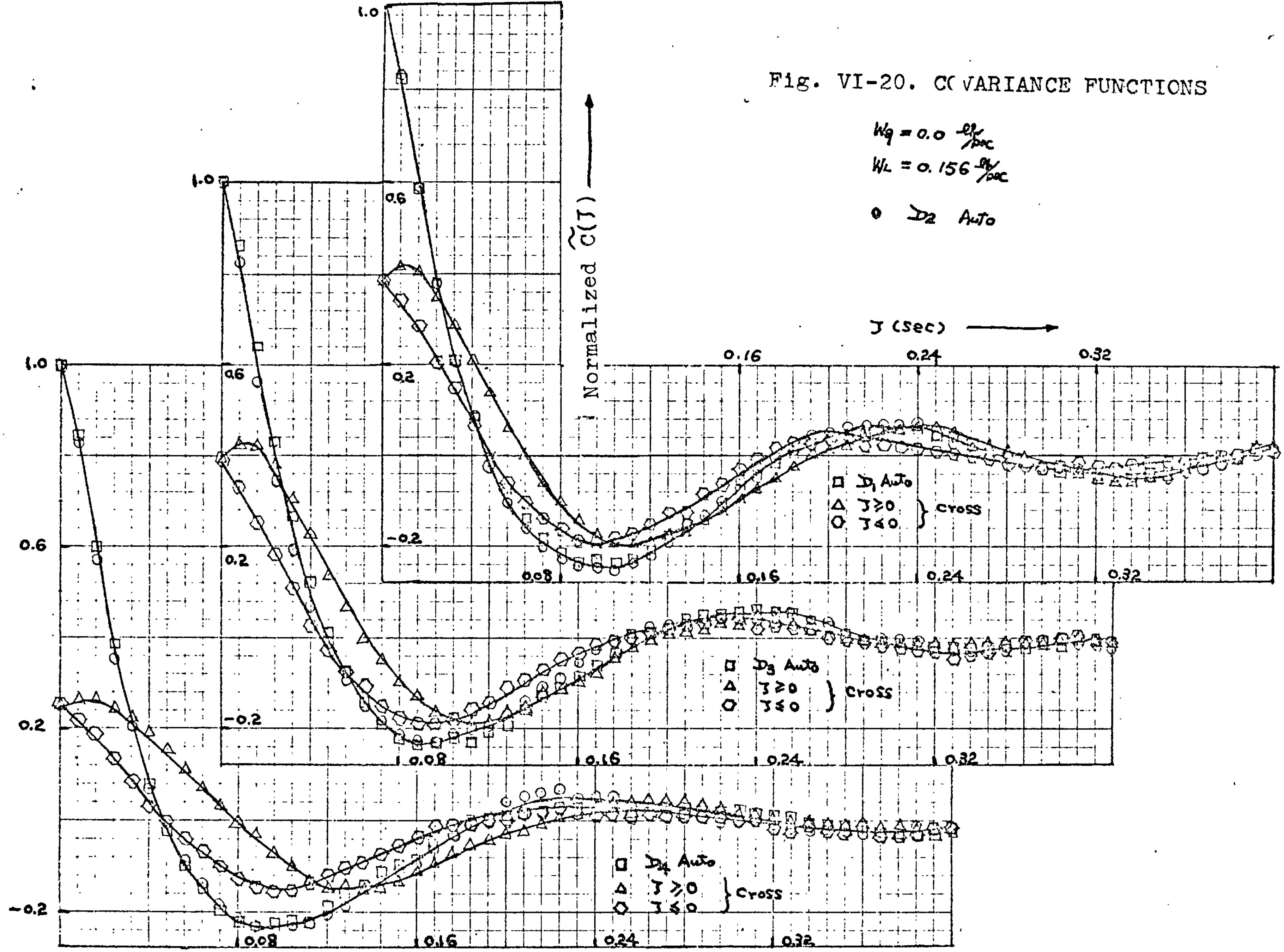
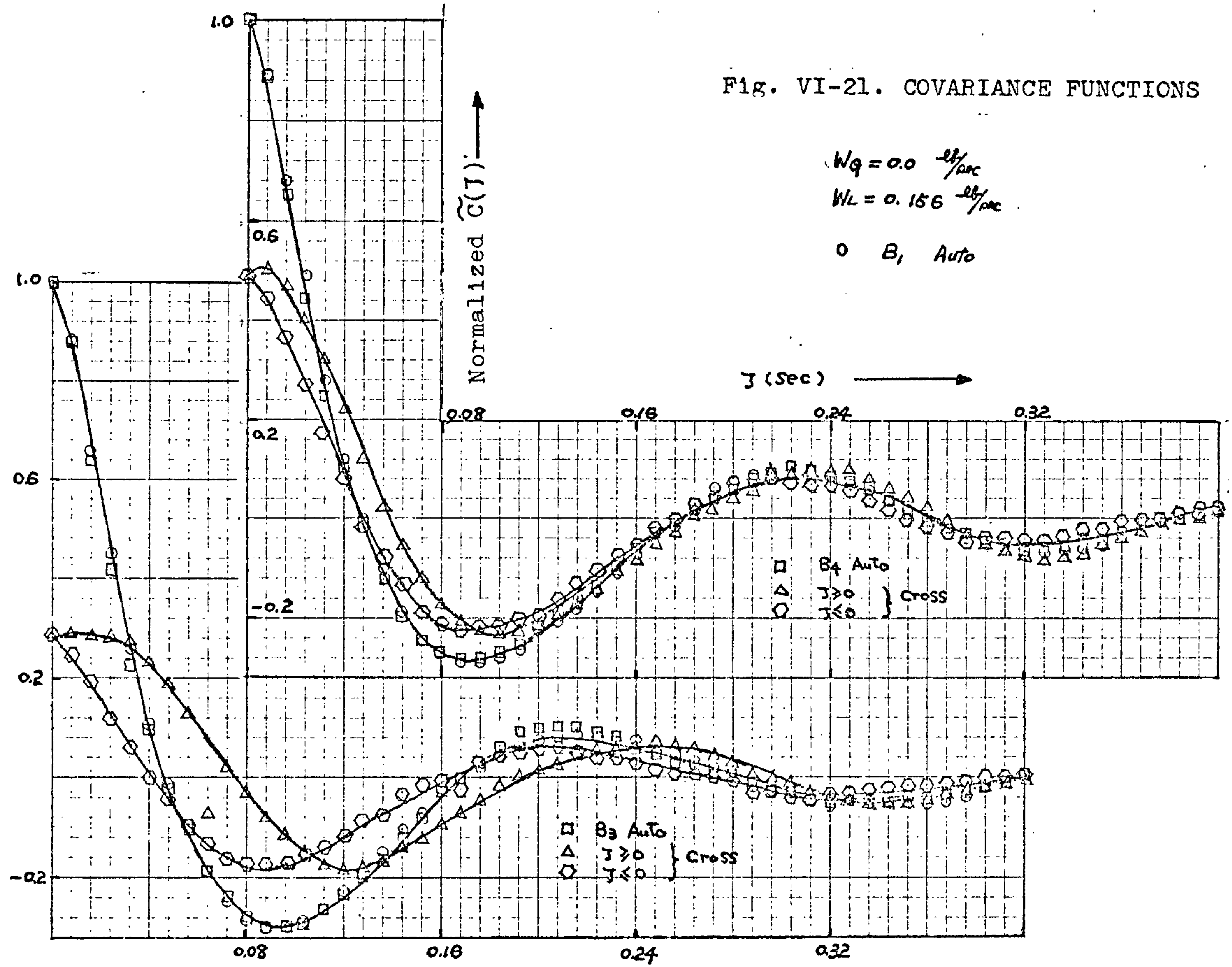


Fig. VI-20. COVARIANCE FUNCTIONS

Fig. VI-21. COVARIANCE FUNCTIONS



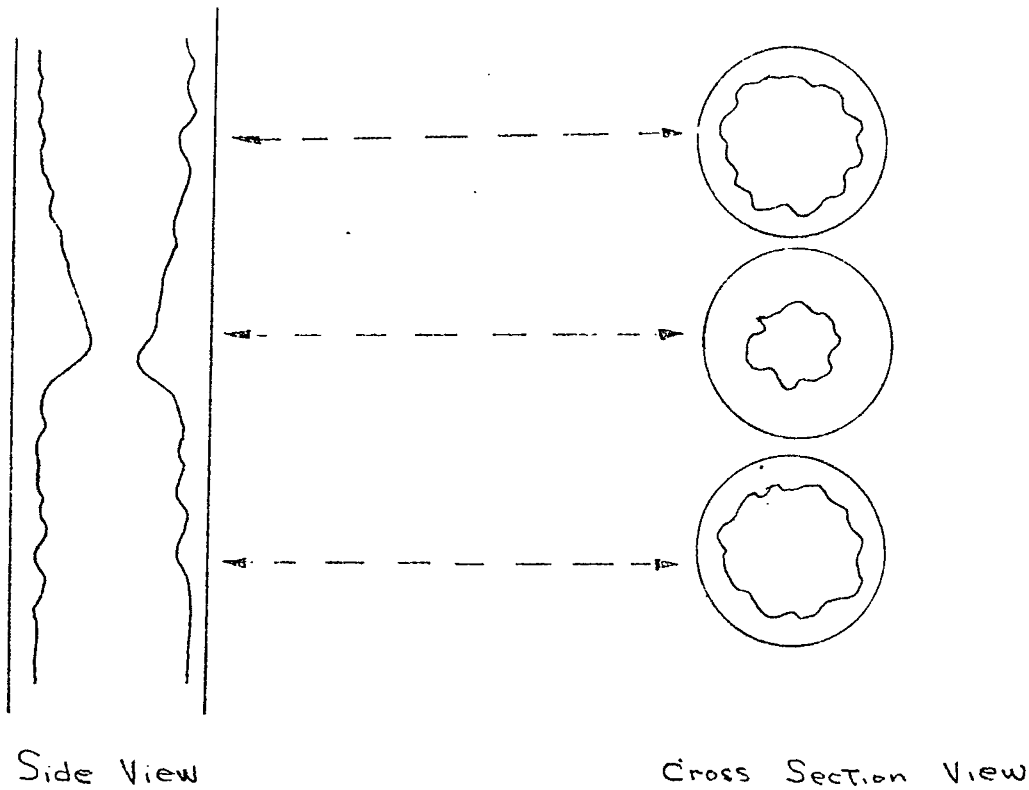


FIG. VI-22. WAVE AROUND THE PERIPHERY

5. LENGTH EFFECT

In this section, the effect of length on properties of film thickness and wave structure will be examined.

5-1. FILM PROPERTIES

The mean film thickness $\langle h \rangle$ measured at various positions along the test section are given in Fig. VI-23. Although the variation of the mean thickness along the length is small, the data show a definite trend which indicates a decrease in

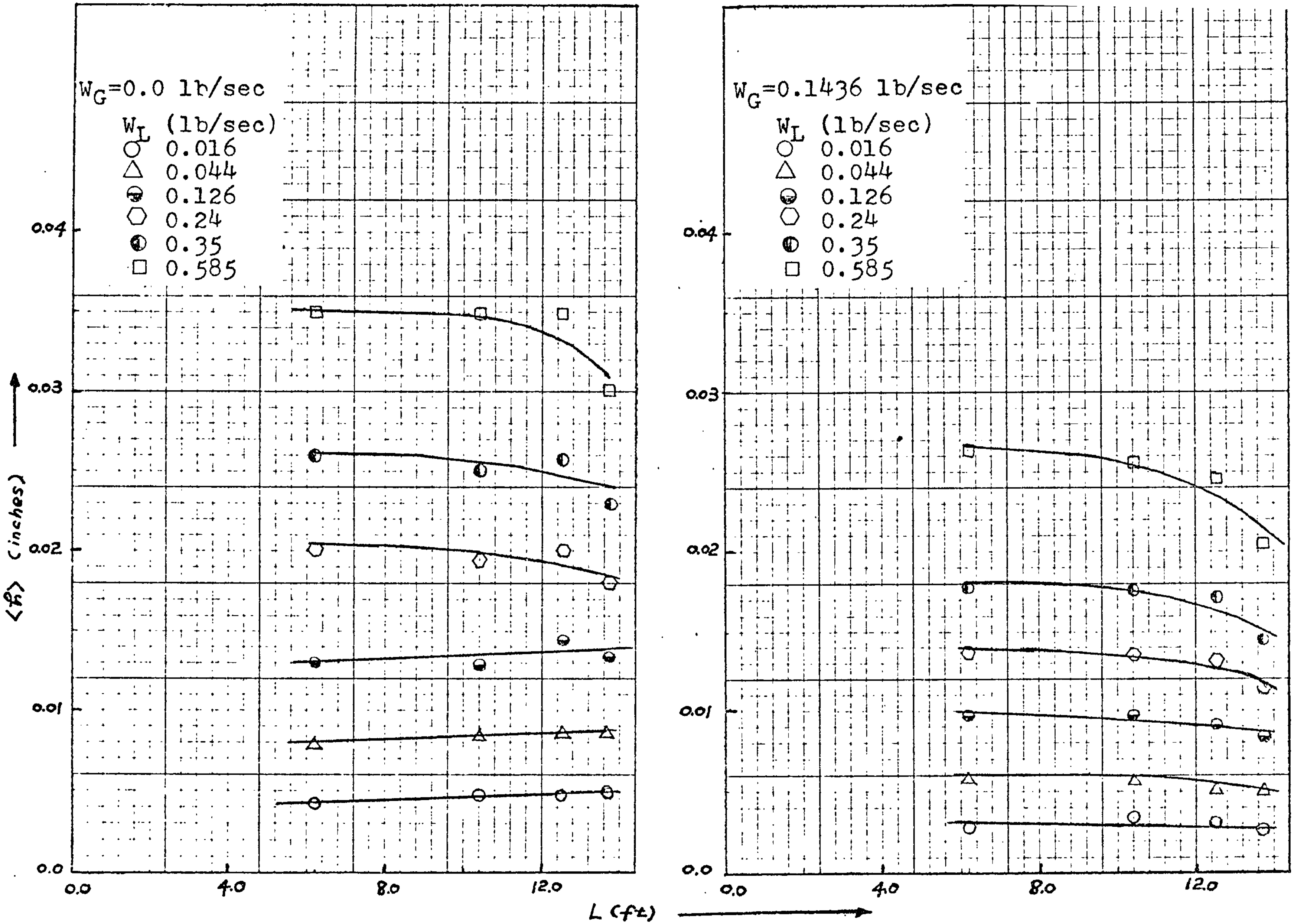


Fig. VI-23. LENGTH EFFECT ON MEAN FILM THICKNESS the mean film thickness with increasing distance from the inlet except low liquid rates. The second central moments of film thickness C_2 are also plotted in Fig. VI-24. There is an increase in the values of the second moment with length up to 12' and then a decrease in that with length from 12' for no gas flow. This suggests that the waves amplify and then decay. At low liquid rates the data with gas flow show the same trends as without gas flow. At high liquid rates it shows a decrease in the value of moment with length. This indicates that the waves decay along the length. The probability density functions for film thickness at various positions which are given in Chapter IV, show a difficult structure at cell C_4.

The modal frequency given in Chapter IV decreases with increasing distance from the inlet. The normalized spectral densities of film thickness given in Chapter IV, are approximately the same for D_2, B_1 and A_3 cells. But the spectral density of the film thickness measured at C_4 contains less energy in the low frequency range than that measured at D_2, B_1 and A_3 cells. This implies that the large waves coalesce as they move down the length of the tube.

5-2. WAVE PROPERTIES

The effect of length on the wave velocity, amplitude, frequency and the ratio of the length of the wave back to

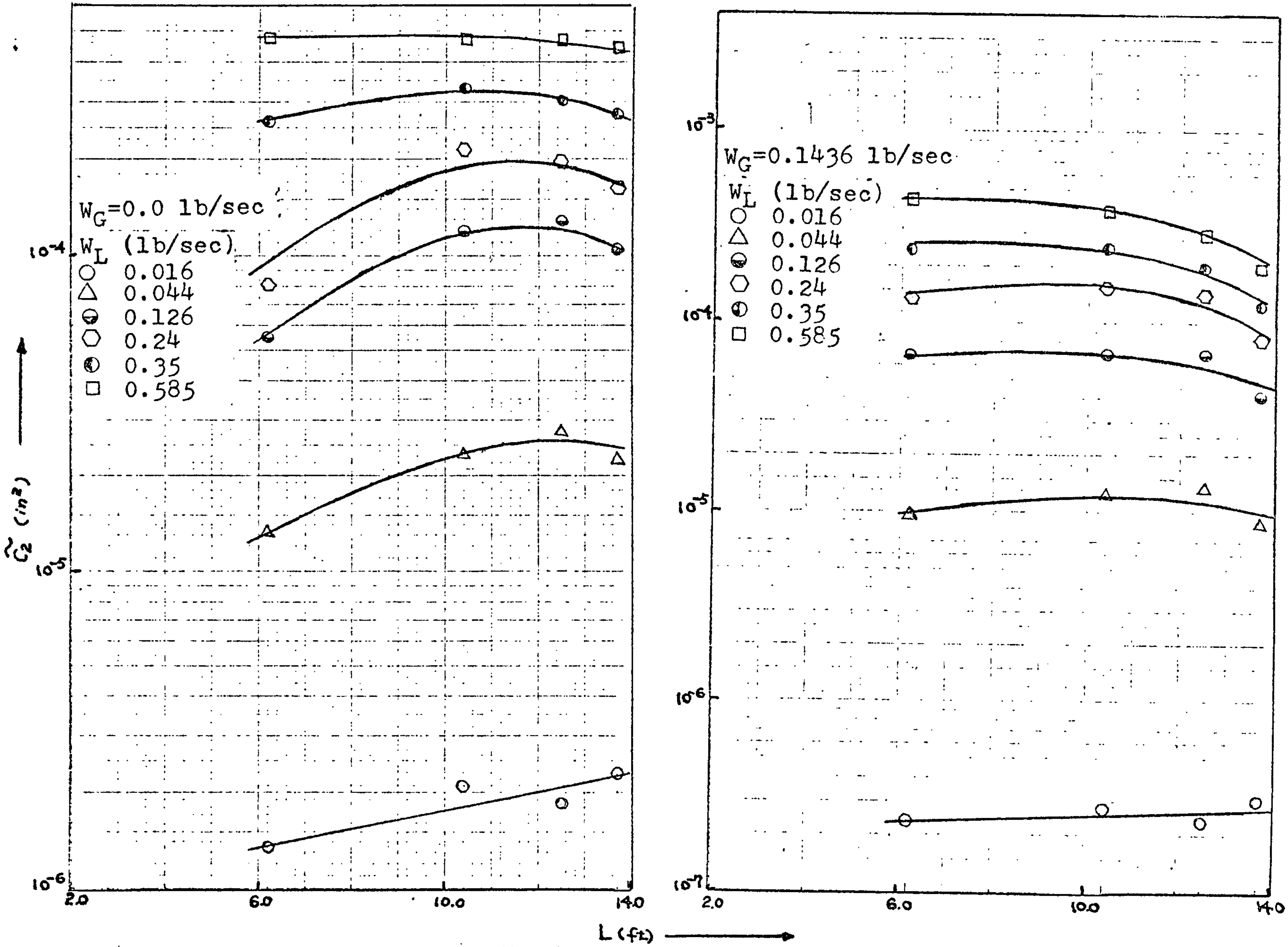


Fig. VI-24. LENGTH EFFECT ON SECOND CENTRAL MOMENT the wave front is presented in this section.

(i) The wave velocity

The wave velocity calculated from equation (VI-7) at various positions along the tube are plotted in Fig. VI-25. The solid vertical lines represent the position of the probe. The data indicate that the wave velocity increases with the distance from inlet. If the velocity is not a constant value, then equations (VI-3), (VI-4) and (VI-7) need to be modified. Let the wave velocity at position $x^{(1)}$ and position $x^{(2)}$ be $c^{(1)}$ and $c^{(2)}$ respectively

then equations (VI-1) and (VI-2) become

$$h_1'(t) = h'\left(t - \frac{x^{(1)}}{c^{(1)}}\right) \quad \text{at } x = x^{(1)} \quad \text{------- (VI-56)}$$

$$h_2'(t) = h'\left(t - \frac{x^{(2)}}{c^{(2)}}\right) \quad \text{at } x = x^{(2)} \quad \text{----- (VI-57)}$$

hence equations (VI-3) and (VI-4) become

$$\tilde{C}_{12}(\tau) = \tilde{C}_{11}\left(\tau + \frac{x^{(2)}}{c^{(2)}} - \frac{x^{(1)}}{c^{(1)}}\right) \quad \text{----- (VI-58)}$$

$$\tilde{S}_{12}(f) = e^{+i2\pi f\left(\frac{x^{(2)}}{c^{(2)}} - \frac{x^{(1)}}{c^{(1)}}\right)}\,\tilde{S}_{11}(f) \quad \text{---- (VI-59)}$$

The phase spectrum will be

$$\tilde{\theta}_{12}(f) = 2\pi f\left(\frac{x^{(2)}}{c^{(2)}} - \frac{x^{(1)}}{c^{(1)}}\right) \quad \text{----- (VI-60)}$$

Let the conductivity cells, C_4, A_3, B_1 and D_2 be located at positions $x^{(1)}$, $x^{(2)}$, $x^{(3)}$ and $x^{(4)}$, and the wave velocity at those positions are $c^{(1)}$, $c^{(2)}$, $c^{(3)}$ and $c^{(4)}$ respectively.

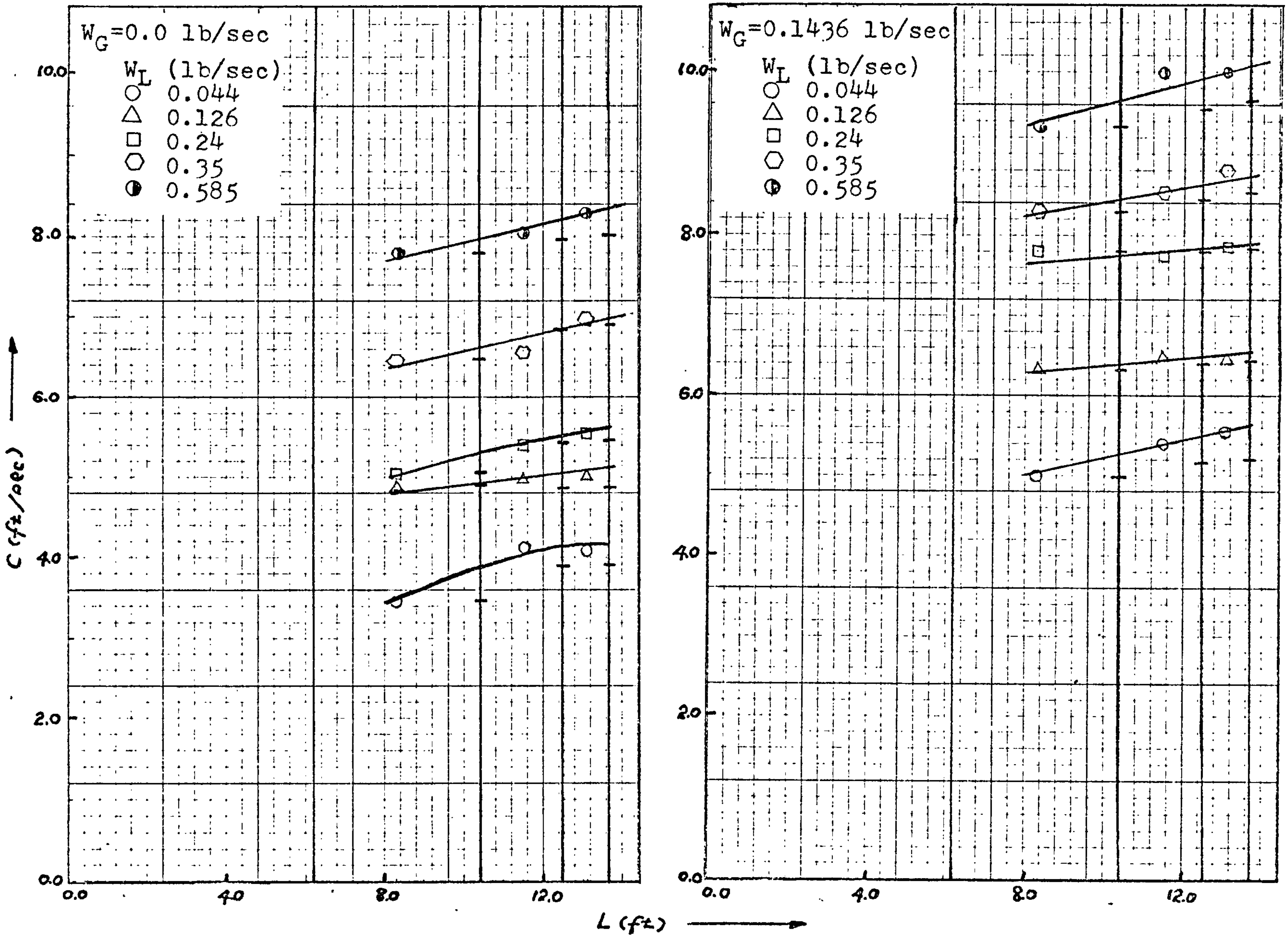


Fig. VI-25. LENGTH EFFECT ON WAVE VELOCITY

Similarly, the phase spectrum equations will be

$$\tilde{\theta}_{23}(f) = 2\pi f\left(\frac{x^{(3)}}{c^{(3)}} - \frac{x^{(2)}}{c^{(2)}}\right) \quad ------- \quad (\text{VI-61})$$

$$\tilde{\theta}_{24}(f) = 2\pi f\left(\frac{x^{(4)}}{c^{(4)}} - \frac{x^{(3)}}{c^{(3)}}\right) \quad ------ \quad (\text{VI-62})$$

The above equations (VI-60), (VI-61) and (VI-62) contain four unknowns. If the position $x^{(1)}$ is set to be zero, then the wave velocity can be solved except $c^{(1)}$. The values of $c^{(2)}$, $c^{(3)}$ and $c^{(4)}$ are also plotted as the short solid horizontal lines in the above Fig. VI-25. On the whole, the assumption of the constant velocity is not a bad approximation except in the neighborhood of the wave inception.

(ii) The wave amplitude

The length effect on the wave amplitude for the large and small waves are given in Fig. VI-26. and Fig. VI-27. The wave amplitude for the small waves is independent of length except at high liquid rates. This might suggest that the small waves are at an equilibrium state. At high liquid rates the data for wave amplitude of the small wave show considerable scatter. The wave amplitude of the large waves for the case of no gas flow, first grows with the length and then decays. For the case of gas flow, the mean wave amplitude of the large wave decreases with length except at low liquid rates. This indicates that the large waves grows over the distance from the inlet less than 6 ft for

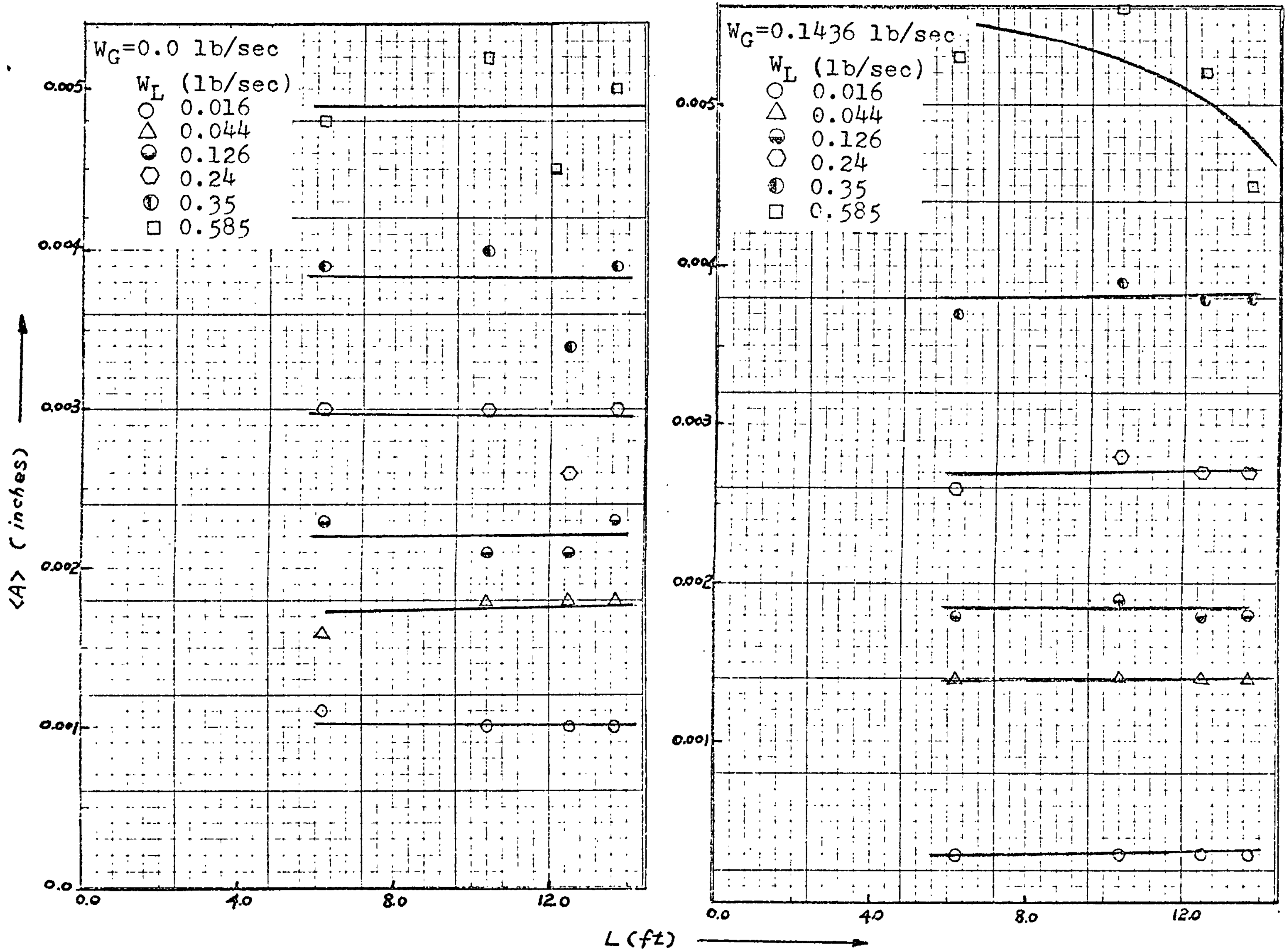


Fig. VI-26. AMPLITUDE OF THE SMALL WAVES

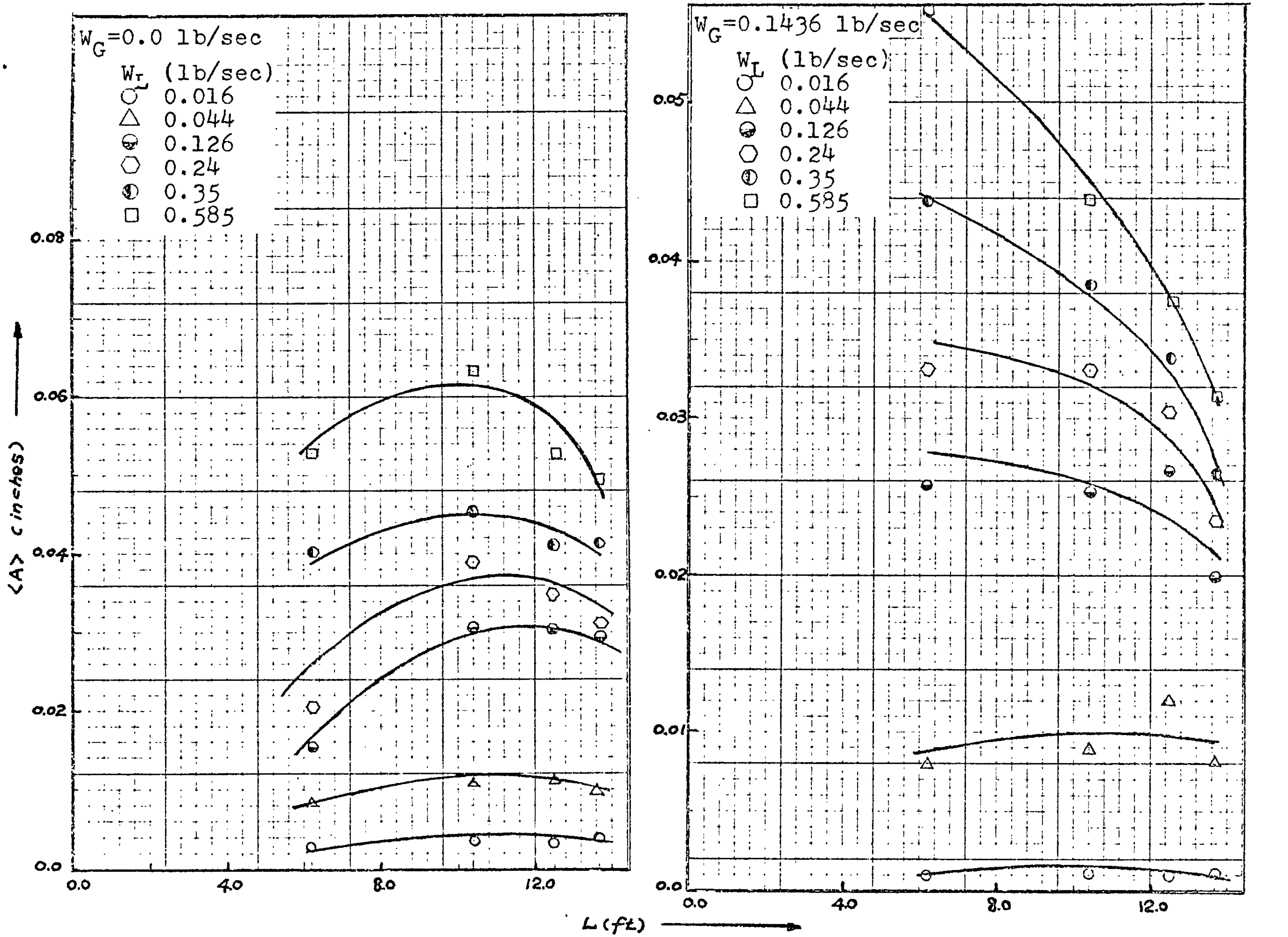


Fig. VI-27. AMPLITUDE OF THE LARGE WAVES gas flow.

Assuming a linear relation between the four positions, the amplification factor (or growth rate) A_p can be calculated as follows:

$$A_p = \frac{dA/dx}{A} \qquad \text{(VI-63)}$$

The values of A_p are given in Table VI-4.

TABLE VI-4. AMPLIFICATION FACTOR A_P

$x^{(4)}$(ft)	W_G = 0.0 lb/sec 8.3'	11.45'	13.1'	W_G= 0.1436 lb/sec 8.3'	11.45'	13.1'
W_L(lb/sec)	A_P(1 / inch) x 10^3					
0.016	+4.7	-4.28	+11.65	+1.74	-3.36	+6.25
0.044	+5.63	+1.04	- 8.8	+2.13	+1.14	-27.0
0.126	+11.1	-0.25	-2.65	-3.91	+2.22	-26.9
0.24	+12.65	-4.48	-7.85	-0.06	-3.28	-18.4
0.35	+2.47	-3.81	-0.52	-2.53	-5.02	-17.6
0.585	+3.7	-7.2	-4.62	-4.76	-6.0	-13.1

(iii) The wave frequency, wave base and wave separation

The wave frequency for both the large waves and small waves obtained at various positions are given in Fig. VI-28 and Fig. VI-29. The small wave frequency for the case of

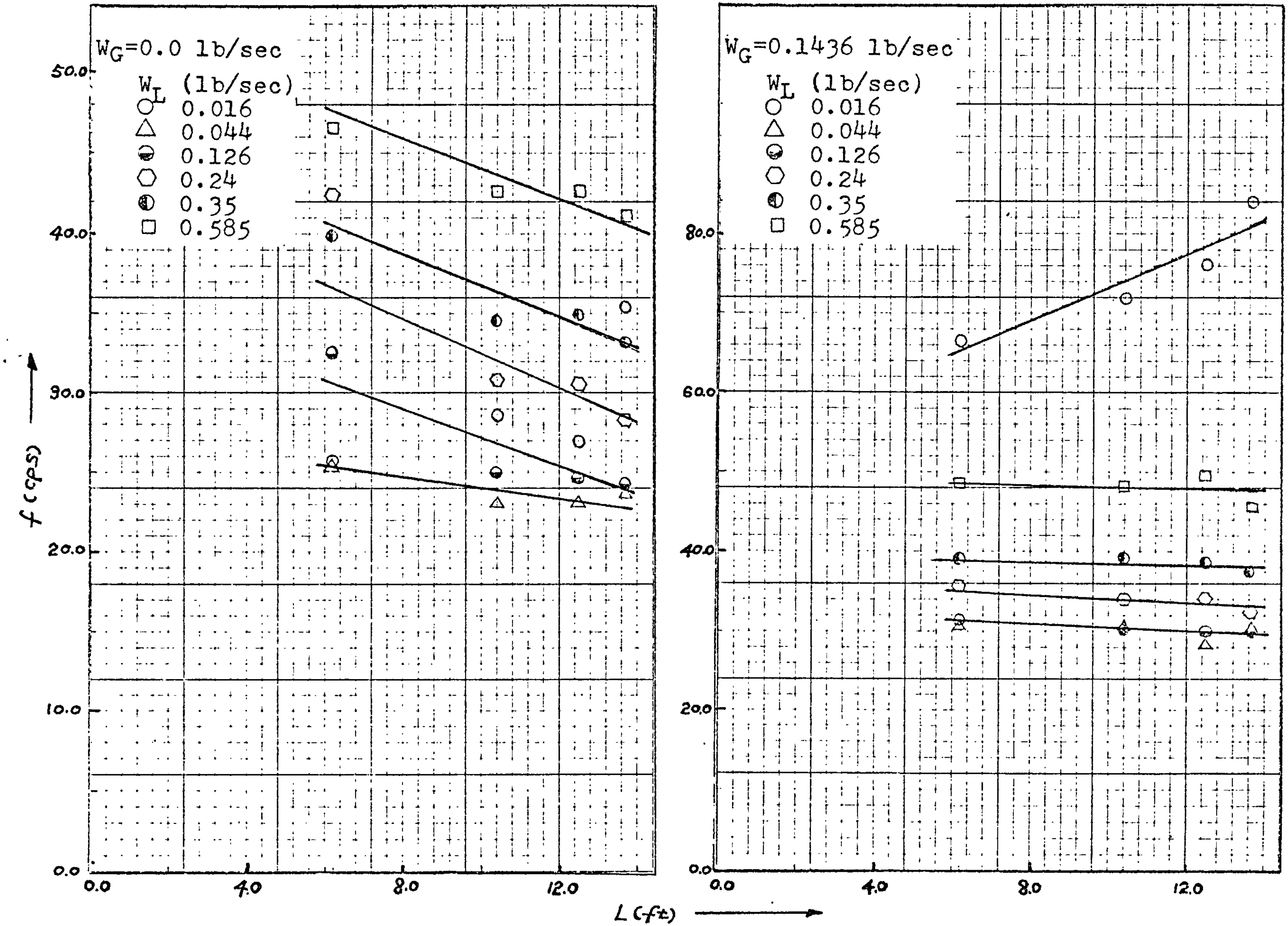


Fig. VI-28. FREQUENCY OF THE SMALL WAVES

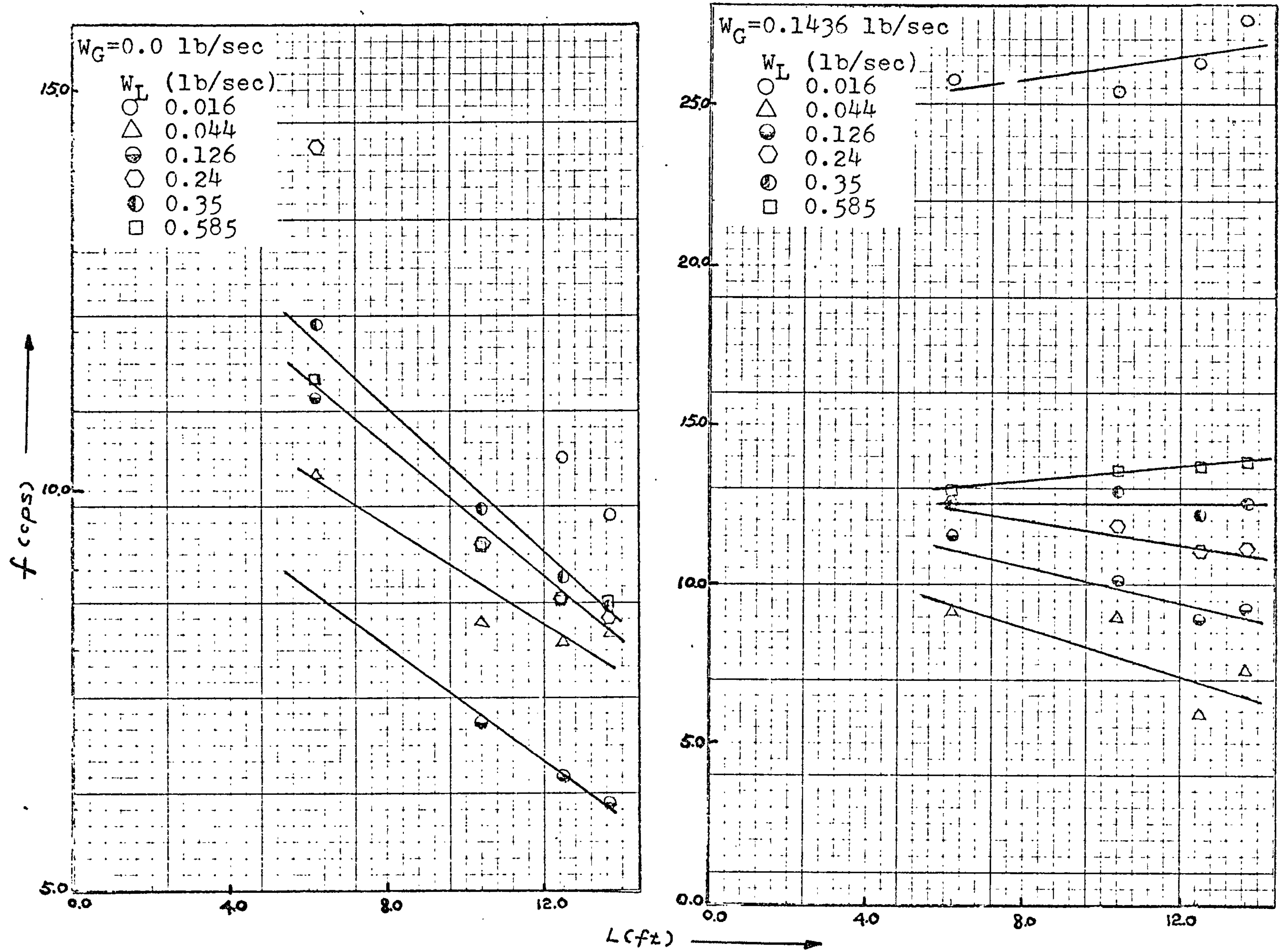


Fig. VI-29. FREQUENCY OF THE LARGE WAVES no gas flow suggests a small decreasing value with the length. While for the case of gas flow, they are quite constant except at the lowest liquid rates.

The large waves at the condition of no gas flow show a rapidly decreasing frequency with distance from inlet. This suggests wave coalescence. On the other hand, the wave frequency for large waves with gas flow does not show such a trend. This might suggest that the shear due to the gas flow trends to break the large waves and to generate enough new waves on the interface to compensate for those lost by coalescence. The wave base for the small waves and the wave separation for the large waves show the reverse effect of the wave frequency. These are plotted in Fig. VI-30 and Fig. VI-31.

(iv) The ratio of the wave back to the wave front

The ratio of the wave back to the wave front $\langle T_{bk}\rangle/\langle T_{fn}\rangle$ for both small waves and large waves are given in Figs. VI-32 and VI-33. For the case of no gas flow, there is no definite trend appearing in the data. For the case of gas flow, the data for the small waves show a decreasing value with the length except at the low liquid rates, while the data of the large waves suggest a constant value at each liquid rate.

6. WAVE STRUCTURE

The experimental data for the wave parameters as presented in Chapter V and the discussions in the previous section allows

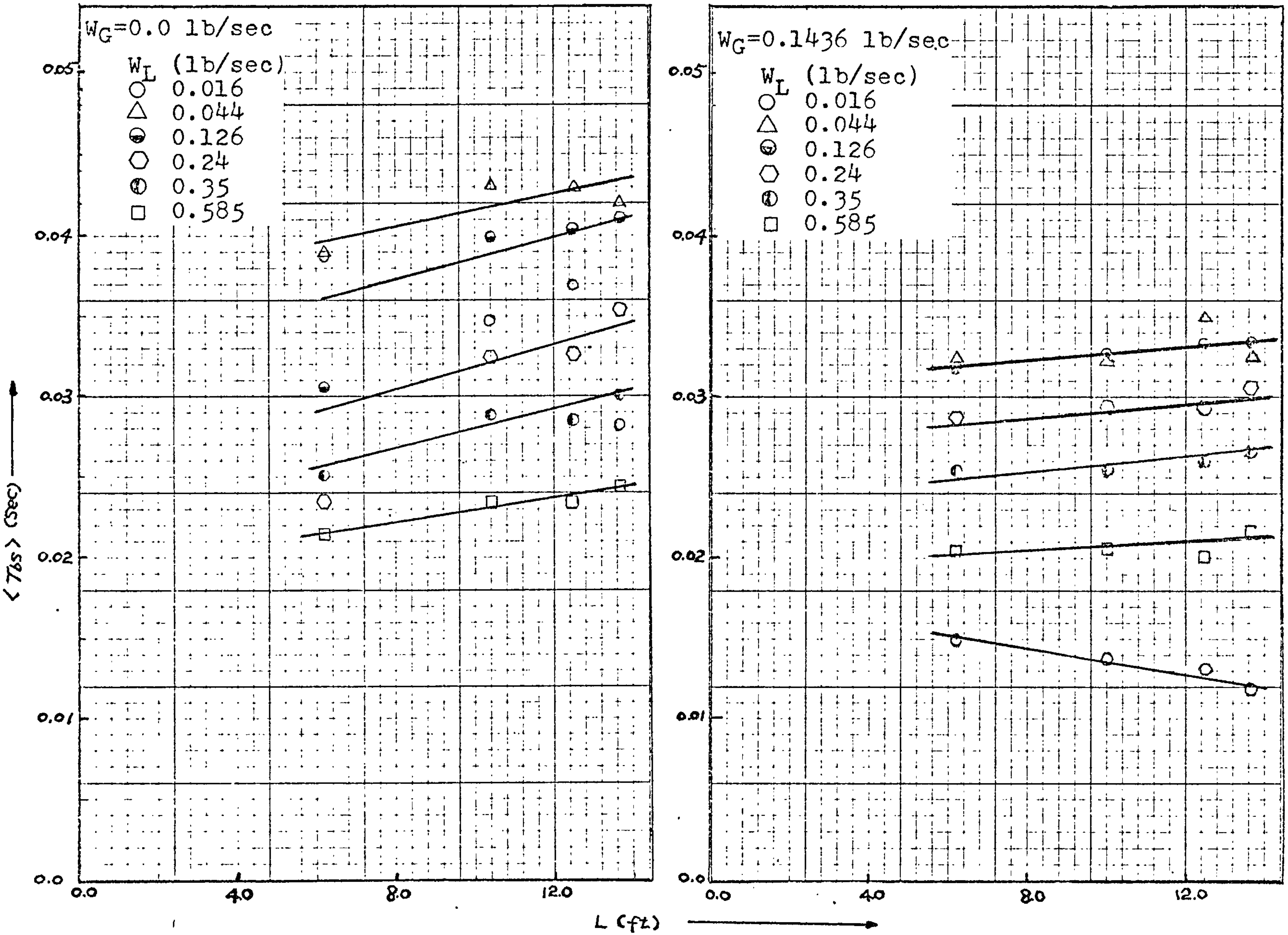


Fig. VI-30. BASE OF THE SMALL WAVES

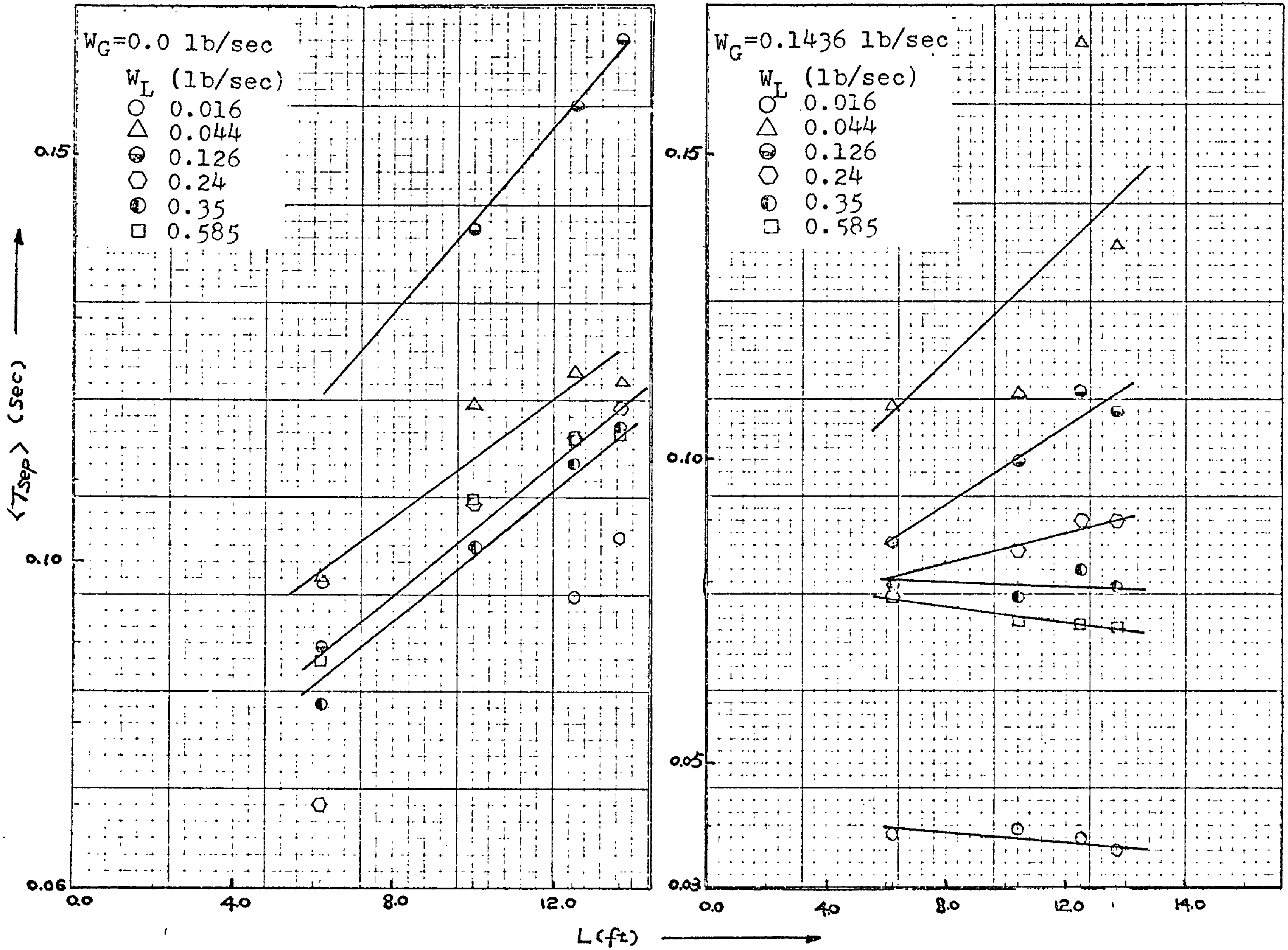


Fig. VI-31. SEPARATION TIME OF THE LARGE WAVES

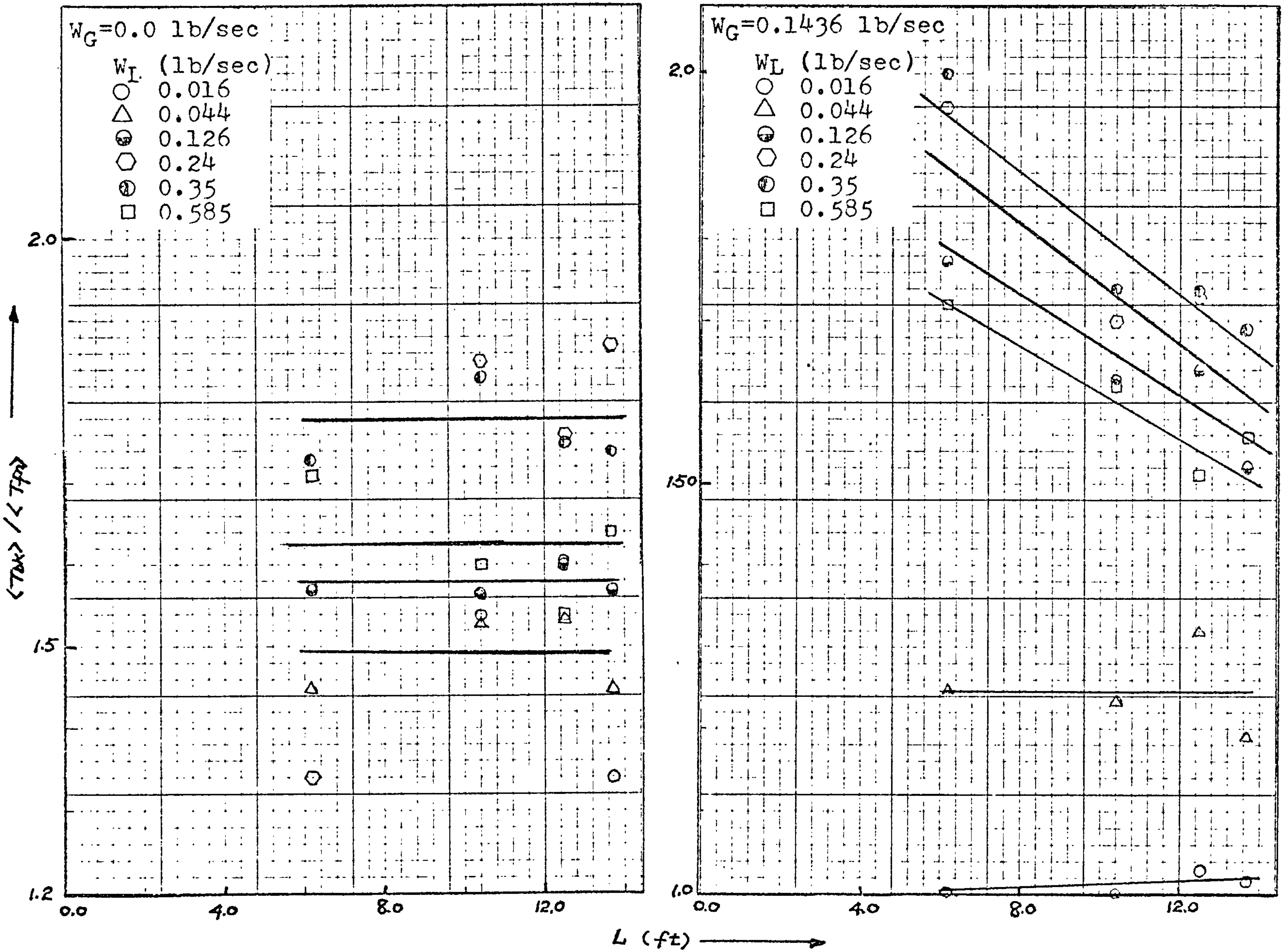


Fig. VI-32. $\langle T_{bk} \rangle / \langle T_{fn} \rangle$ OF THE SMALL WAVES

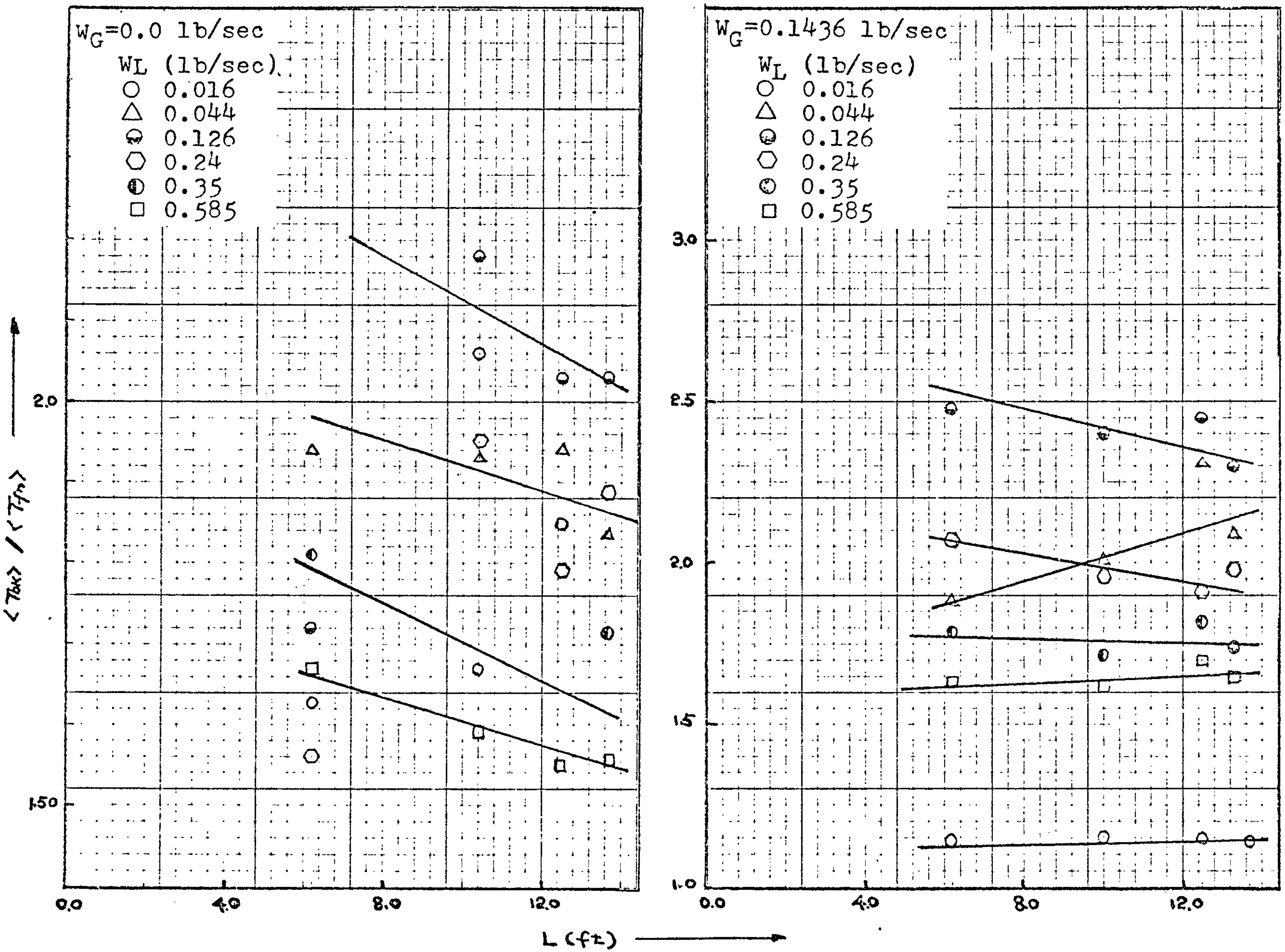


Fig. VI-33. $\langle T_{bk} \rangle / \langle T_{fn} \rangle$ OF THE LARGE WAVES one to summarize the wave structure. Furthermore the relation between the wave structure and the probability density of film thickness will also be explored.

6-1. SUBSTRATE STRUCTURE

In all previous studies the substrate thickness, h_s', was defined such that $\tilde{P}\{\hat{h}(t) \leq h < h_s'\} = 0$ and $\tilde{P}\{\hat{h}(t) \leq h > h_s'\} \neq 0$ The relation of this h_s' to the probability density function $\tilde{f}(h)$ and the probability distribution are shown as follows:

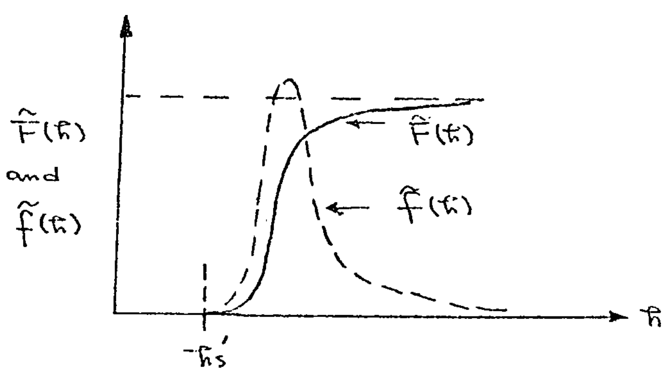


FIG. VI-34. DEFINITION OF SUBSTRATE IN THE PREVIOUS STUDIES.

The value of h_s' calculated this way is strongly depending on the probability intervals chosen in the measurement technique. The physical meaning of this assumption is that there is a smooth continuous sublayer of liquid film between two consecutive wave crests. But the data in this study show that there are small waves sitting on the substrate, and the number of small waves are not small as seen from the data in Table VI-5. Hence the above definitions are not suitable.

TABLE VI-5. NUMBER OF WAVES

	W_G=0.0 lb/sec(in 171 sec)			W_G=0.1436lb/sec(in 180 sec)		
W_L (lb/sec)	small wave	small wave on large wave	large wave	small wave	small wave on large wave	large wave
0.044	1254	486	1423	2940	178,	1402
0.126	1502	782	1071	2363	397	1634
0.35	2228	931	1503	2434	647	1903

The substrate in the present study will be defined as the portion of film thickness, h_s, which is occupied by small waves under the mean film thickness $\langle h \rangle$. Since the amplitude of small waves fluctuates within a narrow range, the contribution due to $h_s(t)$ on the probability density function of $h(t)$ will show a modal peak around the mean value of $\langle h_s \rangle$. This relation can be easily demonstrated by Fig. VI-35.
It is clear that the probability density function $\widetilde{f}(h_s)$ can be obtained by conditional sampling only the data of h_s. In order to avoid the above tedious conditional sampling calculation, one can roughly estimate the probability density $\widetilde{f}(h_s)$ from

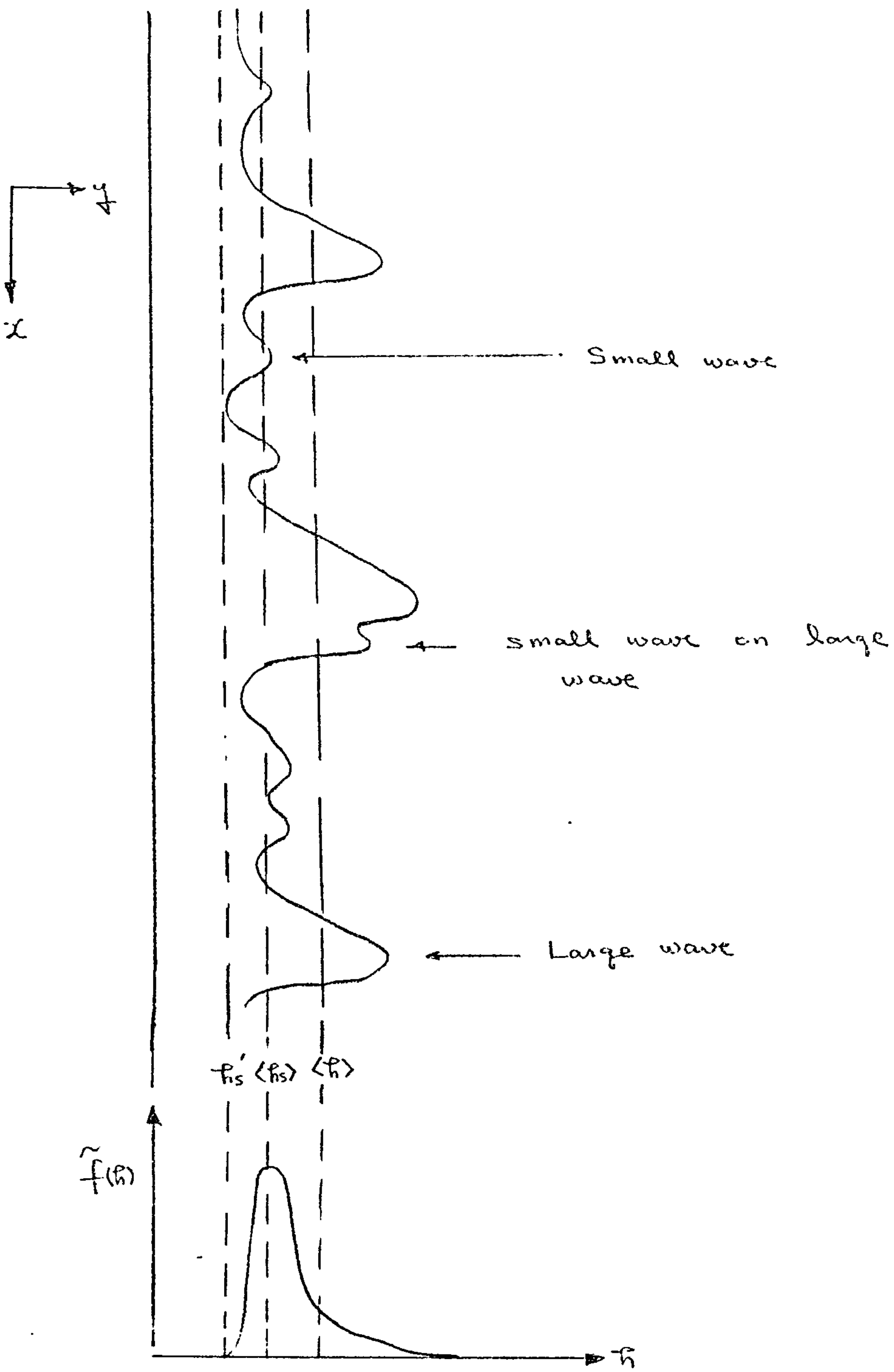


Fig. VI-35. WAVE STRUCTURE AND PROBABILITY DENSITY OF FILM THICKNESS the probability density of film thickness $\widetilde{f}(h)$. Since the wave amplitude of the small waves is quite small, its wave slope in the time domain should be quite linear over most of the range. Then the probability density function of h_s should be approximately symmetrical around $\langle h_s \rangle$ which is roughly equal to the modal value of $\widetilde{f}(h)$. Based on the above assumption, the probability density function of substrate $\widetilde{f}(h_s)$ can be approximately extracted from $\widetilde{f}(h)$ by the following procedures.

(a) The probability density function $\widetilde{f}(h)$ can be represented as the curve a b c d e f g h i j k in Fig. VI-36.

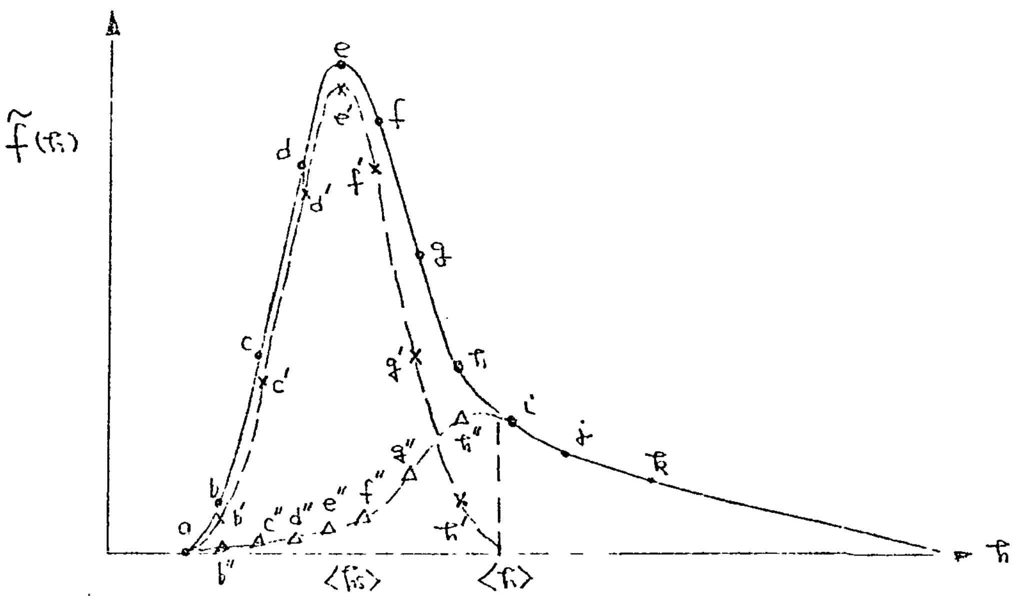


Fig. VI-36. ESTIMATION OF THE PROBABILITY DENSITY FUNCTION OF SUBSTRATE

(b) Since $\tilde{f}(h_s)$ is symmetrical about $\langle h_s \rangle$ in the neighborhood of $\langle h_s \rangle$ and the $\langle h_s \rangle$ is approximately equal the modal value e of $\tilde{f}(h)$, then one would obtain the point f', g', h', for the substrate by setting them equal to d, c, b.

(c) Taking the difference between pairs of (f, f'), (g, g') and (h, h'), one would obtain the curve f", g", h" for large waves.

(d) Interpolating the curve f", g", h" to point a, one would obtain the curve b", c", d" and e" for the large waves, and subtracting the above value from b, c, d, e, one obtains the curve b', c', d' and e' for the substrate.

(e) Hence we decompose the probability density $\tilde{f}(h)$ into two curves. One curve a, b', c', d', e', f', g', h' represent the substrate and another curve a, b", c", d", e", f", g", h", i, j, k represents the density for large waves. Call the above two curves $\widetilde{CV}_s$ and $\widetilde{CV}_w$ respectively.

From the above separation processes, one would obtain:

$$F_s = \int \widetilde{CV}_s \, dh \quad \text{— — — — — — —} \quad (\text{VI}-64)$$

$$F_w = \int \widetilde{CV}_w \, dh \quad \text{— — — — — — —} \quad (\text{VI}-65)$$

$$\tilde{f}(h_s) = \widetilde{CV}_s / F_s \quad \text{— — — — — —} \quad (\text{VI}-66)$$

$$\widetilde{f}(h_w) = \widetilde{CV}_w / F_w \quad \text{------------} \quad (VI-67)$$

where F_s = the time fraction occupied by substrate

F_w = the time fraction occupied by large waves

$\widetilde{f}(h_w)$ = the probability density function of the film thickness during passage of large waves and the small waves on the large waves.

But the time fraction F_s can also obtained from measurement of the wave base of the small waves and the wave separation of the large waves as follows:

$$T_s = \sum_{i=1}^{N_s} T_{bsi} = N_s \cdot \langle T_{bs} \rangle \quad \text{--------} \quad (VI-68)$$

$$T = \sum_{i=1}^{N_L} T_{sepi} = N_L \cdot \langle T_{sep} \rangle \quad \text{--------} \quad (VI-69)$$

$$F_s = \frac{T_s}{T} \quad \text{------------} \quad (VI-70)$$

$$F_w = 1 - F_s \quad \text{------------} \quad (VI-71)$$

where T_s = total time occupied by substrate

T_{bsi} = the wave base of small waves

N_s = total number of small waves

T_{sepi} = the wave separation of large waves

N_L = total number of large waves

This provides a check for the probability density function of substrate $\widetilde{f}(h_s)$ obtained from equation (VI-66). The data of F_s obtained from both equations (VI-64) and (VI-70) are given in Fig. VI-37. They agree reasonably well except at very low liquid rates. At very low liquid rates the estimation of the normalized $\widetilde{f}(h_s)$ should not have a large error because the density has a very narrow distribution. The mean values of the substrate $\langle h_s \rangle$, are plotted with the expected values of $\langle h_{max} \rangle$ and $\langle h_{min} \rangle$ for the small waves in Fig. VI-38. The data of $\langle h_s \rangle$ are bounded by $\langle h_{max} \rangle$ and $\langle h_{min} \rangle$, but they are close to the values of $\langle h_{min} \rangle$ than that of $\langle h_{max} \rangle$.

The small waves on the substrate have a very narrow distributions for the probability density of the wave parameters such as amplitude, base, wave front and wave back. Its wave velocity, C_s, is much lower than that of the large waves. This might suggest that there exist only a single mode of waves on the substrate. The probability density function of the wave maximum and the wave minimum for the small waves have much wider spread than that of wave amplitude. This indicates that although only a single mode of small wave is on the substrate, its relative position from the wall is affected by the large waves which exist in its neighborhood.

6-2. LARGE WAVE STRUCTURE

The relative relation between the large wave parameters $\langle h_{max} \rangle$, $\langle h_{min} \rangle$ and the mean film thickness $\langle h \rangle$ are given in

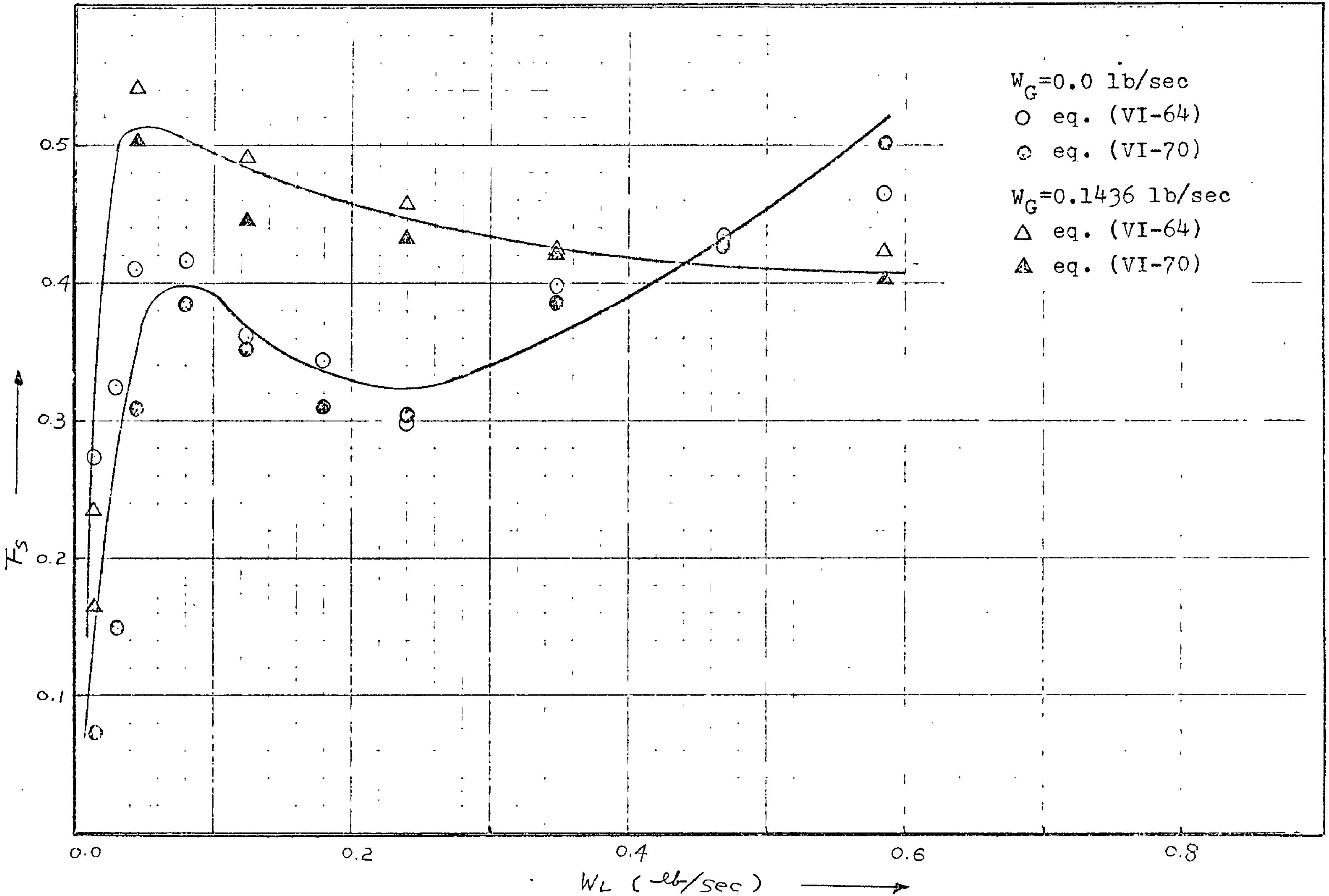


Fig. VI-37. FRACTION OF SUBSTRATE

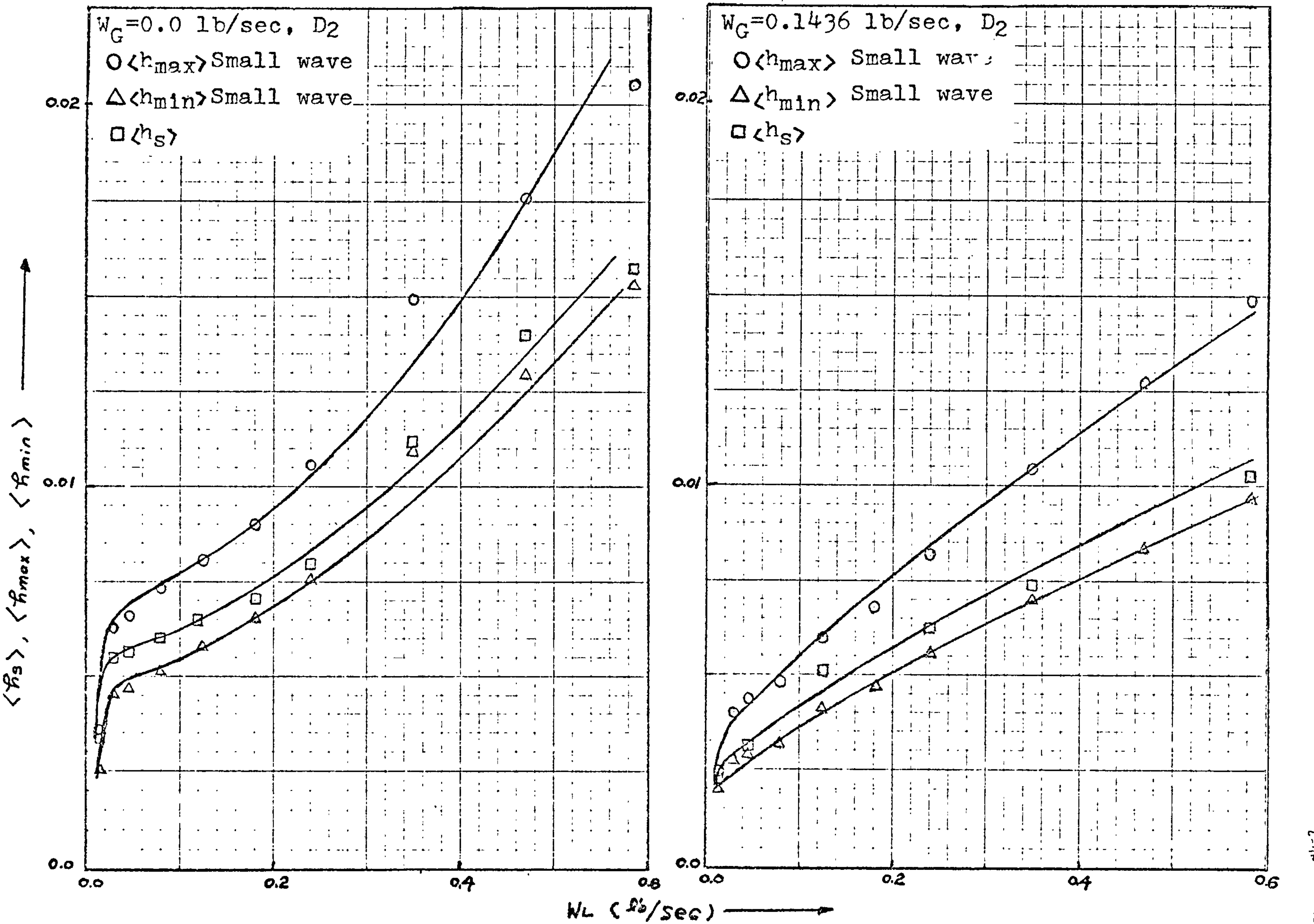


Fig. VI-38. SUBSTRATE STRUCTURE

Fig. VI-39. The mean film thickness $\langle h \rangle$ is well bounded by the mean maximum and the mean minimum of the large waves, and the ratio of $\{\langle h_{max} \rangle - \langle h \rangle\}$ to $\{\langle h \rangle - \langle h_{min} \rangle\}$ are approximately three to four except at very low liquid rates. The wave amplitude of the large waves $\langle A \rangle$, two times standard deviation of the film thickness $2\tilde{\sigma}_t$, and $2\tilde{\sigma}_w$ which is obtained from $\tilde{f}(h_w)$ are plotted in Fig. VI-40. The trend of $2\tilde{\sigma}_t$ and $2\tilde{\sigma}_w$ correspond well to that of $\langle A \rangle$. Although the values $2\tilde{\sigma}_t$ are smaller than the actual wave amplitude $\langle A \rangle$, it is not a bad first approximation for the wave amplitude. Twice the standard deviation has been used in previous studies when the actual data of wave amplitude was not measured.

The histogram function of the large waves presented in Chapter V shows certain trends of the data which will now be examined.

Since the histogram of wave maximum corresponds well to that of wave amplitude, the discussion below will base on the histogram of wave amplitude.

(a) Single mode region

A single modal peak on the wave amplitude histogram shows around A=0.0" - 0.01" for low liquid rates W_L = 0.0161 $\sim$ 0.044 lb/sec. The position of the modal peak decreases with the gas flow. A transition to the condition of a second

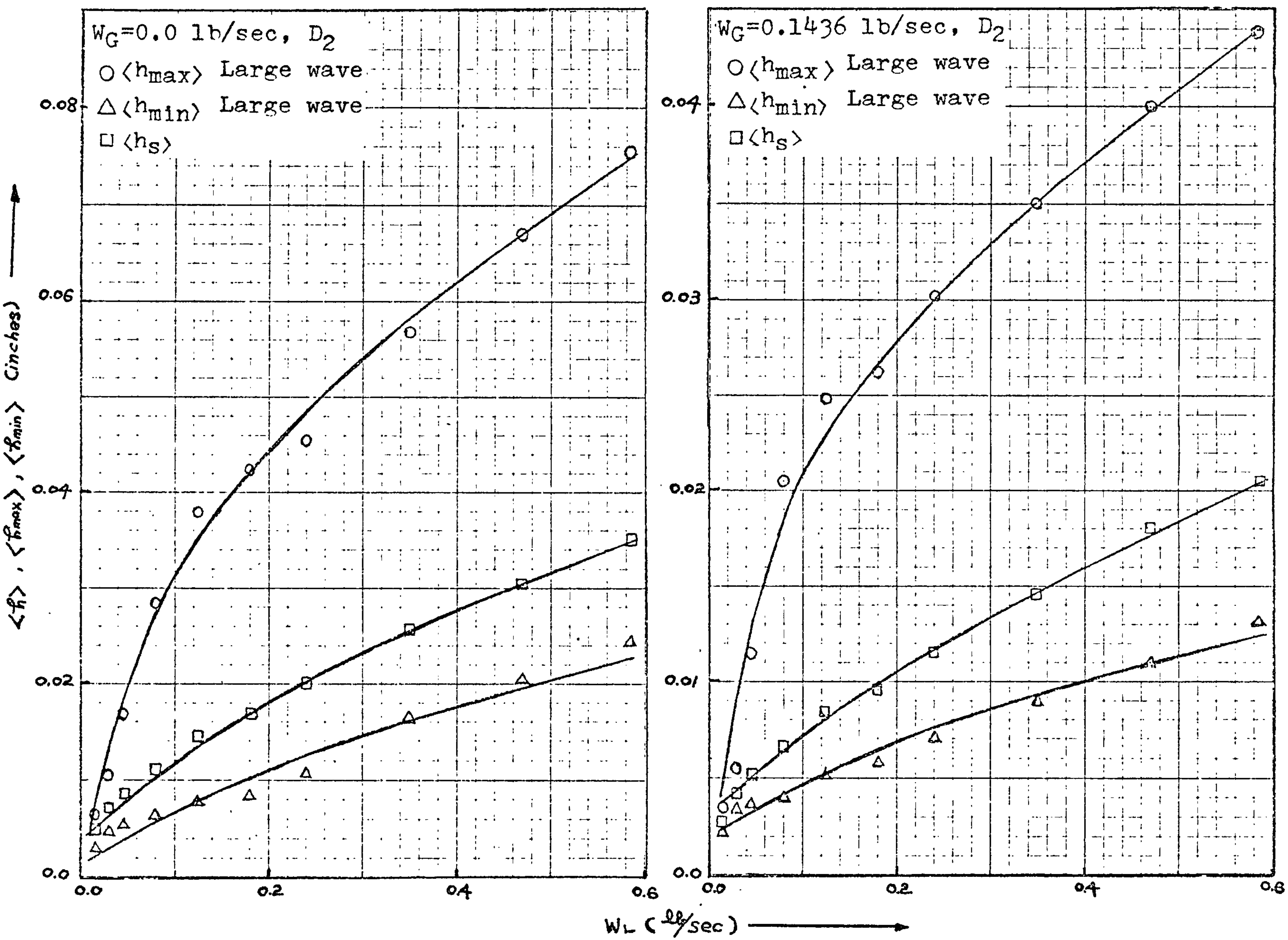


Fig. VI-39. LARGE WAVE STRUCTURE

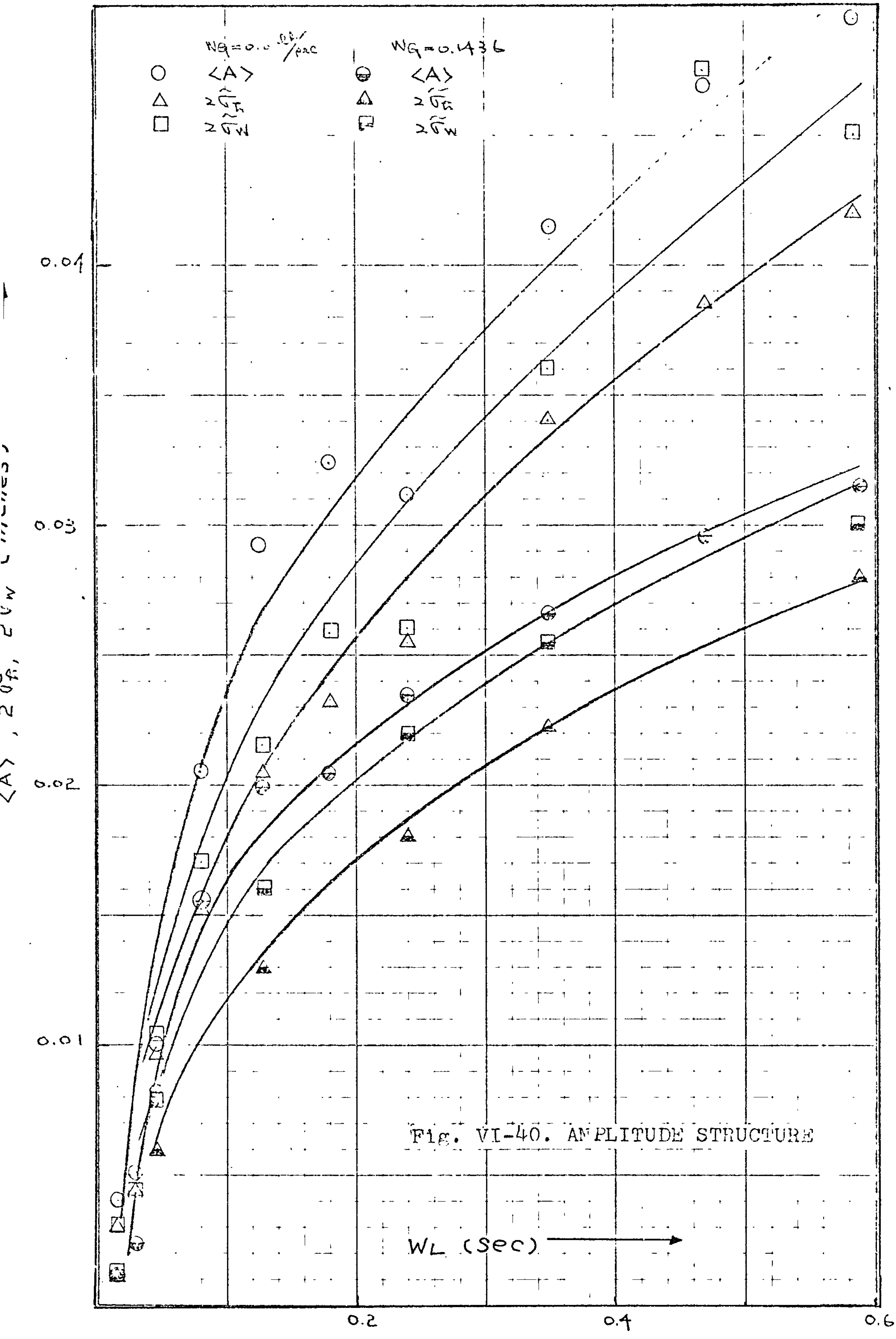


Fig. VI-40. AMPLITUDE STRUCTURE

modal peak above 0.01" begins to occur at W_L = 0.044 lb/sec

(b) Double mode region

As the liquid rate increases, a clearly observable double modal peak appears on the histogram. The first modal peak is located in the same range as the single mode peak discussed above. The second modal peak shows in the region A = 0.02" ~ 0.04". The range of liquid rate are 0.08 lb/sec ~ 0.18 lb/sec for W_G = 0.0 and 0.08 lb/sec ~ 0.24 lb/sec. for W_G = 0.1436. Another transition appears to exist near the highest liquid rate. At this condition, a relatively small peak starts to appear for A=0.04".

(c) Triple mode region

As the liquid rate further increases, another strong modal peak appears at the position about A = 0.05" ~ 0.06", while the other two peaks remain approximately at the same positions. The range of liquid flow rate is 0.24 lb/sec ~ 0.35 lb/sec for W_G = 0.0 lb/sec and 0.35 lb/sec ~ 0.47 lb/sec. for W_G = 0.1436 lb/sec.

(d) Another double modal region

As the liquid rate increases above 0.35 lb/sec for no gas flow and above 0.47 lb/sec for gas flow the modal peak located about A = 0.02" ~ 0.04" disappears, and the structure becomes a double modal peak again.

In the time domain, the wave base histogram exhibits a unique type of distribution. A clearly defined single structure exists. Hence the properties of the base can be well described by the mean value and the variance which are given in Chapter V. On the other hand, the histogram of the wave separation shows quite a different character which will be discussed as follows:

(a) For the case of no gas flow, a modal value appears around the value $T_{sep} = 0.075$ sec, and a narrow band distribution exists in the neighborhood of this peak value. There also appears two side lobes around this modal peak. The side lobe located below the modal peak suggests a very weak peak exists around $T_{sep} = 0.035$ sec. The side lobe above the modal peak first increases in width and magnitude with liquid rate until a peak value of $T_{sep} = 0.15$ sec. Then the spread of this side lobe decreases with liquid rate and the peak disappears.

(b) For the case of gas flow $W_G = 0.1436$ lb/sec, a single modal peak exists at very low liquid rates. The suggestion of a multiple peak structure emerges for the liquid rates 0.044 lb/sec $\sim$ 0.08 lb/sec. As the liquid rate increases, the spread of the curve decreases and a clearly double modal peak structure is formed for the liquid rates above 0.126 lb/sec.

A very common stochastic processes is the Poisson Processes (Random point in time) which occurs in many physical situations. The number of random points K between time t_1 and t_2 are given as Poisson distribution.

$$\hat{P}\left\{K \text{ in } (t_1, t_2)\right\} = e^{-\xi t} \frac{(\xi t)^K}{K!} \quad \text{---} \quad (\text{VI}-72)$$

And the separation time T_{sep} between the random points are described by the following equation:

$$\hat{f}(T_{sep}) = \xi e^{-\xi T_{sep}} U(T_{sep}) \quad \text{---} \quad (\text{VI}-73)$$

where ξ is the number of Random point per sec.

$U(\xi)$ is the unit step function.

The detailed description of the Poisson Processes and the proof of the equation (VI-72) and (VI-73) is given in Papoulis (P- 1). The comparison between equation (VI-73) and the large wave separation distribution are given in Fig. VI-41 and Fig. VI-42. The difference in these figures are expected, because the wave processes possess a finite wave base which is not negligible compared to the wave separation.

