A STUDY OF TWO-PHASE FLOW IN A LARGE DIAMETER HORIZONTAL PIPELINE AND THE MEASUREMENT OF INTERFACIAL LEVEL GRADIENT IN SMOOTH STRATIFIED FLOW CONDITIONS

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by

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To:

My Parents

My wife

And my three sons Zakariya,

Abdulkareem, and Mohamed.

ABSTRACT

This study investigates the behaviour of two-phase flow in large diameter horizontal pipelines. The study was divided into two main parts:

(i) General two-phase flow in 203 mm diameter pipeline, where the pressure drop and void fraction were measured. The pressure drop was measured using 23 bottom tapping points along a 34 m test section. The results were compared with six well known pressure drop models; these models did not allow for diameter size effect, it was therefore not surprising that good agreement was not achieved. A traversing γ-ray apparatus was designed and constructed for the measurements of void fraction. Void fraction measurements were compared with geometrical void fraction calculation, and very satisfactory agreements were obtained. The apparatus was also tested under a different number of chordal positions (steps) to determine the influence of the number of steps on the accuracy of the results. The void fraction results were compared with nine correlations found in the literature; the effect of pipe size was clear. A flow pattern map was also drawn for a 203 mm pipeline, which covered all the possible flow patterns (annular flow could not be obtained in this size of pipe, with the available air supply), and compared with three well known flow pattern maps, where a little agreement was found.

(ii) The measurement of interfacial level gradient in the smooth stratified flow conditions. Two depth gauges (probes) were designed, constructed and calibrated for the measurement of the water level change along the test section. The two probes were placed 12 metres apart in the test section, where the flow conditions considered settled. The measurement accuracy of the probes was within 1 mm of liquid height, i.e. less than 1%. Two theoretical models in the field of stratified flow were tested and then modified to improve their ability to predict the present data, and perhaps

other data obtained from large diameter pipelines. A model based on the present set of data, following Bishop et. al (1986) approach was proposed, which predicts the present data within RMS of 8%.

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Nomenclature

Symbol	Description	Dimension
A	Cross sectional area	m^2
B	Coefficient in Chisholm correlation (Table 2.1.3)	
C	Hughmark concentration factor (Fig. 2.1.11)	
D , d	Tube diameter	m
G	Mass velocity	kg/m^2s
g	Gravitational acceleration	
h , H	Liquid Height	m
H_L	Liquid Hold-up (= 1-α)	
I, I_o, I_x	γ-ray intensities	
K	Parameter used in Rouhani correlation	
M_F	Mass flow rate of liquid	kg/s
M_g	Mass flow rate of gas	kg/s
N_{FR} , Fr	Froud number (U^2m/gd)	
P	Pressure	kn/m^2
P	Perimeter	m
Q	Volume flow rate	m^3/s

Q_f	Volume flow rate of liquid	m^3/s
Q_G , Q_g	Volume flow rate of gas	m^3/s
Re	Reynolds number $\left(\frac{\rho D U}{\mu}\right)$	
Re_f	Reynolds number of liquid $\left(\frac{GD}{\mu_f}\right)$	
Re_g	Reynolds number of gas $\left(\frac{GD}{\mu_g}\right)$	
S	Slip factor	
S	Perimeter	m
T	Temperature	°C or k
U_f , u_L	Liquid velocity	m/s
U_g , u_G	Gas velocity	m/s
U_m	Mixture velocity	m/s
U_R	$= 1.18\left[g\sigma\left(\frac{\rho_f-\rho_g}{\rho_f^2}\right)\right]$ (Rouhani correlation)	
V_f	Specific volume of liquid = $1/\rho_f$	m^3/kg
V_g	Specific volume of gas = $1/\rho_g$	m^3/kg
x	Length	m

x	Mass dryness fraction (Quality)	
χ , X	Lockhart-Martinelli parameter	
Z	Factor in Hughmark correlation	
z	Length	m
Z	Factor in Chenoweth-Martin correlation	
Z_R	Reynolds number correction factor	

GREEK

β	Volume dryness fraction
β	Inclination angle
Γ	Factor in Chisholm correlation
λ	Friction factor = 4f (Fanning factor)
λ	Factor in Baker correlation
λ_1	Single phase friction factor
λ_2 , λ_{TP}	Two-phase friction factor
λ_{fo}	Friction factor for Reynolds number corresponding to total mass flow as liquid
λ_{go}	Friction factor for Reynolds number corresponding to total mass flow as gas

λ_H	Friction factor under homogeneous flow conditions	
μ_f	Viscosity of liquid	Ns/m^2
μ_g	Viscosity of gas	Ns/m^2
μ_H	Two phase viscosity under homogeneous flow conditions	Ns/m^2
ρ_f	Density of liquid	kg/m^3
ρ_g	Density of gas	kg/m^3
ρ_H	Two phase density with homogeneous flow conditions	kg/m^3
ρ_m	Two phase mixture density ($=\alpha\rho_g + (1-\alpha)\,\rho_f$)	kg/m^3
$\varphi^2{}_f$	Ratio of two phase friction pressure drop to single phase friction pressure drop if liquid fraction of total flow rate flowed alone	
$\varphi^2{}_{fo}$	Ratio of two phase friction pressure drop to single phase pressure drop if total flow rate was liquid	
$\varphi^2{}_g$	Ratio of two phase friction pressure drop to single phase friction pressure drop if gas fraction of total flow rate flowed alone	

φ^2_{go}	Ratio of two phase friction pressure drop to single phase pressure drop if total flow rate was gas	
ψ	Parameter in Baker correlation	
ε	Expansion Factor (Eq. 3.3.1)	
σ	Surface tension	
τ	Shear stress	N/m^2
α	Void Fraction	
γ	Gamma ray	
$\left(\frac{dp}{dz}\right)$, $\left(\frac{dp}{dx}\right)$	Pressure gradient	N/m^3
$\left(\frac{\Delta p}{\Delta z}\right)$	Pressure gradient (used in the Appendices)	N/m^3
$\left(\frac{dp_f}{dz}\right)$, $\left(\frac{dp}{dz}\right)_F$	Friction pressure gradient if liquid flowed alone	N/m^3
$\left(\frac{dp_f}{dz}\right)_{fo}$	Friction pressure gradient if total mass flow rate was liquid	
$\left(\frac{dp_f}{dz}\right)_g$	Friction pressure gradient if gas flowed alone	

$\left(\frac{dp_f}{dz}\right)_{go}$	Friction pressure gradient if total mass flow rate was gas
Tilde ( )	To denote dimensionless terms

Subscript

AVE, Ave	Percentage average error values
f, L	Liquid
g, G	Gas
H, Homo	Homogeneous
i	Interfacial
iG	Interfacial Gas
iL	Interfacial Liquid
m	Mixture
RMS	Percentage root mean square error value
S	Superficial
TOT, tot	Total
TP	Two-phase
tl	Turbulent Laminar
ll	Laminar Laminar

lt	Laminar Turbulent
tt	Turbulent Turbulent
WG	Wall Gas (Tube wall in the gas phase)
WL	Wall Liquid (Tube wall in the liquid phase)

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CHAPTER (1)

CHAPTER ONE

1.0 INTRODUCTION

Two-phase flow phenomena are found in a wide range of engineering systems, such as conventional power plants, boiling water reactors and evaporators of refrigeration systems, as well as in a variety of evaporative and condensive heat exchangers in the chemical and petroleum industries. Over the past three decades, problems in two-phase flow have challenged many investigators, as these phenomena affect not only the efficient and economical design of equipment, but also its safety in operation. It is thus critically important to be able to predict the conditions (flow patterns, pressure drop, etc.) under which a two-phase flow system will perform reliably and safely. Such understanding is central to the design, control, and performance prediction of these systems.

Therefore, the need for reliable design methods, and the importance of two-phase flow in many industrial applications, especially in the energy-related industries have been the driving force behind a very large research effort over the past three decades. This work has been carried out at universities, national laboratories, and at the industrial research and design organizations in many countries of the world

For many years, two-phase flow studies have been carried out at The University Of Strathclyde over a wide range of conditions and applications. Work has been carried out on large diameter horizontal tubes (78 mm and 127 mm diameters) using air and water as the working fluids.

Two-phase, two-component flow has been the subject of intensive investigation in recent years. Complete understanding of this subject, however, has not been achieved as yet. This is mainly because of the interdependence among the various flow parameters (flow patterns. pressure drop, void fraction, etc.) and the dependence of these parameters on the many variables involved in this type of flow, such as fluid properties, superficial velocities, flow geometry, etc..

Therefore, the subject of two-phase flow analysis contains all the difficulties associated with single phase flow analysis and, in addition, information is required on the proportions of the two phases present and on their disposition in the conduit (usually a tube). This phase disposition, flow pattern, is particularly important in the development of the flow models but is difficult to predict with any degree of accuracy or conviction. Furthermore, the experimental data which are used to validate models or produce empirical correlations are heavily biased towards the simple operating conditions of small diameter tubes (< 50 mm diameter), common working fluids (air-water, steam-water), low operating pressures (since tubes are often transparent) and often short lengths of test sections.

There are many applications, particularly in the nuclear, chemical, and petroleum where horizontal two-phase flows occur in much larger diameter pipes, and in some cases at elevated pressures. For example, the two-phase flow behaviour in large diameter horizontal pipes is of importance in connection with the safety analysis of small-break loss-of-coolant accidents (LOCAs) in pressurized water reactors (PWRs), because of its effect on the decay heat removal from the reactor core, and also of importance in the design of oil-gas pipelines. The application of the correlations, therefore, often require severe extrapolations not only in respect of fluid properties and conditions (which is perhaps understandable) but in respect of tube diameter.

It is, therefore, important to collect experimental data in large diameter tubes (> 50 mm) to ascertain how important the tube size parameter on other flow parameters, such as friction factor, pressure drop, void fraction, flow patterns, etc, These in general constitute the main aims of this study.

From the previous two-phase flow studies on large diameter tubes in The University Of Strathclyde the following are a few of the findings that have emerged:

(i) In the larger diameter tubes, the two-phase flow patterns are more distorted compared with those existing in small tubes.

(ii) Experimental data from flow patterns other than stratified flow could often be reasonably predicted by existing correlations. Stratified flow, however, was a noticeable exception and inevitably yielded large errors between experiment and prediction. This was linked to the possible existence of interficial level gradient (ILG) in the liquid phase. Hence, this finding necessitated further investigation to the stratified flow pattern.

(iii) Much longer test section lengths are required with large diameter tubes.

Consequently it was decided to re-design and re-construct the large diameter facility, going for larger diameter test tube and allowing for the incorporation of water level measurements (for stratified flows only) along the test section, as well be described in full in chapters 3, 4, and 5.

The aims of this thesis, therefore, are:

(a) To carry out a comprehensive experimental test programme involving the flow of air and water in 203 mm diameter horizontal tube (34 m long) to provide large number of data for both single and two-phase flows in large diameter pipeline to help in validating and analysing some of the available correlations.

(b) To develop and automate an instrumentation to measure and record the interficial level gradient, ILG (the change in water level along the test section).

(c) To develop a tube traversing γ-rays attenuation apparatus for void fraction measurement, and to test its accuracy for different number of stations (chordal positions) within the tube.

(d) To carry out analysis of these experimental data and compare the results (pressure drop and void fraction) with some existing correlations.

(e) To observe all the possible flow patterns for the available water and gas flow rates, to draw the results on U_{sf} and U_{sg} coordinates, and to compare it with three of the well known flow pattern maps.

(f) To develop a stratified flow model based on Bishop and Deshpande, 1986, model.

CHAPTER (2)

CHAPTER TWO

2.0 LITERATURE REVIEW

Although the first publication on multiphase flow of real significance was published in 1940's (Lockhart & Martinelli), the first known work in the subject was published in 1830. Since then a large amount of literature is available on multiphase flow . This makes it difficult to cover all the subject in the limited time given to this project. Some reviews have been presented previously and these are contained in references [30], [23], [41], [61], [70], [69], [60] and [108].

The present review, however, is divided into two main parts:

Part 1- General two-phase flow

Part 2- Stratified two-phase flow

The first part deals with a summary and update of general two-phase flow in slightly less detailed manner. The second part deals in more detail with the subject of this thesis i.e. with stratified two-phase flow .

2.1 GENERAL TWO-PHASE FLOW

2.1.1. Flow Patterns

The main characterizing feature of two-phase flows is the fact that an interface exists between the two phases and, in gas-liquid flows, this interface takes a wide variety of forms. These forms of phase distribution in two-phase flow terminology are called "flow regimes" or "flow patterns". In horizontal, co-current gas-liquid flow, the observed flow patterns in transparent pipes have indicated a dependency on the flow rates of both gas and liquid phases. The main complicating feature in horizontal flow is that gravitational forces act on the liquid phase causing it to be displaced towards the bottom of the pipe. It should be stressed at the outset that this classification of types of flow, though extremely useful, is still highly qualitative and often very subjective. Many different flow patterns have been defined and a wide variety of names have been used. In a literature survey carried out at Strathclyde University in 1975 [108], over 78 flow pattern names or labels were detected and this number has been exceeded since then. However, in general, six or seven flow pattern labels in horizontal two-phase flow are widely recognized [61], [70], [95], [106], [117], [121], these being:

Bubbly flow - gas in a form of bubbles tend to flow at the top of the tube.

Plug flow - the bullet-shaped bubbles coalesce to form elongated bubbles or plugs of gas, which again, they move along in position closer to the top of the tube.

Stratified flow - here, the gravitational separation is complete, liquid flowing along the bottom of the tube and gas along the top part.

Wavy flow - as the gas velocity is increased in stratified flow, waves are formed on the gas-liquid interface giving the "wavy-flow" regime.

Slug flow - when the waves in wavy flow grow big enough to touch the upper curacy of the tube, then the slug-flow regime is entered, with large frothy slugs of liquid interspersed with regions where is a wavy stratified layer at the bottom of the tube.

Annular flow - here, the liquid flows on the wall of the tubes as an annulus, and the gas phase flows in the centre. In horizontal annular flows, the film at the bottom of the tube is often very much thicker than the film at the top owing to gravitational effects, there is usually some entrainment of the liquid phase to droplets in the gas core.

Dispersed or Mist flow - mainly gas with liquid droplets.

The common way of obtaining flow pattern information is by visual observation, which is subject to different interpretation by different investigations. A confusing variety of classifications exist in the literature [5], [11], [42], [43], [74], [87], [89], [85], [99], [114] and [122].

2.1.1.1 - Flow Pattern Maps

The most common method of presenting flow pattern data is in form of flow pattern maps. These are two dimensional plots of some chosen variables assumed to represent the occurrence of the flow patterns and their transition boundaries. Most investigators have adopted this mainly empirical procedure to some degree. This involving plotting all of the flow pattern data on a two coordinate graph or map. Few authors give physical explanations or reasoning for using particular combinations of dimensionless numbers or flow variables as the map coordinates. One of most common coordinate system used is one involving the superficial velocity of each phase, i.e. U_{sf} and U_{sg}.

One of the earliest flow pattern maps presented was that by Baker [15], figure 2.1.1, which is still widely used for horizontal channels. Here the coordinates are:

G_{sg}/λ and $G_{sf}\lambda\psi/G_{sg}$

but it is perhaps more convenient to transpose these into

G_{sg}/λ and ψG_{sf}

i.e the superficial gas mass velocity plotted against the superficial liquid mass velocity, and the map is shown on this basis in figure 2.1.1.

Where G_{sf} = superficial mass velocity of liquid (= $\rho_f U_{sf}$)

G_{sg} = superficial mass velocity of gas (= $\rho_g U_{sg}$)

$$\lambda = \left[\left(\frac{\rho_g}{\rho_a}\right)\left(\frac{\rho_f}{\rho_w}\right)\right]^{0.5}$$

$$\psi = \left(\frac{\sigma_w}{\sigma_\ell}\right)\left[\frac{\mu_\ell}{\mu_w}\left(\frac{\rho_w}{\rho_\ell}\right)^2\right]^{1/3}$$

ρ_g , ρ_ℓ are the gas and liquid densities

σ_ℓ , μ_ℓ the surface tension and viscosity for the liquid respectively

and the suffixes 'a' and 'w' refer to air and water conditions at atmospheric pressure and temperature 20 °C.

Another horizontal flow pattern map is that by Hoogendoorn [73], figure 2.1.2, which is based on the experimental observations of air-water and air-oil mixtures in horizontal smooth pipes with inner diameters ranging from 24 mm to 140 mm. and rough pipes with inner diameter of 50 mm. The coordinates of his flow patterns map are mixture velocity U_m and volume fraction β , with

$$U_m = \frac{Q_g + Q_\ell}{A} \quad \text{and} \quad \beta = \frac{Q_g}{Q_g + Q_\ell}$$

where A is the cross-sectional area of the tube

Q_g = volume flow rate of gas

Q_ℓ = volume flow rate of liquid

Mandhane et. al. [95] made a careful examination of flow pattern data. In the absence of a theoretical framework [71], they used a map of $U_{s\ell}$ versus U_{sg} to coordinate about 1000 data points in horizontal pipes ranging from 13 to 150 mm in diameter. Most of data were for line sizes in 13 - 50 mm diameter range, so the location of these empirically drawn boundaries was strongly influenced by these data. The map is shown in figure 2.1.3, and perhaps it is still the most widely used horizontal flow pattern. The boundaries between the various flow patterns were defined for air-water mixture at atmospheric

,pressure and temperature , and expressions were given to correct these for other fluid mixtures. These entailed multiplying the *boundary values* for air-water by some function of X and Y

where

$$X = \left[\frac{\rho_g}{\rho_a}\right]^{0.333}\left[\frac{\rho_f}{\rho_w}.\frac{\sigma_w}{\sigma_f}\right]^{0.25}\left[\frac{\mu_g}{\mu_a}\right]^{0.2}$$

$$Y = \left[\frac{\mu_f}{\mu_w}\right]^{0.2}\left[\frac{\rho_f}{\rho_w}.\frac{\sigma_w}{\sigma}\right]^{0.25}$$

with

$\rho_a = 1.295$ kg/m^3 $\sigma_w = 0.0724$ N/m

$\mu_a = 1.8 \times 10^{-5}$ kg/ms $\rho_w = 1000$ kg/m^3

$\mu_w = 0.001$ kg/ms

Simpson et al [109] presented a flow pattern map based on experimental data obtained from the work on air-water mixtures flowing in large diameter tubes of nominal diameter 127 mm and 216 mm. The map coordinates were superficial velocities of gas and liquid. Comparison of this flow pattern map with Baker and Hoogendoorn was made [3] which showed reasonable agreement. The above three maps mentioned are only representative of many more.

In a survey carried out at Srathclyde University in 1976 (which had restricted publication) over 33 different flow pattern maps were quoted. Spedding and Nguyen [116] also presented a list of flow pattern maps and coordinates ,which showed some of many different coordinates employed by researchers.

2.1.2 - Pressure Drop Prediction

The pressure drop in two-phase flow is a parameter of great importance in the design of both adiabatic systems and systems with phase change, such as boilers and condensers. In forced-circulation systems, the pressure drop governs the pumping requirement, and in natural-circulation systems, the pressure drop dictates the circulation rate and, hence, the other system parameters.

The great importance of pressure drop prediction is reflected in the large number of models and correlations that are available. Here, only a few which are widely used are discussed. None of the general correlations for two-phase pressure drop is particularly accurate. This is due partly to their failure to explicitly include factors, such as entrance conditions, and also due partly to the fact that the same correlation is used to represent many different physical situations; that is, in the general correlations no particular reference is made to flow pattern. In addition to the flow-regime and entrance effects mentioned above, another factor influencing the accuracy of prediction of pressure drop data is the inherent inaccuracy of the available data.

The pressure gradient for two phase flow in uniform channel is given by

$$-\frac{dp}{dx} = -\frac{dp_f}{dx}-\frac{dp_a}{dx}-\frac{dp_g}{dx} \qquad (2.1.1)$$

where dp/dx is the pressure gradient and the three terms on the right-hand side of the equation are respectively the frictional, accelerational, and gravitational components of the pressure gradient.

In horizontal, gas-liquid flow, which is the main field of interest here, the gravitational pressure drop component is absent and the momentum or acceleration pressure component is usually negligible. Thus the total pressure drop approximates closely to the friction pressure drop (this approximation proofed incorrect in some cases of stratified flows in large diameter pipeline when hydraulic gradient existed i.e. non-uniform stratified flow). The two-phase frictional pressure gradient is usually correlated in terms of factors which multiply single-phase gradients (two-phase friction pressure drop multipliers). This multipliers, normally symbolised by φ^2_{fo}, is the ratio of the two-phase pressure drop to the corresponding single-phase all liquid pressure drop with the same total mass flowrate. The concept was first introduced by Lockhart and Martinelli (1949) and has been widely used since.

The two phase pressure drop can be predicted on the basis of either homogeneous flow or separated flow. In homogeneous flow, the two phases are considered to be intimately mixed with no relative motion between them, either locally or overall. The separated flow model, on the other hand, recognizes that the two phases can exist separately and can have different velocities i.e. slip can exist between the phases.

2.1.2.1 - Homogeneous flow model

The homogeneous two phase pressure drop is a friction factor model, similar to single phase flow, with mean mixture property and velocity values being used. Hence, the frictional pressure gradient is

$$\left(\frac{dp_f}{dx}\right)_{HOM} = \frac{\lambda_2 U_m^2}{2d \quad v_m} \qquad (2.1.2)$$

where v_m = mixture specific volume = $x v_g + (1-x) v_f$

U_m = mixture velocity = $G V_m$

λ_2 = friction factor which is a function of Reynolds Number and is obtained from Moody curves or a Blassius type equation $\lambda = K\, Re^n$ similar to single phase flow. The two phase Reynolds Number is evaluated from

$$Re = \frac{G\, d}{\mu_m} \qquad (2.1.3)$$

where μ_m is the mixture viscosity and it is the evaluation of μ_m which is the only controversial aspect of the homogeneous flow model.

Different investigators have recommended different methods of evaluating μ_m based on their experimental data. For example

McAdames et al. 1942, [94] gives

$$\frac{1}{\mu_m} = \frac{x}{\mu_g}+\frac{1-x}{\mu_f} \tag{2.1.4}$$

Cicchitti et al. 1960, [39] gives

$$\mu_m = x\mu_g+(1-x)\mu_f \tag{2.1.5}$$

Dukler et al. 1964, [49] gives

$$\mu_m = \beta\mu_g+(1-\beta)\mu_f \tag{2.1.6}$$

There are other recommended expressions.

None of the above is really very satisfactory. The most commonly used form is that due to McAdames et al.(1942).

Some investigators have also recommended the conditions under which the homogeneous flow model can be used for accurate predictions. For example, Hussain et al. [78] suggested the homogeneous flow model was valid for

$G \geq 2700$ kg/m^2 s (2×10^6 lb/h ft^2)

based on his experimental data.

Husain et al [78] also presented various empirical expressions for μ_m in order to be able to apply the homogeneous model over a range of mass velocity values.

Most experimenters who measure pressure drops or pressure gradient in two phase flow use the homogeneous flow model as a vehicle of comparison.

2.1.2.2 - Separated flow model

In theoretical terms, many investigators have produced models for two-phase flow, allowing for slip or relative motion between the phases, in terms of either 3 equations (i.e. conservation equations for mass, momentum and energy for the combined flow) or 6 equations (i.e. conservation equations for mass, momentum and energy for each phase separately and allowing for interfacial effects).

In horizontal, gas-liquid flows, the 3 equations model is the most popular since this requires experimental information in terms of friction and void factor or slip. Void fraction effects will be dealt with later but, in any case, it is the friction component which dominates in adiabatic horizontal flow.

Historically, the most widely used correlation for the calculation of the two-phase frictional pressure drop is that of Lockhart & Martinelli, 1949. In spite of its deficiencies, many (perhaps most) technical calculations are still done using this method; for that reason, it is presented here.

Lockhart & Martinelli, 1949 [93], made one of the earliest attempts to produce a general correlation of two-phase frictional pressure gradient. They presented plots of two-phase friction multipliers against a parameter χ, where

$$\chi^2 = \frac{\rho_g}{\rho_f} \left[\frac{\mu_f}{\mu_g}\right]^n \left[\frac{M_f}{M_g}\right]^{2-n} \tag{2.1.7}$$

with n being the exponent in the Blasius type equation $\lambda = K\,Re^{-n}$ having a value between 0.25 for smooth tubes and 0 for rough tubes.

Two different friction multipliers were presented φ^2_f and φ^2_g. φ^2_f was the ratio of the two phase pressure drop to the single phase liquid pressure drop when the liquid component flow rate of the mixture flowed alone, and φ^2_g was the corresponding quantity for the gas flowrate flowing alone in the tube. Figure 2.1.4 illustrates the curves produced by Lockhart & Martinelli. The different curves being shown, depending on whether the respective liquid and gas phases were laminar (l) or turbulent (t).

A simple and accurate analytic representation of the Lockhart & Martinelli graphic relationships for the multipliers is that of Chisholm, 1967:

$$\phi_f^2 = 1+\frac{C}{\chi}+\frac{1}{\chi^2} \qquad (2.1.8)$$

$$\phi_g^2 = 4 + C\chi+\chi^2 \qquad (2.1.9)$$

where C is a dimensionless parameter whose value is depends on the nature (i.e. laminar or turbulent) of the phase-alone flows. Chisholm suggests values for C as given in Table 2.1.1.

Many investigators have used their (and other) data banks to produce correlations or expressions to allow the evaluation of the two phase friction multipliers φ^2_{fo}. Amongst the most common, at least as far as the chemical process, boiler and nuclear industries are concerned, are those of Baroczy [20], Chisholm [37], Dukler [49] and Chenoweth-Martin [34], but there are many more. The oil industry tend to use more empirical equations and expressions relating the special fluids and special conditions encountered in that industry, e.g. Beggs and Brill [21], Oliemans [102], Hagedorn and Brown [65], etc.

Perhaps the most widely used advanced empirical correlation is that of Baroczy (1965). This is a general correlation which evaluates the two phase multiplier φ^2_{fo} as function of property index, mass dryness fraction and mass velocity.

The method of evaluation is as follows:

Step 1: Obtain the appropriate value of multiplier φ^2_{fo} from Table 2.1.2 corresponding to the particular value of property index $(\mu_f/\mu_g)^{0.2}$ (ρ_g/ρ_f).

This accounts for fluid used, (pressure, etc.) and dryness fraction x. These values relate to a mass velocity of 1356 kg/s.m^2 (10^6 lb/h.ft^2).

Baroczy provided the correction factors shown in figures 2.1.5 and 2.1.6 for other mass velocities.

Step 2: Correct for mass velocity effects by multiplying the φ^2_{fo} value obtained from Table 2.1.2 by the correction factor obtained from figures 2.1.5 or 2.1.6.

This correlation has the disadvantage of being graphic in nature, but a correlation that fits the Baroczy curves quit well and extends the range of data covered is that of Chisholm (1973).

Chisholm correlation is of the form

$$\phi_{fo}^2 = 1 + [\Gamma^2 - 1]\,[Bx^{(2-n)/2}(1-x)^{(2-n)/2} + x^{(2-n)}] \qquad (2.1.10)$$

where $\Gamma^2 = \left[\frac{dp_f}{dx}\right]_{go} / \left[\frac{dp_f}{dx}\right]_{fo} = \frac{\rho_f}{\rho_g}\left[\frac{\mu_g}{\mu_f}\right]^n$

with $\left[\frac{dp_f}{dx}\right]_{go} = \frac{\lambda_{go}G^2}{2d\,\rho_g}$

and $\left[\frac{dp_f}{dx}\right]_{fo} = \frac{\lambda_{fo}G^2}{2d\,\rho_f}$

The λ values are obtained from $\lambda = K\,Re^{-n}$ with λ_{go} corresponding to $Re = \frac{Gd}{\mu_g}$ and λ_{fo} to $Re = \frac{Gd}{\mu_f}$

The exponent 'n' varies between 0 (for very rough tubes) to 0.25 (for smooth tubes). Values of B were obtained from experiment and for smooth tubes are given in Table 2.1.3.

The Dukler [49] correlation has a sounder theoretical base than many other correlations, and case II relates to separated flow.