In the last chapter, a weak proportionality between the wave maximum and the wave separation was found from the joint histogram of them, and in this chapter, T'_{sep} which the wave separation between two consecutive large waves with $h_{max} > 2\langle h\rangle$ is much larger than the value of T_{sep} was also found. In the wave velocity analysis, the

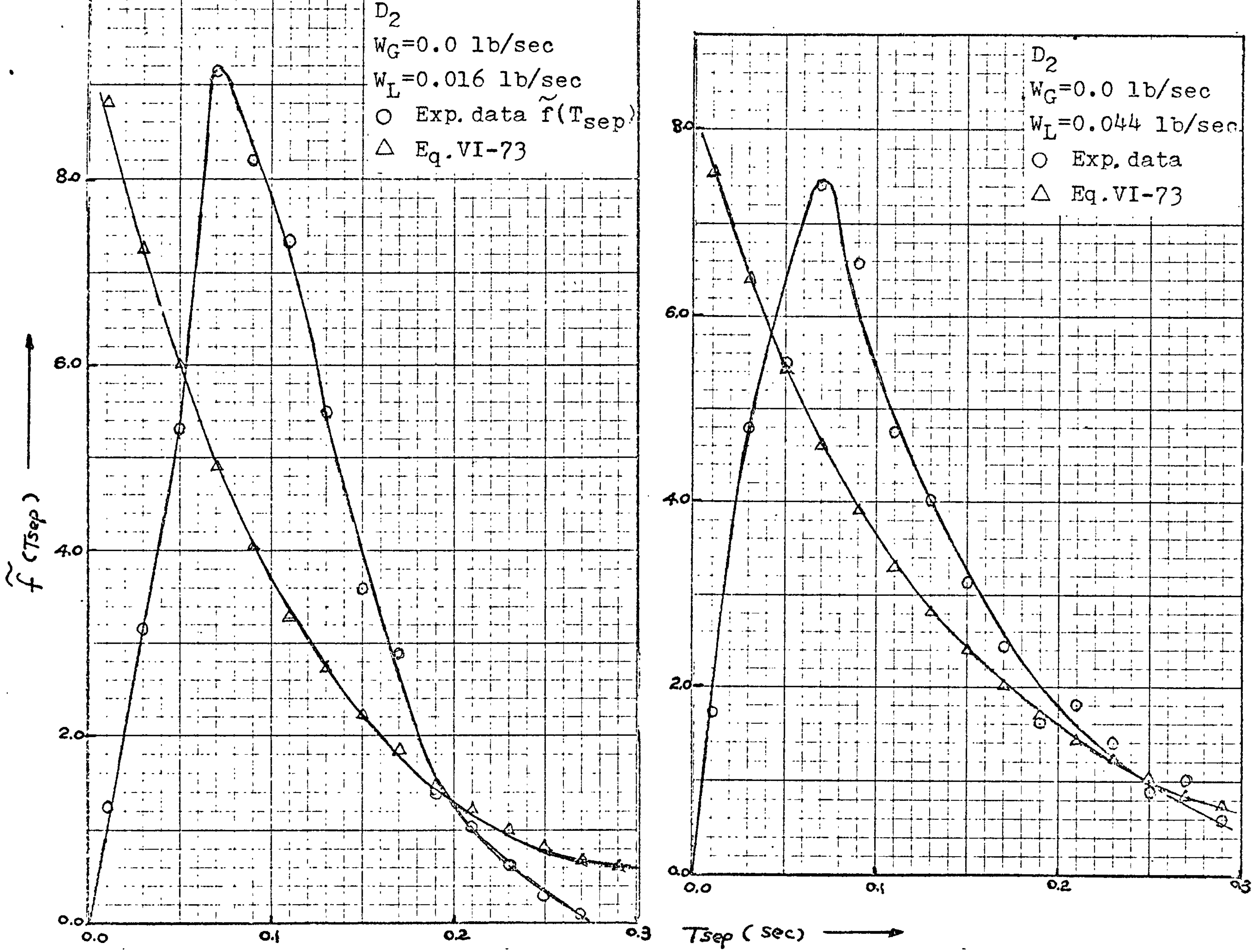


Fig. VI-41. POISSON'S ARRIVAL TIME

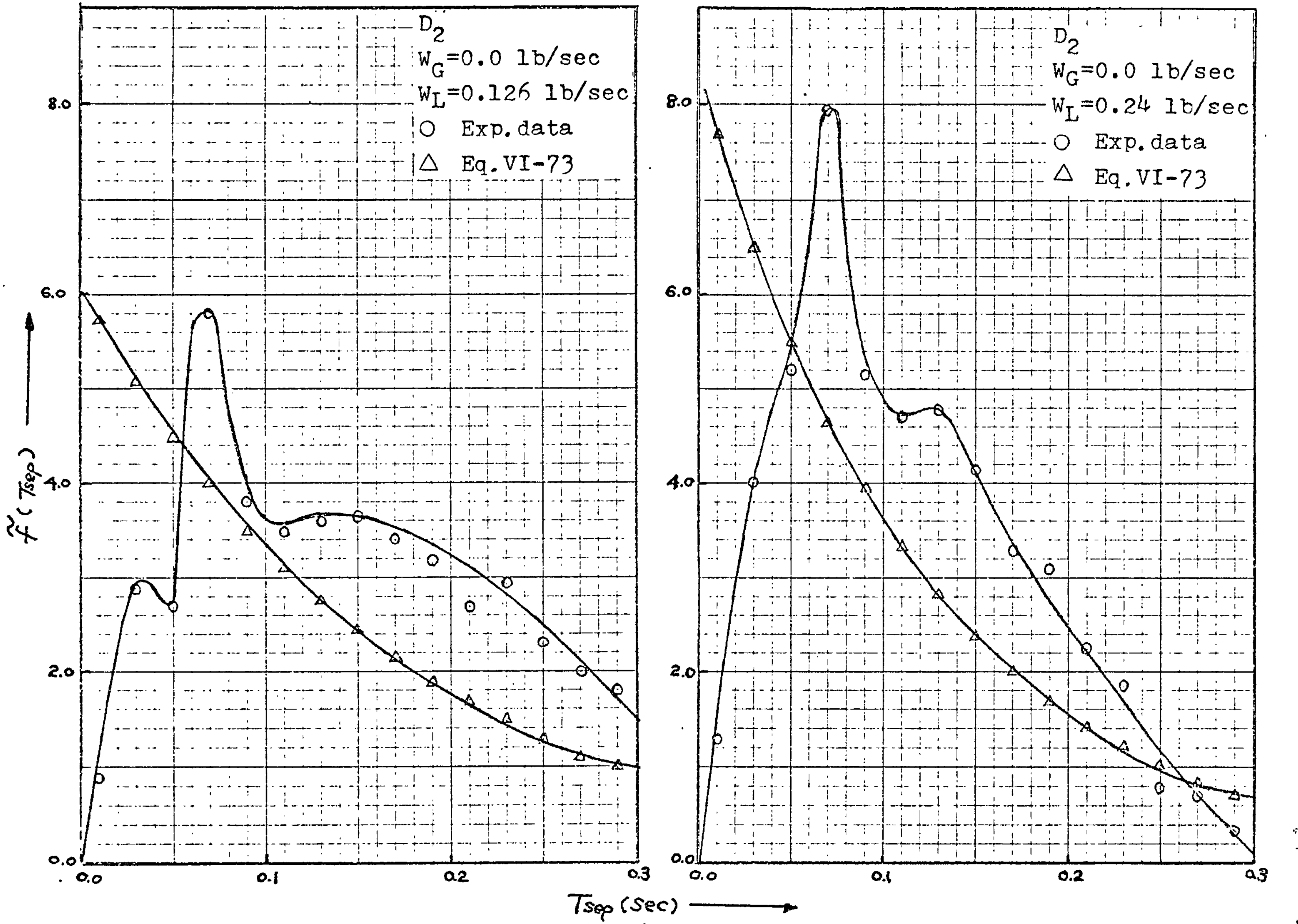


Fig. VI-42. POISSON'S ARRIVAL TIME

fact that the wave velocity depends on the wave frequency is also established. On the whole the following conclusions are obtained for large waves.

(a) There exists three characteristic wave sizes for the large waves on falling films. In the most range of liquid flow rates, there are only approximately two characteristic wave sizes for the large waves.

(b) The wave with larger amplitude is associated with the larger wave separation. This implies that if a very large wave passes by, the chance to have another very large wave in a short time is very small.

(c) The above suggests that the large waves actually carry most of the mass. Therefore whenever a very large wave occurs, there is not enough mass left to generate another very large wave.

(d) Since the wave frequency is inversely proportional to the wave separation; the larger waves generally move with larger velocity. From the location of a $\langle h \rangle$ on the wave maximum histogram, it seems that the large waves with the larger characteristics wave size move with the primary velocity C and control the statistical of film thickness such as $f_m, \mathcal{J}_m$.

The above qualitative picture confirms the Krantz and Goren's recent report (k-5) in which a bimodal waves with distinct wave velocities was found by artifical generation of waves.

7. INTERFACIAL SHEAR STRESS DUE TO WAVES

The first study of the interactions between gas and liquid on the falling film was done by Wicks (W-4) in this laboratory. He found that there must exist a form drag on the wave in order to predict the air flow rate based on the smooth film model. He obtained an indirect estimate of the drag coefficent. The direct measurement of this form drag presents a very difficult problem even for ocean waves and laboratory wind waves. In this section, the form drag is extracted from the simultaneous measurement of pressure fluctuation and film thickess on falling film.

7-1. WAVE STRESS ANALYSIS

The x direction component of the force per unit area exerted on an instantaneous wave is

$$\frac{F_x(t)}{A_L} = \frac{1}{2L}\int_{-L}^{+L} p(x, h, t)\, \frac{\partial h(x,t)}{\partial x}\, dx \qquad \text{(VI-74)}$$

where A_L is projected wave area on x - coordinate

2_L is wave length

$P(x, h, t)$ is surface pressure on wave.

From the equation, one can evaluate the time average form drag around the waves.

$$J_{FD} = \langle \frac{F_x(t)}{A_L} \rangle$$
$$= \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} \frac{1}{2L} \int_{-L}^{+L} p(x,h,t) \frac{dh(x,t)}{dx} dx\, dt \quad \text{---} \quad (VI-75)$$

Interchange the integration and equation becomes

$$J_{FD} = \frac{1}{2L} \int_{-L}^{+L} \left\{ \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} p(x,h,t) \frac{dh(x,t)}{dx} dt \right\} dx \quad \text{---} \quad (VI-76)$$

Assuming the waves are moving without changing shape at constant velocity C, then the independent variable x and t will reduce only to t, and the equation becomes

$$J_{FD} = (-\frac{1}{c}) \left\{ \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} p(h,t) \frac{dh(t)}{dt} dt \right\} \quad \text{————} \quad (VI-77)$$

If the simultaneous time series p(h,t) and $\frac{dh(t)}{dt}$ are available, the above equation provides the information on the form drag around the waves. Since the available time series is h(t) instead of $\frac{dh}{dt}$, the differentiation of time series will usually introduce a large error. Let $\dot{h}(t) = \frac{dh(t)}{dt}$, then the equation (VI-77) is actually a cross-correlation between $\dot{h}(t)$ and p(h,t) at time lag zero.

$$J_{FD} = -\frac{1}{c} \tilde{R}_{p\dot{h}}(0) \quad \text{—————} \quad (VI-78)$$

but

$$\tilde{R}_{p\dot{h}}(0) = -\frac{d\hat{R}_{ph}(0)}{d\tau} = -\frac{d\tilde{C}_{ph}(0)}{d\tau} \quad \text{--} \quad (VI-79)$$

The proof of equation (VI-79) is given in Papoulis (P-1). Substitute equations (VI-79), (IV-23) and (IV-25) into equation (VI-78) to obtain

$$J_{FD} = -\frac{2\pi}{C}\int_{-\infty}^{+\infty} f\,\tilde{Q}_{ph}(f)\,df \qquad \text{(VI-80)}$$

where $\tilde{Q}_{ph}(f)$ is quadrature spectrum of p(h,t) and h(t)

Since the liquid film is so thin, it is very plausible to assume that the wall pressure p(0, t) is identical to the pressure on the wave surface. But in order to make sure of the above assumption the following calculation is made. Consider y-direction momentum equation (II-3) and assume waves are moving at constant velocity C, then integrate the equation from y = 0 to y = h

$$p(\tau,h) = p(\tau,0) + \rho\int_0^h \left(\frac{u}{c}-1\right)v_\tau\,dy - \rho\int_0^h v\frac{\partial v}{\partial y}\,dy$$
$$+\mu\int_0^h\left(-\frac{1}{C^2}\frac{\partial^2 v}{\partial \tau^2}+\frac{\partial^2 v}{\partial y^2}\right)dy \qquad \text{(VI-81)}$$

A preliminary test by given a wave shape h(t) and various velocity profile shows that the viscous terms $\mu\int_0^h\left(-\frac{1}{C^2}\frac{\partial^2 v}{\partial \tau^2}+\frac{\partial^2 v}{\partial y^2}\right)dy$ are one order magnitude smaller than the inertia term along the wave length. Hence the equation can be simplified

$$p(\tau,h) = p(\tau,0) + \rho\int_0^h \left(\frac{u}{c}-1\right)v_\tau\,dy - \frac{\rho v^2}{2}(\tau,h) \qquad \text{(VI-82)}$$

Make a Taylor series expansion of u and v_t about y = h

$$v_\tau(\tau,y) = v_\tau(\tau,h) + v_{\tau y}(\tau,h)\cdot(y-h) + \cdots \qquad \text{(VI-83)}$$

$$u(\tau,y) = u(\tau,h) + u_y(\tau,h)\cdot(y-h) + \cdots \qquad \text{(VI-84)}$$

and retain only the first term

$$p(t,h) = p(t,0) + \rho\left(\frac{u(t,h)}{c} - 1\right) v_t(t,h)\,h - \rho\,\frac{v^2(t,h)}{2} \quad \text{--- (VI-85)}$$

From the kinematic condition and assuming $u(t,h)$ is small the equation becomes

$$p(t,h) = p(t,0) - \rho\left\{1 - \frac{u(t,h)}{c}\right\}^2 \frac{d^2h}{dt^2}\,h - \frac{\rho}{2}\left\{1 - \frac{u(t,h)}{c}\right\}^2 \left(\frac{dh}{dt}\right)^2 \quad \text{--- (VI-86)}$$

Now let assume u(t,h) is a very weak function of t and h such that $u(t,h) \simeq$ const.

Hence

$$\lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} p(t,h)\,\frac{dh}{dt}\,dt = P_A - \left\{1 - \frac{u(t,h)}{c}\right\}^2 P_B - \left\{1 - \frac{u(t,h)}{c}\right\}^2 P_C \quad \text{--- (VI-87)}$$

where

$$P_A = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} p(t,h)\,\frac{dh}{dt}\,dt$$

$$P_B = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} \frac{d^2h}{dt^2}\,h\,\frac{dh}{dt}\,dt$$

$$P_C = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} \left(\frac{dh}{dt}\right)^2 \frac{dh}{dt}\,dt$$

A direct calculation of terms P_A, P_B and P_C from time series p(t,0) and h(t) shows that P_A terms is much greater than terms P_B and P_C. Typical values of P_A, P_B and P_C are given in Table VI-6.

TABLE VI-6. COMPARISON OF VARIOUS TERM IN FORM DRAG AT W_G = 0.1436

W_L(lb/sec)	P_A	P_B	P_C
0.126	-0.246×10^{-1}	-0.25×10^{-2}	$+0.734\times10^{-3}$
0.24	-0.347×10^{-1}	-0.68×10^{-2}	$+0.163\times10^{-2}$
0.35	-0.603×10^{-1}	-0.11×10^{-1}	$+0.22\times10^{-2}$

Furthermore the value $\left(1 - \frac{u(t,\hbar)}{C}\right)^2$ is much less than 1. Therefore one can say

$$\lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{+T} p(t,\hbar)\,\frac{d\hbar}{dt}\,dt = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{+T} p(t,0)\,\frac{d\hbar}{dt}\,dt \quad \text{--- (VI-88)}$$

Hence the quardrature spectrum $\tilde{Q}_{p\hbar}$ can be approximated from the wall pressure p(t,0) and film thickness h(t).

7-2. WAVE STRESS DATA AND DRAG COEFFICIENT

The drag coefficient of the wave is defined as:

$$C_D = \frac{\tau_{FD}\,A_W}{A_p\,\frac{\rho_G U_R^2}{2g_c}} \quad \text{--- --- --- --- --- --- --- --- (VI-89)}$$

where A_W is projected area of wave on the y-plane

$\pi D \langle\lambda\rangle$

A_P is projected area of wave on the x-plane

$\pi D \langle A\rangle$

U_R is the relative velocity of gas phase to wave at interface U_G - C.

ρ_G is the density of the gas

In the above equation, the values of $\langle\lambda\rangle$ and $\langle A\rangle$ are obtained from the characteristic wave length and the characteristic wave amplitude of the large waves. Since the gas phase Reynolds number is very high, it is reasonable to use the average gas velocity for U_G. The equation (VI-90) becomes

$$C_D = \frac{\tau_{FD}}{\frac{\langle A\rangle}{\langle\lambda\rangle} \cdot \frac{\rho_G (U_G - C)^2}{2 g_c}} \quad \text{— — — — —} \quad (\text{VI}-90)$$

The values of wall stress τ_w from pressure drop, form drag τ_{FD} from equation (VI-80) and drag coefficient C_D from equation (VI-90) are given in Table VI-7.

The data show that the form drag is only 2.0-4.0% of the wall stress. It is obvious that the form drag will not affect the mean velocity profile in the gas phase too much. The present data of the drag coefficient is about the same order magnitude. As that of Wicks' work. But lack of data for $\langle A\rangle$ and $\langle\lambda\rangle$ in Wicks' work lead him to assume $\langle A\rangle/\langle\lambda\rangle = 1$, the measurement in this study shows the value of $\langle A\rangle/\langle\lambda\rangle =$ 0.002 - 0.004. Hence the drag coefficient obtained by this study will be two order magnitude smaller than that of Wicks' study provided the same value of $\langle A\rangle/\langle\lambda\rangle$ was used.

There are two possible reasons for the above inconsistence between Wicks' estimations and the experimental

TAPLE VI-7. WALL STRESS, FORM DRAG AND DRAG COEFFICIENT

W_G (lb/sec)	W_L (lb/sec)	$\tau_W = \frac{D}{4}\frac{dP}{dL}$ (lbf/ft^2)	τ_{FD} (lbf/ft^2)	τ_{FD}/τ_W (%)	C_D
	0.24	0.0752	0.0018	2.4	0.176
0.0976	0.35	0.0985	0.00254	2.58	0.26
	0.585	0.142	0.00217	1.53	0.20
	0.126	0.111	0.00259	2.33	0.156
	0.24	0.152	0.00436	2.87	0.232
0.1436	0.35	0.176	0.0068	3.86	0.332
	0.585	0.249	0.00798	3.21	0.356
	0.126	0.182	0.00372	2.05	0.197
	0.24	0.249	0.00548	2.20	0.232
0.1742	0.35	0.273	0.00714	2.61	0.252
	0.585	0.380	0.00934	2.46	0.310

data in this study.

(a) The validity of the velocity profile in Wick's work

Wicks integrated Dukler's turbulent velocity profile from the wall to the liquid interface to obtain the interface velocity U_i and the interface shear τ_{iL} . Assuming various τ_{iG} at interface, he integrated the velocity profile for the gas phase to match the known gas flow rate by using U_i as gas velocity at interface. Then the form drag will be

$$\tau_{FD} = \tau_{iL} - \tau_{iG} \qquad \text{(VI-91)}$$

Since the velocity profile on the falling film has never been measured, the argument is that if the liquid mean velocity profile away from the wall is much flatter than Dukler's turbulent velocity profile. Then this will give a smaller value U_i and τ_{iL} at interface. A smaller U_i will required a larger τ_{iG} to match the gas flow rate. Hence the form drag will become much smaller than that from the Dukler turbulent velocity profile. The evident to suggest a flatter mean velocity profile will be discussed in the next chapter.

(b) The content of information from the wall pressure fluctuation

A similar technique used in this study was recently used

By Dobson (D-1) to measure the drag of wind waves. The other measurements of wave drag of the ocean wave and the laboratory wind wave were obtained from the velocity profile of the wind above the wave such as Plate, Chang, and Hidy (P-8), Chang, Plate and Hidy (C-2), Wu (W-8) and stewart (S-6). The value of the drag coefficient from their reports is close to the value obtained from this study, but none of their data showed the high drag coefficient as Wicks' work. There is much spectulation about wind-wave interactions. One of the most interesting works was done by Wu (W-6, W-7, W-9). He proposed that there exists a region such that the air separation from waves is developed due to the form drag provided by small capillary waves rather than large gravity waves. In this region, the small capillary waves move much slower than the large waves. Hence the slope of the small waves is much steeper than that of the large waves. Therefore many of small air separations will occur on the lee of small waves. This is also the case of falling film in which the value of $\langle A \rangle / \langle \lambda \rangle$ for small waves is around 0.03 - 0.07 and for large waves is around 0.003 - 0.004. Furthermore the number of small waves is 1.5 - 2 times the number of large waves from the wave traces. But the small waves are strongly three dimensional, and the large waves are strongly two dimensional. Therefore the ratio of the number of the small waves to that of the large waves per unit area will be around 5 - 8. Unfortunately the pressure sensor used in this study was unable to pick up all the pressure fluctuation due to the small waves. This can be easily seen from the energy contain of the $\widetilde{Q}_{pk}(f)$ in the frequency range of the small waves. The complete picture of gas-liquid interaction can only be obtained if the simultaneous measurement of the gas velocity field is available.

CHAPTER VII

THEORETICAL CONSIDERATIONS

1. INTRODUCTION

In the preceeding three chapters, data describing the the characteristic on the falling film with and without gas flow show that the process is indeed a stochastic one. But earlier theoretical work described in Chapter III assumed a deterministic analysis except for Telles' model.

Any attempt to predict complete characteristics of the falling film is doomed to failure from this evidence. The stochastics approach recommended in this chapter is only one possible way to practically predict behavior of such a complicated system. The goal of these approaches is to give a more fundamental understanding and to provide an extension of the stochastic approach to this complex wavy flow.

2. RANDOM WAVE MODEL

In general the linear and non-linear theories of the wavy liquid film discussed in Chapter III, considered the wave motion as:

$$\bar{h}(t) = A \sin 2\pi f_1 t \qquad \text{(VII-1)}$$

under the above consideration, the spectral density function and the auto-correlation function will be;

$$\tilde{S}(f) = A^2 \delta(f - f_1) \quad \text{--------} \quad (\text{VII-2})$$

$$\tilde{R}(\tau) = A^2 \cos 2\pi f_1 \tau \quad \text{--------} \quad (\text{VII-3})$$

The delta function for the spectrum and the cosine function for the correlation as shown above are not observed from the experimental data.

In 1959, Tick (T-4) proposed a random model for gravity waves on the ocean. The main concept of this model is that a stochastic input is given to the velocity field and this is used to find the spectral density function of the free surface. A summary of Tick's method is given in Appendix E. A similar principle will be used here for falling films to obtain a non-delta function spectrum for the wave surface h(t).

2-1. FORMULATION OF THE PROBLEM

For two dimensional flow of an incompressible fluid, the Nusselt equation is assumed to describe the primary flow. Refer to Fig. VII-1.

$$\rho g + \mu \frac{dU_1^2}{dy} = 0 \quad \text{--------} \quad (\text{VII-4})$$

The boundary conditions are

$$U_1 = 0 \qquad \text{at} \quad y_1 = h_0 \quad \text{------} \quad (\text{VII-5})$$

$$\frac{dU_1}{dy} = 0 \qquad \text{at} \quad y_1 = h_1 \quad \text{------} \quad (\text{VII-6})$$

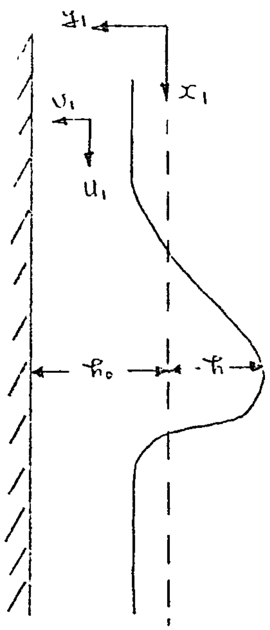


Fig. VII-1. CONFIGURATION OF FLOW FIELD

This undisturbed primary flow will give the parabolic velocity profile and the mean velocity as:

$$U_1(y) = \frac{g}{2\nu}\left(h_0^2 - y_1^2\right) \qquad \text{(VII-7)}$$

$$U_0 = \frac{g h_0^2}{3\nu} \qquad \text{(VII-8)}$$

where h_0 is the mean film thickness

U_0 is the mean velocity

Furthermore if one defines the Reynolds number and Froude number as follow:

$$Re = \frac{4 U_0 h_0}{\nu} \qquad \text{(VII-9)}$$

$$Fr = \frac{U_0}{(g h_0)^{1/2}} \qquad \text{(VII-10)}$$

The primary flow will give

$$12\, Fr^2 = Re \qquad \text{(VII-11)}$$

Now consider the disturbed flow field as described by the following set of equations and boundary conditions.

$$\left.\begin{aligned}
&\frac{\partial u_1}{\partial x_1}+\frac{\partial v_1}{\partial y_1}=0\\
&\frac{\partial u_1}{\partial t_1}+u_1\frac{\partial u_1}{\partial x_1}+v_1\frac{\partial u_1}{\partial y_1}=-\frac{1}{\rho}\frac{\partial p_1}{\partial x_1}+g+\nu\left(\frac{\partial^2 u_1}{\partial x_1^2}+\frac{\partial^2 u_1}{\partial y_1^2}\right)\\
&\frac{\partial v_1}{\partial t_1}+u_1\frac{\partial v_1}{\partial x_1}+v_1\frac{\partial v_1}{\partial y_1}=-\frac{1}{\rho}\frac{\partial p_1}{\partial x_1}+\nu\left(\frac{\partial^2 v_1}{\partial x_1^2}+\frac{\partial^2 v_1}{\partial y_1^2}\right)
\end{aligned}\right\}\text{---}\quad(\text{VII}-12)$$

The no-slip boundary condition at solid wall gives

$$\left.\begin{aligned}u_1&=0\\ v_1&=0\end{aligned}\right\}\quad \text{at}\quad y=h_0\quad\text{---------}\quad(\text{VII}-13)$$

The stress and kinematic boundary conditions at free surface are

$$\left.\begin{aligned}
&\frac{\partial v_1}{\partial x_1}+\frac{\partial u_1}{\partial y_1}=0\\
&-p_1+2\mu\frac{\partial v_1}{\partial y_1}+\sigma\frac{\partial^2 h}{\partial x^2}=0\\
&v_1=\frac{\partial h}{\partial t_1}+u_1\frac{\partial h}{\partial x_1}
\end{aligned}\right\}\quad \text{at}\quad y=h\quad\text{-----}\quad(\text{VII}-14)$$

The following three manipulations will be done on the above equations and boundary conditions.

(a) Introduce dimensionless groups

$$\left.\begin{aligned}
(u,v,U)&=(u_1,v_1,U_1)/U_0\\
(x,y,\eta)&=(x_1,y_1,h)/h_0\\
p&=p_1/\rho U_0^2\\
t&=t_1U_0/h_0
\end{aligned}\right\}\text{-------}\quad(\text{VII}-15)$$

(b) Define the perturbation quantities for the primary flow field

$$\left.\begin{aligned} u &= U(y) + u' \\ v &= v' \\ p &= p' \end{aligned}\right\} \qquad \text{(VII-16)}$$

(c) Introduce the stream function

$$\left.\begin{aligned} u' &= \psi_y \\ v' &= -\psi_x \end{aligned}\right\} \qquad \text{(VII-17)}$$

By substituting equations (VII-4), (VII-5), (VII-6), (VII-11), (VII-15), (VII-16) and (VII-17) into equations (VII-12), (VII-13) and (VII-14), one obtains

$$\left.\begin{aligned} \psi_{yt} + (U + \psi_y)\,\psi_{yx} - (U_y + \psi_{yy})\,\psi_x &= -p'_x + \frac{4}{Re}(\psi_{yxx} + \psi_{yyy}) \\ -\psi_{xt} - (U + \psi_y)\,\psi_{xx} + \psi_x\,\psi_{xy} &= -p'_y - \frac{4}{Re}(\psi_{xxx} + \psi_{xyy}) \end{aligned}\right\} \qquad \text{(VII-18)}$$

Boundary conditions

$$\left.\begin{aligned} \psi_y &= 0 \\ \psi_x &= 0 \end{aligned}\right\} \quad \text{at } y = 1 \qquad \text{(VII-19)}$$

$$\left.\begin{aligned} U_y + \psi_{yy} - \psi_{xx} &= 0 \\ -p' - \frac{8}{Re}\psi_{xy} + \frac{1}{We}\eta_{xx} &= 0 \\ \eta_t + (U + \psi_y)\,\eta_x + \psi_x &= 0 \end{aligned}\right\} \quad \text{at } y = \eta \qquad \text{(VII-20)}$$

where $We = \frac{\rho h_0 V_0^2}{\sigma}$ is a surface tension parameter called Weber number.

The above equations present two difficulties; one is that the motion is unsteady, the other one is that the free surface boundary condition is evaluated at the unknown surface η. In order to avoid the above difficulties, the following steps are taken:

(a) Assuming the motion is the form of a progressing wave,

$$\left.\begin{aligned} \psi(x, y, t) &= \psi\left(t - \frac{x}{c}, y\right) \\ p'(x, y, t) &= p'\left(t - \frac{x}{c}, y\right) \\ \eta(x, t) &= \eta\left(t - \frac{x}{c}\right) \end{aligned}\right\} \text{------- (VII-21)}$$

A time scale is used instead of the usual length scale so that the final form of the spectrum of η is deduced in frequency space rather than in wave number space.

(b) Make the Taylor expansion about y = 0 on the following variables:

$$\left.\begin{aligned} \psi(t, y) &= \psi(t, 0) + \psi_y(t, 0)\, y + \psi_{yy}(t, 0)\, \frac{y^2}{2} + \cdots \\ p'(t, y) &= p'(t, 0) + p'_y(t, 0)\, y + p'_{yy}(t, 0)\, \frac{y^2}{2} + \cdots \\ U(y) &= U(0) + U_y(0)\, y + U_{yy}(0)\, \frac{y^2}{2} + \cdots \end{aligned}\right\} \text{--- (VII-22)}$$

Substitute equation (VII-21) into equations (VII-18), (VII-19) and (VII-20), and also substitute equation (VII-22) into equation (VII-20). Furthermore the assumption that the surface velocity dominates the motion, first suggested by Anshus (A-2, A-3) is also applied to the basic equation (VII-18). This enables one to use $U(0)$ and $U_y(0)$ instead of $U(y)$ and $U_y(y)$. Hence the above set of equations and boundary conditions become

$$\left.\begin{aligned}&\frac{1}{c}P_t' + \frac{4}{Re}\left\{\frac{1}{c^2}\psi_{y\tau\tau} + \psi_{yyy}\right\} + \left\{\frac{3}{2}\frac{1}{c} - 1\right\}\psi_{y\tau} \\ &\qquad = \frac{1}{c}\left\{\psi_{yy}\psi_\tau - \psi_y\psi_{y\tau}\right\} \\ &-P_y' + \frac{4}{Re}\frac{1}{c}\left\{\frac{1}{c^2}\psi_{\tau\tau\tau} + \psi_{\tau yy}\right\} + \frac{1}{c}\left\{\frac{3}{2}\frac{1}{c} - 1\right\}\psi_{\tau\tau} \\ &\qquad = \frac{1}{c^2}\left\{\psi_\tau\psi_{\tau y} - \psi_y\psi_{\tau\tau}\right\}\end{aligned}\right\} \quad \text{--- (VII-23)}$$

And the boundary conditions are

$$\left.\begin{aligned}\frac{1}{c}\psi_\tau &= 0 \\ \psi_y &= 0\end{aligned}\right\} \quad \text{at } y = 1 \quad \text{------ (VII-24)}$$

$$\left.\begin{aligned}&-3\eta + \psi_{yy} - \frac{1}{c^2}\psi_{\tau\tau} = \frac{1}{c^2}\psi_{\tau\tau y}\eta - \psi_{yyy}\eta \\ &-p' + \frac{8}{Re}\frac{1}{c}\psi_{\tau y} + \frac{1}{We\,c^2}\eta_{\tau\tau} = p_y'\eta - \frac{8}{Re}\frac{1}{c}\psi_{\tau yy}\eta \\ &\left(1 - \frac{3}{2}\frac{1}{c}\right)\eta_\tau - \frac{1}{c}\psi_\tau = \frac{1}{c}\left(\psi_y\eta_\tau + \psi_{\tau y}\eta\right)\end{aligned}\right\} \quad \text{--- (VII-25)}$$

The above equations and boundary conditions are written in such form that the linear terms are on the left hand side and the nonlinear terms are on the right hand side.

2-2. SOLUTION OF THE LINEAR EQUATION

Separate the solution in the manner similar to Tick

$$\left.\begin{aligned}\psi(\tau, y) &= \psi^{(1)}(\tau, y) + \psi^{(2)}(\tau, y) \\ p'(\tau, y) &= p^{(1)}(\tau, y) + p^{(2)}(\tau, y) \\ \eta(\tau) &= \eta^{(1)}(\tau) + \eta^{(2)}(\tau)\end{aligned}\right\} \quad \text{---- (VII-26)}$$

where the quantities $\psi^{(1)}$, $p^{(1)}$ and $\eta^{(1)}$ are solutions of the linear part of the above equations (VII-23), (VII-24) and (VII-25). The quantities $\psi^{(2)}$, $p^{(2)}$ and $\eta^{(2)}$ are the small correction on the linear part of solutions due to the nonlinear terms.

Consider only the linear part of the equations (VII-23), (VII-24) and (VII-25). The equations become

$$\frac{Re}{4}\frac{1}{c}\, p_t^{(1)} + \frac{1}{c^2}\,\psi_{ytt}^{(1)} + \psi_{yyy}^{(1)} + \frac{Re}{4}\left(\frac{3}{2}\frac{1}{c}-1\right)\psi_{yt}^{(1)} = 0 \quad \text{--- (VII-27)}$$

$$-\frac{Re}{4}\, c\, p_y^{(1)} + \frac{1}{c^2}\,\psi_{ttt}^{(1)} + \psi_{tyy}^{(1)} + \frac{Re}{4}\left(\frac{3}{2}\frac{1}{c}-1\right)\psi_{tt}^{(1)} = 0 \quad \text{--- (VII-28)}$$

The boundary conditions are:

$$\left.\begin{aligned} \psi_t^{(1)} &= 0 \\ \psi_y^{(1)} &= 0 \end{aligned}\right\} \text{ at } y=1 \quad \begin{aligned} &\text{------ (VII-29)} \\ &\text{------ (VII-30)} \end{aligned}$$

$$\left.\begin{aligned} -3\eta^{(1)} + \psi_{yy}^{(1)} - \frac{1}{c^2}\,\psi_{tt}^{(1)} &= 0 \\ -p^{(1)} + \frac{8}{Re\, c}\,\psi_{ty}^{(1)} + \frac{1}{We\, c^2}\,\eta_{tt}^{(1)} &= 0 \\ \left(1-\frac{3}{2}\frac{1}{c}\right)\eta_t^{(1)} - \frac{1}{c}\,\psi_t^{(1)} &= 0 \end{aligned}\right\} \text{ at } y=0 \quad \begin{aligned} &\text{------ (VII-31)} \\ &\text{------ (VII-32)} \\ &\text{------ (VII-33)} \end{aligned}$$

Eliminating the variables $P^{(1)}$ and $\eta^{(1)}$ in the above equations (VII-27) through (VII-33), one obtains

$$\psi^{(1)}_{yyyy} + \frac{2}{c^2}\psi^{(1)}_{\tau\tau yy} + \frac{1}{c^4}\psi^{(1)}_{\tau\tau\tau\tau} + \frac{Re}{4}\left(\frac{3}{2}\frac{1}{c}-1\right)\cdot$$

$$\left(\psi^{(1)}_{yy\tau} + \frac{1}{c^2}\psi^{(1)}_{\tau\tau\tau}\right) + \frac{3}{4}\frac{Re}{c}\psi^{(1)}_{\tau} = 0 \quad ----(\text{VII-34})$$

The boundary conditions are:

$$\left.\begin{array}{l}\psi^{(1)}_{\tau} = 0 \\ \psi^{(1)}_{y} = 0\end{array}\right\} \text{at } y=1 \quad \begin{array}{r}------(\text{VII-35}) \\ ------(\text{VII-36})\end{array}$$

and

$$\frac{3}{c}\psi^{(1)}_{\tau} + \left(\frac{3}{2}\frac{1}{c}-1\right)\left(\psi^{(1)}_{\tau yy} - \frac{1}{c^2}\psi^{(1)}_{\tau\tau\tau}\right) = 0 \quad ---(\text{VII-37})$$

$$\left(\frac{3}{2}\frac{1}{c}-1\right)\left(\psi^{(1)}_{yyy} + \frac{3}{c^2}\psi^{(1)}_{\tau\tau y}\right) + \frac{Re}{4}\left(\frac{3}{2}\frac{1}{c}-1\right)^2\psi^{(1)}_{y\tau}$$

$$- \frac{Re}{4c^4 We}\psi^{(1)}_{\tau\tau\tau} = 0 \quad ---(\text{VII-38})$$

at $y=0$

Now let $\psi^{(1)}$ be a stochastic process, thus the generalized Fourier Transform of $\hat{\psi}^{(1)}$ exists and the form $\hat{\psi}^{(1)}$ can be expressed as:

$$\hat{\psi}^{(1)}(\tau, y) = \int_{-\infty}^{+\infty} e^{+i\omega\tau}\, d\hat{G}_1(\omega, y) \quad ----(\text{VII-39})$$

where $\omega = \frac{2\pi f h_0}{U_0}$ is a dimensionless angular frequency.

By substituting equation (VII-39) into equation (VII-34), the basic equation becomes a fourth order ordinary differential equation in y at given ω as:

$$(D_1^4 + K_1 D_1^2 + K_2)\, d\hat{G}_1(\omega, y) = 0 \qquad \text{-------} \qquad (\text{VI}-40)$$

where

$$D_1 = \frac{\partial}{\partial y}$$

$$K_1 = i\,\frac{R_e}{4}\left(\frac{3}{2}\frac{1}{c} - 1\right)\omega - 2\,\frac{\omega^2}{c^2}$$

$$K_2 = \frac{\omega^4}{c^4} - i\,\frac{R_e}{4}\left(\frac{3}{2}\frac{1}{c} - 1\right) + i\,3\,\frac{R_e}{4}\frac{\omega}{c}$$

The form of the solution $dG_1(\omega, y)$ can be written as:

$$d\hat{G}_1(\omega, y) = e^{a_1 y}\, d\hat{A}_1(\omega) + e^{a_2 y}\, d\hat{A}_2(\omega) + e^{a_3 y}\, d\hat{A}_3(\omega) + e^{a_4 y}\, d\hat{A}_4(\omega) \qquad \text{--------} \qquad (\text{VI}-41)$$

where

$$a_1(\omega) = \left(\frac{-K_1 + \sqrt{K_1^2 - 4K_2}}{2}\right)^{1/2}$$

$$a_2(\omega) = \left(\frac{-K_1 - \sqrt{K_1^2 - 4K_2}}{2}\right)^{1/2}$$

$$a_3(\omega) = -\left(\frac{-K_1 + \sqrt{K_1^2 - 4K_2}}{2}\right)^{1/2}$$

$$a_4(\omega) = -\left(\frac{-K_1 - \sqrt{K_1^2 - 4K_2}}{2}\right)^{1/2}$$

By substituting equations (VII-39) and (VII-41) into the boundary conditions (VII-35), (VII-36), and (VII-37), one can solve the quantities $dA_1(\omega)$, $dA_2(\omega)$ and $dA_3(\omega)$ in terms $dA_4(\omega)$ as:

$$d\hat{G}_1(\omega, y) = F^{(1)}(Re, c, \omega, y)\, d\hat{G}(\omega) \qquad \text{(VII-42)}$$

where $\qquad d\hat{G}(\omega) = d\hat{A}_4(\omega)$

$$F^{(1)}(Re, c, \omega, y) = Fl_3\, e^{a_1 y} + FL_2\, e^{a_2 y} + FL_1\, e^{a_3 y} + e^{a_4 y}$$

$$FL_1(a_1, a_2, a_3, a_4, \omega) = -FD(a_4, \omega)\,/\,FD(a_3, \omega)$$

$$FL_2(a_1, a_2, a_3, a_4, \omega) = \left\{-FB(a_3, \omega)\cdot FL_1 - FB(a_4, \omega)\right\} / FB(a_2, \omega)$$

$$Fl_3(a_1, a_2, a_3, a_4, \omega) = \left\{-FL_1\, e^{a_3} - FL_2\, e^{a_2} - e^{a_4}\right\} e^{-a_1}$$

$$FA(a_j, \omega) = i\left\{3\frac{\omega}{c} + \left(\frac{3}{2}\frac{1}{c} - 1\right)\omega a_j^2 + \left(\frac{3}{2}\frac{1}{c} - 1\right)\frac{\omega^3}{c^2}\right\} \qquad j = 1, 2, 3, 4$$

$$FB(a_j, \omega) = (a_1 - a_j)\, e^{a_j} \qquad j = 2, 3, 4$$

$$FC(a_j, \omega) = FA(a_1, \omega)\, e^{a_j} - FA(a_j, \omega)\, e^{a_1} \qquad j = 2, 3, 4$$

$$FD(a_j, \omega) = FC(a_2, \omega)\, FB(a_j, \omega) - FB(a_2, \omega)\, FC(a_j, \omega)$$

$$j = 2, 3, 4$$

Hence the linear part of stream function will be

$$\hat{\psi}^{(1)}(t,y) = \int_{-\infty}^{+\infty} e^{+i\omega t} F^{(1)}(Re, C, \omega, y)\, d\hat{G}(\omega) \quad --- \quad (\text{VII}-43)$$

Substituting the above equation (VII-43) into the last boundary condition (VII-38), one obtains the closure for the wave velocity C.

$$\left(\frac{3}{2}\,\frac{1}{C} - 1\right)\left\{F^{(1)}_{yyy}(Re, C, \omega, 0) + \frac{3}{C^2}(i\omega)^2 F^{(1)}_{y}(Re, C, \omega, 0)\right\}$$

$$+ \frac{Re}{4}\left(\frac{3}{2}\,\frac{1}{C} - 1\right)^2 (i\omega)\, F^{(1)}_{y}(Re, C, \omega, 0) - \frac{Re}{4\,We}\,\frac{1}{C^4}\, F^{(1)}(Re, C, \omega, 0)$$

$$= 0 \quad --- - --- - --- \quad (\text{VII}-44)$$

The linear solution for the surface η can be obtained from equation (VII-31) as:

$$\hat{\eta}^{(1)}(t) = \int_{-\infty}^{+\infty} e^{+i\omega t} H^{(1)}(Re, C, \omega)\, d\hat{G}(\omega) \quad ----- \quad (\text{VII}-45)$$

where

$$H^{(1)}(Re, C, \omega) = \frac{1}{3}\left\{F^{(1)}_{yy}(Re, C, \omega, 0) + \frac{\omega^2}{C^2} F^{(1)}(Re, C, \omega, 0)\right\}$$

2-3. SPECTRAL DENSITY FUNCTION OF $\hat{\eta}^{(1)}(t)$

In the above section, the random process $d\hat{G}(\omega)$ is the differential of one dimensional random process of uncorrelated increments which have the properties.

$$\langle d\hat{G}(\omega_1)\, d\hat{G}^{*}(\omega_2)\rangle = \begin{cases} 2\pi\,\hat{S}(\omega)\,d\omega & \text{if } \omega=\omega_1=\omega_2 \\ 0 & \text{if } \omega_1 \neq \omega_2 \end{cases} \quad \text{--- (VII-46)}$$

By the definition, the auto-correlation of $\hat{\eta}^{(1)}(t)$ will be

$$\tilde{R}^{(1)}(\tau) = \langle \eta^{(1)}(t+\tau)\,\eta^{(1)*}(t)\rangle \quad \text{-------- (VII-47)}$$

and, it is also related to the spectrum of $\hat{\eta}^{(1)}(t)$ by

$$\tilde{R}^{(1)}(\tau) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} e^{+i\omega\tau}\,\tilde{S}^{(1)}(\omega)\,d\omega \quad \text{------ (VII-48)}$$

Substituting equations (VII-45) and (VII-46) into equation (VII-47), one obtains the auto-correlation as

$$\tilde{R}^{(1)}(\tau) = 2\pi\int_{-\infty}^{+\infty} e^{i\omega\tau}\,H^{(1)}(Re,C,\omega)\,H^{(1)}(Re,C,\omega)\,\tilde{S}(\omega)\,d\omega \quad \text{--- (VII-49)}$$

By comparing equation (VII-49) with equation (VII-48), the spectrum of $\hat{\eta}^{(1)}(t)$ is seen to be

$$\tilde{S}^{(1)}(\omega) = (2\pi)^2\,H^{(1)}(Re,C,\omega)\,H^{(1)*}(Re,C,\omega)\,\tilde{S}(\omega) \quad \text{--- (VII-50)}$$

There is no restriction of the above process $\tilde{S}(\omega)$. In the present case, the white noise process which is the most common random process occuring in many physical phenomena, is used. The spectrum $\tilde{S}(\omega)$ of the white noise process is

$$\hat{S}(\omega) = 1 \qquad \text{(VII-51)}$$

The value of C in the above equation can be introduced in two different ways. One is to use the experimental value C. The experimental dimensionless C is very close to the value of the most rapidly amplified wave from the stability theory if the primary flow is assumed to satisfy the Nusselt equation. In this case, equation (VII-44) is discarded. Another way is to solve C from the equation (VII-44). The spectrum $\hat{S}^{(1)}(\omega)$ of $\hat{\eta}^{(1)}(t)$ is almost identical from the above two differect inputs of C. This confirms the prediction from the stability theory that the most rapidly amplified waves control the surface.

The spectrum $\hat{S}^{(1)}(\omega)$ of $\hat{\eta}^{(1)}(t)$ calculated at two different flow rates is shown in Fig. VII-2. The shape of the spectrum is qualitatively similar to that of the experimental one. But the modal frequency is much higher than the experimental value and the slope of the equilbrium range - 2 is a little lower than the experimental value. The trend of the modal frequency which increases with flow rate is the same as that of the experimental data.

2-4. FORMULATION OF NONLINEAR PART OF THE EQUATION

Since the linear part of the solutions $\hat{\psi}^{(1)}$, $\hat{\eta}^{(1)}$, and $\hat{P}^{(1)}$ statisfies the equations (VII-27) through (VII-33), the nonlinear part of equation can be obtained by substituting

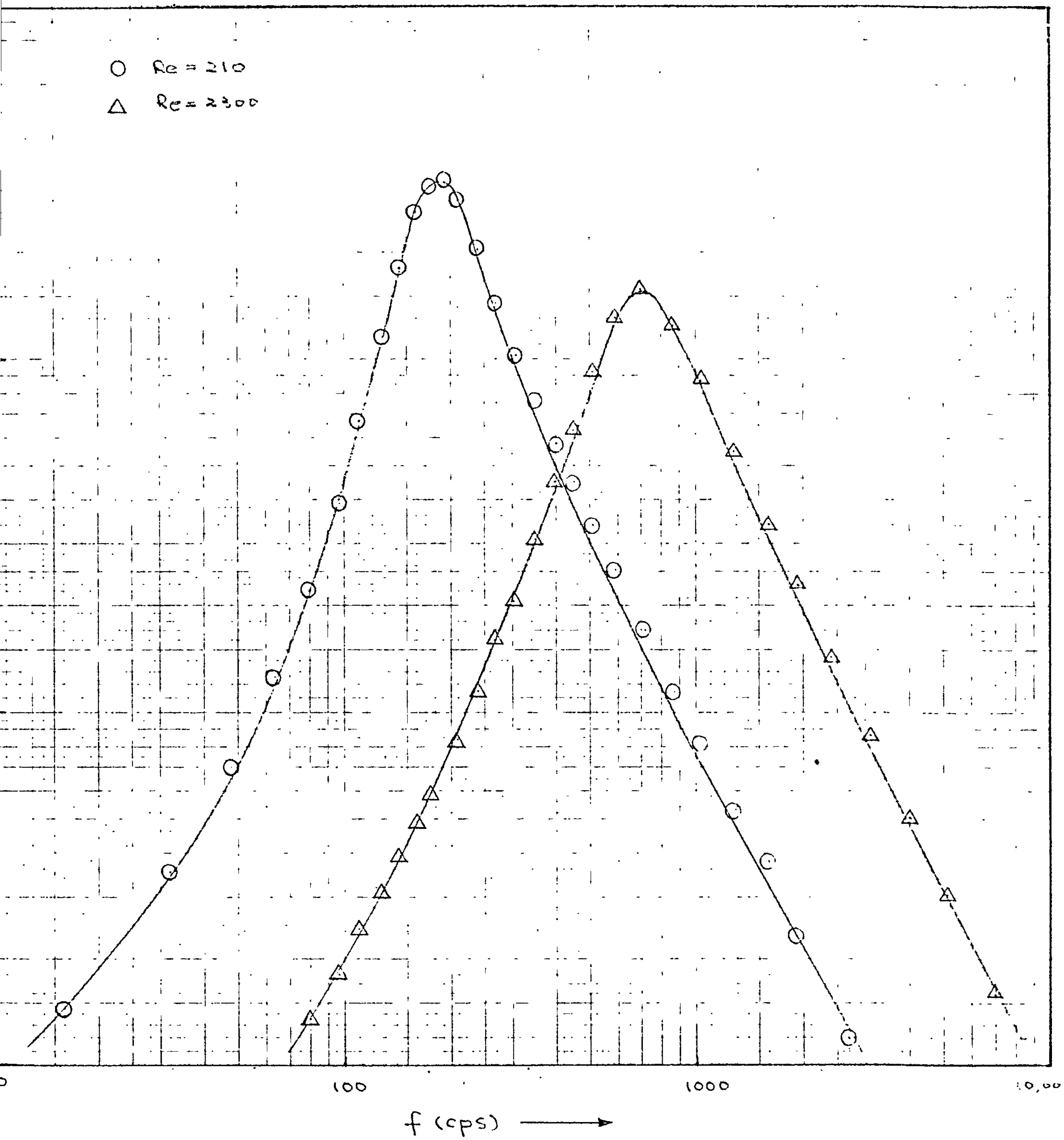


FIG. VII-2. THEORETICAL SPECTRUM $\widetilde{S}^{(1)}(f)$

equation (VII-26) into the equations (VII-23) through (VII-25) as follows:

$$\left.\begin{aligned}
&\frac{1}{c} P^{(2)}_{t} + \frac{4}{Re}\left\{\frac{1}{c^2}\psi^{(2)}_{y t t} + \psi^{(2)}_{y y y}\right\} + \left\{\frac{3}{2}\frac{1}{c} - 1\right\}\psi^{(2)}_{y t} = \\
&\qquad \frac{1}{c}\left\{\psi^{(1)}_{y y}\psi^{(1)}_{t} - \psi^{(1)}_{y}\psi^{(1)}_{y t}\right\} \\
&-P^{(2)}_{y} + \frac{4}{Re}\frac{1}{c}\left\{\frac{1}{c^2}\psi^{(2)}_{t t t} + \psi^{(2)}_{t y y}\right\} + \frac{1}{c}\left\{\frac{3}{2}\frac{1}{c} - 1\right\}\psi^{(2)}_{t t} = \\
&\qquad \frac{1}{c^2}\left\{\psi^{(1)}_{t}\psi^{(1)}_{t y} - \psi^{(1)}_{y}\psi^{(1)}_{t t}\right\}
\end{aligned}\right\} \text{-- (VII-52)}$$

The boundary conditions are

$$\left.\begin{aligned}
\psi^{(2)}_{t} &= 0 \\
\psi^{(2)}_{y} &= 0
\end{aligned}\right\} \text{ at } y = 1 \quad \text{- - - - - - (VII-53)}$$

$$\left.\begin{aligned}
&-3\eta^{(2)} + \psi^{(2)}_{y y} - \frac{1}{c^2}\psi^{(2)}_{t t} = \frac{1}{c^2}\psi^{(1)}_{t t y}\eta^{(1)} - \psi^{(1)}_{y y y}\eta^{(1)} \\
&-P^{(2)} + \frac{8}{Re}\frac{1}{c}\psi^{(2)}_{t y} + \frac{1}{We}\frac{1}{c^2}\eta^{(2)}_{t t} = P^{(1)}_{y}\eta^{(1)} - \frac{8}{Re}\frac{1}{c}\psi^{(1)}_{t y y}\eta^{(1)} \\
&\left(1 - \frac{3}{2}\frac{1}{c}\right)\eta^{(2)}_{t} - \frac{1}{c}\psi^{(2)}_{t} = \frac{1}{c}\left(\psi^{(1)}_{y}\eta^{(1)}_{t} + \psi^{(1)}_{t y}\eta^{(1)}\right)
\end{aligned}\right\} \text{ at } y = 0 \text{ - - - - - (VII-54)}$$

The solution can be assumed in the similar manner as

$$\hat{\psi}^{(2)}(\tau, \gamma) = \int\int e^{i(\omega+\omega')\tau} F^{(2)}(R_e, C, \omega, \omega', \gamma)\, d\hat{G}(\omega)\, d\hat{G}(\omega') \quad \text{--(VII-55)}$$

The above unknown $F^{(2)}(R_e, C, \omega, \omega', \gamma)$ can be solved numerically. But in order to evaluate the higher moments $\langle d\hat{G}(\omega_1)\, d\hat{G}(\omega_2)\, d\hat{G}^*(\omega_3)\, d\hat{G}^*(\omega_4)\rangle$ and $\langle d\hat{G}(\omega_1)\, d\hat{G}(\omega_2)\, d\hat{G}^*(\omega_3)\rangle$ wh'ch are related to the nonlinear part of spectrum, one would assume that the process is such that it is possible to decompose the higher moments to the lower moments such as for a Gaussians in Tick's work. Then it is very obvious that the nonlinear part of spectrum will generate a small secondary peak on the higher frequency side of the linear part of spectrum as shown in Tick's result. Since the modal frequency of the linear part of spectrum is already much higher than the experimental one. It is apparent that the nonlinear part of spectrum deduced from the above method does not cause better agreement with data. Therefore the numerical solution of nonlinear spectrum was not attemped in this study. But the formulation of the nonlinear part of the spectrum is given in Appendix E., and the detailed derivation on the linear part of spectrum is given in Appendix E. The computer program used to evaluate the linear solution is given in Appendix A.

3. EXTENSION OF TELLES' MODEL

The fundamental theory of the shot noise process has been well developed by Rice (R-2) in early 1944. Assuming the stochastic time series of the shot noise processes represented by a Gram-Charlier series, Horton (H-10, H-11, H-12) was able to extract the shape of individual single events from the experimental auto correlation function by using the Rice's theory. As mentioned in Chapter II, Telles (T-2, T-3) used Horton's method to obtain the coefficients of the Gram-Charlier series for a single large waves. Then the equations of motion for an isolated large waves were solved to give the velocity profile and the wave velocity by a quasi-linerization procedure. But the prediction of the wave velocity by Telles is far from the experimental value. This is probably due to the following reasons:

(a) Telles used the second and third central moments to solve the coefficients of the Gram-Charlier series for the isolated wave instead of using the auto-correlation which was not available from his measurements. But the second central moment contains all of the fluctuations due to small waves, large waves and noise. Thus it contains less information about the wave shape. Furthermore the reliability of the measurement of the third central moment is small.

(b) Telles applied quasi-linearization to the equation of motion, but not to the nonlinear kinematic conditions. The principle which enable him to solve the nonlinear boundary condition, is not clearly pointed out in Telles' work. The Gram-Charlier series is a set of orthogonal functions as follows:

$$Z_j(x) = \frac{(-1)^j}{\sqrt{2\pi}} H_j(x) \exp\left\{-\frac{x^2}{2}\right\} \quad \text{-- -- ---} \quad (\text{VII}-56)$$

where $H_j(x)$ is a Hermite polynominal.

The properties of the Hermite polynominal given as:

$$H_{j+k}(x_1+x_2) = 2^{-\frac{j+k}{2}} \sum_{k=0}^{j+k} \binom{j+k}{k} H_j(x_1\sqrt{2})\, H_2(x_2\sqrt{2}) \quad \text{---} \quad (\text{VII}-57)$$

and the properties between Z_j and H_k

$$\int_{-\infty}^{+\infty} Z_j(x)\, H_k(x)\, dx = (-1)^j j!\, \delta_{jk} \quad \text{-- -- ---} \quad (\text{VII}-58)$$

where

$$\delta_{jk} = \begin{cases} 1 & \text{if } j=k \\ 0 & \text{if } j \neq k \end{cases}$$

make it possible to decompose the differential equations into a set of algebraic equations which is solvable. This is very similar to the principle which is used to solve the nonlinear equation in tubulence by the Wiener-Hermite expansion. Although there exists a distinct difference between the two techniques. It is obvious that the same procedure can be applied not only on the nonlinear kinematic boundary condition but also to the equations of motion.

(c) Furthermore, the quasi-linearization is an iteration process. Only the first iteration, for which the quasi-linearization gives a linear equation in Z_j, was solved by Telles. If one proceeds into the higher iteration, the equation will again contain the nonlinear term $Z_j Z_K$. Hence the advantage in using the quasi-linearization is lost in the second iteration.

Based on the above considerations, the modification of the Horton's method to use the more reliable experimental data on the auto covariance function from this work, and the extension of Telles' idea to higher order approximation without quasi-linearization are presented in the following section. The Horton's method and the Telles' model is given in detail in Appendix F.

3-1. COEFFICIENTS OF THE GRAM-CHARLIER SERIES FOR AN ISOLATED WAVE

Assuming the wave processes is a shot noise process as

$$\hat{h}(t) = m_L + \sum_{k=-\infty}^{+\infty} m(t - \hat{t}_k) \qquad \text{(VII-59)}$$

and each individual identical wave m(t) above the substrate m_L can be represented by the Gram-Charlier series as

$$m(t) = \sum_{j=0}^{n} m_j Z_j(\xi) \quad \text{------} \quad (\text{VII}-60)$$

where m_j is the coefficient of the Gram-Charlier series.

$$\xi = \frac{t}{T}$$

T is the unspecified duration time of the wave. The mean and auto covariance function of h(t) will be

$$\langle \hat{h}(t) \rangle = m_L + fTm_0 \quad \text{--------} \quad (\text{VII}-61)$$

$$\begin{aligned} \tilde{C}(\tau) &= \langle \hat{h}(t+\tau)\,\hat{h}(t) \rangle - \langle \hat{h}^2(t) \rangle \\ &= \sum_{j,k}^{n} (-1)^j m_j' m_k' Z^{i+j}(\tau'/\sqrt{2}) \quad \text{---} \quad (\text{VII}-62) \end{aligned}$$

where f is the average number of wave which arrive per sec.

$$m_j' = (fT\,2^{-j}/\sqrt{2})^{1/2} m_j$$

$$\tau' = \frac{\tau}{T}$$

The auto-covariance function can also be expressed by the Gram-Charlier series as

$$\tilde{C}(\tau) = \sum_{p=0}^{\infty} d_{2p} Z_{2p}\left(\frac{\tau'}{\sqrt{2}}\right) \quad \text{-----} \quad (\text{VII}-63)$$

Given an experimental $\tilde{C}(\tau)$, one could evaluate the coefficient d_{2p} by

$$d_{2p} = \frac{1}{\sqrt{2}\,(2p)!} \int_{-\infty}^{+\infty} \left\{ \tilde{C}(\tau'T) - \tilde{C}(\infty) \right\} H_{2p}(\tau'\sqrt{2})\, d\tau' \quad \text{--} \quad (\text{VII}-64)$$

In the above equation, $\left\{\tilde{C}(\tau'T) - \tilde{C}(\infty)\right\}$ is used instead of

$C(\zeta'\tau)$ because only part of $\widetilde{C}(\zeta'\tau)$ data is used to calculate the above integral. A periodicity exists due to the large waves which have $h_{max} > 2\langle h \rangle$. One would ask what is auto covariance function if the wave process is a shot noise one? Since it depends on the wave shape, the auto covariance estimated from the average wave shape measured, will probably have the shape as shown in Fig. VII-3 (a). It will have a small negative peak at the average wave base $\langle T_{bs} \rangle$, and it will approach zero at the average wave separation $\langle T_{sep} \rangle$. But the actual auto covariance function always looks as shown in Fig. VII-3 (b). It always shows a large negative peak and a small secondary positive lobe. Since the secondary positive lobe represents a non-shot noise process, it is desirable to subtract the periodic component $\widetilde{C}_p(\zeta)$. The subtraction procedure is shown in Figs. VII-3 (c) and (d). Hence the coefficient is actually calculated by

$$d_{2p} = \frac{1}{\sqrt{2}\,(2p)!} \int_{-\infty}^{+\infty} \left\{ \widetilde{C}(\zeta'\tau) - \widetilde{C}_p(\zeta'\tau) \right\} H_{2p}(\zeta'\sqrt{2})\, d\zeta' \quad \text{---- (VII-65)}$$

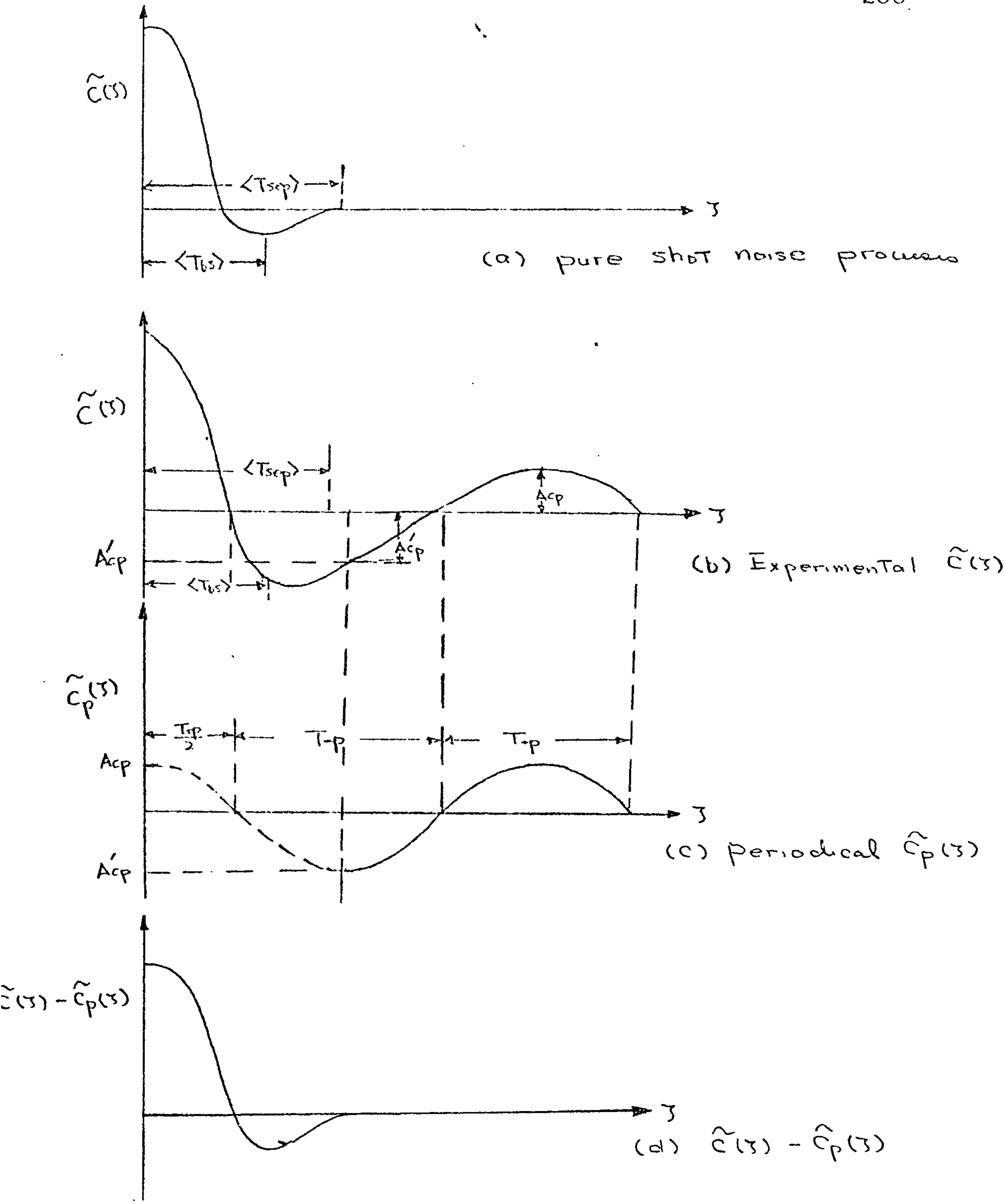


FIG. VII-3. SUBSTRACTION OF PERIODIC COMPONENT

A similar principle as Telles and Horton employed is used here to determine the unspecified time constant T. The criterion is that the constant T is obtained when the right hand side of equation (VII-63) gives the best fit of the experimental value $\widetilde{C}(\tau)$ for $\tau > 0$. A typical curve of auto covariance function calculated from the above equations (VII-65) and (VII-63) is shown in Fig. VII-4. The fit is fairly good except at $\tau > 0$ where the noise and small waves also contribute a large amount of energy. Comparing equations (VII-63) and (VII-62), one is able to obtain the coefficient m_0, m_1, m_2 --- from the d_0, d_2, d_4 --- as

$$d_{2p} = \sum_{j,k=0}^{2p} (j+k=2p)\,(-1)^{j}\, m_j' m_k' \quad \text{--------- (VII-66)}$$

For practical reason, consider only two terms in auto covariance, then

$$\left.\begin{aligned} d_0 &= m_0'^2 \\ d_2 &= -m_1^2 \end{aligned}\right\} \quad \text{--------- (VII-67)}$$

In the above equation (VII-67), one assume that m_2 and m_3 are much smaller than m_0 and m_1. The values of m_L, m_0, and m_1 for a single isolated wave at various flow rates calculated from equations (VII-67) and (VII-61) are tabulated in Table VII-1.

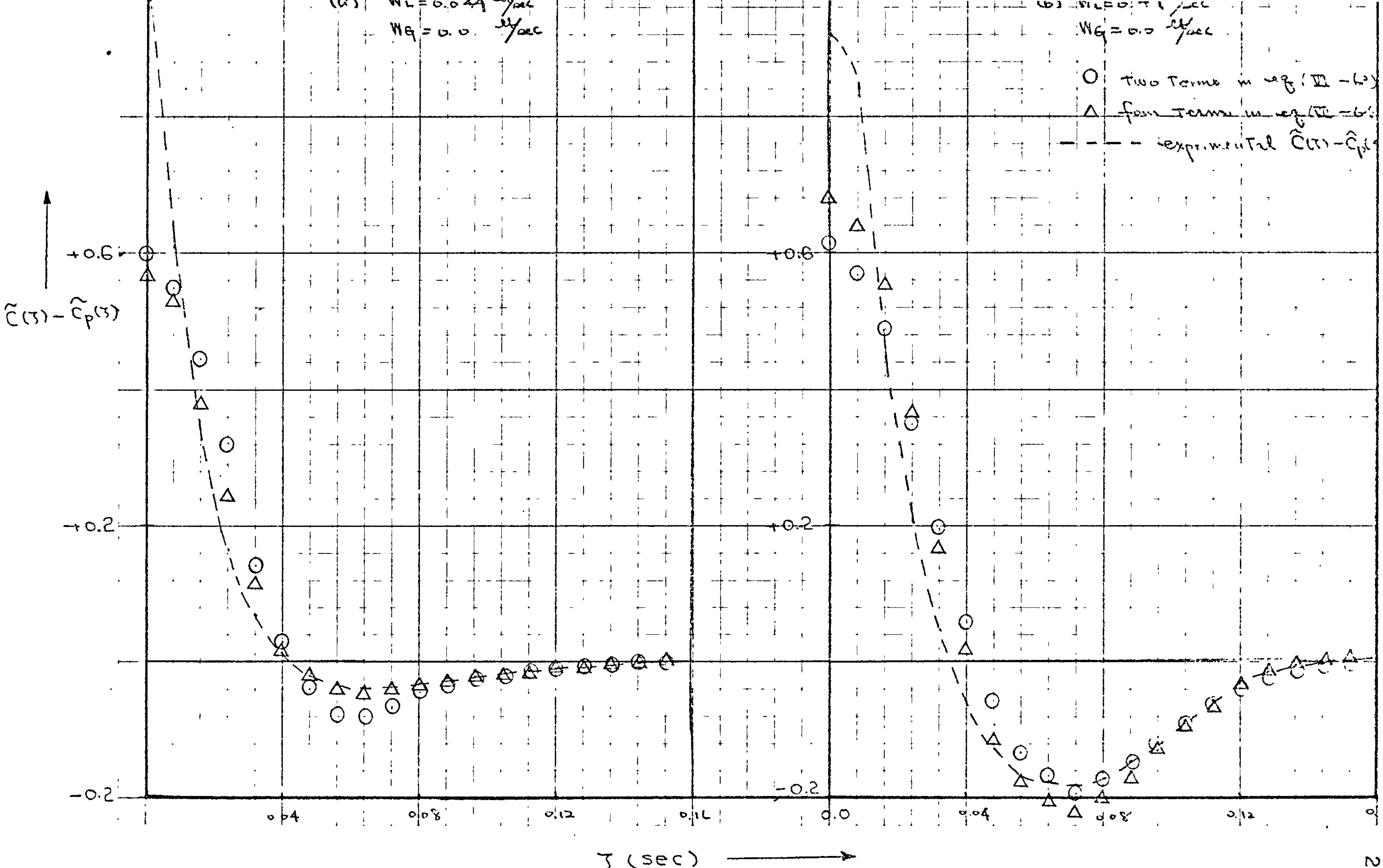


FIG. VII-4. COMPARISON OF $\widetilde{C}(\zeta) - \widetilde{C}_p(\zeta)$ AND $\sum_{n=0}^{\infty} d_{2p} Z_{2p}(\xi)$

TABLE VII-1

COEFFICIENT OF THE GRAM-CHARLIER SERIES FOR AN ISOLATED WAVE AT W_G = 0.0 lb/sec

W_L(lb/sec)	T(sec)	m_L(in)	m_0(in)	m_1(in)
?.016	0.019	0.0042	0.0028	0.0063
0.044	0.026	0.0058	0.0133	0.0181
0.08	0.044	0.0081	0.0112	0.0218
0.18	0.027	0.0130	0.0192	0.0624
0.47	0.028	0.0238	0.0278	0.0771

Increasing the number of terms in m_i for an isolated wave will introduce additional difficulty, because a given set of d_i from the experimental $\tilde{C}(\tau)$ will not always give a set of m_i as the solution of equation (VII-66).

3-2. SOLUTION FOR AN ISOLATED WAVE

A single wave event in the above shot noise process will be

$$\begin{aligned} h(t) &= m_L + m(t) \\ &= m_L + \sum_{i=0}^{n} m_i Z_i(\xi) \qquad \text{(VII-68)} \end{aligned}$$

One try to answer the following question " if this single wave event obeys the equation of motion, what will be the wave velocity and the velocity profile of this wave?"

The basic equations and boundary conditions which used in this study are the same as that in Telles' work; the y-direction motion and the pressure terms are neglected, the normal stress condition and the term $\frac{\partial v}{\partial x}$ in shear stress condition at surface are also neglected. By using the stream function and the dimensionless group given in equation (VII-69),

$$\left.\begin{aligned} (x, y, \eta) &= (x_1, y_1, h)/x_0 \\ (\eta_L, \eta_0, \eta_1, \cdots) &= (m_L, m_0, m_1, \cdots)/x_0 \\ \psi &= \psi_1/\nu \\ \psi(x, t, y) &= \psi(x-ct, y) \\ \eta(x,t) &= \eta(x-ct, y) \\ x_0 &= cT \end{aligned}\right\} \quad --- \quad (\text{VII}-69)$$

the set of equations (VII-12), (VII-13) and (VII-14) in which the coordinate y_1 is in the reverse direction, become

$$\psi_{yyy} + G' + (S - \psi_y)\psi_{xy} + \psi_x \psi_{yy} = 0 \quad --- \quad (\text{VII}-70)$$

The boundary conditions are

$$\left.\begin{aligned} \psi_x &= 0 \\ \psi_y &= 0 \end{aligned}\right\} \text{ at } y = 0 \quad ---- \quad (\text{VII}-71)$$

$$\left.\begin{aligned} \psi_{yy} &= 0 \\ \psi_x &= (S - \psi_y)\eta_x \end{aligned}\right\} \text{ at } y = \eta \quad ---- \quad (\text{VII}-72)$$

where

$$S = \frac{c x_0}{\nu}$$

$$G' = \frac{g x_0}{\nu^2}$$

and

$$\eta(x) = \eta_L + \sum_{i=0}^{n} \eta_i z_i(x) \quad \text{------} \quad (\text{VII-73})$$

is a known given wave surface of isolated wave. Let assume the stream function ψ can also be expressed in terms of Gram-Charlier series as:

$$\psi(x, y) = f_L(y) + \sum_{i=0}^{n} f_i(y) z_i(x) \quad \text{----} \quad (\text{VII-74})$$

Substituting equations (VII-73) and (VII-74) into the equations (VII-70), (VII-71) and (VII-71), and also using the basic properties of the Gram-Charlier series

$$z_{i+1}(x) = \frac{d}{dx} z_i(x) \quad \text{------} \quad (\text{VII-75})$$

the set of equations become

$$\left\{ f_L''' + G' \right\} + \left\{ f_0''' \right\} z_0 + \sum_{i=1}^{n} \left\{ f_i''' + S f_{i-1}' - f_L' f_{i-1}' + f_L'' f_{i-1} \right\} z_i$$
$$- \sum_{i=0}^{n} f_i' z_i \sum_{i=0}^{n} f_i' z_{i+1} + \sum_{i=0}^{n} f_i z_{i+1} \sum_{i=0}^{n} f_i'' z_i = 0 \quad \text{---} \quad (\text{VII-76})$$

The boundary conditions are

$$\left.\begin{aligned}&\sum_{i=0}^{n} f_i Z_{i+1} = 0\\ &f_L' + \sum_{i=0}^{n} f_i' z_i = 0\end{aligned}\right\} \text{ at } y=0 \quad \text{------- (VII-77)}$$

$$f_L'' + \sum_{i=0}^{n} f_i' z_i = 0 \quad \text{at } y=\eta \quad \text{------- (VII-78)}$$

$$\sum_{i=0}^{n} f_i Z_{i+1} = (S - f_L' - \sum_{i=0}^{n} f_i' Z_i) \sum_{i=0}^{n} \eta_i Z_{i+1} \text{ at } y=\eta \text{ -- (VII-79)}$$

Since as $x \to \pm\infty$, the function $Z_i \longrightarrow 0$ the above set of equations reduces

$$\left.\begin{aligned}&f_L''' + G = 0\\ &f_L' = 0 \quad \text{at} \quad y=0\\ &f_L'' = 0 \quad \text{at} \quad y=\eta_L\end{aligned}\right\} \text{------ (VII-80)}$$

Therefore one obtains

$$f_L(y) = G'\left(\frac{\eta_L}{2} y^2 - \frac{1}{6} y^3\right) \text{ ---- (VII-81)}$$

The function $z_i(x)$ is a function of x, Hence the boundary condition at y = 0 will lead to

$$\left.\begin{aligned}&f_i = 0\\ &f_i' = 0\end{aligned}\right\} \quad i = 0, \text{---}, n$$

Then the form of the function f_i can be assumed as

$$f_i(y) = \sum_{j=0}^{\infty} \alpha_{ij} y^{j+2} \text{ ------ (VII-82)}$$

Multiply the Hermite function H_k on equation (VII-76) and integrated over x , this will produce n+1 equations

$$\left.\begin{aligned} f_0''' &= \int_{-\infty}^{+\infty} \left\{ \sum_{i=0}^{n} f_i z_i \sum_{i=0}^{n} f_i' z_{i+1} - \sum_{i=0}^{n} f_i z_{i+1} \sum_{i=0}^{n} f_i'' z_i \right\} H_0 \, dx \\ f_k''' + S f_{k-1}' - f_i' f_{k-1}' + f_i'' f_{k-1} &= \\ (-1)^k \int_{-\infty}^{+\infty} & \left\{ \sum_{i=0}^{n} f_i' z_i \sum_{i=0}^{n} f_i' z_{i+1} - \right. \\ & \left. \sum_{i=0}^{n} f_i z_{i+1} \sum_{i=0}^{n} f_i'' z_i \right\} H_k \, dx \\ & k = 1, \cdots, n \end{aligned}\right\} \text{--(VII-83)}$$

By substituting equation (VII-82) into equation (VII-83) and collecting terms in y, the solution for the unknown coefficient α_{ij} will be

$$\alpha_{ij} = \alpha_{ij} \left\{ S, G', \eta_L, \alpha_{00}, \cdots, \alpha_{n0} \right\}$$

$$j = 1, \cdots \quad \text{and } i = 0, \cdots, n \quad \text{---(VII-84)}$$

where G' and η_L are known value known value

The similar processes (multiplying H_k and integrating over x) are applied on equation (VII-78),

$$(-1)^k G' \eta_k = \int_{-\infty}^{+\infty} \left\{ \sum_{i=0}^{n} f_i' z_i \right\} H_k \, dx$$

$$k = 0, \cdots, n \quad \text{---------(VII-85)}$$

this will generate another n+1 equations and

$$\alpha_{i0} = \alpha_{i0}\{S, G', \eta_L, \eta_0, ----, \eta_n\} \quad i=0,\cdots,n \quad --- (\text{VII}-86)$$

the kinematic condition (VII-79) is also treated in the same way, the equation will be

$$S\eta_k = (-1)^k \int_{-\infty}^{+\infty} \left\{ \sum_{i=0}^{n} f_i Z_{i+1} + (f_L' + \sum_{i=0}^{n} f_i Z_i) \sum_{i=0}^{n} \eta_i Z_{i+1} \right\} \cdot H_{k+1}\, dx$$

$$k = 0, \cdots, n-1 \quad ------ (\text{VII}-87)$$

This will eliminate another n unknowns and give

$$\left.\begin{aligned} S &= S\{G', \eta_L, \eta_0, \eta_1\} \\ \eta_i &= \eta_i\{G', \eta_L, \eta_0\, \eta_1\} \end{aligned}\right\} \quad ---------- (\text{VII}-88)$$

In the practical calculation, equations (VII-73) and (VII-74) are truncated as:

$$\left.\begin{aligned} \eta(x) &= \eta_L + \eta_0 Z_0 + \eta_1 Z_1 \\ \psi(x,y) &= f_L(y) + f_0(y) Z_0 + f_1(y) Z_1 \end{aligned}\right\} \quad ----- (\text{VII}-89)$$

(i) if the $f_i(y)$ are truncated up to y^2 terms as

$$f_i = \alpha_{i0} y^2 \qquad i = 0, 1 \quad -------- (\text{VII}-90)$$

the solution will be

$$S = G'\left(\eta_L^2 + \frac{\eta_0^2}{6\pi\sqrt{3}} + \frac{\eta_1^2}{6\pi\sqrt{3}} + \frac{\eta_0\eta_L}{2\sqrt{\pi}}\right) \quad ------- (\text{VII}-91)$$

(ii) if the $f_i(y)$ are truncated up to y^4 terms as

$$f_i = \alpha_{i0} y^2 + \alpha_{i1} y^3 + \alpha_{i2} y^4 \quad i = 0, 1 \quad ------ (\text{VII}-92)$$

the result will be given as

$$G' k_0 = \alpha_{00}\left\{2 - \left(\frac{\eta_L}{2\sqrt{\pi}} + \frac{\eta_0}{3\pi\sqrt{3}}\right) S k_1\right\}$$

$$-G' k_1 = -2\alpha_{10} + S\alpha_{00}\left\{\eta_L^2 + \frac{\eta_0^2}{6\pi\sqrt{3}} + \frac{\eta_1^2}{6\pi\sqrt{3}} + \frac{\eta_L\eta_0}{2\sqrt{\pi}}\right\}$$

$$-S\tau_o = -\alpha_{oo}\left\{\eta_i^2 + \frac{\eta_i\eta_o}{\sqrt{\pi}} + \frac{\eta_o^2}{2\pi\sqrt{3}} + \frac{\eta_1^2}{6\pi\sqrt{3}}\right\} - \alpha_{10}\frac{\eta_o\eta_1}{3\pi\sqrt{3}} + G'\eta_o\left\{\frac{\eta_o^2}{12\pi\sqrt{3}} + \frac{\eta_1^2}{12\pi\sqrt{3}} - \frac{\eta_i^2}{2}\right\} + S\alpha_{oo}\eta_o\left\{\frac{\eta_i^2\eta_1}{6\pi\sqrt{3}} + \frac{3\eta_i\eta_o\eta_1}{32\pi\sqrt{2\pi}} + \frac{3\eta_o^2\eta_1}{100\pi^2\sqrt{5}} + \frac{\eta_1^3}{100\pi^2\sqrt{5}}\right\} \quad \text{-- (VII-93)}$$

The detailed derivation of the above equations are given in Appendix F.

The solution obtained from equations (VII-91) and (VII-93) are compared with Telles' prediction and experimental data in Fig. VII-5. Since Telles only used one term in the Gram-Charlier series and velocity profile up to y^2 term, the present prediction from equation (VII-91) which used two terms in the Gram-Charlier series, seems to improve the result a little but not enough to be close to the experimental data. The result from equation (VII-93) which used two terms in the Gram-Charliers series and velocity up to y^4 terms, bring the prediction value much close to the experimental value, but the curve seem to oscilate around the experimental value.

4. SUBSTRATE FLOW AND CLOSURE OF THE LIQUID FLOW RATE

In the previous chapters, the probability density function of film thickness $\tilde{f}_{\hat{h}}(h)$, substrate $\tilde{f}_{\hat{h}_s}(h)$, and large waves $\tilde{f}_{\hat{h}_w}(h)$ are presented. Suppose the velocity profiles at each h value are known, then the flow rate or

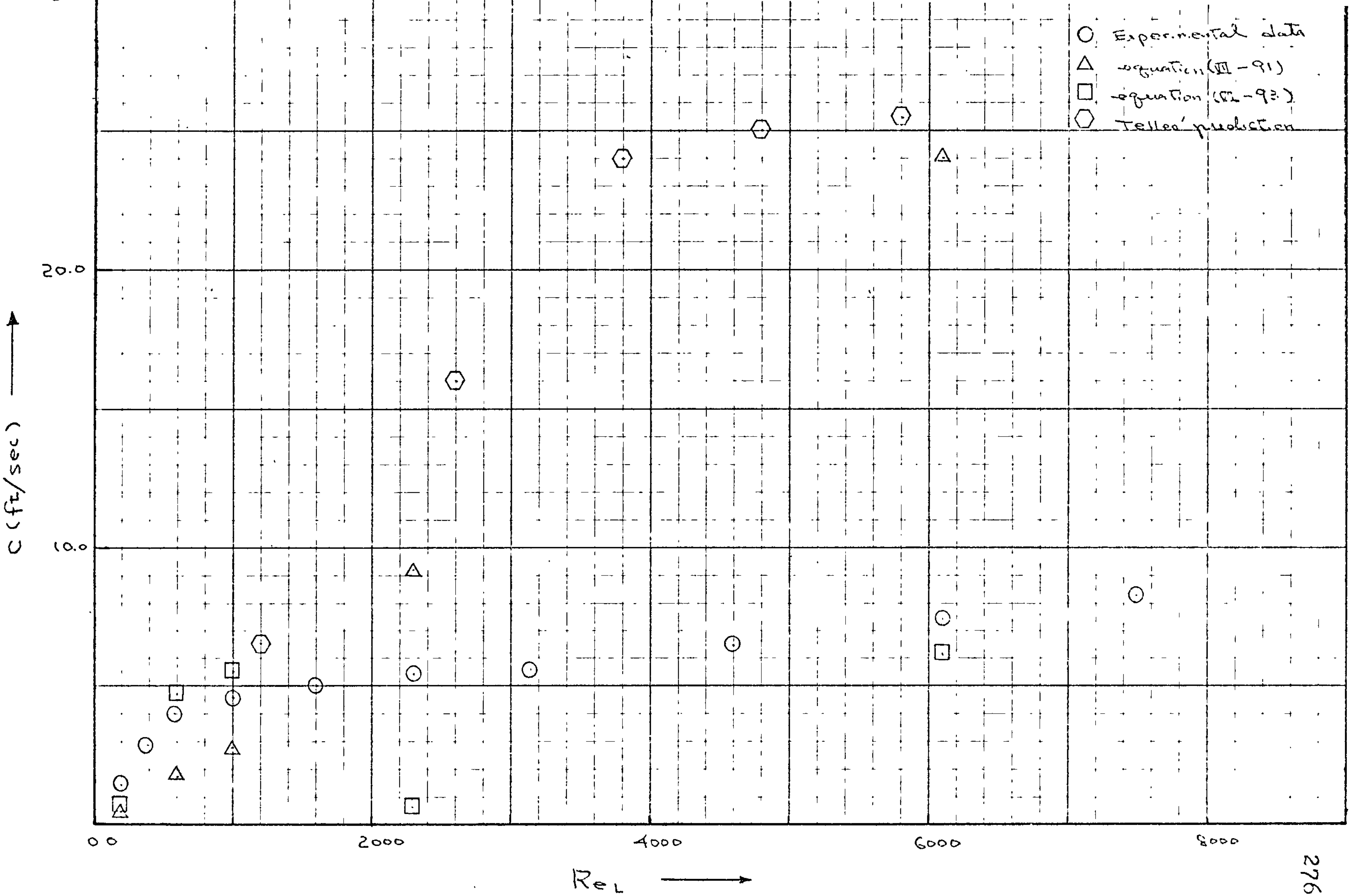


FIG. VII-5. COMPARISON OF EXPERIMENTAL DATA AND THEORETICAL PREDICTION FOR WAVE VELOCITY the Reynolds number of this flow can be calculated from the above probability density functions. Since the total flow rate and the Reynolds number are known for any one condition, this permits one to check the validity of velocity profiles which have been assumed to exist in films but never been measured.

4-1. VELOCITY PROFILES FOR THE FILM THICKNESS h(t)

Only two velocity profiles have been used on falling liquid films. These are the Nusselt's laminar velocity profile and the Dukler's turbulent velocity profile as shown in the following two equations:

$$u(y) = \frac{\rho_L g}{\mu_L}\left\{ h y - \frac{y^2}{2} \right\} \qquad \text{(VII-94)}$$

$$\left.\begin{aligned} \tau_L &= \frac{1}{g_c}(\mu_L + \varepsilon_1 \rho_L)\frac{du}{dy} \\ \varepsilon_1 &= n_1^2 u y \left(1 - e^{-\frac{n^2 u y}{\nu_L}}\right) \qquad y^+ \leq 20 \\ \varepsilon_2 &= n_2 \left(\frac{du}{dy}\right)^3 \Big/ \left(\frac{d^2u}{dy^2}\right)^2 \qquad y^+ > 20 \end{aligned}\right\} \qquad \text{(VII-95)}$$

where n_1 and n_2 are numerical constants

$$y^+ = \frac{u_* \rho_L y}{\mu_L}$$

$$u^* = \sqrt{\frac{\tau_w g}{\rho_L}}$$

$$\tau_w = \tau_i + h \rho_L$$

$$= \left(\rho g - \frac{dp}{dL}\right)\frac{r}{2} + h \rho_L$$

Now let's assume the velocity profile of the whole wavy surface h can be described by the above two equations and scaled by the instantaneous film thickness h(t), the definition of the Reynolds number is given in the following equation:

$$Re_L = \frac{4W_L}{\pi D \mu_L}$$

$$= \frac{4\Gamma_L}{\mu_L} \quad \text{-------- (VII-96)}$$

The average Reynolds number can be calculated from

$$\langle Re_L \rangle = \frac{4.0\, \rho_L}{\mu_L} \int_{-\infty}^{+\infty} \left\{ \int_0^{\hat{h}} u(y)\,dy \right\} \tilde{f}_{\hat{h}}(\hat{h})\,d\hat{h} \quad \text{---- (VII-97)}$$

The average Reynold number obtained from the above equations (VII-94), (VII-95) and (VII-97) for various liquid rates with and without gas flow are compared with the experimental value in Table VII-2 and Table VII-3. In those tables, $\langle Re_L \rangle^{(l)}$ referred the average Reynolds number calculated from equations (VII-94) and (VII-97), and $\langle Re_L \rangle^{(t)}$ referred the average Reynolds number calculated from equations (VII-95) and (VII-97). In Table VII-3, the Reynolds number Re_L' is defined as

$$Re_L' = \frac{4\,(W_L - ENT)}{\pi D \mu}$$

where ENT = entrainment rate.

From these tables, the average Reynolds number calculated from the laminar parabolic velocity profile failed to match the experimental value. On the other hand, the average Reynolds number calculated from the Dukler's turbulent velocity gives

TABLE VII-2

COMPARISON OF AVERAGE REYNOLDS NUMBER AT

W_G=0.0 lb/sec

W_L	0.016	0.028	0.044	0.08	0.126
Re_L	211.0	367	572	1016	1605
$\langle Re_L \rangle^{(l)}$	44.7	146.6	426.6	1050.8	2249.5
$\langle Re_L \rangle^{(t)}$	44.5	139.4	383.5	944.5	1844.3
W_L	0.18	0.24	0.35	0.47	0.585
Re_L	2299.0	3151	4572	6109	7560
$\langle Re_L \rangle^{(l)}$	3865.6	5100.3	11402.0	23389	24417.0
$\langle Re_L \rangle^{(t)}$	2485.5	3098.0	4410.0	6146.3	6970.5

TABLE VII-3

COMPARISON OF AVERAGE REYNOLDS NUMBER AT

W_G=0.1436 lb/sec

W_L	0.016	0.044	0.126	0.24	0.35	0.585
Re_L	230.0	589.0	1568.0	2898	4134	6759
$\langle Re_L \rangle^{(t)}$	99.8	474.2	936.3	1908	2789.6	4219.4
Re_L'	230.0	589.0	1520.0	2730	3760	1000

fair agreement with the experimental Reynolds number on the large liquid rates with gas flow, but fail to show good agreement with gas flow. On the whole, both laminar and Dukler's velocity profiles are not suitable for all ranges of flow rate. The disagreement is due to the fact that the velocity distribution used in the above parallel flow ignores acceleration term.

4-2. SUBSTRATE FLOW

Two velocity profiles based on the smooth film model are not able to be applied to the whole wavy surface. Since the wave amplitude on the substrate is very small, the substrate between two large waves can be considered to be in a parallel flow. Hence the above two velocity profiles should be valid on the substrate. The average Reynold number on the substrate can be obtained

$$Re_{Ls} = \frac{4.0\,\rho_L}{\mu_L} \int_{-\infty}^{+\infty} \left\{ \int_0^{h} u(y)\,dy \right\} \tilde{f}_{\hat{h}_s}(h)\,dh \quad --- \quad (\text{VII}-98)$$

and the fraction of mass flow rate on the substrate can be calculated from

$$F_{ms} = Re_{Ls} \cdot F_s / Re_L \quad ---------- \quad (\text{VII}-99)$$

where F_s is the time fraction of the substrate from equation (VI-70)

The values of Re_{Ls} and F_{ms} with and without gas flow are given in Table VII-4 and Table VII-5. The values of Re_{Ls} for no gas flow calculated from the Nusselt's laminar velocity profile and Dukler's turbulent velocity profiles are very close. Only the values of Re_{LS} obtained from parabolic velocity profile for no gas flow are given in the Table. Although the time fraction of the substrate is 30 % to 50 % as given in the previous chapter, the mass fraction of input liquid flowing in the substrate is only 2 % to 8 % for no gas flow and 5 % to 20 % for gas flow.

4-3. CLOSURE OF THE LIQUID FLOW RATE

In the entrance region, the wave amplitude is smaller as compared with the mean film thickness. Only very small disturbances due to the wave motion exist on the velocity field in the liquid. Hence the wave and the mass of liquid are moving with distinct velocities. As both travelling downward, they eventually arrive at a nearly equilibrium state such that the wave amplitude is very large, the wave contains most of the liquid mass, and both the wave and the liquid mass under the wave are moving at almost same speed. Therefore the whole lump of liquid moves at the wave velocity. This is very similar to slug flow phenomena in a horizontal pipe. If the above speculation is true, one could evaluate the average mass of liquid carried by the wave as:

$$\left.\begin{aligned} & u(y) = C \\ & \langle \Gamma_{LW} \rangle = \rho_L \int_{-\infty}^{+\infty} \left\{ \int_0^{h} u(y)\,dy \right\} f_{\hat{h}_W}(h)\,dh \\ & \langle W_{LW} \rangle = \Gamma_{LW} \cdot \pi D \end{aligned}\right\} \quad \text{---} \quad (\text{VII}-100)$$

TABLE VII-4

CLOSURE OF LIQUID FLOW RATE AT W_G = 0.0 lb/sec

W_L(lb/sec)	0.016	0.028	0.044	0.08	0.126
Re_L	211.0	367	572	1016	1605
Re_{Ls}	12.7	52.9	55.1	67.3	86.8
F_{ms}	0.017	0.048	0.039	0.028	0.019
Re_{Lw}	292.5	726.1	1502.4	2172.0	2969.4
$\langle Re_L\rangle^{(c)}$	215.5	501.0	909.7	1296.2	1930.8
W_L	0.18	0.24	0.35	0.47	0.585
Re_L	2299	3151	4572	6109	7560
Re_{Ls}	108.0	168.9	472.0	1017.6	1292.0
F_{ms}	0.016	0.016	0.041	0.072	0.079
Re_{Lw}	3586.4	4378.5	7463.7	10384	12580
$\langle Re_L\rangle^{(c)}$	2388.8	3114.2	4665.2	6316.3	7373.3

TABLE VII-5

CLOSURE OF LIQUID FLOW RATE AT W_G = 0.1436 lb/sec

W_L(lb/sec)	0.016	0.044	0.126	0.24	0.35	0.585
Re_L'	230	589.0	1520.0	2730	3700	6000.0
ReLs	76.7	325.8	412.2	849.2	1409.0	1580.0
F_{ms}	0.056	0.275	0.107	0.134	0.157	0.106
Re_{Lw}	177.1	1284.6	2489.1	4027.0	5493.6	8832.5
$\langle Re_L\rangle^{(c)}$	153.4	761.7	1462.0	2565.0	3766.4	5683.0

Then the closure of the flow rate and the Reynolds number:

$$\left.\begin{aligned} \langle W_L \rangle &= \langle W_{LS} \rangle F_S + \langle W_{LW} \rangle F_W \\ \langle Re_L \rangle^{(c)} &= \langle Re_{LS} \rangle F_S + \langle Re_{LW} \rangle F_W \end{aligned}\right\} \quad --- \quad (\text{VII}-101)$$

where $$\langle Re_{LW} \rangle = \frac{4 \cdot \langle \Gamma_W \rangle}{\mu_L}$$

The values of $\langle Re_{LW} \rangle$, $\langle Re_L \rangle^{(c)}$ and $\langle Re_{LS} \rangle$ are given in Tables VII-4 and VII-5. The result shows reasonable agreement with the experimental Reynolds number. Some of data in which a higher value $c/u_0 > 2$ exists at flow rate $W_L \simeq 0.044$ lb/sec will give a higher Reynolds number. This indicates that the wave and the liquid mass under the wave are still not quite moving at same speed at those flow rates and measuring positions. Therefore the assumption $u(y) = c$ gives a large error on the closure of liquid flow rate at this condition. On the whole, this suggests that the actual velocity might be flatter than the turbulent velocity profile.

5. COMPARISON OF EXISTING THEORIES AND DATA

The average substrate Reynolds number obtained in the previous section from the probability density function now makes it possible to compare small wave data with the available theory. In the past, comparison between theoretical prediction and experimental data was very difficult due to the following two reasons.

(a) All theories except Telles', involve quantities which are normalized by the average velocity $\langle u \rangle$. The average velocity in the film is defined as follows and thus depends on the velocity profile, a distribution which can not be measured.

$$\left.\begin{aligned} \bar{u} &= \frac{1}{h}\int_0^h u(y)\,dy \\ \langle u \rangle &= \frac{1}{T}\int_0^T \bar{u}(t)\,dt \end{aligned}\right\} \qquad \text{(VII-102)}$$

(b) The theories derived from stability consideration and from integral methods, except that of Ruckenstein's, assume the average velocity $\langle u \rangle = u_o$, while u_o is the mean velocity as given by the Nusselt's equation. If this is the case, then the following relationship between the mean film thickness and the Reynolds number follows:

$$N_T = \left(\frac{3}{4}\right)^{1/3} Re_L^{1/3} \qquad \text{(VII-103)}$$

where $N_T = \langle h \rangle \left(\frac{g}{\nu^2}\right)^{1/3}$ is called Nusselt number

Unfortunately, the above assumption does not hold especially while large waves are present as shown in Fig. VII-6. In this figure, experimental data are compared with the prediction of the Nusselt equation and also with Dukler's turbulent velocity destribution in which $\beta = \frac{F r g^{1/3}}{2\nu_L^{2/3}}$ and $F = \frac{\rho_G \frac{g}{g_c} - \frac{dp}{dL}}{\rho_L \frac{g}{g_c}}$, are dimensionless pressure drop parameters. Hence the dimensionless quantities involing $\langle u \rangle$ calculated from the Nusselt or Dukler's theory is inadequate for comparison with theory.

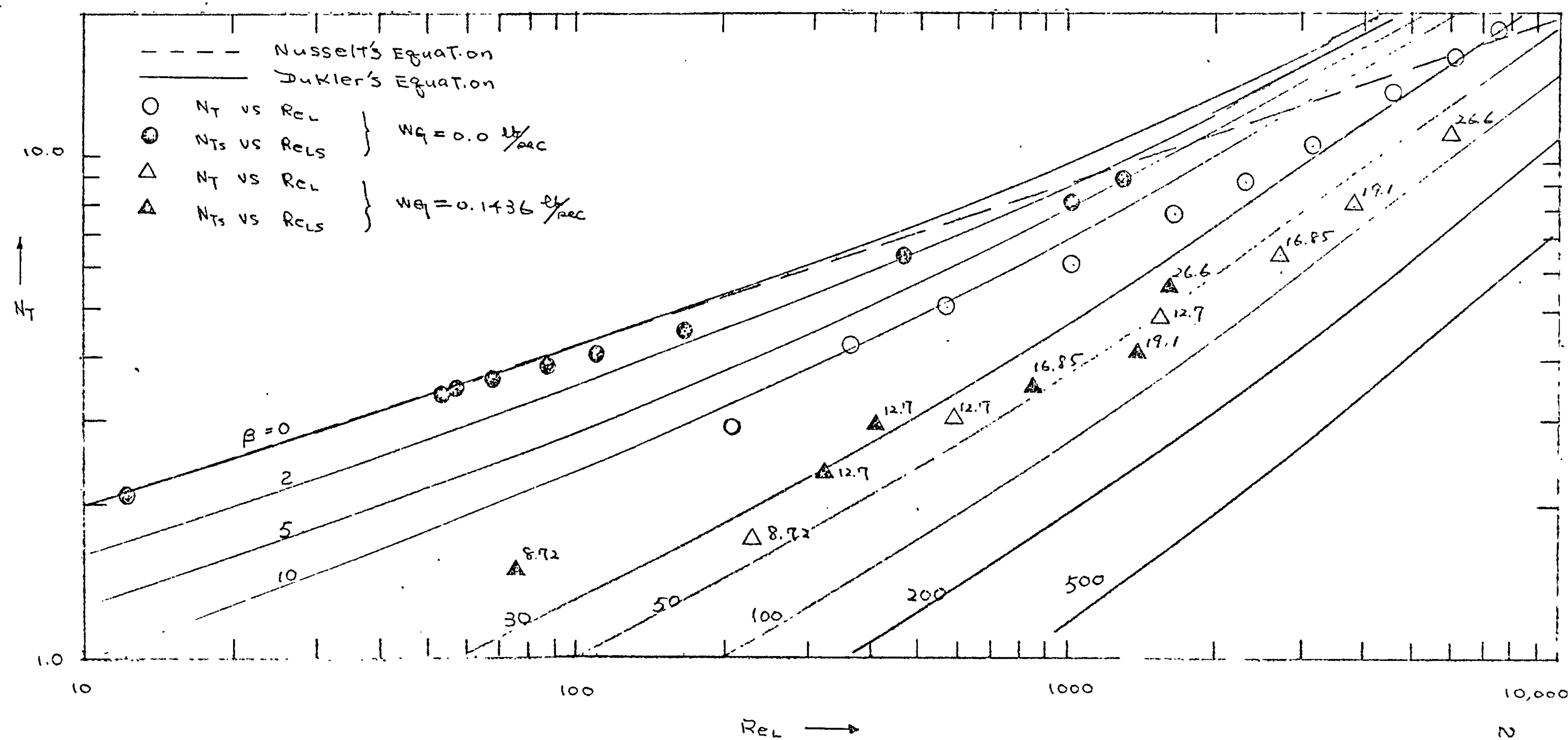


FIG. VII-6. DIMENSIONLESS FILM THICKNESS N_T

5-1. SELECTION OF PARAMETERS FOR COMPARISON

In order to compare with the theory, one define a new average velocity $\langle u\rangle'$ such that the following equation holds

$$R_{e_L} = \frac{4\langle h\rangle\langle u\rangle'}{\nu} \qquad (\text{VII}-104)$$

then the parameter can be comparied with theory are

$$W_e = \frac{\langle u\rangle'\langle h\rangle}{\gamma} \qquad \text{Weber number}$$

$$N_\lambda = \frac{\lambda}{2\pi}\sqrt{\frac{g}{\gamma}} \qquad \text{dimensionless wave length}$$

$$\alpha = \frac{c}{\langle u\rangle'} \qquad \text{dimensionless wave velocity}$$

$$\supset A_{eg} = \frac{\langle A\rangle}{\langle h\rangle} \qquad \text{dimensionless amplitude}$$

$$G^* = 0.108\, R_e^2\, W_e \qquad \text{Goren's dimensionless group}$$

$$f\ (\text{cps}) \qquad \text{dimensional wave frequency}$$

The above parameters apply both small and large waves. In the case of the small waves, the substrate Reynolds number Re_{Ls} is used in equation (VII-104). A subscript S will designate small waves since the small wave data is quite close to the Nusselts equation (parabolic velocity profile). Then the deviation of $\langle u_s\rangle'$ from $\langle u_s\rangle$ can be estimated by

$$\frac{\langle u\rangle}{\langle u_s\rangle'} = \frac{\langle h_s\rangle^2 + \hat{\sigma}_{hs}^2}{\langle h_s\rangle^2} = 1 + \frac{\hat{\sigma}_{hs}^2}{\langle h_s\rangle^2} \qquad (\text{VII}-105)$$

since $\hat{\sigma}_{hs}^2 \ll \langle h_s\rangle^2$, the approximation for the small waves is reasonable. In the case of the large waves, the velocity profile is unknown. The validity of the equation (VII-104) can not be justified. But the input liquid Reynolds number, Re_L, based on the total input flow rate is used for correlating the large waves.

5-2. COMPARISON OF THEORIES WITH DATA

Comparison of theories with data for no gas flow is shown in Fig. VII-7 through Fig. VII-10. The theory of extension of Telles' model is inadequate to compare with data and other theories.

(a) In Fig. VII-7, the frequency data are plotted against the Reynolds number. Four typical theories and the present theory on the random wave model all fail to give reasonable modal frequency for the large waves. The reason might be due to the fact that the governing equations for primary flow is assumed to be the Nusselt equation. Many other theories, which have been presented but not plotted on the graph, present values falling between the Kapitza's theory and Rushton's theory. All the theoretical predictions agree much closer with the small wave data than the large wave especially Ruckensten's theory. The velocity profile of the Ruckensten's theory is assumed a 6th degree polynomial of y with unknown coefficients. He used Kapitza's experimental data on amplitude to determine one coefficient. Hence we expect a good agreement of his theory with Kapitza's theory.

(b) In Fig. VII-8 and Fig. VII-9 the dimensionless wave velocity α and the dimensionless wave length N_{λ} vs. Weber number are plotted. The large wave data do not agree with existing theories at all. The small wave data for wave length

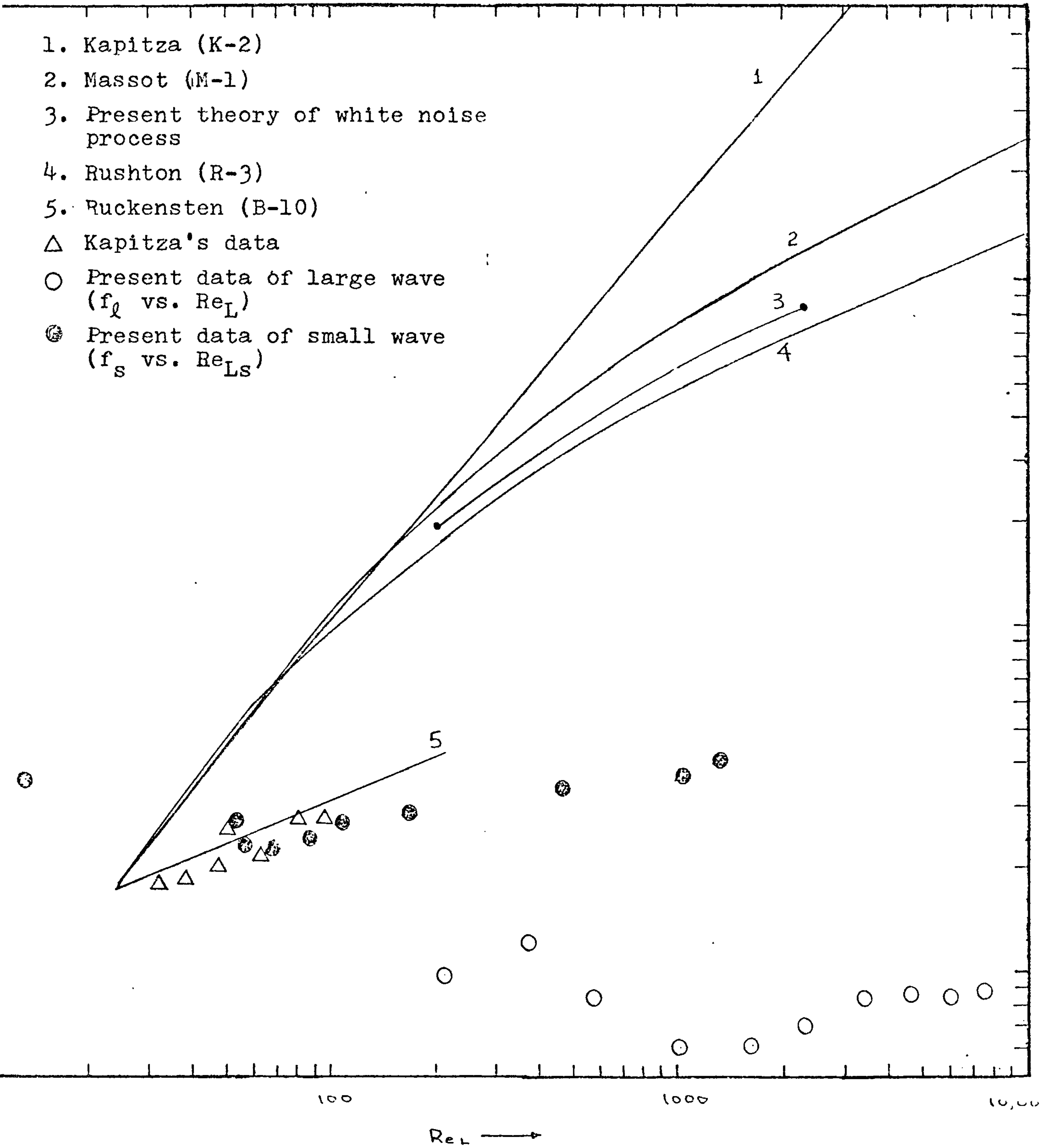


FIG. VII-7. WAVE FREQUENCY

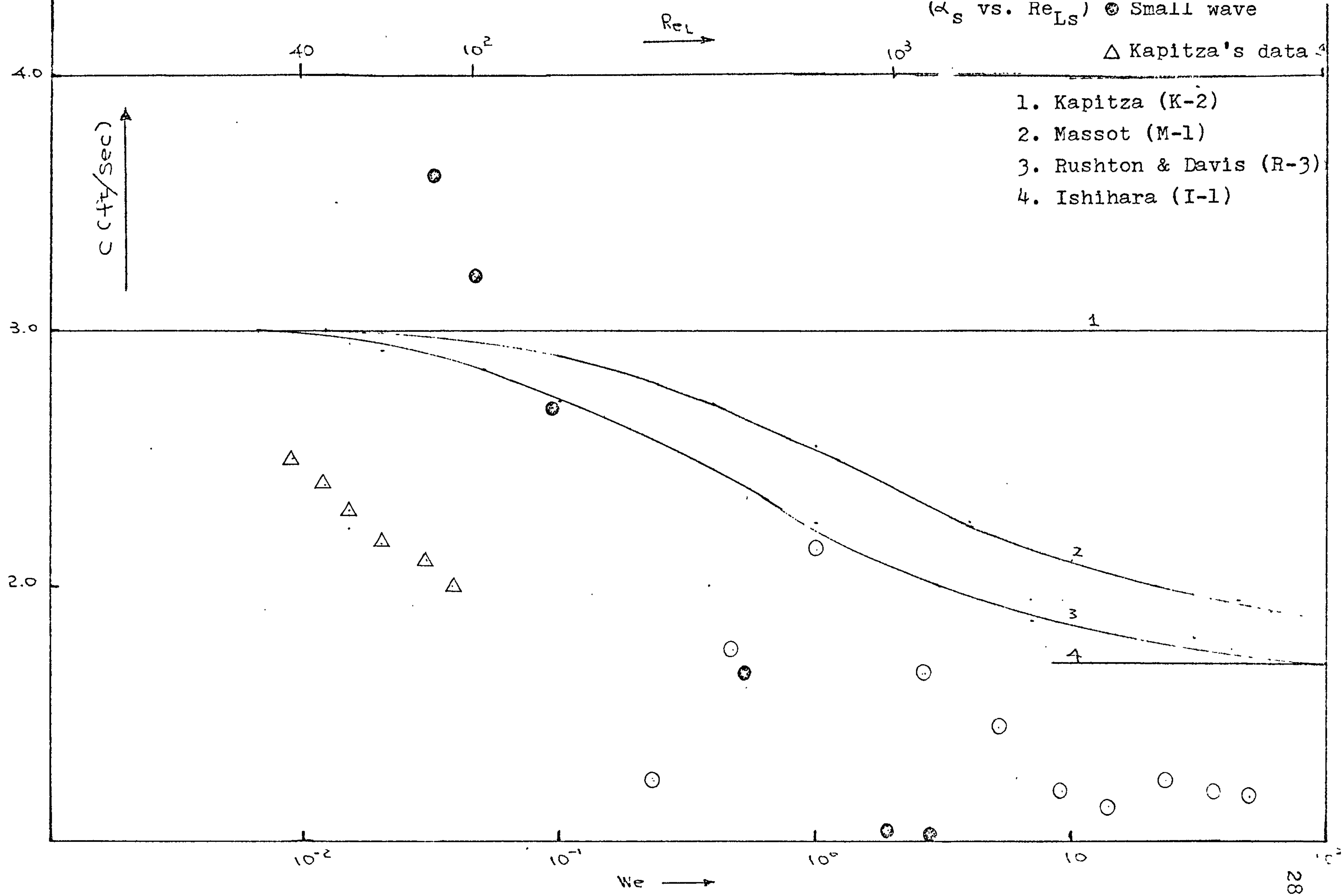


FIG. VII-8. DIMENSIONLESS WAVE VELOCITY

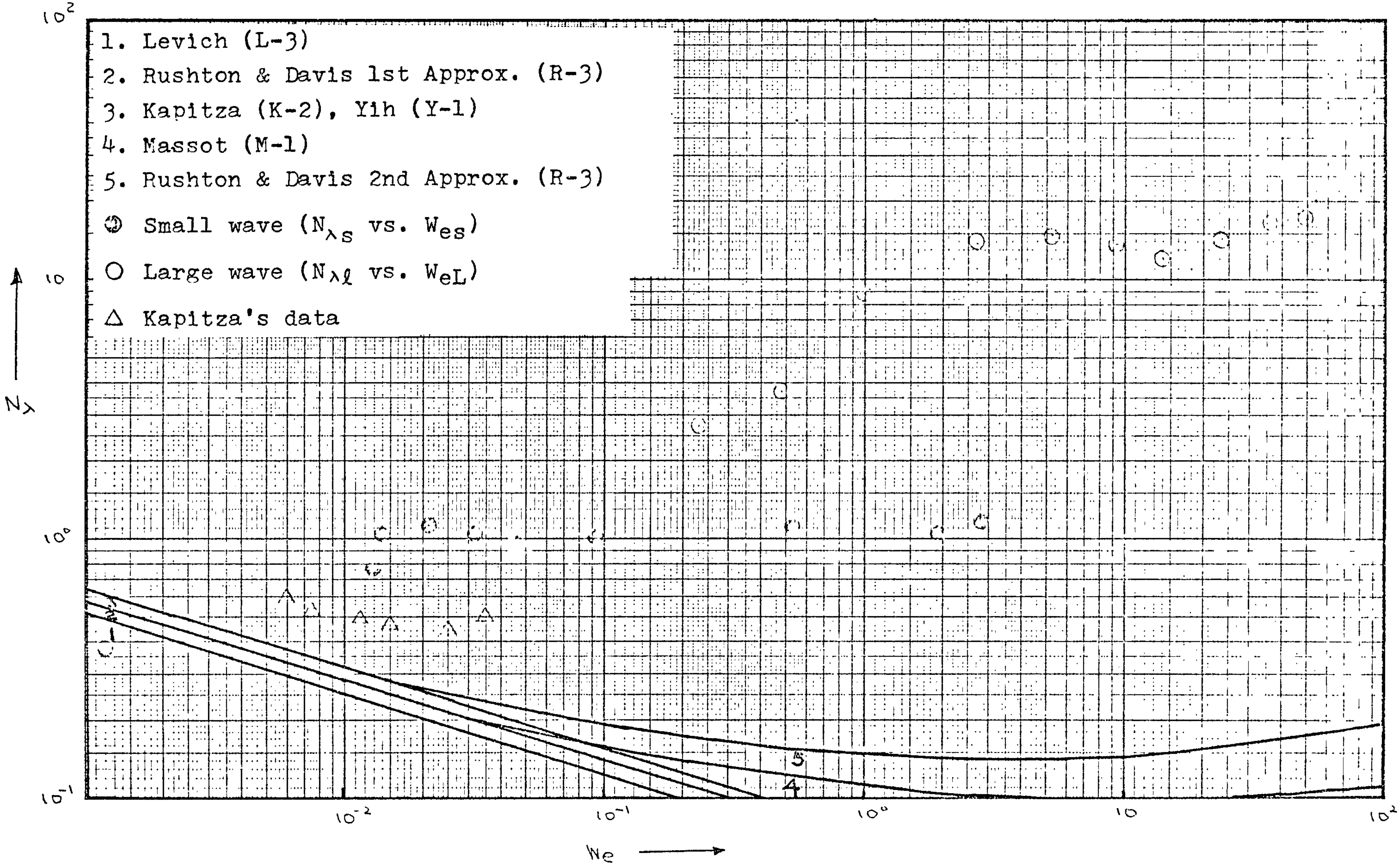


FIG. VII-9. DIMENSIONLESS WAVE LENGTH

is in the range of Kapitza's data but also in poor agreement with theory. The wave velocity data of the small wave is much higher than the value $\alpha = 3$ from all the theory for the small Weber number. But as mentioned in Chapter II, Lin (L-4, L-5, L-6) recently predicted the wave velocity $\alpha > 3$ based on the nonlinear stability theory.

(c) In Fig. VII-10, the half dimensionless wave amplitude A_{eq} is plotted vs. the Reynolds number. The data for the small wave shows a constant value 0.14 which is smaller than all the theories. While the data for the large waves show much higher values than most of the theory except Anshus' theory. In Fig. VII-11, the data of A_{eq} is plotted vs. the correlation parameter G^{*} proposed by Goren. The correlation is obviously not suitable for either the small and large waves.

5-3. SHALLOW WATER THEORY AND THE FALLING FILM

From the above comparison, it seems that all the theories except that of Telles' are not valid for describing the large waves on the falling film. In this section, the relative importance of the various terms in the equation of motion will be examined by the shallow water theory. The result should give a clear picture of the equation which should be used for the primary flow. The basic assumption of shallow water theory is that the depth of water is small compared with some

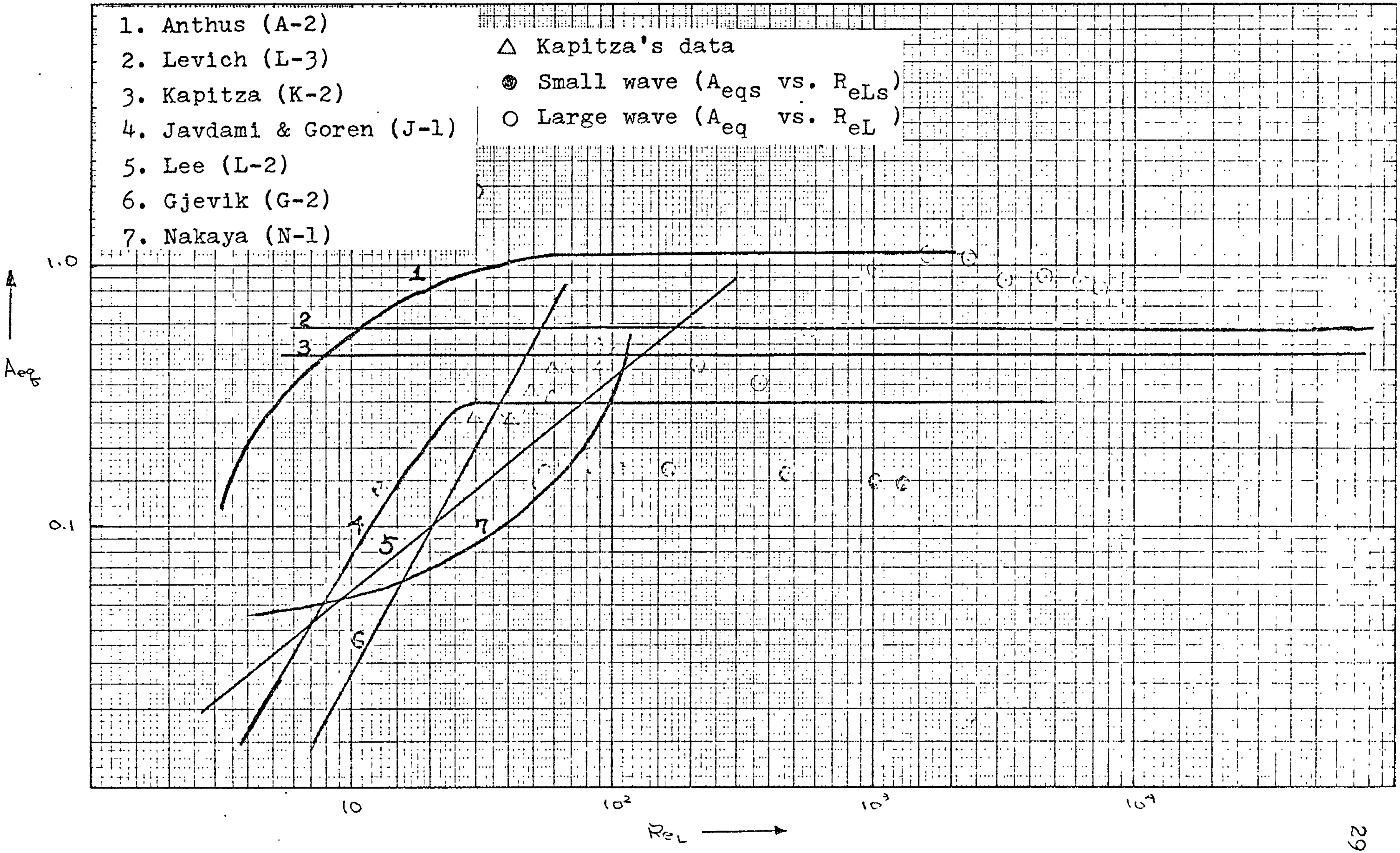


FIG. VII-10. DIMENSIONLESS WAVE AMPLITUDE

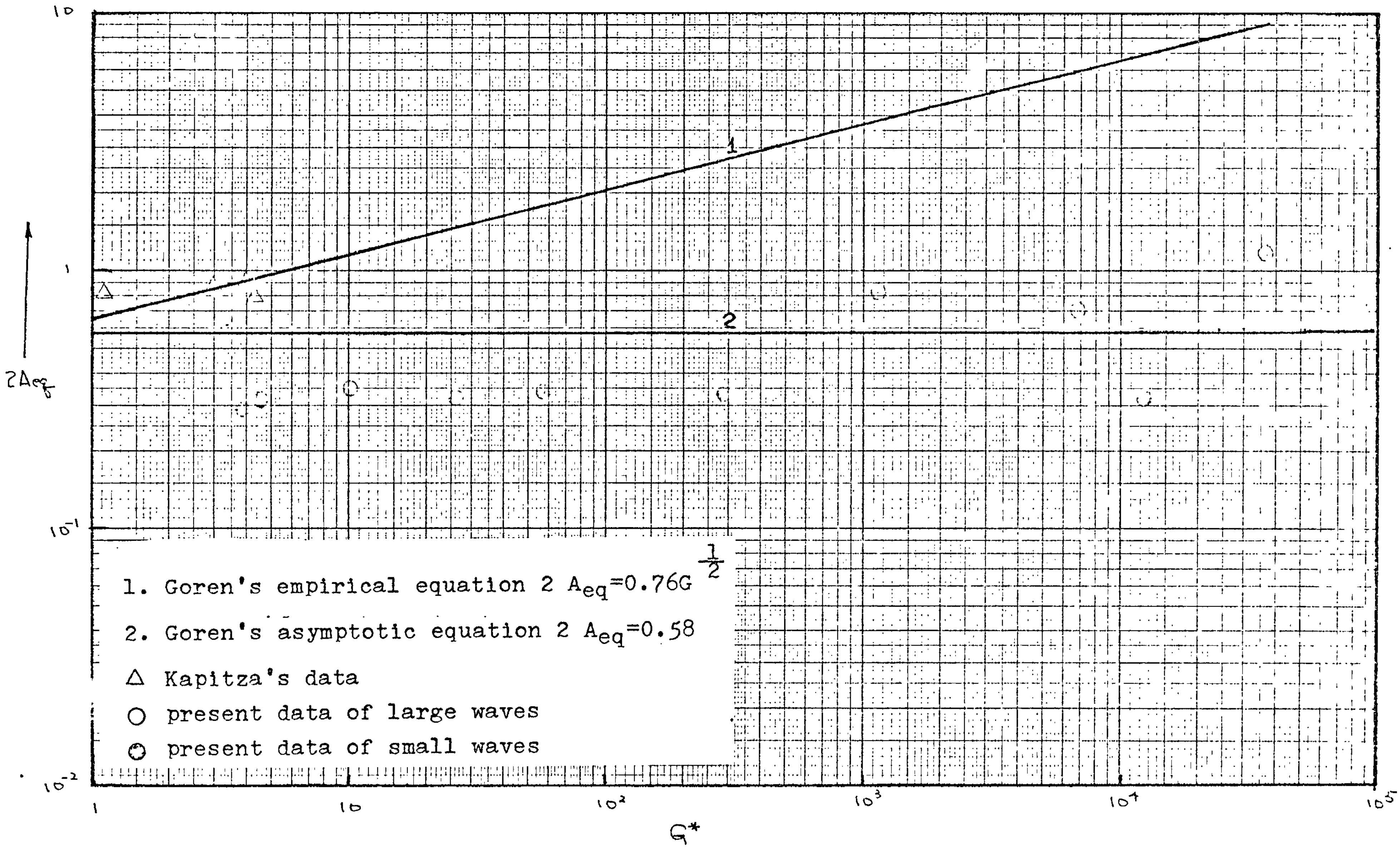


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FIG. VII-11. GOREN'S CORRELATION PARAMETERS other significant length, such as wave length. In this theory it is not necessary to assume that the displacement and slope of the water surface are small.

Start with the basic equation (VII-12) and the boundary condition equations (VII-13) and (VII-14), and introduce the following dimensionless variables.

$$\left.\begin{aligned}
u &= u_1/\langle u\rangle \\
v &= v_1/\left\{\frac{\langle h\rangle}{\langle\lambda\rangle}\langle u\rangle\right\} \\
\eta &= h/\langle h\rangle \\
p &= p_1/\rho\langle u\rangle^2 \\
x &= x_1/\langle\lambda\rangle \\
y &= y_1/\langle h\rangle \\
t &= t_1/\left\{\frac{\langle\lambda\rangle}{\langle u\rangle}\right\}
\end{aligned}\right\} \text{------(VII-106)}$$

where $\langle h\rangle$ is the mean film thickness

$\langle\lambda\rangle$ is the mean wave length

$\langle u\rangle$ is the mean velocity

The equations become

$$\left.\begin{aligned}
& u_x + v_y = 0 \\
& \varepsilon\left\{u_t + uu_x + vu_y + p_x\right\} = \frac{g\langle h\rangle}{\langle u\rangle^2} + \frac{1}{Re_L}\left\{\varepsilon^2 u_{xx} + u_{yy}\right\} \\
& \varepsilon^2\left\{v_t + uv_x + vv_y\right\} = -p_y + \frac{1}{Re_L}\,\varepsilon\left\{\varepsilon^2 v_{xx} + v_{yy}\right\}
\end{aligned}\right\} \text{---(VII-107)} \atop \text{(a)(b)(c)}$$

The boundary conditions are

$$\left.\begin{aligned}
u &= 0 \\
\varepsilon v &= 0
\end{aligned}\right\} \text{ at } y = 1 \text{ ------------ (VII-108)}$$

$$\left.\begin{array}{l} \frac{4}{Re_L}\left\{u_y + \varepsilon^2 v_x\right\} = 0 \\ -p + \frac{8}{Re_L}\varepsilon v_y + \frac{1}{We}\varepsilon^2 \eta_{xx} = 0 \\ \varepsilon\left\{\eta_t + u\eta_x - v\right\} = 0 \end{array}\right\} \text{ at } y = \eta \quad - - - - (\text{VII-109}) \; (a)(b)(c)$$

where $\varepsilon = \frac{\langle h \rangle}{\langle \lambda \rangle}$ is shallow water parameter

From equation (VII-107) (b), it is clearly indicated that the primary flow can be described by the Nusselt's equation, only if the following condition holds

$$\varepsilon \ll \frac{4}{Re_L} \quad - - - - - - - (\text{VII-110})$$

In Table VII- 6, the value of $\frac{4}{Re_L}$ is compared with the value of ε for both large and small waves at W_G = 0.0 lb/sec. In most of the condition, the above equation (VII-110) does not hold except for the small waves at low Reynolds number. Hence it is obvious that the theory is unable to predict what one observes on the falling film and it is only good for the very small Reynolds number flow or the entrance region where $\langle \lambda \rangle \to \infty$ Since the ratio of $\frac{4.0}{Re_L}$ to ε of the small waves is large than that of the large waves, and the variation of h_s is much smaller than h, the data for the small waves is naturally much closer to the theoretical prediction compared to the data of the large wave. From the above expansion, one can also validate the approximation of p_y = 0 from the equation (VII-107)(c). If $\frac{4.0}{Re_L} \simeq \varepsilon$, then the basic equation will be

$$u_t + uu_x + vv_y + p_x = \frac{g\langle h \rangle}{\langle u \rangle^2} + u_{yy} \quad - - - - - (\text{VII-111})$$

TABLE VII-6

SHALLOW WATER PARAMETER

R_{eL}	$\frac{4.0}{R_{eL}}$	ε	R_{eLS}	$\frac{4.0}{R_{eLS}}$	ε
211	0.019	0.00262	12.7	0.315	0.014
367	0.0109	0.00294	52.9	0.0757	0.0105
572	0.0070	0.00144	55.1	0.0728	0.00796
1016	0.00394	0.00115	67.3	0.0595	0.00792
1605	0.00249	0.00136	86.8	0.0462	0.00925
2299	0.00174	0.00173	108.0	0.0371	0.0105
3151	0.00127	0.00226	168.9	0.0238	0.0113
4572	0.00088	0.00238	472.0	0.0085	0.015
6109	0.000655	0.00246	1017.6	0.00393	0.02
7560	0.00053	0.00267	1292.0	0.00310	0.0224

This is the same equation used by Telles and Ruckenstein. In the case of Telles' model, $p_{y} = 0$ is assumed. The limitation of their model is due to the assumption of the stochastic processes for the Telles' case and the linearization procedures for the Ruckensten's case.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

1. WAVE STRUCTURE CHARACTERIZATION

In this study an attempt was made to describe the surface waves occuring on a falling film by statistical means. The Reynolds number for the liquid phase varied from 200 to 7,500 and for the co-current gas phase from 0 to 113,000. The statistical method is one which considers the instantaneous film thickness, $h(t)$, measured at several stations to be represented by a time series which is stationary. This time series was processed by different techniques to extract a variety of information to characterize the wave structure as shown in the schematic diagram of Fig. VIII-1.

As shown in Fig. VIII-1, the processes applied to the time series to extract the information are described as follows:

(a) Process A is a standard time series analysis for film thickness.

(b) Process B uses the mean film thickness $\langle h \rangle$ as a criterion to classify the waves into three groups; large waves, small waves moving on the substrate, and small waves travelling on the large waves. The statistics of a series of parameters characterizing

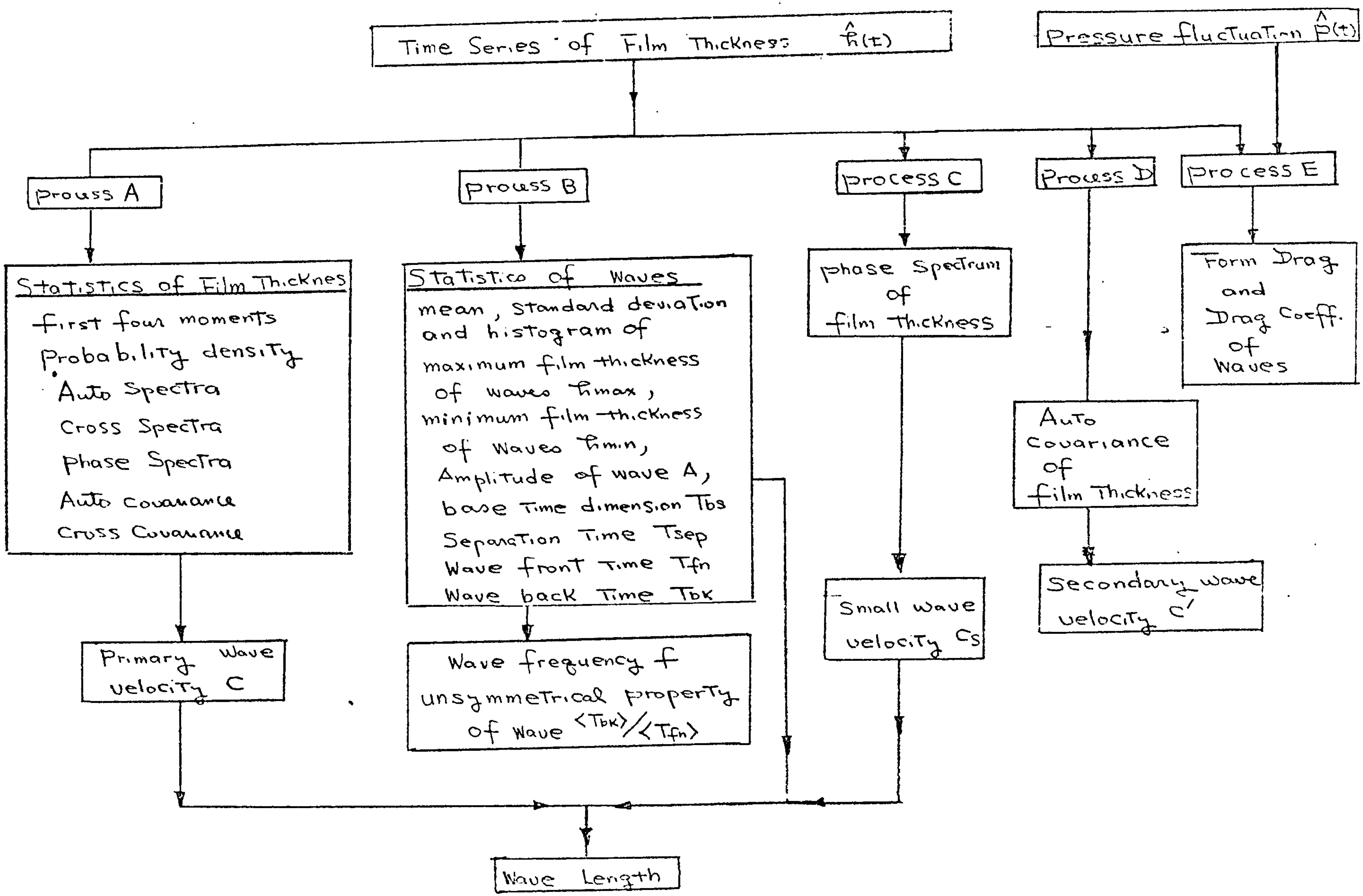

Fig. VIII-1 Summary of Time Series Analysis the waves are then calculated from the film thickness data.

(c) Process C calculates the phase spectrum using a special technique of time shifting to extract the celerity of the small waves.

(d) Process D calculate the auto covariance function using a technique of time shifting and subtraction of two simultaneous time series. This makes the the calculation of a secondary wave possible.

(e) Process E integrates the quadrature spectrum between film thickness and wall pressure fluctuation and provides information about the drag coefficient around the waves.

These analyses resulted in the following conclusions:

(a) Three distinct types of waves were clearly identified; large waves, small waves moving on the substrate and small waves travelling on the large waves. The large waves and the small waves on the substrate move at distinctly different velocities and the wave properties are each characterized by their own probability densities. The small waves on large waves include two types of wave motion: the large waves couple closely together, and the small waves riding on top of the large waves.

Therefore the statistics of this type of wave appear to be a mixture of the statistics of both large waves and the small waves.

(b) At low liquid rates, the large waves display an amplitude distribution with a single mode located at 0.01" - 0.02". But as the liquid rate is increased, a bimodal wave amplitude structure appears with one mode located as before at 0.010" - 0.020" and a second group of waves with amplitude at 0.04" - 0.05" or 0.05" - 0.06". But it is of interest that over this entire range of liquid rate the wave base exhibits a single modal distribution. A weak relation between the wave amplitude and the wave separation distance was also established. Under conditions where a bimodal distribution of amplitude exists, the large amplitude waves appear to be weakly periodic while the waves of smaller amplitude are more random nature. This suggests that the waves of smaller amplitude might be a shot noise type process.

(c) In the case of small waves, a single mode of narrow distribution exists for all wave parameters at all flow conditions.

(d) The large waves show a strong two dimensionality and slowly changing properties along the length. This is caused by the change in the wave amplitude, the wave separation and the wave velocity. Growth rate constants were also determined for the large waves. The small waves show a strong three dimensionality and an equilibrium state for all the wave parameters along the length of the test section.

(e) The relationship between the large wave parameters; T'_{sep}, T_{bs}, $\tilde{\sigma}_{Amp}$ and the statistical parameters of film thickness; f_m, ζ_m, C_2, ζ_{min} were established.

(f) The existence of a single constant slope in the high frequency range of the power spectrum was clearly established at all gas and liquid rates. This suggests that an equilibrium subrange of the spectrum exists in the wave process. The detailed physical meaning is not clear at this moment.

(g) Cross correlation between pressure and the amplitude of wave permits the shear to be calculated. It is clear that the contribution of large waves to the measured pressure drop and added shear in two phase flow is less than 10%. One then concludes that the small wave structure is the cause for the observed high rate of momentum transfer when waves are present.

To expand this study, the following areas of investigation are recommended:

(a) Using a large number measuring stations with short spacing along the length, obtain simultaneous film thickness time series in a multiple channel system. This measurement permits one to perform a two dimensional Fourier analysis and to extract the precise wave velocity for each different wave component.

(b) Determine the small wave spectrum by conditional sampling on the substrate.

(c) Calculate the drag force from the experimental measurement of the gas velocity field over the wave.

2. WAVE STRUCTURE ANALYSIS

Two detailed random wave models have been developed for the primary wavy flow on falling films. The first model uses a white-noise input on the velocity field. Its purpose is to generate a non delta function type of the spectrum which is observed experimentally. The second model is based on the extension of Telles' shot noise process, and its purpose is to predict the wave velocity the wave shapes and the velocity profile. The probability density of film thickness was separated into two parts; one for large waves and one for substrate. This enable one to calculate substrate flow rate and large wave flow rate. These analyses resulted in the following conclusions:

(a) The white noise model is successful in producing a non-delta function type of spectrum, although the solution is only good for very small Reynolds number or in the entrance region. The technique should be useful in the future studies.

(b) The present extension on Telles' model gives much more successful result than the Telles' original model.

(c) It was possible for the first time to determine the fraction of liquid flowing in the substrate and that in waves. Although at any point the substrate exists for above 50% of the time; less than 10% of the liquid flow there. The velocity and Reynolds number of substrate flow was evaluated along with the characters of waves on the substrate.

(d) The Reynolds number of flows on the large waves was determined by wave velocity and it suggests that extremely high liquid rates exist there. For example at a liquid input Reynolds number of 2300, the expected value of the Reynolds number of the large waves can be as high as 3600. Individual wave Reynolds number can be substantially higher.

(e) The substrate moves at low Reynolds number. So it is possible for the first time to test many theories for wave motion of low Reynolds number. All existing theories are inadequate.

(f) No existing theories describe the large wave properties with any degree of accuracy.

(g) Extension of the Telles method has some good possibilities for the large waves.

The recommended areas for expanding the present analytical study are as follows:

(a) Extend the random wave model to the turbulent velocity profile which is more suitable for the higher Reynolds number flows.

(b) Modify the Rice shot-noise process for the case of random wave amplitude such that

$$\hat{h}(t) = \sum_{-\infty}^{+\infty} \hat{a}_k m(t - \hat{t}_k)$$

and also to the case where the duration of wave pulses are not much smaller than the wave separation.

(c) Investigate the available velocity profiles for the large waves to give reasonable closure on the liquid flow rate.

(d) Extend the flow rate closure analysis to the gas phase.

(e) Extend Telles' model for the case of gas flow.

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NOMENCLATURE

A = Wave amplitude (ft).

A_{eq} = Dimensionless wave amplitude.

A_F = Amplification factor (1/in).

a_n = Coefficient of Ruckensten's velocity profile.

A_{meq} = Mean effective cross-sectional area (cm).

$A_P = \pi D \langle A \rangle$ (ft^2).

$A_W = \pi D \langle \lambda \rangle$ (ft^2).

b_n = Coefficient of Ruckensten's velocity profile.

C = wave velocity (ft/sec).

C' = Secondary wave velocity (ft/sec).

C_S = Small wave velocity (ft/sec).

C_D = Drag coefficient.

$\tilde{C}_2$ = Second central moment.

$\tilde{C}_3$ = Third central moment.

$\tilde{C}_4$ = Fourth central moment.

$\tilde{C}(\tau)$ = Covariance function.

D = Diameter of test section (ft).

d_i = Coefficient of the Gram-Charlier series on correlation function.

ENT = entrainments rate (lb/sec).

$\tilde{F}$ = Probability distribution function.

F_x = Force per unit area due to pressure fluctuations (lbf/ft^2).

F_{ms} = Mass fraction of substrate

F_s = Time fraction of the small waves on substrate.

F_w = Time fraction of the large waves.

F_r = Froude number.

f = Frequency (cps).

$\tilde{f}$ = Probability density function.

f_i = Coefficient of the Gram-Charlier series on stream function.

f_ℓ = Large wave frequency (cps).

f_ℓ' = Large wave frequency of $h_{max} > 2 \langle h \rangle$ (cps).

f_m = Modal frequency (cps).

f_m' = Secondary modal frequency (cps).

f_s = Small wave frequency (cps).

$G = R_e W_e^{1/2}$

G^* = Goren dimensionless group.

G' = Dimensionless gravity field intensity.

G_s = Specific conductance (mhos/cm).

G_m = Conductance (mhos).

G_{ms} = Conductance of electrolyte from standard cemm (mohs).

G_{mu} = Conductance of electrolyte from unknown cell (mhos).

g = Gravitational force (ft/sec^2).

H_i = Hermite polynomials.

$\tilde{H}$ = histogram.

$\bar{h}$ = Film thickness (in).

$\bar{h}_o$ = Mean film thickness (in).

$\bar{h}_{max}$ = Wave maximum (in).

$\bar{h}_{min}$ = Wave minimum (in).

$\bar{h}_s$ = Substrate film thickness (in).

i = $\sqrt{-1}$

$\tilde{K}(f)$ = Coherency spectrum.

K_{cc} = Cell constant (1/cm).

K_{ccu} = Unknown cell constant (1/cm).

K_{ccS} = Cell constant of standard cell (1/cm).

L_{me} = Mean length between conductivity cell electrode (cm).

L = Distance (ft).

m_i = Coefficient of the Gram-Charlier series on wave shape.

N_L = Total number of large waves.

N_{SL} = Total number of small waves on large waves.

N_S = Total number of small waves on substrate.

N_w = Dimensionless wave number.

N_λ = Dimensionless wave length.

N_T = Nusselt number.

P = Pressure (lbf/ft^2).

$\tilde{P}$ = Probability of event.

$\tilde{Q}(f)$ = Quadrature spectrum.

$\tilde{R}(f)$ = Correlation function.

r = Radius of test section (ft).

Re_L = Liquid Reynold number.

Re_G = Gas Reynold number.

S = Telles' dimensionless wave velocity.

$\tilde{S}(f)$ = Spectrum.

$\tilde{S}_A(f)$ = Cross amplitude spectrum.

S_{eq} = Slope of spectrum in equilibrium range.

T = Time scale (sec).

T_{bs} = Wave base (sec).

T_{fn} = Wave front (sec).

T_{bk} = Wave back (sec).

T_{sep} = Wave separation (sec).

T_{sep}' = Wave separation of $h_{max} > 2 \langle h \rangle$ (sec).

t, t_1 = Time coordinate (sec).

u, u_1 = x directional velocity (ft/sec).

u_0 = Mean velocity (ft/sec).

$\bar{u}$ = Local average velocity (ft/sec).

U = Velocity of primary flow (ft/sec).

U_R = Relative wave velocity (ft/sec).

U_G = Average gas velocity (ft/sec).

u_* = Friction velocity (ft/sec).

v = y - directional velocity (ft/sec).

We = Weber number.

W_L = Liquid flow rate (lb/sec).

W_G = Gas flow rate (lb/sec).

x, x_1 = Coordinate direction (ft).

$\tilde{x}_0$ = Length scale.

y, y_1 = Coordinate direction (ft).

y^+ = Dimensionless distance.

Z_i = Functions of the Gram-Charlier series.

z = Coordinate direction.

α = Dimensionless wave velocity.

$\alpha_{i\gamma}$ = Constant of velocity coefficient.

β = Pressure drop parameter.

Γ_L = Mass flow rate (lb/ft-sec).

γ = Kinematic surface tension (ft^2/sec).

δ = Delta function.

ε = Shallow wave parameter.

ε_1 = Eddy viscosity (ft^2/sec).

η = Dimensionless film thickness.

$\tilde{\theta}$ = Phase spectrum.

$\tilde{\Lambda}$ = Co-spectrum.

λ = Wave length (ft).

μ = Viscosity (lb/ft sec).

ν = Kinematic viscosity (ft^2/sec).

ρ = Density (lb/ft^3).

σ = Surface tension (dyne/cm^2).

$\tilde{\sigma}$ = Standard deviation.

τ = Time lag (sec).

τ' = Dimensionless time lag.

τ_i = Interface shear (lbf/ft^2).

τ_{FD} = Form drag (lbf/ft^2).

τ_W = Wall shear stress (lbf/ft^2).

τ_1 = Time lag of maximum value of cross covariance (sec).

τ_{min} = Mean base time (sec).

τ_m = Mean period (sec).

ϕ_1 = y dependent function of stream function.

ϕ_0 = y dependent function of stream function.

ψ = Stream function.

ω = Angular frequency (rad./sec).

SUBSCRIPT AND SUPERSCRIPT

s - Small wave on substrate.

l - Large waves.

sl - Small waves on large waves.

w - Large waves including small waves riding on it.

$\sim$ - Statistical quantity.

$\wedge$ - Random variables.

$\langle\ \rangle$ - Expected value.

APPENDIX A

COMPUTER PROGRAM

Program no. 1

Hybrid program for converting continuous analog voltage signal into digital time series of film thickness.


```
C       TWO CHANNEL DIGITIZING PROGRAM
C
        REAL*8 CCWAD(2), RCBAD(4), FSAVE(4)
        INTEGER*2 LOCAD(05044)
        DIMENSION X(02522),Y(02522),RTSAVE(61),CELL(2),ZX(2,20),ZY(2,20),
       1CIR(2),TM(2),AP(2),ICOC(2),IX(72),IY(72)
C
C       NP=05040
C
        LOCAD(1)=1
        KCON=0
        KKK=2
  1     WRITE (15,200)
 200    FORMAT ('TYPE NO. OF SAMPLES-I5 05040 ')
        KCON=KCON+1
        READ (15,100) NP
 100    FORMAT (I5)
        READ (5,401) WL,WG,TEPL,TEPG,VCPL,VCPG,COFA,COFB,TN
 401    FORMAT (6F10.5,3A4)
        READ (5,402) MM,ISS,IT,XMU,YMU
 402     FORMAT (2I3,I6,F10.1,F10.1)
         READ (5,406) VAX,VBX,VADX,VBDX
         READ (5,406) VAY,VBY,VADY,VBDY
 406      FORMAT (4F10.5)
        WRITE (6,494) VAX,VBX,VADX,VBDX
        WRITE (6,494) VAY,VBY,VADY,VBDY
 494    FORMAT (/,10X,'REFERENCE VOLTAGE ',/,10X,' VA = ',F10.5,5X,' VB =
       1',F10.5,5X,'VAD = ',F10.5,5X,'VBD = ',F10.5)
        REL=(4.0*WL*6.0)/(3.14159*0.000672*VCPL)
        REG=(4.0*WG*6.0)/(3.14159*0.000672*VCPG)
        IREL=INT(REL)
        IREG=INT(REG)
        N=NP/2
        WRITE (6,321) N,WL,WG
 321    FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,//,10X,'WATER FLOW RA
       1TE = ',F10.5,'LB/SEC',5X,'AIR FLOW RATE = ',F10.5,'LB/SEC',//)
        WRITE (6,404) TN,COFA,COFB
 404     FORMAT (10X,'TAPE NO = ',A4,5X,'CONFIGURATION = ',2A4,//)
        WRITE (6,405) REL,REG
 405    FORMAT (10X,' WATER REYNOLD NO. = ', E11.4,10X,' AIR REYNOLD NO. =
       1 ',E11.4,//)
        WRITE (6,414) TEPL,TEPG,VCPL,VCPG
 414     FORMAT (10X,'TEPL = ',F10.5,5X,'TEPG = ',F10.5,5X,'VCPL = ',F10.5
       1,5X,'VCPG = ',F10.5,//)
        FIT=FLOAT(IT)
        FN=FLOAT(N)
        T=FN/FIT
        WRITE (6,403) ISS,IT,T
 403    FORMAT (10X,'NO. OF POINTS FOR AVERAGING = ',I3,5X,'SAMPLING FREQU
       1ENCY = ',I6,' CPS',//,10X,'SAMPLING LENGTH = ',F10.5, ' SEC',//)
        WRITE(6,107) XMU,YMU
 107     FORMAT(10X,' XMU =',F10.1,10X,'YMU = ',F10.1,/)
        CALL READAD (CCWAD,NP, 3,LOCAD)
        CALL FRCBSU (RCBAD,28,CCWAD)
        DO 911 I=1,2
        READ (5,912) CELL(I),CIR(I),TM(I),AP(I)
        WRITE (6,915)  CELL(I),CIR(I),AP(I),TM(I)
        IF (AP(I).LT.0.0) GO TO 301
        ICOC(I)=1
        GO TO 302
 301    ICOC(I)=0
        WRITE (6,117)
 117    FORMAT (10X,'$$$$$$$$$$$$$$$$')
        DO 303 J=1,20
        ZX(I,J)=0.0
 303    ZY(I,J)=0.0
         GO TO 119
 302     CONTINUE
        DO 913 J=1,20,5
        KK=J+4
 913    READ (5,914) (ZX(I,K),ZY(I,K),K=J,KK)
 912    FORMAT (A2,A2,A4,F10.5)
 914    FORMAT (10F8.3)
 119     WRITE (6,118) ICOC(I)
 118      FORMAT (10X,' ICOC = ',I2)
 911    CONTINUE
```

```
      WRITE (6,304)  (ICOC(I),I=1,2)
  304 FORMAT (5X,'ICOC(1) =',I1,5X,'ICOC(2) = ',I1,/)
      WRITE (6,915) (CELL(I),CIR(I),AP(I),TN(I),I=1,2)
  915 FORMAT ('  CELL NO. =  ', A2,5X,'CIRCUIT NO. = ',A2,5X,' AMP OF CA
     1RRIER = ',F10.5,5X,'TAPE NO. = ',A4,//)
      DO 916 I=1,20
  916 WRITE (6,917) (ZX(J,I),ZY(J,I),J=1,2)
  917 FORMAT (5X,'ZX =',F10.5,2X,'ZY =',F10.5,2X,'ZX =',F10.5,2X,'ZY =',
     1F10.5)
      VVXY=0.0
      VVYY=0.0
      VVXX=0.0
      VVXXX=0.0
      VVYYY=0.0
      VVXXXX=0.0
      VVYYYY=0.0
      YMM=0.0
      XMM=0.0
      NN=0
C
C     INPUT CONDITION ON DIGITAL TAPE
C
      WRITE (1,501) KCON,N,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
  501 FORMAT (I2,I5,I2,2F10.1,2F8.4,2I7,2F10.3,A4,I6,A2,A2)
      IF (KKK.EQ.2) GO TO 21
      VADX=VVADX
      VADY=VVADY
      VBDX=VVBDX
      VBDY=VVBDY
      GO TO 22
   21 CONTINUE
      DO 151 IJ=1,2
      VVA=0.0
      VVB=0.0
      DO 152 IK=1,5
      CALL FRTIO (RCBAD,IRET)
      CALL FCHECK (RCBAD,IRET,1)
      DO 153 I=1,N
      J=N-I+1
      Y(J)=LOCAD(2*J+1)/81.91
       X(J)=LOCAD(2*J)/81.91
      Y(J)=Y(J)/100.0
      X(J)=X(J)/100.0
       Y(J)=-Y(J)
       X(J)=-X(J)
      VB=VB+Y(J)
  153 VA=VA+X(J)
      VA=VA/FN
      VB=VB/FN
      VVA=VVA+VA
  152 VVB=VVB+VB
      VVA=VVA/5.0
      VVB=VVB/5.0
      IF (IJ.EQ.1) GO TO 154
      VBDX=VVA
      VBDY=VVB
      VVBDX=VBDX
      VVBDY=VBDY
      GO TO 155
  154 VADX=VVA
      VADY=VVB
      VVADX=VADX
      VVADY=VADY
  155 PAUSE 'MOUNT ANALOG TAPE REF'
  151  CONTINUE
   22 WRITE (6,494) VAX,VBX,VADX,VBDX
      WRITE (6,494) VAY,VBY,VADY,VBDY
   20 CONTINUE
      CALL FRTIO (RCBAD,IRET)
      CALL FCHECK (RCBAD,IRET,1)
      DO 10 I=1,N
      J=N-I+1
      Y(J)=LOCAD(2*J+1)/81.91
       X(J)=LOCAD(2*J)/81.91
      Y(J)=(-Y(J))/100.0
      X(J)=(-X(J))/100.0
      Y(J)=VBY+(Y(J)-VBDY)*(VAY-VBY)/(VADY-VBDY)
   10 X(J)=VBX+(X(J)-VBDX)*(VAX-VBX)/(VADX-VBDX)
      XM=0.0
      YM=0.0
      DO 30 LL=1,2
      DO 999  L=1,N
```

```
      IF (LL.EQ.2) GO TO 918
      S=X(L)
      IF(ICOC(LL).EQ.0) GO TO 305
      GO TO 919
305   C=S
      GO TO 920
918   S=Y(L)
      IF (ICOC(LL).EQ.0) GO TO 306
      GO TO 919
306   C=S
      GO TO 920
919   IF (S.LE.ZX(LL,1)) GO TO 901
      GO TO 902
901   C=ZY(LL,1)
      WRITE (6,407)
407    FORMAT (1X,'L*')
      GO TO 920
902   IF (S.GE.ZX(LL,20)) GO TO 903
      GO TO 904
903   C=ZY(LL,20)
      WRITE (6,408)
408    FORMAT (1X,'H*')
      GO TO 920
904    IF (S.GE.ZX(LL,18)) GO TO 931
      IF (S.GE.ZX(LL,16)) GO TO 905
      IF (S.GE.ZX(LL,13)) GO TO 907
      IF (S.GE.ZX(LL,10)) GO TO 908
      IF (S.GE.ZX(LL,7)) GO TO 909
      IF (S.GE.ZX(LL,4)) GO TO 910
      IZ=1
      IZZ=4
      GO TO 906
910   IZ=4
      IZZ=7
      GO TO 906
909   IZ=7
      IZZ=10
      GO TO 906
908   IZ=10
      IZZ=13
      GO TO 906
907   IZ=13
      IZZ=16
      GO TO 906
905   IZ=16
      IZZ=18
      GO TO 906
931    IZ=18
      IZZ=20
906   C=0.0
      DO 40 I=IZ,IZZ
      ZXI=ZX(LL,I)
      P=1.0
      DO 50 J=IZ,IZZ
      IF (I.EQ.J) GO TO 50
      ZXJ=ZX(LL,J)
      A=(S-ZXJ)/(ZXI-ZXJ)
      P=P*A
50    CONTINUE
      B=P*ZY(LL,I)
      C=C+B
40    CONTINUE
920   IF(LL.EQ.2) GO TO 921
      X(L)=C
      XM=XM+X(L)
      GO TO 999
921   Y(L)=C
      YM=YM+Y(L)
999    CONTINUE
30     CONTINUE
      XM=XM/FN
      YM=YM/FN
      VXY=0.0
      VYY=0.0
      VXX=0.0
      VXXX=0.0
      VYYY=0.0
      VXXXX=0.0
      VYYYY=0.0
      DO 666 I=1,N
      VX=X(I)-XM
      VY=Y(I)-YM
```

```
      VX2=VX*VX
      VY2=VY*VY
      VXX=VXX+VX2
      VYY=VYY+VY2
      VXY=VXY+VX*VY
      VX3=VX2*VX
      VY3=VY2*VY
      VXXX=VXXX+VX3
      VYYY=VYYY+VY3
      VXXXX=VXXXX+VX3*VX
  666 VYYYY=VYYYY+VY3*VY
      VXX=VXX/FN
      VYY=VYY/FN
      VXY=VXY/FN
      VXXX=VXXX/FN
      VYYY=VYYY/FN
      VXXXX=VXXXX/FN
      VYYYY=VYYYY/FN
      WRITE (6,665) XM,YM,VXX,VYY,VXY
  665 FORMAT (2X,'XM = ',E11.4,2X,'YM = ',E11.4,2X,'VXX = ',E11.4,2X,'VY
     1Y = ',E11.4,2X,'VXY = ',E11.4)
      WRITE (6,667) VXXX,VYYY,VXXXX,VYYYY
  667 FORMAT(2X,'VXXX =',E11.4,2X,'VYYY = ',E11.4,2X,'VXXXX = ',E11.4,2X
     1,'VYYYY = ',E11.4)
      VVXY=VVXY+VXY
      VVXX=VVXX+VXX
      VVYY=VVYY+VYY
      VVXXX=VVXXX+VXXX
      VVYYY=VVYYY+VYYY
      VVXXXX=VVXXXX+VXXXX
      VVYYYY=VVYYYY+VYYYY
      XMM=XMM+XM
      YMM=YMM+YM
      WRITE (6,300) (X(I),Y(I),I=1,5)
      WRITE (6,300) (X(I),Y(I),I=2516,2520)
  300 FORMAT(2X,10(F8.5,2X))
C
C     STORE DATA INTO DIGITAL TAPE
C
      NN=NN+1
      WRITE(1,502) XM,YM,VXX,VYY,VXY,VXXX,VYYY,VXXXX,VYYYY
  502 FORMAT(2F8.5,7E11.4)
      DO 503 I=1,35
      KK=(I-1)*72
      DO 504 J=1,72
      II=KK+J
      X(II)=X(II)*XMU
      Y(II)=Y(II)*YMU
      IX(J)=INT(X(II))
  504 IY(J)=INT(Y(II))
      WRITE(1,505) (IX(J),J=1,72)
      WRITE(1,505) (IY(J),J=1,72)
  505 FORMAT(72I5)
  503  CONTINUE
      IF (NN .LT.MM)   GO TO 20
      FMM=FLOAT(MM)
      WRITE(6,201) MM
  201 FORMAT (20X,'NO.OF SAMPLE =',I5,//)
      VVXY=VVXY/FMM
      VVXX=VVXX/FMM
      VVYY=VVYY/FMM
      VVXXX=VVXXX/FMM
      VVYYY=VVYYY/FMM
      VVXXXX=VVXXXX/FMM
      VVYYYY=VVYYYY/FMM
      XMM=XMM/FMM
       YMM=YMM/FMM
      WRITE (6,665) XMM,YMM,VVXX,VVYY,VVXY
      WRITE(6,667) VVXXX,VVYYY,VVXXXX,VVYYYY
      VVXY2=VVXX*VVYY
      SVXY=SQRT(VVXY2)
      WRITE (6,868) VVXY2,SVXY
  868 FORMAT (5X,' VVXX.VVYY = ',E11.4,5X,' SVXY = ',E11.4)
      WRITE (6,656) CELL(1),CIR(1),CELL(2),CIR(2)
  656 FORMAT (10X,'X CHANNEL = ',A2,A2,//,10X,'Y CHANNEL = ',A2,A2,//)
      WRITE(1,506) XMM,YMM,VVXX,VVYY,VVXY,VVXXX,VVYYY,VVXXXX,VVYYYY,
     1VVXY2,SVXY
  506 FORMAT(2F8.5,9E11.4)
      PAUSE 'MOUNT ANALOG TAPE'
      WRITE (15,507)
```

```
507  FORMAT ('TYPE KKK-I1 0=CONTINUE OR 1=STOP OR 2=CHANGE TAPE')
     READ (15,508) KKK
508  FORMAT(I1)
     IF (KKK.EQ.0) GO TO 1
     IF (KKK.EQ.2) GO TO 1
     ENDFILE 1
     REWIND 1
     READ (1,501)  KCON,NI,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
    1CELL(1),CELL(2)
     WRITE (6,101) KCON,N,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
    1CELL(1),CELL(2)
101  FORMAT(1H1,10X,'KCON = ',I2,5X,'NT = ',I5,5X,'MM = ',I2,/,
    110X,'XMU = ',F10.1,5X,'YMU = ',F10.1,/,
    210X,'WL = ',F8.4,5X,'WG = ',F8.4,/,
    310X,'IREL =',I7,5X,'IREG = ',I7,/,
    410X,'TEPL = ',F10.3,5X,'TEPG = ',F10.3,/,
    510X,'TN = ',A4,5X,'IT = ',I6,/,
    610X,'X CELL = ',A2,5X,'Y CELL = ',A2,//)
     DO 219 L=1,MM
     READ (1,502) XM,YM,VXX,VYY,VXY,VXXX,VYYY,VXXXX,VYYYY
     WRITE (6,665) XM,YM,VXX,VYY,VXY
     WRITE (6,667) VXXX,VYYY,VXXXX,VYYYY
     DO 102 I=1,35
     KK=(I-1)*72
     READ (1,505) (IX(J),J=1,72)
     READ (1,505) (IY(J),J=1,72)
     DO 103 J=1,72
     II=KK+J
     X(II)=FLOAT(IX(J))/XMU
103  Y(II)=FLOAT(IY(J))/YMU
102  CONTINUE
     WRITE (6,300) (X(I),Y(I),I=1,5)
     WRITE(6,300) (X(I),Y(I),I=2516,2520)
219  CONTINUE
     READ (1,506) XMM,YMM,VVXX,VVYY,VVXY,VVXXX,VVYYY,VVXXXX,VVYYYY,
    1VVXY2,SVXY
     WRITE (6,665) XMM,YMM,VVXX,VVYY,VVXY
     WRITE(6,667) VVXXX,VVYYY,VVXXXX,VVYYYY
     WRITE (6,868) VVXY2,SVXY
     STOP
     END
```

Program no. 2

Hybrid program for calculating moments, histogram, probability density function, and probability distribution function of film thickness.

```
C
C     PROBABILITY FUNCTION OF WAVE
C
      REAL*8 CCWAD(2), RCBAD(4), FSAVE(4)
      INTEGER*2 LOCAD(10000)
      DIMENSION X(05000),RTSAVE(61),H(71),B(71),FF(71),PF(71),PFF(71),
     1PH(71),XI(6),ZX(20),ZY(20)
      EQUIVALENCE (X(1), LOCAD(2))
      LOCAD(1)=0
      WRITE (15,200)
 200  FORMAT ('TYPE NO. OF SAMPLES-I5 05000 ')
C
C     N=05000
C
      READ (15,100) N
 100  FORMAT (I5)
      READ (5,401) WL,WG,TEPL,TEPG,VCPL,VCPG,COFA,COFB,TN
 401  FORMAT (6F10.5,3A4)
      REL=(4.0*WL*6.0)/(3.14159*0.000672*VCPL)
      REG=(4.0*WG*6.0)/(3.14159*0.000672*VCPG)
      WRITE (6,231) N,WL,WG
 231  FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,//,10X,'WATER FLOW RA
     1TE = ',F10.5,'LB/SEC',5X,'AIR FLOW RATE = ',F10.5,'LB/SEC',//)
      WRITE (6,405) REL,REG
 405  FORMAT (10X,' WATER REYNOLD NO. = ', E11.4,10X,' AIR REYNOLD NO. =
     1 ',E11.4,//)
      WRITE (6,414) TEPL,TEPG,VCPL,VCPG
 414   FORMAT (10X,'TEPL = ',F10.5,5X,'TEPG = ',F10.5,5X,'VCPL = ',F10.5
     1,5X,'VCPG = ',F10.5,//)
      WRITE (6,404) TN,COFA,COFB
 404   FORMAT (10X,'TAPE NO = ',A4,5X,'CONFIGURATION = ',2A4,//)
```

```
      CALL READAD (CCWAD,N,10,LOCAD)
      CALL FRCBSU (RCBAD,28,CCWAD)
      READ (5,402) M,MM,IT
 402  FORMAT (2I3,I6)
       READ (5,406) VA,VB,VAD,VBD
 406    FORMAT (4F10.5)
      WRITE (6,494) VA,VB,VAD,VBD
 494  FORMAT (/,10X,'REFERENCE VOLTAGE ',/,10X,' VA = ',F10.5,5X,' VB =
     1',F10.5,5X,'VAD = ',F10.5,5X,'VBD = ',F10.5)
      WRITE (6,403) M,IT
 403  FORMAT (10X,'NO. OF PROBABILITY INTERVALS = ',I3,5X,'SAMPLING FREQ
     1UENCY = ',I6,' CPS',//)
      READ (5,912) CELL,CIR,TN,AP
 912  FORMAT (A2,A2,A4,F10.5)
      WRITE (6,915) CELL,CIR,AP,TN
 915  FORMAT ('  CELL NO. =  ', A2,5X,'CIRCUIT NO. = ',A2,5X,' AMP OF CA
     1RRIER = ',F10.5,5X,'TAPE NO. = ',A4,//)
      DO 913 I=1,20,5
      KK=I+4
 913    READ (5,914) (ZX(J),ZY(J),J=I,KK)
 914  FORMAT (10F8.3)
      DO 916 I=1,20
 916  WRITE (6,14) ZX(I),ZY(I)
  14  FORMAT (2X,'ZX = ',F10.5,2X,' ZY = ',F10.5)
      XI(1)=(0.05-0.0)/50.0
      XI(2)=(0.1-0.05)/10.0
      XI(3)=(0.2-0.1)/4.0
      XI(4)=(0.4-0.2)/4.0
      XI(5)=(0.5-0.4)/1.0
      XI(6)=(1.0-0.5)/1.0
      DO 800 I=1,50
      FI=FLOAT(I)
 800  B(I)=(FI-0.5)*XI(1)
      DO 803 I=1,10
      FI=FLOAT(I)
      II=I+50
 803   B(II)=0.05+(FI-0.5)*XI(2)
      DO 801 I=1,4
      FI=FLOAT(I)
      II=I+60
 801   B(II)=0.1+(FI-0.5)*XI(3)
      DO 802 I=1,4
      FI=FLOAT (I)
      II=I+64
 802   B(II)=0.2+(FI-0.5)*XI(4)
       B(69)=0.45
      B(70)=0.75
      DO 30 I=1,M
      PH(I)=0.0
 30   PFF(I)=0.0
      NN=0
 20   CONTINUE
      CALL FRTIO (RCBAD,IRET)
      CALL FCHECK (RCBAD,IRET,1)
      DO 10 I=1,N
      J=N-I+1
      X(J) = LOCAD (J+1)/81.91
      X(J)=X(J)/100.0
 10   X(J)=VB+(X(J)-VBD)*(VA-VB)/(VAD-VBD)
      DO 999 L=1,N
      S= X(L)
      IF (S.LE.ZX(1))     GO TO 901
      GO TO 902
 901  C=ZY(1)
      WRITE (6,407)
 407   FORMAT (1X,'L*')
      GO TO 31
 902   IF (S.GE.ZX(20)) GO TO 903
      GO TO 904
 903  C=ZY(20)
      WRITE (6,408)
 408   FORMAT (1X,'H*')
      GO TO 31
 904   IF (S.GE.ZX(18)) GO TO 911
      IF (S.GE.ZX(16)) GO TO 905
      IF (S.GE.ZX(13)) GO TO 907
      IF (S.GE.ZX(10)) GO TO 908
      IF (S.GE.ZX(7))  GO TO 909
      IF (S.GE.ZX(4))  GO TO 910
      IZ=1
      IZZ=4
```

```
      GO TO 906
911    IZ=18
      IZZ=20
906   C=0.0
      DO 40 I=IZ,IZZ
      ZXI=ZX(I)
      P=1.0
      DO 50 J=IZ,IZZ
      IF (I.EQ.J) GO TO 50
      ZXJ=ZX(J)
      A=(S-ZXJ)/(ZXI-ZXJ)
      P=P*A
 50   CONTINUE
      BB=P*ZY(I)
      C=C+BB
40     CONTINUE
31    X(L)=C
999   CONTINUE
      CALL PROB (N,X,H,FF,M,XI)
      DO 41 I=1,M
       PH(I)=PH(I)+H(I)
41    PFF(I)=PFF(I)+FF(I)
       NN=NN+1
      IF (NN.LT.MM) GO TO 20
      FMM=FLOAT(MM)
      DO 51 I=1,M
      PH(I)=PH(I)/FMM
51    PFF(I)=PFF(I)/FMM
      WRITE(6,201) MM
 201 FORMAT (20X,'NO.OF SAMPLE =',I5,//,20X,'PROBABILITY DENSITY AND DI
     1STRIBUTION',//)
      DO 70 I=1,50
70     PF(I)=PH(I)/XI(1)
      DO 73 I=1,10
      II=I+50
73    PF(II)=PH(II)/XI(2)
        DO 71 I=1,4
       II=I+60
71     PF(II)=PH(II)/XI(3)
      DO 72 I=1,4
       II=I+64
72     PF (II)=PH(II)/XI(4)
      PF(69)=PH(69)/XI(5)
      PF(70)=PH(70)/XI(6)
      XM=0.0
      DO 81 I=1,M
81     XM=XM+PH(I)*B(I)
      C1=0.0
      C2=0.0
      C3=0.0
      C4=0.0
       DO 80 I=1,M
       C1=C1+PH(I)*(B(I)-XM)
       C2=C2+PH(I)*(B(I)-XM)**2
       C3=C3+PH(I)*(B(I)-XM)**3
80     C4=C4+PH(I)*(B(I)-XM)**4
      WRITE (6,123) XM ,C1,C2,C3,C4
123   FORMAT (10X,'MEAN=',F9.5,2X,'1ST CENTRAL MOMENT=',F9.5,//,
     110X,'2ND CENTRAL MOMENT =',E9.3,2X,'3RD CENTRAL MOMENT= ',E9.3,//,
     210X,'4TH CENTRAL MOMENT= ',E9.3,/)
       WRITE (6,222)
222   FORMAT (20X,'PROBABILITY DENSITY ',//,10X,'FILM THICKNESS',8X,'***
     1*HISTOGRAM****',5X,'***DISTRIBUTION***',5X,'*****DENSITY*****')
       DO 333 I=1,M
333   WRITE (6,444) B(I),PH(I),PFF(I),PF(I)
444   FORMAT(10X,'B(I) = ',F10.5,5X,'H(I) = ',F10.5,5X,'FF(I) = ',F10.5,
     15X,'F(I) = ',F10.5)
       WRITE (6,101)
101   FORMAT (1H1,10X,'HISTOGRAM')
       CALL PLOT (B,PH,M)
      WRITE (6,102)
102    FORMAT (1H1,10X,'PROBABILITY DENSITY ')
      CALL PLOT (B,PF,M)
      WRITE (6,103)
103    FORMAT (1H1,10X,'PROBABILITY DISTRIBUTION ')
      CALL PLOT (B,PFF,M)
      IREL=INT(REL)
      IREG=INT(REG)
       DO 601 I=1,2
      I1=1+(I-1)*35
      I2=35+(I-1)*35
```

```
      WRITE (6,602)
 602  FORMAT (1H1,//////////)
      WRITE (6,603) WL,WL,WL,WG,WG,WG
 603  FORMAT (1X,'|WL (LB/SEC)',3('|',F7.4),'|',/,1X,'|WG (LB/SEC)',3('|
     1',F7.4),'|')
      WRITE (6,608) IREL,IREL,IREL,IREG,IREG,IREG
 608  FORMAT (1X,'| REL. NO.   ',3('|',I7),'|',/,1X,'| REG. NO.   ',3('|',
     1I7),'|')
      WRITE (6,604) TEPL,TEPL,TEPL,TEPG,TEPG,TEPG
 604  FORMAT (1X,'|TL (       )',3('|',F7.3),'|',/,1X,'|TG (       )',3('|
     1',F7.3),'|')
      WRITE (6,605) TN,TN,TN,CELL,CELL,CELL
 605  FORMAT (1X,'|RUN NO. =  ',3('| ',A4,2X),'|',/,1X,'|CELL NO. = ',3(
     1'|   ',
     2   A2,3X),'|',/,1X,'|    FILM    |',23X,'|',/,1X,'| THICKNESS | HI
     3ST. | DIST. | DENS. |',/,1X,'| ( INCHES) |',23X,'|')
      DO 606 J=I1,I2
 606  WRITE (6,607) B(J),PH(J),PFF(J),PF(J)
 607  FORMAT (1X,'|',F10.5,' |',F7.4,'|',F7.4,'|',F7.2,'|')
 601  CONTINUE
      STOP
      END
      SUBROUTINE PROB(N,X,H,FF,M,XI)
      DIMENSION X(N),H(M),FF(M),XI(5)
      DO 40 I=1,M
 40   H(I)=0.0
      XMAX=X(1)
      XMIN=X(1)
      DO 50 I=1,N
      IF (X(I).GT.XMAX) XMAX=X(I)
      IF (X(I).LT.XMIN) XMIN=X(I)
      IF (X(I).LT.0.05) GO TO 51
      IF (X(I).LT.0.1) GO TO 71
      IF (X(I).LT.0.2) GO TO 52
      IF (X(I).LT.0.4) GO TO 53
      IF (X(I).LT.0.5) GO TO 54
      J=70
      GO TO 57
 51   A=(X(I)/0.05)*50.0
      J=INT(A)+1
      GO TO 57
 71   A=((X(I)-0.05)/(0.1-0.05))*10.0
      J=50+INT(A)+1
      GO TO 57
 52   A=((X(I)-0.1)/(0.2-0.1))*4.0
      J=60+INT(A)+1
      GO TO 57
 53   A=((X(I)-0.2)/(0.4-0.2))*4.0
      J=64+INT(A)+1
      GO TO 57
 54   J=69
 57   H(J)=H(J)+1.0
 50   CONTINUE
      FN=FLOAT(N)
      DO 60 I=1,M
 60   H(I)=H(I)/FN
      DO 70 I=1,M
      FF(I)=0.0
      DO 80 J=1,I
 80   FF(I)=FF(I)+H(J)
 70   CONTINUE
      WRITE (6,555) FF(M),XMAX,XMIN
 555  FORMAT (10X,' SUMMATION OF PH = ',F12.5, 5X,'XMAX = ',F10.5,5X,'XM
     1IN = ',F10.5)
      RETURN
      END
      SUBROUTINE PLOT (X, Y, M)
      DATA BLANK, ANG, BNG /1H ,1H*, 1H./
      DIMENSION X(M), Y(M), OUT(101), YPR(11)
      YMIN=Y(1)
      YMAX=Y(1)
      DO 11 I=2,M
      IF (YMAX .GE. Y(I)) GO TO 21
      YMAX =Y(I)
 21   IF ( YMIN  .GE. Y(I)) YMIN = Y(I)
 11   CONTINUE
      YSCAL = (YMAX - YMIN )/ 100.
      YPR(1)= YMIN
      DO 70 KN=1,9
 70   YPR(KN+1)= YPR(KN) + YSCAL* 10.0
      YPR(11)= YMAX
      WRITE (6,200) ( YPR(I),I=1,11)
      XPR = X(1)
```

```
      DO 20 IX=1,101,10
   20 OUT(IX) =BNG
      JP= INT(((Y(1)- YMIN)/YSCAL) + 1.0)
      OUT (JP)= ANG
       WRITE (6,100) XPR , (OUT(IZ),IZ=1,101)
  100 FORMAT (F12.5,5X,101A1)
      NN=M-2
      DO 30 I=1,NN
      XPR= X(I+1)
      DO 40 IX=2,100
   40 OUT(IX)= BLANK
      OUT(1)= BNG
      OUT (101)= BNG
      JP= INT(((Y(I+1)-YMIN)/YSCAL)+1.0)
      OUT(JP)= ANG
      WRITE (6,100) XPR,(OUT(IZ),IZ=1,101)
   30 CONTINUE
      XPR= X(M)
      DO 50 IX=1,101
   50 OUT(IX)= BLANK
      DO 60 IX=1,101,10
   60 OUT(IX)= BNG
      JP=(((Y(M)-YMIN)/YSCAL) + 1.0)
      OUT(JP)= ANG
      WRITE (6,100) XPR, (OUT(IZ),IZ=1,101)
      WRITE (6,200) ( YPR(I),I=1,11)
  200 FORMAT (/,8X,11(E9.3,'/'))
      RETURN
      END
```