The method is based on the equation

$$\left(\frac{dp}{dz}\right)_F = \frac{\lambda_2 G^2}{2d\,\rho_{NS}}\cdot\psi$$

where $\rho_{NS} = \beta\rho_g + (1-\beta)\,\rho_f = \frac{Q_g\rho_g + Q_f\rho_f}{Q_g + Q_f}$

$$\lambda_2 = \lambda_1\left[1 + \frac{-\log_e(1-\beta)}{1.281 - 0.478[-\log_e(1-\beta)] + 0.444[-\log_e(1-\beta)]^2 - 0.094[-\log_e(1-\beta)]^3 + 0.0843[-\log_e(1-\beta)]^4}\right]$$

$$\psi = \frac{\rho_f}{\rho_{NS}}\cdot\frac{(1-\beta)^2}{1-\alpha} + \frac{\rho_g}{\rho_{NS}}\cdot\frac{\beta^2}{\alpha}$$

λ is evaluated from single phase λ-Re characteristic corresponding to

$$Re = \frac{G\,d\,\psi}{\mu_{NS}} \; ; \qquad \text{where,}$$

$$\mu_{NS} = \beta\mu_g + (1-\beta)\,\mu_f$$

A correlation by Chenoweth and Martin [34] was derived from data collected from large diameter tubes and gives value of φ^2_{fo}. The values of φ^2_{fo} can be obtained from the graph φ^2_{fo} versus (1-β), shown in figure 2.1.7 with an additional dependent parameter.

$$z = \frac{\left[\frac{dp_f}{dz}\right]_{go}}{\left[\frac{dp_f}{dz}\right]_{fo}} \qquad (2.1.12)$$

Alternatively, the table of data used for constructing figure 2.1.7 can be used directly and this is given in Table 2.1.4.

The two other correlations widely used in the oil industry is that by Biggs and Brill [21]. This has expressions for evaluating each of the pressure drop components due to friction, density or gravity, and momentum. The other is due to Oliemans [102]. The friction component of this correlation is also based on a friction factor type model. For more details on the methods of evaluating the pressure drop, refer to references [21] and [102].

A more recent correlation by Friedel [52] was based on a large bank of data collected from various sources over wide ranges of dependent parameters. The correlation was totally empirical and statistically derived to give the best overall fit to the data in the bank. The form of expression determined for φ^2_{fo} and the details of evaluation is given in reference [52].

The correlations mentioned in particular here are by no means exhaustive of those available in the literature. Other investigators have presented correlations relating to particular flow patterns or groups of flow patterns. This has applied particularly to the intermittent type flows (mainly slug), and annular type flows where the 6 equation (or similar) is used in the prediction, and much information is required on interfacial effects such as shear stress, droplet entrainment and droplet deposition.

2.1.3 - Void Fraction (holdup) Measurement And Prediction

In the study of two phase flow and in the design and operations of process equipments involving two phase flow, it has now been well recognized that it is important to have a detailed knowledge of the holdup pertaining to the situation. Cases where void fraction (holdup) is required include the calculations of the mean fluid density, the heat contents, the heat transfer coefficients, momentum and hydrostatic components of pressure drops, the water circulation rates in boilers, etc. A vast range of methods have been proposed for the measurement of void fraction, few are mentioned here, but an extensive listing of the methods and appropriate references is given by Hewitt (1978a) [69].

2.1.3.1 - Void Fraction Measurement Methods

Due to the vast number of methods found in the literature, it is not the intention of the author to give an extensive review of all the methods. Therefore, in this section only those that have been widely applied, or that have special advantages, are mentioned in less detailed manner. For detailed descriptions of these methods and a list of others see Hewitt (1978a), [69].

Four main types of void fraction measurements are given here, each of which has its own method or methods of evaluation, and these are listed below.

1 - Chordal-averge void fraction. An average void fraction across the diameter of a channel of circular cross section is measured. This type of void fraction measurements is only possible by means of radiation absorption methods, and there is no convenient alternative method of getting this particular average.

2 - Cross-sectional average. The average void fraction is sought over a given channel cross section. This is obtained by integrating chordal-average measurements over the cross section. This type of void fraction measurements is again uses radiation absorption methods (travesable single-beam radiation or multibeam radiation methods) or alternatively, measurements can be made using impedance void gauges but with less accuracy.

3 - Channel-average measurements. Here the average void fraction is required over a full section of channel. A convenient and generally satisfactory method for obtaining this type of void fraction is the use of quick-closing valves.

4 - Local void measurements. Here the void fraction is measured at a particular position within the channel. Usually, this void fraction is a time average at a point. In this case, local optical or electrical void probes are normally employed, although side-scatter gamma techniques can be used for steady-state measurements.

Void Fraction Measurement Using
Gamma and X-Ray Absorption Techniques

The principle of operation of these methods or techniques is that beams of γ-rays or X-rays are attenuated by the materials through which they pass (channel walls and two phase mixture), by a combination of photoelectric, pair-production, and Compton scattering effects [68]. The importance of these scattering mechanisms effects depend on the energy of the incident photon beam and on the substance through which it is passing. The γ-ray absorption method essentially gives a chordal mean value for void fraction. To obtain a cross-sectional average void fraction there at least two ways

(i) Traverse a collimated beam across the tube, measuring the chordal mean values as a function of different positions across the tube diameter, and then determining the cross-sectional average by means of a suitable mathematical manipulation of the chordal mean values. This method is used in subsequent determination of the void fraction, and therefore, will be detailed further more in chapter 5.

(ii) Use multibeam gamma or X-ray densitometers. Here, multibeams are taken from single gamma or X-ray source see figure 2.1.8 and 2.1.9.

Measurement of Void Fraction
Using Quick-Closing Valves

In this method two valves are used; one at the beginning and the other at the end of the channel over which the void fraction needed to be found. The valves are simultaneously closed at the appropriate moment, and the liquid trapped in the channel is drained, and its volume measured. The channel average void fraction can be determined since the channel volume is known. Care must be taken in the design of these valves when open not to obstruct the flow (i.e. the diameter of the valves should be the same as that of the tube) and in the case of high pressure systems, solenoid-operated valves are used. The measure problems in employing this method is the time required to close the valves and to drain off the system, and the time required to start and to bring the system back to steady state.

Local Void Fraction Measurement Using
the Side-Scatter Gamma Technique

The principle of operation of this method is that a gamma-ray interacts with an atomic electron and gives some of its energy. The photon then with a lower energy and altered course. The energy E' of the scattered photon is related to the initial energy E and the scattering angle θ by the equation

$$E' = \frac{E}{1 + 1.96E(1 - \cos\theta)} \qquad (2.1.13)$$

The scattered photon can also be detected, by collimating both the beam and the detection, so that only photons scattered from a particular point are detected. Therefore, it is possible to obtain the local void fraction. The major problem of this technique is that the intensity of scattered beam is very small. Hence, to obtain a reasonable accuracy, very long counting times are required.

Measurement of Void Fraction
Using Neutron Scattering

In this method, the section in which the void fraction is to be measured is placed in a fast neutron beam, and the scattered and the transmitted fluxes are measured by counting. The arrangement is illustrated in figure 2.1.10. If the incident beam is at a relatively uniform intensity, then the scattered thermal flux depends only on the amount of hydrogenous material in the cross section, and not on the distribution. However, the construction of a special source would normally be considered to be unacceptably expensive.

Measurement of Void Fraction
Using Impedance Gauges

The principle of this method is based on the fact that the electrical impedance of a two-phase flow depends on the concentration and distribution of the phases. Depending on the system, the impedance will be governed by either conductance or capacitance. Generally, it is better to operate at high enough frequency to allow the domination of the capacitance, since there are often changes in the liquid conductivity due to the change in temperature, whereas the dielectric constant varies less.
The relationship between void fraction α and the admittance (the reciprocal of impe-

dance) A is often calculated from the Maxwell's equations (1881); for a homogeneous dispersion of gas bubbles in liquid, we have

$$\alpha = \left[\frac{A - A_c}{A + 2A_c}\right]\left[\frac{C_G + 2C_L}{C_G - C_L}\right] \qquad (2.1.14)$$

where A_c is the admittance of the gauge when immersed in the liquid phase alone, and C_G and C_L are the gas and liquid phass conductivities if the conductivity is dominating, and the dielectric constants of the gas and liquid if the capacity is dominating. Different impedance values can be obtained for a given void fraction, because of sensitivity of this technique to flow pattern

2.1.3.2 - Void Fraction Correlations

The primary purpose of this section is to present prediction methods for void fraction. These can be expressed either in terms of void fraction itself or, alternatively, in terms of the velocity ratio (slip) S, which is defined as the ratio of the average gas and liquid velocities u_G and u_L and is related to the void fraction as shown below:

Slip factor $S = \frac{U_g}{U_f} = \frac{x}{1-x}\cdot\left(\frac{1-\alpha}{\alpha}\right)\frac{\rho_f}{\rho_g}$ hence

$$\alpha = \left[1 + S\left(\frac{1-x}{x}\right)\frac{\rho_g}{\rho_f}\right]^{-1} \qquad (2.1.15)$$

where $\alpha = \frac{A_g}{A}$ $\qquad 1-\alpha = \frac{A_f}{A}$

$$\alpha = \frac{xG}{\rho_g U_g} \quad \text{similarly} \quad 1-\alpha = \frac{(1-x)G}{\rho_f U_f}$$

and total C/s area $A = A_g + A_f$

For homogeneous flow the slip factor is zero (S=0), and therefore equation (2.1.15) for homogeneous flow reduces to

$$\alpha = \frac{x\rho_f}{x\rho_f + (1-x)\rho_g} \qquad (2.1.16)$$

Due to the number of calculation methods available in the literature, it is often difficult to choose the appropriate method for the particular situation being considered. Furthermore, even after deciding on a certain calculation method, there is still uncertainty as to the limitations of the method, and the range of conditions under which it may be extrapolated with reasonable confidence. And due to the time and space given to the author for this study as a whole and to this section in particular; only few void fraction correlations are mentioned here, also the author by making this choice, he is not recommending the use of these correlations in preference of the rest available in the literature, although these correlation has been chosen by the previous workers on large diameter pipelines [3], [4], [110], [111].

In section 2.1.2.2, the Lockhart & Martinelli (1949) relationships for frictional pressure drop were reviewed. Lockhart & Martinelli also give a graphic relationship (shown in figure 2.1.4) for void fraction α in terms of the Martinelli parameter χ. The curve relating α to χ in figure 2.1.4 is well fitted [68] for the turbulent-turbulent region by the expression

$$\alpha = \frac{\phi_f - 1}{\phi_f} \qquad (2.1.17)$$

Hughmark [77] gave a void fraction correlation based on Bankoff's work [17]. This correlation is recommended for both vertical and horizontal flows. The correlation was of the form $\alpha = C\,\beta$ with the values of the parameter C being empirically deduced from large bank of experimental data and against a property index Z

where $$Z = Re^{1/6} \cdot Fr^{1/8} \cdot (1-\beta)^{-1/4}$$

with $$Re = \frac{G \quad d}{\beta\mu_g + (1-\beta)\,\mu_f}$$

$$Fr = \frac{U_H^2}{g\,d}$$

A plot of C versus Z is shown in figure 2.1.11.

Smith [112] assumed an annular type flow with homogeneous core of gas or vapour with entrained liquid droplets. The correlation was expressed in terms of the slip factor s, where

$$s = E_f + (1 - E_f)\left[\frac{\rho_f/\rho_g + E_f\left(\frac{1}{x} - 1\right)}{1 + E_f\left(\frac{1}{x} - 1\right)}\right]^{1/2}$$

Smith suggested a value of $E_f = 0.4$, giving

$$s = 0.4 + 0.6\left[\frac{\rho_f/\rho_g + 0.4\left(\frac{1}{x} - 1\right)}{1 + 0.4\left(\frac{1}{x} - 1\right)}\right]^{1/2}$$

Rouhani [104] presented a correlation which was derived for bubbly flows, but it does work for other flows, and to the form

$$\alpha = \frac{x v_g}{K\{x v_g + (1 - x) v_f\} + \frac{U_R}{G}}$$

where,

$$K = 1 + 0.12(1 - X)$$

and

$$U_R = 1.18\left\{\frac{g\sigma(\rho_f - \rho_g)}{\rho_f^2}\right\}^{0.25}$$

where U_R is the bubble rise velocity

Chisholm [38] also gave in terms of the slip factor the following expression

$$s = \left[x\frac{\rho_f}{\rho_g} + (1 - x)\right]^{1/2}$$

Eaton [50] obtained the liquid hold-up H_L from experimental data involving water, oil, and gas mixtures. The result is given in graphical form of H_L versus X_E shown in figure 2.1.12, where

$$X_E = \frac{N_{fv}^{0.575}}{N_{gv}} \cdot \frac{1}{N_d^{0.0277}} \cdot \left[\frac{P}{P_b}\right]^{0.05} \cdot \left[\frac{N_f}{N_{f\,water\,15°C}}\right]^{0.1}$$

P_b = Standard atmosphere (1.013 bar)

$$N_{fv} = U_{sf}\left[\frac{\rho_f}{g\sigma}\right]^{1/4} \qquad (liquid \quad velocity \quad influence \quad number)$$

$$N_{gv} = U_{sg}\left[\frac{\rho_f}{g\sigma}\right]^{1/4} \qquad (gas \quad velocity \quad influence \quad number)$$

$$N_d = d\left[\frac{\rho_f g}{\mu_f}\right]^{1/2} \qquad (\text{pipe} \quad diameter \quad influence \quad number)$$

$$N_f = \mu_f\left[\frac{g}{\rho_f \sigma^3}\right]^{1/4}$$

Beggs and Brill [21] considered the segregated, distributed and intermittent flow patterns. The flow pattern was determined as follows:

if $N_{FR} < L_1$ - segregated flow

if $N_{FR} > L_1$ - and $> L_2$ - distributed flow

if $L_1 < N_{FR} < L_2$ - intermittent flow

where $N_{FR} = \frac{U_m^2}{g\,d}$

$L_1 = \exp(-4.62 - 3.757X - 0.481X^2 - 0.0207X^3)$

$L_2 = \exp(1.061 - 4.602X - 1.609X_2 - 0.179X_3 + 0.000635X_5)$

and $X = \ln(1 - \beta)$

Liquid hold-up for horizontal flow for each flow regime is calculated from

$$H_L = \frac{a\,(1-\beta)^b}{N_{FR}^c}$$

with the constants a, b and c obtained from table 2.1.5 given below.