Program no. 3

Digital program for calculating auto spectrum, cross amplitude spectrum, phase spectrum, auto covariance and cross covariance of two simultaneous time series.

```
C
C       CROSS AND AUTO POWER DIGITAL PROGRAM
C
       DIMENSION X(02520),Y(02520),IX(72),IY(72),CELL(2),DATX(2,1260),
      1DATY(2,1260),NX(1),NY(1),PR(1025),PI(1025),PX(1025),PY(1025),
      2FR(256),TR(500),AM(256),PS(256),PPX(256),PPY(256)
       EQUIVALENCE (X(1),DATX(1,1))
       EQUIVALENCE (Y(1),DATY(1,1))
       READ (5,100) N,ISS,ICS,ICE
  100  FORMAT (I5,I3,I2,I2)
  1    READ (1,501)  KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
      1CELL(1),CELL(2)
  501  FORMAT (I2,I5,I2,2F10.1,2F8.4,2I7,2F10.3,A4,I6,A2,A2)
       WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
      1CELL(1),CELL(2)
  101  FORMAT(1H1,10X,'KCON = ',I2,5X,'NT = ',I5,5X,'MM = ',I2,/,
      110X,'XMU = ',F10.1,5X,'YMU = ',F10.1,/,
      210X,'WL = ',F8.4,5X,'WG = ',F8.4,/,
      310X,'IREL =',I7,5X,'IREG = ',I7,/,
      410X,'TEPL = ',F10.3,5X,'TEPG = ',F10.3,/,
      510X,'TN = ',A4,5X,'IT = ',I6,/,
      610X,'X CELL = ',A2,5X,'Y CELL = ',A2,//)
       M=N/2
       NX(1)=N
       NY(1)=N
       FIT=FLOAT(IT)
       FN=FLOAT(N)
       T=FN/FIT
       WRITE(6,104) N, ICS,ICE
  104  FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,5X,'ICS = ',I2,5X,'IC
      1E = ',I2,/)
       WRITE (6,105) ISS,IT,T
  105  FORMAT (10X,'NO. OF POINTS FOR AVERAGING = ',I3,5X,'SAMPLING FREQU
      1ENCY = ',I6,' CPS',//,10X,'SAMPLING LENGTH = ',F10.5, ' SEC',//)
       MA=M+1
       DO 31 I=1,MA
       PR(I)=0.0
       PI(I)=0.0
       PX(I)=0.0
  31   PY(I)=0.0
       IF (ICS.EQ.KCON) GO TO 106
       ICON=0
       GO TO 107
```

```
107    CONTINUE
       DO 219 L=1,MM
       READ (1,502) XM,YM,VXX,VYY,VXY,VXXX,VYYY,VXXXX,VYYYY
502    FORMAT(2F8.5,7E11.4)
       IF (ICON.EQ.1) GO TO 801
       DO 802 I=1,70
802    READ (1,803)
803    FORMAT (1X)
       GO TO 219
801    WRITE (6,665) XM,YM,VXX,VYY,VXY
       WRITE (6,667) VXXX,VYYY,VXXXX,VYYYY
665    FORMAT (2X,'XM = ',E11.4,2X,'YM = ',E11.4,2X,'VXX = ',E11.4,2X,'VY
      1Y = ',E11.4,2X,'VXY = ',E11.4)
667    FORMAT(2X,'VXXX =',E11.4,2X,'VYYY = ',E11.4,2X,'VXXXX = ',E11.4,2X
      1,'VYYYY = ',E11.4)
       DO 102 I=1,35
       KK=(I-1)*72
       READ (1,505) (IX(J),J=1,72)
       READ (1,505) (IY(J),J=1,72)
505    FORMAT (72I5)
       DO 103 J=1,72
       II=KK+J
       X(II)=FLOAT(IX(J))/XMU
103    Y(II)=FLOAT(IY(J))/YMU
102    CONTINUE
       WRITE (6,300) (X(I),Y(I),I=1,5)
       WRITE(6,300) (X(I),Y(I),I=2516,2520)
300    FORMAT(2X,10(F8.5,2X))
       DO 108 I=1,N
       X(I)=X(I)-XM
       Y(I)=Y(I)-YM
108    CONTINUE
       CALL FOUR2 (X,NX,1,-1,0)
       CALL FOUR2 (Y,NY,1,-1,0)
       DO 41 I=1,MA
       DATX(1,I)=DATX(1,I)/FIT
       DATX(2,I)=DATX(2,I)/FIT
       DATY(1,I)=DATY(1,I)/FIT
       DATY(2,I)=DATY(2,I)/FIT
       SAVEA=(DATX(1,I)*DATY(1,I)+DATX(2,I)*DATY(2,I))/T
       SAVEB=(DATY(1,I)*DATX(2,I)-DATX(1,I)*DATY(2,I))/T
       SAVEC=(DATX(1,I)*DATX(1,I)+DATX(2,I)*DATX(2,I))/T
       SAVED=(DATY(1,I)*DATY(1,I)+DATY(2,I)*DATY(2,I))/T
       PX(I)=PX(I)+SAVEC
       PY(I)=PY(I)+SAVED
       PR(I)=PR(I)+SAVEA
        PI(I)=PI(I)+SAVEB
41     CONTINUE
219    CONTINUE
       READ (1,506) XMM,YMM,VVXX,VVYY,VVXY,VVXXX,VVYYY,VVXXXX,VVYYYY,
      1VVXY2,SVXY
506    FORMAT(2F8.5,9E11.4)
       WRITE (6,665) XMM,YMM,VVXX,VVYY,VVXY
       WRITE(6,667) VVXXX,VVYYY,VVXXXX,VVYYYY
       WRITE (6,868) VVXY2,SVXY
868    FORMAT (5X,' VVXX.VVYY = ',E11.4,5X,' SVXY = ',E11.4)
       FMM=FLOAT(MM)
       WRITE(6,201) MM
 201   FORMAT (20X,'NO.OF SAMPLE =',I5,//)
       IF (ICON.EQ.0) GO TO 1
       DO 51 I=1,MA
       PR(I)=PR(I)/FMM
       PI(I)=PI(I)/FMM
       PX(I)=PX(I)/FMM
       PY(I)=PY(I)/FMM
51     CONTINUE
       M2=M-1
       SUM=(PR(1)+PR(M))/2.0
       SUMX=(PX(1)+PX(M))/2.0
       SUMY=(PY(1)+PY(M))/2.0
       DO 45 I=2,M2
       SUMX=SUMX+PX(I)
       SUMY=SUMY+PY(I)
45     SUM=SUM+PR(I)
       SUM=2.0*SUM/T
       SUMX=2.0*SUMX/T
       SUMY=2.0*SUMY/T
       WRITE (6,55)SUM,SUMX,SUMY
       AMO=SQRT(PR(1)*PR(1)+PI(1)*PI(1))
       PSO=ATAN(PI(1)/PR(1))
```

```
      PYO=PY(1)
      PK=3.14159265
      ISSS=M/ISS
      WRITE (6,111) ISSS
  111 FORMAT (10X,' ISSS = ',I3,/)
      FISS=FLOAT(ISS)
      DO 63 J=1,ISSS
      IA=ISS*(J-1)+1
      IIA=ISS*J
      AMA=0.0
      AMD=0.0
      PSD=0.0
      PSX=0.0
      PSY=0.0
      DO 64 I=IA,IIA
      AMA=AMA+SQRT(PR(I)*PR(I)+PI(I)*PI(I))
      AMD=AMD+PR(I)
      PSD=PSD+PI(I)
      PSX=PSX+PX(I)
      PSY=PSY+PY(I)
   64 CONTINUE
      SAVEA=AMD/FISS
      SAVEB=PSD/FISS
      AM(J)=AMA/FISS
      PPX(J)=PSX/FISS
      PPY(J)=PSY/FISS
      IF(SAVEB) 810,820,830
  810 IF (SAVEA) 840,850,860
  820 IF (SAVEA) 870,880,860
  830 IF (SAVEA) 890,811,860
  840 PHZ=ATAN(SAVEB/SAVEA)-PK
      GO TO 822
  850 PHZ=-PK/2.0
      GO TO 822
  860 PHZ=ATAN(SAVEB/SAVEA)
       GO TO 822
  870 PHZ=-PK
      GO TO 822
  880 PHZ=0.0
      GO TO 822
  890  PHZ=ATAN(SAVEB/SAVEA)+PK
      GO TO 822
  811 PHZ=PK/2.0
  822 PS(J)=PHZ
   63 CONTINUE
      PXO=PXO/VVXX
      PYO=PYO/VVYY
      AMO=AMO/SVXY
      AM(1)=AM(1)/SVXY
      PPX(1)=PPX(1)/VVXX
      PPY(1)=PPY(1)/VVYY
      FR(1)=((FLOAT(ISS)-1.0)/2.0)/T
      DO 65 I=2,ISSS
      AM(I)=AM(I)/SVXY
      PPX(I)=PPX(I)/VVXX
      PPY(I)=PPY(I)/VVYY
   65 FR(I)=FR(I-1)+((FLOAT(ISS))/T)
   55  FORMAT (/,10X,' SUM OF POWER (SVXY) = ',E12.5,/,10X,' SUM OF POWE
     1R (VVXX) = ',E12.5,/,10X,' SUM OF POWER (VVYY) = ',E12.5,/)
       DO 415 I=2,ISSS
       I1=ISSS-I+1
       I2=I1+1
       FR(I2)=FR(I1)
       PPX(I2)=PPX(I1)
       PPY(I2)=PPY(I1)
       AM(I2)=AM(I1)
  415  PS(I2)=PS(I1)
       FR(1)=0.0
       AM(1)=AMO
       PS(1)=PSO
       PPX(1)=PXO
       PPY(1)=PYO
       WRITE (6,203)
  203  FORMAT(/,2(1X,'FREQ.(CPS)     PHASE     AMPLITUDE  X POWER     Y POWE
     1R '),/)
       WRITE (6,202) (FR(I),PS(I),AM(I),PPX(I),PPY(I),I=1,ISSS)
  202  FORMAT (2(1X,F10.4,4(1X,E10.3)))
       CALL PLOT (FR,AM,PPX,PPY,55)
       CALL PLOT (FR,PS,PS,PS,55)
       DO 52 I=1,MA
       DATX(1,I)=PR(I)*FIT
```

```
      DATY(1,I)=DATX(1,I)
      DATY(2,I)=-DATX(2,I)
52    CONTINUE
      CALL FOUR2 (X,NX,1,1,-1)
      CALL FOUR2 (Y,NY,1,1,-1)
      TT=1.0/FIT
      TR(1)=0.0
      PR(1)=X(1)/FN
      PI(1)=Y(1)/FN
      PR(1)=PR(1)/SVXY
      PI(1)=PI(1)/SVXY
      DO 53 I=2,M
      FFI=FLOAT(I)
      PR(I)=(X(I)/FN)*(T/(T-FFI*TT))
      PI(I)=(Y(I) /FN)*(T/(T-FFI*TT))
      PR(I)=PR(I)/SVXY
      PI(I)=PI(I)/SVXY
53     CONTINUE
      DO 57 I=2,500
       TR(I)=TR(I-1)+TT
57    CONTINUE
      DO 56 I=1,MA
      DATX(1,I)=PX(I)*FIT
      DATX(2,I)=0.0*FIT
      DATY(1,I)=PY(I)*FIT
56    DATY(2,I)=0.0*FIT
      CALL FOUR2 (X,NX,1,1,-1)
      CALL FOUR2 (Y,NY,1,1,-1)
      PX(1)=X(1)/FN
      PY(1)=Y(1)/FN
      PPPX=PX(1)
      PPPY=PY(1)
      PX(1)=PX(1)/PPPX
      PY(1)=PY(1)/PPPY
      DO 58 I=2,M
      FFI=FLOAT(I)
      PX(I)=(X(I)/FN)*(T/(T-FFI*TT))
      PY(I)=(Y(I) /FN)*(T/(T-FFI*TT))
      PX(I)=PX(I)/PPPX
58    PY(I)=PY(I)/PPPY
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,55) SVXY,PPPX,PPPY
      WRITE (6,204)
204   FORMAT (/,2(1X,'TIME (SEC)    X LAG Y    X LEAD Y     X AUTO.     Y AU
     1TO. '),/)
      WRITE (6,202) (TR(I),PR(I),PI(I),PX(I),PY(I),I=1,500)
      CALL PLOT(TR,PR,PX,PY,ISSS)
      CALL PLOT(TR,PI,PX,PY,ISSS)
      ITTT=ISSS/45
      DO 610 K=1,2
      DO 601 I=1,ITTT
      I1=1+(I-1)*45
      I2=45+(I-1)*45
      WRITE (6,602)
602    FORMAT (1H1,///)
      WRITE (6,603) WL,WL,WG,WG
603   FORMAT (1X,2('|WL (LB/SEC)|',2X,F11.4,3X),1X,'|',/,1X,2('|WG (LB/S
     1EC)|',2X,F11.4,3X),1X,'|')
      WRITE (6,608) IREL,IREL,IREG,IREG
 608   FORMAT (1X,2('| REL. NO.   |',2X,I11,3X),1X,'|',/,1X,2('| REG. NO.
     1  |',2X,I11,3X),1X,'|')
      WRITE (6,604) TEPL,TEPL,TEPG,TEPG
604   FORMAT (1X,2('|TL (        )|',2X,F11.3,3X),1X,'|',/,1X,2('|TG (
     1  )|',2X,F11.3,3X),1X,'|')
      WRITE (6,605) TN,TN,CELL(1),CELL(1),CELL(2),CELL(2)
605   FORMAT (1X,2('|RUN NO. =   |',6X,A4,6X),1X,'|',/,1X,2('|X CELL NO.
     1|',7X,A2,7X),1X,'|',/,1X,2('|Y CELL NO. |',7X,A2,7X),1X,'|')
      IF (K.EQ.1) GO TO 611
      WRITE (6,612) VVXX,VVXX,VVYY,VVYY
612   FORMAT (1X,2('|   VVXX =    |',2X,E11.4,3X),1X,'|',/,1X,2('|  VVYY =
     1    |',2X,E11.4,3X),1X,'|',/,1X,'|TIME (SEC) |X AUTO.|Y AUTO. |','F
     2REQ. (CPS)|X POWER |Y POWER |')
      DO 613 J=I1,I2
613   WRITE (6,614) TR(J),PX(J),PY(J),FR(J),PPX(J),PPY(J)
614   FORMAT (1X,'|',F10.5,' |',F7.4,'|',F7.4,' |',F10.3,' |',F8.5,'|',F
     18.5,'|')
      GO TO 601
611   WRITE (6,609) SVXY,SVXY
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609  FORMAT (1X,2('|   SVXY =    |',2X,E11.4,3X),1X,'|',/,1X,'|TIME (SEC)
    1 |X LAG Y|X LEAD Y|', 'FREQ. (CPS)| PHASE |AMPLITUDE|')
     DO 606 J=11,12
606  WRITE (6,607) TP(J),PR(J),PI(J),FR(J),PS(J),AM(J)
607  FORMAT (1X,'|',F10.5,' |',F7.4,'|',F7.4,' |',F10.3,' |',F7.4,'|',F
    19.6 ,'|')
601  CONTINUE
610   CONTINUE
     IF (ICC.EQ.KCON) GO TO 109
     ICS=ICS+1
     GO TO 1
109  REWIND 1
     STOP
     END
     SUBROUTINE FOUR2 (DATA,N,NDIM,ISIGN,IFORM)
C    COOLEY-TUKEY FAST FOURIER TRANSFORM IN USASI BASIC FORTRAN.
C    MULTI-DIMENSIONAL TRANSFORM, EACH DIMENSION A POWER OF TWO,
C    COMPLEX OR REAL DATA.
C    TRANSFORM(K1,K2,...) = SUM(DATA(J1,J2,...)*EXP(ISIGN*2*PI*SQRT(-1)
C    *((J1-1)*(K1-1)/N(1)+(J2-1)*(K2-1)/N(2)+...))), SUMMED FOR ALL
C    J1 AND K1 FROM 1 TO N(1), J2 AND K2 FROM 1 TO N(2),
C    ETC. FOR ALL NDIM SUBSCRIPTS.  NDIM MUST BE POSITIVE AND
C    EACH N(IDIM) MUST BE A POWER OF TWO.  ISIGN IS +1 OR -1.
C    LET NTOT = N(1)*N(2)*...*N(NDIM).  THEN A -1 TRANSFORM
C    FOLLOWED BY A +1 ONE (OR VICE VERSA) RETURNS NTOT
C    TIMES THE ORIGINAL DATA.  IFORM = 1, 0 OR -1, AS DATA IS
C    COMPLEX, REAL OR THE FIRST HALF OF A COMPLEX ARRAY.  TRANSFORM
C    VALUES ARE RETURNED TO ARRAY DATA.  THEY ARE COMPLEX, REAL OR
C    THE FIRST HALF OF A COMPLEX ARRAY, AS IFORM = 1, -1 OR 0.
C    THE TRANSFORM OF A REAL ARRAY (IFORM = 0) DIMENSIONED N(1) BY N(2)
C    BY ... WILL BE RETURNED IN THE SAME ARRAY, NOW CONSIDERED TO
C    BE COMPLEX OF DIMENSIONS N(1)/2+1 BY N(2) BY ....  NOTE THAT IF
C    IFORM = 0 OR -1, N(1) MUST BE EVEN, AND ENOUGH ROOM MUST BE
C    RESERVED.  THE MISSING VALUES MAY BE OBTAINED BY COMPLEX CONJUGA-
C    TION.  THE REVERSE TRANSFORMATION, OF A HALF COMPLEX ARRAY DIMEN-
C    SIONED N(1)/2+1 BY N(2) BY ..., IS ACCOMPLISHED BY SETTING IFORM
C    TO -1.  IN THE N ARRAY, N(1) MUST BE THE TRUE N(1), NOT N(1)/2+1.
C    THE TRANSFORM WILL BE REAL AND RETURNED TO THE INPUT ARRAY.
C    RUNNING TIME IS PROPORTIONAL TO NTOT*LOG2(NTOT), RATHER THAN
C    THE NAIVE NTOT**2.  FURTHERMORE, LESS ERROR IS BUILT UP.
C    WRITTEN BY NORMAN BRENNER OF MIT LINCOLN LABORATORY, JANUARY 1969.
C    SEE-- IEEE AUDIO TRANSACTIONS (JUNE 1967), SPECIAL ISSUE ON FFT.
     DIMENSION DATA(1), N(1)
     NTOT=1
     DO 10 IDIM=1,NDIM
10   NTOT=NTOT*N(IDIM)
     IF (IFORM) 70,20,20
20   NREM=NTOT
     DO 60 IDIM=1,NDIM
     NREM=NREM/N(IDIM)
     NPREV=NTOT/(N(IDIM)*NREM)
     NCURR=N(IDIM)
     IF (IDIM-1+IFORM) 30,30,40
30   NCURR=NCURR/2
40   CALL BITRV (DATA,NPREV,NCURR,NREM)
     CALL COOL2 (DATA,NPREV,NCURR,NREM,ISIGN)
     IF (IDIM-1+IFORM) 50,50,60
50   CALL FIXRL (DATA,N(1),NREM,ISIGN,IFORM)
     NTOT=(NTOT/N(1))*(N(1)/2+1)
60   CONTINUE
     RETURN
70   NTOT=(NTOT/N(1))*(N(1)/2+1)
     NREM=1
     DO 100 JDIM=1,NDIM
     IDIM=NDIM+1-JDIM
     NCURR=N(IDIM)
     IF (IDIM-1) 80,80,90
80   NCURR=NCURR/2
     CALL FIXRL (DATA,N(1),NREM,ISIGN,IFORM)
     NTOT=NTOT/(N(1)/2+1)*N(1)
90   NPREV=NTOT/(N(IDIM)*NREM)
     CALL BITRV (DATA,NPREV,NCURR,NREM)
     CALL COOL2 (DATA,NPREV,NCURR,NREM,ISIGN)
100  NREM=NREM*N(IDIM)
     RETURN
     END
```

```
      SUBROUTINE BITRV (DATA,NPREV,N,NREM)
C     SHUFFLE THE DATA BY BIT REVERSAL.
C     DIMENSION DATA(NPREV,N,NREM)
C     COMPLEX DATA
C     EXCHANGE DATA(J1,J4REV,J5) WITH DATA(J1,J4,J5) FOR ALL J1 FROM 1
C     TO NPREV, ALL J4 FROM 1 TO N (WHICH MUST BE A POWER OF TWO), AND
C     ALL J5 FROM 1 TO NREM.  J4REV-1 IS THE BIT REVERSAL OF J4-1.  E.G.
C     SUPPOSE N = 32.  THEN FOR J4-1 = 10011, J4REV-1 = 11001, ETC.
      DIMENSION DATA(1)
      IP0=2
      IP1=IP0*NPREV
      IP4=IP1*N
      IP5=IP4*NREM
      I4REV=1
C     I4REV = 1+(J4REV-1)*IP1
      DO 60 I4=1,IP4,IP1
C     I4 = 1+(J4-1)*IP1
      IF (I4-I4REV) 10,30,30
 10   I1MAX=I4+IP1-IP0
      DO 20 I1=I4,I1MAX,IP0
C     I1 = 1+(J1-1)*IP0+(J4-1)*IP1
      DO 20 I5=I1,IP5,IP4
C     I5 = 1+(J1-1)*IP0+(J4-1)*IP1+(J5-1)*IP4
      I5REV=I4REV+I5-I4
C     I5REV = 1+(J1-1)*IP0+(J4REV-1)*IP1+(J5-1)*IP4
      TEMPR=DATA(I5)
      TEMPI=DATA(I5+1)
      DATA(I5)=DATA(I5REV)
      DATA(I5+1)=DATA(I5REV+1)
      DATA(I5REV)=TEMPR
 20   DATA(I5REV+1)=TEMPI
C     ADD ONE WITH DOWNWARD CARRY TO THE HIGH ORDER BIT OF J4REV-1.
 30   IP2=IP4/2
 40   IF (I4REV-IP2) 60,60,50
 50   I4REV=I4REV-IP2
      IP2=IP2/2
      IF (IP2-IP1) 60,40,40
 60   I4REV=I4REV+IP2
      RETURN
      END
      SUBROUTINE COOL2 (DATA,NPREV,N,NREM,ISIGN)
C     DISCRETE FOURIER TRANSFORM OF LENGTH N.  IN-PLACE COOLEY-TUKEY
C     ALGORITHM, BIT-REVERSED TO NORMAL ORDER, SANDE-TUKEY PHASE SHIFTS.
C     DIMENSION DATA(NPREV,N,NREM)
C     COMPLEX DATA
C     DATA(J1,K4,J5) = SUM(DATA(J1,J4,J5)*EXP(ISIGN*2*PI*I*(J4-1)*
C     (K4-1)/N)), SUMMED OVER J4 = 1 TO N FOR ALL J1 FROM 1 TO NPREV,
C     K4 FROM 1 TO N AND J5 FROM 1 TO NREM.  N MUST BE A POWER OF TWO.
C     METHOD--LET IPREV TAKE THE VALUES 1, 2 OR 4, 4 OR 8, ..., N/16,
C     N/4, N.  THE CHOICE BETWEEN 2 OR 4, ETC., DEPENDS ON WHETHER N IS
C     A POWER OF FOUR.  DEFINE IFACT = 2 OR 4, THE NEXT FACTOR THAT
C     IPREV MUST TAKE, AND IREM = N/(IFACT*IPREV).  THEN--
C     DIMENSION DATA(NPREV,IPREV,IFACT,IREM,NREM)
C     COMPLEX DATA
C     DATA(J1,J2,K3,J4,J5) = SUM(DATA(J1,J2,J3,J4,J5)*EXP(ISIGN*2*PI*I*
C     (K3-1)*((J3-1)/IFACT+(J2-1)/(IFACT*IPREV)))), SUMMED OVER J3 = 1
C     TO IFACT FOR ALL J1 FROM 1 TO NPREV, J2 FROM 1 TO IPREV, K3 FROM
C     1 TO IFACT, J4 FROM 1 TO IREM AND J5 FROM 1 TO NREM.  THIS IS
C     A PHASE-SHIFTED DISCRETE FOURIER TRANSFORM OF LENGTH IFACT.
C     FACTORING N BY FOURS SAVES ABOUT TWENTY FIVE PERCENT OVER FACTOR-
C     ING BY TWOS.  DATA MUST BE BIT-REVERSED INITIALLY.
C     IT IS NOT NECESSARY TO REWRITE THIS SUBROUTINE INTO COMPLEX
C     NOTATION SO LONG AS THE FORTRAN COMPILER USED STORES REAL AND
C     IMAGINARY PARTS IN ADJACENT STORAGE LOCATIONS.  IT MUST ALSO
C     STORE ARRAYS WITH THE FIRST SUBSCRIPT INCREASING FASTEST.
      DIMENSION DATA(1)
      TWOPI=6.2831853072*FLOAT(ISIGN)
      IP0=2
      IP1=IP0*NPREV
      IP4=IP1*N
      IP5=IP4*NREM
      IP2=IP1
C     IP2=IP1*IPROD
      NPART=N
 10   IF (NPART-2) 60,30,20
 20   NPART=NPART/4
      GO TO 10
C     DO A FOURIER TRANSFORM OF LENGTH TWO
 30   IF (IP2-IP4) 40,160,160
 40   IP3=IP2*2
C     IP3=IP2*IFACT
      DO 50 I1=1,IP1,IP0
```

```
C     I1 = 1+(J1-1)*IP0
      DO 50 I5=I1,IP5,IP3
C     I5 = 1+(J1-1)*IP0+(J4-1)*IP3+(J5-1)*IP4
      I3A=I5
      I3B=I3A+IP2
C     I3 = 1+(J1-1)*IP0+(J2-1)*IP1+(J3-1)*IP2+(J4-1)*IP3+(J5-1)*IP4
      TEMPR=DATA(I3B)
      TEMPI=DATA(I3B+1)
      DATA(I3B)=DATA(I3A)-TEMPR
      DATA(I3B+1)=DATA(I3A+1)-TEMPI
      DATA(I3A)=DATA(I3A)+TEMPR
   50 DATA(I3A+1)=DATA(I3A+1)+TEMPI
      IP2=IP3
C     DO A FOURIER TRANSFORM OF LENGTH FOUR (FROM BIT REVERSED ORDER)
   60 IF (IP2-IP4) 70,160,160
   70 IP3=IP2*4
      IP3=IP2*IFACT
C     COMPUTE TWOPI THRU WR AND WI IN DOUBLE PRECISION, IF AVAILABLE.
      THETA=TWOPI/FLOAT(IP3/IP1)
      SINTH=SIN(THETA/2.)
      WSTPR=-2.*SINTH*SINTH
      WSTPI=SIN(THETA)
      WR=1.
      WI=0.
      DO 150 I2=1,IP2,IP1
C     I2 = 1+(J2-1)*IP1
      IF (I2-1) 90,90,80
   80 W2R=WR*WR-WI*WI
      W2I=2.*WR*WI
      W3R=W2R*WR-W2I*WI
      W3I=W2R*WI+W2I*WR
   90 I1MAX=I2+IP1-IP0
      DO 140 I1=I2,I1MAX,IP0
C     I1 = 1+(J1-1)*IP0+(J2-1)*IP1
      DO 140 I5=I1,IP5,IP3
C     I5 = 1+(J1-1)*IP0+(J2-1)*IP1+(J4-1)*IP3+(J5-1)*IP4
      I3A=I5
      I3B=I3A+IP2
      I3C=I3B+IP2
      I3D=I3C+IP2
C     I3 = 1+(J1-1)*IP0+(J2-1)*IP1+(J3-1)*IP2+(J4-1)*IP3+(J5-1)*IP4
      IF (I2-1) 110,110,100
C     APPLY THE PHASE SHIFT FACTORS
  100 TEMPR=DATA(I3B)
      DATA(I3B)=W2R*DATA(I3B)-W2I*DATA(I3B+1)
      DATA(I3B+1)=W2R*DATA(I3B+1)+W2I*TEMPR
      TEMPR=DATA(I3C)
      DATA(I3C)=WR*DATA(I3C)-WI*DATA(I3C+1)
      DATA(I3C+1)=WR*DATA(I3C+1)+WI*TEMPR
      TEMPR=DATA(I3D)
      DATA(I3D)=W3R*DATA(I3D)-W3I*DATA(I3D+1)
      DATA(I3D+1)=W3R*DATA(I3D+1)+W3I*TEMPR
  110 T0R=DATA(I3A)+DATA(I3B)
      T0I=DATA(I3A+1)+DATA(I3B+1)
      T1R=DATA(I3A)-DATA(I3B)
      T1I=DATA(I3A+1)-DATA(I3B+1)
      T2R=DATA(I3C)+DATA(I3D)
      T2I=DATA(I3C+1)+DATA(I3D+1)
      T3R=DATA(I3C)-DATA(I3D)
      T3I=DATA(I3C+1)-DATA(I3D+1)
      DATA(I3A)=T0R+T2R
      DATA(I3A+1)=T0I+T2I
      DATA(I3C)=T0R-T2R
      DATA(I3C+1)=T0I-T2I
      IF (ISIGN) 120,120,130
  120 T3R=-T3R
      T3I=-T3I
  130 DATA(I3B)=T1R-T3I
      DATA(I3B+1)=T1I+T3R
      DATA(I3D)=T1R+T3I
  140 DATA(I3D+1)=T1I-T3R
      TEMPR=WR
      WR=WSTPR*TEMPR-WSTPI*WI+TEMPR
  150 WI=WSTPR*WI+WSTPI*TEMPR+WI
      IP2=IP3
      GO TO 60
  160 RETURN
      END
```

```
      SUBROUTINE FIXRL (DATA,N,NREM,ISIGN,IFORM)
C     FOR IFORM = 0, CONVERT THE TRANSFORM OF A DOUBLED-UP REAL ARRAY,
C     CONSIDERED COMPLEX, INTO ITS TRUE TRANSFORM.  SUPPLY ONLY THE
C     FIRST HALF OF THE COMPLEX TRANSFORM, AS THE SECOND HALF HAS
C     CONJUGATE SYMMETRY.  FOR IFORM = -1, CONVERT THE FIRST HALF
C     OF THE TRUE TRANSFORM INTO THE TRANSFORM OF A DOUBLED-UP REAL
C     ARRAY.  N MUST BE EVEN.
C     USING COMPLEX NOTATION AND SUBSCRIPTS STARTING AT ZERO, THE
C     TRANSFORMATION IS--
C     DIMENSION DATA(N,NREM)
C     ZSTP = EXP(ISIGN*2*PI*I/N)
C     DO 10 I2=0,NREM-1
C     DATA(0,I2) = CONJ(DATA(0,I2))*(1+I)
C     DO 10 I1=1,N/4
C     Z = (1+(2*IFORM+1)*I*ZSTP**I1)/2
C     I1CNJ = N/2-I1
C     DIF = DATA(I1,I2)-CONJ(DATA(I1CNJ,I2))
C     TEMP = Z*DIF
C     DATA(I1,I2) = (DATA(I1,I2)-TEMP)*(1-IFORM)
C 10  DATA(I1CNJ,I2) = (DATA(I1CNJ,I2)+CONJ(TEMP))*(1-IFORM)
C     IF I1=I1CNJ, THE CALCULATION FOR THAT VALUE COLLAPSES INTO
C     A SIMPLE CONJUGATION OF DATA(I1,I2).
      DIMENSION DATA(1)
      TWOPI=6.283185307*FLOAT(ISIGN)
      IP0=2
      IP1=IP0*(N/2)
      IP2=IP1*NREM
      IF (IFORM) 10,70,70
C     PACK THE REAL INPUT VALUES (TWO PER COLUMN)
 10   J1=IP1+1
      DATA(2)=DATA(J1)
      IF (NREM-1) 70,70,20
 20   J1=J1+IP0
      I2MIN=IP1+1
      DO 60 I2=I2MIN,IP2,IP1
      DATA(I2)=DATA(J1)
      J1=J1+IP0
      IF (N-2) 50,50,30
 30   I1MIN=I2+IP0
      I1MAX=I2+IP1-IP0
      DO 40 I1=I1MIN,I1MAX,IP0
      DATA(I1)=DATA(J1)
      DATA(I1+1)=DATA(J1+1)
 40   J1=J1+IP0
 50   DATA(I2+1)=DATA(J1)
 60   J1=J1+IP0
 70   DO 80 I2=1,IP2,IP1
      TEMPR=DATA(I2)
      DATA(I2)=DATA(I2)+DATA(I2+1)
 80   DATA(I2+1)=TEMPR-DATA(I2+1)
      IF (N-2) 200,200,90
 90   THETA=TWOPI/FLOAT(N)
      SINTH=SIN(THETA/2.)
      ZSTPR=-2.*SINTH*SINTH
      ZSTPI=SIN(THETA)
      ZR=(1.-ZSTPI)/2.
      ZI=(1.+ZSTPR)/2.
      IF (IFORM) 100,110,110
 100  ZR=1.-ZR
      ZI=-ZI
 110  I1MIN=IP0+1
      I1MAX=IP0*(N/4)+1
      DO 190 I1=I1MIN,I1MAX,IP0
      DO 180 I2=I1,IP2,IP1
      I2CNJ=IP0*(N/2+1)-2*I1+I2
      IF (I2-I2CNJ) 150,120,120
 120  IF (ISIGN*(2*IFORM+1)) 130,140,140
 130  DATA(I2+1)=-DATA(I2+1)
 140  IF (IFORM) 170,180,180
 150  DIFR=DATA(I2)-DATA(I2CNJ)
      DIFI=DATA(I2+1)+DATA(I2CNJ+1)
      TEMPR=DIFR*ZR-DIFI*ZI
      TEMPI=DIFR*ZI+DIFI*ZR
      DATA(I2)=DATA(I2)-TEMPR
      DATA(I2+1)=DATA(I2+1)-TEMPI
      DATA(I2CNJ)=DATA(I2CNJ)+TEMPR
      DATA(I2CNJ+1)=DATA(I2CNJ+1)-TEMPI
      IF (IFORM) 160,180,180
 160  DATA(I2CNJ)=DATA(I2CNJ)+DATA(I2CNJ)
      DATA(I2CNJ+1)=DATA(I2CNJ+1)+DATA(I2CNJ+1)
 170  DATA(I2)=DATA(I2)+DATA(I2)
```

```
      DATA(I2+1)=DATA(I2+1)+DATA(I2+1)
  180 CONTINUE
      TEMPR=ZR-.5
      ZR=ZSTPR*TEMPR-ZSTPI*ZI+ZR
  190 ZI=ZSTPR*ZI+ZSTPI*TEMPR+ZI
C     RECURSION SAVES TIME, AT A SLIGHT LOSS IN ACCURACY.  IF AVAILABLE,
C     USE DOUBLE PRECISION TO COMPUTE ZR AND ZI.
  200 IF (IFORM) 270,210,210
C     UNPACK THE REAL TRANSFORM VALUES (TWO PER COLUMN)
  210 I2=IP2+1
      I1=I2
      J1=IP0*(N/2+1)*NREM+1
      GO TO 250
  220 DATA(J1)=DATA(I1)
      DATA(J1+1)=DATA(I1+1)
      I1=I1-IP0
      J1=J1-IP0
  230 IF (I2-I1) 220,240,240
  240 DATA(J1)=DATA(I1)
      DATA(J1+1)=0.
  250 I2=I2-IP1
      J1=J1-IP0
      DATA(J1)=DATA(I2+1)
      DATA(J1+1)=0.
      I1=I1-IP0
      J1=J1-IP0
      IF (I2-1) 260,260,230
  260 DATA(2)=0.
  270 RETURN
      END
      SUBROUTINE PLOT (X, Y, Z, W, M)
      DATA BLANK, ANG, BNG, CNG,DNG,ENG,FNG/1H ,1H*,1H.,1H:,1H+,1HX,1HY/
      DIMENSION X(M), Y(M), OUT(101), YPR(11),Z(M),W(M)
      YMIN=Y(1)
      YMAX=Y(1)
      DO 11 I=2,M
      IF (YMAX .GE. Y(I)) GO TO 21
      YMAX =Y(I)
   21 IF ( YMIN  .GE. Y(I)) YMIN = Y(I)
   11 CONTINUE
      DO 13 I=1,M
      IF (YMAX.GE.Z(I)) GO TO 22
      YMAX=Z(I)
   22 IF (YMAX.GE.W(I)) GO TO 23
      YMAX=W(I)
   23 IF (YMIN.LE.Z(I)) GO TO 24
      YMIN=Z(I)
   24 IF (YMIN.GE.W(I)) YMIN=W(I)
   13 CONTINUE
      YSCAL = (YMAX - YMIN )/ 100.
      IF (YMIN.LT.0.0) GO TO 102
      MIN=0
      GO TO 103
  102 MIN=1
  103 WRITE (6,101)
  101 FORMAT (1H1)
      YPR(1)= YMIN
      DO 70 KN=1,9
   70 YPR(KN+1)= YPR(KN) + YSCAL* 10.0
      YPR(11)= YMAX
      WRITE (6,200) ( YPR(I),I=1,11)
      IF (MIN.EQ.1) IP=INT(((0.0-YMIN)/YSCAL)+1.0)
      XPR = X(1)
      DO 10 IX=1,101
   10 OUT(IX)= BLANK
      DO 20 IX=1,101,10
   20 OUT(IX) =BNG
      IF (MIN.EQ.1) OUT(IP)=CNG
      JP= INT(((Y(1)- YMIN)/YSCAL) + 1.0)
      KP= INT(((Z(1)- YMIN)/YSCAL) + 1.0)
      LP= INT(((W(1)- YMIN)/YSCAL) + 1.0)
      OUT(KP)=ENG
      OUT(LP)=FNG
      OUT (JP)= ANG
       WRITE (6,100) XPR , (OUT(IZ),IZ=1,101)
  100 FORMAT (1X,F8.3,4X,101A1)
      NN=M-2
      DO 30 I=1,NN
      XPR= X(I+1)
      DO 40 IX=2,100
   40 OUT(IX)= BLANK
      FI=FLOAT(I)/10.0
```

```
      IIF=I/10
      FJ=FLOAT(IIF)
      IF (FI.NE.FJ) GO TO 104
      DO 12 IX=1,101,10
 12   OUT (IX)=DNG
 104  OUT(1)= BNG
      OUT (101)= BNG
      IF (MIN.EQ.1) OUT(IP)=CNG
      JP= INT(((Y(I+1)-YMIN)/YSCAL)+1.0)
      KP= INT(((Z(I+1)-YMIN)/YSCAL)+1.0)
      LP= INT(((W(I+1)-YMIN)/YSCAL)+1.0)
      OUT(KP)=ENG
      OUT (LP)=FNG
      OUT(JP)= ANG
      WRITE (6,100) XPR,(OUT(IZ),IZ=1,101)
 30   CONTINUE
      XPR= X(M)
      DO 50 IX=1,101
 50   OUT(IX)= BLANK
      DO 60 IX=1,101,10
 60   OUT(IX)= BNG
      IF (MIN.EQ.1) OUT(IP)=CNG
      JP= INT(((Y(M)-YMIN)/YSCAL) + 1.0)
      KP= INT(((Z(M)-YMIN)/YSCAL) + 1.0)
      LP= INT(((W(M)-YMIN)/YSCAL) + 1.0)
      OUT(KP)=ENG
      OUT (LP)=FNG
      OUT(JP)= ANG
      WRITE (6,100) XPR, (OUT(IZ),IZ=1,101)
      WRITE (6,200) ( YPR(I),I=1,11)
 200  FORMAT (/,8X,11(E9.3,' '))
      RETURN
      END
```

Program no. 4

Digital program for extracting a sequences of wave minimum, wave front time, wave maximum, and wave back time from the time series of film thickness.

```
C
C     CONSTRUCT TIME SERIES OF MIN FRONT MAX LEE MIN
C
      DIMENSION IZ(2,2520),IIX(72),IIY(72),CELL(2),IW(2,1080),IM(2),
     1ITP(50),ICW(2,270)
      READ(5,100) ISF,ISD,ICS,ICE
 100  FORMAT (2I3,2I2)
      WRITE (6;200) ISF,ISD,ICS,ICE
 200  FORMAT (10X,'ISF = ',I3,2X,'ISD = ',I3,2X,'ICS = ',I2,2X,'ICE = ',
     1I2)
      KNCO=0
 1    READ (1,501)  KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
 501  FORMAT (I2,I5,I2,2F10.1,2F8.4,2I7,2F10.3,A4,I6,A2,A2)
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
 101  FORMAT(1H1,10X,'KCON = ',I2,5X,'NT = ',I5,5X,'MM = ',I2,/,
     110X,'XMU = ',F10.1,5X,'YMU = ',F10.1,/,
     210X,'WL = ',F8.4,5X,'WG = ',F8.4,/,
     310X,'IREL =',I7,5X,'IREG = ',I7,/,
     410X,'TEPL = ',F10.3,5X,'TEPG = ',F10.3,/,
     510X,'TN = ',A4,5X,'IT = ',I6,/,
     610X,'X CELL = ',A2,5X,'Y CELL = ',A2,//)
      FIT=FLOAT(IT)
      FNT=FLOAT(NT)
      T=FNT/FIT
      WRITE(6,104) NT, ICS,ICE
 104  FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,5X,'ICS = ',I2,5X,'IC
     1E = ',I2,/)
      WRITE (6,105) ISF,ISD,IT,T
 105  FORMAT (10X,' ISF = ',I3,5X,' ISD = ',I3,5X,'SAMPLING FREQUENCY =
     1',I6,' CPS',//,10X,'SAMPLING LENGTH = ',F10.5,' SEC ',//)
      IF (ICS.EQ.KCON) GO TO 106
      ICON=0
      GO TO 107
 106   ICON=1
      KNCO=KNCO+1
      MSL=NT-ISF
      MS=1080-ISD
      WRITE (2,501)  KNCO,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
```

```
     1CELL(1),CELL(2)
 107  CONTINUE
      DO 219 L=1,NM
      READ (1,502) XM,YM,VXX,VYY,VXY,VXXX,VYYY,VXXXX,VYYYY
 502  FORMAT(2F8.5,7E11.4)
      IF (ICON.EQ.1) GO TO 801
      DO 802 I=1,70
 802  READ (1,803)
 803  FORMAT (1X)
      GO TO 219
 801  WRITE (6,665) XM,YM,VXX,VYY,VXY
      WRITE (6,667) VXXX,VYYY,VXXXX,VYYYY
 665  FORMAT (2X,'XM = ',E11.4,2X,'YM = ',E11.4,2X,'VXX = ',E11.4,2X,'VY
     1Y = ',E11.4,2X,'VXY = ',E11.4)
 667  FORMAT(2X,'VXXX =',E11.4,2X,'VYYY = ',E11.4,2X,'VXXXX = ',E11.4,2X
     1,'VYYYY = ',E11.4)
      DO 102 I=1,35
      KK=(I-1)*72
      READ (1,505) (IIX(J),J=1,72)
      READ (1,505) (IIY(J),J=1,72)
 505  FORMAT (72I5)
      DO 103 J=1,72
      II=KK+J
      TX=(FLOAT(IIX(J))/XMU)*1000.0
      TY=(FLOAT(IIY(J))/YMU)*1000.0
      IZ(1,II)=IFIX(TX)*100
 103  IZ(2,II)=IFIX(TY)*100
 102  CONTINUE
      WRITE (6,300) (IZ(1,I),IZ(2,I),I=1,5)
      WRITE (6,300) (IZ(1,I),IZ(2,I),I=2516,2520)
 300  FORMAT (2X,10(I5,2X))
C
C     CONSTRUCT TIME SERIES
C
      XU=XM*XMU
      YU=YM*YMU
      IM(1)=IFIX(XU)
      IM(2)=IFIX(YU)
      DO 110 I=1,2
      IS=1
      IC=1
 12   IF (IZ(I,IC).LT.IM(I)) GO TO 11
       IC=IC+1
       GO TO 12
 11   IA=IC+1
      IB=IA+1
      IF(IZ(I,IA).LT.IZ(I,IC)) GO TO 998
 996  IC=IC+1
      GO TO 11
 998  IF (IZ(I,IA)-IZ(I,IB)) 25,997,996
 997  IC=IC+1
      IA=IC+1
      IB=IA+1
      IF (IZ(I,IA)-IZ(I,IB)) 25,997,996
 25   IF (IS.GT.MS) GO TO 313
      IF (IZ(I,IA).GE.IM(I)) GO TO 996
      ISS=1
      IW(I,IS)=IZ(I,IA)
      IWS=0
 15    IC=IC+1
       IA=IC+1
      IB=IA+1
      IWS=IWS+1
      IF (IZ(I,IA).GT.IZ(I,IC)) GO TO 995
      GO TO 15
 995  IF (IZ(I,IA)-IZ(I,IB)) 15,994,27
 994  IC=IC+1
      IA=IC+1
      IB=IA+1
      IWS=IWS+1
      IF (IZ(I,IA)-IZ(I,IB)) 15,994,27
 27   IF (ISS.EQ.1) GO TO 771
      GO TO 772
 771  IF (IZ(I,IA).LT.IM(I)) GO TO 773
      IC=IC+1
      GO TO 11
 773  ISS=0
 772  IS=IS+1
      IW(I,IS)=IWS
      IS=IS+1
      IW(I,IS)=IZ(I,IA)
```

```
      IWS=0
 28    IC=IC+1
      IA=IC+1
      IB=IA+1
      IWS=IWS+1
      IF (IZ(I,IA).LT.IZ(I,IC)) GO TO 993
      GO TO 23
 993  IF (IZ(I,IA)-IZ(I,IB)) 29,992,28
 992  IC=IC+1
      IA=IC+1
      IB=IA+1
      IWS=IWS+1
      IF (IZ(I,IA)-IZ(I,IB)) 29,992,28
 29   IS=IS+1
      IW(I,IS)=IWS
      IP=IS-1
       IS=IS+1
      IW(I,IS)=IZ(I,IA)
      IF (IW(I,IS).GT.IM(I).OR.IW(I,IP).GT.IM(I)) GO TO 131
       IF (IS.GT.MS) GO TO 313
      IF (IW.GT.MSL) GO TO 13
 131  IF (IS.GT.1070) GO TO 132
      IWS=0
      GO TO 15
 132  WRITE(6,133)
 133  FORMAT(10X,' LAST WAVE IS NOT SMALL WAVE')
 313  CONTINUE
 13   ITS=IS
      NWS=(ITS-1)/4
      IS=IS+1
      DO 108 J=IS,1080
 108  IW(I,J)=0
      WRITE (6,201) IM(I),ITS,NWS
 201  FORMAT (10X,'IM = ',I5,5X,'ITS = ',I5,5X,'NWS = ',I5)
      WRITE (6,300) (IW(I,J),J=1,IC)
C
C     IDENTIFY THE WAVES
C        1 : SMALL WAVE
C        2 : SMALL WAVE ON LARGE WAVE
C        3 : LARGE WAVE
C
      ID=1
 414   IY=3+(ID-1)*4
      IY1=IY-2
       IY2=IY+2
      IF (IW(I,IY).LT.IM(I).AND.IW(I,IY1).LT.IM(I).AND.IW(I,IY2).LT.IM(I
     1)) GO TO 32
      IF (IW(I,IY).GE.IM(I).AND.IW(I,IY1).LT.IM(I).AND.IW(I,IY2).LT.IM(I
     1)) GO TO 33
      IF (IW(I,IY).GT.IM(I).AND.IW(I,IY1).LT.IM(I).AND.IW(I,IY2).GE.IM(I
     1)) GO TO 34
      IDW(I,ID)=0
      WRITE (6,818)
 818  FORMAT (10X,'IDW.EQ.ZERO')
      GO TO 393
 32   IDW(I,ID)=1
       GO TO 393
 33   IDW(I,ID)=3
      GO TO 393
 34   IDP=1
      ITP(IDP)=IW(I,IY)
 35   IDP=IDP+1
      ID=ID+1
      IY=3+(ID-1)*4
      IY2=IY+2
      ITP(IDP)=IW(I,IY)
      IF (IW(I,IY2).GE.IM(I)) GO TO 35
      IWX=ITP(1)
      DO 36 J=2,IDP
      IF (ITP(J).GT.IWX) IWX=ITP(J)
 36   CONTINUE
      IIDP=0
      DO 373 J=1,IDP
      IF (ITP(J).EQ.IWX) GO TO 38
 384  II=ID-IDP+J
      IDW(I,II)=2
      GO TO 373
 38   IF (IIDP.EQ.1) GO TO 384
      II=ID-IDP+J
      IDW(I,II)=3
      IIDP=1
```

```
373   CONTINUE
393   ID=ID+1
      IF (ID.GT.NWS) GO TO 41
      GO TO 414
41    CONTINUE
      DO 112 J=ID,270
112   IDW(I,J)=0
      WRITE (6,300) (IDW(I,ID),ID=1,10)
      WRITE (2,504) IM(I),ITS,NWS
504   FORMAT (3I5)
      DO 113 J=1,15
      KK=(J-1)*72
      DO 111 K=1,72
      II=KK+K
111   IIX(K)=IW(I,II)
      WRITE (2,505) (IIX(K),K=1,72)
113   CONTINUE
      WRITE (2,507) (IDW(I,ID),ID=1,135)
      WRITE (2,507) (IDW(I,ID),ID=136,270)
507   FORMAT (135I1)
110   CONTINUE
219   CONTINUE
      READ (1,506) XMM,YMM,VVXX,VVYY,VVXY,VVXXX,VVYYY,VVXXXX,VVYYYY,
     1VVXY2,SVXY
506   FORMAT(2F8.5,9E11.4)
      WRITE (6,665) XMM,YMM,VVXX,VVYY,VVXY
      WRITE(6,667) VVXXX,VVYYY,VVXXXX,VVYYYY
      WRITE (6,868) VVXY2,SVXY
868   FORMAT (5X,' VVXX.VVYY = ',E11.4,5X,' SVXY = ',E11.4)
      IF (ICON.EQ.0) GO TO 1
      IF (ICE.EQ.KCON) GO TO 109
      ICS=ICS+1
      GO TO 1
109   ENDFILE 2
      REWIND 2
      REWIND 1
      READ  (2,501)  KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      DO 804 I=1,2
      READ  (2,504) IM(I),ITS,NWS
      WRITE (6,201) IM(I),ITS,NWS
      DO 805 J=1,15
      KK=(J-1)*72
      READ  (2,505) (IIX(K),K=1,72)
      DO 806 L=1,72
      II=KK+L
806   IW(I,II)=IIX(L)
805   CONTINUE
      WRITE (6,300) (IW(I,J),J=1,10)
      READ  (2,507) (IDW(I,ID),ID=1,135)
      READ  (2,507) (IDW(I,ID),ID=136,270)
      WRITE (6,300) (IDW(I,ID),ID=1,10)
804   CONTINUE
      DO 333 I=1,54
      I1 = 1+(I-1)*20
      I2 = 1+I*20
      WRITE(6,334) (IW(1,J),J=I1,I2)
334   FORMAT(1X,21I5)
      I3 = 1+(I-1)*5
      I4 = I*5
333   WRITE(6,335)(IDW(1,J),J=I3,I4)
335   FORMAT(11X,I5,4(15X,I5))
      STOP
      END
```

Program no. 5

Digital program for calculating mean, standard deviation, and wave parameters in amplitude domain.

```
C     WAVE PROPERTIES PROGRAM NO. 1
C
      DIMENSION IIX(72),CELL(2),IW(2,1080),IM(2),IDW(2,270),XYMU(2),
     1 WSS(3,270),  WSL(3,270),  WLL(3,270),WI(80),  WT(3,80),  WMM(3),
     2NWS(2),PSS(2,3,80),PSL(2,3,80),PLL(2,3,80),WMSS(2,3) ,WMSL(2,3),
     3WMLL(2,3),NSS(2),NSL(2),NLL(2),XI(6),P(2,3,80),NOTWS(2),
     4WDSS(2,3),WDSL(2,3),WDLL(2,3),WSD(3)
      READ (5,100) ICS,ICE
100   FORMAT (2I2)
1     READ (1,501)  KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
```

```
 101  FORMAT(1H1,10X,'KCON = ',I2,5X,'NT = ',I5,5X,'MM = ',I2,/,
     110X,'XMU = ',F10.1,5X,'YMU = ',F10.1,/,
     210X,'WL = ',F8.4,5X,'WG = ',F8.4,/,
     310X,'IREL =',I7,5X,'IREG = ',I7,/,
     410X,'TEPL = ',F10.3,5X,'TEPG = ',F10.3,/,
     510X,'TN = ',A4,5X,'IT = ',I6,/,
     610X,'X CELL = ',A2,5X,'Y CELL = ',A2,//)
      FIT=FLOAT(IT)
      FNT=FLOAT(NT)
      T=FNT/FIT
      WRITE(6,104) NT, ICS,ICE
 104  FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,5X,'ICS = ',I2,5X,'IC
     1E = ',I2,/)
      WRITE (6,105) ICS,ICE,IT,T
 105  FORMAT (10X,' ICS = ',I3,5X,' ICE = ',I3,5X,'SAMPLING FREQUENCY =
     1',I6,' CPS',//,10X,'SAMPLING LENGTH = ',F10.5,' SEC ',//)
      IF (ICS.EQ.KCON) GO TO 106
      ICON=0
      GO TO 107
 106   ICON=1
 107   CONTINUE
      M=80
      XI(1)=(0.02-0.0)/20.0
      XI(2)=(0.12-0.02)/50.0
      XI(3)=(0.2-0.12)/4.0
      XI(4)=(0.4-0.2)/4.0
      XI(5)=(0.5-0.4)/1.0
      XI(6)=(1.0-0.5)/1.0
      DO 150 I=1,20
      FI=FLOAT(I)
      II=I
 150  WI(II)=(FI-0.5)*XI(1)
      DO 151 I=1,50
      FI=FLOAT(I)
      II=I+20
 151  WI(II)=(FI-0.5)*XI(2)+0.02
      DO 152 I=1,4
      FI=FLOAT(I)
      II=I+70
 152  WI(II)=(FI-0.5)*XI(3)+0.12
      DO 153 I=1,4
      FI=FLOAT(I)
      II=I+74
 153  WI(II)=(FI-0.5)*XI(4)+0.2
      WI(79)=0.45
      WI(80)=0.75
      WRITE (6,196) (WI(I),I=1,80)
      DO 130 I=1,2
      NSS(I)=0
      NSL(I)=0
      NLL(I)=0
      DO 131 J=1,3
      WMSS(I,J)=0.0
      WMSL(I,J)=0.0
      WMLL(I,J)=0.0
      WDSS(I,J) = 0.0
      WDSL(I,J) = 0.0
      WDLL(I,J) = 0.0
      DO 132 K=1,M
      PSS(I,J,K)=0.0
      PSL(I,J,K)=0.0
 132  PLL(I,J,K)=0.0
 131  CONTINUE
 130  CONTINUE
      XYMU(1)=XMU
      XYMU(2)=YMU
      FMM=FLOAT(MM)
      DO 219 L=1,MM
      DO 804 I=1,2
      READ  (1,504) IM(I),ITS,NWS(I)
      IF (ICON.EQ.1) GO TO 801
      DO 802 J=1,15
 802  READ (1,803)
 803  FORMAT (1X)
      GO TO 807
 801  WRITE (6,201) IM(I),ITS,NWS(I)
      DO 805 J=1,15
      KK=(J-1)*72
      READ  (1,505) (IIX(K),K=1,72)
      DO 806 K=1,72
      II=KK+K
```

```
806   IW(I,II)=IIX(K)
805   CONTINUE
      WRITE (6,300) (IW(I,J),J=1,10)
807   READ  (1,507) (IDW(I,ID),ID=1,135)
      READ  (1,507) (IDW(I,ID),ID=136,270)
      WRITE (6,300) (IDW(I,ID),ID=1,10)
804   CONTINUE
505   FORMAT (72I5)
300   FORMAT (2X,10(I5,2X))
201   FORMAT (10X,'IM = ',I5,5X,'ITS = ',I5,5X,'NWS = ',I5)
504   FORMAT (3I5)
507   FORMAT (135I1)
C
C     CAL. PROB. OF AMPLITUDE, MAX. AND MIN.
C
      IF (ICON.EQ.0) GO TO 219
      DO 102 I=1,2
      NTS=NWS(I)
      NWSS=0
      NWSL=0
      NWLL=0
      DO 103 J=1,NTS
      IF (IDW (I,J).EQ.3) GO TO 124
       IF (IDW(I,J).EQ.2) GO TO 125
      IA=1+(J-1)*4
      IC=3+(J-1)*4
      IB=1+J*4
      NWSS=NWSS+1
      ITW=IW(I,IA)+IW(I,IB)
      AVMI=FLOAT'ITW)/(XYMU(I)*2.0)
        WSS(3,NWSS)=FLOAT(IW(I,IB))/XYMU(I)
        WSS(2,NWSS)=FLOAT(IW(I,IC))/XYMU(I)
        WSS(1,NWSS)=  WSS(2,NWSS)-AVMI
      GO TO 103
124   JF=J
      JB=J
      IA=1+(J-1)*4
      IB=1+J*4
      LWM1=IW(I,IA)
      LWM2=IW(I,IB)
112   JF=JF-1
      IF(IDW(I,JF).NE.2) GO TO 111
      IB=1+JF*4
      IF (IW(I,IB).LT.IM(I)) GO TO 111
      IA=1+(JF-1)*4
      LWM1=IW(I,I
      GO TO 112
111   JB=JB+1
      IF(IDW(I,J      .2  GO TO 108
      IA=1+(JB-1
      IF (IW(I,IA).LT.IM(I)) GO TO 108
      IB=1+JB*4
      LWM2=IW(I,IB)
      GO TO 111
108   NWLL=NWLL+1
      IC=3+(J-1)*4
      ITW=LWM2+LWM1
      AVMI=FLOAT(ITW)/(XYMU(I)*2.0)
        WLL(3,NWLL)=FLOAT(LWM2)/XYMU(I)
        WLL(2,NWLL)=FLOAT(IW(I,IC))/XYMU(I)
        WLL(1,NWLL)=  WLL(2,NWLL)-AVMI
      GO TO 103
125   IA=1+(J-1)*4
      IB=1+J*4
      IC=3+(J-1)*4
      NWSL=NWSL+1
      ITW=IW(I,IA)+IW(I,IB)
      AVMI=FLOAT(ITW)/(XYMU(I)*2.0)
        WSL(3,NWSL)=FLOAT(IW(I,IB))/XYMU(I)
        WSL(2,NWSL)=FLOAT(IW(I,IC))/XYMU(I)
        WSL(1,NWSL)=  WSL(2,NWSL)-AVMI
103   CONTINUE
      IF (L.EQ.1) GO TO 198
      GO TO 199
198   WRITE (6,196) ((WSS (K,J),K=1,3), J=1,NWSS)
196   FORMAT (1X,10(F10.5,1X))
      WRITE (6,196) ((WSL(K,J),K=1,3),J=1,NWSL)
      WRITE (6,    ) ((WLL(K,J),K=1,3),J=1,NWLL)
      WRITE (6       (WI(J),J=1,80)
199   CONTINUE
      NSS(I)=N       NWSS
```

```
      NSL(I)=NSL(I)+NWSL
      NLL(I)=NLL(I)+NWLL
      WRITE (6,303) NSS(I),NSL(I),NLL(I)
303   FORMAT (10X,3(I6,2X))
      CALL PROB(NWSS,WSS,WT,XI,M,WMM,WSD)
      DO 133 J=1,3
      WMSS(I,J)=WMSS(I,J)+  WMM(J)
      WDSS(I,J)=WDSS(I,J)+WSD(J)
      DO 134 K=1,M
134   PSS(I,J,K)=PSS(I,J,K)+  WT(J,K)
133   CONTINUE
      CALL PROB (NWSL,WSL,WT,XI,M,WMM,WSD)
      DO 135 J=1,3
      WMSL(I,J)=WMSL(I,J)+  WMM(J)
      WDSL(I,J)=WDSL(I,J)+WSD(J)
      DO 136 K=1,M
136   PSL(I,J,K)=PSL(I,J,K)+  WT(J,K)
135   CONTINUE
      CALL PROB(NWLL,WLL,WT,XI,M,WMM,WSD)
      DO 137 J=1,3
      WMLL(I,J)=WMLL(I,J)+  WMM(J)
      WDLL(I,J)=WDLL(I,J)+WSD(J)
      DO 138 K=1,M
138   PLL(I,J,K)=PLL(I,J,K)+  WT(J,K)
137    CONTINUE
102    CONTINUE
219   CONTINUE
      IF (ICON.EQ.0) GO TO 1
      DO 139 I=1,2
      DO 140 J=1,3
      WDSS(I,J)=WDSS(I,J)/FMM
      WDSL(I,J)=WDSL(I,J)/FMM
      WDLL(I,J)=WDLL(I,J)/FMM
      WDSS(I,J)=SQRT(WDSS(I,J))
      WDSL(I,J)=SQRT(WDSL(I,J))
      WDLL(I,J)=SQRT(WDLL(I,J))
      WMSS(I,J)=WMSS(I,J)/FMM
      WMSL(I,J)=WMSL(I,J)/FMM
140   WMLL(I,J)=WMLL(I,J)/FMM
139    CONTINUE
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114)
114   FORMAT (10X,'******  HISTOGRAM  ******')
      WRITE (6,115) (NSS(I),I=1,2)
115   FORMAT (10X,'*** NO. OF SMALL WAVES = ',I5,' * ',I5,'  ***')
      WRITE (6,126)
126   FORMAT (10X,'**  AMPLITUDE  ******  MAXIMUM  *******  MINIMUM  ***
     1*')
      WRITE (6,116) ((WMSS(I,J),I=1,2),J=1,3)
116   FORMAT (3X,'MEAN = ',6(2X,F7.4))
      WRITE(6,601) ((WDSS(I,J),I=1,2),J=1,3)
601   FORMAT (3X,'S.D. = ',6(2X,F7.4))
      DO 117 I=1,M
117   WRITE (6,118) WI(I),((PSS(J,K,I),J=1,2),K=1,3)
118   FORMAT (3X,F7.4,6(2X,F7.0))
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114)
      WRITE (6,119) (NSL(I),I=1,2)
119   FORMAT (10X,'*** NO. OF SMALL WAVES ON LARGE WAVES = ',I5,' * ',I5
     1,'   ***')
      WRITE (6,126)
      WRITE (6,116) ((WMSL(I,J),I=1,2),J=1,3)
      WRITE(6,601) ((WDSL(I,J),I=1,2),J=1,3)
      DO 120 I=1,M
120   WRITE (6,118) WI(I),((PSL(J,K,I),J=1,2),K=1,3)
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114)
      WRITE (6,121) (NLL(I),I=1,2)
121   FORMAT (10X,'*** NO. OF LARGE WAVES = ',I5,' * ',I5,'    ***')
      WRITE (6,126)
      WRITE (6,116) ((WMLL(I,J),I=1,2),J=1,3)
      WRITE (6,601) ((WDLL(I,J),I=1,2),J=1,3)
      DO 122 I=1,M
122   WRITE (6,118) WI(I),((PLL(J,K,I),J=1,2),K=1,3)
      DO 606 J=1,2
      NOTWS(J)=NLL(J)+NSL(J)+NSS(J)
      DO 607 K=1,3
      DO 608 I=1,M
```

```
608   P(J,K,I)=PSS(J,K,I)+PSL(J,K,I)+PLL(J,K,I)
607   CONTINUE
606   CONTINUE
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,609) (NOTWS(I),I=1,2)
609   FORMAT (10X,'*** NO. OF TOTAL WAVES =', I5, ' * ',I5,'    ***')
      WRITE (6,126)
      DO 610 I=1,M
610   WRITE (6,118) WI(I), ((P(J,K,I),J=1,2),K=1,3)
      IF (ICE.EQ.KCON) GO TO 109
      ICS=ICS+1
      GO TO 1
109   REWIND 1
      STOP
      END
      SUBROUTINE PROB(N,X,WT,XI,M,WMM,WSD)
      DIMENSION   X(3,N),  WT(3,M),XI(6),  WMM(3),WSD(3)
      DO 42 J=1,3
      DO 43 K=1,M
43      WT(J,K)=0.0
      WSD(J)=0.0
42      WMM(J)=0.0
      DO 41 J=1,3
      DO 40 K=1,N
        WMM(J)=  WMM(J)+  X(J,K)
      IF(X(J,K).LE.0.02) GO TO 45
      IF(X(J,K).LE.0.12) GO TO 46
      IF(X(J,K).LE.0.20) GO TO 47
      IF(X(J,K).LE.0.40) GO TO 48
      IF(X(J,K).LE.0.50) GO TO 49
      JJ=80
      GO TO 44
45    XMIN=0.0
      XMAX=0.02
      FM=20.0
      A=((  X(J,K)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+1
      GO TO 44
46    XMIN=0.02
      XMAX=0.12
      FM=50.0
      A=((  X(J,K)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+21
      GO TO 44
47    XMIN=0.12
      XMAX=0.2
      FM=4.0
      A=((  X(J,K)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+71
      GO TO 44
48    XMIN=0.2
      XMAX=0.4
      FM=4.0
      A=((  X(J,K)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+75
      GO TO 44
49    JJ=79
44      WT(J,JJ)=  WT(J,JJ)+1.0
40    CONTINUE
        WMM(J)=  WMM(J)/FLOAT(N)
41    CONTINUE
      DO 51 J=1,3
      DO 50 K=1,N
50    WSD(J)=WSD(J)+(X(J,K)-WMM(J))*(X(J,K)-WMM(J))
      WSD(J)=WSD(J)/FLOAT(N)
51    CONTINUE
      RETURN
      END
```

Program no. 6

Digital program for calculating mean, standard deviation, and wave parameters in time domain.

```
C
C      WAVE PROPERTIES PROGRAM NO. 2
C
       DIMENSION IIX(72),CELL(2),IW(2,1080),IM(2),IPW(2,270),XYMU(2),
     1  WSS(4,270),  WSL(4,270),  WLL(4,270),WI(95),  WT(4,95),  WMM(4),
     2NWS(2),PSS(2,4,95),PSL(2,4,95),PLL(2,4,95),WMSS(2,4) ,WMSL(2,4),
     3WMLL(2,4),NSS(2),NSL(2),NLL(2),P(2,4,48),NOTWS(2)
```

```
      READ (5,100) ICS,ICE
100   FORMAT (2I2)
1     READ (1,501)  KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
501   FORMAT (I2,I5,I2,2F10.1,2F8.4,2I7,2F10.3,A4,I6,A2,A2)
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
101   FORMAT(1H1,10X,'KCON = ',I2,5X,'NT = ',I5,5X,'MM = ',I2,/,
     110X,'XMU = ',F10.1,5X,'YMU = ',F10.1,/,
     210X,'WL = ',F8.4,5X,'WG = ',F8.4,/,
     310X,'IREL =',I7,5X,'IREG = ',I7,/,
     410X,'TEPL = ',F10.3,5X,'TEPG = ',F10.3,/,
     510X,'TN = ',A4,5X,'IT = ',I6,/,
     610X,'X CELL = ',A2,5X,'Y CELL = ',A2,//)
      FIT=FLOAT(IT)
      FNT=FLOAT(NT)
      T=FNT/FIT
      WRITE(6,104) NT, ICS,ICE
104   FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,5X,'ICS = ',I2,5X,'IC
     1E = ',I2,/)
      WRITE (6,105) ICS,ICE,IT,T
105   FORMAT (10X,' ICS = ',I3,5X,' ICE = ',I3,5X,'SAMPLING FREQUENCY =
     1',I6,' CPS',//,10X,'SAMPLING LENGTH = ',F10.5,' SEC ',//)
      IF (ICS.EQ.KCON) GO TO 106
      ICON=0
      GO TO 107
106    ICON=1
107    CONTINUE
      M=48
      DO 130 I=1,2
      NSS(I)=0
      NSL(I)=0
      NLL(I)=0
      DO 131 J=1,4
      WMSS(I,J)=0.0
      WMSL(I,J)=0.0
      WMLL(I,J)=0.0
      DO 132 K=1,M
      PSS(I,J,K)=0.0
      PSL(I,J,K)=0.0
132   PLL(I,J,K)=0.0
131   CONTINUE
130   CONTINUE
      XYMU(1)=XMU
      XYMU(2)=YMU
      FMM=FLOAT(MM)
      DO 219 L=1,MM
      DO 804 I=1,2
      READ  (1,504) IM(I),ITS,NWS(I)
      IF (ICON.EQ.1) GO TO 801
      DO 802 J=1,15
802   READ (1,803)
803   FORMAT (1X)
      GO TO 807
801   WRITE (6,201) IM(I),ITS,NWS(I)
      DO 805 J=1,15
      KK=(J-1)*72
      READ  (1,505) (IIX(K),K=1,72)
      DO 806 K=1,72
      II=KK+K
806   IW(I,II)=IIX(K)
805   CONTINUE
      WRITE (6,300) (IW(I,J),J=1,10)
807   READ  (1,507) (IDW(I,ID),ID=1,135)
      READ  (1,507) (IDW(I,ID),ID=136,270)
      WRITE (6,300) (IDW(I,ID),ID=1,10)
804   CONTINUE
505   FORMAT (72I5)
300   FORMAT (2X,10(I5,2X))
201   FORMAT (10X,'IM = ',I5,5X,'ITS = ',I5,5X,'NWS = ',I5)
504   FORMAT (3I5)
507   FORMAT (135I1)
C
C     CAL. PROB. OF FRONT, BACK, BASE, AND SEPERATION
C
      IF (ICON.EQ.0) GO TO 219
      DO 102 I=1,2
      NTS=NWS(I)
      NWSS=0
      NWSL=0
      NWLL=0
```

```
      DO 103 J=1,NTS
      IF (IOW (I,J).EQ.3) GO TO 124
       IF (IOW(I,J).EQ.2) GO TO 125
      IA=2+(J-1)*4
      IC=2+J*4
      IB=J*4
      NWSS=NWSS+1
      ITW=IW(I,IC)+IW(I,IB)
      WSS(4,NWSS)=FLOAT(IW(I,IA))/FIT
        WSS(3,NWSS)=FLOAT(IW(I,IB))/FIT
        WSS(2,NWSS)=WSS(4,NWSS)+WSS(3,NWSS)
        WSS(1,NWSS)=FLOAT(ITW)/FIT
      GO TO 103
 124  JF=J
      JS=J
      IA=2+(J-1)*4
      IB=J*4
      ITW1=IW(I,IA)
      ITW2=IW(I,IB)
 112  JF=JF-1
      IF(IOW(I,JF).NE.2) GO TO 111
      IIB=1+JF*4
      IF (IW(I,IIB).LT.IM(I)) GO TO 111
      IA=2+(JF-1)*4
      IB=JF*4
      ITW1=ITW1+IW(I,IA)+IW(I,IB)
      GO TO 112
 111  JB=JB+1
      IF(IOW(I,JB).NE.2) GO TO 108
      IIA=1+(JB-1)*4
      IF (IW(I,IIA).LT.IM(I)) GO TO 108
      IA=2+(JB-1)*4
      IB=JB*4
      ITW2=ITW2+IW(I,IA)+IW(I,IB)
      GO TO 111
 108  JS=JB
      ITW3=ITW2
 149  IF(IOW(I,JS).EQ.3.OR.IOW(I,JS).EQ.0) GO TO 110
      IA=2+(JS-1)*4
      IB=JS*4
      ITW3=ITW3+IW(I,IA)+IW(I,IB)
      JS=JS+1
      GO TO 149
 110  IA=2+(JS-1)*4
      ITW3=ITW3+IW(I,IA)
      NWLL=NWLL+1
      WLL(4,NWLL)=FLOAT(ITW1)/FIT
      WLL(3,NWLL)=FLOAT(ITW2)/FIT
      WLL(2,NWLL)=WLL(4,NWLL)+WLL(3,NWLL)
      WLL(1,NWLL)=FLOAT(ITW3)/FIT
      GO TO 103
 125  IA=2+(J-1)*4
      IB=J*4
      IC=2+J*4
      NWSL=NWSL+1
      ITW=IW(I,IC)+IW(I,IB)
      WSL(4,NWSL)=FLOAT(IW(I,IA))/FIT
        WSL(3,NWSL)=FLOAT(IW(I,IB))/FIT
      WSL(2,NWSL)=WSL(4,NWSL)+WSL(3,NWSL)
      WSL(1,NWSL)=FLOAT(ITW)/FIT
 103  CONTINUE
      IF (L.EQ.1) GO TO 198
      GO TO 199
 198  WRITE (6,196) ((WSS (K,J),K=1,4), J=1,NWSS)
 196  FORMAT (1X,15(F10.5,1X))
      WRITE (6,196) ((WSL(K,J),K=1,4),J=1,NWSL)
      WRITE (6,196) ((WLL(K,J),K=1,4),J=1,NWLL)
 199  CONTINUE
      NSS(I)=NSS(I)+NWSS
      NSL(I)=NSL(I)+NWSL
      NLL(I)=NLL(I)+NWLL
      WRITE (6,303) NSS(I),NSL(I),NLL(I)
 303  FORMAT (10X,3(I6,2X))
      CALL PROB(NWSS,WSS,WT,WI,M,WMM)
      DO 133 J=1,4
      WMSS(I,J)=WMSS(I,J)+  WMM(J)
      DO 134 K=1,M
 134  PSS(I,J,K)=PSS(I,J,K)+  WT(J,K)
 133  CONTINUE
      CALL PROB (NWSL,WSL,WT,WI,M,WMM)
      DO 135 J=1,4
```

```
      WMSL(I,J)=WMSL(I,J)+  WMM(J)
      DO 136 K=1,M
136   PSL(I,J,K)=PSL(I,J,K)+  WT(J,K)
135   CONTINUE
      CALL PROF(NWLL,WLL,WT,WI,M,WMM)
      DO 137 J=1,4
      WMLL(I,J)=WMLL(I,J)+  WMM(J)
      DO 138 K=1,M
138   PLL(I,J,K)=PLL(I,J,K)+  WT(J,K).
137    CONTINUE
102    CONTINUE
219   CONTINUE
      IF (ICON.EQ.0) GO TO 1
      DO 139 I=1,2
      DO 140 J=1,4
      WMSS(I,J)=WMSS(I,J)/FMM
      WMSL(I,J)=WMSL(I,J)/FMM
140   WMLL(I,J)=WMLL(I,J)/FMM
139    CONTINUE
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114)
114   FORMAT (10X,'******  HISTOGRAM  ******')
      WRITE (6,115) (NSS(I),I=1,2)
115   FORMAT (10X,'*** NO. OF SMALL WAVES = ',I5,' * ',I5,'  ***')
      WRITE (6,126)
126   FORMAT (10X,'**  SEPERATION  *******  BASE  **********  BACK  ****
     1*****  FRONT  *****')
      WRITE (6,116) ((WMSS(I,J),I=1,2),J=1,4)
116   FORMAT (3X,'MEAN = ',8(2X,F7.4))
      DO 117 I=1,M
117   WRITE (6,118) WI(I),((PSS(J,K,I),J=1,2),K=1,4)
118   FORMAT (3X,F7.4,8(2X,F7.0))
      DO 601 J=1,2
      WRITE (7,602) WG,WL,CELL(J)
602   FORMAT (2F10.5,A2)
601   WRITE (7,603) ((PSS(J,K,I),I=1,M), K=1,4)
603   FORMAT (16F5.0)
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114)
      WRITE (6,119) (NSL(I),I=1,2)
119   FORMAT (10X,'*** NO. OF SMALL WAVES ON LARGE WAVES = ',I5,' * ',I5
     1,'   ***')
      WRITE (6,126)
      WRITE (6,116) ((WMSL(I,J),I=1,2),J=1,4)
      DO 120 I=1,M
120   WRITE (6,118) WI(I),((PSL(J,K,I),J=1,2),K=1,4)
      DO 604 J=1,2
      WRITE (7,602) WG, WL, CELL(J)
604   WRITE (7,603) ((PSL(J,K,I),I=1,M),K=1,4)
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114)
      WRITE (6,121) (NLL(I),I=1,2)
121   FORMAT (10X,'*** NO. OF LARGE WAVES = ',I5,' * ',I5,'   ***')
      WRITE (6,126)
      WRITE (6,116) ((WMLL(I,J),I=1,2),J=1,4)
      DO 122 I=1,M
122   WRITE (6,118) WI(I),((PLL(J,K,I),J=1,2),K=1,4)
      DO 605 J=1,2
      WRITE (7,602) WG,WL,CELL(J)
605   WRITE (7,603) ((PLL(J,K,I),I=1,M),K=1,4)
      DO 606 J=1,2
      NOTWS(J)=NLL(J)+NSL(J)+NSS(J)
      DO 607 K=1,4
      DO 608 I=1,M
608   P(J,K,I)=PSS(J,K,I)+PSL(J,K,I)+PLL(J,K,I)
607   CONTINUE
606   CONTINUE
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,609) (NOTWS(I),I=1,2)
609   FORMAT (10X,'*** NO. OF TOTAL WAVES =', I5, ' * ',I5,'   ***')
      WRITE (6,126)
      DO 610 I=1,M
610   WRITE (6,118) WI(I), ((P(J,K,I),J=1,2),K=1,4)
      DO 611 J=1,2
```

```
      WRITE (7,602) FG,FL,CELL(J)
 611  WRITE (7,603) ((P(J,K,I),I=1,M),K=1,4)
      IF (ICS.EQ.KCON) GO TO 109
      ICS=ICS+1
      GO TO 1
 109  REWIND 1
      STOP
      END
      SUBROUTINE PROF(N,X,WT,WI,M,WMM)
      DIMENSION   X(4,N),  WT(4,M),WI(M),  WMM(4)
      XMIN=0.0
      XMAX=0.96
      FM=FLOAT(M)
      XI=(XMAX-XMIN)/FM
      DO 42 J=1,4
      DO 43 K=1,M
 43     WT(J,K)=0.0
 42     WMM(J)=0.0
      DO 41 J=1,4
      II=0
      DO 40 K=1,N
        WMM(J)=  WMM(J)+  X(J,K)
      A=((  X(J,K)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+1
      IF (JJ.LE.M)  GO TO 44
      II=II+1
      JJ=M
 44     WT(J,JJ)=  WT(J,JJ)+1.0
 40   CONTINUE
      IF (II.EQ.0) GO TO 46
      WRITE (6,45) J,II
 45   FORMAT (10X,'*** J = ',I1,' NO. OF WAVES OUT OF RANGE = ',I5,'***')
 46     WMM(J)=  WMM(J)/FLOAT(N)
 41   CONTINUE
      DO 90 I=1,M
      FI=FLOAT(I)
 90   WI(I)=XMIN+(FI-0.5)*XI
      RETURN
      END
```

Program no. 7

Digital program for calculating joint histogram of wave maximum and wave separation of the large waves.

```
C
C      WAVE PROPERTIES PROGRAM NO. 3
C
       DIMENSION IIX(72),CELL(2),IW(2,1080),IM(2),IDW(2,270),XYMU(2),WI(4
      10),WII(24),W(2,270),JWT(40,24),NWS(2),XI(6),JP(2,40,24),NLL(2),
      2W2(2,270),NLL2(2),JP2(2,40,24)
       READ (5,100) ICS,ICE
 100   FORMAT (2I2)
 1     READ (1,501)  KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
      1CELL(1),CELL(2)
 501   FORMAT (I2,I5,I2,2F10.1,2F8.4,2I7,2F10.3,A4,I6,A2,A2)
       WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
      1CELL(1),CELL(2)
 101   FORMAT(1H1,10X,'KCON = ',I2,5X,'NT = ',I5,5X,'MM = ',I2,/,
      110X,'XMU = ',F10.1,5X,'YMU = ',F10.1,/,
      210X,'WL = ',F8.4,5X,'WG = ',F8.4,/,
      310X,'IREL =',I7,5X,'IREG = ',I7,/,
      410X,'TEPL = ',F10.3,5X,'TEPG = ',F10.3,/,
      510X,'TN = ',A4,5X,'IT = ',I6,/,
      610X,'X CELL = ',A2,5X,'Y CELL = ',A2,//)
       FIT=FLOAT(IT)
       FNT=FLOAT(NT)
       T=FNT/FIT
       WRITE(6,104) NT, ICS,ICE
 104   FORMAT (10X,'NO. OF POINTS PER SAMPLE = ',I5,5X,'ICS = ',I2,5X,'IC
      1E = ',I2,/)
       WRITE (6,105) ICS,ICE,IT,T
 105   FORMAT (10X,' ICS = ',I3,5X,' ICE = ',I3,5X,'SAMPLING FREQUENCY =
      1',I6,' CPS',//,10X,'SAMPLING LENGTH = ',F10.5,' SEC ',//)
       IF (ICS.EQ.KCON) GO TO 106
       ICON=0
       GO TO 107
 106    ICON=1
 107    CONTINUE
       M=40
       XI(1)=(0.12-0.0)/30.0
       XI(2)=(0.2-0.12)/4.0
```

```
      XI(3)=(0.4-0.2)/4.0
      XI(4)=(0.5-0.4)/1.0
      XI(5)=(1.0-0.5)/1.0
      DO 150 I=1,30
      FI=FLOAT(I)
      II=I
150   WI(II)=(FI-0.5)*XI(1)
      DO 151 I=1,4
      FI=FLOAT(I)
      II=I+30
151   WI(II)=(FI-0.5)*XI(2)+0.12
      DO 152 I=1,4
      FI=FLOAT(I)
      II=I+34
152   WI(II)=(FI-0.5)*XI(3)+0.2
      WI(39)=0.45
      WI(40)=0.75
      N=24
      XI(6)=(0.96-0.0)/24.0
      DO 153 I=1,N
      FI=FLOAT(I)
      II=I
153   WII(II)=(FI-0.5)*XI(6)
      DO 130 I=1,2
      NLL(I)=0
      NLL2(I)=0
      DO 131 J=1,M
      DO 132 K=1,N
      JP2(I,J,K)=0
132   JP(I,J,K)=0
131   CONTINUE
130.  CONTINUE
      XYMU(1)=XMU
      XYMU(2)=YMU
      FMM=FLOAT(MM)
      DO 219 L=1,MM
      DO 804 I=1,2
      READ  (1,504) IM(I),ITS,NWS(I)
      IF (ICON.EQ.1) GO TO 801
      DO 802 J=1,15
802   READ (1,803)
803   FORMAT (1X)
      GO TO 807
801   WRITE (6,201) IM(I),ITS,NWS(I)
      DO 805 J=1,15
      KK=(J-1)*72
      READ  (1,505) (IIX(K),K=1,72)
      DO 806 K=1,72
      II=KK+K
806   IW(I,II)=IIX(K)
805   CONTINUE
      WRITE (6,300) (IW(I,J),J=1,10)
807   READ  (1,507) (IDW(I,ID),ID=1,135)
      READ  (1,507) (IDW(I,ID),ID=136,270)
      WRITE (6,300) (IDW(I,ID),ID=1,10)
804   CONTINUE
505   FORMAT (72I5)
300   FORMAT (2X,10(I5,2X))
201   FORMAT (10X,'IM = ',I5,5X,'ITS = ',I5,5X,'NWS = ',I5)
504   FORMAT (3I5)
507   FORMAT (135I1)
C
C     CAL. JOINT PROB. OF MAX. AND SEPERATION
C
      IF (ICON.EQ.0) GO TO 219
      DO 102 I=1,2
      NTS=NWS(I)
      NWLL=0
      DO 103 J=1,NTS
      IF(IDW(I,J).EQ.3) GO TO 124
      GO TO 103
124   JS=J
      IB=J*4
      ITW3=IW(I,IB)
111   JS=JS+1
      IF(IDW(I,JS).EQ.3.OR.IDW(I,JS).EQ.0) GO TO 110
      IA=2+(JS-1)*4
      IB=JS*4
      ITW3=ITW3+IW(I,IA)+IW(I,IB)
      GO TO 111
110   IA=2+(JS-1)*4
```

```
      ITW3=ITW3+IW(I,IA)
      IC=3+(J-1)*4
      NWLL=NWLL+1
      W(1,NWLL)=FLOAT(IW(I,IC))/XYMU(I)
      W(2,NWLL)=FLOAT(ITW3)/FIT
  103 CONTINUE
      NLL(I)=NLL(I)+NWLL
      IF (L.EQ.05) WRITE (6,777)
      CALL PROBJ (NWLL,W,JWT,M,N)
      IF (L.EQ.05) WRITE (6,777)
  777 FORMAT (10X,' *****************************')
      DO 133 J=1,M
      DO 134 K=1,N
  134 JP(I,J,K)=JP(I,J,K)+JWT(J,K)
  133 CONTINUE
      XYM2=2.0*FLOAT(IM(I))/XYMU(I)
      NWLL2=0
      DO 400 J=1,NWLL
      IF (W(1,J).GE.XYM2) GO TO 401
      GO TO 400
  401 JS=J
      NWLL2=NWLL2+1
      W2(1,NWLL2)=W(1,J)
      W2(2,NWLL2)=W(2,J)
  402 JS=JS+1
      IF (W(1,JS).GE.XYM2) GO TO 400
      W2(2,NWLL2)=W2(2,NWLL2)+W(2,JS)
      GO TO 402
  400 CONTINUE
      NLL2(I)=NLL2(I)+NWLL2
      IF (L.EQ.09) WRITE (6,777)
      CALL PROBJ (NWLL2,W2,JWT,M,N)
      IF (L.EQ.09) WRITE (6,777)
      DO 403 J=1,M
      DO 404 K=1,N
  404 JP2(I,J,K) = JP2(I,J,K)+JWT(J,K)
  403 CONTINUE
      WRITE (6,303) NLL(I),NLL2(I)
  303 FORMAT(10X,'NLL=', I6,5X,'NLL2 = ',I6)
  102 CONTINUE
  219 CONTINUE
      IF (ICON.EQ.0) GO TO 1
      DO 135 I=1,2
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,114) CELL(I),NLL(I)
  114 FORMAT (10X,'*****JOINT HISTOGRAM OF ', A2,'  AND  NLL = ',I6,'
     1*****')
      WRITE (6,115)
  115 FORMAT(/,1X,'WAVE MAX ', 24('    +'),/)
      DO 136 J=1,M
  136 WRITE (6,116) WI(J),(JP(I,J,K),K=1,N)
  116 FORMAT(1X,F8.5,1X,24I4)
      N1=N-1
      WRITE (6,117) (WII(J),J=1,N1,2)
  117 FORMAT (/,'  WAVE     ',12(F6.3,' +'))
      WRITE (6,118) (WII(J),J=2,N,2)
  118 FORMAT (' SEPARATION   ', 12(F6.3,' +'))
  135 CONTINUE
      DO 405 I=1,2
      WRITE (6,101) KCON,NT,MM,XMU,YMU,WL,WG,IREL,IREG,TEPL,TEPG,TN,IT,
     1CELL(1),CELL(2)
      WRITE (6,406) CELL(I),NLL2(I)
  406 FORMAT (10X,'*****JOINT HISTOGRAM OF ', A2,'  AND  NLL2= ',I6,'
     1*****')
      WRITE (6,115)
      DO 407 J=1,M
  407 WRITE(6,116) WI(J),(JP2(I,J,K),K=1,N)
      WRITE (6,117) (WII(J),J=1,N1,2)
      WRITE (6,118) (WII(J),J=2,N,2)
  405  CONTINUE
      IF (ICE.EQ.KCON) GO TO 109
      ICS=ICS+1
      GO TO 1
  109 REWIND 1
      STOP
      END
```

```
      DIMENSION W(2,NW),JWT(M,N)
      DO 42 J=1,M
      DO 43 K=1,N
   43 JWT(J,K)=0
   42 CONTINUE
      DO 40 I=1,NW
      IF(W(1,I).LE.0.12) GO TO 45
      IF(W(1,I).LE.0.20) GO TO 46
      IF(W(1,I).LE.0.40) GO TO 47
      IF(W(1,I).LE.0.50) GO TO 48
      JJ=40
      GO TO 44
   45 XMIN=0.0
      XMAX=0.12
      FM=30.0
      A=((W(1,I)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+1
      GO TO 44
   46 XMIN=0.12
      XMAX=0.2
      FM=4.0
      A=((W(1,I)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+31
      GO TO 44
   47 XMIN=0.4
      XMAX=0.2
      FM=4.0
      A=((W(1,I)-XMIN)/(XMAX-XMIN))*FM
      JJ=IFIX(A)+35
      GO TO 44
   48 JJ=39
   44 XMIN=0.0
      XMAX=0.96
      FN=FLOAT(N)
      A=((W(2,I)-XMIN)/(XMAX-XMIN))*FN
      KK=IFIX(A)+1
      IF(KK.LE.N) GO TO 49
      KK=N
   49 JWT(JJ,KK)=JWT(JJ,KK)+1
   40 CONTINUE
      RETURN
      END
```

Program no. 8

Digital program for estimating the linear part of power spectrum by the White Noise input.

```
C
C     LINEAR POWER SPECTRUM AND CONS. C
C
      DIMENSION W(550),S1(550)
      COMPLEX CGF(550)
      COMPLEX CG,CS,CRE,WP,CG0,CG1,CG2,COR,DFOC,FOC1,FOC,FO0,FO1,FO2,
     1FO3,FO4,RAT,CW,AC,SC,ACC,H1,H1C,F1C,SCP,AI,A,AR
      COMPLEX FL1,FL2,FL3,A1,A2,A3,A4
C     INPUT DATA
    1 READ(5,100,END=99) REL,C,ARO,XNU,HM,HH,ZI
  100 FORMAT(3F10.3,4E11.4)
      VCPL=XNU*ARO/0.000672
      WL=REL*3.14159*0.000672/(6.0*4.0)
      Q=(REL*XNU)/4.0
      UM=Q*12.0/HM
      CM=C/UM
      WRITE (6,200) WL,REL,Q,C,VCPL,HM,HH,XNU,UM,CM
  200 FORMAT (1H1,//,10X,'***  INPUT CONDITION  ***',//,
     110X,'WL = ',F10.5,' LB/SEC',5X,' REL= ',F10.0,8X,' Q = ',F10.5,' F
     2T2/SEC ',/,10X,' C = ',F10.5,' FT/SEC',3X,' VCPL = ',F10.5,
     3' CP ',3X,' HM = ',F10.5,' IN ',/,10X,'HH = ',E11.4,' IN2 ',
     45X,' XNU = ',E10.3,' FT2/SEC',1X,'UM = ',F10.5,1X,'CM = ',F10.5)
      RE=Q/XNU
      HO=((3.0*XNU*Q)/32.2)**(1.0/3.0)
      HOI=HO*12.0
      UO=Q/HO
      C=C/UO
      CC=C-1.5
      S=ZI/(RE**(5.0/3.0))
      WRITE (6,300) HO,HOI,UO,C,CC,RE,ZI,S
  300 FORMAT (//,10X,'***  NUSSELT CONSTANT  ***',//,
     110X,' HO = ',E11.4,' FT ',3X,'HOI = ',E11.4,' IN ',3X,' UO = ',
     1F10.5,' FT/SEC',/10X,'DIMENSIONLESS C = ',F10.5,3X,'RELATIVE CC =
     2',F10.5,5X,'RE = ',F10.5,/,10X,'ZI = ',F10.3,5X,'S = ',F10.5,//)
```

```
      READ (5,400) W(1),DW,N
400   FORMAT (2F10.5,I5)
      CG=CMPLX(C,0.0)
      CS=CMPLX(S,0.0)
      CRE=CMPLX(RE,0.0)
      EPS=0.1E-04
      WRITE (6,500)
500   FORMAT(1X,'FREQ.(CPS)  WDL   WAVE NO.  CONST. C     AFOC',7X,'S1',10
     1X,'S1P',/)
      DO 10 I=1,N
      WDL=W(I)*HO/UO
      WP=CMPLX(WDL,0.0)
      CW=WP/CMPLX(C,0.0)
      CWR=REAL(CW)
C     SET INITIAL POINT
      CALL FLINE (CG    ,CS,CRE,CW,FOO,FO1,FO2,FO3,FL1,FL2,FL3,A1,A2,A3,
     1A4,FOC,DFOC)
      CGF(I)=CG
      COR=FOC/DFOC
      AFOC=CABS(FOC)
      AC=CMPLX(3.0,0.0)
      H1=(FO2+CW*CW*FOO)/AC
      H1C=CONJG(H1)
      CP=(2.0*3.14159)**2
      SC=H1*H1C
      S1(I)=CP*REAL(SC)
      ACC=CG-CMPLX(1.5,0.0)
      F1C=CONJG(FOO)
      SCP=FOO*F1C
      RACC=ACC*CONJG(ACC)
      S1P=REAL(SCP)*CP/RACC
      WRITE (6,600) W(I),WDL,CWR,C,AFOC,S1(I),S1P
600   FORMAT(1X,F10.1,F6.2,E10.3,F10.5,E10.3,2E11.4)
10    W(I+1)=W(I)+DW
      SUM=(S1(1)+S1(N))/2.0
      M=N-1
      DO 20 I=2,M
20    SUM=SUM+S1(I)
      SUM=2.0*SUM*DW*HO/UO
      DO 30 I=1,N
30    S1(I)=S1(I)/SUM
      WRITE (6,700) SUM
700   FORMAT(//,10X,'NORMALIZED SPECTRUM INPUT WHITE NOISE ',/,10X,'SUM
     1= ',E11.4,/,1X,5(' **W(I)**   **S1(I)** '))
      WRITE (6,800) (W(I),S1(I),I=1,N)
800   FORMAT (1X,5(F10.1,E11.4))
      GO TO 1
99    STOP
      END

       SUBROUTINE FLINE (CG,CS,CRE,CW,FOO,FO1,FO2,FO3,FL1,FL2,FL3,A1,A2,
     1A3,A4,FOC,DFOC)
       COMPLEX CK1,CK2,CK3,CK4,CK5,CK6,A1,A2,A3,A4,CFA1,CFA2,CFA3,CFA4,
     1CFB2,CFB3,CFB4,CFC2,CFC3,CFC4,CFD3,CFD4,FL1,FL2,FL3,FL2A,FL2B,
     2FL2C,FL3A,FL3B,FL3C,AW,ACC,AW1,AC,CFA,A,CFB,CFC,FA,FB,FC,FD,CG,CS,
     3CRE,WP,FOO,FO1,FO2,FO3,FO4,FOC,CW,AI,AWW,AWWW,ACG,AC2,AC4,
     4DCK1,DCK2,DA1,DA2,DA3,DA4,DFA,DA,DFB,DFC,CDFA,DFD,CDFB,CDFC,DFA1,
     5DFA2,DFA3,DFA4,DFB2,DFB3,DFB4,DFC2,DFC3,DFC4,DFD3,DFD4,DFL1,DFL2,
     6DFL3,DFOO,DFO1,DFO3,DFOC
       FA(AW1,AW,AC,ACC,A)=AW1*(AC-ACC*(A*A+AW))
       FB(A1,A)=(A1-A)*CEXP(A)
       FC(A,A1,CFA1,CFA)=(CFA1*CEXP(A))-(CFA*CEXP(A1))
       FD(CFC2,CFB,CFB2,CFC)=CFC2*CFB-CFB2*CFC
       DFA(AW1,AW,ACC,AC2,A,DA)=-AW1*(A*A+AW+ACC*AC2*A*DA)
       DFB(DA1,DA,A,CFB)=(DA1-DA)*CEXP(A)+CFB*DA
       DFC(DFA1,CFA1,CDFA,CFA,A,DA,A1,DA1)=DFA1*CEXP(A)+CFA1*CEXP(A)*DA-
     1CDFA*CEXP(A1)-CFA*CEXP(A1)*DA1
       DFD(CFC2,CDFB,DFC2,CFB,DFB2,CFC,CFB2,CDFC)=CFC2*CDFB+DFC2*CFB-DFB2
     1*CFC-CFB2*CDFC
C      CALCULATE FOUR ROOT OF REDUCED EQUATION
       ACC=CG-CMPLX(1.5,0.0)
       AI=CMPLX(0.0,1.0)
       AC=CMPLX(3.0,0.0)
       AW=CW*CW
       AW1=AI*CW
       AWW=AW*CW
       AWWW=AWW*CW
       AC2=CMPLX(2.0,0.0)
       AC4=CMPLX(4.0,0.0)
       CK1=-AI*CRE*ACC*CW-AW*AC2
       CK2=AWWW+AW1*CRE*(ACC*AW+AC)
       CK3=CK1*CK1-AC4*CK2
       CK4=CSQRT(CK3)
```

```
      CK5=(-CK1+CK4)/AC2
      CK6=(-CK1-CK4)/AC2
      A1=CSQRT(CK5)
      A3=-A1
      A2=CSQRT(CK6)
      A4=-A2
      DCK1=-AW1*CRE
      DCK2=AI*CRE*AWW
      DA1=(-DCK1+((CK1*DCK1-AC2*DCK2)/CK4))/(AC4*A1)
      DA2=(-DCK1-((CK1*DCK1-AC2*DCK2)/CK4))/(AC4*A2)
      DA3=-DA1
      DA4=-DA2
C     CALCULATE FUNCTION F1(C,RE,W,0)
      CFA1=FA(AW1,AW,AC,ACC,A1)
      CFA2=FA(AW1,AW,AC,ACC,A2)
      CFA3=FA(AW1,AW,AC,ACC,A3)
      CFA4=FA(AW1,AW,AC,ACC,A4)
      DFA1=DFA(AW1,AW,ACC,AC2,A1,DA1)
      DFA2=DFA(AW1,AW,ACC,AC2,A2,DA2)
      DFA3=DFA(AW1,AW,ACC,AC2,A3,DA3)
      DFA4=DFA(AW1,AW,ACC,AC2,A4,DA4)
      CFB2=FB(A1,A2)
      CFB3=FB(A1,A3)
      CFB4=FB(A1,A4)
      DFB2=DFB(DA1,DA2,A2,CFB2)
      DFB3=DFB(DA1,DA3,A3,CFB3)
      DFB4=DFB(DA1,DA4,A4,CFB4)
      CFC2=FC(A2,A1,CFA1,CFA2)
      CFC3=FC(A3,A1,CFA1,CFA3)
      CFC4=FC(A4,A1,CFA1,CFA4)
      DFC2=DFC(DFA1,CFA1,DFA2,CFA2,A2,DA2,A1,DA1)
      DFC3=DFC(DFA1,CFA1,DFA3,CFA3,A3,DA3,A1,DA1)
      DFC4=DFC(DFA1,CFA1,DFA4,CFA4,A4,DA4,A1,DA1)
      CFD3=FD(CFC2,CFB3,CFB2,CFC3)
      CFD4=FD(CFC2,CFB4,CFB2,CFC4)
      DFD3=DFD(CFC2,CFB3,DFC2,CFB3,DFB2,CFC3,CFB2,DFC3)
      DFD4=DFD(CFC2,CFB4,DFC2,CFB4,DFB2,CFC4,CFB2,DFC4)
      FL1=-(CFD4/CFD3)
      DFL1=(-FL1*DFD3-DFD4)/CFD3
      FL2A=-CFB3*FL1
      FL2B=-CFB4
      FL2C=FL2A+FL2B
      FL2=FL2C/CFB2
      DFL2=-(FL1*DFB3+CFB3*DFL1+DFB3+FL2*DFB2)/DFB2
      FL3A=(-FL2)*CEXP(A2)
      FL3B=(-FL1)*CEXP(A3)
      FL3C=-CEXP(A4)
      FL3=(FL3A+FL3B+FL3C)/CEXP(A1)
      DFL3=(-(CEXP(A2)*(DFL2+FL2*DA2)+CEXP(A3)*(DFL1+FL1*DA3)+CEXP(A4)*
     1DA4)/CEXP(A1))-FL3*DA1
        F00=FL3+FL2+FL1+(1.0,0.0)
      DF00=DFL3+DFL2+DFL1
        F01=A1*FL3+A2*FL2+A3*FL1+A4
      DF01=FL3*DA1+FL2*DA2+FL1*DA3+DA4+A1*DFL3+A2*DFL2+A3*DFL1
          F02=A1*A1*FL3+A2*A2*FL2+A3*A3*FL1+A4*A4
           F03=(A1**3)*FL3+(A2**3)*FL2+(A3**3)*FL1+A4**3
      DF03=AC*(A1*A1*DA1*FL3+A2*A2*DA2*FL2+A3*A3*DA3*FL1+A4*A4*DA4)+(A1*
     1*3)*DFL3+(A2**3)*DFL2+(A3**3)*DFL1
           F04=(A1**4)*FL3+(A2**4)*FL2+(A3**4)*FL1+A4**4
      FOC=ACC*(AC*AI*AW*F01-F03)+AW1*CRE*ACC*ACC*F01+AI*CRE*CS*AWW*F00
      DFOC=AC*AI*AW*(F01+ACC*DF01)-(F03+ACC*DF03)+AW1*CRE*ACC*(AC2*F01+
     1ACC*DF01)+AI*CRE*CS*AWW*DF00
      RETURN
      END
```

APPENDIX B

ERROR ANALYSIS

1. MEASUREMENT ERROR

In this section, the error due to the measurement of the film thickness and the pressure fluctuation is examined carefully in order to make sure that the experimental result presented in this study is reliable.

1-1. THE MEASUREMENT OF THE FILM THICKNESS

The error of the film thickness data is contributed from either the conductivity monitoring circuit, or the Ampex tapes recorder, or the Hybrid computer, or the calibration technique as follows:

(a) The conductivity monitoring circuit is designed such that the fluctuation voltages is less than ± 2 mv with negligible D. C. drift and the frequency respond is good up to 100 cps. The random error due to this circuit on film thickness will be negligible less than ± 0.0001"

(b) The Ampex tape recorder is used at speed of $3\frac{3}{4}$ ips. At this speed, the frequency response is good up to 1250 cps and the noise will be around RMS 10 mv. Hence the error from the tape recorder will be around ± 0.0002" film thickness.

(c) The error due to the sumer and the A-D converter is negligible compared to that of the tape recorder.

(d) The accuracy of the calibration is limited by the calibration plug which can be accurately adjusted to 0.0005". But the error due to the calibration will be a systematic one which is always be the same for the same calibration unless recalibrate the cell.

The other error due to temperature and salinty will be considerably small, since the compensation of these factors were done by standard cell. The error band of the film thickness data is approximately |0.0005"| from the above consideration. It will increase slightly for the higher film thickness measurement due to the non-linearity of the calibration curve.

1-2. THE MEASUREMENT OF THE WALL PRESSURE FLUCTUATION

The main error of the pressure fluctuation measurement is due to the pressure transducer and the calibration of the transducer. The main character of the pressure transducer has been given in Chapter III. The non-linearity of the transducer can be fully compensated by means of the Reactance converter, while the hystersis is not measurably small. Hence the error of the transducer is mainly due to the zero shift and sensitivity shift which is about 0.05%. The above error is around 0.001 psi if 0.16mm diaphragm is used. This error can be further reduced by maintaining the temperature of the transducer constant. The calibration of the transducer was done by the manometer.

If the fluid in the manometer is water, one can calibrate up to 0.003 psi. The approximated estimation of pressure fluctuation done by Webb is around 0.007 psi - 0.1 psi for a single large wave. One would expect the present measuring system is well enough to pick up the wall fluctuation due to the large wave.

2. STATISTICAL ERROR

In this study, the various statistical parameters have been estimated by the digital process. The error associated with those estimation is briefly discussed in this section. The detailed discussion of the statistical error estimation is referred to Bendat (B-1, B-2), Blackman and Tukey (B-6), and Bevington (B-5).

2-1. SAMPLING THE RANDOM DATA

Suppose a random time series record $\hat{x}(t)$ exists only for the time interval 0 to T Sec, and suppose also that its Fouriers Transform $\hat{X}(f)$ exists only in a frequency interval from -B to B cps. The fundamental frequency increament 1/T is called a Nyquist co-interval, and the fundamental time increment 1/2B is called a Nyquist interval. Then the of discrate samples required to describe $\hat{x}(t)$ is

$$n = 2BT \qquad \text{(B-1)}$$

The n=2BT discrete samples will be statistically independent samples for the case of bandwidth limited Gaussian white noise. For the digital process, if the sampling time interval is Δt sec, then the useful data will be from 0 to $1/2\Delta t$ cps. The cutoff frequency $f_c = \frac{1}{2\Delta t}$ is known as the Nyquist frequency, and $1/\Delta t$ is the sampling frequency. The choice of Δt must be small enough so that aliasing will not be a problem.

2-2. ESTIMATION OF MEAN AND VARIANCE

The normalized standard error for a mean value estimate $\hat{\mu}_x$ from a sample $\hat{x}(t)$ with a true mean value $\mu_x \neq 0$ and standard deviation σ_x is

$$\epsilon = \frac{s.d.\{\hat{\mu}_x\}}{\mu_x} \simeq \frac{1}{\sqrt{2BT}}\left(\frac{\sigma_x}{\mu_x}\right) \qquad (B-2)$$

where s. d. is the standard deviation

The normalized standard error for a variance estimate $\hat{\sigma}_x^2$ from a sampling record $\hat{x}(t)$ with a true rms value of σ_x is

$$\epsilon = \frac{s.d.\{\hat{\sigma}_x^2\}}{\sigma_x^2} \simeq \frac{1}{\sqrt{BT}} \qquad (B-3)$$

In this study, the estimation of mean and variance for the case of film thickness will be

$$2BT = 2048 \times 20 = 40{,}960$$

and for the case of wave parameters will be

$$2BT = 1000 \sim 2000$$

2-3. ESTIMATION OF THE PROBABILITY DENSITY FUNCTION

A reasonable approximation of the normalized standard error for the first order probability density function $\hat{\tilde{f}}(x)$

from a sample record $\hat{x}(t)$ with a true probability density of is

$$\epsilon = \frac{\text{s.d.}\{\hat{\tilde{f}}(x)\}}{\tilde{f}(x)} \simeq \frac{1}{\sqrt{2BTW\tilde{f}(x)}} \quad \text{-----} \; (B\text{-}4)$$

where W is the probability interval

The equation (B-4) is plotted in Fig. B-1 with various values of $\tilde{f}(x)$. In the case of the film thickness, the value of WBT is 50 - 1220 in various ranges. In the case of the wave parameters, the value of WBT is about 5 in the amplitude domain and 10 in the time domain.

2-4. ESTIMATION OF THE CORRELATION FUNCTION

The normalized standard error for an auto-covariance function estimate $\hat{\tilde{C}}_{xx}(\tau)$ from a sample record $\hat{x}(t)$ with a true auto-covariance function $\tilde{C}_{xx}(\tau)$ is

$$\epsilon = \frac{\text{s.d.}\{\hat{\tilde{C}}_{xx}(\tau)\}}{\tilde{C}_{xx}(\tau)} \simeq \frac{1}{\sqrt{2BT}}\left(1 + \frac{\tilde{C}^2_{xx}(0)}{\tilde{C}_{xx}(\tau)}\right)^{\frac{1}{2}} \quad \text{----} \; (B\text{-}5)$$

similarly, the normalized standard error for an cross-covariance is

$$\epsilon = \frac{\text{s.d.}\{\hat{\tilde{C}}_{xy}(\tau)\}}{\tilde{C}_{xy}(\tau)} \simeq \frac{1}{\sqrt{2BT}}\left(1 + \frac{\tilde{C}_{xx}(0)\,\tilde{C}_{yy}(0)}{\tilde{C}^2_{xy}(\tau)}\right)^{\frac{1}{2}} \quad \text{---} \; (B\text{-}6)$$

In the present study, the value of 2BT covariance is

$$2BT = 20 \times 2048 = 40{,}960$$

2-5. ESTIMATION OF THE SPECTRAL DENSITY FUNCTION

The problem involving estimation of the spectral density function is more complicate than other statistical parameters. The main considerations for the power spectrum estimation are

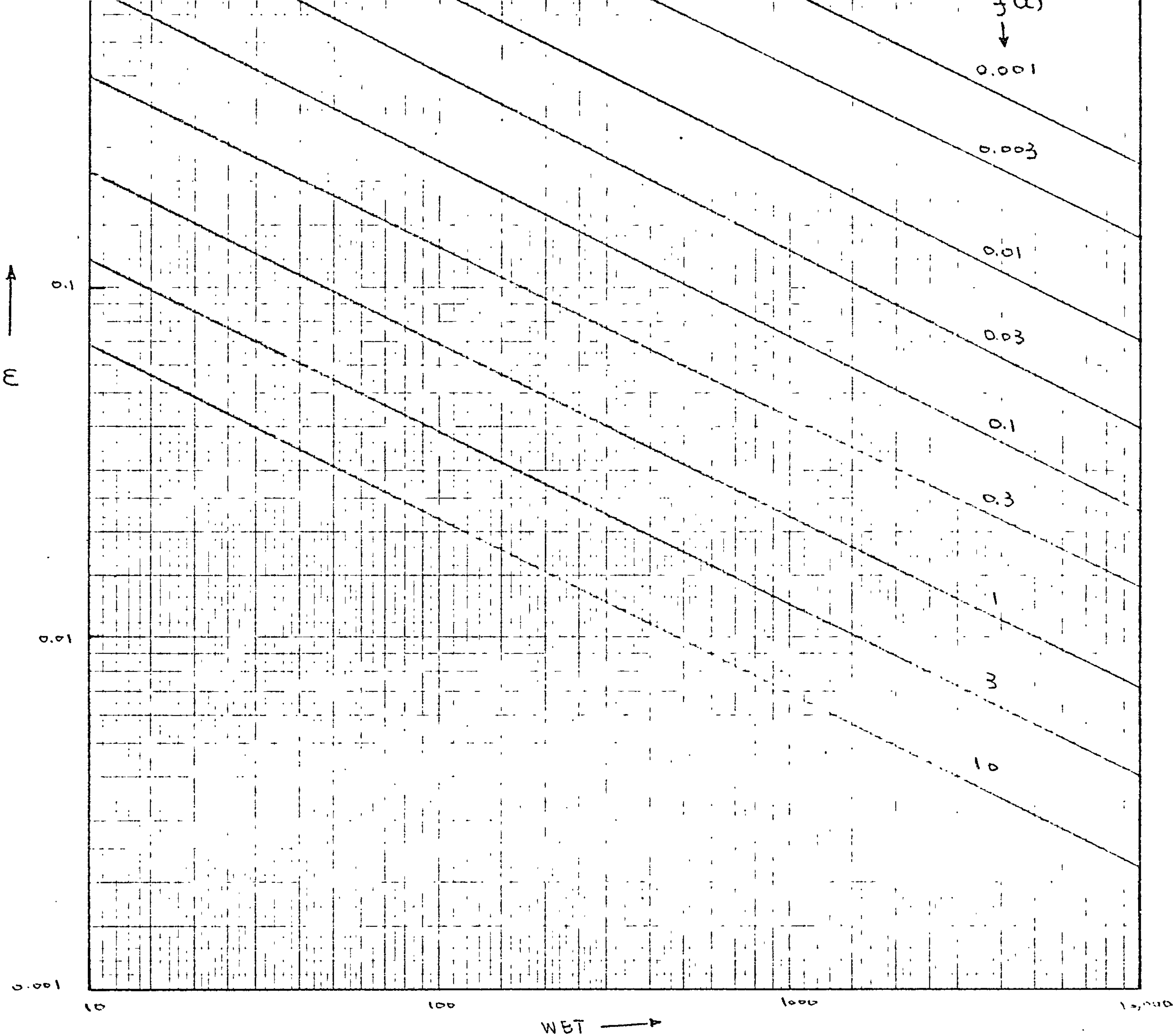


FIG. B-1. STATISTICAL ERROR OF THE PROBABILITY DENSITY as follows:

(a) Nyquist frequency: the Nyquist frequency given as $f_c = \frac{1}{2\Delta t}$ is sometime called the folding frequency. If fc is small and $\hat{x}(t)$ contains energy in the frequency range $f \geqslant f_c$, then the power spectrum of $f \geqslant f_c$ will be folded back into the region $0 \leqslant f \leqslant f_c$. This problem is usually called the aliasing problem. There are two ways to avoid the above phenomena. One is to use low-pass filter, another one is to use a small sampling interval Δ t. In this study the latter way is chosen to avoid this problem. The criteria to determine the fc is to select fc to be two times greater than the maximum frequency of interest fm. In this study fm$\simeq$30 cps - 40 cps the fc is selected at 125 cps.

(b) Spectral window: this problem comes from only the finite length of information used to get the Fourier Transformation. Let consider $\tilde{C}(\tau)$ is an auto-covariance function and $\tilde{C}'(\tau)$ is only a finite portion of $\tilde{C}(\tau)$ as

$$\tilde{C}'(\tau) = D_i(\tau)\, \tilde{C}(\tau) \text{ ------------ } (B-7)$$

where Di(τ) is a lag window. Then the spectrum of $\tilde{C}'(\tau)$ will be

$$\tilde{S}'(f) = Q_i(f) \bullet \tilde{S}(f) \text{ ------------ } (B-8)$$

where Qi(f) is called a spectral window

Qi $\longleftrightarrow$ Di is a Fourier Transform paie

S(f) is the spectrum from $\tilde{C}(\tau)$

$\bullet$ is a convolution operation

The problem is that when the $D_i(\tau)$ is a rectangular window, then

$$Q_i(f) = \frac{T \sin \pi f T}{\pi f T} \qquad (B-9)$$

if $T \rightarrow \infty$, $Q_i(f) = \delta(f)$. The problem comes from where the T is finite and not large. Then there will be a trains of side lobe at each $f = \frac{1}{T}$ for estimation of $\tilde{S}'(f)$.

In general a non rectangular lag window such as Hanning given in equation (B-10) is used to correct the above problem.

$$D_i = \frac{1}{2}\left(1 - \cos \frac{2\pi t}{T}\right) \qquad (B-10)$$

For the digital processes, a smoothing processes which is equilent to the Hanning lag window can be directly applied to the spectrum as:

$$\tilde{S}'(f_k) = 0.25\,\hat{S}'(f_{k-1}) + 0.5\,\hat{S}'(f_k) + 0.25\,\hat{S}'(f_{k+1}) \qquad (B-11)$$

In this study, the rectangular window was used on the data $\hat{x}(t)$ and the estimation of the spectrum is

$$\tilde{S}(f) = \lim_{T\to\infty} \frac{1}{T}\left|\int_{-T}^{+T} p_i(t)\, x(t)\, e^{-i2\pi f t}\, dt\right|^2 \qquad (B-12)$$

where $p_i(t)$ is a data window. Then the lag window will be

$$D_i(\tau) = \frac{1}{T}\int_{-T}^{+T} p_i(\xi)\, p_i(\xi+\tau)\, d\xi = \begin{cases} 1 - \frac{\tau}{T} & \tau > 0 \\ 1 + \frac{\tau}{T} & \tau < 0 \end{cases} \qquad (B-13)$$

$D_i(\tau)$ is a triangular lag window, and the spectral window $Q_i(f)$ corresponding to this $D_i(\tau)$ gives a very small side lobe as given in many references.

(c) Error estimation

The normalized standard error for a power spectral density function estimate $\hat{\tilde{S}}(f)$ from a sample record $\hat{x}(t)$ with a true power spectral density function $\tilde{S}(f)$ is

$$\epsilon = \frac{s.d.\{\hat{\hat{S}}(f)\}}{\tilde{S}(f)} \simeq \frac{1}{\sqrt{B_e T}} \text{ --------- } \quad (B-14)$$

where B_e is the equivalent ideal bandwidth in cps of the narrow bandwidth resolution filter.

In general, one use the confidence limits for a spectral estimate $\hat{\hat{S}}(f)$ corresponding to a level of confidence α as

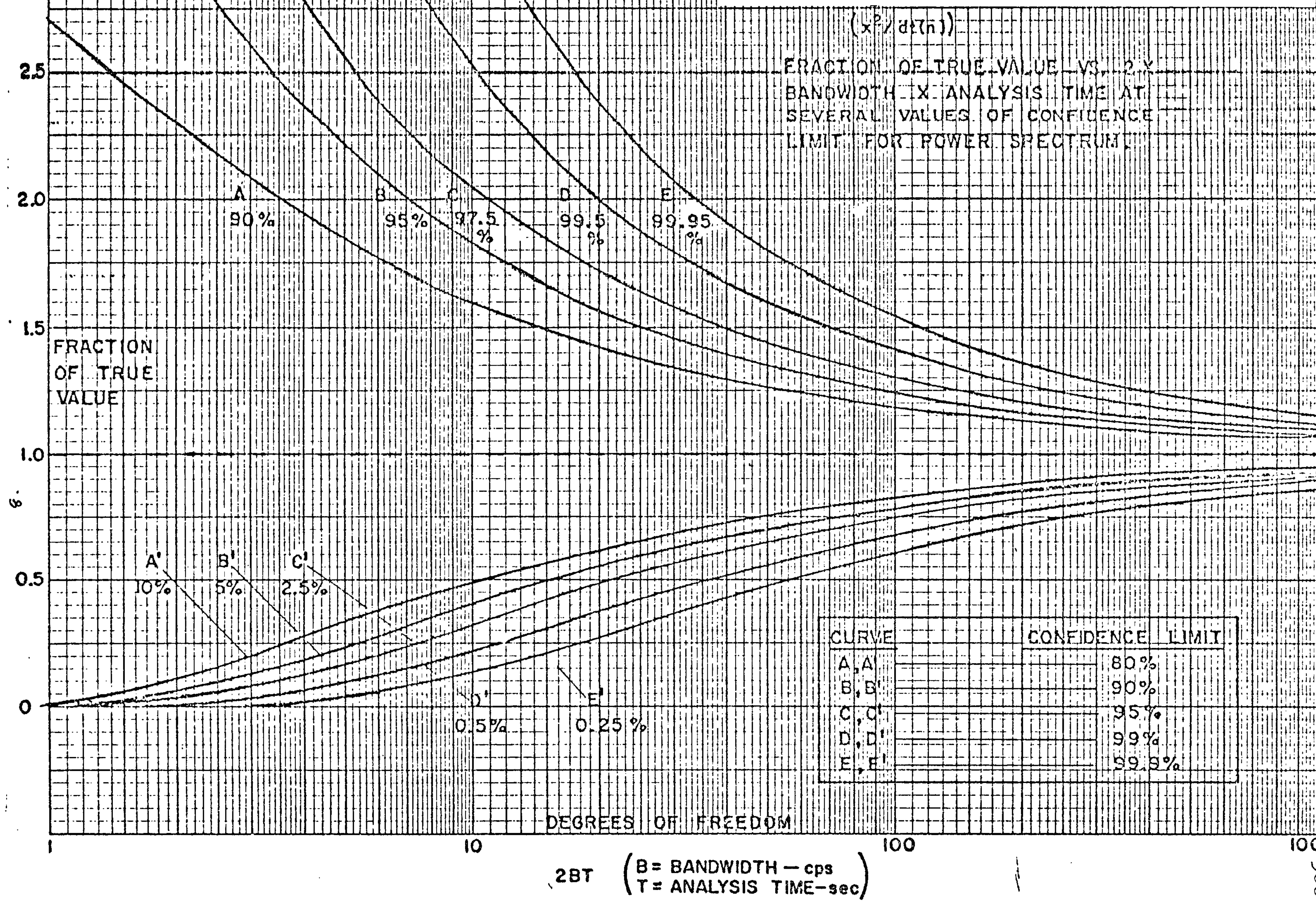
$$\hat{\hat{S}}(f)\,\frac{df(n)}{\chi^2_{(1-\frac{\alpha}{2})}} \leq \tilde{S}(f) \leq \hat{\hat{S}}(f)\,\frac{df(n)}{\chi^2_{(\frac{\alpha}{2})}} \text{ ------- } \quad (B-15)$$

where $\chi^2/df(n)$ is Chi-square with n degree freedom

The equation (B-15) is plotted in Fig. B-2. In the case of the present study, n = 2 x 4 x 20 = 160.

All the statistical parameters described in the above section 2 are reproducable for different sample of time series at same flow rate.

FIG. B-2. CONFIDENCE LIMIT FOR POWER SPECTRUM



APPENDIX C

STATISTICAL DATA OF FILM THICKNESS

MEAN FILM THICKNESS AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------$\langle h \rangle \times 10^3$ (inch)---------				
0.016	4.85	3.53	3.38	2.72	2.84
0.028	7.29	5.52	5.40	4.34	3.51
0.044	8.49	6.38	6.53	5.04	3.86
0.08	10.6	8.03	7.89	6.58	5.24
0.126	13.4	9.97	10.1	8.39	7.11
0.18	15.4	11.65	11.42	9.61	8.65
0.24	18.0	13.82	13.49	11.47	10.41
0.35	23.0	17.55	17.10	14.58	13.32
0.47	27.0	20.28	20.53	17.88	16.15
0.585	30.5	23.0	23.19	20.53	17.97

SECOND CENTRAL MOMENT AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- $\widetilde{C_2} \times 10^6$ (inch) ---------				
0.016	2.29	1.33	0.63	0.30	0.17
0.028	4.95	2.26	1.51	0.81	0.54
0.044	22.7	11.09	11.13	8.94	5.52
0.08	57 5	33.0	38.75	22.91	14.44
0.126	205.0	57.12	70.64	41.44	30.18
0.18	135.0	74.45	89.53	56.54	45.31
0.24	164.0	96.20	126.8	83.51	64.79
0.35	286.0	135.8	195.6	125.3	94.83
0.47	374.0	164.2	254.7	168.8	119.1
0.585	444.0	226.4	295.1	197.4	130.7

THIRD CENTRAL MOMENT AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------$\widetilde{C_3} \times 10^8$ (inch)---------				
0.016	0.34	0.14	0.031	0.006	0.0037
0.028	1.33	0.21	0.12	0.039	0.057
0.044	34.4	12.03	14.33	12.29	5.893
0.08	109.0	46.99	77.11	32.89	17.03
0.126	217.0	80.69	161.2	70.86	45.84
0.18	293.0	101.1	213.9	110.5	77.98
0.24	367.0	137.3	356.2	185.5	121.5
0.35	869.0	236.6	588.9	292.3	177.2
0.47	1210.0	313.0	751.3	403.3	222.7
0.585	1510.0	503.8	848.2	459.4	221.5

FOURTH CENTRAL MOMENT AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------$\widetilde{C_4} \times 10^{10}$ (inch) ---------				
0.016	0.182	0.058	0.012	0.0026	0.0014
0.028	1.59	0.16	0.077	0.021	0.060
0.044	100.0	23.79	30.47	23.45	8.773
0.08	379.0	112.6	215.9	67.24	28.97
0.126	900.0	209.7	554.8	178.3	101.1
0.18	1360.0	280.9	788.9	326.7	198.2
0.24	1790.0	448.7	1570.0	654.0	357.7
0.35	5110.0	952.8	2869.0	1173.0	593.5
0.47	7740.0	1370.0	3817.0	1788.0	832.0
0.585	10300.0	2413.0	4449.0	2110.0	850.7

MEAN FILM THICKNESS AT B_1 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	----------$\langle h \rangle \times 10^3$ (inch)	----------			
0.016	4.76	3.86	3.44	3.11	2.64
0.028	7.20	5.95	5.24	4.49	3.98
0.044	8.62	7.19	6.73	5.21	4.50
0.08	11.2	9.49	8.57	6.90	6.22
0.126	14.5	12.19	11.20	9.09	8.25
0.18	16.8	14.27	12.75	10.64	9.81
0.24	19.9	17.27	15.35	13.22	11.97
0.35	25.8	22.29	19.93	17.14	16.00
0.47	30.3	26.01	24.21	21.16	19.26
0.585	34.9	29.42	27.49	24.63	23.35

SECOND CENTRAL MOMENT AT B_1 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- $\widetilde{C}_2 \times 10^6$ (inch)	----------			
0.016	1.83	1.28	0.49	0.23	0.85
0.028	5.17	2.49	1.35	0.70	0.56
0.044	27.6	16.22	15.25	13.41	10.17
0.08	68.6	54.56	60.66	38.05	28.67
0.126	129.0	95.86	108.5	69.60	55.82
0.18	165.0	127.2	137.4	91.36	80.06
0.24	196.0	163.3	188.7	141.2	114.3
0.35	305.0	227.0	277.5	198.8	168.5
0.47	402.0	268.1	364.4	251.4	197.1
0.585	470.0	337.9	412.5	294.3	249.6

MEAN FILM THICKNESS AT A_3 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- $\langle h \rangle \times 10^3$ (inch)	----------	----------	----------	----------
0.016	4.74	4.45	3.74	3.33	3.29
0.044	8.48	8.09	7.22	5.74	5.38
0.126	13.9	13.0	11.32	9.76	8.97
0.24	19.4	18.6	15.84	13.55	12.69
0.35	25.1	24.48	20.53	17.65	16.91
0.585	34.9	33.2	28.12	25.63	23.66

SECOND CENTRAL MOMENT AT A_3 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- $\tilde{C}_2 \times 10^6$ (inch)	----------	----------	----------	----------
0.016	2.10	1.83	0.61	0.27	0.19
0.044	23.6	15.76	11.60	12.49	11.66
0.126	120.0	111.1	103.7	68.93	57.83
0.24	213.0	220.5	226.3	155.4	137.1
0.35	361.0	346.7	343.2	250.4	224.6
0.585	472.0	611.7	529.9	388.5	330.7

MEAN FILM THICKNESS AT C_4 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- $\langle h \rangle \times 10^3$ (inch)	----------	----------	----------	----------
0.016	4.26	3.95	3.41	2.87	2.82
0.044	7.95	7.59	7.06	5.88	5.25
0.126	14.0	13.37	12.44	9.81	8.81
0.24	20.3	19.80	16.06	13.73	12.73
0.35	26.0	24.5	20.96	17.78	16.76
0.585	35.73	33.73	29.87	26.34	23.51

SECOND CENTRAL MOMENT AT C_4 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- $\tilde{C}_2 \times 10^6$ (inch)	----------	----------	----------	----------
0.016	1.36	1.36	0.50	0.23	0.15
0.044	13.4	7.6	4.59	9.74	10.12
0.126	55.7	61.71	96.08	68.89	59.05
0.24	80.4	107.2	183.1	137.4	125.1
0.35	262.0	287.6	293.6	244.0	201.4
0.585	479.0	410.1	577.3	448.9	312.3

WL (LB/SEC)	0.0160	0.0160	0.0160	0.0160	0.0160	0.0280	0.0280	0.0280	0.0280	0.0440
WG (LB/SEC)	0.0	0.0450	0.0976	0.1436	0.1742	0.0	0.0	0.0	0.0	0.1742
REL. NO.	211	211	228	229	224	367	367	367	367	545
REG. NO.	0	20837	62650	92859	112711	0	0	0	0	112711
TL (°F)	80.000	80.100	86.600	87.050	85.000	79.600	79.600	79.600	79.600	75.150
TG (°F)	73.000	71.000	70.000	69.500	69.000	73.000	73.000	73.000	73.000	69.000
RUN NO. =	005A	012A	009A	008A	010A	005B	005B	005B	005B	010C
CELL NO. =	D2	D2	D2	D2	D2	D2	B1	C4	A3	D2
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.29	0.0	0.0	2.86	0.0	0.0	0.0	0.0	0.0
0.00150	0.0	10.28	31.32	76.15	634.79	0.0	0.0	0.0	0.0	13.07
0.00250	17.57	433.70	409.06	611.90	359.37	0.0	0.01	0.24	0.01	340.25
0.00350	348.71	267.95	393.58	292.61	2.98	16.24	21.01	56.47	30.80	417.33
0.00450	237.60	163.85	142.45	19.26	0.0	118.82	130.69	173.32	155.73	128.08
0.00550	162.93	87.71	22.44	0.08	0.0	172.41	189.37	231.22	189.71	34.05
0.00650	121.99	30.99	1.13	0.0	0.0	184.93	211.56	225.52	184.43	15.00
0.00750	70.96	4.93	0.02	0.0	0.0	171.18	168.43	151.01	156.40	9.12
0.00850	28.27	0.30	0.0	0.0	0.0	132.87	109.62	78.98	114.09	6.79
0.00950	3.98	0.0	0.0	0.0	0.0	90.56	67.93	40.27	72.60	5.67
0.01050	2.23	0.0	0.0	0.0	0.0	53.94	40.51	20.59	43.27	4.36
0.01150	0.48	0.0	0.0	0.0	0.0	27.79	24.19	10.65	24.51	3.87
0.01250	0.08	0.0	0.0	0.0	0.0	14.64	14.68	5.84	12.69	3.54
0.01350	0.0	0.0	0.0	0.0	0.0	7.15	8.52	2.98	5.95	3.32
0.01450	0.0	0.0	0.0	0.0	0.0	3.78	4.85	1.62	3.90	2.74
0.01550	0.0	0.0	0.0	0.0	0.0	1.72	2.97	0.58	2.27	2.63
0.01650	0.0	0.0	0.0	0.0	0.0	1.13	1.77	0.35	1.24	2.22
0.01750	0.0	0.0	0.0	0.0	0.0	0.81	1.09	0.17	0.87	1.79
0.01850	0.0	0.0	0.0	0.0	0.0	0.51	0.67	0.12	0.46	1.78
0.01950	0.0	0.0	0.0	0.0	0.0	0.47	0.46	0.05	0.28	1.08
0.02050	0.0	0.0	0.0	0.0	0.0	0.25	0.40	0.02	0.12	1.03
0.02150	0.0	0.0	0.0	0.0	0.0	0.20	0.33	0.0	0.18	0.79
0.02250	0.0	0.0	0.0	0.0	0.0	0.20	0.23	0.0	0.12	0.57
0.02350	0.0	0.0	0.0	0.0	0.0	0.10	0.18	0.0	0.09	0.33
0.02450	0.0	0.0	0.0	0.0	0.0	0.11	0.16	0.0	0.07	0.18
0.02550	0.0	0.0	0.0	0.0	0.0	0.09	0.11	0.0	0.07	0.17
0.02650	0.0	0.0	0.0	0.0	0.0	0.05	0.03	0.0	0.06	0.08
0.02750	0.0	0.0	0.0	0.0	0.0	0.03	0.11	0.0	0.03	0.09
0.02850	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.04
0.02950	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.03
0.03050	0.0	0.0	0.0	0.0	0.0	0.02	0.01	0.0	0.01	0.0
0.03150	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	0.0
0.03250	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0
0.03350	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.03450	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0

TAPLE C-2 (continued)

WL (LB/SEC)	0.0440	0.0440	0.0440	0.0440	0.1260	0.1260
WG (LB/SEC)	0.0	0.0450	0.0976	0.1436	[illegible]	0.0450
REL. NO.	572	561	565	589	1005	1542
REG. NO.	0	28788	62438	91867	0	28788
TL (°F)	78.900	77.400	78.000	81.250	77.300	74.200
TG (°F)	73.000	72.000	72.000	72.000	73.000	72.000
RUN NO. =	005C	012C	009C	008C	003E	012E
CELL NO. =	D2	D2	D2	D2	D2	D2
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.0	0.0	0.0	0.0	0.0
0.00150	0.0	0.0	0.12	0.06	0.0	0.0
0.00250	0.04	16.27	11.06	40.90	0.0	2.06
0.00350	19.78	145.44	121.00	326.30	2.92	68.50
0.00450	112.69	234.51	264.43	347.20	44.28	180.43
0.00550	180.59	191.09	233.05	149.57	134.96	168.41
0.00650	167.35	144.51	144.58	48.95	142.76	107.49
0.00750	131.47	90.21	80.80	21.47	106.43	67.65
0.00850	98.78	57.61	45.20	12.81	72.05	51.46
0.00950	71.98	33.94	25.19	8.73	53.96	38.54
0.01050	52.51	21.12	16.89	6.73	40.53	32.48
0.01150	34.96	13.66	12.38	4.79	34.43	27.99
0.01250	24.63	10.33	8.54	4.30	29.47	23.80
0.01350	17.65	7.25	5.92	3.66	26.14	22.04
0.01450	14.15	5.78	4.35	3.32	23.39	19.85
0.01550	11.08	4.43	3.98	2.67	20.94	17.82
0.01650	9.02	3.79	3.48	2.37	19.47	15.77
0.01750	7.74	3.28	2.26	1.76	17.40	15.10
0.01850	5.93	2.52	2.11	2.03	16.96	13.71
0.01950	5.10	2.38	1.72	1.69	15.80	13.28
0.02050	4.33	1.73	1.65	1.61	14.45	11.55
0.02150	3.73	1.66	1.48	1.62	13.72	10.39
0.02250	3.44	1.35	1.34	1.28	13.03	10.01
0.02350	3.30	1.29	1.03	1.22	13.03	9.33
0.02450	2.13	1.07	0.83	0.91	11.21	8.74
0.02550	2.40	0.90	0.76	0.83	11.36	8.14
0.02650	1.92	0.74	1.06	0.84	10.83	7.44
0.02750	1.71	0.51	0.60	0.60	9.68	6.55
0.02850	1.23	0.45	0.72	0.65	9.54	5.65
0.02950	1.30	0.27	0.67	0.34	8.30	4.78
0.03050	1.09	0.35	0.46	0.20	7.15	4.50
0.03150	1.06	0.33	0.54	0.20	7.65	4.38
0.03250	0.77	0.18	0.43	0.15	7.38	4.25
0.03350	0.90	0.12	0.33	0.08	7.06	3.02
0.03450	0.78	0.19	0.28	0.10	6.35	2.97
0.03550	0.68	0.11	0.21	0.02	6.15	2.28
0.03650	0.50	0.06	0.18	0.01	5.03	1.72
0.03750	0.43	0.08	0.11	0.01	4.32	1.34
0.03850	0.25	0.06	0.11	0.0	3.83	1.26
0.03950	0.33	0.09	0.06	0.0	3.47	1.05
0.04050	0.19	0.05	0.0	0.01	2.55	0.78
0.04150	0.16	0.0	0.02	0.0	2.45	0.83
0.04250	0.11	0.02	0.03	0.01	1.96	0.53
0.04350	0.13	0.03	0.0	0.0	1.80	0.54
0.04450	0.11	0.02	0.0	0.0	1.61	0.23
0.04550	0.17	0.0	0.01	0.0	1.48	0.29
0.04650	0.07	0.02	0.01	0.0	1.33	0.23
0.04750	0.14	0.0	0.01	0.0	1.31	0.16
0.04850	0.05	0.0	0.0	0.0	1.02	0.12
0.04950	0.05	0.0	0.0	0.0	0.99	0.11
0.05250	0.04	0.0	0.00	0.0	0.74	0.07
0.05750	0.02	0.0	0.0	0.0	0.33	0.02
0.06250	0.02	0.0	0.0	0.0	0.18	0.00
0.06750	0.02	0.0	0.0	0.0	0.11	0.0
0.07250	0.01	0.0	0.0	0.0	0.10	0.0
0.07750	0.01	0.0	0.0	0.0	0.05	0.0
0.08250	0.0	0.0	0.0	0.0	0.05	0.0
0.08750	0.00	0.0	0.0	0.0	0.03	0.0
0.09250	0.0	0.0	0.0	0.0	0.01	0.0
0.09750	0.0	0.0	0.0	0.0	0.00	0.0
0.11250	0.0	0.0	0.0	0.0	0.00	0.0
0.13750	0.0	0.0	0.0	0.0	0.0	0.0
0.16250	0.0	0.0	0.0	0.0	0.0	0.0
0.18750	0.0	0.0	0.0	0.0	0.0	0.0
0.22500	0.0	0.0	0.0	0.0	0.0	0.0
0.27500	0.0	0.0	0.0	0.0	0.0	[illegible]

TABLE C-2 (continued)

WL (LB/SEC)	0.1260	0.1260	0.1260	0.2400	0.2400	0.2400
WG (LB/SEC)	0.0976	0.1436	0.1742	0.0	0.0450	0.0976
REL. NO.	1518	1567	1504	3151	2901	2842
REG. NO.	62474	92022	112968	0	23785	62650
TL (°F)	73.000	75.450	72.300	79.650	73.250	71.700
TG (°F)	71.500	71.000	68.000	75.000	72.000	70.000
RUN NO. =	009E	008E	010E	006H	012G	009G
CELL NO. =	D2	D2	D2	D2	D2	D2
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.0	0.0	0.0	0.0	0.0
0.00150	0.01	0.28	0.06	0.0	0.0	0.0
0.00250	1.99	9.59	24.82	0.0	0.05	0.04
0.00350	31.97	82.32	193.24	0.30	11.19	5.00
0.00450	154.07	206.15	256.27	15.12	66.34	43.52
0.00550	210.18	211.49	172.29	50.49	113.21	110.94
0.00650	153.55	138.37	92.42	78.42	107.78	137.86
0.00750	98.68	79.92	54.85	74.88	84.72	126.63
0.00850	63.21	50.12	36.96	70.85	67.52	101.06
0.00950	42.96	33.99	26.34	61.86	53.61	76.92
0.01050	31.94	24.29	18.39	52.09	46.42	55.37
0.01150	23.22	18.87	14.36	45.65	39.91	40.30
0.01250	18.13	14.62	10.99	39.99	34.03	32.70
0.01350	14.85	11.69	8.93	34.83	30.42	26.11
0.01450	12.40	9.90	8.57	31.26	27.03	19.78
0.01550	10.35	9.81	6.76	28.58	24.18	15.89
0.01650	9.77	8.46	5.95	26.69	21.85	14.99
0.01750	8.94	6.54	5.71	25.42	19.26	12.64
0.01850	7.13	6.28	5.80	23.48	17.83	11.49
0.01950	6.66	5.75	5.11	21.29	17.32	10.05
0.02050	6.61	5.61	5.13	20.82	16.54	8.79
0.02150	6.28	5.24	5.12	18.96	14.81	8.12
0.02250	5.14	5.09	4.90	18.27	14.67	7.49
0.02350	5.56	4.88	4.57	17.89	14.09	6.96
0.02450	5.31	5.02	4.33	16.60	13.22	6.65
0.02550	4.59	4.95	4.33	15.33	12.41	6.08
0.02650	4.52	4.62	4.03	14.69	12.26	6.08
0.02750	4.14	3.11	3.61	13.77	11.82	5.72
0.02850	4.33	3.33	3.30	13.86	9.12	5.89
0.02950	3.91	3.64	2.56	12.05	3.69	5.62
0.03050	4.20	3.69	2.48	12.20	9.66	5.04
0.03150	3.71	3.87	1.69	11.54	8.95	5.28
0.03250	4.36	3.33	1.58	11.65	8.49	5.21
0.03350	4.17	3.12	1.48	11.52	8.63	5.05
0.03450	3.74	2.91	0.86	9.94	7.48	5.24
0.03550	3.37	2.01	0.70	9.71	6.73	5.05
0.03650	3.18	1.66	0.53	8.97	6.24	4.92
0.03750	2.87	1.33	0.33	7.37	5.54	4.13
0.03850	2.55	0.97	0.16	6.50	4.53	4.13
0.03950	2.28	0.72	0.20	5.85	3.61	3.74
0.04050	1.94	0.59	0.10	5.22	2.87	3.26
0.04150	1.86	0.37	0.06	4.90	2.60	3.24
0.04250	1.47	0.37	0.04	4.32	2.32	2.76
0.04350	1.34	0.23	0.04	3.55	1.97	2.52
0.04450	1.12	0.16	0.02	3.44	1.68	2.71
0.04550	0.88	0.28	0.01	3.24	1.34	1.95
0.04650	0.86	0.08	0.02	2.62	1.33	2.06
0.04750	0.85	0.08	0.0	2.73	1.13	1.75
0.04850	0.53	0.08	0.0	2.23	0.93	1.89
0.04950	0.50	0.04	0.0	1.72	0.43	1.17
0.05250	0.39	0.03	0.0	1.03	0.24	0.77
0.05750	0.21	0.01	0.0	1.11	0.26	0.97
0.06250	0.13	0.0	0.0	1.18	0.12	1.11
0.06750	0.03	0.0	0.0	1.08	0.03	0.79
0.07250	0.01	0.0	0.0	0.60	0.0	0.33
0.07750	0.0	0.0	0.0	0.24	0.0	0.06
0.08250	0.0	0.0	0.0	0.10	0.0	0.01
0.08750	0.0	0.0	0.0	0.06	0.0	0.00
0.09250	0.0	0.0	0.0	0.02	0.0	0.00
0.09750	0.0	0.0	0.0	0.02	0.0	0.0
0.11250	0.0	0.0	0.0	0.00	0.0	0.0
0.13750	0.0	0.0	0.0	0.0	0.0	0.0
0.16250	0.0	0.0	0.0	0.0	0.0	0.0
0.18750	0.0	0.0	0.0	0.0	0.0	0.0
0.22500	0.0	0.0	0.0	0.0	0.0	0.0
0.27500	0.0	0.0	0.0	0.0	0.0	0.0

WL (LB/SEC)	0.2400	0.2400	0.3500	0.3500	0.3500	0.3500
WG (LB/SEC)	0.1436	0.1742	0.0	0.0450	0.0976	0.1436
REL. NO.	2897	2768	4572	4214	4109	4134
REG. NO.	92178	113551	0	23788	63149	92912
TL (°F)	73.150	69.750	79.250	72.950	71.050	71.500
TG (°F)	70.000	65.000	75.000	72.000	69.000	69.000
RUN NO. =	008G	010G	006G	012H	009H	008H
CELL NO. =	D2	D2	D2	D2	D2	D2
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.0	0.0	0.0	0.0	0.0
0.00150	0.02	0.0	0.0	0.0	0.0	0.04
0.00250	2.38	0.51	0.0	0.01	0.11	0.43
0.00350	22.81	25.00	0.11	2.10	0.87	6.38
0.00450	90.45	110.12	2.35	15.84	11.66	36.01
0.00550	146.38	158.96	13.00	39.38	42.26	75.00
0.00650	144.30	148.32	27.33	64.09	74.21	101.24
0.00750	114.86	114.74	40.06	74.84	92.07	105.07
0.00850	87.65	83.44	50.07	74.47	98.55	95.06
0.00950	64.48	61.69	53.71	69.57	88.72	80.50
0.01050	45.96	44.02	56.29	60.52	72.01	64.83
0.01150	35.03	32.28	52.81	52.73	59.44	51.70
0.01250	26.82	25.82	51.59	47.25	48.48	42.09
0.01350	21.36	19.19	48.14	40.75	40.13	35.96
0.01450	17.13	15.99	41.86	34.46	34.87	26.69
0.01550	13.83	13.69	38.54	31.71	28.18	23.18
0.01650	11.91	11.00	34.06	27.75	23.77	20.18
0.01750	10.86	9.93	31.61	24.45	19.36	17.64
0.01850	8.75	8.40	28.72	21.86	17.49	14.18
0.01950	9.01	7.42	25.96	19.83	15.97	13.29
0.02050	7.32	6.81	23.82	18.83	13.76	11.99
0.02150	7.37	6.45	21.48	17.57	12.00	10.35
0.02250	6.15	5.84	19.23	16.37	11.14	9.59
0.02350	5.91	5.63	19.29	16.76	10.85	9.38
0.02450	5.69	5.58	17.40	14.78	9.71	8.27
0.02550	5.39	5.60	16.11	14.88	8.75	7.59
0.02650	5.25	5.59	15.52	14.37	8.07	7.33
0.02750	5.10	5.93	14.66	14.11	8.35	7.14
0.02850	5.03	5.02	13.82	10.95	7.38	5.80
0.02950	5.15	4.05	13.72	9.92	7.13	6.00
0.03050	4.27	4.72	12.80	10.63	6.52	6.34
0.03150	4.34	4.72	12.22	11.16	6.27	6.34
0.03250	5.01	5.00	12.21	12.25	6.52	6.39
0.03350	5.09	5.47	11.55	10.90	6.15	5.56
0.03450	5.06	5.59	11.52	10.00	6.45	5.91
0.03550	4.07	4.46	9.83	9.14	5.98	5.21
0.03650	3.95	3.97	9.05	8.32	5.89	5.33
0.03750	3.79	3.32	8.35	7.91	5.38	5.06
0.03850	3.48	3.03	7.94	6.97	4.95	5.02
0.03950	3.15	2.14	6.71	6.55	4.44	4.72
0.04050	3.06	1.71	6.71	5.80	3.95	4.59
0.04150	2.35	1.80	6.20	5.40	3.80	4.11
0.04250	2.13	1.44	5.61	4.49	3.40	3.91
0.04350	2.43	1.13	5.13	4.05	3.38	3.94
0.04450	2.04	0.84	5.24	3.63	3.34	3.12
0.04550	1.83	0.87	4.61	3.39	3.13	3.34
0.04650	1.52	0.46	4.32	3.49	3.05	3.22
0.04750	1.26	0.45	4.35	2.80	2.29	2.65
0.04850	1.14	0.33	3.81	2.55	2.92	2.25
0.04950	0.80	0.25	2.52	1.63	2.12	1.50
0.05250	0.48	0.10	1.68	0.98	1.35	1.02
0.05750	0.37	0.08	1.95	1.03	1.65	0.98
0.06250	0.32	0.05	2.85	0.93	2.23	0.91
0.06750	0.17	0.01	2.98	0.60	2.10	0.58
0.07250	0.03	0.00	2.46	0.14	1.15	0.18
0.07750	0.00	0.0	1.46	0.02	0.36	0.04
0.08250	0.0	0.0	0.79	0.01	0.08	0.00
0.08750	0.0	0.0	0.58	0.00	0.03	0.00
0.09250	0.0	0.0	0.33	0.00	0.01	0.0
0.09750	0.0	0.0	0.20	0.0	0.00	0.0
0.11250	0.0	0.0	0.06	0.0	0.00	0.0
0.13750	0.0	0.0	0.00	0.0	0.0	0.0
0.16250	0.0	0.0	0.00	0.0	0.0	0.0
0.18750	0.0	0.0	0.0	0.0	0.0	0.0
0.22500	0.0	0.0	0.0	0.0	0.0	0.0
0.27500	0.0	0.0	0.00	0.0	0.0	0.0
0.32500	0.0	0.0	0.0	0.0	0.0	0.0
0.37500	0.0	0.0	0.0	0.0	0.0	0.0
0.45000	0.0	0.0	0.0	0.0	0.0	0.0
0.75000	0.0	0.0	0.0	0.0	0.0	0.0

TABLE C-2 (continued)

WL (LB/SEC)	0.3500	0.5850	0.5850	0.5850	0.5850	0.5850
WG (LB/SEC)	0.1742	0.0	0.0450	0.0976	0.1436	0.1742
REL. NO.	3997	7560	7016	6790	6758	6577
REG. NO.	113551	0	28804	63257	33177	113551
TL (°F)	69.000	78.400	72.650	70.200	69.850	67.850
TG (°F)	65.000	75.000	71.500	68.200	67.500	65.000
RUN NO. =	010H	006E	012J	009J	008J	010J
CELL NO. =	D2	D2	D2	D2	D2	D2
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.0	0.0	0.0	0.0	0.0
0.00150	0.0	0.0	0.0	0.0	0.0	0.0
0.00250	0.06	0.0	0.0	0.0	0.01	0.0
0.00350	4.91	0.0	0.04	0.0	0.35	0.46
0.00450	37.72	0.09	0.43	0.81	4.71	5.80
0.00550	90.05	0.40	3.20	5.63	14.68	21.98
0.00650	110.67	1.54	11.01	15.87	31.23	42.40
0.00750	109.53	4.49	22.69	29.42	47.47	61.40
0.00850	97.05	10.87	36.14	43.61	57.46	70.81
0.00950	79.29	19.72	47.44	57.13	64.18	72.78
0.01050	65.73	28.79	57.58	61.33	66.37	67.63
0.01150	50.22	37.57	58.04	62.90	61.17	62.15
0.01250	40.51	40.58	55.11	58.12	54.35	56.87
0.01350	33.33	40.47	50.65	53.72	48.34	50.10
0.01450	26.57	41.36	46.95	48.25	43.57	43.80
0.01550	21.87	41.31	42.04	42.98	39.54	36.65
0.01650	18.50	39.77	37.19	38.61	34.32	32.50
0.01750	15.27	37.78	34.65	34.24	30.07	28.34
0.01850	14.08	36.15	31.77	29.91	27.68	25.79
0.01950	12.20	33.45	27.41	27.62	26.11	23.14
0.02050	11.57	30.72	27.50	23.91	22.62	21.74
0.02150	9.76	28.63	25.05	23.17	20.86	19.06
0.02250	9.53	27.03	23.35	20.14	19.01	17.65
0.02350	8.83	26.31	21.96	18.72	17.57	16.17
0.02450	8.56	25.44	20.03	16.20	16.05	15.14
0.02550	8.15	22.25	19.12	16.06	14.80	14.19
0.02650	7.54	21.76	18.58	15.00	14.01	12.79
0.02750	7.53	19.95	17.48	13.12	13.04	12.00
0.02850	6.95	19.18	12.95	12.23	12.31	11.99
0.02950	4.72	17.13	12.36	11.29	9.70	9.42
0.03050	4.97	16.58	13.82	10.71	9.12	8.72
0.03150	5.94	16.68	13.05	9.85	9.26	9.03
0.03250	6.55	16.75	13.75	9.70	9.99	10.32
0.03350	6.97	16.58	12.88	9.45	9.08	10.17
0.03450	7.44	13.95	12.25	8.93	9.30	9.55
0.03550	7.16	13.82	11.55	8.30	8.33	9.20
0.03650	6.61	11.33	10.14	7.32	8.14	8.62
0.03750	5.76	10.87	9.63	6.40	6.96	8.54
0.03850	5.09	10.00	8.74	6.43	6.82	7.98
0.03950	4.91	8.64	7.64	6.06	5.87	7.01
0.04050	3.77	8.27	7.03	5.63	5.89	6.19
0.04150	3.61	7.16	6.77	4.86	5.62	6.25
0.04250	3.14	7.03	6.65	5.22	5.07	5.52
0.04350	2.69	6.23	6.77	4.78	5.27	4.53
0.04450	1.93	6.44	5.52	4.36	4.34	4.46
0.04550	2.04	5.24	5.58	4.50	5.19	3.42
0.04650	1.67	5.17	5.65	4.57	4.62	3.47
0.04750	1.38	5.52	5.04	3.92	4.55	2.97
0.04850	1.38	5.07	5.19	3.67	4.58	2.79
0.04950	0.83	3.15	3.68	2.35	2.99	1.88
0.05250	0.44	2.24	1.93	1.98	1.90	1.03
0.05750	0.35	2.85	2.46	2.59	2.55	1.10
0.06250	0.20	3.95	3.42	3.71	2.78	0.82
0.06750	0.08	4.80	3.95	4.79	2.56	0.32
0.07250	0.01	4.51	1.58	3.47	1.26	0.06
0.07750	0.00	3.39	0.22	1.44	0.34	0.01
0.08250	0.0	2.45	0.02	0.46	0.08	0.0
0.08750	0.0	1.85	0.00	0.10	0.00	0.0
0.09250	0.0	1.40	0.0	0.05	0.01	0.0
0.09750	0.0	1.00	0.0	0.01	0.0	0.0
0.11250	0.0	0.37	0.0	0.00	0.0	0.0
0.13750	0.0	0.04	0.0	0.0	0.0	0.0
0.16250	0.0	0.01	0.0	0.0	0.0	0.0
0.18750	0.0	0.00	0.0	0.0	0.0	0.0
0.22500	0.0	0.00	0.0	0.0	0.0	0.0
0.27500	0.0	0.00	0.0	0.0	0.0	0.0
0.32500	0.0	0.0	0.0	0.0	0.0	0.0
0.37500	0.0	0.0	0.0	0.0	0.0	0.0
0.45000	0.0	0.0	0.0	0.0	0.0	0.0
0.75000	0.0	0.0	0.0	0.0	0.0	0.0

WL (LB/SEC)	0.0800	0.0800	0.0800	0.0800	0.1800	0.1800
WG (LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0
REL. NO.	1016	1016	1016	1016	2299	2299
REG. NO.	0	0	0	0	0	0
TL (°F)	77.100	77.100	77.100	77.100	77.500	77.500
TG (°F)	73.000	73.000	73.000	73.000	73.000	73.000
RUN NO. =	005D	005D	005D	005D	005F	005F
CELL NO. =	D2	B1	A3	C4	D2	B1
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.0	0.0	0.0	0.0	0.0
0.00150	0.0	0.0	0.0	0.0	0.0	0.0
0.00250	0.0	0.03	0.23	0.0	0.0	0.0
0.00350	12.92	13.02	14.05	12.17	1.24	0.54
0.00450	96.74	118.24	129.03	122.21	35.06	32.27
0.00550	168.57	176.70	165.09	141.33	100.38	106.79
0.00650	144.96	142.89	127.09	118.75	119.59	116.88
0.00750	109.00	93.93	94.64	102.60	95.09	81.97
0.00850	75.89	63.75	71.97	74.95	69.08	58.95
0.00950	59.18	46.97	53.09	58.29	53.15	47.32
0.01050	46.96	37.37	43.90	50.00	44.26	39.98
0.01150	35.18	30.95	34.80	41.17	38.67	34.50
0.01250	29.73	26.01	29.23	35.39	32.55	29.89
0.01350	24.49	22.35	25.19	31.60	29.56	27.25
0.01450	20.01	19.06	20.94	27.48	25.38	25.01
0.01550	17.53	18.04	19.62	24.03	21.66	22.57
0.01650	15.25	17.28	17.63	22.28	21.19	22.22
0.01750	13.86	15.44	15.51	18.95	19.44	20.85
0.01850	11.98	13.98	13.47	18.05	18.39	18.79
0.01950	11.10	13.30	12.67	14.52	18.14	17.45
0.02050	11.21	11.81	10.75	12.27	16.56	17.34
0.02150	10.16	12.09	9.55	10.31	15.89	17.41
0.02250	9.22	11.28	9.80	9.02	15.14	17.70
0.02350	7.92	9.73	8.48	7.60	13.84	16.18
0.02450	7.11	9.32	7.76	6.59	13.50	15.18
0.02550	6.64	8.12	7.09	5.33	13.46	14.69
0.02650	5.76	7.63	6.47	5.04	11.88	14.58
0.02750	5.04	6.85	5.40	4.43	12.79	14.16
0.02850	4.95	6.06	5.12	3.46	11.34	12.95
0.02950	4.13	5.56	4.58	2.82	11.01	11.89
0.03050	3.85	4.67	4.64	2.71	8.14	11.36
0.03150	3.59	3.89	3.64	2.06	8.39	9.96
0.03250	3.15	3.86	3.44	1.88	8.45	9.89
0.03350	2.70	3.50	3.15	2.06	8.93	8.77
0.03450	2.48	2.80	2.66	1.63	8.53	8.36
0.03550	2.60	2.26	1.40	1.36	7.76	6.44
0.03650	1.91	2.04	1.30	1.29	6.51	6.36
0.03750	1.48	2.21	1.65	1.18	5.95	6.90
0.03850	1.44	2.11	1.79	0.96	5.78	6.58
0.03950	1.51	2.00	1.55	0.85	4.61	7.26
0.04050	1.06	1.97	1.92	0.58	4.31	6.99
0.04150	1.00	1.65	1.31	0.59	3.78	6.30
0.04250	0.78	1.33	1.52	0.30	3.76	5.79
0.04350	0.68	1.26	1.01	0.33	2.98	4.62
0.04450	0.66	0.92	0.75	0.20	2.87	4.51
0.04550	0.61	0.82	0.72	0.19	2.73	4.05
0.04650	0.51	0.64	0.41	0.21	2.44	3.02
0.04750	0.39	0.56	0.34	0.14	2.31	3.07
0.04850	0.47	0.48	0.37	0.12	1.65	2.73
0.04950	0.49	0.47	0.33	0.12	1.26	2.04
0.05250	0.19	0.30	0.19	0.05	0.99	1.68
0.05750	0.08	0.15	0.10	0.03	0.88	1.04
0.06250	0.07	0.06	0.07	0.02	0.62	0.43
0.06750	0.04	0.02	0.05	0.01	0.46	0.26
0.07250	0.02	0.01	0.17	0.00	0.36	0.16
0.07750	0.02	0.00	0.02	0.0	0.22	0.15
0.08250	0.01	0.01	0.0	0.0	0.15	0.07
0.08750	0.01	0.01	0.0	0.0	0.08	0.08
0.09250	0.00	0.00	0.0	0.0	0.05	0.03
0.09750	0.00	0.00	0.0	0.0	0.05	0.02
0.11250	0.00	0.0	0.0	0.0	0.01	0.00
0.13750	0.0	0.0	0.0	0.0	0.00	0.00
0.16250	0.0	0.0	0.0	0.0	0.0	0.0
0.18750	0.0	0.0	0.0	0.0	0.0	0.0
0.22500	0.0	0.0	0.0	0.0	0.0	0.00
0.27500	0.0	0.0	0.0	0.0	0.0	0.0
0.32500	0.0	0.0	0.0	0.0	0.0	0.0
0.37500	0.0	0.0	0.0	0.0	0.0	0.0
0.45000	0.0	0.0	0.0	0.0	0.0	0.0
0.75000	0.0	0.0	0.0	0.0	0.0	0.0

TABLE C-2 (continued)

WL (LB/SEC)	0.1800	0.1800	0.4700	0.4700	0.4700	0.4700
WG (LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0
REL. NO.	2299	2299	6043	6043	6043	6043
REG. NO.	0	0	0	0	0	0
TL ( )	77.500	77.500	78.000	78.000	78.000	78.000
TG ( )	73.000	73.000	73.000	73.000	73.000	73.000
RUN NO. =	005F	005F	006F	006F	006F	006F
CELL NO. =	A3	C4	D2	B1	A3	C4
FILM THICKNESS (INCHES)	DENS.	DENS.	DENS.	DENS.	DENS.	DENS.
0.00050	0.0	0.0	0.0	0.0	0.0	0.0
0.00150	0.0	0.0	0.0	0.0	0.0	0.0
0.00250	0.0	0.0	0.0	0.0	0.0	0.0
0.00350	2.49	0.0	0.0	0.0	0.0	0.0
0.00450	52.10	1.02	0.02	0.03	0.27	0.01
0.00550	112.55	7.42	1.73	0.77	2.74	1.67
0.00650	110.03	20.71	6.43	4.79	9.48	5.85
0.00750	81.37	33.37	14.86	11.23	17.60	12.13
0.00850	62.06	43.20	24.22	16.95	23.32	17.91
0.00950	48.03	51.02	33.94	22.28	27.43	23.38
0.01050	40.70	58.49	41.27	26.13	34.96	29.58
0.01150	35.07	65.68	48.72	28.53	39.27	31.67
0.01250	31.78	71.11	48.63	30.45	41.83	34.12
0.01350	28.15	73.78	46.26	34.30	40.57	35.54
0.01450	25.57	71.49	45.79	34.07	38.68	35.77
0.01550	23.73	67.74	40.15	32.81	37.45	36.96
0.01650	22.23	61.00	37.22	33.21	34.25	38.65
0.01750	20.53	57.41	34.28	31.19	33.05	37.34
0.01850	18.04	51.66	33.77	31.27	30.62	37.61
0.01950	17.53	41.99	29.99	30.40	29.06	31.99
0.02050	17.34	33.41	27.97	29.50	27.03	28.49
0.02150	16.52	28.06	26.16	29.12	25.77	26.70
0.02250	15.69	22.85	25.22	28.67	23.63	24.56
0.02350	14.12	19.18	22.84	26.98	22.23	22.64
0.02450	13.90	17.36	21.07	26.04	21.12	20.85
0.02550	13.67	14.47	20.68	23.71	18.44	19.51
0.02650	12.30	11.98	19.85	23.08	18.75	18.32
0.02750	11.74	10.28	19.00	21.38	17.87	16.94
0.02850	11.44	8.83	17.08	20.33	16.87	16.86
0.02950	10.18	7.58	12.48	18.93	16.00	16.71
0.03050	9.77	6.77	12.33	17.01	15.53	14.55
0.03150	9.58	5.46	14.06	15.24	14.69	14.69
0.03250	8.64	4.66	13.81	14.76	13.67	14.01
0.03350	8.23	4.59	14.25	13.39	13.14	13.09
0.03450	7.35	3.65	13.33	13.09	12.19	13.68
0.03550	6.30	3.31	12.55	10.44	10.47	11.60
0.03650	6.40	2.95	11.35	10.51	11.03	11.85
0.03750	5.86	2.50	10.66	12.07	10.17	12.74
0.03850	5.55	2.37	9.38	12.63	10.52	12.86
0.03950	5.17	2.02	8.56	12.38	10.25	12.09
0.04050	4.98	1.96	7.88	12.98	10.12	12.69
0.04150	4.41	1.77	7.22	12.36	9.37	11.99
0.04250	4.06	1.23	6.26	11.66	8.36	11.41
0.04350	3.49	0.87	5.91	10.72	8.23	10.30
0.04450	3.50	0.86	5.76	10.42	6.99	10.53
0.04550	3.26	0.65	5.28	8.46	7.04	9.29
0.04650	2.80	0.66	4.72	8.28	6.94	8.54
0.04750	2.72	0.38	4.77	7.41	6.66	7.77
0.04850	2.15	0.45	4.41	6.65	5.97	7.93
0.04950	2.25	0.32	3.36	6.57	5.48	7.32
0.05250	1.39	0.16	2.92	11.06	2.48	4.84
0.05750	0.30	0.07	3.17	2.86	0.81	4.48
0.06250	0.35	0.05	3.22	2.22	0.90	4.30
0.06750	0.43	0.01	2.83	1.81	1.06	3.63
0.07250	1.02	0.01	2.54	1.70	5.23	2.92
0.07750	1.22	0.0	2.31	1.61	12.58	2.12
0.08250	0.07	0.00	1.82	1.75	1.15	1.67
0.08750	0.05	0.0	1.55	1.64	0.83	1.29
0.09250	0.02	0.00	1.19	1.65	0.53	1.00
0.09750	0.03	0.0	0.85	2.03	0.53	1.20
0.11250	0.01	0.0	0.27	0.35	0.46	0.34
0.13750	0.00	0.0	0.20	0.11	0.27	0.08
0.16250	0.0	0.0	0.02	0.00	0.13	0.03
0.18750	0.0	0.0	0.01	0.00	0.06	0.01
0.22500	0.0	0.0	0.00	0.07	0.03	0.01
0.27500	0.0	0.0	0.0	0.0	0.0	0.0
0.32500	0.0	0.0	0.0	0.0	0.0	0.0
0.37500	0.0	0.0	0.0	0.0	0.0	0.0
0.45000	0.0	0.0	0.0	0.0	0.0	0.0
0.75000	0.0	0.0	0.0	0.0	0.0	0.0

TABLE C-3

***** AUTO SPECTRA, CROSS SPECTRA, AND COHERENCY SPECTRA *****

WG(LB/SEC)	0.0	0.0	0.0		0.0	0.0	0.0	
WL(LB/SEC)	0.0160	0.0160	0.0160		0.0280	0.0280	0.0280	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0127	0.0166	0.0111	0.5893	0.0094	0.0113	0.0073	0.5011
0.67	0.0149	0.0193	0.0127	0.5594	0.0207	0.0228	0.0167	0.5906
1.16	0.0158	0.0190	0.0116	0.4508	0.0273	0.0260	0.0197	0.5446
1.65	0.0171	0.0213	0.0102	0.2866	0.0238	0.0247	0.0126	0.2706
2.14	0.0181	0.0200	0.0095	0.2474	0.0230	0.0235	0.0096	0.1716
2.63	0.0202	0.0198	0.0087	0.1908	0.0264	0.0235	0.0132	0.2825
3.11	0.0206	0.0174	0.0055	0.0859	0.0252	0.0227	0.0076	0.1022
3.60	0.0216	0.0213	0.0079	0.1348	0.0281	0.0283	0.0111	0.1543
4.09	0.0241	0.0262	0.0084	0.1128	0.0323	0.0289	0.0054	0.0315
4.58	0.0363	0.0319	0.0119	0.1216	0.0350	0.0227	0.0064	0.0520
5.07	0.0391	0.0321	0.0143	0.1630	0.0338	0.0260	0.0063	0.0449
5.55	0.0409	0.0453	0.0181	0.1766	0.0309	0.0304	0.0055	0.0327
6.53	0.0435	0.0412	0.0137	0.1047	0.0341	0.0427	0.0084	0.0489
7.51	0.0357	0.0424	0.0097	0.0617	0.0276	0.0340	0.0056	0.0334
8.48	0.0459	0.0375	0.0092	0.0490	0.0285	0.0282	0.0061	0.0459
9.46	0.0323	0.0311	0.0073	0.0527	0.0262	0.0322	0.0048	0.0275
11.41	0.0246	0.0217	0.0033	0.0210	0.0255	0.0252	0.0055	0.0469
13.37	0.0157	0.0179	0.0027	0.0256	0.0181	0.0169	0.0031	0.0308
15.81	0.0135	0.0120	0.0020	0.0238	0.0111	0.0126	0.0026	0.0467
18.25	0.0083	0.0096	0.0014	0.0250	0.0094	0.0095	0.0021	0.0479
22.64	0.0065	0.0040	0.0008	0.3375	0.0059	0.0056	0.0009	0.0235
25.08	0.0034	0.0031	0.0007	0.0409	0.0043	0.0035	0.0006	0.0266
27.53	0.0026	0.0022	0.0004	0.0283	0.0026	0.0031	0.0007	0.0565
30.46	0.0019	0.0012	0.0003	0.0337	0.0020	0.0021	0.0004	0.0336
34.85	0.0010	0.0009	0.0001	0.0183	0.0013	0.0014	0.0003	0.0518
40.22	0.0006	0.0006	0.0001	0.0241	0.0009	0.0008	0.0001	0.0292
50.48	0.0002	0.0002	0.0000	0.0106	0.0004	0.0003	0.0001	0.0907
60.24	0.0002	0.0002	0.0001	0.3268	0.0002	0.0002	0.0000	0.0455
70.01	0.0002	0.0003	0.0002	0.6984	0.0002	0.0003	0.0002	0.4654
80.26	0.0000	0.0000	0.0	0.0	0.0001	0.0000	0.0000	0.0417

WG(LB/SEC)	0.0	0.0	0.0		0.0	0.0	0.0	
WL(LB/SEC)	0.0440	0.0440	0.0440		0.0800	0.0800	0.0800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0102	0.0128	0.0084	0.5456	0.0046	0.0060	0.0030	0.3275
0.67	0.0267	0.0310	0.0251	0.7570	0.0135	0.0163	0.0123	0.6805
1.16	0.0391	0.0459	0.0361	0.7241	0.0254	0.0291	0.0243	0.7980
1.65	0.0546	0.0586	0.0484	0.7311	0.0408	0.0442	0.0376	0.7835
2.14	0.0542	0.0474	0.0381	0.5643	0.0449	0.0455	0.0399	0.7778
2.63	0.0457	0.0460	0.0330	0.5175	0.0533	0.0484	0.0429	0.7125
3.11	0.0412	0.0455	0.0302	0.4876	0.0629	0.0615	0.0507	0.6649
3.60	0.0414	0.0416	0.0259	0.3890	0.0590	0.0529	0.0442	0.6275
4.09	0.0513	0.0380	0.0274	0.3842	0.0470	0.0509	0.0345	0.4994
4.58	0.0348	0.0396	0.0213	0.3293	0.0427	0.0372	0.0256	0.4133
5.07	0.0348	0.0331	0.0145	0.1815	0.0535	0.0431	0.0346	0.5207
5.55	0.0325	0.0302	0.0134	0.1837	0.0422	0.0468	0.0303	0.4656
6.53	0.0298	0.0268	0.0083	0.0861	0.0307	0.0350	0.0140	0.1818
7.51	0.0229	0.0236	0.0059	0.0653	0.0255	0.0247	0.0115	0.2120
8.48	0.0199	0.0218	0.0080	0.1466	0.0226	0.0226	0.0067	0.0880
9.46	0.0212	0.0166	0.0044	0.0550	0.0141	0.0185	0.0043	0.0702
11.41	0.0130	0.0151	0.0037	0.0706	0.0135	0.0162	0.0024	0.0269
13.37	0.0119	0.0118	0.0020	0.0290	0.0093	0.0115	0.0033	0.1033
15.81	0.0083	0.0085	0.0020	0.0586	0.0086	0.0077	0.0020	0.0631
18.25	0.0053	0.0077	0.0012	0.0332	0.0062	0.0058	0.0020	0.1099
22.64	0.0046	0.0047	0.0007	0.0200	0.0041	0.0036	0.0008	0.0415
25.08	0.0033	0.0035	0.0006	0.0295	0.0028	0.0032	0.0005	0.0234
27.53	0.0026	0.0028	0.0006	0.0485	0.0022	0.0023	0.0005	0.0470
30.46	0.0020	0.0019	0.0003	0.0312	0.0017	0.0018	0.0003	0.0333
34.85	0.0015	0.0013	0.0002	0.0187	0.0014	0.0012	0.0003	0.0700
40.22	0.0011	0.0008	0.0002	0.0376	0.0008	0.0008	0.0001	0.0306
50.48	0.0006	0.0004	0.0001	0.0616	0.0003	0.0003	0.0000	0.0300
60.24	0.0004	0.0002	0.0000	0.0202	0.0002	0.0002	0.0000	0.0331
70.01	0.0003	0.0002	0.0001	0.0714	0.0001	0.0001	0.0000	0.0682
80.26	0.0002	0.0000	0.0000	0.0900	0.0000	0.0000	0.0	0.0

WG(LB/SEC)	0.0	0.0	0.0		0.0	0.0	0.0	
WL(LB/SEC)	0.1260	0.1260	0.1260		0.1800	0.1800	0.1800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0033	0.0045	0.0025	0.4372	0.0036	0.0044	0.0026	0.4347
0.67	0.0069	0.0086	0.0059	0.5821	0.0070	0.0080	0.0061	0.6723
1.16	0.0145	0.0174	0.0138	0.7560	0.0091	0.0115	0.0082	0.6433
1.65	0.0203	0.0211	0.0184	0.7887	0.0140	0.0149	0.0119	0.6798
2.14	0.0338	0.0330	0.0296	0.7861	0.0193	0.0237	0.0186	0.7524
2.63	0.0438	0.0473	0.0403	0.7864	0.0310	0.0300	0.0263	0.7425
3.11	0.0516	0.0468	0.0428	0.7560	0.0413	0.0400	0.0352	0.7413
3.60	0.1013	0.0978	0.0936	0.8846	0.0619	0.0611	0.0552	0.8039
4.09	0.0627	0.0575	0.0522	0.7565	0.0654	0.0578	0.0547	0.7922
4.58	0.0596	0.0436	0.0432	0.7191	0.0709	0.0690	0.0632	0.8153
5.07	0.0521	0.0528	0.0386	0.5420	0.0770	0.0625	0.0584	0.7092
5.55	0.0338	0.0345	0.0234	0.4677	0.0557	0.0427	0.0379	0.6027
6.53	0.0335	0.0316	0.0199	0.3730	0.0382	0.0378	0.0266	0.4906
7.51	0.0296	0.0273	0.0148	0.2695	0.0269	0.0228	0.0131	0.2787
8.48	0.0320	0.0279	0.0144	0.2317	0.0240	0.0291	0.0136	0.2648
9.46	0.0188	0.0185	0.0071	0.1450	0.0203	0.0213	0.0101	0.2390
11.41	0.0153	0.0124	0.0037	0.0717	0.0145	0.0166	0.0054	0.1220
13.37	0.0110	0.0111	0.0021	0.0365	0.0111	0.0129	0.0028	0.0545
15.81	0.0077	0.0082	0.0018	0.0530	0.0081	0.0118	0.0025	0.0667
18.25	0.0059	0.0060	0.0012	0.0393	0.0085	0.0075	0.0021	0.0710
22.64	0.0037	0.0035	0.0002	0.0048	0.0036	0.0045	0.0006	0.0224
25.08	0.0023	0.0032	0.0006	0.0486	0.0032	0.0030	0.0006	0.0418
27.53	0.0018	0.0021	0.0004	0.0362	0.0020	0.0026	0.0002	0.0082
30.46	0.0017	0.0018	0.0003	0.0283	0.0019	0.0020	0.0003	0.0234
34.85	0.0010	0.0013	0.0002	0.0193	0.0012	0.0014	0.0002	0.0349
40.22	0.0006	0.0008	0.0001	0.0389	0.0006	0.0009	0.0002	0.0603
50.48	0.0003	0.0003	0.0000	0.0289	0.0003	0.0005	0.0001	0.0694
60.24	0.0001	0.0001	0.0000	0.0500	0.0001	0.0002	0.0000	0.0926
70.01	0.0001	0.0001	0.0000	0.0833	0.0001	0.0001	0.0000	0.0865
80.26	0.0000	0.0000	0.0	0.0	0.0000	0.0001	0.0	0.0

WG(LB/SEC)	0.0	0.0	0.0		0.0	0.0	0.0	
WL(LB/SEC)	0.2400	0.2400	0.2400		0.3500	0.3500	0.3500	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0042	0.0042	0.0031	0.5270	0.0042	0.0041	0.0031	0.5732
0.67	0.0070	0.0066	0.0055	0.6628	0.0053	0.0043	0.0036	0.5680
1.16	0.0113	0.0112	0.0095	0.7148	0.0101	0.0092	0.0081	0.7192
1.65	0.0138	0.0138	0.0110	0.6361	0.0156	0.0143	0.0129	0.7486
2.14	0.0168	0.0171	0.0134	0.6199	0.0222	0.0230	0.0199	0.7764
2.63	0.0179	0.0230	0.0159	0.6157	0.0330	0.0289	0.0261	0.7137
3.11	0.0225	0.0266	0.0199	0.6614	0.0371	0.0417	0.0354	0.8117
3.60	0.0536	0.0562	0.0493	0.8064	0.0649	0.0624	0.0595	0.8741
4.09	0.0579	0.0652	0.0547	0.7932	0.0544	0.0556	0.0489	0.7914
4.58	0.0619	0.0519	0.0488	0.7418	0.0535	0.0455	0.0434	0.7737
5.07	0.0566	0.0467	0.0414	0.6468	0.0507	0.0464	0.0420	0.7496
5.55	0.0571	0.0538	0.0436	0.6206	0.0409	0.0363	0.0303	0.6195
6.53	0.0452	0.0398	0.0265	0.3893	0.0468	0.0413	0.0333	0.5761
7.51	0.0381	0.0317	0.0208	0.3569	0.0409	0.0314	0.0220	0.3772
8.48	0.0279	0.0236	0.0123	0.2281	0.0306	0.0278	0.0182	0.3900
9.46	0.0227	0.0257	0.0125	0.2684	0.0233	0.0201	0.0121	0.3143
11.41	0.0170	0.0165	0.0052	0.0984	0.0154	0.0163	0.0067	0.1816
13.37	0.0143	0.0168	0.0038	0.0590	0.0163	0.0144	0.0066	0.1839
15.81	0.0109	0.0098	0.0018	0.0313	0.0105	0.0111	0.0022	0.0401
18.25	0.0057	0.0070	0.0011	0.0280	0.0062	0.0075	0.0018	0.0740
22.64	0.0035	0.0048	0.0011	0.0772	0.0052	0.0047	0.0009	0.0310
25.08	0.0027	0.0037	0.0004	0.0199	0.0037	0.0036	0.0005	0.0187
27.53	0.0024	0.0022	0.0004	0.0246	0.0025	0.0028	0.0007	0.0802
30.46	0.0019	0.0025	0.0005	0.0508	0.0014	0.0021	0.0004	0.0671
34.85	0.0010	0.0020	0.0002	0.0273	0.0011	0.0015	0.0003	0.0591
40.22	0.0006	0.0009	0.0001	0.0390	0.0005	0.0009	0.0001	0.0456
50.48	0.0003	0.0004	0.0001	0.0673	0.0002	0.0003	0.0000	0.0326
60.24	0.0002	0.0002	0.0000	0.0281	0.0001	0.0002	0.0000	0.0214
70.01	0.0001	0.0001	0.0000	0.1282	0.0001	0.0002	0.0000	0.0662
80.26	0.0000	0.0000	0.0	0.0	0.0000	0.0001	0.0000	0.0286

WG(LB/SEC)	0.0	0.0	0.0		0.0	0.0	0.0	
WL(LB/SEC)	0.4700	0.4700	0.4700		0.5850	0.5850	0.5850	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0074	0.0068	0.0063	0.7916	0.0038	0.0032	0.0028	0.6627
0.67	0.0055	0.0055	0.0044	0.6517	0.0052	0.0047	0.0042	0.7229
1.16	0.0096	0.0084	0.0078	0.7671	0.0059	0.0067	0.0056	0.7855
1.65	0.0133	0.0143	0.0121	0.7771	0.0114	0.0116	0.0101	0.7703
2.14	0.0181	0.0193	0.0168	0.8058	0.0191	0.0225	0.0189	0.8333
2.63	0.0263	0.0296	0.0243	0.7544	0.0242	0.0256	0.0216	0.7542
3.11	0.0305	0.0312	0.0281	0.8275	0.0366	0.0370	0.0310	0.8508
3.60	0.0593	0.0556	0.0543	0.8919	0.0536	0.0563	0.0524	0.9087
4.09	0.0638	0.0591	0.0570	0.8608	0.0560	0.0557	0.0524	0.8805
4.58	0.0717	0.0591	0.0593	0.3302	0.0570	0.0553	0.0524	0.8697
5.07	0.0603	0.0567	0.0522	0.7966	0.0642	0.0590	0.0564	0.8388
5.55	0.0500	0.0424	0.0394	0.7312	0.0427	0.0391	0.0348	0.7287
6.53	0.0377	0.0350	0.0290	0.6375	0.0334	0.0324	0.0282	0.6407
7.51	0.0329	0.0312	0.0225	0.4920	0.0326	0.0293	0.0238	0.5902
8.48	0.0245	0.0301	0.0193	0.5029	0.0277	0.0315	0.0220	0.5544
9.46	0.0223	0.0210	0.0123	0.3205	0.0268	0.0287	0.0202	0.5299
11.41	0.0176	0.0184	0.0101	0.3145	0.0205	0.0199	0.0132	0.4531
13.37	0.0118	0.0130	0.0053	0.1826	0.0114	0.0127	0.0064	0.2857
15.81	0.0087	0.0109	0.0037	0.1426	0.0116	0.0102	0.0049	0.2033
18.25	0.0066	0.0060	0.0020	0.0985	0.0071	0.0100	0.0041	0.2381
22.64	0.0047	0.0053	0.0014	0.0829	0.0045	0.0047	0.0012	0.0671
25.08	0.0028	0.0031	0.0008	0.0710	0.0031	0.0037	0.0010	0.0826
27.53	0.0022	0.0028	0.0004	0.0275	0.0023	0.0023	0.0004	0.0288
30.46	0.0018	0.0020	0.0003	0.0241	0.0020	0.0014	0.0003	0.0232
34.85	0.0012	0.0014	0.0003	0.0466	0.0011	0.0012	0.0003	0.0595
40.22	0.0005	0.0007	0.0001	0.0413	0.0009	0.0005	0.0001	0.0253
50.48	0.0002	0.0004	0.0001	0.0561	0.0002	0.0003	0.0000	0.0323
60.24	0.0001	0.0002	0.0000	0.0407	0.0001	0.0002	0.0000	0.0364
70.01	0.0001	0.0001	0.0000	0.0769	0.0001	0.0002	0.0000	0.1634
80.26	0.0000	0.0001	0.0000	0.0333	0.0000	0.0000	0.0	0.0

WG(LB/SEC)	0.0450	0.0450	0.0450		0.0450	0.0450	0.0450	
WL(LB/SEC)	0.0160	0.0160	0.0160		0.0280	0.0280	0.0280	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0074	0.0087	0.0049	0.3682	0.0074	0.0090	0.0055	0.4456
0.67	0.0121	0.0104	0.0082	0.5384	0.0144	0.0163	0.0114	0.5518
1.16	0.0139	0.0135	0.0093	0.4616	0.0124	0.0125	0.0092	0.5462
1.65	0.0171	0.0181	0.0117	0.4438	0.0163	0.0172	0.0115	0.4752
2.14	0.0158	0.0175	0.0101	0.3657	0.0145	0.0159	0.0080	0.2758
2.63	0.0189	0.0199	0.0093	0.2279	0.0159	0.0257	0.0105	0.2714
3.11	0.0199	0.0176	0.0078	0.1739	0.0230	0.0157	0.0099	0.2745
3.60	0.0226	0.0194	0.0102	0.2361	0.0156	0.0178	0.0085	0.2628
4.09	0.0196	0.0256	0.0098	0.1913	0.0212	0.0201	0.0064	0.0957
4.58	0.0246	0.0258	0.0120	0.2268	0.0230	0.0239	0.0082	0.1006
5.07	0.0313	0.0260	0.0102	0.1284	0.0254	0.0257	0.0092	0.1291
5.55	0.0243	0.0264	0.0089	0.1246	0.0331	0.0295	0.0102	0.1069
6.53	0.0328	0.0334	0.0060	0.0332	0.0308	0.0274	0.0041	0.0200
7.51	0.0383	0.0394	0.0120	0.0959	0.0417	0.0391	0.0080	0.0389
8.48	0.0456	0.0393	0.0088	0.0434	0.0319	0.0306	0.0057	0.0329
9.46	0.0354	0.0290	0.0067	0.0436	0.0283	0.0365	0.0053	0.0268
11.41	0.0306	0.0236	0.0034	0.0158	0.0227	0.0267	0.0036	0.0213
13.37	0.0196	0.0184	0.0026	0.0190	0.0171	0.0190	0.0028	0.0242
15.81	0.0136	0.0142	0.0020	0.0204	0.0140	0.0119	0.0024	0.0351
18.25	0.0095	0.0078	0.0025	0.0885	0.0091	0.0137	0.0023	0.0423
22.64	0.0043	0.0060	0.0011	0.0468	0.0062	0.0055	0.0015	0.0639
25.08	0.0043	0.0029	0.0008	0.0575	0.0047	0.0047	0.0011	0.0542
27.53	0.0027	0.0029	0.0007	0.0705	0.0032	0.0033	0.0002	0.0035
30.46	0.0018	0.0023	0.0004	0.0445	0.0028	0.0021	0.0004	0.0301
34.85	0.0012	0.0014	0.0003	0.0447	0.0014	0.0016	0.0004	0.0719
40.22	0.0008	0.0006	0.0002	0.0712	0.0011	0.0009	0.0002	0.0269
50.48	0.0002	0.0002	0.0001	0.0720	0.0004	0.0003	0.0001	0.0296
60.24	0.0001	0.0001	0.0000	0.1039	0.0002	0.0002	0.0000	0.0423
70.01	0.0001	0.0001	0.0000	0.0278	0.0001	0.0001	0.0000	0.0455
80.26	0.0000	0.0000	0.0	0.0	0.0001	0.0000	0.0000	0.0286

WG(LB/SEC)	0.0450	0.0450	0.0450		0.0450	0.0450	0.0450	
WL(LB/SEC)	0.0440	0.0440	0.0440		0.0800	0.0800	0.0800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0091	0.0150	0.0089	0.5874	0.0055	0.0073	0.0042	0.4382
0.67	0.0248	0.0310	0.0237	0.7282	0.0146	0.0202	0.0144	0.7073
1.16	0.0469	0.0458	0.0407	0.7715	0.0352	0.0375	0.0330	0.8260
1.65	0.0504	0.0530	0.0425	0.6768	0.0439	0.0468	0.0412	0.8275
2.14	0.0499	0.0353	0.0327	0.6074	0.0514	0.0555	0.0483	0.8174
2.63	0.0430	0.0443	0.0327	0.5618	0.0488	0.0540	0.0434	0.7135
3.11	0.0501	0.0466	0.0340	0.4959	0.0637	0.0597	0.0540	0.7663
3.60	0.0356	0.0402	0.0228	0.3638	0.0554	0.0557	0.0459	0.6818
4.09	0.0402	0.0342	0.0212	0.3279	0.0460	0.0438	0.0321	0.5126
4.58	0.0398	0.0446	0.0229	0.2950	0.0454	0.0452	0.0326	0.5173
5.07	0.0322	0.0309	0.0152	0.2325	0.0328	0.0332	0.0201	0.3708
5.55	0.0313	0.0365	0.0127	0.1418	0.0504	0.0458	0.0338	0.4958
6.53	0.0302	0.0293	0.0121	0.1662	0.0299	0.0331	0.0201	0.4101
7.51	0.0234	0.0228	0.0073	0.1001	0.0261	0.0203	0.0099	0.1833
8.48	0.0254	0.0230	0.0038	0.0244	0.0217	0.0269	0.0104	0.1840
9.46	0.0179	0.0168	0.0043	0.0625	0.0197	0.0221	0.0093	0.1976
11.41	0.0146	0.0173	0.0029	0.0331	0.0186	0.0141	0.0038	0.0543
13.37	0.0121	0.0120	0.0035	0.0840	0.0102	0.0096	0.0018	0.0328
15.81	0.0117	0.0103	0.0016	0.0206	0.0081	0.0089	0.0020	0.0552
18.25	0.0071	0.0069	0.0016	0.0532	0.0065	0.0065	0.0011	0.0268
22.64	0.0052	0.0045	0.0011	0.0513	0.0036	0.0038	0.0009	0.0553
25.08	0.0033	0.0033	0.0006	0.0319	0.0027	0.0027	0.0006	0.0478
27.53	0.0027	0.0032	0.0008	0.0706	0.0028	0.0022	0.0005	0.0344
30.46	0.0020	0.0024	0.0005	0.0516	0.0019	0.0016	0.0003	0.0382
34.85	0.0013	0.0013	0.0002	0.0284	0.0011	0.0011	0.0003	0.0759
40.22	0.0008	0.0007	0.0001	0.0291	0.0007	0.0007	0.0002	0.0509
50.48	0.0004	0.0004	0.0000	0.0173	0.0003	0.0003	0.0000	0.0299
60.24	0.0002	0.0002	0.0000	0.0189	0.0002	0.0001	0.0000	0.0672
70.01	0.0001	0.0001	0.0000	0.0364	0.0001	0.0001	0.0000	0.0238
80.26	0.0000	0.0000	0.0	0.0	0.0000	0.0000	0.0	0.0

WG(LB/SEC)	0.0450	0.0450	0.0450		0.0450	0.0450	0.0450	
WL(LB/SEC)	0.1260	0.1260	0.1260		0.1800	0.1800	0.1800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0041	0.0045	0.0032	0.5732	0.0039	0.0042	0.0027	0.4395
0.67	0.0070	0.0093	0.0067	0.6794	0.0070	0.0089	0.0067	0.7242
1.16	0.0165	0.0184	0.0151	0.7524	0.0118	0.0137	0.0109	0.7371
1.65	0.0237	0.0233	0.0205	0.7600	0.0198	0.0220	0.0186	0.7929
2.14	0.0318	0.0360	0.0302	0.7971	0.0197	0.0244	0.0187	0.7290
2.63	0.0450	0.0502	0.0432	0.8253	0.0299	0.0333	0.0271	0.7391
3.11	0.0546	0.0593	0.0514	0.8150	0.0409	0.0451	0.0384	0.7996
3.60	0.0697	0.0638	0.0603	0.8183	0.0589	0.0632	0.0555	0.8268
4.09	0.0650	0.0577	0.0542	0.7841	0.0697	0.0626	0.0579	0.7683
4.58	0.0517	0.0490	0.0430	0.7301	0.0674	0.0643	0.0594	0.8149
5.07	0.0523	0.0468	0.0406	0.6731	0.0613	0.0562	0.0488	0.6923
5.55	0.0476	0.0434	0.0330	0.5276	0.0482	0.0481	0.0374	0.6029
6.53	0.0423	0.0346	0.0276	0.5197	0.0396	0.0321	0.0236	0.4381
7.51	0.0311	0.0323	0.0207	0.4290	0.0319	0.0305	0.0193	0.3829
8.48	0.0220	0.0248	0.0118	0.2563	0.0321	0.0286	0.0194	0.4097
9.46	0.0219	0.0185	0.0085	0.1782	0.0201	0.0196	0.0094	0.2247
11.41	0.0118	0.0164	0.0034	0.0589	0.0146	0.0143	0.0029	0.0414
13.37	0.0101	0.0096	0.0018	0.0340	0.0145	0.0121	0.0035	0.0686
15.81	0.0100	0.0074	0.0021	0.0567	0.0087	0.0075	0.0011	0.0195
18.25	0.0055	0.0063	0.0019	0.1035	0.0059	0.0050	0.0011	0.0433
22.64	0.0031	0.0036	0.0006	0.0350	0.0034	0.0042	0.0006	0.0296
25.08	0.0024	0.0028	0.0003	0.0179	0.0024	0.0027	0.0006	0.0551
27.53	0.0019	0.0021	0.0004	0.0442	0.0017	0.0022	0.0004	0.0355
30.46	0.0014	0.0016	0.0003	0.0367	0.0015	0.0016	0.0003	0.0370
34.85	0.0009	0.0011	0.0001	0.0147	0.0009	0.0010	0.0002	0.0268
40.22	0.0006	0.0007	0.0001	0.0253	0.0005	0.0006	0.0001	0.0426
50.48	0.0003	0.0003	0.0000	0.0192	0.0002	0.0003	0.0001	0.0576
60.24	0.0001	0.0001	0.0000	0.0462	0.0001	0.0001	0.0000	0.0256
70.01	0.0001	0.0001	0.0000	0.0238	0.0001	0.0001	0.0000	0.0179
80.26	0.0000	0.0000	0.0	0.0	0.0000	0.0000	0.0	0.0

CELL FREQ.(CPS)	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
WG(LB/SEC)	0.0450	0.0450	0.0450		0.0450	0.0450	0.0450	
WL(LB/SEC)	0.2400	0.2400	0.2400		0.3500	0.3500	0.3500	
	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0036	0.0041	0.0026	0.4422	0.0041	0.0045	0.0031	0.5328
0.67	0.0074	0.0080	0.0061	0.6335	0.0065	0.0068	0.0055	0.6895
1.16	0.0109	0.0128	0.0104	0.7708	0.0081	0.0082	0.0065	0.6459
1.65	0.0181	0.0192	0.0165	0.7860	0.0131	0.0141	0.0116	0.7277
2.14	0.0177	0.0197	0.0152	0.6646	0.0170	0.0197	0.0158	0.7464
2.63	0.0272	0.0270	0.0215	0.6288	0.0247	0.0273	0.0208	0.6436
3.11	0.0408	0.0404	0.0355	0.7644	0.0368	0.0356	0.0315	0.7560
3.60	0.0454	0.0449	0.0402	0.7929	0.0409	0.0415	0.0363	0.7753
4.09	0.0508	0.0445	0.0424	0.7967	0.0574	0.0532	0.0493	0.7964
4.58	0.0608	0.0575	0.0509	0.7415	0.0756	0.0737	0.0690	0.8551
5.07	0.0691	0.0630	0.0565	0.7338	0.0628	0.0552	0.0515	0.7645
5.55	0.0503	0.0538	0.0400	0.5921	0.0427	0.0372	0.0333	0.6970
6.53	0.0510	0.0440	0.0354	0.5581	0.0389	0.0386	0.0290	0.5586
7.51	0.0327	0.0337	0.0214	0.4165	0.0319	0.0332	0.0213	0.4265
8.48	0.0314	0.0296	0.0166	0.2976	0.0219	0.0207	0.0107	0.2544
9.46	0.0280	0.0240	0.0150	0.3350	0.0239	0.0206	0.0116	0.2724
11.41	0.0179	0.0177	0.0074	0.1723	0.0195	0.0210	0.0096	0.2239
13.37	0.0140	0.0109	0.0034	0.0761	0.0128	0.0160	0.0048	0.1121
15.81	0.0094	0.0086	0.0014	0.0247	0.0086	0.0079	0.0024	0.0861
18.25	0.0073	0.0066	0.0019	0.0757	0.0062	0.0072	0.0012	0.0337
22.64	0.0040	0.0039	0.0010	0.0705	0.0040	0.0040	0.0010	0.0627
25.03	0.0026	0.0032	0.0007	0.0659	0.0031	0.0038	0.0004	0.0165
27.53	0.0020	0.0026	0.0004	0.0360	0.0014	0.0022	0.0004	0.0419
30.46	0.0014	0.0018	0.0003	0.0468	0.0017	0.0015	0.0003	0.0462
34.85	0.0009	0.0010	0.0002	0.0488	0.0010	0.0013	0.0001	0.0177
40.22	0.0006	0.0007	0.0001	0.0406	0.0005	0.0006	0.0001	0.0154
50.48	0.0003	0.0003	0.0000	0.0308	0.0002	0.0003	0.0000	0.0336
60.24	0.0001	0.0001	0.0000	0.0303	0.0001	0.0001	0.0000	0.0280
70.01	0.0001	0.0001	0.0000	0.0208	0.0001	0.0001	0.0000	0.0185
80.26	0.0000	0.0000	0.0	0.0	0.0000	0.0000	0.0	0.0

CELL FREQ.(CPS)	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
WG(LB/SEC)	0.0450	0.0450	0.0450		0.0450	0.0450	0.0450	
WL(LB/SEC)	0.4700	0.4700	0.4700		0.5850	0.5850	0.5850	
	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0043	0.0046	0.0038	0.7307	0.0051	0.0049	0.0041	0.6659
0.67	0.0056	0.0061	0.0048	0.6844	0.0047	0.0045	0.0036	0.6161
1.16	0.0085	0.0086	0.0075	0.7613	0.0077	0.0066	0.0060	0.7041
1.65	0.0127	0.0122	0.0107	0.7487	0.0120	0.0137	0.0111	0.7471
2.14	0.0176	0.0213	0.0171	0.7850	0.0145	0.0158	0.0132	0.7561
2.63	0.0206	0.0261	0.0204	0.7752	0.0213	0.0209	0.0184	0.7625
3.11	0.0371	0.0393	0.0350	0.8387	0.0325	0.0378	0.0315	0.8071
3.60	0.0405	0.0458	0.0395	0.8395	0.0424	0.0511	0.0428	0.8458
4.09	0.0485	0.0528	0.0463	0.8377	0.0475	0.0479	0.0442	0.8571
4.58	0.0548	0.0555	0.0497	0.8133	0.0655	0.0661	0.0614	0.8705
5.07	0.0713	0.0637	0.0616	0.8339	0.0563	0.0534	0.0507	0.8541
5.55	0.0542	0.0466	0.0440	0.7668	0.0564	0.0472	0.0459	0.7916
6.53	0.0387	0.0426	0.0332	0.6707	0.0389	0.0360	0.0310	0.6850
7.51	0.0324	0.0258	0.0210	0.5251	0.0279	0.0273	0.0203	0.5377
8.48	0.0328	0.0288	0.0215	0.4907	0.0346	0.0317	0.0248	0.5608
9.46	0.0253	0.0265	0.0162	0.3919	0.0237	0.0256	0.0161	0.4302
11.41	0.0178	0.0144	0.0094	0.3454	0.0203	0.0188	0.0122	0.3904
13.37	0.0122	0.0164	0.0068	0.2354	0.0137	0.0144	0.0083	0.3459
15.81	0.0097	0.0101	0.0040	0.1604	0.0103	0.0112	0.0047	0.1958
18.25	0.0083	0.0087	0.0025	0.0881	0.0076	0.0091	0.0036	0.1869
22.64	0.0045	0.0039	0.0011	0.0747	0.0038	0.0040	0.0010	0.0597
25.08	0.0026	0.0037	0.0006	0.0375	0.0031	0.0036	0.0009	0.0749
27.53	0.0029	0.0027	0.0004	0.0252	0.0019	0.0022	0.0004	0.0424
30.46	0.0019	0.0019	0.0003	0.0327	0.0017	0.0017	0.0004	0.0589
34.85	0.0010	0.0013	0.0003	0.0780	0.0010	0.0011	0.0002	0.0310
40.22	0.0005	0.0008	0.0001	0.0538	0.0005	0.0007	0.0001	0.0490
50.48	0.0003	0.0003	0.0000	0.0332	0.0002	0.0003	0.0001	0.0741
60.24	0.0001	0.0001	0.0000	0.0238	0.0001	0.0001	0.0000	0.0462
70.01	0.0001	0.0001	0.0000	0.0208	0.0001	0.0001	0.0000	0.0208
80.26	0.0000	0.0001	0.0000	0.0417	0.0000	0.0001	0.0	0.0