Flow Pattern	a	b	c
Segregated	0.980	0.4846	0.0868
Intermittent	0.845	0.5351	0.0173
Distributed	1.065	0.5824	0.0609

Table 2.1.5 Parameters a, b, and c For Beggs & Brill Liquid Hold-up Correlation

Beggs and Brill also accounted for the effect of pipe inclination and gave another expression for H_L, as function of the flow pattern and the degree of inclination.

Guzhov [64] also presented a correlation applies to plug and stratified flow in inclined pipes in the range of ± 9° from horizontal.

For stratified uphill flow, and for uphill and downhill plug flow the hold-up was found to be independent of inclination as follows

$$H_L = 1 - 0.81\,\beta\,[1 - \exp(-2.2\sqrt{N_{FR}})]$$

where $N_{FR} = \dfrac{U_m^2}{g\,d}$

For stratified downhill flow, is dependent on the following parameter

$$X = \frac{f\,(1-\beta)^2 N_{FR}}{2\sin\theta}$$

For $0 \le X < 0.18$; $H_L = X^{0.4}$

and $0.18 \le X \le 1.0$; $H_L = 1 - 0.615\,(1 - X)\cdot$

Mukherjee and Brill [100] produced a correlation for liquid hold-up which was flow direction (uphill, downhill or horizontal) and flow pattern dependent.

Many other two phase flow investigators gave correlations either in form of hold-up (1-α), void fraction (α) or in terms of slip factor (s), which either for particular type of flow or for more than one flow pattern.

2.2 - STRATIFIED TWO PHASE FLOW

Stratified flow is defined in two-phase flow terminology as the flow where liquid phase flows at the bottom of the tube, and the gas phase on the upper part of the tube. Stratified flow has been investigated in general by many researchers; stratified-wavy flow has been the subject of more detailed investigation. Although stratified flow is considered as the simplest of all other flow regimes, it is proved from the previous two-phase flow studies in large diameter tubes, [3], [4], [110], [111], that experimental data from flow patterns other than stratified flow could often be reasonably predicted by existing correlations. Stratified flow however, was a notable exception and inevitably yielded large errors between experiment and prediction. It was also reported that stratified flow in large diameter tubes is always superimposed in the other flow regimes; i.e. even in annular flow there is a greater thickness of water at the bottom with less at the top of tube.

Two regimes of stratified flow are specified:

1 -_*Smooth Stratified:* where the smooth interface between the liquid and the gas (at low liquid and gas flowrates) exists.

2 -_*Wavy Stratified:* It is the flow where interfacial waves exist (at higher gas flow rates) between the two phases.

Bishop and Deshpande (1986) [24] studied the smooth stratified flow in horizontal pipes, and two types were identified (uniform and non-uniform flows) depending on the change of the liquid depth along the tube, i.e. depends on the existence of interficial level gradient (ILG).

Andritsos and Hanratty (1987) [7] also defined two types of interfacial waves:

1 - Regular two-dimentional waves

2 - Large-amplitude irregular waves

Hanratty and Engen (1957) [66], classified the wave patterns in rectangular channel which appear on the liquid surface as the gas is increased at fixed water velocity, as follows:

(1) *Two-dimensional wave region-* Small amplitude, long crested waves extending across the width of the channel.

(2) *Three-dimensional wave region (pebbly)-* Short crested waves give the surface a "pebbled" appearance.

(3) *Roll wave region-* Large amplitude and large wavelength waves move over the pebbly interface.

(4) *Atomized region-* Liquid droplets are torn off the interface and deposit on the channel walls.

2.2.1 - Modeling of Stratified Flow

In the past forty years an extensive literature has appeared on the prediction of pressure drop and holdup for the horizontal two-phase flow in general, and for the stratified flow in particular. One of the first widely used correlation, which gives the pressure and holdup for flow in a horizontal pipe, was proposed by Lockhart and Martinelli (1949),[93]. This semi-empirical correlation was based on experimental data covering almost all the flow regimes encountered in horizontal flow. The basic concept of the Lockhart-Martinelli is that the dimensionless pressure drop φ_G or φ_L, the liquid holdup, R, are unique functions of the flow parameter χ. These groups are defined as:

$$\phi_G^2 = \frac{(dp/dx)_{TP}}{(dp/dx)_G} \tag{2.2.1}$$

$$\phi_L^2 = \frac{(dp/dx)_{TP}}{(dp/dx)_L} \tag{2.2.2}$$

$$\chi^2 = \frac{(dp/dx)_L}{(dp/dx)_G} \tag{2.2.3}$$

where $(dp/dx)_{TP}$ is the two-phase pressure drop and $(dp/dx)_G$, $(dp/dx)_L$ are the frictional pressure drops for the gas and the liquid phases flowing alone in the pipe. The major advantage, as well as the chief drawback of this correlation, is that it can be used for all flow patterns. It was early recognized (Berrgelin and Gazley,1949 [22]; Baker, 1954 [15]; Hoogendoorn, 1959) [73] that this correlation overpredicted pressure drops in stratified flow, sometimes by more than 100%.

The next development in the modeling of the stratified flows was the presentation of empirical equations for pressure drop and holdup, developed specifically for stratified flow or for combinations of flow patterns. Examples can be found in papers by Baker (1954 [15] and 1958 [16]), Hoogendoorn (1959) [73], Eaton et al. (1967) [50], Beggs and Brill (1973) [21] Barnette (1987) [19], Furukawa et. al.(1987) [55], Goodreau (1979) [59], Gregory (1983) [62 & 63] and others. Dukler et al. (1964) [48 & 49] and Mandhane et al. (1974 and 1977) [95 & 96] presented critical evaluation studies of existing correlations for frictional pressure drop and hold-up. The difficulty with the correlation approach, however, is there is little consistency; one correlation may work well for one pipeline and poorly for another, leading to a certain amount of inspired gusswork in the application and use of the correlations.

As additional theory and large-scale laboratory data started to emerge throughout the world in late sixties mechanistic approaches towards the modelling of stratified flow were adopted. Yu and Sparrow (1967) [123] obtained an analytical solution for laminar-laminar stratified flow that related pressure drop and hold-up to flow conditions. Chisholm (1967) [36] tried to justify the use of the L-M parameters in horizontal two-phase flow. However, the final equations, applicable to all flow regimes, depended on an empirical function. Johannessen (1972) [82] was the first who presented a theoretical basis for use of L-M parameters in stratified flow. The major disadvantage of his analysis was that he neglected the shear stress at the interface and considered only the turbulent gas-turbulent liquid case. He modelled the gas phase as a flow in a closed duct, but he calculated the liquid phase frictional losses using open-channel procedures. Taitel and Dukler (1976a) [118] extended Johannessen's analysis to all cases and took into account the effect of interfacial shear stress. A momentum balance for fully developed flow gives:

$$-A_L\left[\frac{dp}{dx}\right]_L - \tau_{WL}P_L + \tau_i s_i = 0 \qquad (2.2.4)$$

$$-A_G\left[\frac{dp}{dx}\right]_G - \tau_{WG}P_G - \tau_i s_i = 0 \qquad (2.2.5)$$

Where, A is the area of each phase, τ_W, the wall shear stress, p, the length of the perimeter, s_i the width of the interface and τ_i the interfacial shear stress. Taitel and Dukler assumed the following quantities

$$\tau_{WG} = f_G \frac{\rho_G u_G^2}{2} \tag{2.2.6}$$

$$\tau_{WL} = f_L \frac{\rho_L u_L^2}{2} \tag{2.2.7}$$

$$\tau_i = f_i \frac{\rho_G (u_G - u_i^{\prime})^2}{2} \tag{2.2.8}$$

$$Re_L = \frac{D_L u_L}{\nu_L} \quad , \qquad Re_G = \frac{D_G u_G}{\nu_G} \qquad (2.2.9, \quad 2.2.10)$$

$$D_L = \frac{4A_L}{P_L} \quad , \qquad D_G = \frac{4A_G}{P_G + s_i} \qquad (2.2.11, \quad 2.2.12)$$

Assuming $f_i = f_G$ and that $u_G >> u_i^{\prime}$ and calculating the wall friction factors through the Blasius equation, they showed that both parameters φ_G or φ_L and X are unique functions of the dimensionless film thickness, h/D.

Chen and Spedding (1981) [31] also tried to justify the use of L-M parameters for stratified flow in a pipe, without considering a force balance and the interfacial shear stress. Their result, however, is very similar to that of Johannessen.

Aggour and Sims (1978) [1] obtained a theoretical solution of stratified flow between two parallel plates by using the 1/7 power laws to represent the turbulent velocity profiles. The final results were expressed in the form of L-M parameters and are similar to those of Taitel-Dukler.

Agrawal, Gregory and Govier (1973) [2] proposed an iterating procedure based on equations (2.2.4), (2.2.5), (2.2.6) and (2.2.8). The interfacial friction factor was calculated from the empirical equation suggested by Eillis and Gay (1959) [51] for channel flow

$$f_i = 1.293\, Re_G^{-0.57} \qquad (2.2.13)$$

The wall shear stress in the liquid phase was estimated from equation (2.2.7), by using a pseudo-average liquid velocity.

Russel et al. (1974) [105] solved numerically the equation of motion for the laminar liquid phase and presented graphically the relation between a dimensionless flow rate , Q^*_L, and the film thickness assuming $\tau_i = \tau_{WG}$. In fact, this solution is almost identical to that of Taitel-Dukler for the case of turbulent gas-laminar liquid, with the small differences between the two models due to the better modelling of the shear stress of the liquid in Russel's model.

Cheremisinoff and Davis (1979) [35] extended Russel's model to a turbulent liquid phase. In their numerical analysis, they used Von Karman's equation for the turbulent core and Deissler's equation for the wall region. They assumed that the interfacial friction factor can be given by:

$f_i = 0.00355$ for smooth interface (2.2.14)

$f_i = 0.0142$ for small-amplitude waves (2.2.15)

$f_i = 0.008 + 2 \times 10^{-5} Re^*_L$ for roll waves (2.2.16)

where

$$Re^*_L = \frac{u_{LS}}{\nu_L}\left[\frac{\pi D^2}{4S_i}\right] \qquad (2.2.17)$$

For small h/D, Re^*_L is very close to Re_L. The above correlation were taken from the papers of Cohen and Hanarrty (1968) [40] and Miya et al. (1971) [98] respectively, and are based on data from channel flows.

Shoham and Taitel (1984) [107] extended the work by Cheremisinoff and Davis. A modified Van Driest model was used for the wall region, while a constant value for the eddy viscosity was assumed for the turbulent core. In contrast with the model of Cheremisinoff and Davis a radial dependence of the velocity was not assumed. Their analysis [6] would seem to be an improvement for upward flows.

2.2.1.1 - Modelling Of Interfacial Shear Stress

The primary need in the modelling of stratified flow is to develop an appropriate model for the interfacial friction factor. Crowley and Rothe (1988) [44] have shown the dependence of the holdup and pressure drop solutions for stratified flow upon the interfacial friction factor ratio f_i / f_{wg} (in the range of 1 to 10).

In the simplest approach, the interfacial friction factor is assumed to be the same as the friction factor at the gas-wall interface (Taitel-Dukler, 1976) [118]. This assumption of $f_i = f_{wg}$ or $f_i / f_{wg} = 1$ is the equivalent of assuming a smooth gas-liquid interface , i.e. the effect of waves at the interface is neglected. This model represents the bounding limit (lower bound) to the possible effects of interfacial shear. Crowley et. al. (1988) [44] have shown that this model tends to overpredict the liquid holdup and to under-predict the pressure drop for stratified flows.

The next class of models is empirical equations which mainly attempt to correlate interfacial shear data for stratified-wavy flows in a channel. These correlation include the ones proposed by Hanratty and Engen (1957) [66], Ellis and Gay (1959) [51], Smith and Tait (1966) [113], Cohen and Hanratty (1968) [40], Davis (1969) [47], Miya et. al. (1971) [98], Gayral et. al. (1979) [56] and Tsiklaurt et. al. (1979).

Ellis and Gay correlated their results using Blasius type equation. They found that the friction factor for a smooth surface is:

$$f_G = 1.293\, Re_G^{-0.57} \tag{2.2.18}$$

while the friction factor for a wavy surface is:

$$f_i = 0.28\, Re_G^{-0.222} \left[\frac{y_o}{h} \right]^{0.1724} \tag{2.2.19}$$

where $Re_G = h_G U_G / \nu_G$ gas-phase Reynolds number for a channel

h_G = gas phase thickness

and y_o = roughness characteristic.

Cohen and Hanratty [40] found that for flows over three-dimensional waves, the interfacial friction factor assumes a constant value and it is only mildly affected by the roughness characteristic. The interfacial friction factors for roll waves calculated by Miya et. al. [98], using an assumption of two-steady states, showed a linearity with respect to liquid phase Reynolds number, Re_L. This linear expression was reported by Anditsos (1986) [6] as:

$$f_i = 0.008 + (2 \times 10^{-5}\, Re_L) \tag{2.2.20}$$

where $Re_L = u_L\, h / \nu_L$

Smith and Tait [113] covered a large range of liquid and gas flow rates in their study. Their data show that the interfacial friction is approximately the same as that for a smooth wall when the interface is smooth, but that it increases with increasing gas velocity after the inception of waves.

The experiments of Gayral et. al. [56] can be approximated by the correlation:

$$\tau_i = 0.015\, (Re_G \times 10^{-5})^3\, \rho_L\, g\, h \tag{2.2.21}$$

Tsiklauri et. al. gave a theoretical equation for the interfacial shear stress which, however, underpredicts their own data (Andritsos, 1986) [6]. Andritsos recommended an equation for the interfacial friction factor, which correlates well their data:

$$f_i = 0.0055 + 0.026\, Re_L \times 10^{-3} \qquad (2.2.22)$$

A study of interfacial shear stresses for horizontal stratified flow in a pipe was carried out by Kowalski (1984) [88]. In this study the interfacial shear stress was determined by two methods (Andritsos and Hanratty) [6]; (1) from a momentum balance (2) from an extrapolation to the interface of measurements of the Reynolds shear stresses. The latter method is based on the fact that the Reynolds shear stress usually dominates over the viscous component of the shear stress. The following equations were recommended for smooth and wavy interfaces respectively:

$$f_i = 0.96\, Re_G^{*\,-0.52} \qquad (2.2.23)$$

$$f_i = 7.5 \times 10^{-5}(1-\alpha)^{-0.25}\, Re_G^{-0.3}\, Re_L^{0.83} \qquad (2.2.24)$$

where $Re_G = \dfrac{U_G D_G}{\nu_G}$, $Re_L = \dfrac{U_L D_L}{\nu_L}$, $Re_G^* = \dfrac{U_{SG} D_G}{\nu_G}$

Kowalski found that the interfacial friction factor obtained from Reynolds stress measurements were 15 to 30% lower than those calculated through the momentum balance.