WG(LB/SEC)	0.0976	0.0976	0.0976		0.0976	0.0976	0.0976	
WL(LB/SEC)	0.0160	0.0160	0.0160		0.0280	0.0280	0.0280	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0037	0.0037	0.0018	0.2288	0.0107	0.0044	0.0029	0.1766
0.67	0.0041	0.0041	0.0023	0.3213	0.0080	0.0076	0.0049	0.3922
1.16	0.0067	0.0072	0.0046	0.4325	0.0108	0.0112	0.0082	0.5569
1.65	0.0094	0.0090	0.0059	0.4194	0.0129	0.0130	0.0088	0.4622
2.14	0.0096	0.0115	0.0057	0.2977	0.0131	0.0178	0.0133	0.5516
2.63	0.0137	0.0166	0.0097	0.4165	0.0204	0.0185	0.0131	0.4555
3.11	0.0121	0.0120	0.0068	0.3164	0.0208	0.0204	0.0138	0.4512
3.60	0.0104	0.0106	0.0046	0.1949	0.0214	0.0227	0.0112	0.2578
4.09	0.0108	0.0103	0.0026	0.0601	0.0269	0.0264	0.0150	0.3165
4.58	0.0161	0.0135	0.0037	0.0648	0.0203	0.0216	0.0075	0.1297
5.07	0.0154	0.0129	0.0046	0.1081	0.0263	0.0273	0.0138	0.2650
5.55	0.0123	0.0144	0.0049	0.1375	0.0265	0.0230	0.0106	0.1865
6.53	0.0167	0.0178	0.0045	0.0675	0.0275	0.0235	0.0069	0.0732
7.51	0.0180	0.0169	0.0045	0.0680	0.0223	0.0260	0.0057	0.0569
8.48	0.0161	0.0216	0.0033	0.0323	0.0246	0.0251	0.0042	0.0282
9.46	0.0222	0.0215	0.0052	0.0568	0.0222	0.0282	0.0065	0.0683
11.41	0.0261	0.0265	0.0047	0.0327	0.0195	0.0201	0.0033	0.0271
13.37	0.0231	0.0232	0.0041	0.0368	0.0236	0.0199	0.0046	0.0449
15.81	0.0234	0.0223	0.0055	0.0582	0.0131	0.0150	0.0022	0.0252
18.25	0.0185	0.0174	0.0034	0.0364	0.0150	0.0122	0.0023	0.0280
22.64	0.0119	0.0081	0.0018	0.0323	0.0101	0.0105	0.0018	0.0317
25.08	0.0091	0.0076	0.0019	0.0513	0.0089	0.0059	0.0016	0.0488
27.53	0.0063	0.0052	0.0009	0.0230	0.0050	0.0049	0.0009	0.0368
30.46	0.0034	0.0042	0.0007	0.0373	0.0034	0.0039	0.0009	0.0671
34.85	0.0031	0.0026	0.0008	0.0772	0.0025	0.0023	0.0004	0.0317
40.22	0.0018	0.0016	0.0003	0.0394	0.0017	0.0015	0.0002	0.0207
50.48	0.0006	0.0004	0.0001	0.0436	0.0007	0.0006	0.0002	0.0993
60.24	0.0007	0.0008	0.0006	0.5176	0.0007	0.0007	0.0004	0.2803
70.01	0.0017	0.0021	0.0018	0.8844	0.0012	0.0013	0.0011	0.7858
80.26	0.0001	0.0001	0.0000	0.0317	0.0001	0.0001	0.0000	0.0400

WG(LB/SEC)	0.0976	0.0976	0.0976		0.0976	0.0976	0.0976	
WL(LB/SEC)	0.0440	0.0440	0.0440		0.0800	0.0800	0.0300	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0111	0.0155	0.0106	0.6480	0.0030	0.0032	0.0019	0.3816
0.67	0.0266	0.0348	0.0269	0.7794	0.0103	0.0125	0.0095	0.6970
1.16	0.0434	0.0440	0.0396	0.8230	0.0145	0.0147	0.0123	0.7104
1.65	0.0398	0.0434	0.0353	0.7218	0.0201	0.0205	0.0174	0.7354
2.14	0.0314	0.0332	0.0259	0.6418	0.0233	0.0239	0.0197	0.6967
2.63	0.0351	0.0372	0.0255	0.4968	0.0265	0.0244	0.0208	0.6652
3.11	0.0346	0.0352	0.0263	0.5687	0.0367	0.0340	0.0308	0.7609
3.60	0.0342	0.0354	0.0244	0.4916	0.0340	0.0327	0.0284	0.7276
4.09	0.0343	0.0330	0.0225	0.4485	0.0310	0.0300	0.0233	0.5832
4.58	0.0308	0.0269	0.0168	0.3416	0.0318	0.0253	0.0211	0.5514
5.07	0.0292	0.0300	0.0139	0.2278	0.0283	0.0306	0.0218	0.5501
5.55	0.0256	0.0296	0.0126	0.2087	0.0297	0.0313	0.0234	0.5918
6.53	0.0225	0.0248	0.0072	0.0921	0.0273	0.0300	0.0189	0.4371
7.51	0.0229	0.0242	0.0102	0.1890	0.0248	0.0248	0.0138	0.3079
8.48	0.0187	0.0215	0.0063	0.0981	0.0237	0.0184	0.0085	0.1658
9.46	0.0220	0.0178	0.0053	0.0707	0.0214	0.0234	0.0091	0.1671
11.41	0.0136	0.0140	0.0032	0.0523	0.0193	0.0177	0.0064	0.1204
13.37	0.0105	0.0101	0.0032	0.0992	0.0130	0.0154	0.0034	0.0586
15.81	0.0083	0.0111	0.0018	0.0334	0.0115	0.0105	0.0021	0.0367
18.25	0.0085	0.0079	0.0017	0.0448	0.0103	0.0092	0.0030	0.0941
22.64	0.0064	0.0065	0.0011	0.0314	0.0075	0.0066	0.0011	0.0229
25.08	0.0056	0.0048	0.0010	0.0369	0.0052	0.0058	0.0010	0.0302
27.53	0.0036	0.0042	0.0007	0.0332	0.0061	0.0061	0.0012	0.0360
30.46	0.0033	0.0031	0.0003	0.0117	0.0036	0.0043	0.0006	0.0223
34.85	0.0023	0.0021	0.0002	0.0060	0.0030	0.0027	0.0007	0.0600
40.22	0.0018	0.0013	0.0002	0.0212	0.0025	0.0017	0.0003	0.0169
50.48	0.0007	0.0006	0.0002	0.0872	0.0008	0.0012	0.0001	0.0063
60.24	0.0005	0.0005	0.0001	0.0851	0.0005	0.0006	0.0001	0.0459
70.01	0.0004	0.0005	0.0002	0.2844	0.0004	0.0004	0.0001	0.0693
80.26	0.0001	0.0001	0.0000	0.0093	0.0002	0.0002	0.0000	0.0281

WG(LB/SEC)	0.0976	0.0976	0.0976		0.0976	0.0976	0.0976	
WL(LB/SEC)	0.1260	0.1260	0.1260		0.1800	0.1800	0.1800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0020	0.0022	0.0011	0.2673	0.0018	0.0020	0.0010	0.2478
0.67	0.0048	0.0054	0.0038	0.5692	0.0041	0.0041	0.0030	0.5325
1.16	0.0076	0.0076	0.0062	0.6688	0.0070	0.0083	0.0061	0.6360
1.65	0.0098	0.0108	0.0082	0.6320	0.0120	0.0114	0.0096	0.6822
2.14	0.0157	0.0169	0.0138	0.7127	0.0148	0.0156	0.0125	0.6763
2.63	0.0196	0.0197	0.0169	0.7436	0.0160	0.0153	0.0125	0.6395
3.11	0.0231	0.0203	0.0183	0.7129	0.0182	0.0200	0.0151	0.6293
3.60	0.0258	0.0262	0.0214	0.6785	0.0248	0.0227	0.0195	0.6726
4.09	0.0317	0.0367	0.0285	0.6988	0.0335	0.0305	0.0275	0.7388
4.58	0.0379	0.0396	0.0334	0.7415	0.0349	0.0328	0.0298	0.7751
5.07	0.0352	0.0325	0.0287	0.7171	0.0355	0.0355	0.0307	0.7465
5.55	0.0397	0.0294	0.0280	0.6709	0.0321	0.0291	0.0248	0.6600
6.53	0.0235	0.0234	0.0159	0.4634	0.0314	0.0231	0.0193	0.5149
7.51	0.0283	0.0262	0.0185	0.4602	0.0345	0.0277	0.0221	0.5139
8.48	0.0234	0.0235	0.0145	0.3835	0.0277	0.0205	0.0169	0.5037
9.46	0.0240	0.0240	0.0146	0.3714	0.0229	0.0206	0.0133	0.3785
11.41	0.0174	0.0191	0.0084	0.2149	0.0168	0.0175	0.0079	0.2152
13.37	0.0179	0.0137	0.0055	0.1241	0.0170	0.0172	0.0085	0.2465
15.81	0.0122	0.0119	0.0032	0.0697	0.0127	0.0136	0.0046	0.1225
18.25	0.0110	0.0113	0.0023	0.0423	0.0119	0.0096	0.0033	0.0989
22.64	0.0083	0.0087	0.0021	0.0637	0.0071	0.0077	0.0022	0.0884
25.08	0.0064	0.0055	0.0010	0.0270	0.0050	0.0062	0.0012	0.0450
27.53	0.0051	0.0049	0.0007	0.0226	0.0048	0.0059	0.0010	0.0329
30.46	0.0037	0.0035	0.0005	0.0208	0.0030	0.0042	0.0007	0.0411
34.85	0.0025	0.0025	0.0003	0.0151	0.0033	0.0030	0.0007	0.0462
40.22	0.0016	0.0023	0.0002	0.0175	0.0018	0.0018	0.0002	0.0196
50.48	0.0009	0.0010	0.0002	0.0417	0.0008	0.0008	0.0001	0.0225
60.24	0.0004	0.0006	0.0001	0.0434	0.0005	0.0005	0.0001	0.0133
70.01	0.0003	0.0004	0.0001	0.0556	0.0003	0.0004	0.0001	0.1861
80.26	0.0001	0.0002	0.0000	0.0179	0.0001	0.0001	0.0000	0.0400

WG(LB/SEC)	0.0976	0.0976	0.0976		0.0976	0.0976	0.0976	
WL(LB/SEC)	0.2400	0.2400	0.2400		0.3500	0.3500	0.3500	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0021	0.0021	0.0011	0.2782	0.0024	0.0022	0.0012	0.2845
0.67	0.0043	0.0043	0.0031	0.5417	0.0048	0.0046	0.0034	0.5319
1.16	0.0077	0.0077	0.0064	0.6961	0.0075	0.0080	0.0060	0.6014
1.65	0.0129	0.0112	0.0100	0.6941	0.0111	0.0126	0.0101	0.7285
2.14	0.0188	0.0183	0.0159	0.7379	0.0167	0.0173	0.0154	0.8148
2.63	0.0198	0.0211	0.0171	0.6962	0.0184	0.0201	0.0165	0.7420
3.11	0.0274	0.0261	0.0232	0.7515	0.0248	0.0254	0.0221	0.7745
3.60	0.0301	0.0298	0.0266	0.7909	0.0313	0.0321	0.0288	0.8217
4.09	0.0297	0.0334	0.0268	0.7245	0.0319	0.0345	0.0295	0.7897
4.58	0.0345	0.0347	0.0307	0.7863	0.0297	0.0300	0.0252	0.7126
5.07	0.0290	0.0298	0.0246	0.6990	0.0387	0.0379	0.0322	0.7056
5.55	0.0288	0.0307	0.0240	0.6492	0.0366	0.0344	0.0296	0.6976
6.53	0.0294	0.0261	0.0208	0.5640	0.0337	0.0284	0.0250	0.6552
7.51	0.0283	0.0284	0.0199	0.4917	0.0281	0.0263	0.0215	0.6279
8.48	0.0229	0.0231	0.0134	0.3412	0.0275	0.0262	0.0179	0.4439
9.46	0.0250	0.0237	0.0156	0.4126	0.0232	0.0214	0.0136	0.3751
11.41	0.0227	0.0208	0.0119	0.3004	0.0212	0.0212	0.0122	0.3308
13.37	0.0156	0.0192	0.0082	0.2226	0.0182	0.0148	0.0071	0.1844
15.81	0.0120	0.0128	0.0036	0.0865	0.0135	0.0130	0.0050	0.1422
18.25	0.0125	0.0107	0.0038	0.1063	0.0094	0.0098	0.0033	0.1166
22.64	0.0067	0.0075	0.0016	0.0505	0.0062	0.0062	0.0017	0.0784
25.08	0.0061	0.0060	0.0017	0.0799	0.0051	0.0063	0.0014	0.0573
27.53	0.0051	0.0040	0.0009	0.0403	0.0037	0.0047	0.0008	0.0333
30.46	0.0036	0.0040	0.0007	0.0345	0.0032	0.0042	0.0007	0.0412
34.85	0.0025	0.0025	0.0002	0.0090	0.0026	0.0028	0.0007	0.0697
40.22	0.0017	0.0018	0.0002	0.0115	0.0015	0.0018	0.0003	0.0331
50.48	0.0008	0.0010	0.0001	0.0283	0.0006	0.0009	0.0001	0.0278
60.24	0.0005	0.0005	0.0001	0.0209	0.0004	0.0005	0.0001	0.0862
70.01	0.0003	0.0003	0.0001	0.1235	0.0003	0.0003	0.0001	0.1183
80.26	0.0001	0.0002	0.0000	0.0171	0.0001	0.0001	0.0000	0.0077

WG(LB/SEC)	0.0976	0.0976	0.0976		0.0976	0.0976	0.0976	
WL(LB/SEC)	0.4700	0.4700	0.4700		0.5850	0.5850	0.5850	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0015	0.0020	0.0009	0.3022	0.0026	0.0029	0.0017	0.3994
0.67	0.0029	0.0033	0.0021	0.4323	0.0046	0.0039	0.0031	0.5355
1.16	0.0052	0.0068	0.0047	0.6115	0.0082	0.0076	0.0063	0.6519
1.65	0.0116	0.0130	0.0109	0.7844	0.0117	0.0131	0.0104	0.7080
2.14	0.0138	0.0147	0.0124	0.7586	0.0164	0.0154	0.0143	0.8032
2.63	0.0205	0.0207	0.0177	0.7414	0.0213	0.0230	0.0200	0.8159
3.11	0.0267	0.0289	0.0249	0.8006	0.0271	0.0278	0.0248	0.8159
3.60	0.0284	0.0321	0.0274	0.8232	0.0358	0.0352	0.0324	0.8315
4.09	0.0312	0.0297	0.0272	0.7967	0.0452	0.0419	0.0403	0.8571
4.58	0.0424	0.0391	0.0370	0.8251	0.0386	0.0407	0.0354	0.7971
5.07	0.0326	0.0347	0.0291	0.7503	0.0413	0.0434	0.0383	0.8194
5.55	0.0382	0.0413	0.0354	0.7934	0.0378	0.0378	0.0322	0.7263
6.53	0.0377	0.0302	0.0287	0.7240	0.0303	0.0353	0.0278	0.7116
7.51	0.0345	0.0327	0.0269	0.6395	0.0272	0.0260	0.0202	0.5756
8.48	0.0265	0.0308	0.0218	0.5832	0.0231	0.0243	0.0177	0.5594
9.46	0.0252	0.0220	0.0168	0.5063	0.0298	0.0248	0.0201	0.5455
11.41	0.0205	0.0193	0.0131	0.4351	0.0185	0.0129	0.0093	0.3630
13.37	0.0156	0.0173	0.0081	0.2456	0.0165	0.0149	0.0084	0.2910
15.81	0.0134	0.0169	0.0083	0.3052	0.0122	0.0138	0.0063	0.2357
18.25	0.0099	0.0077	0.0026	0.0878	0.0091	0.0093	0.0028	0.0898
22.64	0.0063	0.0080	0.0023	0.1035	0.0051	0.0058	0.0010	0.0361
25.08	0.0053	0.0046	0.0013	0.0692	0.0047	0.0046	0.0015	0.1099
27.53	0.0040	0.0046	0.0008	0.0366	0.0031	0.0039	0.0006	0.0264
30.46	0.0025	0.0031	0.0008	0.0779	0.0024	0.0031	0.0007	0.0635
34.85	0.0019	0.0025	0.0004	0.0370	0.0015	0.0019	0.0003	0.0364
40.22	0.0013	0.0014	0.0002	0.0215	0.0011	0.0011	0.0003	0.0693
50.48	0.0005	0.0007	0.0001	0.0320	0.0004	0.0006	0.0001	0.0390
60.24	0.0003	0.0004	0.0000	0.0141	0.0002	0.0003	0.0001	0.0627
70.01	0.0002	0.0003	0.0001	0.3000	0.0002	0.0003	0.0001	0.2401
80.26	0.0001	0.0001	0.0000	0.0085	0.0001	0.0001	0.0000	0.0331

WG(LB/SEC)	0.1436	0.1436	0.1436		0.1436	0.1436	0.1436	
WL(LB/SEC)	0.0160	0.0160	0.0160		0.0280	0.0280	0.0280	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0071	0.0072	0.0040	0.3130	0.0070	0.0071	0.0050	0.4957
0.67	0.0056	0.0061	0.0020	0.1190	0.0079	0.0075	0.0054	0.4896
1.16	0.0045	0.0046	0.0024	0.2801	0.0091	0.0082	0.0061	0.4952
1.65	0.0039	0.0048	0.0022	0.2491	0.0123	0.0120	0.0086	0.4989
2.14	0.0053	0.0062	0.0021	0.1339	0.0144	0.0158	0.0114	0.5729
2.63	0.0108	0.0133	0.0089	0.5483	0.0215	0.0225	0.0164	0.5581
3.11	0.0046	0.0049	0.0018	0.1521	0.0192	0.0201	0.0124	0.4005
3.60	0.0043	0.0045	0.0015	0.1253	0.0157	0.0172	0.0082	0.2464
4.09	0.0051	0.0052	0.0019	0.1428	0.0166	0.0212	0.0085	0.2057
4.58	0.0047	0.0067	0.0024	0.1771	0.0201	0.0203	0.0091	0.2036
5.07	0.0077	0.0064	0.0023	0.1096	0.0214	0.0170	0.0074	0.1521
5.55	0.0044	0.0058	0.0016	0.1035	0.0255	0.0209	0.0098	0.1810
6.53	0.0062	0.0064	0.0012	0.0389	0.0214	0.0240	0.0083	0.1329
7.51	0.0068	0.0060	0.0013	0.0384	0.0160	0.0186	0.0041	0.0566
8.48	0.0060	0.0081	0.0013	0.0366	0.0191	0.0191	0.0040	0.0437
9.46	0.0078	0.0084	0.0015	0.0363	0.0177	0.0205	0.0030	0.0250
11.41	0.0091	0.0111	0.0022	0.0493	0.0185	0.0209	0.0033	0.0282
13.37	0.0138	0.0152	0.0036	0.0635	0.0133	0.0222	0.0041	0.0576
15.81	0.0203	0.0198	0.0046	0.0536	0.0150	0.0171	0.0054	0.1142
18.25	0.0189	0.0224	0.0050	0.0591	0.0121	0.0140	0.0020	0.0245
22.64	0.0217	0.0175	0.0033	0.0292	0.0104	0.0106	0.0015	0.0205
25.08	0.0144	0.0128	0.0023	0.0281	0.0091	0.0076	0.0025	0.0895
27.53	0.0129	0.0102	0.0020	0.0309	0.0064	0.0051	0.0013	0.0510
30.46	0.0099	0.0099	0.0011	0.0128	0.0065	0.0051	0.0009	0.0315
34.85	0.0061	0.0052	0.0009	0.0286	0.0037	0.0037	0.0010	0.0698
40.22	0.0040	0.0034	0.0007	0.0360	0.0024	0.0025	0.0004	0.0292
50.48	0.0015	0.0010	0.0003	0.0691	0.0013	0.0008	0.0001	0.0158
60.24	0.0005	0.0007	0.0001	0.0317	0.0005	0.0004	0.0001	0.0351
70.01	0.0003	0.0005	0.0001	0.0600	0.0003	0.0003	0.0000	0.0308
80.26	0.0002	0.0004	0.0000	0.0178	0.0001	0.0001	0.0000	0.0205

***** TABLE C-3 (continued) *****

WG(LB/SEC)	0.1436	0.1436	0.1436		0.1436	0.1436	0.1436	
WL(LB/SEC)	0.0440	0.0440	0.0440		0.0800	0.0800	0.0800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0058	0.0079	0.0050	0.5328	0.0014	0.0018	0.0004	0.0764
0.67	0.0184	0.0217	0.0175	0.7699	0.0029	0.0036	0.0018	0.3078
1.15	0.0215	0.0247	0.0206	0.7907	0.0068	0.0065	0.0050	0.5540
1.65	0.0267	0.0289	0.0231	0.6884	0.0089	0.0100	0.0073	0.5924
2.14	0.0248	0.0259	0.0206	0.6612	0.0128	0.0141	0.0111	0.6845
2.63	0.0246	0.0291	0.0201	0.5676	0.0165	0.0151	0.0128	0.6756
3.11	0.0227	0.0278	0.0182	0.5240	0.0175	0.0214	0.0157	0.6576
3.60	0.0248	0.0252	0.0174	0.4861	0.0211	0.0220	0.0180	0.6956
4.09	0.0260	0.0280	0.0184	0.4638	0.0252	0.0293	0.0229	0.7112
4.58	0.0244	0.0240	0.0161	0.4456	0.0204	0.0246	0.0176	0.6147
5.07	0.0242	0.0263	0.0157	0.3864	0.0222	0.0224	0.0175	0.6139
5.55	0.0231	0.0241	0.0140	0.3507	0.0223	0.0254	0.0188	0.6237
6.53	0.0205	0.0241	0.0118	0.2819	0.0212	0.0254	0.0173	0.5565
7.51	0.0202	0.0193	0.0094	0.2291	0.0236	0.0230	0.0158	0.4632
8.48	0.0165	0.0202	0.0068	0.1403	0.0221	0.0200	0.0128	0.3731
9.46	0.0165	0.0167	0.0057	0.1160	0.0178	0.0194	0.0112	0.3608
11.41	0.0191	0.0168	0.0061	0.1148	0.0204	0.0222	0.0106	0.2490
13.37	0.0142	0.0126	0.0041	0.0959	0.0166	0.0122	0.0056	0.1571
15.81	0.0145	0.0118	0.0029	0.0478	0.0119	0.0116	0.0029	0.0613
18.25	0.0085	0.0098	0.0017	0.0352	0.0095	0.0131	0.0031	0.0752
22.64	0.0064	0.0077	0.0013	0.0364	0.0073	0.0073	0.0018	0.0600
25.08	0.0059	0.0075	0.0007	0.0127	0.0084	0.0074	0.0018	0.0543
27.53	0.0059	0.0051	0.0015	0.0729	0.0069	0.0076	0.0016	0.0467
30.46	0.0053	0.0056	0.0008	0.0216	0.0051	0.0049	0.0010	0.0386
34.85	0.0040	0.0036	0.0010	0.0721	0.0039	0.0039	0.0009	0.0534
40.22	0.0029	0.0024	0.0005	0.0412	0.0024	0.0029	0.0007	0.0796
50.48	0.0017	0.0015	0.0003	0.0294	0.0018	0.0017	0.0004	0.0598
60.24	0.0010	0.0009	0.0002	0.0469	0.0009	0.0010	0.0002	0.0353
70.01	0.0005	0.0005	0.0001	0.0385	0.0007	0.0006	0.0001	0.0481
80.26	0.0003	0.0003	0.0001	0.0452	0.0004	0.0003	0.0001	0.0389

WG(LB/SEC)	0.1436	0.1436	0.1436		0.1436	0.1436	0.1436	
WL(LB/SEC)	0.1260	0.1260	0.1260		0.1800	0.1800	0.1800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0015	0.0019	0.0007	0.1791	0.0018	0.0019	0.0006	0.1035
0.67	0.0032	0.0042	0.0025	0.4592	0.0031	0.0038	0.0018	0.2756
1.16	0.0054	0.0055	0.0038	0.4716	0.0053	0.0061	0.0039	0.4639
1.65	0.0075	0.0083	0.0059	0.5454	0.0087	0.0099	0.0072	0.6101
2.14	0.0079	0.0105	0.0067	0.5406	0.0123	0.0109	0.0090	0.6076
2.63	0.0148	0.0155	0.0123	0.6632	0.0165	0.0184	0.0143	0.6692
3.11	0.0167	0.0200	0.0141	0.5970	0.0169	0.0179	0.0147	0.7162
3.60	0.0194	0.0226	0.0167	0.6368	0.0239	0.0293	0.0220	0.6950
4.09	0.0197	0.0245	0.0179	0.6649	0.0265	0.0267	0.0230	0.7501
4.58	0.0240	0.0261	0.0210	0.7065	0.0259	0.0237	0.0199	0.6472
5.07	0.0232	0.0246	0.0196	0.6732	0.0259	0.0275	0.0219	0.6736
5.55	0.0336	0.0342	0.0288	0.7230	0.0246	0.0264	0.0207	0.6612
6.53	0.0247	0.0230	0.0176	0.5449	0.0247	0.0266	0.0197	0.5884
7.51	0.0249	0.0253	0.0182	0.5279	0.0297	0.0258	0.0209	0.5683
8.48	0.0216	0.0210	0.0131	0.3800	0.0220	0.0244	0.0159	0.4724
9.46	0.0238	0.0218	0.0148	0.4231	0.0217	0.0200	0.0135	0.4187
11.41	0.0184	0.0214	0.0086	0.1889	0.0195	0.0180	0.0099	0.2763
13.37	0.0124	0.0149	0.0062	0.2098	0.0196	0.0185	0.0101	0.2841
15.81	0.0150	0.0113	0.0045	0.1188	0.0143	0.0112	0.0056	0.1948
18.25	0.0124	0.0111	0.0029	0.0615	0.0107	0.0107	0.0017	0.0256
22.64	0.0078	0.0101	0.0020	0.0488	0.0083	0.0087	0.0020	0.0566
25.08	0.0079	0.0078	0.0015	0.0391	0.0062	0.0070	0.0012	0.0329
27.53	0.0076	0.0049	0.0009	0.0231	0.0068	0.0066	0.0015	0.0497
30.46	0.0051	0.0048	0.0012	0.0560	0.0035	0.0049	0.0008	0.0360
34.85	0.0036	0.0034	0.0005	0.0235	0.0035	0.0041	0.0006	0.0254
40.22	0.0024	0.0022	0.0005	0.0489	0.0025	0.0028	0.0003	0.0119
50.48	0.0012	0.0013	0.0002	0.0326	0.0014	0.0013	0.0002	0.0326
60.24	0.0008	0.0008	0.0002	0.0776	0.0006	0.0006	0.0001	0.0201
70.01	0.0006	0.0005	0.0001	0.0432	0.0004	0.0004	0.0001	0.0391
80.26	0.0002	0.0002	0.0001	0.0626	0.0003	0.0002	0.0000	0.0431

WG(LB/SEC)	0.1436	0.1436	0.1436		0.1436	0.1436	0.1436	
WL(LB/SEC)	0.2400	0.2400	0.2400		0.3500	0.3500	0.3500	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0019	0.0026	0.0011	0.2421	0.0018	0.0019	0.0006	0.1020
0.67	0.0033	0.0038	0.0020	0.3372	0.0031	0.0037	0.0018	0.2910
1.16	0.0046	0.0063	0.0041	0.5578	0.0051	0.0058	0.0040	0.5272
1.65	0.0105	0.0112	0.0093	0.7251	0.0079	0.0083	0.0065	0.6534
2.14	0.0133	0.0157	0.0120	0.6925	0.0137	0.0120	0.0109	0.7237
2.63	0.0165	0.0186	0.0147	0.7026	0.0187	0.0189	0.0161	0.7321
3.11	0.0227	0.0240	0.0206	0.7793	0.0165	0.0192	0.0155	0.7874
3.60	0.0295	0.0274	0.0253	0.7903	0.0213	0.0197	0.0179	0.7633
4.09	0.0250	0.0256	0.0209	0.6822	0.0274	0.0285	0.0250	0.7969
4.58	0.0287	0.0267	0.0231	0.6948	0.0351	0.0356	0.0320	0.8201
5.07	0.0301	0.0327	0.0257	0.6736	0.0406	0.0354	0.0330	0.7546
5.55	0.0322	0.0324	0.0263	0.6891	0.0367	0.0353	0.0321	0.7939
6.53	0.0325	0.0316	0.0270	0.7119	0.0329	0.0253	0.0242	0.7056
7.51	0.0279	0.0280	0.0215	0.5932	0.0271	0.0286	0.0229	0.6748
8.48	0.0266	0.0230	0.0191	0.5977	0.0271	0.0270	0.0209	0.5950
9.46	0.0245	0.0219	0.0142	0.3770	0.0283	0.0272	0.0214	0.5962
11.41	0.0180	0.0190	0.0117	0.4010	0.0221	0.0208	0.0145	0.4582
13.37	0.0183	0.0158	0.0088	0.2708	0.0162	0.0158	0.0092	0.3331
15.81	0.0146	0.0131	0.0063	0.2057	0.0159	0.0163	0.0087	0.2908
18.25	0.0131	0.0110	0.0040	0.1082	0.0094	0.0105	0.0041	0.1715
22.64	0.0087	0.0107	0.0027	0.0805	0.0077	0.0082	0.0027	0.1159
25.08	0.0064	0.0055	0.0007	0.0147	0.0064	0.0069	0.0018	0.0729
27.53	0.0057	0.0053	0.0012	0.0515	0.0056	0.0052	0.0011	0.0444
30.46	0.0043	0.0045	0.0011	0.0673	0.0034	0.0041	0.0007	0.0379
34.85	0.0029	0.0035	0.0006	0.0403	0.0030	0.0034	0.0008	0.0650
40.22	0.0018	0.0021	0.0004	0.0387	0.0018	0.0024	0.0004	0.0394
50.48	0.0009	0.0014	0.0002	0.0420	0.0010	0.0011	0.0002	0.0341
60.24	0.0004	0.0005	0.0001	0.0335	0.0004	0.0005	0.0001	0.0237
70.01	0.0003	0.0003	0.0001	0.0769	0.0002	0.0003	0.0000	0.0113
80.26	0.0001	0.0002	0.0000	0.0167	0.0001	0.0002	0.0000	0.0121

WG(LB/SEC)	0.1436	0.1436	0.1436		0.1436	0.1436	0.1436	
WL(LB/SEC)	0.4700	0.4700	0.4700		0.5850	0.5850	0.5850	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0016	0.0016	0.0007	0.1795	0.0023	0.0022	0.0011	0.2266
0.67	0.0037	0.0034	0.0022	0.3797	0.0036	0.0034	0.0020	0.3362
1.16	0.0056	0.0064	0.0045	0.5715	0.0053	0.0058	0.0041	0.5418
1.65	0.0074	0.0076	0.0058	0.5940	0.0092	0.0082	0.0070	0.6506
2.14	0.0124	0.0113	0.0101	0.7296	0.0111	0.0099	0.0090	0.7354
2.63	0.0185	0.0188	0.0160	0.7321	0.0124	0.0120	0.0094	0.5877
3.11	0.0232	0.0210	0.0198	0.8033	0.0186	0.0200	0.0171	0.7857
3.60	0.0278	0.0291	0.0254	0.7989	0.0244	0.0242	0.0218	0.8047
4.09	0.0302	0.0298	0.0268	0.7975	0.0306	0.0317	0.0277	0.7894
4.58	0.0311	0.0295	0.0275	0.8223	0.0300	0.0297	0.0265	0.7851
5.07	0.0314	0.0342	0.0291	0.7864	0.0356	0.0375	0.0325	0.7900
5.55	0.0350	0.0322	0.0296	0.7784	0.0404	0.0419	0.0374	0.8251
6.53	0.0388	0.0344	0.0311	0.7224	0.0280	0.0286	0.0234	0.6855
7.51	0.0295	0.0278	0.0225	0.6136	0.0372	0.0305	0.0287	0.7247
8.48	0.0261	0.0273	0.0216	0.6543	0.0269	0.0267	0.0206	0.5908
9.46	0.0296	0.0236	0.0203	0.5878	0.0244	0.0273	0.0190	0.5404
11.41	0.0229	0.0205	0.0156	0.5213	0.0230	0.0199	0.0140	0.4280
13.37	0.0193	0.0177	0.0112	0.3682	0.0189	0.0173	0.0113	0.3917
15.81	0.0129	0.0160	0.0083	0.3383	0.0159	0.0147	0.0079	0.2685
18.25	0.0093	0.0093	0.0041	0.1974	0.0110	0.0105	0.0064	0.3609
22.64	0.0069	0.0076	0.0022	0.0936	0.0053	0.0070	0.0022	0.1264
25.08	0.0052	0.0071	0.0013	0.0446	0.0054	0.0054	0.0023	0.1764
27.53	0.0052	0.0050	0.0007	0.0202	0.0038	0.0040	0.0015	0.1574
30.46	0.0026	0.0037	0.0006	0.0350	0.0035	0.0040	0.0007	0.0307
34.85	0.0023	0.0027	0.0005	0.0359	0.0024	0.0028	0.0007	0.0808
40.22	0.0013	0.0018	0.0003	0.0282	0.0015	0.0017	0.0004	0.0615
50.48	0.0007	0.0009	0.0002	0.0689	0.0006	0.0008	0.0001	0.0245
60.24	0.0004	0.0004	0.0000	0.0056	0.0003	0.0005	0.0001	0.0509
70.01	0.0002	0.0002	0.0000	0.0417	0.0002	0.0003	0.0000	0.0290
80.26	0.0001	0.0001	0.0000	0.0205	0.0001	0.0002	0.0000	0.0227

WG(LB/SEC)	0.1742	0.1742	0.1742		0.1742	0.1742	0.1742	
WL(LB/SEC)	0.0160	0.0160	0.0160		0.0280	0.0280	0.0280	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0051	0.0114	0.0032	0.1775	0.0241	0.0222	0.0196	0.7216
0.67	0.0071	0.0102	0.0023	0.1074	0.0315	0.0254	0.0246	0.7548
1.16	0.0051	0.0073	0.0015	0.0604	0.0256	0.0176	0.0141	0.4547
1.65	0.0052	0.0058	0.0015	0.0775	0.0164	0.0166	0.0082	0.2480
2.14	0.0049	0.0063	0.0009	0.0267	0.0162	0.0119	0.0062	0.2018
2.63	0.0076	0.0180	0.0061	0.2765	0.0204	0.0168	0.0099	0.2880
3.11	0.0052	0.0049	0.0012	0.0587	0.0170	0.0149	0.0061	0.1472
3.60	0.0044	0.0065	0.0009	0.0313	0.0165	0.0145	0.0063	0.1659
4.09	0.0043	0.0047	0.0007	0.0257	0.0189	0.0157	0.0076	0.1928
4.58	0.0048	0.0052	0.0017	0.1205	0.0142	0.0175	0.0059	0.1405
5.07	0.0053	0.0112	0.0011	0.0212	0.0180	0.0208	0.0069	0.1279
5.55	0.0051	0.0054	0.0011	0.0453	0.0179	0.0155	0.0054	0.1046
6.53	0.0049	0.0058	0.0010	0.0329	0.0143	0.0188	0.0048	0.0859
7.51	0.0050	0.0070	0.0020	0.1132	0.0210	0.0155	0.0045	0.0634
8.48	0.0053	0.0060	0.0011	0.0362	0.0171	0.0152	0.0023	0.0212
9.46	0.0043	0.0061	0.0013	0.0611	0.0151	0.0186	0.0047	0.0774
11.41	0.0046	0.0053	0.0011	0.0540	0.0145	0.0142	0.0028	0.0374
13.37	0.0050	0.0067	0.0010	0.0280	0.0178	0.0153	0.0021	0.0156
15.81	0.0044	0.0085	0.0010	0.0272	0.0116	0.0134	0.0018	0.0202
18.25	0.0050	0.0096	0.0013	0.0361	0.0093	0.0095	0.0025	0.0687
22.64	0.0065	0.0130	0.0014	0.0218	0.0073	0.0093	0.0014	0.0286
25.08	0.0072	0.0167	0.0025	0.0520	0.0094	0.0084	0.0027	0.0913
27.53	0.0071	0.0162	0.0010	0.0085	0.0080	0.0055	0.0012	0.0314
30.46	0.0072	0.0122	0.0017	0.0320	0.0057	0.0068	0.0013	0.0464
34.85	0.0063	0.0103	0.0013	0.0273	0.0047	0.0048	0.0005	0.0119
40.22	0.0058	0.0060	0.0007	0.0135	0.0033	0.0033	0.0005	0.0248
50.48	0.0045	0.0017	0.0010	0.1442	0.0018	0.0014	0.0003	0.0358
60.24	0.0047	0.0015	0.0008	0.0920	0.0011	0.0009	0.0002	0.0424
70.01	0.0039	0.0009	0.0004	0.0475	0.0005	0.0005	0.0001	0.0319
80.26	0.0044	0.0008	0.0005	0.0584	0.0003	0.0002	0.0000	0.0138

WG(LB/SEC)	0.1742	0.1742	0.1742		0.1742	0.1742	0.1742	
WL(LB/SEC)	0.0440	0.0440	0.0440		0.0800	0.0800	0.0800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0031	0.0046	0.0020	0.2798	0.0015	0.0019	0.0006	0.1448
0.67	0.0084	0.0106	0.0077	0.6716	0.0028	0.0038	0.0018	0.3146
1.16	0.0121	0.0136	0.0095	0.5559	0.0042	0.0051	0.0028	0.3611
1.65	0.0174	0.0191	0.0148	0.6568	0.0071	0.0087	0.0060	0.5784
2.14	0.0215	0.0247	0.0188	0.6677	0.0078	0.0106	0.0067	0.5388
2.63	0.0261	0.0302	0.0234	0.6955	0.0125	0.0131	0.0091	0.5098
3.11	0.0235	0.0276	0.0223	0.7680	0.0132	0.0178	0.0124	0.6522
3.60	0.0223	0.0229	0.0181	0.6391	0.0186	0.0219	0.0163	0.6503
4.09	0.0202	0.0195	0.0157	0.6272	0.0197	0.0226	0.0172	0.6672
4.58	0.0226	0.0230	0.0176	0.5960	0.0224	0.0200	0.0169	0.6377
5.07	0.0191	0.0215	0.0151	0.5545	0.0243	0.0258	0.0210	0.7045
5.55	0.0207	0.0249	0.0131	0.6313	0.0209	0.0244	0.0177	0.6192
6.53	0.0227	0.0209	0.0159	0.5333	0.0218	0.0197	0.0162	0.6112
7.51	0.0193	0.0194	0.0133	0.5134	0.0188	0.0199	0.0127	0.4350
8.48	0.0195	0.0179	0.0122	0.4246	0.0217	0.0198	0.0145	0.4863
9.46	0.0129	0.0137	0.0071	0.2888	0.0190	0.0176	0.0114	0.3864
11.41	0.0185	0.0174	0.0097	0.2954	0.0176	0.0174	0.0103	0.3440
13.37	0.0149	0.0110	0.0043	0.1108	0.0129	0.0147	0.0063	0.2092
15.81	0.0113	0.0130	0.0056	0.2155	0.0117	0.0155	0.0053	0.1564
18.25	0.0103	0.0093	0.0026	0.0699	0.0091	0.0103	0.0028	0.0824
22.64	0.0088	0.0064	0.0016	0.0436	0.0091	0.0096	0.0022	0.0548
25.08	0.0074	0.0076	0.0014	0.0341	0.0091	0.0067	0.0019	0.0571
27.53	0.0058	0.0070	0.0009	0.0210	0.0068	0.0070	0.0018	0.0703
30.46	0.0062	0.0051	0.0010	0.0293	0.0060	0.0052	0.0010	0.0300
34.85	0.0046	0.0040	0.0010	0.0560	0.0062	0.0047	0.0006	0.0141
40.22	0.0037	0.0024	0.0007	0.0520	0.0035	0.0031	0.0005	0.0225
50.48	0.0019	0.0020	0.0005	0.0610	0.0020	0.0018	0.0003	0.0322
60.24	0.0013	0.0010	0.0002	0.0429	0.0012	0.0011	0.0002	0.0264
70.01	0.0008	0.0006	0.0002	0.0725	0.0007	0.0007	0.0002	0.0573
80.26	0.0005	0.0005	0.0001	0.0663	0.0005	0.0004	0.0001	0.0435

WG(LB/SEC)	0.1742	0.1742	0.1742		0.1742	0.1742	0.1742	
WL(LB/SEC)	0.1260	0.1260	0.1260		0.1800	0.1800	0.1800	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0013	0.0013	0.0004	0.1037	0.0018	0.0015	0.0005	0.0946
0.67	0.0032	0.0037	0.0020	0.3561	0.0036	0.0036	0.0020	0.2945
1.15	0.0050	0.0053	0.0035	0.4721	0.0049	0.0040	0.0029	0.4141
1.65	0.0079	0.0086	0.0067	0.6520	0.0081	0.0082	0.0064	0.6113
2.14	0.0102	0.0114	0.0089	0.6782	0.0107	0.0115	0.0089	0.6469
2.63	0.0097	0.0103	0.0077	0.5884	0.0141	0.0153	0.0117	0.6398
3.11	0.0183	0.0187	0.0156	0.7125	0.0139	0.0165	0.0128	0.7083
3.60	0.0183	0.0186	0.0146	0.6283	0.0186	0.0206	0.0169	0.7454
4.09	0.0198	0.0217	0.0177	0.7265	0.0246	0.0272	0.0219	0.7128
4.58	0.0212	0.0235	0.0190	0.7233	0.0234	0.0223	0.0199	0.7554
5.07	0.0244	0.0215	0.0197	0.7405	0.0287	0.0312	0.0257	0.7398
5.55	0.0205	0.0247	0.0187	0.6895	0.0257	0.0242	0.0214	0.7352
6.53	0.0200	0.0233	0.0169	0.6143	0.0243	0.0231	0.0190	0.6413
7.51	0.0221	0.0250	0.0174	0.5489	0.0275	0.0244	0.0202	0.6064
8.48	0.0213	0.0237	0.0162	0.5197	0.0214	0.0244	0.0168	0.5435
9.46	0.0215	0.0204	0.0146	0.4838	0.0263	0.0215	0.0190	0.6380
11.41	0.0191	0.0197	0.0127	0.4286	0.0195	0.0202	0.0132	0.4437
13.37	0.0204	0.0166	0.0104	0.3171	0.0143	0.0142	0.0086	0.3614
15.81	0.0113	0.0132	0.0049	0.1610	0.0146	0.0152	0.0071	0.2295
18.25	0.0109	0.0102	0.0023	0.0470	0.0126	0.0127	0.0052	0.1694
22.64	0.0094	0.0102	0.0012	0.0163	0.0074	0.0097	0.0019	0.0517
25.08	0.0084	0.0074	0.0020	0.0671	0.0087	0.0070	0.0023	0.0870
27.53	0.0064	0.0069	0.0016	0.0582	0.0053	0.0057	0.0013	0.0554
30.46	0.0056	0.0052	0.0012	0.0518	0.0044	0.0051	0.0008	0.0263
34.85	0.0042	0.0038	0.0009	0.0520	0.0039	0.0048	0.0007	0.0298
40.22	0.0033	0.0033	0.0009	0.0678	0.0029	0.0029	0.0003	0.0101
50.48	0.0015	0.0015	0.0003	0.0491	0.0015	0.0017	0.0003	0.0333
60.24	0.0012	0.0010	0.0003	0.0652	0.0006	0.0009	0.0001	0.0365
70.01	0.0005	0.0005	0.0001	0.0364	0.0005	0.0005	0.0000	0.0116
80.26	0.0003	0.0003	0.0000	0.0223	0.0002	0.0003	0.0000	0.0229

WG(LB/SEC)	0.1742	0.1742	0.1742		0.1742	0.1742	0.1742	
WL(LB/SEC)	0.2400	0.2400	0.2400		0.3500	0.3500	0.3500	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0016	0.0016	0.0006	0.1551	0.0014	0.0020	0.0005	0.0769
0.67	0.0029	0.0031	0.0016	0.2810	0.0025	0.0031	0.0016	0.3171
1.16	0.0042	0.0048	0.0034	0.5758	0.0042	0.0043	0.0027	0.3939
1.65	0.0074	0.0083	0.0063	0.6394	0.0058	0.0061	0.0039	0.4439
2.14	0.0096	0.0119	0.0091	0.7207	0.0059	0.0073	0.0050	0.5750
2.63	0.0125	0.0131	0.0108	0.7116	0.0119	0.0112	0.0093	0.6483
3.11	0.0149	0.0143	0.0125	0.7338	0.0143	0.0148	0.0124	0.7272
3.60	0.0213	0.0230	0.0198	0.8004	0.0242	0.0201	0.0198	0.8089
4.09	0.0209	0.0236	0.0194	0.7610	0.0203	0.0199	0.0173	0.7401
4.58	0.0264	0.0277	0.0231	0.7279	0.0245	0.0256	0.0216	0.7442
5.07	0.0253	0.0256	0.0220	0.7489	0.0328	0.0311	0.0278	0.7598
5.55	0.0339	0.0301	0.0288	0.8102	0.0296	0.0293	0.0261	0.7847
6.53	0.0255	0.0249	0.0209	0.6877	0.0316	0.0333	0.0286	0.7764
7.51	0.0253	0.0263	0.0218	0.7140	0.0279	0.0293	0.0236	0.6822
8.48	0.0267	0.0251	0.0198	0.5864	0.0241	0.0238	0.0190	0.6293
9.46	0.0249	0.0232	0.0186	0.5973	0.0247	0.0242	0.0191	0.6087
11.41	0.0204	0.0199	0.0154	0.5802	0.0183	0.0179	0.0126	0.4880
13.37	0.0158	0.0166	0.0103	0.4089	0.0158	0.0176	0.0114	0.4679
15.81	0.0132	0.0153	0.0079	0.3094	0.0128	0.0117	0.0076	0.3867
18.25	0.0119	0.0111	0.0057	0.2494	0.0151	0.0110	0.0073	0.3241
22.64	0.0090	0.0074	0.0023	0.0821	0.0077	0.0087	0.0034	0.1689
25.08	0.0077	0.0066	0.0022	0.0955	0.0067	0.0072	0.0018	0.0654
27.53	0.0062	0.0056	0.0015	0.0659	0.0055	0.0055	0.0018	0.1020
30.46	0.0051	0.0047	0.0011	0.0483	0.0038	0.0046	0.0009	0.0450
34.85	0.0047	0.0042	0.0010	0.0515	0.0035	0.0032	0.0005	0.0237
40.22	0.0024	0.0024	0.0006	0.0646	0.0024	0.0023	0.0005	0.0407
50.48	0.0012	0.0013	0.0002	0.0201	0.0010	0.0013	0.0002	0.0501
60.24	0.0008	0.0006	0.0002	0.0510	0.0006	0.0006	0.0001	0.0130
70.01	0.0003	0.0004	0.0000	0.0189	0.0003	0.0004	0.0000	0.0149
80.26	0.0002	0.0002	0.0000	0.0453	0.0002	0.0003	0.0000	0.0481

***** TABLE C-3 (continued) *****

WG(LB/SEC)	0.1742	0.1742	0.1742		0.1742	0.1742	0.1742	
WL(LB/SEC)	0.4700	0.4700	0.4700		0.5850	0.5850	0.5850	
CELL	B1	D2	CROSS	COHERENCY	B1	D2	CROSS	COHERENCY
FREQ.(CPS)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.18	0.0017	0.0018	0.0009	0.2663	0.0019	0.0019	0.0009	0.2022
0.67	0.0027	0.0028	0.0014	0.2746	0.0030	0.0032	0.0017	0.3157
1.16	0.0044	0.0042	0.0032	0.5399	0.0037	0.0038	0.0024	0.4076
1.65	0.0052	0.0060	0.0045	0.6516	0.0049	0.0065	0.0043	0.5848
2.14	0.0087	0.0084	0.0067	0.6164	0.0057	0.0060	0.0042	0.5194
2.63	0.0126	0.0120	0.0097	0.6257	0.0100	0.0097	0.0080	0.6678
3.11	0.0132	0.0140	0.0114	0.7072	0.0116	0.0144	0.0109	0.7155
3.60	0.0193	0.0208	0.0175	0.7629	0.0160	0.0165	0.0143	0.7804
4.09	0.0202	0.0208	0.0176	0.7377	0.0154	0.0162	0.0130	0.6796
4.58	0.0251	0.0246	0.0224	0.8179	0.0226	0.0246	0.0210	0.7935
5.07	0.0309	0.0306	0.0270	0.7749	0.0303	0.0309	0.0277	0.8166
5.55	0.0028	0.0285	0.0250	7.8916	0.0267	0.0257	0.0229	0.7630
6.53	0.0358	0.0373	0.0031	0.0073	0.0358	0.0403	0.0340	0.8028
7.51	0.0273	0.0238	0.0209	0.6715	0.0288	0.0300	0.0250	0.7215
8.48	0.0320	0.0304	0.0250	0.6432	0.0308	0.0282	0.0250	0.7188
9.46	0.0278	0.0252	0.0220	0.6896	0.0280	0.0263	0.0210	0.5969
11.41	0.0226	0.0225	0.0167	0.5492	0.0251	0.0207	0.0167	0.5385
13.37	0.0208	0.0201	0.0137	0.4472	0.0170	0.0180	0.0106	0.3644
15.81	0.0132	0.0132	0.0073	0.3060	0.0141	0.0162	0.0102	0.4512
18.25	0.0115	0.0102	0.0062	0.3249	0.0125	0.0135	0.0081	0.3912
22.64	0.0071	0.0089	0.0027	0.1173	0.0085	0.0084	0.0032	0.1471
25.08	0.0064	0.0068	0.0025	0.1462	0.0067	0.0071	0.0032	0.2143
27.53	0.0052	0.0054	0.0013	0.0602	0.0056	0.0055	0.0020	0.1268
30.46	0.0055	0.0046	0.0018	0.1342	0.0041	0.0044	0.0013	0.0963
34.85	0.0025	0.0034	0.0006	0.0464	0.0032	0.0028	0.0006	0.0367
40.22	0.0017	0.0027	0.0004	0.0319	0.0021	0.0020	0.0004	0.0297
50.48	0.0011	0.0012	0.0001	0.0172	0.0010	0.0010	0.0002	0.0292
60.24	0.0005	0.0006	0.0001	0.0166	0.0004	0.0005	0.0001	0.0494
70.01	0.0003	0.0004	0.0001	0.0478	0.0003	0.0003	0.0001	0.0563
80.26	0.0002	0.0002	0.0000	0.0217	0.0002	0.0002	0.0000	0.0268

***** PHASE SPECTRA *****

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2
FREQ.(CPS)	***** PHASE IN RADIANS ***			***** PHASE IN RADIANS ***			***** PHASE IN RADIANS *****			
0.18	1.33	0.94	0.85	0.62	0.56	0.52	0.46	0.32	0.26	0.20
1.16	5.59	2.93	2.17	2.00	1.92	1.77	1.71	1.43	1.28	1.05
2.14	10.44	5.33	3.87	3.31	3.06	3.02	2.70	2.22	1.99	1.76
3.11	14.88	7.60	5.62	4.99	4.60	4.28	4.00	3.13	2.95	2.58
4.09	19.65	9.95	7.30	6.60	6.01	5.74	5.21	4.26	3.82	3.53
5.07	24.48	15.44	9.19	8.26	7.43	7.21	6.67	5.43	4.81	4.51
6.04	29.95	18.28	11.13	9.77	8.92	8.74	8.09	6.52	5.93	5.34
7.02	34.43	21.20	12.84	11.10	10.37	10.00	9.27	7.72	6.96	6.27
8.00	40.21	23.88	13.91	12.92	11.75	11.39	10.76	8.62	7.78	6.98
8.97	43.72	23.79	15.20	14.40	13.30	12.52	11.66	9.54	8.30	7.76
9.95	44.21	26.13	17.37	14.94	14.70	13.73	12.75	10.48	9.71	8.82
10.92	48.59	32.47	18.49	16.70	15.62	15.05	14.45	11.65	10.38	9.54
11.90	50.45	36.12	20.55	22.39	16.96	15.93	15.65	12.65	11.35	10.37
12.88	48.84	39.74	22.62	26.27	18.61	17.85	16.42	13.77	12.10	11.17
13.85	48.39	46.57	25.16	33.99	19.17	19.62	17.54	14.25	12.99	12.20
14.83	53.07	50.95	26.96	31.21	21.64	19.37	20.49	15.76	14.11	12.77
15.81	51.94	59.23	27.97	36.06	22.87	22.50	29.04	16.74	15.26	13.52
16.78	50.35	66.16	32.91	43.32	28.56	30.52	33.64	17.81	15.96	14.55
17.76	48.40	70.40	32.36	44.16	32.68	36.99	35.17	18.55	16.81	15.27
18.74	51.68	69.62	34.39	42.25	31.53	37.83	39.50	20.25	17.83	16.00
19.71	56.10	72.95	34.16	45.40	35.43	41.11	47.79	20.64	17.97	17.09
20.69	59.12	74.24	38.03	48.84	40.23	49.10	49.38	21.52	19.72	17.84
21.67	61.14	75.74	37.01	48.95	42.89	53.67	55.25	22.53	21.70	19.15
22.64	65.21	84.55	41.03	51.73	46.65	56.75	56.45	24.01	27.01	19.79
23.62	62.86	86.25	42.41	57.63	50.34	60.79	60.26	24.65	27.87	19.87
24.60	62.33	87.48	45.60	61.43	55.43	62.80	66.90	23.73	30.07	20.75
25.57	68.24	90.51	44.83	64.60	59.12	66.40	71.43	30.12	37.00	22.57
26.55	68.03	91.19	48.88	68.79	61.77	72.23	75.27	33.75	37.15	22.81
27.53	72.61	93.63	52.25	69.75	64.77	72.34	76.10	33.07	43.92	29.82
28.50	74.65	92.43	57.37	70.03	68.94	75.76	80.82	41.41	45.33	30.08
29.48	73.37	96.01	62.03	72.85	75.18	79.47	83.11	42.64	49.29	32.35
30.46	76.11	100.87	69.97	77.29	79.14	83.59	83.59	43.07	55.47	32.58
31.43	76.90	101.76	76.51	82.53	85.06	84.75	87.90	44.32	59.06	33.52
32.41	80.34	102.13	78.59	89.48	86.18	89.69	91.83	46.52	62.83	40.83
33.39	82.73	110.81	83.04	91.14	94.26	95.34	94.92	49.39	65.48	42.33
34.36	88.08	113.76	84.90	97.21	95.21	102.17	97.88	54.73	71.35	48.33
35.34	94.29	119.01	88.66	101.93	98.19	106.60	105.64	54.94	74.94	50.22
36.32	98.00	125.46	92.79	109.57	100.26	108.11	111.18	59.37	77.64	55.69
37.29	100.66	127.06	96.59	117.05	103.09	111.75	117.59	63.70	77.88	56.91
38.27	100.72	132.47	97.69	121.28	110.91	110.89	118.92	66.64	81.29	59.09

WG(LB/SEC)	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2
FREQ.(CPS)	***** PHASE IN RADIANS ***			***** PHASE IN RADIANS ***			***** PHASE IN RADIANS *****			
0.18	0.69	0.24	0.43	0.53	0.53	0.57	0.45	1.89	0.10	0.24
1.16	5.47	3.28	1.90	1.76	1.59	1.45	1.29	1.16	0.98	0.94
2.14	9.96	5.97	3.37	2.93	2.66	2.51	2.31	1.89	1.71	1.67
3.11	14.11	8.87	4.91	4.27	3.79	3.59	3.21	2.72	2.50	2.35
4.09	19.18	11.60	6.68	5.74	5.00	4.65	4.14	3.61	3.41	3.10
5.07	23.25	14.44	8.44	6.99	6.27	5.91	5.33	4.64	4.19	3.91
6.04	27.50	17.54	9.79	8.18	7.43	6.97	6.38	5.57	5.17	4.68
7.02	32.55	20.84	10.63	9.66	8.73	8.30	7.45	6.57	5.84	5.53
8.00	36.58	23.46	12.77	10.87	9.77	9.36	8.45	7.53	6.78	6.27
8.97	42.41	24.88	14.48	12.34	11.07	10.59	9.46	8.28	7.65	7.08
9.95	46.14	26.94	15.62	13.45	12.02	11.73	10.51	9.30	8.30	7.68
10.92	45.62	31.87	17.08	15.04	13.23	12.71	11.55	10.10	9.27	8.57
11.90	49.77	33.46	19.65	16.17	14.80	14.01	12.59	10.74	10.16	9.38
12.88	56.71	39.34	23.69	17.22	15.84	14.89	13.54	11.92	10.93	10.12
13.85	56.41	45.59	29.44	18.34	16.87	16.13	14.52	12.95	11.98	11.06
14.83	60.83	49.99	29.37	20.27	18.54	17.52	15.45	13.92	12.66	11.94
15.81	64.77	50.84	31.35	22.49	19.13	18.88	16.47	15.14	13.60	12.61
16.78	67.50	52.74	38.89	22.32	20.12	19.55	17.37	21.27	14.25	13.32
17.76	67.90	50.89	47.63	28.39	22.27	20.71	19.19	23.57	15.01	14.20
18.74	68.54	58.27	47.70	33.10	23.28	21.72	19.90	26.25	15.91	14.87
19.71	72.22	63.66	51.41	31.83	23.96	23.17	19.23	25.06	16.90	15.38
20.69	75.37	65.46	51.90	34.94	25.25	25.08	21.22	30.08	18.08	16.54
21.67	76.97	68.05	53.75	37.54	25.33	24.48	23.11	35.48	18.59	17.60
22.64	78.57	71.36	54.99	39.98	28.04	27.36	23.70	39.91	19.13	17.85
23.62	82.56	78.78	62.32	42.36	29.15	28.64	23.66	39.72	20.52	18.55
24.60	83.56	82.28	64.11	45.84	30.96	29.24	27.04	41.06	20.77	19.86
25.57	82.36	86.35	67.54	50.08	32.95	29.74	30.51	41.44	21.11	20.23
26.55	89.27	92.95	69.94	54.73	38.03	31.80	32.62	42.13	22.48	21.41
27.53	89.35	97.83	77.32	59.74	38.33	32.65	38.82	43.79	23.17	23.21
28.50	95.48	99.59	75.28	68.64	43.57	33.59	41.67	44.90	24.27	23.79
29.48	99.91	100.05	76.48	71.35	48.33	36.27	43.89	45.63	26.31	24.39
30.46	104.23	100.31	80.35	73.65	47.96	41.04	44.65	49.63	26.50	24.67
31.43	110.69	105.16	87.35	77.83	54.35	49.94	51.51	53.76	26.31	25.75
32.41	118.25	108.59	90.18	78.76	58.24	52.45	59.29	54.34	27.23	32.11
33.39	123.85	109.29	90.54	82.23	62.53	57.42	60.91	54.90	34.94	35.45
34.36	124.61	113.79	93.04	88.92	67.13	60.66	65.06	60.33	37.04	38.91
35.34	125.19	117.50	93.56	88.96	68.42	59.87	69.06	63.87	42.27	41.46
36.32	125.22	119.62	95.47	91.14	75.00	62.94	73.05	64.00	44.00	44.03
37.29	126.43	123.89	102.06	96.48	74.19	62.76	76.52	65.60	45.77	46.76
38.27	127.18	123.91	105.32	99.48	79.82	65.32	77.28	66.45	44.49	50.55

WG(LB/SEC)	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2
FREQ.(CPS)	***** PHASE IN RADIANS ***			***** PHASE IN RADIANS ***			***** PHASE IN RADIANS *****			
0.18	1.21	0.81	0.64	0.42	0.45	0.34	0.33	0.37	0.33	0.29
1.16	5.39	3.14	2.07	1.87	1.76	1.60	1.57	1.43	1.26	1.20
2.14	9.59	6.15	3.82	3.25	3.05	3.00	2.65	2.25	2.08	1.89
3.11	14.17	8.73	5.44	4.64	4.32	4.24	3.78	3.22	3.00	2.70
4.09	18.28	12.07	7.19	6.41	5.85	5.58	5.09	4.38	3.92	3.64
5.07	22.47	14.01	9.00	7.87	7.49	6.88	6.46	5.58	4.94	4.55
6.04	27.86	17.66	10.35	9.25	8.76	8.45	7.88	6.68	6.02	5.52
7.02	32.48	22.10	11.96	10.84	10.26	9.76	9.13	7.66	6.91	6.50
8.00	37.92	25.28	14.23	12.13	11.36	11.12	10.07	8.90	7.65	7.25
8.97	41.04	29.80	15.47	13.20	12.97	12.25	11.58	9.85	8.79	8.07
9.95	47.98	30.58	17.01	15.10	14.44	13.78	12.67	10.94	9.65	8.91
10.92	51.93	30.71	20.57	16.33	15.64	14.64	13.47	11.72	10.63	9.75
11.90	58.83	38.20	28.46	17.22	16.87	16.46	15.19	12.84	11.39	10.73
12.88	66.50	41.54	33.75	20.26	17.91	17.43	16.14	13.86	12.37	11.48
13.85	69.63	44.22	38.00	24.02	19.23	18.41	18.37	14.77	13.36	12.53
14.83	67.85	47.14	45.34	23.40	21.09	20.42	19.34	15.62	14.33	13.23
15.81	70.63	50.80	46.69	23.54	23.46	21.59	20.61	17.27	15.39	14.01
16.78	69.37	58.22	52.27	26.17	29.58	24.17	20.55	17.74	16.25	14.82
17.76	69.71	63.25	60.93	29.52	30.93	30.40	23.41	19.13	17.11	15.92
18.74	73.76	69.08	68.85	33.40	31.03	31.05	30.40	21.88	17.81	16.42
19.71	79.87	70.26	71.20	37.35	38.86	32.47	30.79	21.23	19.00	18.06
20.69	84.54	75.30	71.86	36.53	39.90	30.37	35.45	21.24	19.00	18.14
21.67	85.31	79.80	73.37	38.84	42.30	32.80	38.97	23.55	20.53	19.39
22.64	85.77	79.06	78.91	41.73	44.20	39.15	42.11	24.16	20.81	18.85
23.62	88.44	86.40	88.51	48.42	52.59	46.43	42.82	26.07	22.60	20.88
24.60	96.43	91.72	91.49	48.10	55.26	54.02	41.32	28.29	23.01	22.03
25.57	105.19	93.54	92.97	56.23	60.51	62.20	41.86	29.24	29.58	22.74
26.55	110.31	96.54	98.79	64.52	62.15	67.14	43.54	31.19	30.81	23.29
27.53	112.36	101.58	101.16	63.44	66.99	70.81	46.88	28.43	38.42	23.25
28.50	111.56	107.98	100.82	65.00	74.98	74.08	55.72	29.93	40.03	24.92
29.48	114.89	110.91	104.07	69.87	77.85	79.49	60.22	28.85	44.70	25.67
30.46	118.83	118.08	106.42	68.25	80.86	81.89	65.63	34.50	46.33	27.89
31.43	119.42	120.51	107.67	71.48	82.36	89.61	66.65	38.41	48.21	27.26
32.41	118.43	125.00	112.44	73.21	84.86	89.60	68.44	41.99	48.20	28.88
33.39	118.97	129.95	115.41	74.76	90.01	92.51	69.97	48.08	49.99	35.61
34.36	119.33	131.99	116.88	77.15	91.99	93.19	77.28	50.97	52.12	36.28
35.34	119.84	130.38	123.20	81.43	99.54	94.53	85.89	59.56	57.21	39.14
36.32	119.66	131.88	130.49	84.90	102.46	101.89	88.93	64.42	63.45	41.49
37.29	119.25	134.30	132.36	90.86	108.43	106.54	88.51	67.75	66.46	45.40
38.27	119.34	137.89	134.29	94.14	112.34	105.56	92.76	68.46	67.66	46.89

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2
FREQ.(CPS)	***** PHASE IN RADIANS ***			***** PHASE IN RADIANS ***			***** PHASE IN RADIANS *****			
0.18	0.47	0.43	0.47	0.05	0.82	0.39	0.06	0.13	0.41	0.21
1.16	5.60	3.61	1.64	1.54	1.49	1.38	1.16	0.90	0.93	0.80
2.14	10.18	6.05	2.89	2.83	2.35	2.31	2.05	1.82	1.61	1.54
3.11	13.52	8.77	4.28	3.96	3.40	3.16	2.76	2.65	2.41	2.18
4.09	18.31	11.47	5.57	5.01	4.35	4.16	3.83	3.35	2.95	2.89
5.07	24.58	14.76	6.69	6.49	5.63	5.18	4.69	4.12	3.93	3.55
6.04	26.84	17.31	8.01	7.73	6.71	6.21	5.63	5.12	4.69	4.41
7.02	30.97	20.57	9.25	8.86	7.83	7.20	6.50	5.88	5.34	5.11
8.00	31.60	22.87	10.51	10.24	8.91	8.15	7.55	6.69	6.06	5.88
8.97	34.55	28.90	11.82	11.69	10.02	9.16	8.28	7.46	6.80	6.60
9.95	38.08	32.74	12.68	12.90	11.37	10.18	9.53	8.27	7.64	7.37
10.92	45.54	40.43	14.29	13.88	12.45	11.28	10.24	9.08	8.39	7.91
11.93	47.85	42.72	15.53	15.14	13.54	11.95	11.15	9.80	9.20	8.64
12.88	53.18	44.81	16.78	16.65	14.23	13.09	12.07	10.76	10.19	9.52
13.85	59.00	45.22	17.75	17.82	15.59	14.10	13.01	11.54	10.69	10.16
14.83	64.27	53.25	18.97	18.80	16.36	15.39	14.07	12.58	11.41	10.92
15.81	68.85	56.51	20.70	19.98	17.41	16.10	14.79	13.22	12.39	11.67
16.78	73.85	59.34	22.27	21.60	18.62	17.06	15.76	14.32	12.93	12.52
17.76	75.38	63.07	28.59	22.53	19.66	17.92	16.79	15.04	14.17	13.11
18.74	77.05	65.52	31.71	24.87	21.00	19.47	17.76	15.59	14.53	13.84
19.71	79.18	68.98	31.99	27.18	21.26	20.01	18.03	16.57	15.16	14.59
20.69	82.77	72.70	37.36	32.56	27.83	21.37	19.53	17.47	16.37	15.27
21.67	83.09	78.64	42.60	33.61	30.66	21.47	20.33	18.20	16.94	16.19
22.64	82.16	84.57	42.38	36.04	33.45	22.84	20.53	19.39	17.19	16.64
23.62	83.27	83.54	44.53	37.40	38.46	28.18	22.19	19.39	18.73	17.21
24.60	88.24	85.77	46.75	37.37	40.60	30.06	23.62	20.66	19.34	18.14
25.57	93.66	92.28	49.56	37.28	41.35	32.97	24.31	21.63	20.75	18.94
26.55	94.03	93.08	49.67	40.36	42.55	33.86	24.29	22.32	21.02	19.55
27.53	98.15	95.43	50.51	41.71	47.18	38.52	27.13	22.75	21.54	20.06
28.50	105.14	99.35	56.26	50.90	50.64	46.24	26.09	23.18	21.33	21.41
29.48	107.43	102.12	57.21	50.48	50.09	49.12	32.44	24.67	24.05	22.89
30.46	110.26	102.03	64.72	55.16	55.04	56.93	36.27	25.29	23.37	27.35
31.43	114.66	106.09	68.11	57.28	55.90	61.28	37.30	27.02	25.36	29.45
32.41	118.48	106.75	69.52	63.87	65.58	63.50	39.96	27.32	31.36	31.29
33.39	121.15	110.99	75.16	69.87	68.85	64.16	39.24	28.12	32.42	30.93
34.36	123.88	113.01	79.88	75.12	72.61	67.85	44.10	28.48	32.07	31.87
35.34	130.19	113.46	79.58	78.28	79.27	71.52	44.15	30.98	33.82	32.42
36.32	132.05	121.29	85.11	81.03	84.03	73.84	48.47	33.64	34.83	38.24
37.29	138.76	127.10	90.24	84.03	85.78	77.53	54.01	41.07	40.69	40.44
38.27	138.42	126.46	91.86	86.77	93.46	82.90	58.74	50.56	42.34	39.92

WG(LB/SEC)	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2	B1D2
FREQ.(CPS)	***** PHASE IN RADIANS ***			***** PHASE IN RADIANS ***			***** PHASE IN RADIANS *****			
0.18	0.51	0.53	0.47	0.48	0.39	0.56	0.70	0.55	0.54	-0.08
1.16	5.87	2.68	1.47	1.58	1.26	1.25	1.10	0.99	0.75	0.69
2.14	7.16	5.42	2.69	2.52	2.17	2.01	1.85	1.61	1.55	1.59
3.11	6.13	8.45	3.87	3.56	3.14	2.96	2.68	2.48	2.16	2.05
4.09	7.79	11.52	5.07	4.68	4.02	3.81	3.53	3.20	2.89	2.75
5.07	6.85	14.59	6.23	5.80	4.96	4.70	4.39	3.93	3.55	3.47
6.04	7.27	17.43	7.50	6.93	6.13	5.65	5.22	4.80	4.40	4.14
7.02	6.42	19.94	8.83	8.16	7.06	6.53	6.05	5.58	5.14	4.85
8.00	7.87	22.49	10.02	9.18	8.05	7.51	7.01	6.48	5.81	5.60
8.97	14.15	24.19	11.12	10.31	9.18	8.28	7.79	7.03	6.73	6.41
9.95	13.20	28.31	12.41	11.59	10.06	9.36	8.66	7.90	7.33	7.06
10.92	13.49	32.96	13.62	12.60	11.14	10.18	9.36	8.64	8.10	7.63
11.90	15.04	35.78	14.58	13.65	12.09	11.08	10.32	9.63	8.68	8.35
12.88	18.65	35.76	15.79	14.79	13.01	12.12	11.22	10.28	9.57	8.90
13.85	19.21	42.20	17.27	15.83	13.90	12.95	11.98	11.10	10.23	9.69
14.83	20.15	45.91	18.09	16.86	14.64	13.86	12.88	11.79	10.84	10.37
15.81	21.47	51.64	19.60	18.08	15.87	14.70	13.61	12.67	11.80	11.10
16.78	25.87	58.62	20.82	18.93	16.45	15.52	14.56	13.43	12.52	11.65
17.76	28.28	56.88	21.67	20.56	18.15	16.59	15.63	14.34	13.09	12.43
18.74	33.36	57.74	23.47	21.28	19.15	17.51	16.30	14.86	13.93	13.21
19.71	40.36	59.43	24.03	22.41	19.76	18.45	17.24	15.75	14.42	13.81
20.69	41.94	60.96	25.60	23.18	19.77	19.58	18.01	16.40	15.45	14.62
21.67	43.67	62.99	26.68	24.80	21.54	20.23	18.51	17.55	16.25	15.11
22.64	45.30	64.29	28.17	25.43	23.09	20.49	19.49	18.36	16.62	16.01
23.62	48.20	71.60	29.19	28.45	24.08	22.34	20.63	18.90	17.68	16.44
24.60	51.75	77.90	30.54	32.33	24.14	23.32	21.22	19.67	17.99	17.29
25.57	56.24	82.72	32.30	37.72	24.93	23.93	22.27	20.42	18.92	17.90
26.55	58.08	85.41	31.41	41.63	26.04	24.12	23.36	21.33	19.47	18.37
27.53	64.64	94.02	37.80	42.98	28.84	26.28	23.90	22.38	20.20	19.24
28.50	69.99	92.47	39.57	45.12	29.47	26.88	24.22	23.43	21.31	20.22
29.48	75.54	97.26	42.61	48.47	34.06	27.33	25.55	23.79	21.88	21.30
30.46	83.12	100.43	42.30	49.91	40.54	31.84	26.04	25.13	23.10	21.00
31.43	87.85	104.33	43.14	56.22	41.76	34.47	27.64	24.96	23.77	22.27
32.41	92.35	107.33	42.18	64.96	43.98	36.56	28.87	25.93	24.44	22.84
33.39	98.82	108.18	46.50	70.04	44.77	37.09	34.31	27.16	24.17	22.93
34.36	105.31	107.30	48.17	75.56	48.69	39.03	39.55	28.82	26.19	24.05
35.34	109.23	112.22	55.84	83.38	51.19	44.97	43.08	36.67	26.92	24.51
36.32	115.64	117.36	55.81	90.11	48.51	46.75	44.59	41.75	27.93	25.67
37.29	117.04	124.57	56.77	96.39	54.10	49.30	45.09	43.04	27.46	25.45
38.27	122.11	125.22	55.76	95.47	62.26	47.62	46.10	43.83	27.39	27.22

WG(LB/SEC)	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0160	0.0160	0.0160
CELL	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.1692	0.1692
0.0080	0.8037	0.8164	0.1672	0.1619
0.0160	0.4608	0.4826	0.1573	0.1409
0.0240	0.1752	0.1913	0.1410	0.1105
0.0320	-0.0180	-0.0093	0.1171	0.0821
0.0400	-0.1345	-0.1278	0.0872	0.0603
0.0480	-0.1923	-0.1848	0.0487	0.0432
0.0560	-0.2078	-0.1977	0.0097	0.0288
0.0640	-0.1939	-0.1814	-0.0221	0.0221
0.0720	-0.1614	-0.1474	-0.0439	0.0177
0.0800	-0.1226	-0.1093	-0.0573	0.0144
0.0880	-0.0853	-0.0710	-0.0648	0.0136
0.0960	-0.0551	-0.0356	-0.0637	0.0131
0.1040	-0.0295	-0.0048	-0.0564	0.0144
0.1120	-0.0063	0.0193	-0.0420	0.0188
0.1200	0.0126	0.0331	-0.0206	0.0240
0.1280	0.0236	0.0396	0.0055	0.0219
0.1360	0.0245	0.0422	0.0306	0.0148
0.1440	0.0226	0.0441	0.0528	0.0092
0.1520	0.0222	0.0429	0.0704	0.0044
0.1600	0.0239	0.0417	0.0820	0.0023
0.1680	0.0266	0.0399	0.0888	0.0023
0.1760	0.0278	0.0333	0.0863	0.0031
0.1840	0.0275	0.0229	0.0745	-0.0001
0.1920	0.0225	0.0102	0.0571	-0.0022
0.2000	0.0151	0.0031	0.0378	-0.0042
0.2080	0.0090	0.0003	0.0185	-0.0045
0.2160	0.0070	-0.0010	0.0007	-0.0024
0.2240	0.0048	-0.0086	-0.0114	-0.0008
0.2320	0.0017	-0.0163	-0.0212	-0.0002
0.2400	-0.0053	-0.0205	-0.0296	0.0010
0.2480	-0.0144	-0.0193	-0.0367	0.0044
0.2560	-0.0212	-0.0148	-0.0340	0.0067
0.2640	-0.0246	-0.0114	-0.0243	0.0073
0.2720	-0.0268	-0.0098	-0.0155	0.0050
0.2800	-0.0283	-0.0125	-0.0154	-0.0006
0.2880	-0.0247	-0.0149	-0.0186	-0.0090
0.2960	-0.0194	-0.0171	-0.0183	-0.0206
0.3040	-0.0157	-0.0155	-0.0147	-0.0296
0.3120	-0.0127	-0.0080	-0.0098	-0.0283

WG(LB/SEC)	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0280	0.0280	0.0280	0.0280
CELL	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.0948	0.0948
0.0080	0.7695	0.7823	0.0930	0.0940
0.0160	0.4239	0.4318	0.0862	0.0881
0.0240	0.1659	0.1584	0.0761	0.0830
0.0320	0.0077	-0.0119	0.0639	0.0787
0.0400	-0.0742	-0.1027	0.0450	0.0769
0.0480	-0.1034	-0.1368	0.0228	0.0794
0.0560	-0.1053	-0.1311	0.0004	0.0812
0.0640	-0.0946	-0.1058	-0.0146	0.0771
0.0720	-0.0773	-0.0765	-0.0230	0.0772
0.0800	-0.0586	-0.0507	-0.0293	0.0775
0.0880	-0.0442	-0.0294	-0.0293	0.0786
0.0960	-0.0385	-0.0134	-0.0273	0.0863
0.1040	-0.0370	0.0003	-0.0262	0.0910
0.1120	-0.0352	0.0125	-0.0291	0.0931
0.1200	-0.0279	0.0188	-0.0326	0.0896
0.1280	-0.0170	0.0207	-0.0338	0.0840
0.1360	-0.0081	0.0197	-0.0281	0.0790
0.1440	0.0005	0.0193	-0.0138	0.0683
0.1520	0.0042	0.0188	0.0017	0.0514
0.1600	0.0029	0.0157	0.0146	0.0351
0.1680	-0.0028	0.0092	0.0213	0.0262
0.1760	-0.0070	-0.0008	0.0256	0.0209
0.1840	-0.0075	-0.0133	0.0262	0.0180
0.1920	-0.0052	-0.0253	0.0220	0.0141
0.2000	-0.0019	-0.0323	0.0156	0.0057
0.2080	-0.0003	-0.0316	0.0127	-0.0032
0.2160	-0.0005	-0.0240	0.0102	-0.0087
0.2240	-0.0056	-0.0192	0.0047	-0.0140
0.2320	-0.0123	-0.0188	0.0014	-0.0183
0.2400	-0.0171	-0.0193	-0.0006	-0.0203
0.2480	-0.0180	-0.0179	-0.0026	-0.0202
0.2560	-0.0140	-0.0123	-0.0059	-0.0150
0.2640	-0.0042	-0.0063	-0.0071	-0.0084
0.2720	0.0028	-0.0057	-0.0135	-0.0006
0.2800	0.0021	-0.0030	-0.0215	0.0051
0.2880	-0.0069	0.0064	-0.0251	0.0094
0.2960	-0.0201	0.0147	-0.0254	0.0082
0.3040	-0.0264	0.0159	-0.0202	-0.0027
0.3120	-0.0278	0.0102	-0.0119	-0.0179

WG(LB/SEC)	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0440	0.0440	0.0440	0.0440
CELL	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.3831	0.3831
0.0080	0.7775	0.8083	0.3698	0.3695
0.0160	0.5279	0.5411	0.3355	0.3378
0.0240	0.3487	0.3531	0.2958	0.2937
0.0320	0.2265	0.2303	0.2562	0.2508
0.0400	0.1453	0.1480	0.2200	0.2016
0.0480	0.0874	0.0922	0.1862	0.1551
0.0560	0.0435	0.0523	0.1532	0.1143
0.0640	0.0124	0.0233	0.1230	0.0809
0.0720	-0.0120	0.0025	0.0934	0.0510
0.0800	-0.0327	-0.0125	0.0646	0.0250
0.0880	-0.0493	-0.0231	0.0385	0.0051
0.0960	-0.0603	-0.0314	0.0151	-0.0081
0.1040	-0.0661	-0.0389	-0.0041	-0.0163
0.1120	-0.0692	-0.0449	-0.0185	-0.0252
0.1200	-0.0709	-0.0485	-0.0285	-0.0368
0.1280	-0.0697	-0.0515	-0.0353	-0.0499
0.1360	-0.0672	-0.0548	-0.0397	-0.0587
0.1440	-0.0668	-0.0556	-0.0442	-0.0631
0.1520	-0.0673	-0.0556	-0.0436	-0.0640
0.1600	-0.0661	-0.0543	-0.0523	-0.0635
0.1680	-0.0646	-0.0515	-0.0527	-0.0641
0.1760	-0.0640	-0.0501	-0.0509	-0.0639
0.1840	-0.0631	-0.0526	-0.0497	-0.0599
0.1920	-0.0587	-0.0590	-0.0508	-0.0537
0.2000	-0.0515	-0.0596	-0.0498	-0.0458
0.2080	-0.0489	-0.0566	-0.0485	-0.0409
0.2160	-0.0501	-0.0536	-0.0468	-0.0386
0.2240	-0.0517	-0.0515	-0.0475	-0.0357
0.2320	-0.0512	-0.0496	-0.0505	-0.0317
0.2400	-0.0478	-0.0496	-0.0549	-0.0298
0.2480	-0.0445	-0.0497	-0.0572	-0.0290
0.2560	-0.0426	-0.0490	-0.0543	-0.0298
0.2640	-0.0445	-0.0463	-0.0529	-0.0283
0.2720	-0.0468	-0.0432	-0.0550	-0.0270
0.2800	-0.0466	-0.0443	-0.0471	-0.0312
0.2880	-0.0433	-0.0491	-0.0392	-0.0406
0.2960	-0.0410	-0.0526	-0.0388	-0.0479
0.3040	-0.0405	-0.0517	-0.0393	-0.0498
0.3120	-0.0411	-0.0482	-0.0388	-0.0487

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0000	0.0800	0.0800	0.0800	0.1260	0.1260	0.1260	0.1260	0.1800	0.1800	0.1800	0.1800
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED VALUE *****				***** NORMALIZED VALUE *****				***** NORMALIZED VALUE *****			
0.0	1.0000	1.0000	0.4602	0.4602	1.0000	1.0000	0.5659	0.5659	1.0000	1.0000	0.5537	0.5537
0.0080	0.8263	0.8177	0.4516	0.4434	0.8436	0.8233	0.5468	0.5400	0.8252	0.8013	0.5281	0.5272
0.0160	0.5714	0.5574	0.4216	0.4046	0.5944	0.5622	0.4878	0.4711	0.5542	0.5144	0.4618	0.4549
0.0240	0.3698	0.3586	0.3720	0.3515	0.3817	0.3573	0.4050	0.3714	0.3296	0.2964	0.3682	0.3466
0.0320	0.2250	0.2177	0.3099	0.2791	0.2144	0.2048	0.3152	0.2584	0.1582	0.1413	0.2640	0.2225
0.0400	0.1202	0.1160	0.2437	0.1938	0.0857	0.0898	0.2238	0.1504	0.0303	0.0290	0.1613	0.1037
0.0480	0.0432	0.0432	0.1746	0.1119	-0.0692	0.0022	0.1296	0.0525	-0.0631	-0.0548	0.0629	0.0011
0.0560	-0.0176	-0.0091	0.1078	0.0414	-0.0781	-0.0639	0.0412	-0.0277	-0.1310	-0.1168	-0.0273	-0.0804
0.0640	-0.0643	-0.0476	0.0513	-0.0134	-0.1297	-0.1141	-0.0352	-0.0859	-0.1821	-0.1623	-0.1078	-0.1380
0.0720	-0.0959	-0.0752	0.0043	-0.0526	-0.1662	-0.1498	-0.0980	-0.1277	-0.2207	-0.1940	-0.1741	-0.1735
0.0800	-0.1165	-0.0940	-0.0340	-0.0767	-0.1902	-0.1738	-0.1469	-0.1558	-0.2473	-0.2119	-0.2187	-0.1935
0.0880	-0.1306	-0.1077	-0.0641	-0.0903	-0.2063	-0.1904	-0.1829	-0.1725	-0.2614	-0.2200	-0.2450	-0.2012
0.0960	-0.1404	-0.1174	-0.0900	-0.0985	-0.2143	-0.1983	-0.2052	-0.1800	-0.2640	-0.2201	-0.2590	-0.1982
0.1040	-0.1452	-0.1233	-0.1127	-0.1027	-0.2159	-0.1982	-0.2168	-0.1809	-0.2554	-0.2134	-0.2609	-0.1900
0.1120	-0.1446	-0.1241	-0.1276	-0.1045	-0.2131	-0.1922	-0.2187	-0.1777	-0.2355	-0.1989	-0.2517	-0.1771
0.1200	-0.1428	-0.1225	-0.1367	-0.1044	-0.2077	-0.1819	-0.2117	-0.1731	-0.2075	-0.1765	-0.2306	-0.1610
0.1280	-0.1396	-0.1183	-0.1401	-0.1011	-0.2008	-0.1700	-0.2004	-0.1681	-0.1769	-0.1505	-0.1994	-0.1432
0.1360	-0.1346	-0.1148	-0.1380	-0.0963	-0.1900	-0.1571	-0.1880	-0.1599	-0.1463	-0.1249	-0.1624	-0.1263
0.1440	-0.1275	-0.1105	-0.1316	-0.0907	-0.1754	-0.1425	-0.1737	-0.1488	-0.1117	-0.0999	-0.1239	-0.1076
0.1520	-0.1188	-0.1042	-0.1224	-0.0837	-0.1572	-0.1274	-0.1572	-0.1348	-0.0737	-0.0776	-0.0857	-0.0855
0.1600	-0.1070	-0.0950	-0.1134	-0.0754	-0.1366	-0.1136	-0.1412	-0.1188	-0.0366	-0.0540	-0.0478	-0.0602
0.1680	-0.0930	-0.0835	-0.1053	-0.0671	-0.1142	-0.1007	-0.1236	-0.1026	-0.0049	-0.0294	-0.0126	-0.0324
0.1760	-0.0802	-0.0717	-0.0970	-0.0615	-0.0912	-0.0878	-0.1005	-0.0892	0.0204	-0.0061	0.0189	-0.0050
0.1840	-0.0693	-0.0629	-0.0872	-0.0568	-0.0687	-0.0747	-0.0734	-0.0756	0.0427	0.0125	0.0460	0.0156
0.1920	-0.0589	-0.0576	-0.0757	-0.0534	-0.0456	-0.0595	-0.0462	-0.0574	0.0617	0.0266	0.0696	0.0289
0.2000	-0.0508	-0.0545	-0.0618	-0.0496	-0.0227	-0.0409	-0.0188	-0.0370	0.0787	0.0414	0.0897	0.0386
0.2080	-0.0477	-0.0517	-0.0454	-0.0487	-0.0002	-0.0198	0.0040	-0.0201	0.0893	0.0575	0.1007	0.0440
0.2160	-0.0457	-0.0474	-0.0319	-0.0504	0.0223	0.0013	0.0198	-0.0068	0.0909	0.0679	0.1047	0.0479
0.2240	-0.0427	-0.0445	-0.0231	-0.0526	0.0420	0.0191	0.0304	0.0076	0.0832	0.0708	0.1042	0.0499
0.2320	-0.0367	-0.0407	-0.0189	-0.0546	0.0553	0.0330	0.0425	0.0243	0.0695	0.0697	0.0961	0.0488
0.2400	-0.0332	-0.0353	-0.0160	-0.0533	0.0611	0.0429	0.0559	0.0385	0.0534	0.0656	0.0830	0.0440
0.2480	-0.0278	-0.0313	-0.0121	-0.0507	0.0652	0.0479	0.0641	0.0502	0.0370	0.0543	0.0652	0.0377
0.2560	-0.0230	-0.0305	-0.0075	-0.0498	0.0676	0.0475	0.0678	0.0569	0.0242	0.0350	0.0431	0.0301
0.2640	-0.0196	-0.0298	-0.0062	-0.0505	0.0637	0.0442	0.0647	0.0614	0.0145	0.0124	0.0192	0.0205
0.2720	-0.0157	-0.0278	-0.0084	-0.0493	0.0579	0.0394	0.0589	0.0610	0.0030	-0.0066	-0.0038	0.0131
0.2800	-0.0148	-0.0236	-0.0122	-0.0444	0.0530	0.0335	0.0525	0.0556	-0.0087	-0.0188	-0.0220	0.0029
0.2880	-0.0174	-0.0181	-0.0137	-0.0353	0.0491	0.0330	0.0481	0.0469	-0.0185	-0.0238	-0.0328	-0.0103
0.2960	-0.0203	-0.0165	-0.0141	-0.0247	0.0430	0.0353	0.0463	0.0382	-0.0273	-0.0210	-0.0371	-0.0224
0.3040	-0.0209	-0.0176	-0.0173	-0.0149	0.0345	0.0367	0.0474	0.0297	-0.0351	-0.0184	-0.0364	-0.0274
0.3120	-0.0191	-0.0167	-0.0219	-0.0073	0.0266	0.0386	0.0486	0.0239	-0.0393	-0.0138	-0.0335	-0.0251

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.2400	0.2400	0.2400	0.2400	0.3500	0.3500	0.3500	0.3500	0.4700	0.4700	0.4700	0.4700
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.5005	0.5005	1.0000	1.0000	0.5910	0.5910	1.0000	1.0000	0.6601	0.6601
0.0080	0.8153	0.7863	0.4725	0.4835	0.8166	0.7910	0.5607	0.5425	0.8230	0.8030	0.6013	0.6193
0.0160	0.5215	0.4780	0.4044	0.4224	0.5179	0.4771	0.4719	0.4226	0.5289	0.4933	0.4722	0.4901
0.0240	0.2785	0.2491	0.3122	0.3251	0.2754	0.2400	0.3517	0.2745	0.2849	0.2518	0.3210	0.3211
0.0320	0.0960	0.0928	0.2062	0.2023	0.1039	0.0814	0.2214	0.1382	0.1120	0.0892	0.1812	0.1608
0.0400	-0.0377	-0.0155	0.1006	0.0774	-0.0150	-0.0224	0.1012	0.0301	-0.0090	-0.0200	0.0637	0.0391
0.0480	-0.1307	-0.0905	0.0043	-0.0277	-0.0973	-0.0899	0.0063	-0.0471	-0.0940	-0.0902	-0.0308	-0.0424
0.0560	-0.1884	-0.1412	-0.0766	-0.1014	-0.1508	-0.1306	-0.0650	-0.0959	-0.1517	-0.1354	-0.1053	-0.0969
0.0640	-0.2207	-0.1777	-0.1422	-0.1449	-0.1808	-0.1547	-0.1194	-0.1238	-0.1875	-0.1662	-0.1588	-0.1343
0.0720	-0.2364	-0.2026	-0.1918	-0.1661	-0.1940	-0.1681	-0.1588	-0.1372	-0.2086	-0.1863	-0.1943	-0.1582
0.0800	-0.2427	-0.2145	-0.2231	-0.1706	-0.1970	-0.1762	-0.1846	-0.1423	-0.2201	-0.1962	-0.2175	-0.1707
0.0880	-0.2387	-0.2143	-0.2364	-0.1673	-0.1939	-0.1798	-0.1979	-0.1421	-0.2227	-0.1974	-0.2295	-0.1729
0.0960	-0.2240	-0.2058	-0.2343	-0.1597	-0.1879	-0.1766	-0.2038	-0.1377	-0.2186	-0.1917	-0.2291	-0.1700
0.1040	-0.2024	-0.1913	-0.2224	-0.1498	-0.1785	-0.1639	-0.2038	-0.1319	-0.2081	-0.1806	-0.2183	-0.1641
0.1120	-0.1743	-0.1723	-0.2042	-0.1348	-0.1618	-0.1455	-0.1962	-0.1268	-0.1908	-0.1637	-0.2008	-0.1549
0.1200	-0.1413	-0.1487	-0.1789	-0.1159	-0.1394	-0.1287	-0.1786	-0.1183	-0.1693	-0.1447	-0.1772	-0.1438
0.1280	-0.1045	-0.1217	-0.1478	-0.0963	-0.1156	-0.1136	-0.1534	-0.1036	-0.1444	-0.1265	-0.1499	-0.1316
0.1360	-0.0683	-0.0934	-0.1134	-0.0780	-0.0929	-0.1040	-0.1282	-0.0892	-0.1193	-0.1093	-0.1229	-0.1167
0.1440	-0.0359	-0.0660	-0.0763	-0.0612	-0.0762	-0.0949	-0.1084	-0.0784	-0.0948	-0.0917	-0.0935	-0.0989
0.1520	-0.0069	-0.0420	-0.0371	-0.0428	-0.0651	-0.0846	-0.0906	-0.0725	-0.0696	-0.0747	-0.0608	-0.0765
0.1600	0.0176	-0.0202	0.0003	-0.0222	-0.0565	-0.0726	-0.0724	-0.0676	-0.0416	-0.0562	-0.0310	-0.0532
0.1680	0.0394	-0.0029	0.0336	-0.0054	-0.0454	-0.0610	-0.0522	-0.0594	-0.0129	-0.0361	-0.0084	-0.0302
0.1760	0.0576	0.0111	0.0619	0.0048	-0.0326	-0.0507	-0.0314	-0.0525	0.0111	-0.0168	0.0134	-0.0103
0.1840	0.0695	0.0277	0.0800	0.0113	-0.0212	-0.0388	-0.0101	-0.0457	0.0300	0.0028	0.0382	0.0033
0.1920	0.0696	0.0458	0.0903	0.0171	-0.0140	-0.0241	0.0097	-0.0342	0.0456	0.0238	0.0586	0.0121
0.2000	0.0605	0.0562	0.0964	0.0244	-0.0071	-0.0095	0.0268	-0.0196	0.0587	0.0431	0.0722	0.0216
0.2080	0.0503	0.0575	0.0950	0.0310	0.0025	0.0044	0.0409	-0.0055	0.0668	0.0542	0.0781	0.0329
0.2160	0.0434	0.0539	0.0895	0.0337	0.0133	0.0173	0.0528	0.0069	0.0695	0.0578	0.0737	0.0445
0.2240	0.0389	0.0463	0.0834	0.0359	0.0231	0.0253	0.0584	0.0168	0.0696	0.0537	0.0659	0.0536
0.2320	0.0346	0.0407	0.0730	0.0397	0.0299	0.0327	0.0542	0.0216	0.0706	0.0512	0.0649	0.0596
0.2400	0.0296	0.0357	0.0550	0.0406	0.0341	0.0399	0.0450	0.0241	0.0727	0.0560	0.0670	0.0628
0.2480	0.0239	0.0316	0.0325	0.0332	0.0347	0.0440	0.0370	0.0267	0.0740	0.0602	0.0689	0.0645
0.2560	0.0172	0.0237	0.0150	0.0226	0.0338	0.0432	0.0360	0.0310	0.0702	0.0569	0.0654	0.0627
0.2640	0.0105	0.0152	0.0089	0.0128	0.0342	0.0391	0.0443	0.0327	0.0570	0.0446	0.0561	0.0557
0.2720	0.0046	0.0150	0.0092	0.0050	0.0380	0.0373	0.0508	0.0322	0.0411	0.0325	0.0429	0.0429
0.2800	0.0001	0.0175	0.0078	0.0004	0.0459	0.0378	0.0480	0.0330	0.0251	0.0221	0.0307	0.0261
0.2880	-0.0034	0.0185	0.0018	0.0024	0.0507	0.0383	0.0411	0.0360	0.0080	0.0118	0.0176	0.0081
0.2960	-0.0088	0.0197	-0.0096	0.0100	0.0454	0.0378	0.0366	0.0356	-0.0078	0.0003	0.0002	-0.0077
0.3040	-0.0130	0.0186	-0.0206	0.0148	0.0339	0.0351	0.0295	0.0285	-0.0217	-0.0132	-0.0189	-0.0210
0.3120	-0.0166	0.0120	-0.0257	0.0124	0.0184	0.0277	0.0215	0.0186	-0.0334	-0.0269	-0.0341	-0.0304