Agrawal (1973) [2], Cheremisinoff-Davis (1979) [35], Lin-Hanratty (1984) [91], Shoham-Taitel (1984) [107], and Laurinat-Hanratty (1984) [90] have all attempted to correlate interfacial shear data for stratified-wavy flows as summarized in Table 2.2.1. These correlations have typically been developed based upon experimental data at small pipe sizes (1 to 2 inches) and low gas density (air near atmospheric pressure). The ability of these models to describe stratified flow behaviour at large pipe size and high gas density has been assessed by Crowley and Sam, 1986 [45]. Conclusions from this work are that the models proposed by Agrawal, Lin-Hanratty, and Cheremisinoff-Davis do not scale well to large pipe size and high gas density. The model proposed by Shoham-Taitel, which amounts to a constant ratio of $f_i/f_{wg} \cong 5$, and the model proposed by Laurinat-Hanratty were found to give reasonable agreement with the data.

More recently, attempts have been made to model interfacial friction by more mechanistic approach in which the height of the waves at the gas-liquid interface is modelled, and then the interfacial friction is determined as a "rough-pipe" friction based upon the height of those waves. The models proposed by Andritsos-Hanratty (1986) [6], Oliemans (1987) [101], and Baker (1988) [13 & 14] are in this category see Table 2.2.1. Assessment of the Andritsos-Hanratty model against experimental data at large size and high gas density (Crowley et. al., 1987) [46] shows that this model tends to overpredict the pressure drop to a greater extent than the Laurinat-Hanratty correlation. The method suggested by Oliemans follows the mechanistic approach, but the model for the height of the waves is not presented (it was proprietary). Baker has recently proposed a model consistent with this approach , and one which is very successful in predicting the pressure drop and holdup in operating pipelines (Baker, 1988).

2.2.1.2 - Modelling Of Wall Shear Stresses

Models in the literature vary in the level of detail at which the wall shear stresses (τ_{wl} and τ_{wg}) are treated in the analysis. Three levels are identified here:

(i) The simple use of the Blasius friction factor relationships for smooth pipes, in both phases (liquid and gas), (Taitel and Dukler, 1976) [118].

(ii) Detailed solution of the turbulent or laminar velocity profiles in the liquid phase with the simple model in the gas phase (Cheremisinoff-Davis, 1979 [35]; Shoham-Taitel, 1984, [107]). Cheremisinoff and Davis, chose to develop a correlation for $h(\tau_w/\rho)^{1/2}/\nu$ rather than for f_L. The advantage (as they say) is that such an approach is better able to account for changes in the shape of the velocity profile in the liquid caused by the gas drag at the interface. The disadvantage, in comparison with the original

Taitel-Dukler approach, is that a trial-and-error solution must be used to calculate the pressure drop and h/D.

A modification of the Cheresmisinoff-Davis correlation has been proposed by Andritsos-Hanratty (1987) [7]. The characteristic stress in the liquid was taken as:

$$\tau_C = \frac{2}{3}\tau_{WL}\left(1 - \frac{h}{D}\right) + \frac{1}{3}\tau_i \tag{2.2.25}$$

A friction velocity and a dimensionless liquid height are defined as:

$$u_C^* = (\tau_C/\rho_L)^{1/2} \tag{2.2.26}$$

$$h^+ = h u_C^*/\nu \tag{2.2.27}$$

A reasonable representation for dimensionless liquid height for both turbulent and laminar cases is:

$$h^+ = \left\{ (1.082\, Re_L^{0.5})^5 + \left[0.098\, Re_L^{0.85} / \left(1 - \frac{h}{D}\right)^{0.5} \right]^5 \right\}^{0.2} \tag{2.2.28}$$

Andritsos and Hanratty, however, have concluded that, following the above procedure, a slight improvement of the Blasius equation is gained.

(iii) Detailed solutions of the velocity profiles in both the gas and the liquid phases (Issa, 1988) [80]. Issa has demonstrated that the difference between the predictions of the simple stratified flow analysis suggested by Taitel and Dukler and the very detailed analysis is small, when the interfacial shear is the same. Therefore, simple models such as:

$$\tau_{WL} = f_{WL}\left[\frac{\rho_L U_L^2}{2}\right] \tag{2.2.29}$$

$$\tau_{WG} = f_{WG}\left[\frac{\rho_G U_G^2}{2}\right] \tag{2.2.30}$$

can be used for the wall shear stresses with little loss in accuracy. Here the friction factors f_{WL} and f_{WG} are given by the appropriate friction factor model for the particular pipe being analyzed. For example, a simple Blasius model could be used for smooth pipes.

2.2.1.3 - Interfacial Level Gradient (ILG)

As mentioned earlier, stratified liquid-gas flow is a basic flow pattern from which other patterns develop as the liquid and gas rates are varied. Although stratified flow is simple, achieving stable uniform stratified flow using high-viscosity Newtonian liquids or even low-viscosity liquids in large diameter pipelines presents several difficulties not experienced with small diameters or other liquid-gas flow patterns. One of these difficulties, is the existence of interfacial level gradient [ILG] (change in the liquid depth along the channel). Flow with ILG (non-uniform stratified flow), can possibly affect liquid holdup, flow-pattern transition and the assumption of an equal axial pressure gradient in each phase, which is a basic assumption in the often-used Lockhart-Martinelli (1949) [93] pressure drop model.

Holden (1948) [72], Bergelin & Gazley (1949) [22] and Gazley (1948, 1949) [57 & 58] were the first workers to call attention to the unequal two-phase axial pressure gradients which can exist in stratified flow as a result of non-uniform flow ILG behaviour. Holden and Gazley both measured the liquid level along the test section and the axial static pressure in the gas phase only. Jensen (1972) [81] and Arruda (1970) [12] also measured the liquid level but did not discuss the existence of ILG.

Simpson et al. (1976, 1981) [110 & 111] measured the axial pressure gradient in the gas phase, and in the liquid phase in large-diameter tube, using centreline tapping points. Simpson et al. called special attention to ILG and to the large differences in the two pressure drop measurements and the error introduced by using centreline pressure taps in large diameter tubes if significant ILG exists. Other than Holden, Gazley and Simpson none of the early experimenters reported measurements of ILG or made reference to the presence of ILG.

Recently, Bishop & Deshpande (1986) [24] made an extensive study of the stratified data available in the literature (including the data of Holden, Gazley and Simpson). In their analysis, they used the dimensionless form of the energy equations (one for gas phase and one for the liquid phase), in the same way as Taitel & Dukler (1976a). Bishop considered three terms more in the energy equations compared to those of Taitel & Dukler (equations 2.2.4 and 2.2.5). The three terms are:

(i) Gas kinetic energy term,

$$-\frac{\alpha \rho_G}{2}\frac{d(U_G^2)}{dx}$$

(ii) Liquid kinetic energy term,

$$-\frac{\alpha \rho_L}{2}\frac{d(U_L^2)}{dx}$$

where the parameter α accounts for radial variation in the velocity profile and is 2 for laminar flow of a Newtonian fluid through a circular tube.

(iii) ILG in liquid term,

$$g \rho_L \frac{dh}{dx}$$

where h is the liquid height in the tube

The final dimensionless equation for inclined stratified flow with ILG, obtained by Bishop & Deshpande took the form:

$$\chi^2 F(R_L, n, m) - F\left(R_L, \frac{f_{iL}}{f_{wG}}, \frac{f_{iG}}{f_{wG}}\right) - \ Z - \ 4Y \ = \ 0 \qquad (2.2.31)$$

where F is function relationship involving the parameters within the brackets; n and m are the exponents of the Reynolds number in the friction factor relationship. χ Is the Lockhart-Martinelli parameter, f_{iL} and f_{iG} are the interfacial friction factors for liquid and gas respectively. R_L is the liquid holdup. The parameter Z represents the equivalent relative dimensionless force acting on the liquid in the direction of the flow due to the ILG and any other difference in the two-phase pressure gradient in each phase, and the Y parameter to account for tube inclination (introduced by Taitel & Dukler, 1976a).

Liquid	Gas	Subscript	Value of C
Turbulent	Turbulent	tt	20
Laminar	Turbulent	lt	12
Turbulent	Laminar	tl	10
Laminar	Laminar	ll	5

Table 2.1.1 Values of C to fit the Empirical Curves of Lockhart & Martinelli (Chisholm 1967) [43]

Property Index $\left[\frac{\mu_f}{\mu_g}\right]^{0.2}\left[\frac{\rho_g}{\rho_f}\right]$	Mass Dryness Fraction x															
	0	.001	.005	.01	.02	.035	.05	.075	.1	.15	.2	.3	.4	.6	.8	1.0
0.0001	1	2.2	5.8	9.2	16.0	26.5	47	99	163	376	630	1300	2050	4300	6600	10000
0.001	1	2.15	5.6	8.8	14.8	22.8	34.2	48.2	70	108	148	240	330	538	760	1000
0.004	1	2.08	4.9	7.8	11.9	16.3	22.8	29	36	49.5	63	86	110	155	203	250
0.01	1	1.59	3.3	4.8	7.0	9.6	12.4	16.0	20	27	33.5	43.5	53	69	85	100
0.03	1	1.12	1.55	1.81	2.57	3.45	4.7	6.1	7.9	11	13.2	17.3	21.2	26	30	33.3
0.1	1	1.04	1.12	1.22	1.40	1.78	2.09	2.5	2.00	3.6	4.2	5.5	6.5	8.0	9.1	10
0.3	1	1.01	1.02	1.06	1.13	1.26	1.30	1.5	1.59	1.77	1.93	2.25	2.48	2.00	3.2	3.33
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 2.1.2

ϕ^2_{fo} values for G=10^6 lb/h.ft.^{2}

(1356 kg/m^{2}s) Baroczy (ref 28)

Γ	G kg/m²s	B
≤ 9.5	≤ 500	4.8
	500 < G < 1900	2400/G
	≥ 1900	$55/G^{0.5}$
9.5 < Γ < 28	≤ 600	$520/\Gamma G^{0.5}$
	> 600	21/Γ
≥ 28		$15000/\Gamma^2 G^{0.5}$

Table 2.1.3 Values of Coefficient B from Chisholm

Liquid Volume Fraction (1-β)	Z = 50	Z = 100	Z = 200	Z = 500	Z = 1000
0	50	100	200	500	1000
0.00001	56.5	113	225	565	1125
0.00002	58.5	117	235	585	1175
0.00004	62.0	124	248	620	1230
0.00007	63.5	127	254	635	1200
0.0001	64.5	129	258	645	1150
0.0002	66.0	132	255	580	950
0.0004	67.5	129	249	470	680
0.0007	65.0	121	219	385	470
0.001	62.0	115	199	325	370
0.002	58.0	99	153	215	215
0.004	50.0	82	105	120	120
0.007	41.0	60	71.0	72.5	72.5
0.01	34.5	48	53.0	53.0	53.0
0.02	24.0	29.2	29.2	29.2	29.2
0.04	15.0	16.1	16.1	16.1	16.1
0.07	9.90	9.9	9.90	9.90	9.90
0.1	7.40	7.4	7.40	7.40	7.40
0.2	4.05	4.05	4.05	4.05	4.05
0.4	2.22	2.22	2.22	2.22	2.22
0.7	1.38	1.38	1.38	1.38	1.38
1.0	1.0	1.0	1.0	1.0	1.0

Table 2.1.4 Data for constructing Fig. 2.1.7 Chenoweth and Martin

REFERENCE	SMOOTH INTERFACE	WAVY (ROUGH) INTERFACE
TAITEL-DUKLER (1976)	$f_i = f_{wg}$	No Model
AGRAWAL (1973)	No Model	$f_i = 0.646/Re_g^{-0.59}$
LIN-HANRATTY (1984)	No Model	$f_i = f_{wg}(1 + \beta h_g^+)$ $h_g^+ = h_g \left[\frac{\tau_i}{\rho_g}\right]^{1/2} \left[\frac{\rho_g}{\mu_g}\right]$
CHEREMISINOFF-DAVIS (1979)	$f_i = 0.00355$	$f_i = \left[0.008 + (2\times10^{-5})\left[Re_\ell\right]\right]$
SHOHAM-TAITEL (1984)	$f_i = f_{wg}$	$f_i = 0.0142$
LAURINAT-HANRATTY (1984)	No Model	$f_i = f_{wg}\left[2 + \frac{(2.5\times10^{-5})Re_{\ell s}}{(D/3.281)U_g^{5/2}}\right]$
ANDRITSOS-HANRATTY (1986)	$f_i = f_{wg}$	$f_i = f_{wg}\left(1 + 15h^{*0.5}\right]\left[\left[\frac{V_{sg}}{16.4}\right]\left[\frac{\rho_g}{\rho_{go}}\right]^{0.5} - 1\right]$
OLIEMANS (1987)*	No Model	$\left[\frac{\Delta h_i}{D_g}\right]^* = f(V_g - V_l)$ $\left[\frac{\varepsilon_i}{D_e}\right] = 3\sqrt{2}\left[\frac{\Delta h_i}{D_g}\right]$ $\frac{1}{f_i^{1/2}} = -4\log\left[2\left[\frac{\varepsilon_i}{D_g}\right] + \frac{9.35}{Re_g f_i^{1/2}}\right] + 3.48$
BAKER (1988)	if $(We_g/ArEo^{0.5})$ $\varepsilon_i = \left[\frac{34\sigma}{\rho_g V_i^2}\right]$ $\varepsilon_e = \frac{(S_i\varepsilon_i + S_g\varepsilon_g)}{(S_i + S_g)}$ $\frac{1}{f_i^{1/2}} = 2\log_{10}\left[\frac{(\varepsilon_e/D_e)}{3.7} + \frac{2.51}{Re_{ig} f_i^{1/2}}\right]$	if $(We_g/ArEo^{0.5}) > 0.005$ $\varepsilon_i = \left[\frac{170\sigma(We_g ArEo)^{0.5}}{\rho_g V_i^2}\right]$ ε_e and f_i given by same equations as smooth interface.
*The functional relationship for $\left[\Delta h_i/D_G\right]$ is not given explicitly		

Table 2.2.1 Summary of Interfacial Friction Factor Models for Stratified (Turbulent) Flow (from Ref.[44]).