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450
WL(LB/SEC)	0.5850	0.5850	0.5850	0.5850	0.0160	0.0160	0.0160	0.0160	0.0280	0.0280	0.0280	0.0280
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.6796	0.6796	1.0000	1.0000	0.1444	0.1444	1.0000	1.0000	0.1074	0.1074
0.0080	0.8109	0.8062	0.6099	0.6333	0.7810	0.7782	0.1402	0.1376	0.7436	0.7549	0.1044	0.1005
0.0160	0.5007	0.4979	0.4630	0.4899	0.4071	0.3998	0.1249	0.1255	0.3511	0.3570	0.0973	0.0866
0.0240	0.2491	0.2464	0.2965	0.3074	0.1057	0.0986	0.1031	0.1128	0.0647	0.0598	0.0933	0.0716
0.0320	0.0763	0.0753	0.1475	0.1393	-0.0893	-0.0947	0.0761	0.0983	-0.0953	-0.1060	0.0911	0.0598
0.0400	-0.0400	-0.0361	0.0271	0.0130	-0.1939	-0.1961	0.0445	0.0797	-0.1623	-0.1685	0.0870	0.0488
0.0480	-0.1181	-0.1058	-0.0630	-0.0704	-0.2265	-0.2228	0.0098	0.0613	-0.1760	-0.1667	0.0814	0.0328
0.0560	-0.1690	-0.1476	-0.1266	-0.1213	-0.2096	-0.2017	-0.0230	0.0492	-0.1613	-0.1369	0.0772	0.0166
0.0640	-0.1990	-0.1731	-0.1702	-0.1513	-0.1660	-0.1594	-0.0485	0.0444	-0.1317	-0.1040	0.0737	0.0084
0.0720	-0.2121	-0.1882	-0.1965	-0.1662	-0.1152	-0.1122	-0.0637	0.0380	-0.0987	-0.0782	0.0676	0.0074
0.0800	-0.2134	-0.1939	-0.2100	-0.1716	-0.0693	-0.0648	-0.0664	0.0265	-0.0683	-0.0546	0.0578	0.0050
0.0880	-0.2065	-0.1933	-0.2127	-0.1714	-0.0322	-0.0210	-0.0561	0.0115	-0.0446	-0.0302	0.0419	-0.0013
0.0960	-0.1961	-0.1894	-0.2100	-0.1697	-0.0055	0.0120	-0.0341	-0.0027	-0.0258	-0.0074	0.0180	-0.0086
0.1040	-0.1862	-0.1821	-0.2052	-0.1642	0.0142	0.0291	-0.0074	-0.0123	-0.0089	0.0079	-0.0061	-0.0117
0.1120	-0.1762	-0.1733	-0.1952	-0.1505	0.0266	0.0293	0.0156	-0.0185	0.0051	0.0138	-0.0200	-0.0110
0.1200	-0.1596	-0.1613	-0.1831	-0.1319	0.0272	0.0167	0.0307	-0.0212	0.0131	0.0127	-0.0248	-0.0062
0.1280	-0.1361	-0.1461	-0.1658	-0.1115	0.0189	0.0026	0.0372	-0.0194	0.0142	0.0117	-0.0285	0.0025
0.1360	-0.1110	-0.1249	-0.1408	-0.0909	0.0111	-0.0071	0.0373	-0.0135	0.0129	0.0120	-0.0307	0.0048
0.1440	-0.0866	-0.1004	-0.1097	-0.0731	0.0068	-0.0115	0.0323	-0.0082	0.0122	0.0097	-0.0302	0.0044
0.1520	-0.0617	-0.0764	-0.0758	-0.0607	0.0017	-0.0107	0.0226	-0.0083	0.0124	0.0017	-0.0312	0.0037
0.1600	-0.0346	-0.0533	-0.0445	-0.0417	-0.0085	-0.0092	0.0108	-0.0138	0.0130	-0.0085	-0.0304	0.0010
0.1680	-0.0072	-0.0399	-0.0176	-0.0186	-0.0202	-0.0099	-0.0039	-0.0185	0.0080	-0.0152	-0.0262	-0.0068
0.1760	0.0191	-0.0108	0.0082	0.0026	-0.0269	-0.0148	-0.0145	-0.0198	0.0005	-0.0153	-0.0156	-0.0146
0.1840	0.0406	0.0035	0.0296	0.0159	-0.0258	-0.0205	-0.0143	-0.0221	-0.0043	-0.0098	0.0001	-0.0165
0.1920	0.0554	0.0165	0.0449	0.0220	-0.0253	-0.0251	-0.0044	-0.0273	-0.0116	-0.0052	0.0146	-0.0130
0.2000	0.0599	0.0302	0.0564	0.0244	-0.0141	-0.0270	0.0084	-0.0307	-0.0183	-0.0028	0.0256	-0.0042
0.2080	0.0549	0.0417	0.0685	0.0251	-0.0085	-0.0226	0.0187	-0.0272	-0.0202	0.0011	0.0310	0.0029
0.2160	0.0501	0.0510	0.0804	0.0268	-0.0047	-0.0097	0.0232	-0.0208	-0.0185	0.0034	0.0308	0.0043
0.2240	0.0473	0.0582	0.0885	0.0294	-0.0047	0.0055	0.0206	-0.0164	-0.0123	0.0016	0.0279	0.0014
0.2320	0.0457	0.0628	0.0906	0.0319	-0.0034	0.0128	0.0136	-0.0103	-0.0006	-0.0031	0.0278	-0.0016
0.2400	0.0450	0.0586	0.0802	0.0348	-0.0009	0.0135	0.0037	-0.0023	0.0116	-0.0119	0.0257	-0.0032
0.2480	0.0408	0.0463	0.0599	0.0367	-0.0018	0.0130	-0.0055	0.0039	0.0168	-0.0235	0.0132	-0.0046
0.2560	0.0316	0.0331	0.0383	0.0338	-0.0052	0.0114	-0.0097	0.0058	0.0143	-0.0309	-0.0099	-0.0059
0.2640	0.0197	0.0207	0.0205	0.0255	-0.0074	0.0050	-0.0016	0.0056	0.0098	-0.0273	-0.0285	-0.0107
0.2720	0.0067	0.0122	0.0089	0.0145	-0.0085	-0.0061	-0.0252	0.0048	0.0033	-0.0169	-0.0344	-0.0186
0.2800	-0.0049	0.0023	0.0010	0.0031	-0.0102	-0.0152	-0.0326	0.0029	-0.0048	-0.0083	-0.0323	-0.0240
0.2880	-0.0106	-0.0082	-0.0068	-0.0053	-0.0133	-0.0195	-0.0347	-0.0001	-0.0098	-0.0079	-0.0267	-0.0249
0.2960	-0.0126	-0.0157	-0.0131	-0.0126	-0.0150	-0.0215	-0.0314	-0.0024	-0.0146	-0.0123	-0.0192	-0.0197
0.3040	-0.0154	-0.0157	-0.0155	-0.0191	-0.0122	-0.0221	-0.0218	0.0	-0.0175	-0.0179	-0.0142	-0.0089
0.3120	-0.0170	-0.0099	-0.0162	-0.0231	-0.0061	-0.0232	-0.0114	0.0032	-0.0187	-0.0193	-0.0141	0.0044

WG(LB/SEC)	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450
WL(LB/SEC)	0.0440	0.0440	0.0440	0.0440	0.0800	0.0800	0.0800	0.0800	0.1260	0.1260	0.1260	0.1260
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.3627	0.3627	1.0000	1.0000	0.5190	0.5190	1.0000	1.0000	0.5881	0.5881
0.0080	0.8005	0.7988	0.3540	0.3518	0.8267	0.8294	0.4966	0.5101	0.8387	0.8335	0.5634	0.5611
0.0160	0.5221	0.5191	0.3429	0.3218	0.5679	0.5763	0.4457	0.4649	0.5746	0.5703	0.4997	0.4856
0.0240	0.3286	0.3276	0.3197	0.2811	0.3694	0.3839	0.3756	0.3960	0.3526	0.3541	0.4124	0.3779
0.0320	0.2072	0.2034	0.2789	0.2254	0.2295	0.2470	0.2998	0.3130	0.1873	0.1927	0.3086	0.2557
0.0400	0.1291	0.1206	0.2367	0.1762	0.1311	0.1481	0.2284	0.2291	0.0672	0.0723	0.1993	0.1335
0.0480	0.0756	0.0659	0.1946	0.1343	0.0589	0.0750	0.1604	0.1512	-0.0194	-0.0169	0.0979	0.0282
0.0560	0.0349	0.0283	0.1521	0.0912	0.0046	0.0203	0.0971	0.0813	-0.0830	-0.0782	0.0104	-0.0501
0.0640	0.0043	0.0042	0.1124	0.0497	-0.0347	-0.0227	0.0399	0.0205	-0.1304	-0.1199	-0.0607	-0.1008
0.0720	-0.0197	-0.0141	0.0800	0.0177	-0.0643	-0.0558	-0.0070	-0.0278	-0.1658	-0.1472	-0.1140	-0.1309
0.0800	-0.0372	-0.0286	0.0557	-0.0048	-0.0861	-0.0765	-0.0402	-0.0593	-0.1898	-0.1631	-0.1501	-0.1485
0.0880	-0.0476	-0.0377	0.0374	-0.0218	-0.1011	-0.0869	-0.0615	-0.0752	-0.2017	-0.1701	-0.1757	-0.1573
0.0960	-0.0527	-0.0408	0.0235	-0.0333	-0.1115	-0.0913	-0.0774	-0.0839	-0.2041	-0.1697	-0.1927	-0.1592
0.1040	-0.0539	-0.0417	0.0133	-0.0387	-0.1190	-0.0954	-0.0886	-0.0887	-0.2008	-0.1679	-0.2013	-0.1570
0.1120	-0.0538	-0.0445	0.0069	-0.0442	-0.1250	-0.1007	-0.0957	-0.0892	-0.1926	-0.1672	-0.2028	-0.1512
0.1200	-0.0509	-0.0461	0.0037	-0.0488	-0.1268	-0.1059	-0.1040	-0.0882	-0.1796	-0.1631	-0.1970	-0.1415
0.1280	-0.0477	-0.0432	-0.0013	-0.0501	-0.1229	-0.1080	-0.1130	-0.0893	-0.1632	-0.1538	-0.1838	-0.1323
0.1360	-0.0481	-0.0402	-0.0096	-0.0481	-0.1148	-0.1096	-0.1172	-0.0945	-0.1457	-0.1412	-0.1677	-0.1236
0.1440	-0.0510	-0.0399	-0.0178	-0.0457	-0.1072	-0.1089	-0.1141	-0.1006	-0.1297	-0.1284	-0.1506	-0.1143
0.1520	-0.0545	-0.0391	-0.0236	-0.0436	-0.1036	-0.1037	-0.1083	-0.1035	-0.1130	-0.1136	-0.1324	-0.1012
0.1600	-0.0563	-0.0360	-0.0304	-0.0422	-0.1006	-0.0989	-0.1013	-0.0993	-0.0945	-0.0975	-0.1137	-0.0848
0.1680	-0.0556	-0.0341	-0.0348	-0.0411	-0.0957	-0.0958	-0.0924	-0.0901	-0.0755	-0.0812	-0.0947	-0.0702
0.1760	-0.0552	-0.0327	-0.0354	-0.0431	-0.0895	-0.0913	-0.0855	-0.0796	-0.0557	-0.0674	-0.0760	-0.0576
0.1840	-0.0572	-0.0301	-0.0341	-0.0455	-0.0825	-0.0860	-0.0817	-0.0724	-0.0363	-0.0580	-0.0578	-0.0467
0.1920	-0.0608	-0.0298	-0.0357	-0.0460	-0.0761	-0.0801	-0.0813	-0.0692	-0.0226	-0.0495	-0.0405	-0.0394
0.2000	-0.0619	-0.0330	-0.0368	-0.0465	-0.0695	-0.0739	-0.0810	-0.0712	-0.0155	-0.0414	-0.0249	-0.0383
0.2080	-0.0590	-0.0356	-0.0378	-0.0483	-0.0623	-0.0664	-0.0795	-0.0742	-0.0106	-0.0345	-0.0097	-0.0356
0.2160	-0.0564	-0.0363	-0.0402	-0.0494	-0.0596	-0.0606	-0.0766	-0.0746	-0.0038	-0.0290	0.0046	-0.0291
0.2240	-0.0519	-0.0373	-0.0433	-0.0490	-0.0602	-0.0578	-0.0689	-0.0733	0.0047	-0.0227	0.0145	-0.0218
0.2320	-0.0456	-0.0368	-0.0471	-0.0456	-0.0650	-0.0567	-0.0589	-0.0697	0.0118	-0.0145	0.0189	-0.0170
0.2400	-0.0419	-0.0347	-0.0497	-0.0421	-0.0566	-0.0546	-0.0503	-0.0617	0.0151	-0.0034	0.0254	-0.0159
0.2480	-0.0411	-0.0356	-0.0507	-0.0415	-0.0510	-0.0533	-0.0441	-0.0547	0.0142	0.0062	0.0358	-0.0165
0.2560	-0.0415	-0.0393	-0.0498	-0.0400	-0.0438	-0.0528	-0.0406	-0.0512	0.0111	0.0139	0.0454	-0.0127
0.2640	-0.0442	-0.0433	-0.0437	-0.0387	-0.0343	-0.0524	-0.0389	-0.0488	0.0086	0.0208	0.0480	-0.0040
0.2720	-0.0504	-0.0441	-0.0349	-0.0383	-0.0264	-0.0439	-0.0355	-0.0455	0.0097	0.0233	0.0426	0.0080
0.2800	-0.0554	-0.0413	-0.0288	-0.0383	-0.0201	-0.0410	-0.0255	-0.0450	0.0150	0.0232	0.0356	0.0200
0.2880	-0.0576	-0.0385	-0.0310	-0.0353	-0.0165	-0.0348	-0.0098	-0.0464	0.0196	0.0234	0.0300	0.0283
0.2960	-0.0576	-0.0360	-0.0378	-0.0325	-0.0151	-0.0294	0.0054	-0.0446	0.0238	0.0210	0.0235	0.0305
0.3040	-0.0563	-0.0319	-0.0394	-0.0316	-0.0154	-0.0222	0.0145	-0.0396	0.0255	0.0161	0.0193	0.0267
0.3120	-0.0528	-0.0305	-0.0385	-0.0318	-0.0154	-0.0160	0.0173	-0.0309	0.0258	0.0139	0.0191	0.0233

WG(LB/SEC)	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450
WL(LB/SEC)	0.1800	0.1800	0.1800	0.1800	0.2400	0.2400	0.2400	0.2400	0.3500	0.3500	0.3500	0.3500
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.5904	0.5904	1.0000	1.0000	0.5777	0.5777	1.0000	1.0000	0.5983	0.5983
0.0080	0.8387	0.8285	0.5588	0.5695	0.8311	0.8150	0.5383	0.5559	0.8235	0.8041	0.5712	0.5477
0.0160	0.5731	0.5582	0.4753	0.5009	0.5506	0.5216	0.4473	0.4731	0.5293	0.4980	0.4740	0.4338
0.0240	0.3415	0.3353	0.3593	0.3916	0.3070	0.2824	0.3249	0.3462	0.2811	0.2554	0.3429	0.2829
0.0320	0.1607	0.1706	0.2350	0.2614	0.1212	0.1081	0.1963	0.2049	0.0976	0.0854	0.2087	0.1320
0.0400	0.0222	0.0484	0.1157	0.1326	-0.0147	-0.0148	0.0767	0.0746	-0.0314	-0.0305	0.0890	0.0083
0.0480	-0.0817	-0.0451	0.0093	0.0225	-0.1136	-0.0981	-0.0280	-0.0294	-0.1166	-0.1076	-0.0080	-0.0775
0.0560	-0.1529	-0.1147	-0.0770	-0.0616	-0.1824	-0.1543	-0.1115	-0.1019	-0.1721	-0.1566	-0.0843	-0.1298
0.0640	-0.1977	-0.1634	-0.1423	-0.1195	-0.2252	-0.1917	-0.1736	-0.1465	-0.2066	-0.1832	-0.1432	-0.1586
0.0720	-0.2264	-0.1956	-0.1896	-0.1557	-0.2443	-0.2112	-0.2146	-0.1689	-0.2256	-0.1931	-0.1851	-0.1719
0.0800	-0.2422	-0.2140	-0.2210	-0.1763	-0.2427	-0.2153	-0.2351	-0.1716	-0.2313	-0.1953	-0.2116	-0.1764
0.0880	-0.2445	-0.2212	-0.2369	-0.1863	-0.2302	-0.2065	-0.2369	-0.1617	-0.2271	-0.1947	-0.2245	-0.1746
0.0960	-0.2347	-0.2195	-0.2402	-0.1881	-0.2125	-0.1920	-0.2264	-0.1482	-0.2166	-0.1912	-0.2257	-0.1692
0.1040	-0.2170	-0.2091	-0.2330	-0.1816	-0.1903	-0.1772	-0.2088	-0.1337	-0.2013	-0.1809	-0.2170	-0.1603
0.1120	-0.1954	-0.1916	-0.2148	-0.1675	-0.1618	-0.1579	-0.1862	-0.1166	-0.1810	-0.1630	-0.1997	-0.1472
0.1200	-0.1696	-0.1722	-0.1887	-0.1510	-0.1285	-0.1313	-0.1577	-0.0976	-0.1560	-0.1436	-0.1749	-0.1326
0.1280	-0.1408	-0.1511	-0.1596	-0.1357	-0.0955	-0.1013	-0.1239	-0.0816	-0.1313	-0.1234	-0.1455	-0.1137
0.1360	-0.1130	-0.1283	-0.1294	-0.1212	-0.0677	-0.0744	-0.0895	-0.0698	-0.1063	-0.1007	-0.1152	-0.0886
0.1440	-0.0876	-0.1068	-0.0983	-0.1061	-0.0464	-0.0506	-0.0581	-0.0598	-0.0794	-0.0754	-0.0864	-0.0624
0.1520	-0.0654	-0.0836	-0.0686	-0.0885	-0.0281	-0.0282	-0.0286	-0.0497	-0.0513	-0.0510	-0.0589	-0.0402
0.1600	-0.0456	-0.0594	-0.0416	-0.0693	-0.0126	-0.0080	-0.0008	-0.0372	-0.0225	-0.0313	-0.0307	-0.0214
0.1680	-0.0276	-0.0359	-0.0184	-0.0530	-0.0010	0.0081	0.0249	-0.0217	0.0051	-0.0175	-0.0030	-0.0009
0.1760	-0.0127	-0.0133	0.0016	-0.0410	0.0112	0.0206	0.0459	-0.0071	0.0293	-0.0058	0.0213	0.0195
0.1840	0.0021	0.0050	0.0228	-0.0287	0.0229	0.0300	0.0608	0.0025	0.0491	0.0100	0.0400	0.0348
0.1920	0.0201	0.0177	0.0441	-0.0128	0.0325	0.0346	0.0714	0.0078	0.0627	0.0267	0.0533	0.0441
0.2000	0.0394	0.0272	0.0609	0.0058	0.0387	0.0343	0.0796	0.0096	0.0698	0.0398	0.0631	0.0449
0.2080	0.0548	0.0335	0.0746	0.0253	0.0418	0.0311	0.0824	0.0069	0.0721	0.0479	0.0731	0.0436
0.2160	0.0650	0.0378	0.0806	0.0419	0.0402	0.0270	0.0760	0.0017	0.0690	0.0509	0.0786	0.0429
0.2240	0.0694	0.0405	0.0774	0.0525	0.0324	0.0206	0.0615	-0.0025	0.0621	0.0489	0.0749	0.0396
0.2320	0.0696	0.0400	0.0708	0.0560	0.0218	0.0149	0.0427	-0.0052	0.0522	0.0453	0.0688	0.0324
0.2400	0.0647	0.0375	0.0615	0.0524	0.0128	0.0094	0.0251	-0.0031	0.0359	0.0417	0.0614	0.0227
0.2480	0.0530	0.0331	0.0508	0.0439	0.0062	0.0021	0.0085	0.0026	0.0216	0.0365	0.0535	0.0132
0.2560	0.0396	0.0274	0.0378	0.0341	-0.0001	-0.0068	-0.0076	0.0063	0.0152	0.0309	0.0462	0.0058
0.2640	0.0263	0.0210	0.0221	0.0247	-0.0065	-0.0155	-0.0247	0.0037	0.0144	0.0277	0.0395	-0.0017
0.2720	0.0135	0.0147	0.0064	0.0155	-0.0125	-0.0222	-0.0374	-0.0002	0.0129	0.0243	0.0322	-0.0097
0.2800	0.0027	0.0101	-0.0086	0.0076	-0.0159	-0.0255	-0.0413	0.0006	0.0043	0.0180	0.0223	-0.0148
0.2880	-0.0062	0.0072	-0.0196	0.0006	-0.0156	-0.0248	-0.0385	0.0032	-0.0080	0.0076	0.0085	-0.0161
0.2960	-0.0124	0.0053	-0.0239	-0.0035	-0.0140	-0.0220	-0.0313	0.0037	-0.0191	-0.0050	-0.0061	-0.0180
0.3040	-0.0166	0.0001	-0.0238	-0.0033	-0.0126	-0.0197	-0.0226	0.0037	-0.0267	-0.0183	-0.0206	-0.0205
0.3120	-0.0200	-0.0094	-0.0232	-0.0039	-0.0112	-0.0144	-0.0140	0.0029	-0.0323	-0.0312	-0.0332	-0.0242

WG(LB/SEC)	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0450	0.0976	0.0976	0.0976	0.0976
WL(LB/SEC)	0.4700	0.4700	0.4700	0.4700	0.5850	0.5850	0.5850	0.5850	0.0160	0.0160	0.0160	0.0160
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.6621	0.6621	1.0000	1.0000	0.6953	0.6953	1.0000	1.0000	0.0827	0.0827
0.0080	0.8210	0.8057	0.6335	0.5807	0.8251	0.8072	0.6140	0.6565	0.6224	0.6331	0.0760	0.0709
0.0160	0.5168	0.4984	0.5230	0.4187	0.5202	0.4973	0.4587	0.5092	0.0924	0.1123	0.0688	0.0588
0.0240	0.2586	0.2558	0.3712	0.2399	0.2534	0.2464	0.2846	0.3166	-0.1832	-0.1881	0.0581	0.0487
0.0320	0.0741	0.0886	0.2141	0.0877	0.0625	0.0718	0.1260	0.1394	-0.2394	-0.2535	0.0387	0.0468
0.0400	-0.0520	-0.0252	0.0778	-0.0232	-0.0653	-0.0466	-0.0040	0.0045	-0.1939	-0.1980	0.0174	0.0369
0.0480	-0.1368	-0.1035	-0.0282	-0.0977	-0.1473	-0.1243	-0.1004	-0.0881	-0.1123	-0.1045	-0.0079	0.0255
0.0560	-0.1902	-0.1562	-0.1046	-0.1449	-0.1986	-0.1742	-0.1651	-0.1471	-0.0389	-0.0235	-0.0117	0.0222
0.0640	-0.2187	-0.1891	-0.1574	-0.1734	-0.2294	-0.2041	-0.2062	-0.1809	0.0041	0.0156	-0.0163	0.0188
0.0720	-0.2303	-0.2062	-0.1918	-0.1890	-0.2429	-0.2168	-0.2264	-0.1964	0.0231	0.0248	-0.0093	0.0202
0.0800	-0.2308	-0.2123	-0.2118	-0.1926	-0.2404	-0.2162	-0.2284	-0.1988	0.0199	0.0067	-0.0085	0.0110
0.0880	-0.2245	-0.2096	-0.2210	-0.1841	-0.2254	-0.2079	-0.2197	-0.1937	0.0048	-0.0097	-0.0013	0.0015
0.0960	-0.2104	-0.1991	-0.2232	-0.1708	-0.2027	-0.1912	-0.2026	-0.1821	-0.0182	-0.0179	0.0052	-0.0104
0.1040	-0.1887	-0.1837	-0.2165	-0.1557	-0.1753	-0.1670	-0.1805	-0.1619	-0.0313	-0.0177	0.0131	-0.0162
0.1120	-0.1623	-0.1638	-0.1980	-0.1373	-0.1463	-0.1410	-0.1574	-0.1362	-0.0286	-0.0136	0.0140	-0.0170
0.1200	-0.1324	-0.1422	-0.1721	-0.1149	-0.1167	-0.1166	-0.1334	-0.1100	-0.0263	-0.0123	0.0104	-0.0171
0.1280	-0.1016	-0.1173	-0.1432	-0.0916	-0.0893	-0.0991	-0.1098	-0.0889	-0.0230	-0.0152	0.0095	-0.0047
0.1360	-0.0720	-0.0922	-0.1119	-0.0680	-0.0670	-0.0902	-0.0896	-0.0754	-0.0217	-0.0258	-0.0023	-0.0073
0.1440	-0.0440	-0.0692	-0.0778	-0.0433	-0.0485	-0.0850	-0.0681	-0.0653	-0.0129	-0.0203	-0.0163	-0.0073
0.1520	-0.0175	-0.0475	-0.0466	-0.0213	-0.0298	-0.0770	-0.0433	-0.0558	-0.0103	-0.0164	-0.0290	-0.0162
0.1600	0.0045	-0.0283	-0.0216	-0.0078	-0.0101	-0.0613	-0.0168	-0.0431	-0.0082	-0.0090	-0.0279	-0.0147
0.1680	0.0236	-0.0123	0.0031	0.0017	0.0087	-0.0373	0.0090	-0.0286	-0.0051	-0.0004	-0.0192	-0.0151
0.1760	0.0387	0.0018	0.0297	0.0100	0.0253	-0.0093	0.0317	-0.0090	-0.0021	-0.0002	-0.0094	-0.0112
0.1840	0.0467	0.0158	0.0532	0.0158	0.0416	0.0152	0.0500	0.0136	0.0038	0.0005	-0.0009	-0.0102
0.1920	0.0471	0.0307	0.0709	0.0178	0.0577	0.0351	0.0659	0.0314	-0.0014	-0.0102	-0.0040	-0.0064
0.2000	0.0455	0.0449	0.0795	0.0202	0.0692	0.0536	0.0789	0.0447	-0.0052	-0.0148	-0.0035	-0.0017
0.2080	0.0458	0.0544	0.0806	0.0236	0.0735	0.0674	0.0857	0.0529	-0.0184	-0.0278	-0.0099	-0.0089
0.2160	0.0456	0.0542	0.0761	0.0228	0.0692	0.0729	0.0814	0.0552	-0.0223	-0.0208	-0.0123	-0.0124
0.2240	0.0422	0.0459	0.0681	0.0196	0.0567	0.0697	0.0703	0.0547	-0.0256	-0.0188	-0.0204	-0.0214
0.2320	0.0345	0.0339	0.0581	0.0172	0.0416	0.0610	0.0576	0.0498	-0.0075	-0.0164	-0.0230	-0.0218
0.2400	0.0250	0.0229	0.0468	0.0145	0.0259	0.0488	0.0426	0.0407	0.0101	-0.0207	-0.0150	-0.0208
0.2480	0.0191	0.0146	0.0326	0.0090	0.0115	0.0377	0.0289	0.0280	0.0115	-0.0231	-0.0100	-0.0155
0.2560	0.0144	0.0073	0.0154	0.0038	0.0023	0.0285	0.0182	0.0175	0.0029	-0.0179	0.0	-0.0076
0.2640	0.0048	-0.0002	-0.0019	0.0023	-0.0030	0.0199	0.0054	0.0113	-0.0068	-0.0109	-0.0048	-0.0095
0.2720	-0.0091	-0.0069	-0.0161	0.0032	-0.0100	0.0123	-0.0081	0.0046	-0.0033	0.0004	-0.0025	-0.0080
0.2800	-0.0220	-0.0100	-0.0235	0.0020	-0.0191	0.0037	-0.0170	-0.0034	-0.0077	-0.0004	-0.0101	-0.0101
0.2880	-0.0291	-0.0074	-0.0269	-0.0019	-0.0254	-0.0075	-0.0229	-0.0119	-0.0165	-0.0032	-0.0111	-0.0057
0.2960	-0.0330	-0.0018	-0.0292	-0.0054	-0.0275	-0.0177	-0.0274	-0.0174	-0.0246	-0.0182	-0.0207	-0.0018
0.3040	-0.0341	0.0011	-0.0306	-0.0064	-0.0272	-0.0210	-0.0291	-0.0205	-0.0120	-0.0295	-0.0246	0.0054
0.3120	-0.0302	0.0025	-0.0277	-0.0074	-0.0249	-0.0200	-0.0266	-0.0189	0.0036	-0.0242	-0.0198	0.0125

WG(LB/SEC)	0.0976	0.0976	0.0976	0.0976	0.0098	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976
WL(LB/SEC)	0.0280	0.0280	0.0280	0.0280	0.0440	0.0440	0.0440	0.0440	0.0800	0.0800	0.0800	0.0800
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		**** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.1443	0.1443	1.0000	1.0000	0.3649	0.3649	1.0000	1.0000	0.3792	0.3792
0.0080	0.6637	0.6769	0.1370	0.1410	0.7172	0.7217	0.3428	0.3517	0.6613	0.6459	0.3627	0.3634
0.0160	0.2452	0.2461	0.1210	0.1362	0.4064	0.4141	0.3006	0.3171	0.3031	0.2973	0.3110	0.3022
0.0240	0.0208	0.0029	0.1072	0.1174	0.2338	0.2499	0.2593	0.2757	0.1175	0.1230	0.2326	0.2113
0.0320	-0.0691	-0.0890	0.0911	0.0945	0.1418	0.1614	0.2171	0.2287	0.0258	0.0332	0.1502	0.1242
0.0400	-0.0983	-0.1171	0.0715	0.0756	0.0863	0.1038	0.1752	0.1824	-0.0226	-0.0157	0.0865	0.0513
0.0480	-0.0988	-0.1206	0.0362	0.0631	0.0457	0.0675	0.1406	0.1335	-0.0515	-0.0433	0.0376	-0.0073
0.0560	-0.0911	-0.1110	0.0118	0.0468	0.0173	0.0443	0.1067	0.0944	-0.0657	-0.0617	-0.0008	-0.0420
0.0640	-0.0792	-0.0897	-0.0095	0.0243	-0.0014	0.0234	0.0762	0.0590	-0.0734	-0.0727	-0.0316	-0.0568
0.0720	-0.0619	-0.0621	-0.0256	0.0039	-0.0150	0.0077	0.0541	0.0326	-0.0769	-0.0778	-0.0533	-0.0642
0.0800	-0.0518	-0.0499	-0.0408	-0.0097	-0.0229	-0.0028	0.0378	0.0183	-0.0761	-0.0827	-0.0666	-0.0677
0.0880	-0.0468	-0.0488	-0.0531	-0.0111	-0.0258	-0.0087	0.0268	0.0074	-0.0739	-0.0833	-0.0708	-0.0691
0.0960	-0.0454	-0.0496	-0.0662	-0.0136	-0.0273	-0.0114	0.0168	-0.0031	-0.0734	-0.0786	-0.0690	-0.0708
0.1040	-0.0409	-0.0416	-0.0762	-0.0115	-0.0274	-0.0114	0.0063	-0.0073	-0.0728	-0.0725	-0.0661	-0.0729
0.1120	-0.0320	-0.0295	-0.0772	-0.0104	-0.0309	-0.0121	-0.0014	-0.0074	-0.0702	-0.0664	-0.0638	-0.0704
0.1200	-0.0258	-0.0197	-0.0720	-0.0075	-0.0324	-0.0153	-0.0062	-0.0087	-0.0688	-0.0622	-0.0630	-0.0627
0.1280	-0.0210	-0.0166	-0.0567	-0.0059	-0.0333	-0.0152	-0.0129	-0.0112	-0.0684	-0.0592	-0.0622	-0.0595
0.1360	-0.0199	-0.0257	-0.0423	-0.0125	-0.0339	-0.0150	-0.0198	-0.0145	-0.0665	-0.0501	-0.0593	-0.0570
0.1440	-0.0143	-0.0317	-0.0235	-0.0157	-0.0291	-0.0171	-0.0228	-0.0168	-0.0584	-0.0383	-0.0513	-0.0503
0.1520	-0.0090	-0.0339	-0.0082	-0.0292	-0.0264	-0.0213	-0.0253	-0.0246	-0.0496	-0.0345	-0.0434	-0.0461
0.1600	-0.0031	-0.0258	-0.0046	-0.0368	-0.0257	-0.0260	-0.0270	-0.0302	-0.0502	-0.0313	-0.0394	-0.0355
0.1680	-0.0027	-0.0133	0.0050	-0.0442	-0.0284	-0.0284	-0.0318	-0.0324	-0.0504	-0.0280	-0.0356	-0.0246
0.1760	-0.0148	-0.0101	0.0136	-0.0349	-0.0296	-0.0274	-0.0311	-0.0321	-0.0420	-0.0271	-0.0302	-0.0242
0.1840	-0.0201	-0.0182	0.0253	-0.0252	-0.0254	-0.0250	-0.0265	-0.0281	-0.0354	-0.0247	-0.0249	-0.0276
0.1920	-0.0230	-0.0268	0.0259	-0.0141	-0.0215	-0.0235	-0.0202	-0.0265	-0.0304	-0.0242	-0.0178	-0.0248
0.2000	-0.0104	-0.0134	0.0166	-0.0091	-0.0169	-0.0204	-0.0147	-0.0248	-0.0196	-0.0224	-0.0105	-0.0195
0.2080	0.0009	-0.0037	-0.0003	-0.0125	-0.0189	-0.0215	-0.0125	-0.0213	-0.0154	-0.0244	-0.0132	-0.0188
0.2160	0.0115	0.0075	-0.0209	-0.0114	-0.0237	-0.0209	-0.0105	-0.0206	-0.0133	-0.0251	-0.0268	-0.0228
0.2240	0.0048	0.0067	-0.0332	-0.0106	-0.0284	-0.0222	-0.0076	-0.0209	-0.0101	-0.0237	-0.0308	-0.0275
0.2320	-0.0005	0.0025	-0.0360	-0.0041	-0.0270	-0.0213	-0.0025	-0.0255	-0.0131	-0.0189	-0.0214	-0.0214
0.2400	-0.0079	-0.0049	-0.0298	-0.0042	-0.0274	-0.0176	0.0009	-0.0279	-0.0125	-0.0154	-0.0058	-0.0145
0.2480	-0.0120	-0.0097	-0.0310	-0.0042	-0.0259	-0.0149	-0.0005	-0.0288	-0.0016	-0.0110	-0.0039	-0.0112
0.2560	-0.0051	-0.0128	-0.0192	-0.0037	-0.0237	-0.0152	-0.0004	-0.0285	0.0035	-0.0117	-0.0104	-0.0119
0.2640	0.0010	-0.0146	-0.0065	-0.0040	-0.0216	-0.0151	-0.0016	-0.0022	-0.0036	-0.0216	-0.0101	-0.0129
0.2720	0.0055	-0.0126	0.0094	-0.0083	-0.0222	-0.0175	-0.0010	-0.0003	-0.0118	-0.0243	-0.0043	-0.0162
0.2800	0.0029	-0.0133	0.0083	-0.0118	-0.0273	-0.0228	-0.0076	-0.0022	-0.0181	-0.0161	-0.0004	-0.0173
0.2880	-0.0034	-0.0037	-0.0014	-0.0116	-0.0267	-0.0270	-0.0172	-0.0075	-0.0195	-0.0095	0.0020	-0.0078
0.2960	-0.0110	0.0086	-0.0139	-0.0149	-0.0215	-0.0319	-0.0227	-0.0080	-0.0165	-0.0015	0.0035	-0.0038
0.3040	-0.0083	0.0145	-0.0197	-0.0118	-0.0203	-0.0342	-0.0253	-0.0070	-0.0096	0.0036	0.0026	-0.0044
0.3120	0.0004	0.0089	-0.0087	-0.0079	-0.0209	-0.0325	-0.0281	-0.0049	-0.0038	0.0084	-0.0003	-0.0035

WG(LB/SEC)	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976
WL(LB/SEC)	0.1260	0.1260	0.1260	0.1260	0.1800	0.1800	0.1800	0.1800	0.2400	0.2400	0.2400	0.2400
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.4573	0.4573	1.0000	1.0000	0.4821	0.4821	1.0000	1.0000	0.5038	0.5038
0.0080	0.6649	0.6373	0.4178	0.4149	0.6690	0.6402	0.4158	0.4425	0.6759	0.6508	0.4433	0.4606
0.0160	0.2887	0.2636	0.3154	0.3099	0.2899	0.2615	0.2769	0.3289	0.3001	0.2833	0.3129	0.3366
0.0240	0.0786	0.0724	0.1836	0.1811	0.0745	0.0607	0.1341	0.1995	0.0818	0.0827	0.1702	0.1911
0.0320	-0.0289	-0.0235	0.0731	0.0707	-0.0383	-0.0385	0.0261	0.0787	-0.0339	-0.0203	0.0530	0.0658
0.0400	-0.0872	-0.0733	-0.0107	-0.0122	-0.0988	-0.0915	-0.0493	-0.0087	-0.0965	-0.0727	-0.0318	-0.0186
0.0480	-0.1193	-0.0990	-0.0648	-0.0648	-0.1331	-0.1198	-0.0993	-0.0668	-0.1259	-0.1028	-0.0840	-0.0614
0.0560	-0.1341	-0.1123	-0.0946	-0.0941	-0.1521	-0.1315	-0.1290	-0.1005	-0.1328	-0.1208	-0.1132	-0.0806
0.0640	-0.1357	-0.1186	-0.1106	-0.1073	-0.1557	-0.1351	-0.1465	-0.1134	-0.1277	-0.1298	-0.1258	-0.0899
0.0720	-0.1307	-0.1202	-0.1196	-0.1129	-0.1498	-0.1318	-0.1473	-0.1098	-0.1158	-0.1303	-0.1273	-0.0971
0.0800	-0.1217	-0.1153	-0.1208	-0.1075	-0.1388	-0.1209	-0.1342	-0.1049	-0.1073	-0.1210	-0.1224	-0.0959
0.0880	-0.1135	-0.1075	-0.1159	-0.0981	-0.1269	-0.1075	-0.1155	-0.1000	-0.1010	-0.1020	-0.1093	-0.0904
0.0960	-0.1075	-0.0994	-0.1085	-0.0904	-0.1077	-0.0921	-0.0997	-0.0857	-0.0877	-0.0860	-0.0919	-0.0797
0.1040	-0.1013	-0.0903	-0.1004	-0.0842	-0.0760	-0.0757	-0.0803	-0.0694	-0.0753	-0.0766	-0.0784	-0.0745
0.1120	-0.0905	-0.0798	-0.0864	-0.0746	-0.0485	-0.0643	-0.0597	-0.0566	-0.0650	-0.0676	-0.0704	-0.0773
0.1200	-0.0762	-0.0673	-0.0691	-0.0624	-0.0350	-0.0557	-0.0482	-0.0459	-0.0576	-0.0640	-0.0601	-0.0736
0.1280	-0.0587	-0.0585	-0.0490	-0.0533	-0.0292	-0.0462	-0.0361	-0.0418	-0.0518	-0.0638	-0.0532	-0.0633
0.1360	-0.0393	-0.0573	-0.0415	-0.0433	-0.0250	-0.0359	-0.0215	-0.0454	-0.0436	-0.0631	-0.0491	-0.0505
0.1440	-0.0197	-0.0511	-0.0362	-0.0325	-0.0137	-0.0268	-0.0074	-0.0393	-0.0374	-0.0499	-0.0445	-0.0395
0.1520	-0.0043	-0.0342	-0.0220	-0.0278	-0.0092	-0.0141	0.0051	-0.0294	-0.0274	-0.0354	-0.0359	-0.0321
0.1600	-0.0010	-0.0208	-0.0024	-0.0251	-0.0153	0.0037	0.0115	-0.0201	-0.0176	-0.0300	-0.0199	-0.0251
0.1680	-0.0065	-0.0125	0.0130	-0.0181	-0.0190	0.0131	0.0119	-0.0076	-0.0152	-0.0287	-0.0042	-0.0145
0.1760	-0.0102	-0.0060	0.0207	-0.0183	-0.0109	0.0126	0.0136	0.0050	-0.0200	-0.0189	0.0085	-0.0113
0.1840	-0.0070	0.0013	0.0153	-0.0142	0.0058	0.0091	0.0221	0.0126	-0.0241	-0.0080	0.0090	-0.0204
0.1920	-0.0009	0.0031	0.0095	-0.0036	0.0111	0.0084	0.0206	0.0143	-0.0231	-0.0035	0.0024	-0.0236
0.2000	0.0031	0.0070	0.0071	0.0086	0.0127	0.0070	0.0161	0.0099	-0.0223	0.0018	-0.0050	-0.0218
0.2080	0.0143	0.0214	0.0111	0.0131	0.0163	0.0059	0.0186	0.0089	-0.0155	0.0039	-0.0064	-0.0176
0.2160	0.0171	0.0320	0.0195	0.0130	0.0190	0.0033	0.0156	0.0092	-0.0085	0.0019	0.0010	-0.0118
0.2240	0.0174	0.0275	0.0197	0.0093	0.0142	-0.0015	0.0126	0.0066	-0.0068	0.0022	0.0045	-0.0092
0.2320	0.0146	0.0150	0.0152	0.0083	0.0041	-0.0051	0.0073	0.0035	-0.0054	0.0034	0.0094	-0.0070
0.2400	0.0045	0.0115	0.0106	0.0094	-0.0026	-0.0056	-0.0022	-0.0020	-0.0023	0.0059	0.0096	-0.0029
0.2480	-0.0007	0.0164	0.0073	0.0071	-0.0056	0.0	-0.0067	-0.0039	0.0018	0.0037	-0.0008	-0.0004
0.2560	0.0024	0.0159	0.0086	0.0045	-0.0054	0.0009	-0.0037	-0.0106	0.0060	0.0005	-0.0059	0.0046
0.2640	0.0014	0.0040	0.0102	-0.0017	-0.0065	-0.0041	-0.0018	-0.0168	0.0078	-0.0083	-0.0015	0.0115
0.2720	0.0001	-0.0076	0.0036	-0.0095	-0.0018	-0.0075	-0.0046	-0.0126	0.0076	-0.0075	0.0040	0.0127
0.2800	-0.0103	-0.0173	-0.0042	-0.0148	0.0054	-0.0081	-0.0061	-0.0063	0.0100	0.0010	0.0048	0.0078
0.2880	-0.0158	-0.0164	-0.0149	-0.0148	0.0088	-0.0050	-0.0053	-0.0008	0.0112	0.0087	0.0087	0.0038
0.2960	-0.0181	-0.0134	-0.0234	-0.0094	0.0042	-0.0048	-0.0088	0.0054	0.0084	0.0060	0.0090	-0.0015
0.3040	-0.0167	-0.0128	-0.0278	0.0011	-0.0042	-0.0066	-0.0127	0.0028	0.0026	0.0030	0.0081	-0.0021
0.3120	-0.0125	-0.0135	-0.0286	0.0002	-0.0136	-0.0106	-0.0158	-0.0057	-0.0024	-0.0016	0.0038	-0.0011

WG(LB/SEC)	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976	0.0976
WL(LB/SEC)	0.3500	0.3500	0.3500	0.3500	0.4700	0.4700	0.4700	0.4700	0.5850	0.5850	0.5850	0.5850
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED VALUE *****				***** NORMALIZED VALUE *****				***** NORMALIZED VALUE *****			
0.0	1.0000	1.0000	0.5345	0.5345	1.0000	1.0000	0.6022	0.6022	1.0000	1.0000	0.6332	0.6332
0.0080	0.7010	0.6792	0.4785	0.4738	0.7271	0.7013	0.5244	0.5436	0.7497	0.7337	0.5345	0.5890
0.0160	0.3266	0.3063	0.3372	0.3393	0.3538	0.3329	0.3501	0.3899	0.3904	0.3778	0.3369	0.4433
0.0240	0.0995	0.0914	0.1775	0.1966	0.1062	0.1051	0.1626	0.2159	0.1348	0.1378	0.1367	0.2688
0.0320	-0.0283	-0.0234	0.0440	0.0781	-0.0378	-0.0213	0.0101	0.0721	-0.0159	0.0023	-0.0058	0.1188
0.0400	-0.0987	-0.0834	-0.0445	-0.0080	-0.1188	-0.0913	-0.0891	-0.0264	-0.0988	-0.0753	-0.0910	0.0110
0.0480	-0.1314	-0.1107	-0.0986	-0.0605	-0.1614	-0.1303	-0.1450	-0.0855	-0.1373	-0.1199	-0.1382	-0.0564
0.0560	-0.1435	-0.1196	-0.1260	-0.0847	-0.1789	-0.1465	-0.1709	-0.1172	-0.1562	-0.1457	-0.1619	-0.0954
0.0640	-0.1458	-0.1227	-0.1384	-0.0952	-0.1820	-0.1487	-0.1759	-0.1301	-0.1616	-0.1611	-0.1688	-0.1164
0.0720	-0.1403	-0.1213	-0.1452	-0.1020	-0.1737	-0.1457	-0.1704	-0.1324	-0.1584	-0.1656	-0.1645	-0.1269
0.0800	-0.1342	-0.1181	-0.1442	-0.1038	-0.1574	-0.1414	-0.1577	-0.1265	-0.1479	-0.1621	-0.1559	-0.1296
0.0880	-0.1298	-0.1122	-0.1368	-0.1007	-0.1358	-0.1349	-0.1419	-0.1167	-0.1326	-0.1527	-0.1458	-0.1233
0.0960	-0.1211	-0.1042	-0.1219	-0.0952	-0.1143	-0.1235	-0.1267	-0.1050	-0.1186	-0.1378	-0.1366	-0.1086
0.1040	-0.1059	-0.0976	-0.1043	-0.0879	-0.0935	-0.1089	-0.1077	-0.0897	-0.1092	-0.1198	-0.1254	-0.0956
0.1120	-0.0817	-0.0897	-0.0876	-0.0801	-0.0725	-0.0929	-0.0875	-0.0727	-0.1020	-0.1025	-0.1126	-0.0873
0.1200	-0.0610	-0.0825	-0.0705	-0.0640	-0.0535	-0.0715	-0.0668	-0.0564	-0.0929	-0.0895	-0.1007	-0.0846
0.1280	-0.0464	-0.0750	-0.0541	-0.0525	-0.0396	-0.0455	-0.0459	-0.0422	-0.0830	-0.0771	-0.0861	-0.0795
0.1360	-0.0321	-0.0598	-0.0370	-0.0444	-0.0339	-0.0293	-0.0292	-0.0354	-0.0733	-0.0638	-0.0624	-0.0738
0.1440	-0.0191	-0.0383	-0.0227	-0.0381	-0.0276	-0.0247	-0.0212	-0.0394	-0.0571	-0.0465	-0.0358	-0.0632
0.1520	-0.0118	-0.0235	-0.0099	-0.0316	-0.0216	-0.0276	-0.0122	-0.0360	-0.0377	-0.0309	-0.0140	-0.0484
0.1600	-0.0031	-0.0126	0.0028	-0.0244	-0.0135	-0.0269	-0.0068	-0.0250	-0.0170	-0.0157	0.0051	-0.0326
0.1680	0.0042	-0.0065	0.0115	-0.0163	-0.0026	-0.0177	-0.0005	-0.0184	-0.0018	-0.0053	0.0152	-0.0235
0.1760	0.0053	-0.0037	0.0102	-0.0120	0.0038	-0.0107	0.0078	-0.0125	0.0035	-0.0006	0.0209	-0.0209
0.1840	0.0043	-0.0031	0.0070	-0.0133	0.0031	-0.0098	0.0114	-0.0057	0.0030	0.0044	0.0267	-0.0174
0.1920	0.0001	0.0010	0.0087	-0.0109	0.0021	-0.0090	0.0129	-0.0008	0.0035	0.0102	0.0268	-0.0092
0.2000	-0.0074	0.0047	0.0121	-0.0056	0.0028	-0.0017	0.0113	0.0003	0.0051	0.0181	0.0223	-0.0016
0.2080	-0.0082	0.0048	0.0116	-0.0070	0.0021	0.0029	0.0094	0.0003	0.0089	0.0220	0.0175	0.0012
0.2160	-0.0027	-0.0017	0.0043	-0.0115	0.0004	0.0054	0.0074	-0.0029	0.0186	0.0234	0.0201	0.0061
0.2240	-0.0017	-0.0061	-0.0008	-0.0149	-0.0020	0.0041	0.0015	-0.0033	0.0310	0.0180	0.0266	0.0152
0.2320	-0.0043	-0.0009	-0.0023	-0.0131	-0.0048	0.0033	-0.0020	-0.0007	0.0390	0.0089	0.0299	0.0232
0.2400	-0.0071	0.0040	0.0021	-0.0078	-0.0060	0.0093	0.0	-0.0001	0.0367	0.0055	0.0296	0.0252
0.2480	-0.0065	0.0044	0.0052	-0.0056	-0.0045	0.0198	0.0055	-0.0008	0.0241	0.0062	0.0227	0.0197
0.2560	-0.0028	-0.0006	-0.0016	-0.0042	-0.0059	0.0219	0.0146	0.0016	0.0097	0.0053	0.0129	0.0115
0.2640	0.0025	-0.0047	-0.0070	0.0004	-0.0046	0.0106	0.0160	-0.0017	-0.0015	-0.0015	-0.0002	0.0031
0.2720	0.0041	-0.0016	-0.0053	0.0084	-0.0002	-0.0035	0.0071	-0.0071	-0.0053	-0.0077	-0.0093	-0.0012
0.2800	0.0015	-0.0026	-0.0037	0.0105	0.0023	-0.0164	-0.0065	-0.0112	-0.0033	-0.0100	-0.0080	-0.0006
0.2880	-0.0010	-0.0014	0.0004	0.0046	0.0011	-0.0225	-0.0214	-0.0129	0.0016	-0.0005	-0.0012	-0.0008
0.2960	-0.0061	-0.0012	0.0013	-0.0014	-0.0010	-0.0238	-0.0234	-0.0105	0.0045	0.0087	-0.0021	-0.0008
0.3040	-0.0064	-0.0026	-0.0027	-0.0083	-0.0006	-0.0200	-0.0132	-0.0052	0.0030	0.0118	-0.0048	0.0035
0.3120	-0.0045	-0.0002	-0.0031	-0.0064	0.0039	-0.0032	-0.0070	0.0060	-0.0053	0.0115	-0.0072	0.0061

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0160	0.0160	0.0160	0.0280	0.0280	0.0280	0.0280	0.0440	0.0440	0.0440	0.0440
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.0497	0.0497	1.0000	1.0000	0.1303	0.1303	1.0000	1.0000	0.3201	0.3201
0.0080	0.3857	0.3997	0.0466	0.0368	0.5715	0.5913	0.1194	0.1251	0.5545	0.5902	0.3143	0.3024
0.0160	-0.2422	-0.2050	0.0279	0.0224	0.1370	0.1429	0.1106	0.1102	0.2231	0.2679	0.2697	0.2430
0.0240	-0.2920	-0.2861	0.0109	0.0226	-0.0110	-0.0313	0.1023	0.0941	0.0956	0.1350	0.2000	0.1709
0.0320	-0.1136	-0.1279	0.0019	0.0348	-0.0528	-0.0778	0.0897	0.0837	0.0422	0.0723	0.1325	0.1016
0.0400	0.0376	0.0218	-0.0035	0.0396	-0.0754	-0.0839	0.0752	0.0768	0.0137	0.0372	0.0998	0.0445
0.0480	0.0842	0.0877	-0.0130	0.0344	-0.0778	-0.0693	0.0519	0.0652	-0.0028	0.0137	0.0839	0.0084
0.0560	0.0520	0.0614	-0.0146	0.0248	-0.0642	-0.0540	0.0227	0.0456	-0.0108	-0.0014	0.0662	-0.0104
0.0640	0.0070	0.0115	-0.0066	0.0144	-0.0597	-0.0459	-0.0038	0.0217	-0.0155	-0.0134	0.0506	-0.0176
0.0720	-0.0142	-0.0096	0.0043	-0.0003	-0.0487	-0.0381	-0.0233	0.0101	-0.0250	-0.0155	0.0367	-0.0213
0.0800	-0.0129	-0.0083	0.0210	-0.0032	-0.0388	-0.0383	-0.0375	0.0021	-0.0292	-0.0175	0.0303	-0.0231
0.0880	-0.0040	-0.0098	0.0350	0.0018	-0.0426	-0.0367	-0.0461	-0.0108	-0.0266	-0.0265	0.0266	-0.0245
0.0960	-0.0086	-0.0105	0.0253	0.0088	-0.0434	-0.0330	-0.0476	-0.0221	-0.0302	-0.0329	0.0189	-0.0261
0.1040	-0.0130	-0.0101	0.0060	0.0084	-0.0418	-0.0290	-0.0477	-0.0178	-0.0296	-0.0376	0.0021	-0.0274
0.1120	-0.0115	-0.0100	-0.0025	-0.0028	-0.0353	-0.0266	-0.0522	-0.0059	-0.0297	-0.0369	-0.0109	-0.0289
0.1200	-0.0028	0.0018	-0.0136	-0.0112	-0.0183	-0.0279	-0.0558	-0.0045	-0.0332	-0.0325	-0.0189	-0.0308
0.1280	0.0120	0.0082	-0.0183	-0.0167	-0.0096	-0.0320	-0.0488	-0.0030	-0.0326	-0.0253	-0.0239	-0.0253
0.1360	0.0084	-0.0046	-0.0039	-0.0213	-0.0197	-0.0299	-0.0388	-0.0022	-0.0275	-0.0221	-0.0223	-0.0195
0.1440	-0.0066	-0.0153	0.0266	-0.0235	-0.0268	-0.0169	-0.0239	-0.0052	-0.0269	-0.0223	-0.0140	-0.0242
0.1520	-0.0095	-0.0110	0.0488	-0.0182	-0.0217	-0.0133	-0.0056	-0.0092	-0.0220	-0.0223	-0.0162	-0.0259
0.1600	0.0012	-0.0019	0.0357	-0.0126	-0.0099	-0.0180	0.0121	-0.0129	-0.0168	-0.0216	-0.0202	-0.0208
0.1680	0.0026	0.0063	0.0016	-0.0128	0.0004	-0.0248	0.0207	-0.0232	-0.0131	-0.0210	-0.0149	-0.0152
0.1760	-0.0009	0.0027	-0.0016	-0.0140	0.0028	-0.0289	0.0164	-0.0296	-0.0131	-0.0243	-0.0096	-0.0152
0.1840	0.0015	0.0060	-0.0090	-0.0095	0.0090	-0.0307	0.0066	-0.0204	-0.0107	-0.0251	-0.0054	-0.0165
0.1920	0.0103	0.0122	0.0076	0.0011	0.0087	-0.0225	-0.0066	-0.0124	-0.0127	-0.0216	-0.0067	-0.0178
0.2000	0.0098	0.0042	0.0081	0.0070	-0.0052	-0.0079	-0.0167	-0.0130	-0.0182	-0.0190	-0.0089	-0.0110
0.2080	0.0078	-0.0042	-0.0062	0.0079	-0.0151	-0.0006	-0.0257	-0.0176	-0.0191	-0.0271	-0.0110	-0.0081
0.2160	0.0126	0.0002	-0.0075	0.0107	-0.0138	-0.0011	-0.0268	-0.0203	-0.0180	-0.0261	-0.0154	-0.0128
0.2240	0.0055	0.0063	-0.0043	0.0036	-0.0154	-0.0057	-0.0245	-0.0176	-0.0200	-0.0192	-0.0182	-0.0155
0.2320	-0.0105	0.0053	-0.0007	0.0001	-0.0109	-0.0077	-0.0175	-0.0191	-0.0225	-0.0115	-0.0239	-0.0157
0.2400	-0.0069	0.0040	-0.0026	0.0100	-0.0126	-0.0086	-0.0123	-0.0208	-0.0183	-0.0096	-0.0240	-0.0161
0.2480	0.0085	-0.0004	-0.0193	0.0163	-0.0227	-0.0112	-0.0072	-0.0253	-0.0151	-0.0091	-0.0174	-0.0128
0.2560	0.0066	-0.0083	-0.0199	0.0137	-0.0282	-0.0197	-0.0042	-0.0261	-0.0052	-0.0139	-0.0100	-0.0167
0.2640	-0.0059	-0.0148	-0.0067	0.0089	-0.0302	-0.0167	-0.0010	-0.0200	-0.0033	-0.0209	-0.0074	-0.0191
0.2720	-0.0095	-0.0210	-0.0064	0.0011	-0.0185	-0.0041	0.0028	-0.0136	-0.0145	-0.0195	-0.0062	-0.0193
0.2800	-0.0011	-0.0150	-0.0186	0.0095	-0.0039	-0.0002	0.0079	-0.0061	-0.0206	-0.0181	-0.0118	-0.0221
0.2880	0.0002	-0.0052	-0.0173	0.0191	-0.0004	-0.0011	0.0146	-0.0059	-0.0160	-0.0210	-0.0126	-0.0258
0.2960	-0.0086	-0.0022	-0.0062	0.0129	-0.0047	0.0034	0.0149	-0.0055	-0.0154	-0.0232	-0.0081	-0.0215
0.3040	-0.0152	-0.0054	0.0014	-0.0028	-0.0045	0.0121	0.0103	0.0012	-0.0272	-0.0202	-0.0101	-0.0201
0.3120	-0.0100	-0.0072	0.0047	-0.0116	0.0034	0.0127	0.0109	0.0034	-0.0287	-0.0149	-0.0165	-0.0242

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0800	0.0800	0.0800	0.0800	0.1260	0.1260	0.1260	0.1260	0.1800	0.1800	0.1800	0.1800
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NO.MALIZED		VALUE *****	
0.0	1.0000	1.0000	0.3766	0.3766	1.0000	1.0000	0.3887	0.3887	1.0000	1.0000	0.4369	0.4369
0.0080	0.5085	0.5288	0.3322	0.3453	0.5488	0.5570	0.3265	0.3658	0.5889	0.5825	0.4089	0.3636
0.0160	0.1415	0.1708	0.2368	0.2496	0.1564	0.1813	0.2104	0.2780	0.1995	0.2021	0.3001	0.2285
0.0240	0.0026	0.0235	0.1177	0.1352	-0.0102	0.0229	0.0929	0.1572	0.0108	0.0327	0.1677	0.0922
0.0320	-0.0561	-0.0447	0.0155	0.0476	-0.0787	-0.0504	-0.0059	0.0458	-0.0690	-0.0455	0.0470	-0.0080
0.0400	-0.0840	-0.0770	-0.0443	-0.0200	-0.1097	-0.0926	-0.0676	-0.0228	-0.1073	-0.0853	-0.0365	-0.0624
0.0480	-0.0986	-0.0886	-0.0755	-0.0561	-0.1173	-0.1160	-0.1029	-0.0597	-0.1250	-0.1054	-0.0817	-0.0837
0.0560	-0.0976	-0.0920	-0.0913	-0.0684	-0.1167	-0.1250	-0.1191	-0.0771	-0.1250	-0.1154	-0.1025	-0.0947
0.0640	-0.0853	-0.0930	-0.0900	-0.0767	-0.1089	-0.1213	-0.1247	-0.0806	-0.1120	-0.1157	-0.1112	-0.0942
0.0720	-0.0734	-0.0892	-0.0871	-0.0761	-0.1011	-0.1078	-0.1196	-0.0805	-0.0975	-0.1093	-0.1086	-0.0947
0.0800	-0.0718	-0.0790	-0.0870	-0.0698	-0.0912	-0.0878	-0.1032	-0.0799	-0.0874	-0.1039	-0.0964	-0.0915
0.0880	-0.0719	-0.0791	-0.0735	-0.0603	-0.0790	-0.0700	-0.0878	-0.0759	-0.0808	-0.0948	-0.0879	-0.0776
0.0960	-0.0621	-0.0765	-0.0616	-0.0578	-0.0615	-0.0639	-0.0642	-0.0683	-0.0705	-0.0827	-0.0826	-0.0607
0.1040	-0.0455	-0.0608	-0.0536	-0.0536	-0.0469	-0.0577	-0.0398	-0.0558	-0.0630	-0.0665	-0.0714	-0.0520
0.1120	-0.0340	-0.0505	-0.0418	-0.0516	-0.0393	-0.0510	-0.0280	-0.0461	-0.0514	-0.0566	-0.0565	-0.0457
0.1200	-0.0366	-0.0458	-0.0371	-0.0496	-0.0337	-0.0448	-0.0204	-0.0441	-0.0406	-0.0523	-0.0423	-0.0386
0.1280	-0.0416	-0.0429	-0.0331	-0.0379	-0.0263	-0.0411	-0.0228	-0.0491	-0.0316	-0.0435	-0.0295	-0.0332
0.1360	-0.0349	-0.0401	-0.0241	-0.0346	-0.0274	-0.0408	-0.0231	-0.0467	-0.0212	-0.0279	-0.0204	-0.0260
0.1440	-0.0302	-0.0353	-0.0165	-0.0364	-0.0272	-0.0412	-0.0182	-0.0331	-0.0153	-0.0136	-0.0192	-0.0231
0.1520	-0.0263	-0.0288	-0.0175	-0.0343	-0.0203	-0.0287	-0.0097	-0.0168	-0.0206	-0.0082	-0.0116	-0.0243
0.1600	-0.0207	-0.0204	-0.0207	-0.0173	-0.0085	-0.0082	0.0086	-0.0037	-0.0225	-0.0099	-0.0094	-0.0211
0.1680	-0.0210	-0.0130	-0.0106	-0.0106	0.0049	0.0055	0.0126	0.0011	-0.0195	-0.0125	-0.0130	-0.0160
0.1760	-0.0113	-0.0037	0.0077	-0.0105	0.0122	0.0067	0.0150	0.0002	-0.0173	-0.0169	-0.0164	-0.0096
0.1840	-0.0002	-0.0046	0.0094	-0.0112	0.0153	0.0109	0.0205	-0.0028	-0.0132	-0.0221	-0.0205	-0.0088
0.1920	-0.0082	-0.0076	-0.0143	-0.0096	0.0108	0.0103	0.0172	-0.0073	-0.0169	-0.0238	-0.0240	-0.0159
0.2000	-0.0215	-0.0105	-0.0294	-0.0080	0.0015	-0.0012	0.0198	-0.0054	-0.0177	-0.0193	-0.0244	-0.0254
0.2080	-0.0184	-0.0163	-0.0233	-0.0139	-0.0036	-0.0033	0.0159	0.0015	-0.0134	-0.0106	-0.0143	-0.0230
0.2160	-0.0116	-0.0104	-0.0069	-0.0121	-0.0032	0.0004	0.0122	0.0008	-0.0027	0.0026	0.0065	-0.0095
0.2240	-0.0087	-0.0065	0.0076	-0.0159	-0.0008	-0.0021	0.0127	-0.0018	0.0042	0.0041	0.0213	0.0102
0.2320	-0.0011	-0.0049	0.0138	-0.0189	0.0030	0.0003	0.0151	-0.0054	0.0100	0.0048	0.0193	0.0167
0.2400	0.0052	-0.0039	0.0097	-0.0091	0.0102	0.0056	0.0005	-0.0065	0.0175	0.0037	0.0161	0.0157
0.2480	0.0085	0.0110	0.0136	-0.0050	0.0065	0.0045	-0.0158	0.0012	0.0179	0.0035	0.0126	0.0110
0.2560	0.0111	0.0187	0.0224	-0.0030	-0.0007	0.0001	-0.0250	0.0049	0.0154	0.0045	0.0072	0.0041
0.2640	0.0112	0.0160	0.0196	-0.0020	-0.0054	0.0051	-0.0217	0.0013	0.0185	0.0082	0.0097	0.0030
0.2720	0.0118	0.0177	0.0058	0.0099	-0.0107	0.0080	-0.0075	0.0048	0.0178	0.0171	0.0216	0.0022
0.2800	0.0063	0.0155	-0.0092	0.0219	-0.0149	0.0001	-0.0002	0.0005	0.0062	0.0217	0.0236	0.0039
0.2880	0.0015	0.0040	-0.0121	0.0238	-0.0101	0.0019	0.0013	-0.0063	-0.0039	0.0174	0.0153	0.0067
0.2960	-0.0035	-0.0065	-0.0167	0.0163	-0.0143	0.0026	0.0037	-0.0081	-0.0087	0.0107	0.0040	0.0042
0.3040	-0.0057	-0.0152	-0.0086	0.0070	-0.0144	-0.0014	0.0015	-0.0018	-0.0108	-0.0006	0.0024	0.0022
0.3120	-0.0100	-0.0128	-0.0066	-0.0079	-0.0051	-0.0078	-0.0090	-0.0024	-0.0105	-0.0078	-0.0048	-0.0045

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.2400	0.2400	0.2400	0.2400	0.3500	0.3500	0.3500	0.3500	0.4700	0.4700	0.4700	0.4700
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.4985	0.4985	1.0000	1.0000	0.5815	0.5815	1.0000	1.0000	0.6107	0.6107
0.0080	0.6275	0.6161	0.4561	0.4204	0.6624	0.6428	0.5299	0.4733	0.6855	0.6589	0.5061	0.5395
0.0160	0.2382	0.2345	0.3216	0.2758	0.2708	0.2582	0.3483	0.2914	0.3011	0.2781	0.2971	0.3560
0.0240	0.0409	0.0452	0.1536	0.1308	0.0532	0.0497	0.1447	0.1162	0.0697	0.0607	0.0954	0.1672
0.0320	-0.0551	-0.0397	0.0262	0.0178	-0.0588	-0.0527	-0.0031	-0.0056	-0.0579	-0.0512	-0.0396	0.0321
0.0400	-0.0982	-0.0767	-0.0452	-0.0491	-0.1176	-0.0105	-0.0842	-0.0769	-0.1240	-0.1063	-0.1102	-0.0539
0.0480	-0.1157	-0.0990	-0.0858	-0.0788	-0.1441	-0.1312	-0.1220	-0.1144	-0.1505	-0.1371	-0.1343	-0.1009
0.0560	-0.1220	-0.1116	-0.1114	-0.0925	-0.1502	-0.1437	-0.1349	-0.1273	-0.1591	-0.1487	-0.1416	-0.1202
0.0640	-0.1185	-0.1165	-0.1175	-0.1008	-0.1455	-0.1422	-0.1367	-0.1267	-0.1599	-0.1480	-0.1426	-0.1276
0.0720	-0.1176	-0.1176	-0.1155	-0.0940	-0.1345	-0.1318	-0.1325	-0.1227	-0.1522	-0.1435	-0.1377	-0.1311
0.0800	-0.1174	-0.1111	-0.1132	-0.0851	-0.1272	-0.1224	-0.1265	-0.1154	-0.1355	-0.1357	-0.1303	-0.1254
0.0880	-0.1094	-0.0967	-0.1124	-0.0818	-0.1244	-0.1099	-0.1190	-0.1069	-0.1126	-0.1214	-0.1203	-0.1109
0.0960	-0.0971	-0.0876	-0.1057	-0.0767	-0.1164	-0.0969	-0.1115	-0.0927	-0.0941	-0.1056	-0.1100	-0.0982
0.1040	-0.0808	-0.0818	-0.0860	-0.0671	-0.1005	-0.0853	-0.1019	-0.0774	-0.0829	-0.0907	-0.0999	-0.0852
0.1120	-0.0673	-0.0660	-0.0678	-0.0610	-0.0805	-0.0725	-0.0850	-0.0615	-0.0746	-0.0760	-0.0861	-0.0689
0.1200	-0.0531	-0.0522	-0.0574	-0.0553	-0.0603	-0.0590	-0.0606	-0.0496	-0.0649	-0.0568	-0.0665	-0.0556
0.1280	-0.0409	-0.0451	-0.0408	-0.0516	-0.0381	-0.0427	-0.0391	-0.0412	-0.0518	-0.0386	-0.0444	-0.0448
0.1360	-0.0324	-0.0388	-0.0215	-0.0473	-0.0208	-0.0254	-0.0217	-0.0359	-0.0381	-0.0233	-0.0279	-0.0322
0.1440	-0.0286	-0.0344	-0.0116	-0.0346	-0.0105	-0.0151	-0.0085	-0.0321	-0.0223	-0.0145	-0.0174	-0.0157
0.1520	-0.0208	-0.0273	-0.0110	-0.0278	-0.0031	-0.0153	-0.0036	-0.0265	-0.0095	-0.0100	-0.0068	-0.0050
0.1600	-0.0072	-0.0125	-0.0035	-0.0203	0.0023	-0.0167	0.0005	-0.0196	0.0009	-0.0031	0.0058	-0.0049
0.1680	-0.0006	0.0013	0.0043	-0.0060	0.0106	-0.0124	0.0076	-0.0106	0.0126	0.0060	0.0169	-0.0073
0.1760	-0.0040	0.0101	0.0020	0.0016	0.0213	-0.0059	0.0205	0.0056	0.0198	0.0070	0.0221	-0.0076
0.1840	-0.0075	0.0026	-0.0038	-0.0035	0.0237	0.0037	0.0273	0.0137	0.0126	0.0	0.0203	-0.0056
0.1920	-0.0090	-0.0108	-0.0071	-0.0092	0.0203	0.0221	0.0261	0.0175	-0.0024	-0.0036	0.0170	-0.0069
0.2000	-0.0145	-0.0163	-0.0068	-0.0151	0.0197	0.0409	0.0255	0.0227	-0.0093	-0.0065	0.0155	-0.0077
0.2080	-0.0046	-0.0100	-0.0026	-0.0153	0.0206	0.0389	0.0228	0.0244	-0.0062	-0.0064	0.0077	-0.0049
0.2160	0.0101	0.0026	0.0005	-0.0104	0.0146	0.0267	0.0130	0.0190	-0.0065	-0.0091	-0.0036	-0.0051
0.2240	0.0116	0.0082	0.0084	-0.0038	0.0041	0.0180	0.0077	0.0102	-0.0081	-0.0059	-0.0079	-0.0076
0.2320	0.0046	0.0044	0.0072	0.0023	-0.0061	0.0084	0.0082	0.0021	-0.0091	0.0056	-0.0064	-0.0107
0.2400	-0.0012	-0.0079	-0.0023	-0.0012	-0.0063	0.0012	0.0073	-0.0008	-0.0051	0.0127	-0.0026	-0.0112
0.2480	-0.0070	-0.0187	-0.0092	-0.0080	-0.0038	-0.0045	0.0031	-0.0005	-0.0070	0.0131	-0.0013	-0.0033
0.2560	-0.0096	-0.0186	-0.0108	-0.0055	-0.0069	-0.0095	-0.0055	-0.0036	-0.0066	0.0109	0.0046	0.0072
0.2640	-0.0075	-0.0125	-0.0115	-0.0009	-0.0106	-0.0192	-0.0172	-0.0066	0.0003	0.0056	0.0062	0.0161
0.2720	-0.0084	-0.0124	-0.0129	-0.0047	-0.0152	-0.0258	-0.0271	-0.0077	0.0095	0.0012	0.0043	0.0172
0.2800	-0.0059	-0.0165	-0.0086	-0.0081	-0.0225	-0.0235	-0.0302	-0.0113	0.0135	-0.0032	-0.0003	0.0098
0.2880	0.0008	-0.0129	0.0033	-0.0102	-0.0244	-0.0225	-0.0297	-0.0162	0.0120	-0.0025	-0.0003	0.0069
0.2960	0.0042	0.0058	0.0119	-0.0102	-0.0289	-0.0199	-0.0306	-0.0169	0.0097	0.0028	0.0072	0.0090
0.3040	0.0100	0.0150	0.0117	-0.0057	-0.0271	-0.0190	-0.0299	-0.0167	0.0128	0.0112	0.0117	0.0080
0.3120	0.0132	0.0096	0.0071	0.0018	-0.0234	-0.0150	-0.0250	-0.0132	0.0177	0.0172	0.0094	0.0094

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742
WL(LB/SEC)	0.5850	0.5850	0.5850	0.5850	0.0160	0.0160	0.0160	0.0160	0.0280	0.0280	0.0280	0.0280
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.6260	0.6260	1.0000	1.0000	0.0275	0.0275	1.0000	1.0000	0.1435	0.1435
0.0080	0.6907	0.6666	0.5563	0.5117	0.0228	0.2153	0.0154	0.0115	0.5137	0.5156	0.1312	0.1372
0.0160	0.3027	0.2831	0.3436	0.3132	-0.0474	-0.2621	0.0098	0.0136	0.1475	0.1180	0.1123	0.1261
0.0240	0.0621	0.0562	0.1247	0.1257	-0.0087	-0.0642	0.0043	0.0112	0.0595	0.0248	0.0989	0.1194
0.0320	-0.0695	-0.0667	-0.0301	-0.0058	0.0185	0.1202	0.0100	0.0090	0.0385	0.0026	0.0805	0.1169
0.0400	-0.1389	-0.1305	-0.1161	-0.0806	0.0102	0.0829	0.0013	0.0141	0.0213	-0.0185	0.0521	0.1066
0.0480	-0.1705	-0.1555	-0.1594	-0.1195	0.0057	0.0159	-0.0083	0.0111	0.0083	-0.0149	0.0199	0.0934
0.0560	-0.1782	-0.1646	-0.1766	-0.1377	-0.0018	-0.0120	-0.0005	0.0019	0.0027	-0.0074	0.0034	0.0859
0.0640	-0.1718	-0.1650	-0.1761	-0.1423	0.0007	0.0040	0.0051	0.0054	0.0116	-0.0002	0.0029	0.0748
0.0720	-0.1562	-0.1563	-0.1635	-0.1359	0.0003	0.0253	0.0037	0.0011	0.0233	0.0033	0.0005	0.0622
0.0800	-0.1404	-0.1367	-0.1460	-0.1235	0.0012	0.0158	0.0157	-0.0074	0.0271	0.0142	-0.0058	0.0500
0.0880	-0.1216	-0.1150	-0.1296	-0.1051	0.0004	-0.0015	0.0040	-0.0008	0.0333	0.0181	-0.0083	0.0508
0.0960	-0.1020	-0.1006	-0.1156	-0.0866	0.0062	-0.0040	-0.0044	0.0132	0.0333	0.0195	-0.0023	0.0535
0.1040	-0.0789	-0.0843	-0.0964	-0.0655	0.0018	-0.0043	0.0019	-0.0001	0.0285	0.0125	0.0051	0.0443
0.1120	-0.0537	-0.0615	-0.0706	-0.0405	-0.0045	-0.0076	0.0175	-0.0117	0.0245	0.0019	0.0100	0.0378
0.1200	-0.0359	-0.0428	-0.0469	-0.0288	-0.0022	-0.0050	0.0224	-0.0138	0.0156	0.0067	0.0124	0.0488
0.1280	-0.0202	-0.0338	-0.0249	-0.0268	0.0063	0.0028	0.0098	0.0008	0.0099	0.0188	0.0149	0.0585
0.1360	-0.0097	-0.0238	-0.0100	-0.0266	0.0019	0.0110	-0.0006	0.0102	0.0174	0.0249	0.0065	0.0595
0.1440	-0.0052	-0.0148	0.0047	-0.0254	0.0036	0.0055	0.0126	-0.0067	0.0294	0.0245	-0.0039	0.0614
0.1520	-0.0065	-0.0052	0.0215	-0.0214	0.0017	-0.0087	0.0046	0.0029	0.0315	0.0237	0.0026	0.0549
0.1600	-0.0026	0.0019	0.0275	-0.0128	0.0028	-0.0065	0.0026	0.0101	0.0330	0.0234	0.0146	0.0488
0.1680	0.0079	0.0094	0.0231	-0.0020	0.0046	0.0071	-0.0013	0.0095	0.0254	0.0216	0.0154	0.0517
0.1760	0.0146	0.0102	0.0216	0.0067	0.0011	0.0107	0.0106	0.0064	0.0148	0.0182	0.0161	0.0527
0.1840	0.0205	0.0067	0.0163	0.0130	0.0004	0.0126	0.0221	0.0061	0.0121	0.0255	0.0227	0.0549
0.1920	0.0192	0.0098	0.0117	0.0087	0.0	0.0035	0.0014	0.0052	0.0173	0.0344	0.0271	0.0523
0.2000	0.0108	0.0202	0.0121	0.0036	0.0008	-0.0015	0.0005	0.0074	0.0184	0.0403	0.0202	0.0356
0.2080	0.0022	0.0266	0.0164	0.0086	-0.0017	0.0139	0.0212	0.0093	0.0169	0.0355	0.0184	0.0182
0.2160	0.0032	0.0330	0.0188	0.0157	-0.0018	0.0187	0.0254	0.0039	0.0187	0.0284	0.0191	0.0198
0.2240	0.0164	0.0311	0.0201	0.0224	-0.0013	0.0136	-0.0025	0.0017	0.0166	0.0145	0.0121	0.0281
0.2320	0.0233	0.0270	0.0272	0.0250	0.0018	0.0060	-0.0191	0.0156	0.0197	0.0055	0.0049	0.0377
0.2400	0.0209	0.0240	0.0294	0.0166	0.0055	-0.0044	-0.0039	0.0124	0.0242	0.0073	-0.0019	0.0364
0.2480	0.0107	0.0184	0.0256	0.0050	0.0009	-0.0041	0.0161	0.0022	0.0236	0.0100	-0.0062	0.0302
0.2560	-0.0014	0.0114	0.0164	-0.0005	-0.0048	-0.0068	-0.0057	0.0033	0.0150	0.0124	-0.0022	0.0264
0.2640	-0.0067	-0.0024	0.0056	-0.0016	-0.0012	-0.0130	-0.0158	0.0081	0.0074	0.0028	-0.0018	0.0244
0.2720	-0.0084	-0.0202	-0.0115	-0.0021	-0.0048	-0.0119	-0.0098	-0.0027	0.0113	-0.0085	0.0069	0.0372
0.2800	-0.0116	-0.0318	-0.0248	-0.0087	-0.0048	0.0049	-0.0106	0.0149	0.0069	-0.0035	0.0173	0.0550
0.2880	-0.0166	-0.0357	-0.0294	-0.0197	-0.0002	0.0060	-0.0118	0.0167	0.0060	0.0085	0.0132	0.0340
0.2960	-0.0249	-0.0332	-0.0364	-0.0251	0.0009	-0.0108	-0.0142	0.0095	0.0136	0.0169	0.0044	0.0299
0.3040	-0.0290	-0.0271	-0.0411	-0.0212	-0.0012	-0.0188	-0.0116	0.0004	0.0176	0.0189	0.0021	0.0290
0.3120	-0.0266	-0.0149	-0.0341	-0.0177	0.0036	-0.0039	-0.0039	0.0037	0.0107	0.0152	-0.0002	0.0252

WG(LB/SEC)	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742
WL(LB/SEC)	0.0440	0.0440	0.0440	0.0440	0.0800	0.0800	0.0800	0.0800	0.1260	0.1260	0.1260	0.1260
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.3902	0.3902	1.0000	1.0000	0.3746	0.3746	1.0000	1.0000	0.4152	0.4152
0.0080	0.4687	0.5160	0.3472	0.3592	0.4545	0.4809	0.3116	0.3391	0.5092	0.5141	0.3647	0.3737
0.0160	0.1623	0.2034	0.2703	0.2315	0.1046	0.1386	0.2010	0.2428	0.1245	0.1463	0.2419	0.2265
0.0240	0.0603	0.0909	0.1668	0.1269	-0.0130	0.0097	0.0894	0.1069	-0.0169	0.0001	0.1045	0.0756
0.0320	0.0151	0.0333	0.0779	0.0626	-0.0626	-0.0470	-0.0014	0.0003	-0.0721	-0.0621	0.0039	-0.0180
0.0400	-0.0109	-0.0034	0.0273	0.0098	-0.0876	-0.0754	-0.0540	-0.0571	-0.0987	-0.0906	-0.0577	-0.0621
0.0480	-0.0294	-0.0295	-0.0021	-0.0198	-0.1018	-0.0889	-0.0808	-0.0769	-0.1068	-0.1045	-0.0936	-0.0783
0.0560	-0.0394	-0.0391	-0.0163	-0.0347	-0.1090	-0.0935	-0.0937	-0.0785	-0.1062	-0.1093	-0.1059	-0.0865
0.0640	-0.0420	-0.0392	-0.0254	-0.0408	-0.1048	-0.0967	-0.0921	-0.0733	-0.1010	-0.1084	-0.1074	-0.0900
0.0720	-0.0402	-0.0392	-0.0277	-0.0394	-0.0859	-0.0942	-0.0833	-0.0700	-0.0958	-0.0976	-0.1018	-0.0783
0.0800	-0.0389	-0.0414	-0.0272	-0.0408	-0.0707	-0.0864	-0.0824	-0.0740	-0.0831	-0.0837	-0.0887	-0.0635
0.0880	-0.0411	-0.0428	-0.0336	-0.0415	-0.0574	-0.0774	-0.0752	-0.0677	-0.0663	-0.0740	-0.0814	-0.0560
0.0960	-0.0406	-0.0430	-0.0423	-0.0406	-0.0470	-0.0657	-0.0590	-0.0587	-0.0544	-0.0613	-0.0697	-0.0542
0.1040	-0.0398	-0.0426	-0.0467	-0.0423	-0.0455	-0.0534	-0.0440	-0.0492	-0.0379	-0.0609	-0.0487	-0.0524
0.1120	-0.0449	-0.0400	-0.0452	-0.0403	-0.0421	-0.0387	-0.0365	-0.0413	-0.0326	-0.0494	-0.0307	-0.0488
0.1200	-0.0419	-0.0395	-0.0346	-0.0337	-0.0443	-0.0337	-0.0350	-0.0418	-0.0270	-0.0334	-0.0224	-0.0431
0.1280	-0.0379	-0.0401	-0.0252	-0.0380	-0.0397	-0.0336	-0.0243	-0.0428	-0.0279	-0.0214	-0.0217	-0.0352
0.1360	-0.0341	-0.0399	-0.0225	-0.0438	-0.0232	-0.0352	-0.0116	-0.0358	-0.0249	-0.0136	-0.0122	-0.0244
0.1440	-0.0330	-0.0423	-0.0236	-0.0403	-0.0168	-0.0262	-0.0090	-0.0237	-0.0208	-0.0111	0.0018	-0.0156
0.1520	-0.0335	-0.0385	-0.0307	-0.0401	-0.0103	-0.0230	-0.0123	-0.0088	-0.0145	-0.0085	0.0031	-0.0058
0.1600	-0.0331	-0.0314	-0.0296	-0.0396	-0.0082	-0.0161	-0.0055	-0.0082	-0.0130	-0.0007	-0.0027	0.0042
0.1680	-0.0353	-0.0288	-0.0311	-0.0370	-0.0061	-0.0071	0.0022	-0.0045	-0.0115	0.0016	-0.0053	-0.0022
0.1760	-0.0338	-0.0239	-0.0268	-0.0295	-0.0038	0.0022	0.0034	0.0020	-0.0049	-0.0043	0.0021	-0.0117
0.1840	-0.0305	-0.0227	-0.0228	-0.0294	-0.0027	0.0064	0.0011	0.0011	0.0	-0.0030	0.0103	-0.0110
0.1920	-0.0261	-0.0293	-0.0246	-0.0272	0.0081	0.0008	0.0013	-0.0044	0.0060	0.0014	0.0129	-0.0082
0.2000	-0.0290	-0.0327	-0.0294	-0.0304	0.0129	-0.0100	0.0067	-0.0002	0.0065	0.0006	0.0080	-0.0066
0.2080	-0.0341	-0.0435	-0.0270	-0.0354	0.0111	-0.0049	0.0122	0.0017	0.0029	-0.0029	0.0039	0.0021
0.2160	-0.0371	-0.0486	-0.0301	-0.0422	0.0078	0.0014	0.0157	0.0070	0.0036	0.0	0.0058	0.0041
0.2240	-0.0303	-0.0414	-0.0250	-0.0350	0.0100	0.0042	0.0085	0.0169	0.0037	-0.0044	0.0026	-0.0062
0.2320	-0.0262	-0.0343	-0.0246	-0.0258	0.0133	0.0046	0.0028	0.0031	0.0014	-0.0102	-0.0003	-0.0075
0.2400	-0.0240	-0.0266	-0.0296	-0.0235	0.0179	0.0028	0.0047	-0.0009	-0.0019	-0.0112	-0.0062	0.0011
0.2480	-0.0197	-0.0237	-0.0264	-0.0150	0.0098	0.0043	0.0044	0.0042	-0.0030	-0.0078	-0.0155	0.0017
0.2560	-0.0169	-0.0181	-0.0118	-0.0101	0.0011	0.0092	0.0037	0.0117	-0.0055	-0.0001	-0.0132	0.0011
0.2640	-0.0035	-0.0137	-0.0040	-0.0122	-0.0037	0.0071	0.0003	0.0071	-0.0081	0.0054	-0.0071	0.0020
0.2720	0.0097	-0.0114	0.0047	-0.0076	-0.0065	0.0043	0.0037	-0.0003	-0.0026	0.0034	-0.0036	0.0089
0.2800	-0.0028	-0.0132	0.0025	-0.0081	-0.0031	0.0031	0.0068	-0.0048	0.0033	0.0022	-0.0060	0.0063
0.2880	-0.0125	-0.0121	0.0026	-0.0138	-0.0008	0.0061	0.0088	0.0026	0.0062	0.0011	0.0004	-0.0030
0.2960	-0.0089	-0.0073	0.0021	-0.0109	-0.0110	0.0119	-0.0073	0.0028	0.0069	0.0018	0.0056	-0.0096
0.3040	-0.0038	-0.0121	-0.0092	-0.0076	-0.0148	0.0041	-0.0116	-0.0084	0.0030	0.0003	-0.0033	-0.0013
0.3120	-0.0124	-0.0087	-0.0114	-0.0079	-0.0059	-0.0110	-0.0070	-0.0093	-0.0027	-0.0026	-0.0093	0.0018

WG(LB/SEC)	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742
WL(LB/SEC)	0.1800	0.1800	0.1800	0.1800	0.2400	0.2400	0.2400	0.2400	0.3500	0.3500	0.3500	0.3500
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.5127	0.5127	1.0000	1.0000	0.5621	0.5621	1.0000	1.0000	0.6001	0.6001
0.0080	0.5524	0.5485	0.4398	0.4095	0.5849	0.5826	0.5056	0.4247	0.6107	0.5964	0.4691	0.4915
0.0160	0.1632	0.1665	0.2657	0.2229	0.1854	0.1898	0.3075	0.2101	0.2044	0.1932	0.2223	0.2694
0.0240	-0.0043	0.0069	0.1035	0.0606	0.0035	0.0124	0.1180	0.0411	0.0013	-0.0027	0.0298	0.0839
0.0320	-0.0765	-0.0650	-0.0109	-0.0361	-0.0763	-0.0719	-0.0089	-0.0505	-0.0946	-0.0908	-0.0780	-0.0294
0.0400	-0.1078	-0.0999	-0.0749	-0.0831	-0.1161	-0.1104	-0.0769	-0.0965	-0.1410	-0.1296	-0.1279	-0.0873
0.0480	-0.1181	-0.1120	-0.1017	-0.0993	-0.1327	-0.1243	-0.1133	-0.1148	-0.1555	-0.1439	-0.1463	-0.1153
0.0560	-0.1184	-0.1128	-0.1083	-0.1060	-0.1342	-0.1213	-0.1266	-0.1172	-0.1533	-0.1464	-0.1461	-0.1259
0.0640	-0.1161	-0.1082	-0.1070	-0.1018	-0.1294	-0.1162	-0.1237	-0.1115	-0.1497	-0.1427	-0.1393	-0.1253
0.0720	-0.1052	-0.1026	-0.0988	-0.0915	-0.1241	-0.1106	-0.1149	-0.1009	-0.1380	-0.1304	-0.1319	-0.1174
0.0800	-0.0872	-0.0948	-0.0891	-0.0836	-0.1122	-0.1036	-0.1100	-0.0925	-0.1199	-0.1131	-0.1174	-0.1041
0.0880	-0.0745	-0.0821	-0.0823	-0.0742	-0.1011	-0.0975	-0.1028	-0.0863	-0.1009	-0.0924	-0.0965	-0.0857
0.0960	-0.0635	-0.0667	-0.0759	-0.0640	-0.0917	-0.0893	-0.0926	-0.0768	-0.0752	-0.0775	-0.0752	-0.0715
0.1040	-0.0500	-0.0547	-0.0591	-0.0537	-0.0737	-0.0770	-0.0779	-0.0585	-0.0561	-0.0661	-0.0569	-0.0623
0.1120	-0.0443	-0.0445	-0.0373	-0.0474	-0.0488	-0.0658	-0.0603	-0.0495	-0.0413	-0.0522	-0.0415	-0.0524
0.1200	-0.0369	-0.0398	-0.0329	-0.0402	-0.0283	-0.0461	-0.0444	-0.0447	-0.0317	-0.0323	-0.0256	-0.0376
0.1280	-0.0303	-0.0349	-0.0330	-0.0313	-0.0160	-0.0292	-0.0271	-0.0286	-0.0236	-0.0138	-0.0088	-0.0255
0.1360	-0.0233	-0.0296	-0.0275	-0.0238	-0.0082	-0.0171	-0.0132	-0.0117	-0.0099	-0.0058	0.0026	-0.0225
0.1440	-0.0187	-0.0283	-0.0180	-0.0187	-0.0004	-0.0114	-0.0032	-0.0078	0.0021	0.0009	0.0127	-0.0170
0.1520	-0.0123	-0.0249	-0.0113	-0.0218	0.0055	-0.0040	0.0037	-0.0018	0.0074	0.0142	0.0184	-0.0050
0.1600	-0.0034	-0.0212	-0.0070	-0.0186	0.0077	0.0051	0.0189	-0.0007	0.0053	0.0207	0.0205	0.0097
0.1680	-0.0068	-0.0171	-0.0061	-0.0131	0.0168	0.0162	0.0306	0.0064	0.0017	0.0141	0.0159	0.0090
0.1760	-0.0005	-0.0133	-0.0039	-0.0044	0.0165	0.0203	0.0247	0.0083	0.0037	0.0143	0.0152	0.0046
0.1840	0.0114	-0.0074	0.0043	0.0034	0.0068	0.0169	0.0170	0.0055	0.0048	0.0115	0.0159	0.0021
0.1920	0.0146	0.0044	0.0107	0.0064	-0.0034	0.0067	0.0039	0.0037	0.0056	0.0043	0.0078	0.0010
0.2000	0.0119	0.0137	0.0111	0.0110	-0.0035	0.0012	-0.0033	0.0037	0.0122	0.0011	-0.0056	0.0077
0.2080	0.0032	0.0134	0.0180	0.0117	-0.0016	-0.0008	-0.0034	0.0032	0.0152	0.0043	-0.0017	0.0173
0.2160	0.0065	0.0111	0.0213	0.0083	0.0103	-0.0099	-0.0005	-0.0014	0.0091	0.0087	0.0072	0.0180
0.2240	0.0130	0.0104	0.0189	-0.0012	0.0134	-0.0109	0.0054	-0.0044	0.0103	0.0117	0.0074	0.0117
0.2320	0.0042	0.0098	0.0089	0.0027	0.0090	-0.0004	0.0056	-0.0031	0.0153	0.0168	0.0035	0.0133
0.2400	-0.0070	0.0042	-0.0021	-0.0007	0.0046	0.0110	0.0036	0.0003	0.0131	0.0136	0.0072	0.0181
0.2480	-0.0105	-0.0015	-0.0100	-0.0066	0.0011	0.0116	0.0047	-0.0011	0.0029	0.0010	0.0078	0.0121
0.2560	-0.0160	-0.0045	-0.0178	-0.0082	0.0001	0.0063	0.0037	-0.0049	-0.0082	-0.0072	0.0010	0.0034
0.2640	-0.0102	-0.0008	-0.0176	-0.0023	-0.0132	-0.0015	-0.0009	-0.0129	-0.0087	-0.0047	-0.0015	-0.0091
0.2720	0.0070	0.0020	-0.0090	0.0071	-0.0252	-0.0102	-0.0099	-0.0165	-0.0003	-0.0095	0.0035	-0.0155
0.2800	0.0110	0.0041	0.0022	0.0123	-0.0240	-0.0185	-0.0218	-0.0074	0.0072	-0.0150	-0.0008	-0.0142
0.2880	0.0033	0.0027	0.0004	0.0109	-0.0189	-0.0159	-0.0237	-0.0079	0.0076	-0.0088	-0.0036	-0.0069
0.2960	-0.0044	-0.0072	-0.0070	0.0051	-0.0163	-0.0121	-0.0143	-0.0121	-0.0009	-0.0009	0.0003	0.0032
0.3040	-0.0084	-0.0110	-0.0106	-0.0031	-0.0132	-0.0090	-0.0054	-0.0108	-0.0106	-0.0009	-0.0044	0.0040
0.3120	-0.0109	-0.0083	-0.0074	-0.0118	-0.0008	-0.0040	0.0063	-0.0072	-0.0124	-0.0092	-0.0076	-0.0003