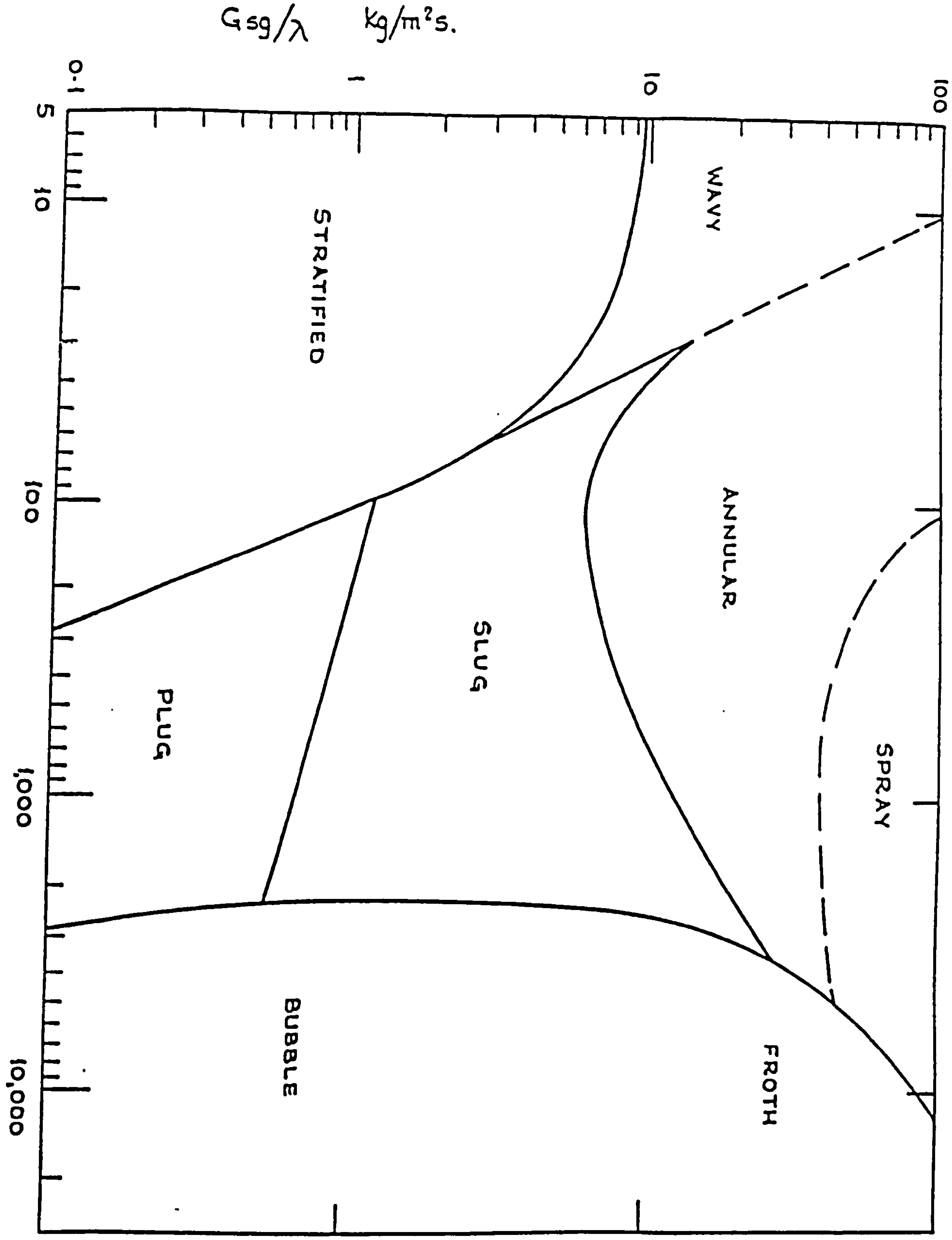


FIG. 2.1.1 FLOW PATTERN MAP FOR HORIZONTAL FLOW (BAKER).

FIG. 2.1.2 FLOW PATTERN MAP FOR HORIZONTAL GAS-OIL FLOW (HOOGENDOORN)

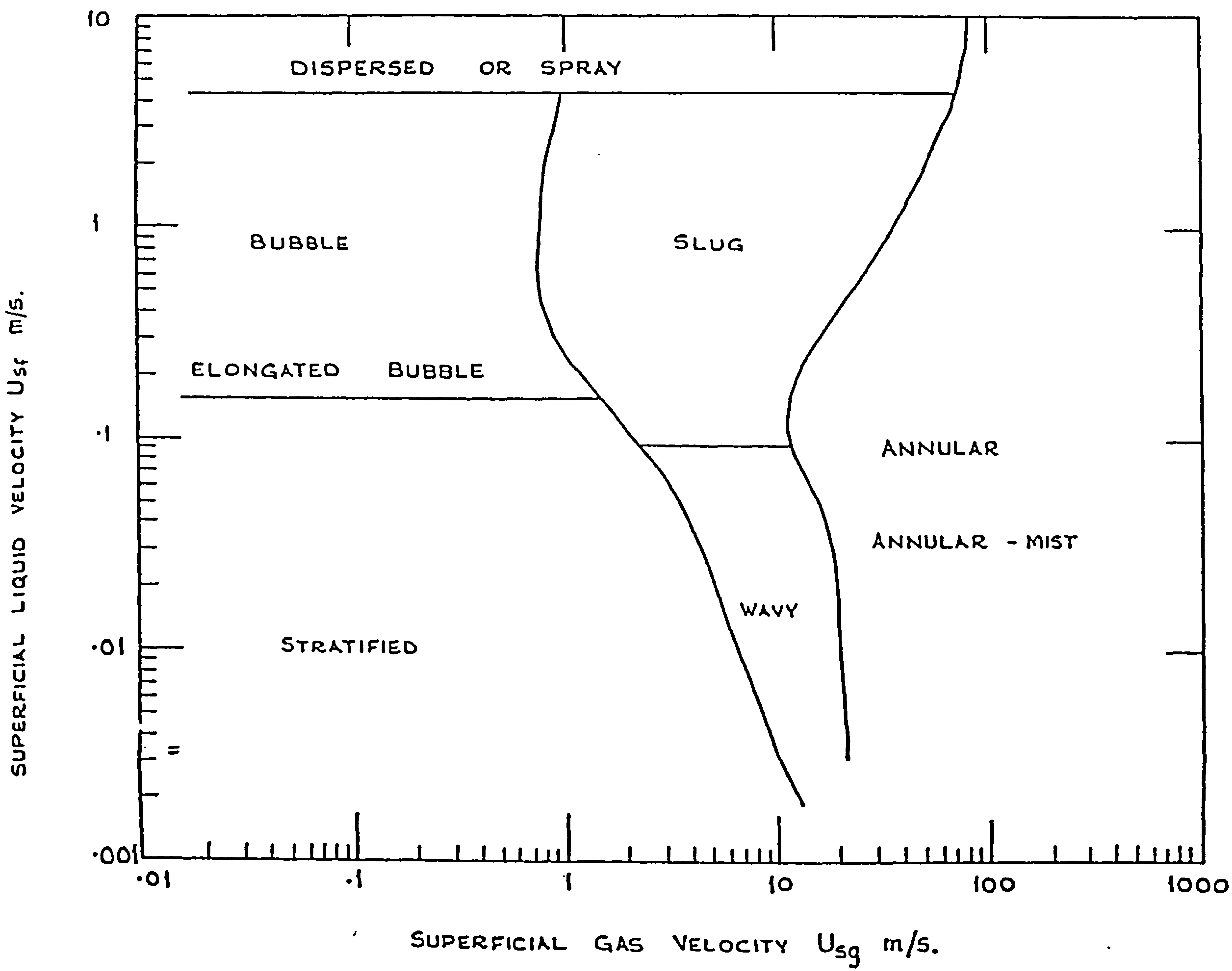


FIG.2.1.3 MANDHANE et. al. FLOW PATTERN MAP

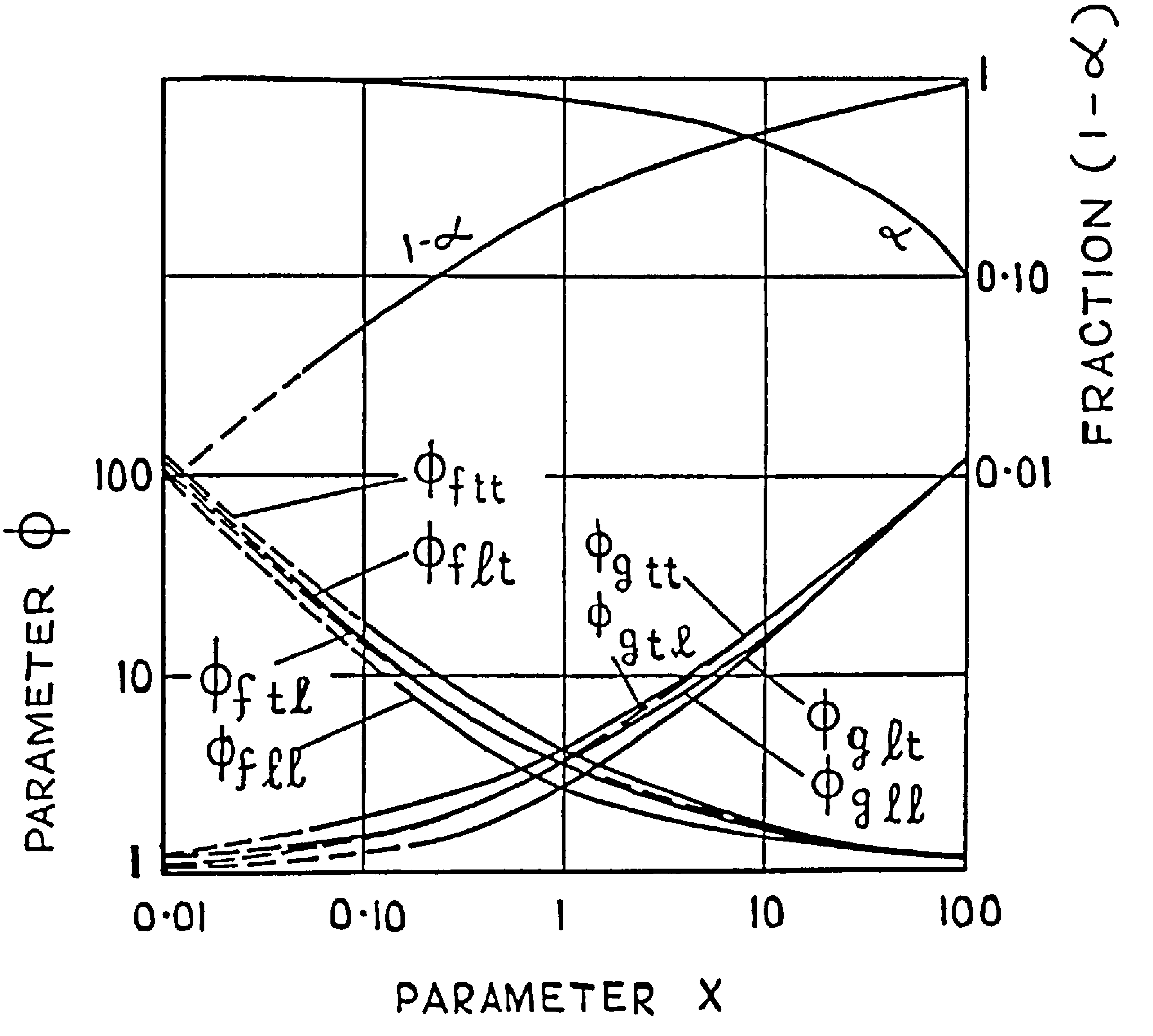
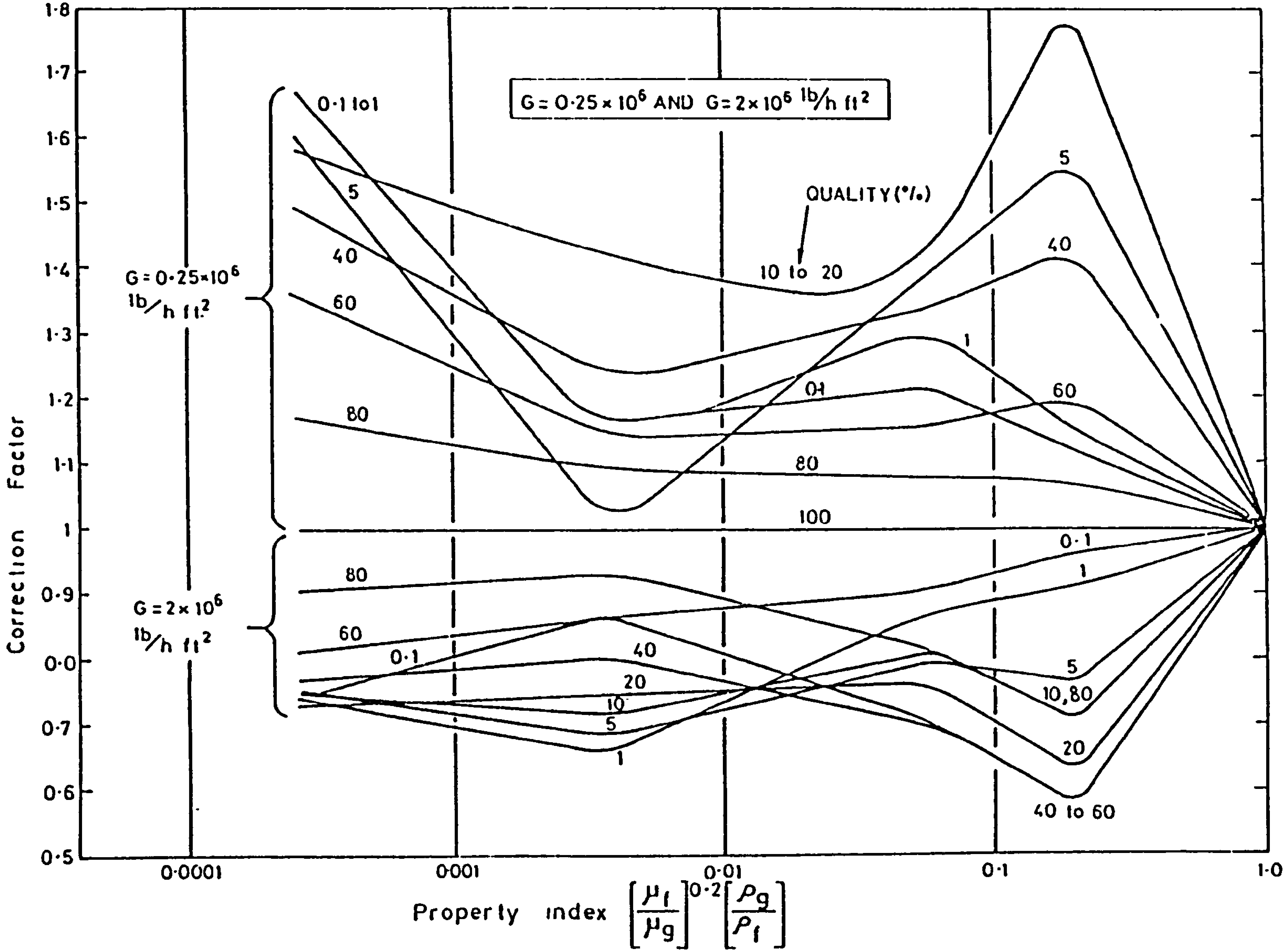