WG(LB/SEC)	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742	0.1742
WL(LB/SEC)	0.4700	0.4700	0.4700	0.4700	0.5850	0.5850	0.5850	0.5850
CELL	B1	D2	LAG	LEAD	B1	D2	LAG	LEAD
TIME(SEC)	***** NORMALIZED		VALUE *****		***** NORMALIZED		VALUE *****	
0.0	1.0000	1.0000	0.6000	0.6000	1.0000	1.0000	0.6306	0.6306
0.0080	0.6187	0.6006	0.5168	0.4586	0.6279	0.6224	0.4878	0.5184
0.0160	0.2146	0.1992	0.2831	0.2370	0.2083	0.2077	0.2278	0.2691
0.0240	0.0042	-0.0038	0.0684	0.0603	-0.0190	-0.0206	0.0114	0.0660
0.0320	-0.1003	-0.0978	-0.0605	-0.0464	-0.1305	-0.1281	-0.1087	-0.0567
0.0400	-0.1467	-0.1350	-0.1198	-0.1010	-0.1792	-0.1613	-0.1529	-0.1166
0.0480	-0.1651	-0.1440	-0.1444	-0.1227	-0.1937	-0.1678	-0.1644	-0.1404
0.0560	-0.1683	-0.1484	-0.1546	-0.1286	-0.1880	-0.1641	-0.1688	-0.1460
0.0640	-0.1572	-0.1437	-0.1536	-0.1280	-0.1685	-0.1542	-0.1638	-0.1379
0.0720	-0.1442	-0.1316	-0.1473	-0.1185	-0.1353	-0.1354	-0.1443	-0.1231
0.0800	-0.1227	-0.1142	-0.1338	-0.0935	-0.1008	-0.1116	-0.1215	-0.1015
0.0880	-0.0922	-0.0910	-0.1053	-0.0683	-0.0741	-0.0912	-0.0932	-0.0797
0.0960	-0.0618	-0.0717	-0.0786	-0.0534	-0.0507	-0.0691	-0.0662	-0.0606
0.1040	-0.0424	-0.0549	-0.0563	-0.0473	-0.0346	-0.0512	-0.0424	-0.0456
0.1120	-0.0358	-0.0417	-0.0418	-0.0406	-0.0229	-0.0324	-0.0189	-0.0288
0.1200	-0.0264	-0.0272	-0.0251	-0.0317	-0.0057	-0.0099	0.0001	-0.0140
0.1280	-0.0173	-0.0184	-0.0106	-0.0280	0.0057	0.0060	0.0151	-0.0026
0.1360	-0.0068	-0.0110	0.0091	-0.0250	0.0117	0.0168	0.0270	0.0014
0.1440	0.0047	-0.0028	0.0227	-0.0152	0.0174	0.0230	0.0328	0.0059
0.1520	0.0176	-0.0041	0.0232	0.0006	0.0229	0.0281	0.0366	0.0169
0.1600	0.0219	0.0013	0.0237	0.0101	0.0272	0.0315	0.0384	0.0282
0.1680	0.0166	0.0127	0.0207	0.0128	0.0294	0.0296	0.0317	0.0304
0.1760	0.0109	0.0158	0.0191	0.0062	0.0242	0.0206	0.0180	0.0238
0.1840	0.0045	0.0108	0.0158	0.0021	0.0111	0.0103	0.0031	0.0139
0.1920	-0.0007	0.0125	0.0094	0.0005	-0.0007	-0.0037	-0.0072	0.0010
0.2000	-0.0013	0.0146	0.0085	0.0048	-0.0056	-0.0146	-0.0095	-0.0106
0.2080	0.0018	0.0106	0.0076	0.0116	-0.0072	-0.0169	-0.0085	-0.0146
0.2160	0.0037	0.0072	-0.0050	0.0138	-0.0139	-0.0149	-0.0110	-0.0177
0.2240	0.0063	0.0036	-0.0073	0.0069	-0.0169	-0.0092	-0.0158	-0.0169
0.2320	0.0	0.0032	-0.0007	0.0068	-0.0104	-0.0022	-0.0094	-0.0120
0.2400	-0.0025	0.0038	0.0044	0.0050	-0.0053	-0.0006	0.0019	-0.0057
0.2480	-0.0027	-0.0019	0.0058	-0.0019	0.0023	-0.0023	0.0102	0.0004
0.2560	0.0044	-0.0031	0.0043	-0.0071	0.0100	0.0055	0.0117	0.0044
0.2640	0.0001	-0.0052	-0.0074	-0.0019	0.0131	0.0104	0.0079	0.0097
0.2720	-0.0156	-0.0133	-0.0189	-0.0001	0.0100	0.0049	0.0053	0.0126
0.2800	-0.0208	-0.0160	-0.0253	-0.0029	0.0013	0.0033	0.0060	0.0067
0.2880	-0.0142	-0.0111	-0.0237	-0.0052	-0.0032	0.0051	0.0035	0.0024
0.2960	-0.0061	-0.0016	-0.0136	-0.0081	-0.0021	0.0046	-0.0083	-0.0024
0.3040	0.0017	0.0043	0.0005	-0.0107	-0.0003	-0.0038	-0.0093	-0.0068
0.3120	0.0092	0.0050	0.0138	-0.0013	-0.0070	-0.0113	-0.0061	-0.0034

APPENDIX D

STATISTICAL DATA OF WAVE PROPERTIES

WAVE AMPLITUDE OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- A (inch) -------------------				
0.016	0.0040	0.0030	------	0.0012	0.0009
0.028	0.0051	0.0035	------	0.0019	0.0015
0.044	0.0099	0.0069	0.0069	0.0082	0.0049
0.08	0.0206	0.0157	0.0209	0.0166	0.0130
0.126	0.0293	0.0219	0.0283	0.0199	0.0162
0.18	0.0323	0.0241	0.0299	0.0205	0.0177
0.24	0.0312	0.0262	0.0326	0.0235	0.0204
0.35	0.0416	0.0291	0.0362	0.0265	0.0231
0.47	0.0468	0.0300	0.0386	0.0296	0.0254
0.585	0.0495	0.0350	0.0387	0.0314	0.0257

STANDARD DEVIATION OF THE LARGE WAVE AMPLITUDE AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- amp (inch) -----------------				
0.016	0.0015	0.0011	------	0.0006	0.0004
0.028	0.0028	0.0016	------	0.0009	0.0008
0.044	0.0092	0.0065	0.0075	0.0081	0.0057
0.08	0.0140	0.0108	0.0133	0.0091	0.0073
0.126	0.0167	0.0108	0.0143	0.0112	0.0097
0.18	0.0182	0.0113	0.0158	0.0133	0.0117
0.24	0.0190	0.0125	0.0194	0.0155	0.0130
0.35	0.0247	0.0158	0.0216	0.0176	0.0139
0.47	0.0273	0.0178	0.0226	0.0191	0.0149
0.585	0.0291	0.0204	0.0232	0.0194	0.0144

WAVE MAXIMUM OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- h_{max} (inch) -----------------				
0.016	0.0072	0.0052	------	0.0034	0.0033
0.028	0.0102	0.0073	------	0.0054	0.0043
0.044	0.0155	0.0111	0.0115	0.0115	0.0071
0.08	0.0269	0.0205	0.0257	0.0204	0.0160
0.126	0.0366	0.0272	0.0341	0.0248	0.0203
0.18	0.0405	0.0301	0.0365	0.0262	0.0228
0.24	0.0407	0.0335	0.0405	0.0302	0.0265
0.35	0.0553	0.0395	0.0462	0.0350	0.0307
0.47	0.0635	0.0429	0.0507	0.0399	0.0347
0.585	0.0690	0.0497	0.0527	0.0437	0.0362

STANDARD DEVIATION OF THE LARGE WAVE MAXIMUM AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- max (inch) -----------------				
0.016	0.0014	0.0010	------	0.0006	0.0004
0.028	0.0025	0.0013	------	0.0008	0.0007
0.044	0.0093	0.0065	0.0073	0.0084	0.0057
0.08	0.0137	0.0107	0.0129	0.0091	0.0070
0.126	0.0160	0.0104	0.0137	0.0111	0.0095
0.18	0.0172	0.0105	0.0152	0.0133	0.0115
0.24	0.0179	0.0117	0.0188	0.0155	0.0128
0.35	0.0232	0.0147	0.0210	0.0174	0.0137
0.47	0.0255	0.0163	0.0219	0.0188	0.0146
0.585	0.0273	0.0186	0.0224	0.0188	0.0140

WAVE MINIMUM OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- h_{min} (inch) ----------				
0.016	0.0032	0.0022	------	0.0022	0.0024
0.028	0.0051	0.0038	------	0.0035	0.0028
0.044	0.0057	0.0043	0.0046	0.0034	0.0023
0.08	0.0064	0.0049	0.0049	0.0040	0.0031
0.126	0.0074	0.0054	0.0060	0.0051	0.0042
0.18	0.0084	0.0061	0.0069	0.0058	0.0052
0.24	0.0098	0.0075	0.0083	0.0070	0.0063
0.35	0.0144	0.0110	0.0107	0.0090	0.0080
0.47	0.0179	0.0138	0.0131	0.0110	0.0098
0.585	0.0212	0.0158	0.0152	0.0131	0.0110

MINIMUM OF D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- r n (inch) ---------				
0.016	0.0006	0.0005	------	0.0005	0.0003
0.028	0.0012	0.0009	------	0.0006	0.0004
0.044	0.0014	0.0011	0.0010	0.0008	0.0005
0.08	0.0019	0.0015	0.0012	0.0010	0.0010
0.126	0.0028	0.0020	0.0018	0.0015	0.0013
0.18	0.0034	0.0025	0.0021	0.0017	0.0016
0.24	0.0041	0.0030	0.0026	0.0022	0.0020
0.35	0.0051	0.0036	0.0033	0.0029	0.0026
0.47	0.0058	0.0040	0.0038	0.0034	0.0031
0.585	0.0060	0.0046	0.0045	0.0042	0.0035

WAVE BASE OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- T_{bs} (sec) ---------				
0.016	0.0973	0.0804	------	0.0304	0.0246
0.028	0.0717	0.0634	0.0513	0.0383	0.0324
0.044	0.0872	0.0784	0.0657	0.0595	0.0497
0.08	0.1061	0.1028	0.0793	0.0680	0.0603
0.126	0.1085	0.1086	0.0757	0.0610	0.0541
0.18	0.1009	0.1050	0.0698	0.0551	0.0509
0.24	0.0858	0.0936	0.0627	0.0520	0.0482
0.35	0.0733	0.0763	0.0553	0.0471	0.0452
0.47	0.0697	0.0669	0.0513	0.0454	0.0427
0.585	0.0654	0.0658	0.0503	0.0438	0.0423

STANDARD DEVIATION OF THE LARGE WAVE BASE AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------- bs (sec) ----------				
0.016	0.0453	0.0396	------	0.0142	0.0102
0.028	0.0309	0.0278	0.0225	0.0191	0.0164
0.044	0.0470	0.0422	0.0363	0.0295	0.0266
0.08	0.0509	0.0508	0.0331	0.0279	0.0243
0.126	0.0476	0.0443	0.0291	0.0255	0.0228
0.18	0.0453	0.0434	0.0276	0.0236	0.0218
0.24	0.0398	0.0393	0.0262	0.0242	0.0203
0.35	0.0345	0.0335	0.0242	0.0225	0.0188
0.47	0.0316	0.0328	0.0227	0.0222	0.0179
0.585	0.0314	0.0320	0.0237	0.0220	0.0185

WAVE SEPARATION OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------	T_{sep}	(sec)	---------	---------
0.016	0.1031	0.0886	------	0.0362	0.0293
0.028	0.0833	0.0722	0.0648	0.0468	0.0401
0.044	0.1222	0.1185	0.1121	0.1365	0.0775
0.08	0.1677	0.1810	0.1606	0.1247	0.1142
0.126	0.1641	0.1689	0.1387	0.1081	0.0957
0.18	0.1433	0.1514	0.1252	0.0955	0.0853
0.24	0.1191	0.1312	0.1130	0.0901	0.0821
0.35	0.1167	0.1177	0.1004	0.0796	0.0717
0.47	0.1198	0.1096	0.0936	0.0746	0.0662
0.585	0.1159	0.1109	0.0910	0.0724	0.0635

RATIO OF WAVE BACK TO WAVE FRONT
OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------	T_{bk}	/ T_{fn}	---------	---------
0.016	1.84	1.83	----	1.14	1.12
0.028	1.60	1.535	1.48	1.215	1.22
0.044	1.835	1.84	1.81	2.09	1.94
0.08	2.065	2.05	2.21	2.72	2.49
0.126	2.030	2.06	2.50	2.30	2.15
0.18	1.995	2.07	2.39	2.20	2.10
0.24	1.88	1.945	2.17	1.98	1.91
0.35	1.715	1.76	1.88	1.74	1.825
0.47	1.60	1.54	1.82	1.72	1.70
0.585	1.555	1.53	1.71	1.65	1.67

STANDARD DEVIATION OF THE LARGE WAVE
SEPARATION AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------	sep	(sec)	---------	---------
0.016	0.0502	0.0483	------	0.0181	0.0134
0.028	0.0422	0.0368	0.0365	0.0250	0.0211
0.044	0.0867	0.0913	0.0967	0.1189	0.0605
0.08	0.1095	0.1268	0.1009	0.0717	0.0699
0.126	0.0935	0.0949	0.0744	0.0624	0.0573
0.18	0.0787	0.0815	0.0679	0.0579	0.0528
0.24	0.0669	0.0697	0.0688	0.0561	0.0492
0.35	0.0678	0.0655	0.0592	0.0489	0.0411
0.47	0.0698	0.0656	0.0574	0.0441	0.0372
0.585	0.0688	0.0658	0.0537	0.0424	0.0345

WAVE FREQUENCY OF THE LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	-------	f	(cps)	---------	---------
0.016	9.7	11.3	----	27.6	34.1
0.028	12.0	13.85	15.4	21.4	24.9
0.044	8.2	8.43	8.91	7.32	12.9
0.08	5.97	5.52	6.23	8.00	8.77
0.126	6.10	5.92	7.20	9.25	10.45
0.18	6.97	6.6	7.97	10.48	11.70
0.24	8.40	7.62	8.85	11.10	12.20
0.35	8.56	8.50	9.95	12.55	13.95
0.47	8.35	9.13	10.7	13.44	15.10
0.585	8.62	9.0	11.0	13.80	15.75

WAVE AMPLITUDE OF THE LARGE WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	A (inch)					
0.016	0.0034	0.0038	0.0030	0.0011	0.0012	0.0011
0.044	0.0112	0.0109	0.0082	0.0120	0.0089	0.0080
0.126	0.0304	0.0306	0.0173	0.0268	0.0253	0.0258
0.24	0.0348	0.0391	0.0203	0.0304	0.0331	0.0332
0.35	0.0413	0.0456	0.0403	0.0339	0.0386	0.0438
0.585	0.0528	0.0637	0.0529	0.0376	0.0439	0.0558

WAVE FREQUENCY OF THE LARGE WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	f (cps)					
0.016	10.42	9.8	10.22	26.3	25.4	25.8
0.044	8.10	8.37	10.20	5.95	9.0	9.17
0.126	6.40	7.08	11.18	8.95	10.1	11.57
0.24	8.67	9.33	14.30	11.08	11.8	12.6
0.35	8.90	9.80	12.12	12.20	12.85	12.58
0.585	8.65	9.30	11.40	13.70	13.6	12.95

WAVE SEPARATION OF THE LARGE WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	T_{sep} (sec)					
0.016	0.0959	0.1021	0.0977	0.038	0.0394	0.0387
0.044	0.1236	0.1195	0.0982	0.1682	0.1111	0.1091
0.126	0.1560	0.1412	0.0895	0.1116	0.0991	0.0864
0.24	0.1153	0.1071	0.0699	0.0903	0.0850	0.0793
0.35	0.1122	0.1019	0.0824	0.0821	0.0778	0.0795
0.585	0.1154	0.1076	0.0878	0.0731	0.0735	0.0772

WAVE RATIO OF WAVE BACK TO WAVE FRONT OF THE LARGE WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	T_{bk} / T_{fn}					
0.016	1.85	2.06	1.63	1.15	1.155	1.140
0.044	1.94	1.93	1.94	2.31	2.01	1.890
0.126	2.03	2.18	1.72	2.45	2.40	2.48
0.24	1.79	1.95	1.56	1.92	1.96	2.07
0.35	1.565	1.67	1.81	1.82	1.72	1.79
0.585	1.54	1.59	1.67	1.70	1.62	1.63

WAVE AMPLITUDE OF THE SMALL WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	----------	A (inch)	----------	----------	----------
0.016	0.0010	0.0010	------	0.0003	0.0003
0.028	0.0016	0.0013	------	0.0005	0.0004
0.044	0.0018	0.0016	0.0016	0.0014	0.0011
0.08	0.0021	0.0018	0.0016	0.0015	0.0014
0.126	0.0021	0.0017	0.0018	0.0018	0.0016
0.18	0.0023	0.0018	0.0020	0.0020	0.0019
0.24	0.0026	0.0021	0.0024	0.0027	0.0023
0.35	0.0034	0.0028	0.0034	0.0031	0.0030
0.47	0.0040	0.0033	0.0041	0.0038	0.0036
0.585	0.0045	0.0037	0.0048	0.0045	0.0039

STANDARD DEVIATION OF THE SMALL WAVE
AMPLITUDE AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------	amp (inch)	----------	----------	----------
0.016	0.0001	0.0002	------	0.0000	0.0001
0.028	0.0007	0.0005	------	0.0002	0.0002
0.044	0.0009	0.0007	0.0006	0.0006	0.0002
0.08	0.0012	0.0009	0.0007	0.0006	0.0005
0.126	0.0012	0.0009	0.0008	0.0008	0.0007
0.18	0.0014	0.0010	0.0010	0.0010	0.0008
0.24	0.0018	0.0013	0.0014	0.0013	0.0012
0.35	0.0023	0.0016	0.0020	0.0018	0.0016
0.47	0.0026	0.0020	0.0025	0.0022	0.0020
0.585	0.0028	0.0023	0.0028	0.0026	0.0022

WAVE MAXIMUM OF THE SMALL WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------	h_{max} (inch)	----------	----------	----------
0.016	0.0036	0.0029	------	0.0024	0.0026
0.028	0.0063	0.0047	------	0.0038	0.0031
0.044	0.0066	0.0051	0.0053	0.0043	0.0030
0.08	0.0073	0.0056	0.0056	0.0048	0.0039
0.126	0.0080	0.0060	0.0067	0.0060	0.0051
0.18	0.0090	0.0066	0.0075	0.0068	0.0061
0.24	0.0106	0.0081	0.0090	0.0082	0.0075
0.35	0.0149	0.0115	0.0118	0.0104	0.0096
0.47	0.0176	0.0139	0.0141	0.0127	0.0117
0.585	0.0205	0.0154	0.0162	0.0148	0.0128

STANDARD DEVIATION OF THE SMALL WAVE
MAXIMUM AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------	max (inch)	----------	----------	----------
0.016	0.0005	0.0003	------	0.0003	0.0002
0.028	0.0009	0.0006	------	0.0005	0.0003
0.044	0.0011	0.0008	0.0007	0.0006	0.0001
0.08	0.0016	0.0011	0.0009	0.0008	0.0007
0.126	0.0021	0.0015	0.0014	0.0012	0.0010
0.18	0.0027	0.0019	0.0017	0.0014	0.0012
0.24	0.0035	0.0025	0.0022	0.0018	0.0017
0.35	0.0046	0.0032	0.0029	0.0024	0.0022
0.47	0.0053	0.0038	0.0035	0.0028	0.0026
0.585	0.0058	0.0043	0.0039	0.0035	0.0029

WAVE MINIMUM OF THE SMALL WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	----------	h_{min} (inch)	----------	----------	----------
0.016	0.0026	0.0019	------	0.0021	0.0023
0.028	0.0046	0.0033	------	0.0035	0.0027
0.044	0.0047	0.0034	0.0037	0:0028	0.0019
0.08	0.0052	0.0038	0.0039	0.0032	0.0025
0.126	0.0058	0.0042	0.0048	0.0041	0.0034
0.18	0.0066	0.0047	0.0054	0.0047	0.0042
0.24	0.0076	0.0057	0.0063	0.0056	0.0050
0.35	0.0109	0.0083	0.0079	0.0069	0.0063
0.47	0.0129	0.0100	0.0094	0.0083	0.0077
0.585	0.0153	0.0111	0.0108	0.0097	0.0084

STANDARD DEVIATION OF THE SMALL WAVE MINIMUM AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------	min (inch)	----------	----------	----------
0.016	0.0005	0.0003	------	0.0005	0.0002
0.028	0.0010	0.0007	------	0.0005	0.0003
0.044	0.0011	0.0008	0.0007	0.0006	0.0003
0.08	0.0014	0.0010	0.0008	0.0007	0.0006
0.126	0.0018	0.0013	0.0012	0.0010	0.0009
0.18	0.0023	0.0015	0.0014	0.0012	0.0010
0.24	0.0030	0.0020	0.0017	0.0015	0.0014
0.35	0.0039	0.0028	0.0023	0.0020	0.0018
0.47	0.0045	0.0033	0.0027	0.0024	0.0022
0.585	0.0051	0.0035	0.0032	0.0029	0.0024

WAVE BASE OF THE SMALL WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	----------	T_{bs} (sec)	----------	----------	----------
0.016	0.0282	0.0350	------	0.0119	0.0119
0.028	0.0368	0.0314	0.0279	0.0150	0.0140
0.044	0.0421	0.0393	0.0336	0.0326	0.0276
0.08	0.0447	0.0418	0.0333	0.0323	0.0312
0.126	0.0412	0.0394	0.0325	0.0333	0.0302
0.18	0.0373	0.0384	0.0329	0.0317	0.0288
0.24	0.0353	0.0362	0.0334	0.0306	0.0276
0.35	0.0301	0.0323	0.0304	0.0266	0.0248
0.47	0.0278	0.0286	0.0268	0.0238	0.0222
0.585	0.0243	0.0261	0.0246	0.0218	0.0212

STANDARD DEVIATION OF THE SMALL WAVE BASE AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	---------	bs (sec)	----------	----------	----------
0.016	0.0266	0.0278	------	0.0042	0.0049
0.028	0.0217	0.0188	0.0146	0.0078	0.0061
0.044	0.0256	0.0232	0.0175	0.0177	0.0148
0.08	0.0252	0.0234	0.0175	0.0184	0.0169
0.126	0.0230	0.0226	0.0179	0.0186	0.0158
0.18	0.0221	0.0219	0.0180	0.0179	0.0148
0.24	0.0208	0.0217	0.0182	0.0174	0.0139
0.35	0.0178	0.0191	0.0163	0.0150	0.0118
0.47	0.0165	0.0170	0.0138	0.0131	0.0106
0.585	0.0144	0.0154	0.0126	0.0118	0.0097

WAVE FREQUENCY OF THE SMALL WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	-------- f (cps)				
0.016	35.4	28.6	----	84.0	84.0
0.028	27.2	31.8	35.8	66.6	71.5
0.044	23.75	26.1	29.8	30.6	36.2
0.08	22.4	23.9	30.0	31.0	32.0
0.126	24.3	25.2	30.8	30.0	33.1
0.18	26.8	26.0	30.4	31.5	34.7
0.24	28.3	27.6	29.9	32.6	36.2
0.35	33.2	31.0	32.9	37.6	40.3
0.47	36.0	35.0	37.3	42.0	45.0
0.585	41.2	38.3	40.6	45.8	47.2

RATIO OF WAVE BACK TO WAVE FRONT
OF THE SMALL WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	--------- T_{bk} / T_{fn}				
0.016	1.34	1.63	----	1.015	0.985
0.028	1.42	1.275	1.18	1.055	1.015
0.044	1.45	1.31	1.255	1.190	1.09
0.08	1.48	1.415	1.33	1.400	1.26
0.126	1.57	1.575	1.54	1.520	1.505
0.18	1.645	1.58	1.67	1.565	1.505
0.24	1.87	1.76	1.715	1.595	1.59
0.35	1.74	1.88	1.815	1.69	1.67
0.47	1.70	1.78	1.69	1.645	1.58
0.585	1.64	1.67	1.63	1.595	1.525

WAVE AMPLITUDE OF THE SMALL WAVE
AT B_1, A_3 and C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	A (inch)					
0.016	0.001	0.0010	0.0011	0.0003	0.0003	0.0003
0.044	0.0018	0.0018	0.0016	0.0014	0.0014	0.0014
0.126	0.0023	0.0021	0.0023	0.0018	0.0019	0.0018
0.24	0.003	0.0030	0.0030	0.0027	0.0028	0.0026
0.35	0.0039	0.0040	0.0039	0.0038	0.0039	0.0037
0.585	0.0050	0.0052	0.0048	0.0052	0.0056	0.0053

WAVE BASE OF THE SMALL WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	T_{bs} (sec)					
0.016	0.0370	0.0348	0.0388	0.0131	0.0139	0.0150
0.044	0.0430	0.0432	0.0390	0.0350	0.0324	0.0324
0.126	0.0404	0.0399	0.0307	0.0333	0.0326	0.0318
0.24	0.0327	0.0325	0.0235	0.0292	0.0294	0.0287
0.35	0.0286	0.0289	0.0251	0.0260	0.0255	0.0255
0.585	0.0234	0.0234	0.0214	0.0201	0.0207	0.0205

WAVE FREQUENCY OF THE SMALL WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	f (cps)					
0.016	27.0	28.7	25.8	76.3	72.0	66.7
0.044	23.2	23.1	25.6	28.6	30.8	30.8
0.126	24.7	25.0	32.6	30.0	30.7	31.4
0.24	30.6	30.8	42.5	34.2	34.0	34.8
0.35	35.0	34.6	39.9	38.5	39.2	39.2
0.585	42.7	42.7	46.7	49.7	48.3	48.8

RATIO OF WAVE BACK TO WAVE FRONT OF THE SMALL WAVE
AT B_1, A_3 AND C_4 CELL

W_G(lb/sec)	0.0			0.1436		
CELL NO.	B_1	A_3	C_4	B_1	A_3	C_4
W_L(lb/sec)	T_{bk} / T_{fn}					
0.016	1.60	1.54	1.34	1.03	1.00	1.00
0.044	1.530	1.53	1.45	1.32	1.235	1.25
0.126	1.605	1.585	1.57	1.64	1.63	1.77
0.24	1.76	1.85	1.34	1.73	1.70	1.96
0.35	1.75	1.83	1.73	1.74	1.74	2.00
0.585	1.54	1.60	1.71	1.51	1.62	1.72

WAVE AMPLITUDE OF THE SMALL WAVES ON LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	-------------	A	-------------	-------------	-------------
0.016	0.0021	0.0020		0.0006	0.0005
0.028	0.0029	0.0021		0.0009	0.0007
0.044	0.0051	0.0035	0.0035	0.0035	0.0027
0.08	0.0074	0.0062	0.0062	0.0049	0.0042
0.126	0.0090	0.0072	0.0082	0.0062	0.0054
0.18	0.0101	0.0083	0.0087	0.0069	0.0060
0.24	0.0100	0.0088	0.0094	0.0082	0.0073
0.35	0.0133	0.0090	0.0111	0.0094	0.0090
0.47	0.0155	0.0099	0.0121	0.0104	0.0097
0.585	0.0166	0.0108	0.0132	0.0111	0.0100

WAVE BASE OF THE SMALL WAVES ON LARGE WAVES AT D_2 CELL

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	-------- WAVE BASE T_{bs}		D_2 CELL		
0.016	0.0653	0.0642		0.0167	0.0144
0.028	0.0485	0.0426	0.0404	0.0203	0.0188
0.044	0.0528	0.0496	0.0411	0.0416	0.0424
0.08	0.0514	0.0515	0.0430	0.0441	0.0381
0.126	0.0447	0.0472	0.0407	0.0360	0.0325
0.18	0.0446	0.0446	0.0369	0.0302	0.0295
0.24	0.0374	0.0389	0.0299	0.0265	0.0266
0.35	0.0309	0.0308	0.0250	0.0232	0.0239
0.47	0.0285	0.0286	0.0268	0.0221	0.0226
0.585	0.0275	0.0269	0.0216	0.0218	0.0221

STANDARD DEVIATION OF THE SMALL WAVE AMPLITUDE ON LARGE WAVES

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	-------------	-------------	AMP	D_2 CELL	----------
0.016	0.0009	0.0003		0.0002	0.0002
0.028	0.0013	0.0007		0.0005	0.0004
0.044	0.0036	0.0023	0.0022	0.0024	0.0015
0.08	0.0050	0.0038	0.0044	0.0035	0.0023
0.126	0.0059	0.0044	0.0051	0.0047	0.0036
0.18	0.0065	0.0049	0.0054	0.0048	0.0042
0.24	0.0070	0.0052	0.0059	0.0058	0.0045
0.35	0.0103	0.0057	0.0076	0.0060	0.0055
0.47	0.0116	0.0068	0.0080	0.0069	0.0055
0.585	0.0122	0.0076	0.0090	0.0074	0.0055

STANDARD DEVIATION OF THE SMALL WAVE BASE ON ON LARGE WAVES

W_G(lb/sec)	0.0	0.045	0.0976	0.1436	0.1742
W_L(lb/sec)	-------------	-------------	bs	D_2 CELL	----------
0.016	0.0378			0.0087	0.0059
0.028	0.0256	0.0221	0.0170	0.0104	0.0080
0.044	0.0344	0.0311	0.0213	0.0213	0.0184
0.08	0.0351	0.0326	0.0224	0.0240	0.0193
0.126	0.0320	0.0312	0.0233	0.0204	0.0171
0.18	0.0316	0.0302	0.0212	0.0183	0.0154
0.24	0.0262	0.0262	0.0173	0.0171	0.0137
0.35	0.0196	0.0197	0.0138	0.0135	0.0120
0.47	0.0167	0.0170	0.0138	0.0120	0.0100
0.585	0.0161	0.0160	0.0102	0.0114	0.0103

AMPLITUDE OF SMALL WAVE ON LARGE WAVE

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL *****			
0.0005	633.	638.	8.	2.	6.	2.	24.	19.	20.	18.
0.0015	39.	327.	46.	27.	23.	32.	112.	70.	57.	49.
0.0025	0.	15.	37.	37.	38.	39.	111.	106.	91.	74.
0.0035	0.	0.	45.	61.	85.	100.	113.	134.	145.	130.
0.0045	0.	0.	10.	29.	70.	74.	82.	96.	131.	104.
0.0055	0.	0.	10.	13.	30.	43.	47.	74.	93.	96.
0.0065	0.	0.	10.	16.	37.	56.	30.	41.	53.	80.
0.0075	0.	0.	3.	6.	20.	23.	23.	33.	41.	39.
0.0085	0.	0.	4.	12.	20.	27.	10.	22.	22.	24.
0.0095	0.	0.	1.	6.	15.	26.	5.	10.	16.	16.
0.0105	0.	0.	1.	2.	12.	17.	3.	13.	10.	12.
0.0115	0.	0.	0.	2.	1.	12.	9.	6.	4.	15.
0.0125	0.	0.	1.	0.	8.	19.	6.	8.	11.	7.
0.0135	0.	0.	0.	2.	4.	4.	2.	3.	5.	3.
0.0145	0.	0.	1.	5.	4.	3.	4.	5.	5.	6.
0.0155	0.	0.	0.	1.	2.	6.	3.	4.	5.	5.
0.0165	0.	0.	0.	0.	2.	2.	3.	0.	8.	5.
0.0175	0.	0.	1.	0.	2.	5.	1.	0.	3.	2.
0.0185	0.	0.	0.	0.	1.	3.	0.	1.	0.	0.
0.0195	0.	0.	0.	0.	3.	3.	0.	1.	3.	2.
0.0210	0.	0.	0.	2.	3.	4.	0.	1.	1.	0.
0.0230	0.	0.	0.	1.	6.	3.	0.	0.	0.	4.
0.0250	0.	0.	0.	0.	5.	6.	0.	0.	0.	1.
0.0270	0.	0.	0.	0.	0.	2.	0.	0.	1.	1.
0.0290	0.	0.	0.	0.	0.	1.	0.	0.	1.	2.
0.0310	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0330	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
0.0350	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0370	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0390	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0410	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0430	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0450	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0470	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0490	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0510	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0530	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0550	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0570	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0590	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0610	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0630	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0650	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0670	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0690	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0710	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0730	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0750	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0770	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0790	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

AMPLITUDE OF LARGE WAVE

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
FLIM(INCH)	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	*****
0.0005	0.	38.	0.	21.	13.	19.	17.	8.	3.	4.
0.0015	267.	151.	101.	70.	27.	23.	38.	24.	17.	23.
0.0025	247.	296.	74.	81.	49.	32.	22.	38.	41.	34.
0.0035	426.	405.	215.	86.	42.	41.	57.	48.	50.	40.
0.0045	350.	287.	112.	44.	37.	36.	52.	67.	52.	39.
0.0055	262.	260.	141.	53.	35.	44.	53.	59.	48.	57.
0.0065	77.	319.	156.	41.	27.	38.	48.	48.	41.	45.
0.0075	20.	132.	68.	54.	30.	49.	39.	51.	40.	33.
0.0085	4.	114.	79.	53.	30.	31.	51.	43.	40.	39.
0.0095	1.	32.	35.	29.	25.	17.	34.	27.	25.	26.
0.0105	0.	36.	55.	56.	39.	42.	37.	40.	26.	31.
0.0115	0.	10.	22.	55.	40.	36.	48.	42.	34.	21.
0.0125	0.	26.	34.	58.	47.	49.	53.	38.	25.	16.
0.0135	0.	9.	23.	51.	53.	54.	51.	43.	15.	12.
0.0145	0.	4.	13.	52.	70.	53.	84.	25.	28.	14.
0.0155	0.	5.	32.	50.	61.	62.	63.	16.	25.	15.
0.0165	0.	1.	16.	34.	59.	70.	57.	22.	20.	12.
0.0175	0.	4.	27.	29.	52.	67.	60.	20.	13.	13.
0.0185	0.	3.	20.	30.	39.	48.	49.	24.	14.	16.
0.0195	0.	0.	10.	19.	40.	45.	40.	10.	14.	16.
0.0210	0.	5.	28.	13.	33.	47.	37.	24.	19.	11.
0.0230	0.	0.	34.	14.	38.	23.	23.	22.	23.	22.
0.0250	0.	0.	21.	12.	35.	24.	25.	26.	20.	22.
0.0270	0.	0.	14.	6.	24.	28.	26.	35.	32.	32.
0.0290	0.	0.	19.	2.	18.	33.	30.	38.	26.	25.
0.0310	0.	0.	18.	4.	16.	28.	30.	49.	36.	26.
0.0330	0.	0.	13.	4.	18.	33.	36.	46.	44.	42.
0.0350	0.	0.	12.	5.	8.	27.	42.	51.	38.	33.
0.0370	0.	0.	7.	4.	7.	19.	33.	63.	54.	39.
0.0390	0.	0.	8.	3.	8.	21.	26.	52.	40.	45.
0.0410	0.	0.	2.	6.	7.	13.	29.	50.	44.	30.
0.0430	0.	0.	5.	4.	9.	20.	31.	48.	48.	49.
0.0450	0.	0.	1.	2.	4.	9.	22.	49.	42.	35.
0.0470	0.	0.	2.	0.	3.	8.	15.	37.	32.	23.
0.0490	0.	0.	1.	1.	6.	7.	15.	41.	55.	47.
0.0510	0.	0.	1.	1.	3.	7.	9.	22.	22.	33.
0.0530	0.	0.	0.	0.	6.	5.	11.	25.	44.	36.
0.0550	0.	0.	0.	0.	4.	1.	3.	23.	23.	27.
0.0570	0.	0.	0.	0.	2.	0.	2.	20.	31.	29.
0.0590	0.	0.	1.	1.	0.	6.	4.	14.	24.	33.
0.0610	0.	0.	1.	1.	4.	1.	2.	14.	25.	32.
0.0630	0.	0.	1.	1.	1.	9.	3.	17.	28.	23.
0.0650	0.	0.	0.	0.	1.	1.	1.	3.	20.	16.
0.0670	0.	0.	0.	0.	0.	1.	0.	9.	14.	18.
0.0690	0.	0.	1.	0.	0.	1.	0.	5.	12.	21.
0.0710	0.	0.	0.	0.	0.	0.	0.	5.	9.	11.
0.0730	0.	0.	0.	0.	1.	1.	0.	6.	10.	14.
0.0750	0.	0.	0.	0.	0.	1.	0.	5.	9.	15.
0.0770	0.	0.	0.	0.	0.	0.	0.	4.	6.	4.
0.0790	0.	0.	0.	0.	0.	0.	0.	3.	6.	10.

AMPLITUDE OF LARGE WAVE

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL *****			
0.0010	2661.	1569.	409.	66.	38.	33.	26.	11.	4.	5.
0.0030	240.	965.	486.	236.	188.	185.	118.	60.	49.	44.
0.0050	0.	41.	42.	40.	132.	206.	170.	145.	67.	50.
0.0070	0.	1.	30.	22.	74.	153.	192.	176.	138.	114.
0.0090	0.	0.	20.	13.	31.	67.	130.	147.	143.	123.
0.0110	0.	0.	34.	28.	19.	38.	74.	118.	133.	121.
0.0130	0.	0.	44.	31.	29.	29.	39.	84.	106.	99.
0.0150	0.	0.	42.	84.	25.	13.	30.	42.	80.	80.
0.0170	0.	0.	64.	122.	57.	25.	25.	45.	67.	63.
0.0190	0.	0.	54.	151.	68.	29.	24.	20.	33.	42.
0.0210	0.	0.	65.	200.	97.	72.	27.	33.	31.	42.
0.0230	0.	0.	36.	133.	101.	87.	35.	18.	29.	36.
0.0250	0.	0.	41.	98.	145.	104.	48.	24.	24.	24.
0.0270	0.	0.	19.	81.	181.	142.	81.	34.	28.	21.
0.0290	0.	0.	7.	51.	163.	137.	128.	62.	34.	36.
0.0310	0.	0.	6.	26.	122.	137.	118.	97.	35.	33.
0.0330	0.	0.	2.	14.	70.	109.	111.	76.	52.	38.
0.0350	0.	0.	0.	9.	31.	75.	105.	88.	76.	38.
0.0370	0.	0.	1.	3.	25.	67.	100.	109.	50.	45.
0.0390	0.	0.	0.	3.	12.	46.	97.	95.	55.	47.
0.0410	0.	0.	0.	0.	8.	18.	57.	58.	46.	46.
0.0430	0.	0.	0.	0.	6.	18.	29.	36.	49.	39.
0.0450	0.	0.	0.	0.	4.	12.	14.	38.	53.	55.
0.0470	0.	0.	0.	0.	4.	10.	32.	44.	43.	89.
0.0490	0.	0.	0.	0.	4.	7.	17.	50.	82.	80.
0.0510	0.	0.	0.	0.	0.	5.	28.	52.	82.	79.
0.0530	0.	0.	0.	0.	0.	7.	14.	44.	64.	80.
0.0550	0.	0.	0.	0.	0.	4.	19.	37.	67.	77.
0.0570	0.	0.	0.	0.	0.	0.	13.	30.	51.	59.
0.0590	0.	0.	0.	0.	0.	1.	9.	39.	46.	48.
0.0610	0.	0.	0.	0.	0.	3.	8.	15.	32.	53.
0.0630	0.	0.	0.	0.	0.	1.	6.	10.	26.	24.
0.0650	0.	0.	0.	0.	0.	0.	0.	4.	12.	11.
0.0670	0.	0.	0.	0.	0.	0.	0.	1.	9.	5.
0.0690	0.	0.	0.	0.	0.	0.	1.	3.	3.	6.
0.0710	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
0.0730	0.	0.	0.	0.	0.	0.	0.	0.	2.	0.
0.0750	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0770	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0790	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0810	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0830	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0850	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0870	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0890	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0910	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0930	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0950	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0970	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0990	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

MAXIMUM OF LARGE WAVE

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
FLIM(INCH)	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	*****
0.0005	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0015	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0025	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0035	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0045	244.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0055	292.	0.	0.	168.	0.	0.	0.	0.	0.	0.
0.0065	458.	0.	0.	87.	69.	0.	0.	0.	0.	0.
0.0075	380.	546.	0.	42.	64.	72.	0.	0.	0.	0.
0.0085	203.	478.	344.	48.	35.	58.	57.	0.	0.	0.
0.0095	60.	392.	203.	31.	21.	27.	55.	0.	0.	0.
0.0105	14.	284.	153.	49.	34.	47.	75.	0.	0.	0.
0.0115	2.	158.	109.	60.	36.	35.	65.	48.	0.	0.
0.0125	1.	110.	80.	44.	30.	36.	46.	122.	0.	0.
0.0135	0.	63.	51.	55.	32.	39.	46.	79.	52.	0.
0.0145	0.	25.	36.	61.	43.	43.	46.	60.	115.	0.
0.0155	0.	25.	41.	55.	34.	30.	39.	57.	69.	87.
0.0165	0.	15.	33.	48.	58.	48.	51.	40.	56.	107.
0.0175	0.	12.	36.	55.	71.	72.	68.	52.	43.	77.
0.0185	0.	7.	26.	46.	62.	77.	73.	36.	35.	37.
0.0195	0.	0.	0.	34.	70.	63.	74.	36.	28.	35.
0.0210	0.	9.	47.	36.	58.	55.	82.	37.	30.	19.
0.0230	0.	6.	41.	22.	41.	67.	51.	24.	28.	23.
0.0250	0.	5.	36.	26.	53.	48.	45.	23.	21.	23.
0.0270	0.	2.	31.	13.	27.	56.	57.	38.	25.	21.
0.0290	0.	0.	31.	12.	36.	34.	45.	17.	18.	12.
0.0310	0.	0.	22.	14.	32.	30.	26.	15.	9.	4.
0.0330	0.	0.	16.	6.	25.	24.	21.	16.	14.	10.
0.0350	0.	0.	17.	5.	31.	29.	19.	23.	18.	13.
0.0370	0.	0.	17.	2.	13.	30.	24.	30.	23.	8.
0.0390	0.	0.	12.	3.	14.	30.	28.	23.	12.	16.
0.0410	0.	0.	11.	5.	10.	24.	36.	32.	22.	19.
0.0430	0.	0.	10.	4.	12.	37.	51.	55.	31.	28.
0.0450	0.	0.	4.	2.	3.	11.	21.	27.	14.	16.
0.0470	0.	0.	2.	3.	8.	24.	46.	59.	52.	25.
0.0490	0.	0.	5.	7.	8.	16.	25.	61.	48.	29.
0.0510	0.	0.	1.	2.	8.	13.	35.	56.	45.	39.
0.0530	0.	0.	2.	0.	4.	9.	32.	90.	71.	72.
0.0550	0.	0.	2.	0.	2.	4.	11.	42.	24.	25.
0.0570	0.	0.	0.	2.	7.	8.	14.	28.	52.	35.
0.0590	0.	0.	0.	0.	4.	6.	10.	42.	42.	37.
0.0610	0.	0.	0.	0.	4.	5.	15.	40.	47.	50.
0.0630	0.	0.	0.	0.	4.	2.	3.	37.	34.	41.
0.0650	0.	0.	1.	2.	2.	4.	7.	31.	73.	57.
0.0670	0.	0.	1.	0.	2.	3.	1.	9.	22.	19.
0.0690	0.	0.	1.	1.	2.	5.	5.	31.	43.	65.
0.0710	0.	0.	0.	0.	1.	4.	1.	16.	26.	27.
0.0730	0.	0.	0.	0.	0.	1.	0.	2.	9.	18.
0.0750	0.	0.	1.	0.	0.	1.	1.	20.	37.	43.
0.0770	0.	0.	0.	0.	0.	1.	0.	6.	13.	6.
0.0790	0.	0.	0.	0.	1.	1.	1.	10.	28.	33.

MAXIMUM OF LARGE WAVE

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
FLIM(INCH)	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	*****
0.0010	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0030	2710.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0050	191.	2090.	793.	0.	0.	0.	0.	0.	0.	0.
0.0070	0.	479.	126.	307.	0.	0.	0.	0.	0.	0.
0.0090	0.	7.	36.	44.	322.	275.	0.	0.	0.	0.
0.0110	0.	0.	23.	15.	104.	249.	257.	0.	0.	0.
0.0130	0.	0.	24.	15.	34.	97.	247.	0.	0.	0.
0.0150	0.	0.	39.	27.	21.	53.	135.	369.	0.	0.
0.0170	0.	0.	49.	56.	23.	24.	80.	209.	155.	0.
0.0190	0.	0.	22.	43.	12.	17.	24.	62.	147.	0.
0.0210	0.	0.	59.	120.	36.	7.	29.	90.	218.	181.
0.0230	0.	0.	57.	165.	61.	22.	20.	59.	132.	222.
0.0250	0.	0.	64.	182.	95.	34.	26.	42.	97.	147.
0.0270	0.	0.	41.	154.	99.	82.	26.	30.	53.	94.
0.0290	0.	0.	38.	112.	127.	83.	24.	16.	31.	71.
0.0310	0.	0.	17.	69.	167.	111.	43.	19.	31.	56.
0.0330	0.	0.	7.	48.	174.	150.	74.	25.	24.	35.
0.0350	0.	0.	5.	28.	131.	138.	115.	23.	21.	29.
0.0370	0.	0.	1.	15.	103.	139.	123.	48.	21.	21.
0.0390	0.	0.	0.	6.	45.	104.	131.	81.	30.	18.
0.0410	0.	0.	1.	1.	28.	64.	102.	88.	35.	19.
0.0430	0.	0.	0.	4.	23.	70.	94.	97.	43.	25.
0.0450	0.	0.	0.	0.	8.	40.	93.	91.	63.	46.
0.0470	0.	0.	0.	0.	7.	13.	66.	109.	64.	43.
0.0490	0.	0.	0.	0.	5.	22.	46.	70.	75.	54.
0.0510	0.	0.	0.	0.	3.	9.	17.	37.	32.	29.
0.0530	0.	0.	0.	0.	3.	10.	26.	39.	43.	47.
0.0550	0.	0.	0.	0.	3.	10.	21.	46.	43.	39.
0.0570	0.	0.	0.	0.	0.	3.	23.	47.	59.	55.
0.0590	0.	0.	0.	0.	0.	5.	22.	44.	59.	56.
0.0610	0.	0.	0.	0.	0.	4.	13.	43.	84.	82.
0.0630	0.	0.	0.	0.	0.	1.	22.	64.	103.	126.
0.0650	0.	0.	0.	0.	0.	0.	3.	17.	37.	47.
0.0670	0.	0.	0.	0.	0.	3.	13.	43.	67.	83.
0.0690	0.	0.	0.	0.	0.	1.	9.	20.	52.	75.
0.0710	0.	0.	0.	0.	0.	0.	0.	8.	38.	70.
0.0730	0.	0.	0.	0.	0.	0.	0.	7.	25.	54.
0.0750	0.	0.	0.	0.	0.	0.	0.	1.	8.	5.
0.0770	0.	0.	0.	0.	0.	0.	1.	1.	7.	9.
0.0790	0.	0.	0.	0.	0.	0.	0.	0.	3.	11.
0.0810	0.	0.	0.	0.	0.	0.	0.	0.	1.	4.
0.0830	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
0.0850	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
0.0870	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0890	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0910	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0930	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0950	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0970	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0990	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

***** HISTOGRAM *****

SEPARATION OF LARGE WAVE

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL *****			
0.0100	41.	59.	49.	10.	21.	22.	39.	31.	50.	51.
0.0300	104.	268.	136.	67.	62.	88.	118.	148.	121.	142.
0.0500	175.	321.	156.	76.	58.	84.	154.	168.	148.	124.
0.0700	303.	534.	211.	117.	124.	134.	236.	225.	203.	208.
0.0900	272.	356.	187.	101.	82.	114.	153.	176.	164.	148.
0.1100	243.	250.	135.	83.	76.	92.	139.	141.	135.	141.
0.1300	182.	153.	114.	73.	77.	108.	141.	121.	118.	103.
0.1500	119.	91.	89.	72.	78.	111.	123.	119.	100.	100.
0.1700	95.	53.	70.	71.	73.	108.	98.	111.	101.	82.
0.1900	47.	26.	46.	52.	68.	87.	92.	82.	94.	64.
0.2100	35.	11.	53.	59.	58.	70.	67.	66.	66.	68.
0.2300	21.	5.	40.	33.	63.	50.	55.	51.	36.	50.
0.2500	9.	7.	25.	43.	50.	66.	23.	29.	38.	28.
0.2700	3.	1.	30.	32.	43.	41.	21.	17.	24.	22.
0.2900	3.	1.	17.	26.	39.	17.	10.	13.	19.	3.
0.3100	2.	0.	14.	25.	34.	12.	3.	5.	7.	6.
0.3300	0.	0.	14.	28.	29.	12.	8.	5.	2.	3.
0.3500	0.	0.	9.	16.	16.	4.	0.	2.	0.	0.
0.3700	0.	0.	4.	9.	8.	6.	0.	2.	1.	0.
0.3900	0.	1.	8.	18.	6.	4.	1.	0.	1.	1.
0.4100	0.	0.	4.	9.	2.	0.	0.	0.	0.	0.
0.4300	0.	0.	4.	8.	2.	0.	0.	0.	0.	0.
0.4500	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.
0.4700	0.	0.	0.	5.	1.	0.	0.	0.	0.	0.
0.4900	0.	0.	2.	1.	0.	0.	0.	0.	0.	0.
0.5100	0.	0.	2.	4.	0.	0.	0.	0.	0.	0.
0.5300	0.	0.	2.	3.	1.	0.	0.	0.	0.	0.
0.5500	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.
0.5700	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.5900	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
0.6100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.6300	0.	0.	1.	1.	0.	0.	0.	0.	0.	0.
0.6500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.6700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.6900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.9100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.9300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.9500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

SEPARATION OF LARGE WAVE

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL *****			
0.0100	575.	273.	86.	40.	58.	73.	106.	115.	131.	123.
0.0300	1345.	1022.	243.	125.	226.	313.	341.	408.	399.	430.
0.0500	689.	610.	174.	128.	148.	232.	257.	287.	298.	280.
0.0700	272.	453.	198.	176.	207.	270.	297.	335.	380.	351.
0.0900	17.	138.	118.	143.	212.	208.	229.	239.	226.	244.
0.1100	3.	54.	89.	155.	165.	202.	179.	191.	169.	170.
0.1300	0.	15.	81.	132.	152.	152.	151.	133.	133.	118.
0.1500	0.	10.	62.	101.	126.	136.	126.	103.	83.	72.
0.1700	0.	0.	49.	95.	116.	94.	91.	55.	46.	37.
0.1900	0.	1.	44.	101.	81.	59.	67.	39.	25.	18.
0.2100	0.	0.	28.	64.	61.	41.	40.	21.	11.	8.
0.2300	0.	0.	34.	48.	39.	25.	20.	12.	1.	2.
0.2500	0.	0.	27.	45.	23.	22.	16.	6.	0.	0.
0.2700	0.	0.	17.	25.	12.	7.	2.	1.	0.	0.
0.2900	0.	0.	26.	13.	5.	5.	1.	0.	1.	0.
0.3100	0.	0.	17.	7.	3.	1.	1.	0.	0.	0.
0.3300	0.	0.	15.	6.	0.	0.	0.	0.	0.	0.
0.3500	0.	0.	15.	4.	0.	0.	1.	0.	0.	0.
0.3700	0.	0.	7.	3.	0.	0.	0.	0.	0.	0.
0.3900	0.	0.	4.	0.	0.	0.	0.	0.	0.	0.
0.4100	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.
0.4300	0.	0.	14.	0.	0.	0.	0.	0.	0.	0.
0.4500	0.	0.	3.	0.	0.	0.	0.	0.	0.	0.
0.4700	0.	0.	7.	0.	0.	0.	0.	0.	0.	0.
0.4900	0.	0.	6.	0.	0.	0.	0.	0.	0.	0.
0.5100	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.
0.5300	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.5500	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.
0.5700	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.
0.5900	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.6100	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.
0.6300	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.6500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.6700	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.
0.6900	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.
0.7100	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.7300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7500	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.7700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.7900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8300	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.8500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.8900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.9100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.9300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.9500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

***** HISTOGRAM *****

BASE OF LARGE WAVE

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL *****			
0.0100	50.	44.	35.	13.	15.	32.	57.	73.	87.	111.
0.0300	82.	266.	157.	72.	79.	79.	131.	194.	199.	181.
0.0500	181.	543.	273.	127.	108.	138.	224.	318.	276.	313.
0.0700	356.	635.	319.	173.	138.	199.	340.	381.	383.	380.
0.0900	335.	320.	218.	156.	148.	211.	269.	258.	275.	210.
0.1100	234.	180.	128.	156.	165.	174.	214.	147.	136.	106.
0.1300	167.	94.	109.	119.	168.	173.	122.	78.	42.	35.
0.1500	114.	36.	75.	90.	112.	102.	65.	33.	25.	9.
0.1700	61.	10.	42.	54.	69.	68.	23.	14.	4.	3.
0.1900	33.	6.	28.	40.	39.	33.	25.	4.	1.	1.
0.2100	14.	2.	18.	22.	18.	13.	9.	3.	0.	0.
0.2300	13.	0.	14.	15.	8.	6.	2.	0.	0.	0.
0.2500	6.	1.	3.	8.	3.	2.	0.	0.	0.	0.
0.2700	6.	0.	1.	4.	1.	0.	0.	0.	0.	0.
0.2900	1.	0.	2.	1.	0.	0.	0.	0.	0.	0.
0.3100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3300	1.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.3500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.4100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.4300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.4500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL			***** NO. OF WAVE PER INTERVAL *****			
0.0100	762.	396.	82.	33.	48.	94.	148.	218.	267.	314.
0.0300	1624.	1293.	388.	204.	342.	461.	548.	632.	614.	572.
0.0500	455.	609.	390.	387.	496.	602.	642.	615.	593.	598.
0.0700	57.	204.	282.	399.	428.	454.	379.	356.	333.	284.
0.0900	3.	57.	138.	231.	216.	171.	146.	93.	75.	73.
0.1100	0.	15.	77.	101.	74.	41.	47.	26.	17.	10.
0.1300	0.	1.	29.	37.	27.	15.	11.	4.	4.	2.
0.1500	0.	1.	11.	16.	1.	2.	3.	1.	0.	0.
0.1700	0.	0.	4.	3.	2.	0.	1.	0.	0.	0.
0.1900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.2100	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
0.2300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.2500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.2700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.2900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3300	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3700	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.3900	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE D-5

HISTOGRAM OF WAVE PARAMETERS OF THE SMALL WAVES

AMPLITUDE OF SMALL WAVE

WG(LB/SEC)	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440
CELL	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE	PER INTERVAL *****	
0.0005	401.	130.	209.
0.0015	9.	495.	708.
0.0025	0.	65.	200.
0.0035	0.	29.	117.
0.0045	0.	1.	20.
0.0055	0.	0.	0.

WG(LB/SEC)	0.0	0.0	0.0
WL(LB/SEC)	0.0800	0.1260	0.1800
CELL	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE	PER INTERVAL *****	
0.0005	202.	223.	234.
0.0015	779.	745.	669.
0.0025	247.	234.	228.
0.0035	177.	201.	178.
0.0045	59.	53.	75.
0.0055	28.	22.	33.
0.0065	9.	21.	17.
0.0075	0.	3.	8.
0.0085	0.	0.	10.
0.0095	0.	0.	0.

WG(LB/SEC)	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE	PER INTERVAL *****		
0.0005	165.	159.	123.	106.
0.0015	552.	669.	628.	562.
0.0025	230.	359.	413.	381.
0.0035	198.	411.	485.	517.
0.0045	96.	199.	248.	319.
0.0055	60.	126.	192.	236.
0.0065	37.	155.	232.	303.
0.0075	19.	46.	81.	132.
0.0085	12.	52.	116.	108.
0.0095	4.	18.	34.	57.
0.0105	3.	18.	33.	48.
0.0115	0.	4.	15.	32.
0.0125	0.	9.	15.	20.
0.0135	0.	2.	6.	14.
0.0145	0.	0.	8.	6.
0.0155	0.	1.	4.	11.
0.0165	0.	0.	0.	4.
0.0175	0.	0.	1.	2.
0.0185	0.	0.	0.	0.

AMPLITUDE OF SMALL WAVE

WG(LB/SEC)	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440
CELL	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE	PER INTERVAL *****	
0.0005	1463.	1421.	1204.
0.0015	0.	84.	1486.
0.0025	0.	0.	250.
0.0035	0.	0.	0.
0.0045	0.	0.	0.
0.0055	0.	0.	0.

WG(LB/SEC)	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0800	0.1260	0.1800
CELL	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE	PER INTERVAL *****	
0.0005	841.	410.	332.
0.0015	1433.	1372.	1305.
0.0025	247.	369.	386.
0.0035	10.	190.	317.
0.0045	0.	22.	41.
0.0055	0.	0.	17.
0.0065	0.	0.	0.
0.0075	0.	0.	0.
0.0085	0.	0.	0.
0.0095	0.	0.	0.

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2
FLIM(INCH)	***** NO. OF WAVE	PER INTERVAL *****		
0.0005	246.	155.	108.	65.
0.0015	1075.	760.	559.	447.
0.0025	439.	413.	397.	350.
0.0035	446.	536.	489.	458.
0.0045	118.	257.	278.	299.
0.0055	78.	121.	181.	216.
0.0065	37.	122.	186.	240.
0.0075	6.	45.	80.	132.
0.0085	0.	20.	71.	127.
0.0095	0.	5.	27.	46.
0.0105	0.	0.	17.	54.
0.0115	0.	0.	3.	12.
0.0125	0.	0.	0.	18.
0.0135	0.	0.	0.	4.
0.0145	0.	0.	0.	0.
0.0155	0.	0.	0.	0.
0.0165	0.	0.	0.	0.
0.0175	0.	0.	0.	0.
0.0185	0.	0.	0.	0.

TABLE D-5 (continued)

BASE OF SMALL WAVE

WG(LB/SEC)	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440
CELL	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE	PER INTERVAL *****	
0.0100	233.	197.	309.
0.0300	92.	265.	362.
0.0500	41.	156.	330.
0.0700	28.	84.	167.
0.0900	6.	13.	56.
0.1100	5.	4.	22.
0.1300	2.	1.	7.
0.1500	1.	0.	0.
0.1700	1.	0.	1.
0.1900	0.	0.	0.
0.2100	1.	0.	0.
0.2300	0.	0.	0.

WG(LB/SEC)	0.0	0.0	0.0
WL(LB/SEC)	0.0800	0.1260	0.1800
CELL	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE	PER INTERVAL *****	
0.0100	273.	316.	380.
0.0300	505.	514.	547.
0.0500	371.	388.	320.
0.0700	225.	215.	150.
0.0900	94.	51.	42.
0.1100	22.	16.	12.
0.1300	11.	1.	1.
0.1500	0.	1.	0.
0.1700	0.	0.	0.

WG(LB/SEC)	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE	PER INTERVAL *****		
0.0100	407.	819.	1123.	1488.
0.0300	603.	968.	1095.	1081.
0.0500	277.	316.	321.	241.
0.0700	126.	101.	75.	45.
0.0900	27.	18.	19.	3.
0.1100	7.	6.	1.	0.
0.1300	0.	0.	0.	0.
0.1500	2.	0.	0.	0.
0.1700	0.	0.	0.	0.

BASE OF SMALL WAVE

WG(LB/SEC)	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0160	0.0280	0.0440
CELL	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE	PER INTERVAL *****	
0.0100	1396.	1233.	809.
0.0300	67.	270.	1366.
0.0500	0.	2.	585.
0.0700	0.	0.	147.
0.0900	0.	0.	28.
0.1100	0.	0.	5.
0.1300	0.	0.	0.
0.1500	0.	0.	0.
0.1700	0.	0.	0.
0.1900	0.	0.	0.
0.2100	0.	0.	0.
0.2300	0.	0.	0.

WG(LB/SEC)	0.1436	0.1436	0.1436
WL(LB/SEC)	0.0800	0.1260	0.1800
CELL	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE	PER INTERVAL *****	
0.0100	755.	686.	784.
0.0300	1184.	1044.	1042.
0.0500	412.	446.	428.
0.0700	147.	156.	121.
0.0900	25.	27.	21.
0.1100	6.	4.	1.
0.1300	1.	0.	1.
0.1500	1.	0.	0.
0.1700	0.	0.	0.

WG(LB/SEC)	0.1436	0.1436	0.1436	0.1436
WL(LB/SEC)	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2
TIME(SEC)	***** NO. OF WAVE	PER INTERVAL *****		
0.0100	840.	1073.	1210.	1423.
0.0300	1088.	1038.	986.	939.
0.0500	396.	270.	176.	99.
0.0700	97.	52.	14.	7.
0.0900	20.	1.	0.	0.
0.1100	4.	0.	0.	0.
0.1300	0.	0.	0.	0.
0.1500	0.	0.	0.	0.
0.1700	0.	0.	0.	0.

***** HISTOGRAM *****

AMPLITUDE OF SMALL WAVE ON LARGE WAVE

WG(LB/SEC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WL(LB/SEC)	0.0160	0.0280	0.0440	0.0800	0.1260	0.1800	0.2400	0.3500	0.4700	0.5850
CELL	D2	D2	D2	D2	D2	D2	D2	D2	D2	D2
FLIM(INCH)	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	***** NO.	OF WAVE	PER INTERVAL	*****
0.0005	21.	5.	19.	16.	21.	12.	80.	49.	29.	26.
0.0015	143.	86.	80.	63.	77.	68.	115.	98.	96.	66.
0.0025	61.	67.	64.	44.	48.	47.	89.	98.	76.	70.
0.0035	26.	114.	102.	75.	62.	66.	88.	95.	89.	75.
0.0045	1.	16.	57.	46.	45.	38.	95.	104.	103.	72.
0.0055	2.	5.	25.	46.	31.	40.	101.	99.	79.	69.
0.0065	0.	6.	44.	56.	66.	57.	82.	70.	71.	53.
0.0075	0.	0.	18.	35.	29.	42.	68.	47.	49.	53.
0.0085	0.	1.	29.	35.	41.	63.	75.	37.	40.	40.
0.0095	0.	0.	8.	29.	37.	39.	23.	31.	27.	31.
0.0105	0.	2.	13.	38.	53.	60.	29.	28.	31.	21.
0.0115	0.	0.	4.	23.	27.	28.	18.	27.	22.	34.
0.0125	0.	0.	9.	29.	56.	52.	15.	22.	24.	21.
0.0135	0.	0.	0.	8.	27.	24.	6.	27.	38.	28.
0.0145	0.	0.	3.	11.	27.	22.	7.	20.	26.	19.
0.0155	0.	0.	4.	17.	33.	39.	2.	21.	28.	22.
0.0165	0.	0.	2.	9.	18.	28.	2.	12.	21.	17.
0.0175	0.	0.	1.	7.	30.	30.	1.	11.	12.	17.
0.0185	0.	0.	0.	5.	10.	15.	3.	9.	19.	16.
0.0195	0.	0.	1.	2.	12.	11.	1.	6.	13.	16.
0.0210	0.	0.	1.	2.	19.	27.	0.	4.	7.	8.
0.0230	0.	0.	1.	7.	6.	25.	0.	4.	8.	9.
0.0250	0.	0.	0.	0.	3.	9.	0.	4.	6.	9.
0.0270	0.	0.	0.	2.	0.	4.	1.	2.	9.	6.
0.0290	0.	0.	1.	1.	2.	2.	0.	2.	1.	1.
0.0310	0.	0.	0.	0.	2.	3.	0.	1.	2.	3.
0.0330	0.	0.	0.	0.	0.	2.	0.	0.	3.	0.
0.0350	0.	0.	0.	0.	0.	0.	0.	1.	0.	1.
0.0370	0.	0.	0.	0.	0.	0.	0.	1.	1.	0.
0.0390	0.	0.	0.	0.	0.	1.	0.	0.	0.	2.
0.0410	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
0.0430	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
0.0450	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0470	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0490	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0510	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0530	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0550	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
0.0570	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0590	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0610	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0630	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0650	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0670	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0690	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0710	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0730	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0750	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0770	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.0790	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

APPENDIX E

DERIVATION OF RANDOM WAVE MODEL

1. TICK'S RANDOM WAVE MODEL

Considering the gravity waves of the infinite crested in the infinite depth, the equations of motion for an irrotational fluid are

$$\phi_{xx} + \phi_{yy} = 0 \qquad \text{(E-1)}$$

$$\frac{p}{\rho} = gy - \phi_t - \frac{1}{2}(\phi_x^2 + \phi_y^2) \qquad \text{(E-2)}$$

The boundary conditions are

$$\phi_y \longrightarrow 0 \quad \text{as } y \longrightarrow \infty \qquad \text{(E-3)}$$

$$\eta_t + \phi_x \eta_x = \phi_y \quad \text{at } y = \eta \qquad \text{(E-4)}$$

$$p = 0 \quad \text{at } y = \eta \qquad \text{(E-5)}$$

where $\phi(x,y,t)$ is a velocity potential.

Assuming the ϕ and η are stationary random processes and can be separated as

$$\left.\begin{aligned} \phi &= \phi^{(1)} + \phi^{(2)} \\ \eta &= \eta^{(1)} + \eta^{(2)} \end{aligned}\right\} \qquad \text{(E-6)}$$

where $\phi^{(1)}$ and $\eta^{(1)}$ are the solution of the linear approximation of the equation, and $\phi^{(2)}$ and $\eta^{(2)}$ are the nonlinear correction terms on the solution.

The solution of linear approximation will be

$$\left.\begin{aligned} \phi^{(1)} &= \int_{-\infty}^{+\infty} e^{i(|\omega|\omega x/g - \omega t)} e^{-\omega^2 y/g}\, d\hat{\xi}(\omega) \\ \eta^{(1)} &= \int_{-\infty}^{+\infty} -i\frac{\omega}{g} e^{i(|\omega|\omega x/g - \omega t)}\, d\hat{\xi}(\omega) \end{aligned}\right\} \qquad \text{(E-7)}$$

where $d\hat{\xi}(\omega)$ has the following properties

$$\langle d\hat{\xi}(\omega)\, d\hat{\xi}^{*}(\omega')\rangle = \begin{cases} \tilde{S}(\omega)\, d\omega & \text{if } \omega = \omega' \\ 0 & \text{if } \omega \neq \omega' \end{cases} \quad \text{-- (E-8)}$$

The linear part of spectrum will be

$$S^{(1)}(\omega) = -\frac{\omega^2}{g}\, \tilde{S}(\omega)$$

And the nonlinear solutions are

$$\phi^{(2)} = 2i \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e^{i\left\{(|\omega|\omega + |\omega'|\omega')\frac{x}{g} - (\omega+\omega')t\right\}}\, G(\omega,\omega')\, d\hat{\xi}(\omega)\, d\hat{\xi}(\omega') \quad \text{-- (E-9)}$$

where $G(\omega,\omega') = \dfrac{\omega(\omega\omega' - |\omega\omega'|)}{(\omega+\omega')^2 - \big|\,|\omega|\omega + |\omega'|\omega'\big|}$

$$\eta^{(2)} = \frac{1}{g} \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e^{i\left\{(|\omega|\omega + |\omega'|\omega')\frac{x}{g} - (\omega+\omega')t\right\}}\, H(\omega,\omega')\, d\hat{\xi}(\omega)\, d\hat{\xi}(\omega')$$

$$\text{— — — — — — — (E-10)}$$

where

$$H(\omega,\omega') = 2F(\omega,\omega') - \frac{1}{2}\omega\omega' + \frac{1}{2}|\omega\omega'| - \omega^2$$

$$F(\omega,\omega') = -i\, G(\omega,\omega')\, (\omega+\omega')$$

Under the assumption of the Gaussiam processes the nonlinear part of spectrum are

$$S^{(2)}(\omega) = \frac{1}{g^2}\int_{-\infty}^{+\infty} K(\lambda,\omega)\, S^{(1)}(\omega-\lambda)\, S^{(1)}(\lambda)\, d\lambda \quad \text{--- (E-11)}$$

where

$$K(\lambda,\omega) = H^2(\lambda,\omega-\lambda) + H(\lambda,\omega-\lambda)\, H(\omega-\lambda,\lambda)$$

2. TRANSFORMATION OF THE SET OF EQUATIONS (VII-27) ~ (VII-33) INTO THE SET OF EQUATIONS (VII-34) ~ (VII-38)

By differentiating equation (VII-27) with respect to y and differentiating equation (VII-28) with respect to t, the equations become

$$\frac{Re}{4}\frac{1}{C}P^{(1)}_{ty}+\frac{1}{C^2}\psi^{(1)}_{yytt}+\psi^{(1)}_{yyyy}+\frac{Re}{4}\left(\frac{3}{2}\frac{1}{C}-1\right)\psi^{(1)}_{yyt}=0 \quad --- \quad (E-12)$$

$$-\frac{Re}{4}\frac{1}{C}P^{(1)}_{ty}+\frac{1}{C^2}\psi^{(1)}_{tttt}+\psi^{(1)}_{ttyy}+\frac{Re}{4}\left(\frac{3}{2}\frac{1}{C}-1\right)\psi^{(1)}_{ttt}=0 \quad ---- \quad (E-13)$$

The above equation (E-13) times the factor $\frac{1}{C}$ and add to equation (E-12), the result will be the basic equation (VII-34).

For the boundary conditions at y = 0, differentiating the equations (VII-31) and (VII-32) with respect to t, one obtains

$$-3\eta^{(1)}_t+\psi^{(1)}_{yyt}-\frac{1}{C^2}\psi^{(1)}_{ttt}=0 \quad ------- \quad (E-14)$$

$$-P^{(1)}_t+\frac{8}{Re\,C}\psi^{(1)}_{tty}+\frac{1}{We}\frac{1}{C^2}\eta^{(1)}_{ttt}=0 \quad ------ \quad (E-15)$$

Substituting the equation (VII-27) into equation (E-15), the equation becomes

$$\frac{3}{C^2}\psi^{(1)}_{tty}+\psi^{(1)}_{yyy}+\frac{Re}{4}\left(\frac{3}{2}\frac{1}{C}-1\right)\psi^{(1)}_{yt}+\frac{Re}{4}\frac{1}{We}\frac{1}{C^3}\eta^{(1)}_{ttt}=0 \quad --- \quad (E-16)$$

Now let's make the following addition and subtraction.

(a) $\left(\frac{3}{2}\frac{1}{c}-1\right) \times$ eq. (E-14) $- 3 \times$ eq. (VII-33),

one obtains equation (VII-37).

(b) $\frac{Re}{4} \cdot \frac{1}{We} \cdot \frac{1}{c^3} \times \frac{\partial^2}{\partial \tau^2}$ eq. (VII-33) $+ \left(\frac{3}{2}\frac{1}{c}-1\right) \times$ eq. (E-16),

one obtains equation (VII-38).

3. THE SOLUTION OF $\hat{\psi}^{(1)}(\tau, z)$ IN EQUATION (VII-43)

By substituting equations (VII-39) and (VII-41) into the equations (VII-35), (VII-36) and (VII-37), one obtains the following three equations :

$$e^{a_1} d\hat{A}_1 + e^{a_2} d\hat{A}_2 + e^{a_3} d\hat{A}_3 + e^{a_4} d\hat{A}_4 = 0 \quad \text{------} \quad (E\text{-}17)$$

$$a_1 e^{a_1} d\hat{A}_1 + a_2 e^{a_2} d\hat{A}_2 + a_3 e^{a_3} d\hat{A}_3 + a_4 e^{a_4} d\hat{A}_4 = 0 \quad \text{---} \quad (E\text{-}18)$$

$$FA(a_1,\omega)\, d\hat{A}_1 + FA(a_2,\omega)\, d\hat{A}_2 + FA(a_3,\omega)\, d\hat{A}_3 + FA(a_4,\omega)\, d\hat{A}_4 = 0 \quad \text{------} \quad (E\text{-}19)$$

where $\quad FA(a_j,\omega) = i\left\{3\frac{\omega}{c} + \left(\frac{3}{2}\frac{1}{c}-1\right)\omega a_j^2 + \left(\frac{3}{2}\frac{1}{c}-1\right)\frac{\omega^3}{c^2}\right\} \quad j=1,\cdots,4$

Eliminating the terms $d\hat{A}_1$ from the above three equations, the set of equations become

$$FB(a_2,\omega)\, d\hat{A}_2 + FB(a_3,\omega)\, d\hat{A}_3 + FB(a_4,\omega)\, d\hat{A}_4 = 0 \quad \text{---} \quad (E\text{-}20)$$

$$FC(a_2,\omega)\, d\hat{A}_2 + FC(a_3,\omega)\, d\hat{A}_3 + FC(a_3,\omega)\, d\hat{A}_4 = 0 \quad \text{---} \quad (E\text{-}21)$$

where $\quad FB(a_j,\omega) = (a_1 - a_j)\, e^{a_j} \quad j = 2, 3, 4$

$\qquad\quad FC(a_j,\omega) = FA(a_1,\omega)\, e^{a_j} - FA(a_j,\omega)\, e^{a_1} \quad j = 2, 3, 4$

One further eliminates the dA_2 from the above two equations, the result becomes

$$d\hat{A}_3 = FL_1(a_1, a_2, a_3, a_4, \omega)\ d\hat{G}(\omega) \qquad \text{(E-22)}$$

where

$$d\hat{G}(\omega) = d\hat{A}_4(\omega)$$

$$FL_1(a_1, a_2, a_3, a_4, \omega) = -\frac{FD(a_4,\omega)}{FD(a_3,\omega)}$$

$$FD(a_j,\omega) = FC(a_2,\omega)\, FB(a_j,\omega) - FB(a_2,\omega)\cdot FC(a_j,\omega) \qquad j = 3,4$$

Substituting the equation (E-22) into equation (E-20), one obtains

$$d\hat{A}_2 = FL_2(a_1, a_2, a_3, a_4, \omega)\ d\hat{G}(\omega) \qquad \text{(E-23)}$$

where

$$FL_2(a_1, a_2, a_3, a_4, \omega) = \left\{-FB(a_3,\omega)\cdot FL_1(a_1, a_2, a_3, a_4, \omega) - FB(a_4,\omega)\right\} / FB(a_2,\omega)$$

Substituting again the equations (E-22) and (E-23) into equation (E-17), one has

$$d\hat{A}_1 = FL_3(a_1, a_2, a_3, a_4, \omega)\ d\hat{G}(\omega) \qquad \text{(E-24)}$$

where

$$FL_3(a_1, a_2, a_3, a_4, \omega) = \left\{-FL_1(a_1, a_2, a_3, a_4, \omega)\, e^{a_3} - FL_2(a_1, a_2, a_3, a_4, \omega) - e^{a_4}\right\} e^{-a_1}$$

Substituting equations (E-22), (E-23), and (E-24) back into equation (VII-41), one will have the equation (VII-42)

4. FORMULATION OF THE NONLINEAR SOLUTION

In the boundary condition (VII-54), the term $p^{(1)}_y$ can be obtained from equation (VII-28) as

$$p^{(1)}_y = \int_{-\infty}^{+\infty} e^{i\omega t} B^{(1)}(Re, C, \omega, y)\, d\hat{G}(\omega) \quad ---- \quad (E\text{-}25)$$

where

$$B^{(1)}(Re, C, \omega, y) = \left\{ \frac{4(i\omega)^3}{Re\, C^3} F^{(1)} + \frac{4(i\omega)}{Re\, C} F^{(1)}_{yy} + \frac{(i\omega)^2}{C}\left(\frac{3}{2}\frac{1}{C}-1\right) F^{(1)} \right\}$$

the solution $\hat{\eta}^{(2)}$ can be expressed as

$$\hat{\eta}^{(2)}(t) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e^{i(\omega+\omega')t} H^{(2)}(Re, C, \omega, \omega')\, d\hat{G}(\omega)\, d\hat{G}(\omega') \quad --- \quad (E\text{-}26)$$

where

$$H^{(2)}(Re, C, \omega, \omega') = \frac{1}{3}\left\{ \left[F^{(2)}_{yy}(Re, C, \omega, \omega', 0) + \frac{(\omega+\omega')^2}{C^2} \cdot F^{(2)}(Re, C, \omega, \omega', 0) \right] + \left[F^{(1)}_{yyy}(Re, C, \omega, 0) + \frac{\omega^2}{C^2} F^{(1)}_y(Re, C, \omega, 0) \right] H^{(1)}(Re, C, \omega') \right\}$$

The process to eliminate $\hat{\eta}^{(2)}$ and $\hat{p}^{(2)}$ in the set of equations can be done in the similar manner as the linear part of solution. The set of equations (VII-53), (VII-54) and (VII-55) become

$$F^{(2)}_{yyyy} + \frac{2i^2(\omega+\omega')^2}{C^2} F^{(2)}_{yy} + \frac{i^4(\omega+\omega')^4}{C^4} F^{(2)} + \frac{Re}{4}\left(\frac{3}{2}\frac{1}{C}-1\right)\left\{ i(\omega+\omega') F^{(2)}_{yy} + \frac{i^3(\omega+\omega')^3}{C^2} F^{(2)} \right\} + \frac{3Re\, i(\omega+\omega')}{4C} F^{(2)} = \frac{Re}{4C}\left\{ \left[F^{(1)}_{yyy} + \frac{(i\omega)^2}{C^2} F^{(1)}_y \right] \cdot i\omega' F^{(1)} - \left[i\omega F^{(1)}_{yy} + \frac{(i\omega)^3}{C^2} F^{(1)} \right] F^{(1)}_y \right\} \quad ----- \quad (E\text{-}27)$$

Boundary conditions are

$$\left.\begin{array}{l} F^{(2)} = 0 \\ F^{(2)}_{y} = 0 \end{array}\right\} \text{at } y=1 \quad \begin{array}{r} \text{--- (E-28)} \\ \text{--- (E-29)} \end{array}$$

$$\frac{3i^2(\omega+\omega')^2}{c^2} F^{(2)}_{y} + F^{(2)}_{yyy} + \frac{Re}{4}\left(\frac{3}{2}\frac{1}{c}-1\right) i(\omega+\omega') F^{(2)}_{y} + \frac{Re\, i^3(\omega+\omega')^3}{4We\; c^3} \cdot$$

$$H^{(2)} = \frac{Re}{4c}\left\{ i\omega B^{(1)} - \frac{8\omega^2}{Re\,c} F^{(1)}_{yy} \right\} H^{(1)} + \frac{Re}{4c}\left\{ B^{(1)} - \frac{8i\omega}{Re\,c} F^{(1)}_{yy} \right\}$$

$$i\omega' H^{(1)} + \frac{Re}{4c} F^{(1)}_{yy}\, i\omega' F^{(1)} - \frac{Re}{4c} F^{(1)}_{y}\, i\omega' F^{(1)}_{y} \quad \text{at } y=0 \text{ --- (E-30)}$$

$$i(\omega+\omega')\left(1-\frac{3}{2}\frac{1}{c}\right) H^{(2)} - \frac{i(\omega+\omega')}{c} F^{(2)} = \frac{1}{c}\left\{ F^{(1)}_{y}\, i\omega' H^{(1)} + \right.$$

$$\left. i\omega F^{(1)}_{y} H^{(1)} \right\} \quad \text{at } y=0 \text{ --- (E-31)}$$

The above set of equations is a fourth order complex linear ordinary differential equation with four linear boundary conditions. The function $F^{(2)}$ can be solved at least by numerical method.

The auto-correlation of $\hat{\eta}^{(2)}$ will be

$$\hat{R}^{(2)}(\tau) = \langle \hat{\eta}^{(2)}(t+\tau)\, \hat{\eta}^{(2)*}(t) \rangle$$
$$= \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e^{i\{(\omega_1+\omega_2)(t+\tau)-(\omega_3+\omega_4)t\}}\, H^{(2)} H^{(2)*}$$
$$\langle d\hat{G}(\omega_1)\, d\hat{G}(\omega_2)\, d\hat{G}^{*}(\omega_3)\, d\hat{G}^{*}(\omega_4) \rangle \text{ --- (E-32)}$$

Under the assumption of Gaussian processes, one can evaluate the above fourth moment of $d\hat{G}(\omega)$ as:

$$
\begin{aligned}
&\langle d\hat{G}(\omega_1)\, d\hat{G}(\omega_2)\, d\hat{G}^*(\omega_3)\, d\hat{G}^*(\omega_4)\rangle \\
&= \langle d\hat{G}(\omega_1)\, d\hat{G}(\omega_2)\rangle \langle d\hat{G}^*(\omega_3)\, d\hat{G}^*(\omega_4)\rangle \\
&\quad + \langle d\hat{G}(\omega_1)\, d\hat{G}^*(\omega_3)\rangle \langle d\hat{G}(\omega_2)\, d\hat{G}^*(\omega_4)\rangle \\
&\quad + \langle d\hat{G}(\omega_1)\, d\hat{G}(\omega_4)\rangle \langle d\hat{G}(\omega_2)\, d\hat{G}^*(\omega_3)\rangle \quad \text{----} \quad (E\text{-}33)
\end{aligned}
$$

and, the spectrum of $\hat{\eta}^{(2)}(t)$ can also be obtained in the similar way as the linear solution, once the auto-correlation $\hat{R}^{(2)}(\tau)$ is evaluated.

By the properties of the Gaussian processes, the auto-correlation and the spectrum of

$$\hat{\eta}(t) = \hat{\eta}^{(1)}(t) + \hat{\eta}^{(2)}(t)$$

will be

$$\tilde{R}(\tau) = \hat{R}^{(1)}(\tau) + \hat{R}^{(2)}(\tau) \quad \text{----} \quad (E\text{-}34)$$

$$\tilde{S}(\omega) = \hat{S}^{(1)}(\omega) + \tilde{S}^{(2)}(\omega) \quad \text{----} \quad (E\text{-}35)$$

APPENDIX F
DERIVATION OF EXTENSION OF TELLES' MODEL

1. DERIVATION IN SECTION 3-1 OF CHAPTER VII (HORTON'S METHOD).

For a shot -noise process

$$\langle \hat{h}(t) - m_L \rangle = f\int_{-\infty}^{+\infty} m(t)\,dt$$

$$= fTm_0 \qquad \text{---------} \quad (F\text{-}1)$$

$$\langle \hat{h}(t+\tau)\,\hat{h}(t) \rangle = \Big\langle \sum_{-\infty}^{+\infty} m(t+\tau-\hat{t}_k) \sum_{-\infty}^{+\infty} m(t-\hat{t}_k) \Big\rangle + 2fTm_0m_L + m_L^2$$

$$= f\int_{-\infty}^{+\infty} m(t+\tau)m(t)\,dt + (fTm_0)^2 + 2fTm_0m_L + m_L^2$$

$$\text{------} \quad (F\text{-}2)$$

$$f\int_{-\infty}^{+\infty} m(t+\tau)m(t)\,dt = \sum_{j,k}^{\infty} (-1)^j m_j' m_k' z^{(j+k)}\Big(\frac{\tau'}{\sqrt{2}}\Big) \qquad \text{---} \quad (F\text{-}3)$$

From the above three equations, the equations(VII-61) and (VII-62) directly follow. The equation (VII-66) is equivalent to the following p+1 equations

$$\left.\begin{aligned}
d_0 &= m_0'^2 \\
d_2 &= 2m_0'm_2' - m_1'^2 \\
d_4 &= 2m_0'm_4' - 2m_1'm_3' + m_2'^2 \\
d_6 &= 2m_0'm_6' - 2m_1'm_5' + 2m_2'm_4' - m_3'^2 \\
&\vdots
\end{aligned}\right\} \quad \text{---} \quad (F\text{-}5)$$

The above set of equations are nonlinear equations. It is obvious that the higher order approximation will give a trimendous difficulty to solve m_0, m_1, ------ m_{2p}. Assuming $m_2' = m_3' = m_4' = \text{------} \simeq 0$, the equation (VII-67) is obtained from equation (F-5).

2. TELLES' SOLUTION

As mentioned in Chapter VII, Telles applied the quasi-linearization on the equation of motion of the first iteration. The solution was obtained based on the following equations.

$$\eta(x) = \eta_L + \eta_0 Z_0 \quad \text{————} \quad (F-6)$$

$$\Psi(x,y) = f_L + \frac{\alpha_0}{2} y^2 Z_0 \quad \text{————} \quad (F-7)$$

His results are

$$\alpha_0 = G' \eta_0 \quad \text{————} \quad (F-8)$$

$$S = G' \left\{ \eta_L^2 + \frac{\eta_0 \eta_L}{2\sqrt{\pi}} + \frac{\eta_0^2}{6\pi\sqrt{3}} \right\} \quad \text{————} \quad (F-9)$$

3. PRESENT SOLUTION

Given the equation (VII-88), the equation (VII-83) becomes

$$\left.\begin{aligned} f_0''' &= \int_{-\infty}^{+\infty} Q H_0 \, dx \\ f_1''' + S f_0' - f_L' f_0' + f_L'' f_0 &= -\int_{-\infty}^{+\infty} Q H_1 \, dx \\ Q &= \{+ f_0'^2 - f_0 f_0''\} Z_0 Z_1 + \{f_0' f_1' - f_0 f_1''\} Z_1^2 \end{aligned}\right\} \text{--} \quad (F-10)$$

since

$$\left.\begin{aligned} &\int_{-\infty}^{+\infty} Z_0 Z_1 H_0 \, dx = 0 \\ &\int_{-\infty}^{+\infty} Z_1^2 H_0 \, dx = \frac{1}{4\sqrt{\pi}} \\ &\int_{-\infty}^{+\infty} Z_0 Z_1 H_1 \, dx = -\frac{1}{4\sqrt{\pi}} \\ &\int_{-\infty}^{+\infty} Z_1^2 H_1 \, dx = 0 \end{aligned}\right\} \text{———} \quad (F-11)$$

the above equations become

$$\left.\begin{aligned} & f_0''' + \frac{1}{4\sqrt{\pi}}\left\{f_0 f_1'' - f_0' f_1'\right\} = 0 \\ & \left\{f_1''' + S f_0' - f_1' f_0' + f_1'' f_0\right\} + \frac{1}{4\sqrt{\pi}}\left\{f_0' f_0'' - f_0'^2\right\} = 0 \end{aligned}\right\} \quad \text{-- (F-12)}$$

and, the equation (VII-84) will be the set of equations as

$$\left.\begin{aligned} & \alpha_{01} = 0 && \alpha_{11} = 0 \\ & \alpha_{02} = 0 && \alpha_{12} = -\frac{\alpha_{00}}{12} S \\ & \alpha_{03} = \frac{1}{120\sqrt{\pi}}\alpha_{00}\alpha_{10} && \alpha_{13} = \frac{\alpha_{00}}{60}\left\{a'\eta_L + \frac{\alpha_{00}}{2\sqrt{\pi}}\right\} \\ & \alpha_{04} = 0 && \alpha_{14} = 0 \\ & \alpha_{05} = \frac{1}{2520\sqrt{\pi}}\alpha_{00}^2 S && \alpha_{15} = -\frac{\alpha_{00}\alpha_{10}}{5040} S \\ & \vdots && \vdots \end{aligned}\right\} \quad \text{--- (F-13)}$$

The equations (VII-85) and (VII-86) become

$$\left.\begin{aligned} G\eta_0 &= \int_{-\infty}^{+\infty} f_0''(\eta) Z_0 H_0 dx + \int_{-\infty}^{+\infty} f_1''(\eta) Z_1 H_0 dx \\ -G\eta_1 &= \int_{-\infty}^{+\infty} f_0''(\eta) Z_0 H_1 dx + \int_{-\infty}^{+\infty} f_1''(\eta) Z_1 H_1 dx \\ -S\eta_0 &= \int_{-\infty}^{+\infty} \left\{f_0(\eta) + f_1'(\eta)\eta_0 + f_0'(\eta)\eta_0 + f_1'(\eta)\eta_0\right\} Z_1 H_1 dx \end{aligned}\right\} \quad \text{-- (F-14)}$$

(i) If equation (VII-90) is assumed and

$$\left.\begin{aligned}
&\int_{-\infty}^{+\infty} Z_0^2 Z_1 H_1\,dx = -\frac{1}{6\pi\sqrt{3}} \\
&\int_{-\infty}^{+\infty} Z_1^3 H_1\,dx = -\frac{1}{6\pi\sqrt{3}} \\
&\int_{-\infty}^{+\infty} Z_0 Z_1 H_1\,dx = -\frac{1}{4\sqrt{\pi}} \\
&\int_{-\infty}^{+\infty} Z_1^2 H_1\,dx = 0 \\
&\int_{-\infty}^{+\infty} Z_0 Z_1^2 H_1\,dx = 0
\end{aligned}\right\} \quad --- \quad (F-15)$$

the above equation (F-12) will give

$$\left.\begin{aligned}
&G\mathfrak{P}_0 = 2\alpha_{00} \\
&G\mathfrak{P}_1 = 2\alpha_{10}
\end{aligned}\right\} \quad --- \quad (F-16)$$

and equation (VII-91)

(ii) If equation (VII-92) is assumed and

$$\left.\begin{aligned}
&\int_{-\infty}^{+\infty} Z_0^2 Z_1 H_0\,dx = \int Z_1^3 H_0\,dx = 0 \\
&\int_{-\infty}^{+\infty} Z_0 Z_1^2 H_0\,dx = \frac{1}{6\pi\sqrt{3}} \\
&\int_{-\infty}^{+\infty} Z_0 Z_1^3 H_1\,dx = -\frac{3}{64\pi\sqrt{2\pi}} \\
&\int_{-\infty}^{+\infty} Z_0^2 Z_1^3 H_1\,dx = -\frac{3}{100\pi^2\sqrt{5}} \\
&\int_{-\infty}^{+\infty} Z_1^5 H_1\,dx = -\frac{3}{100\pi^2\sqrt{5}} \\
&\int_{-\infty}^{+\infty} Z_0^2 Z_1^2 H_1\,dx = \int Z_0^3 Z_1^2 H_1\,dx = 0 \\
&\int_{-\infty}^{+\infty} Z_1^4 H_1\,dx = \int Z_0 Z_1^4 H_1\,dx = 0
\end{aligned}\right\} \quad --- \quad (F-17)$$

The equation (VII-93) is followed from the above equations.