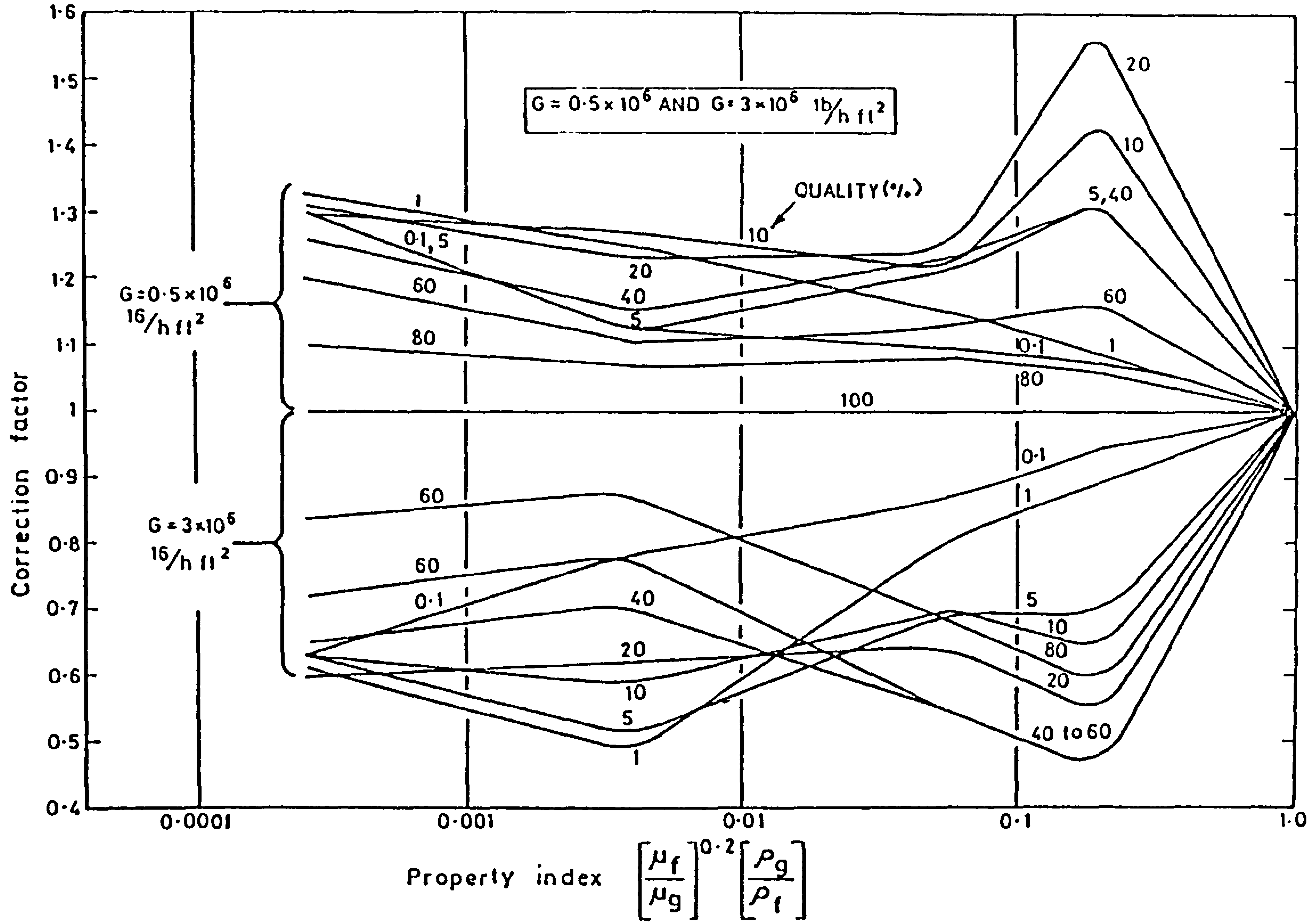
FIG. 2.1.4

RELATIONSHIPS BETWEEN φ, α AND X FOR ALL FLOW MECHANISMS (LOCKHART & MARTINELLI).



BAROCZY MASS VELOCITY CORRECTION FACTORS

FIG. 2.1.5



BAROCZY MASS VELOCITY CORRECTION FACTORS

FIG. 2.1.6

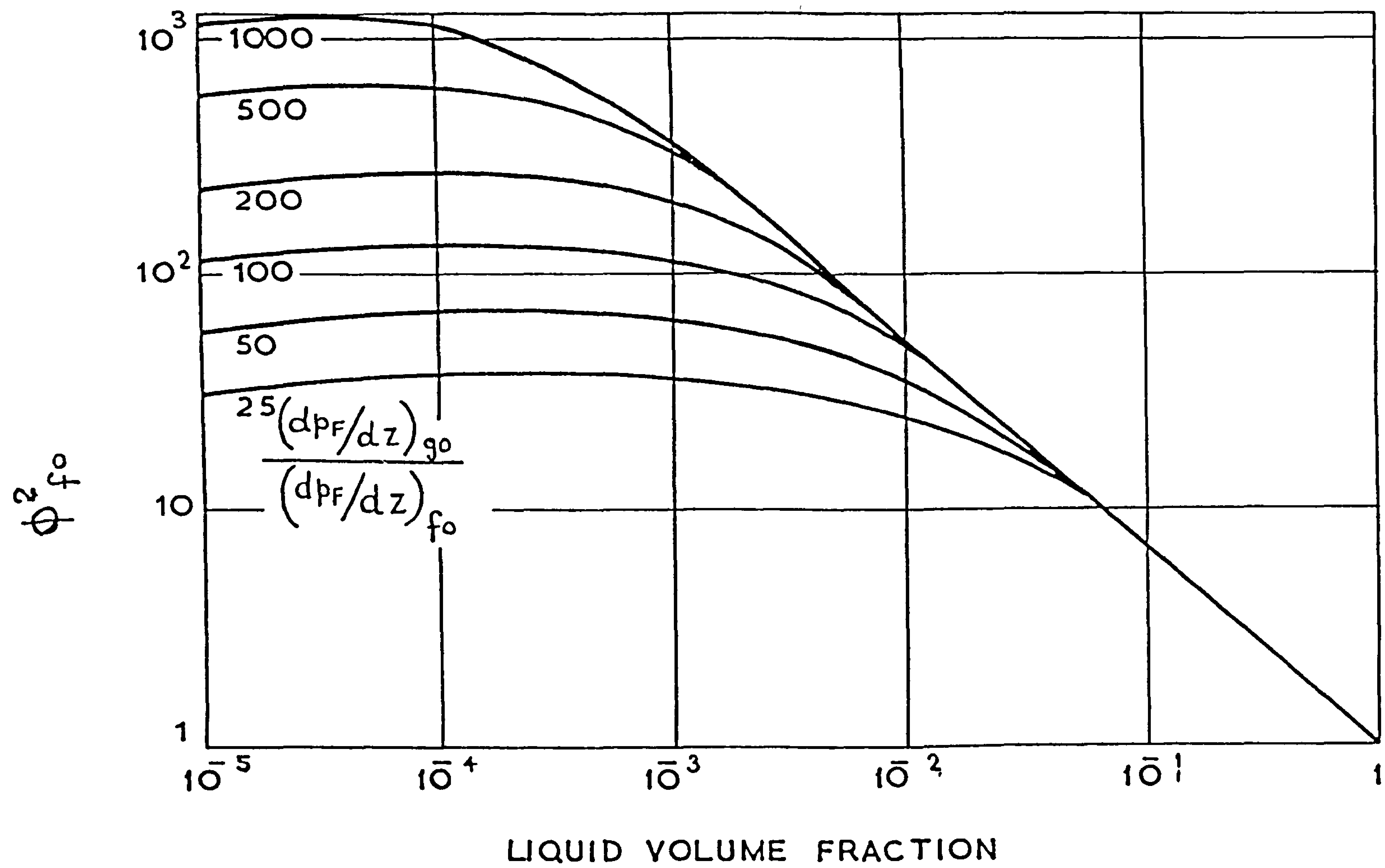


FIG. 2.1.7 TWO-PHASE FRICTION EFFECTS IN LARGE PIPES

(CHENOWETH AND MARTIN)

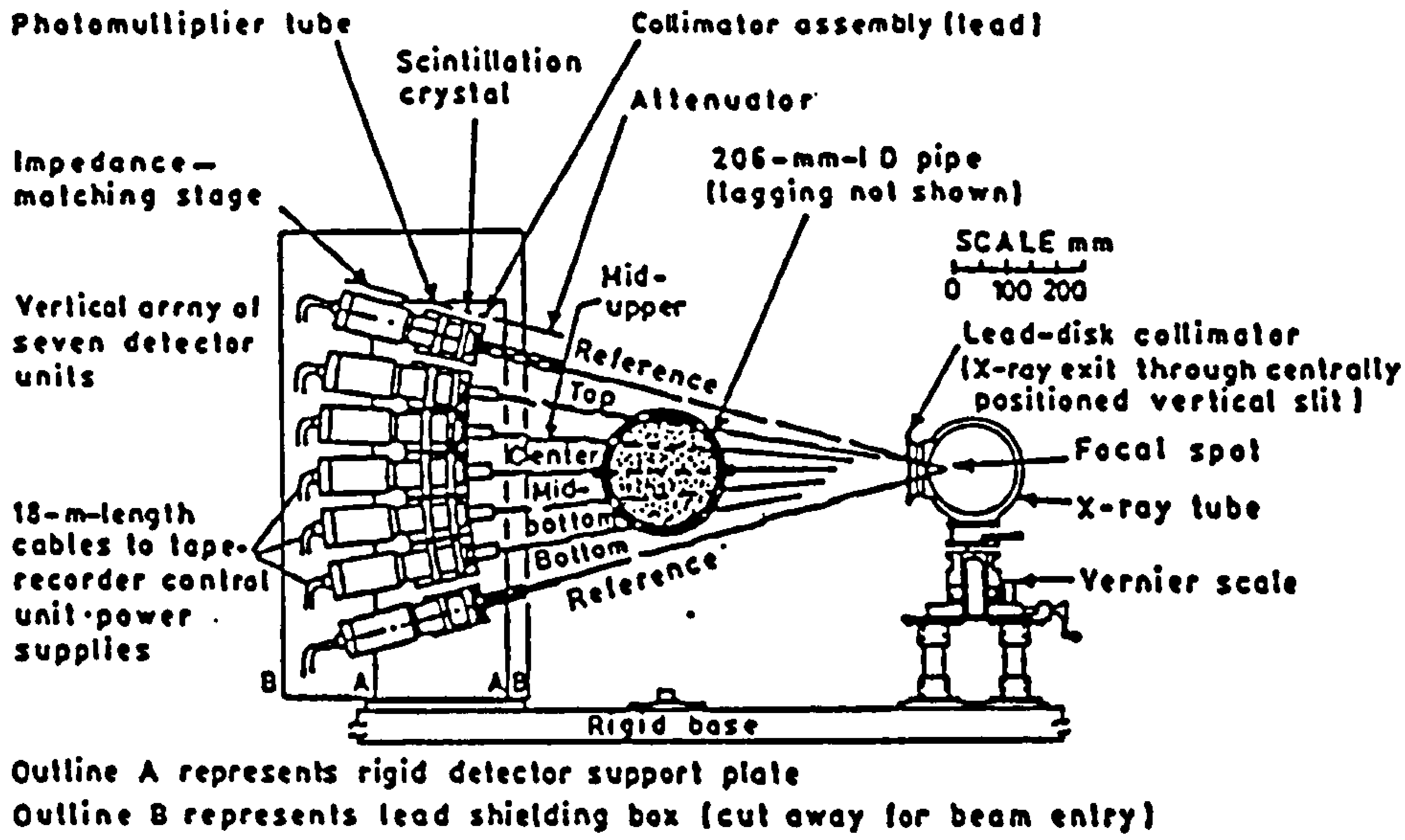


Fig. 2.1.8 Multibeam x-ray system of multiple cordal-mean void fractions

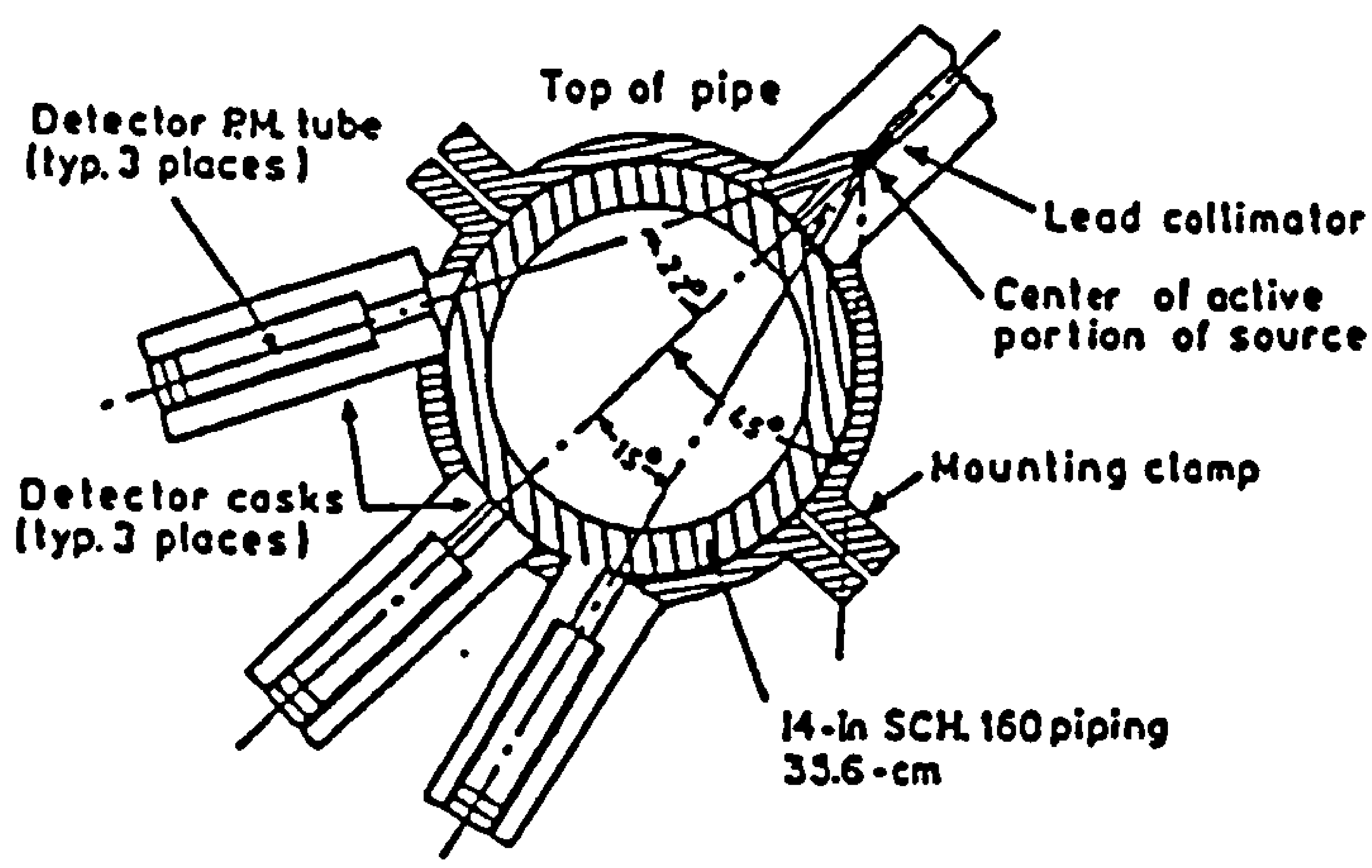


Fig. 2.1.9 Three-beam gamma densitometer

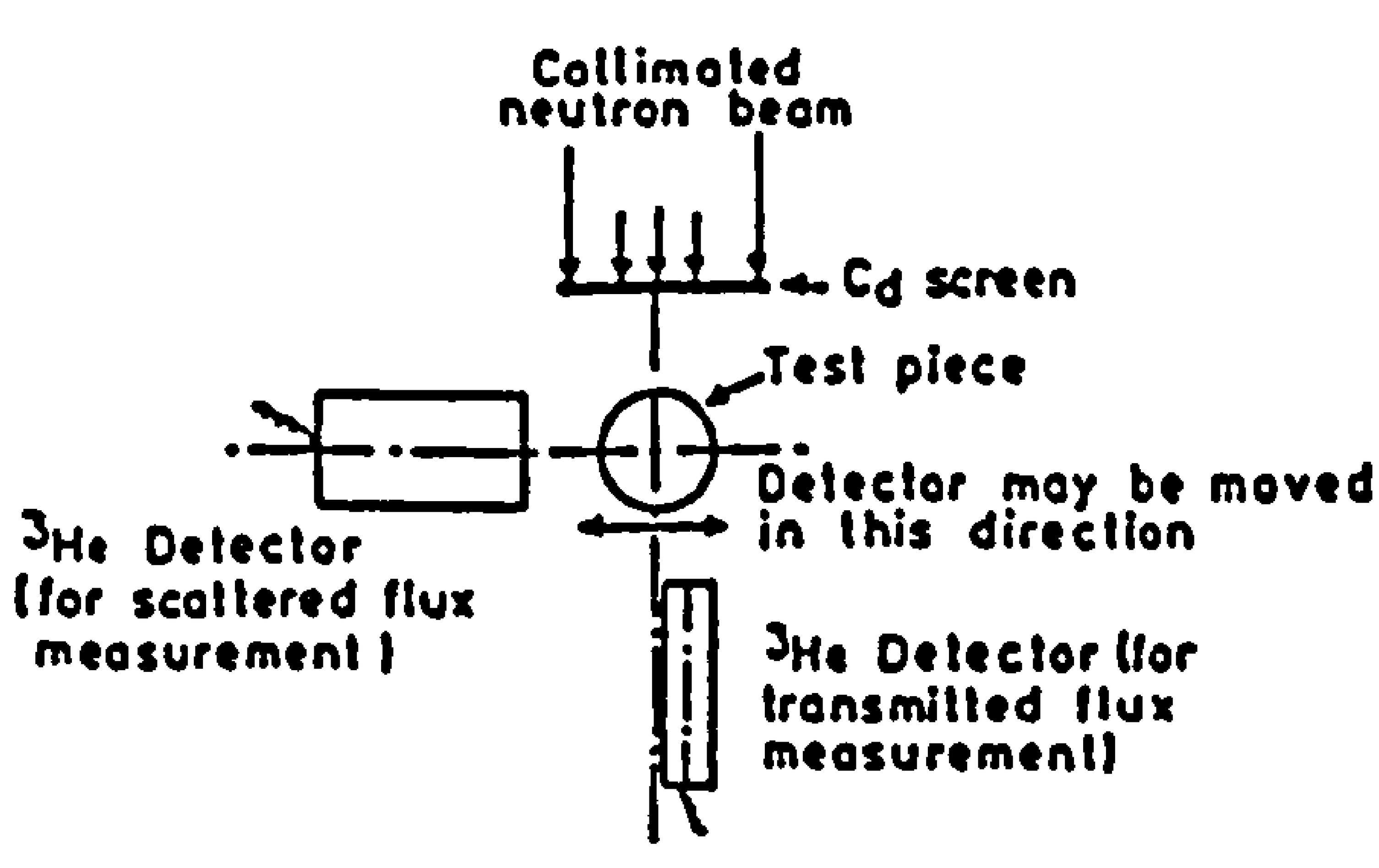


Fig. 2.1.10 Neutron-scattering method for void fraction

$$Z = Re^{1/6} \cdot Fr^{1/8} \cdot (1-\beta)^{-1/4} \quad \text{where} \quad Re = \frac{G\,d}{\beta\mu_g + (1-\beta)\mu_f} \quad \text{and} \quad Fr = \frac{U_H^2}{g\,d}$$

FIG. 2.1.11 VALUES OF HUGHMARK CONCENTRATION FACTOR

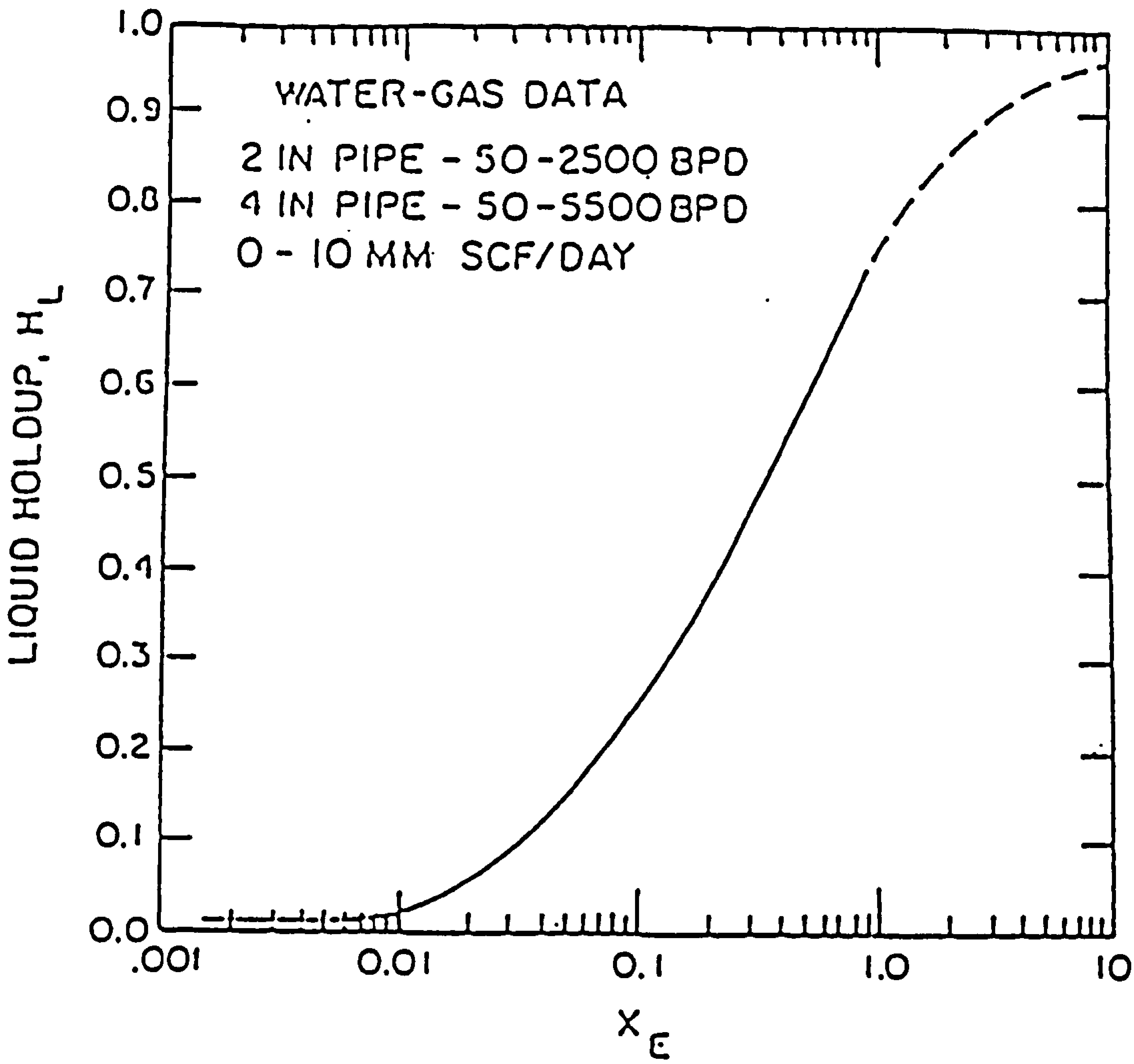


FIG. 2.1.12 Graph of X_E versus H_L. Eaton hold-up correlation.

CHAPTER (3)

CHAPTER THREE

APPARATUS AND GENERAL INSTRUMENTATION

3.1- Test Rig

The layout of the apparatus used in the experimental studies is shown in figure 3.1.1.

The 34 m test section and all other pipe work was made from PVC except 2.55 m clear perspex (observation section). Control valves C1 and C2 were butterfly valves (Crane type mss sp-67) and valves C3 and C4 were gate valves. All of the pipe work was supported by more than 60 welded steel brackets fixed to the walls at a height 1.9 m from floor level. Great care was taken to ensure that these brackets were completely horizontal. This involved the use of laser beam, theodolite, and spirit levels.

A centrifugal pump (Worthington-Simpson monoblock type 4DM6,driven by 30 HP Motor) was used to pump the water from the Water Tank around the circuit, the flow rate being controlled by the valve C1 and the by-pass arrangement to the Water Tank. The water flow rate was measured in terms of the pressure difference across one of the two sharp edged orifice plates (50.75 mm or 88.90 mm diameter depending on the flow rate) inserted into the pipe line at a distance of 41 diameters from bend A. The water then passed to the mixing device, via valve C2, and the emergent air-water mixture entered the test section after traversing two 90° horizontal bends. The mixing device was located at a distance of 35 diameters downstream of the water flow plate as shown in detail in figure 3.1.1, a photograph of the device is also shown in figure 3.1.3. The purpose of the mixer was to promote mixing of the air and the water which entered separately. The water entered through a series of circumferential holes drilled in a blanked off length of flow pipe protruding into the volume chamber of the device. The air also entered via circumferential holes in four blanked off injection pipes inserted radially into the mixer to help break up the air jets and promote mixing. The mixing process was further assisted by wire mesh packing in the volume chamber and at exit from device.

The test section was 34 m long and manufactured from 0.203 m nominal bore PVC tubing with a 2.55 m clear perspex observation section. Thirty six pressure tapping holes 1.6 mm diameter were located initially at 2 m and later 1 m interval along the test section length and diametrically opposite each other on the top and bottom of the tube. The axial positions of these tapping points are shown in figure 3.1.1. The tapping points were all connected to a multi-tube, manometer-piezometer system by means of a flexible connecting tubes as shown in figure 3.1.2 and the photographic views shown in figure 3.1.4. Purging system were also employed in the circuit to free all the connecting tubes from any air lock. Two depth gauges, γ-ray attenuation assembly, and Electromagnetic Flow Meter all constitute part of the test section. Depth gauges and the Gamma ray assembly are given in more details in the chapters 4 and 5 respectively, but the Electromagnetic flow meter figure 3.1.5 is not used in this study.

3.2-Water Flow Rate Measurement

Two orifice plates were used during the experiment to measure the water flow rates. These were installed in the 0.127 m PVC section (41 diameters before the mixing device) and had diameters of 50.75 mm and 88.90 mm for low water flow rates and high water flow rates respectively; a photographic view is shown in figure 3.2.1. These were designed and manufactured according to B.S. 1042 ,1964, more details on the design and calibration of these orifices is given in reference [3].

The calibration results for both orifices were as follows:

Orifice plate 50.75 mm diameter

$$Q = 0.000173\, h^{1/2} \quad m^3/\sec \qquad (3.1.1)$$

Orifice plate 88.90 mm diameter

$$Q = 0.0006256\, h^{1/2} \quad m^3/\sec \qquad (3.1.2)$$

Where, h is the head across the orifice in mm of H_2O.

3.3-Air Flow Rate Measurements

Air flow rates were measured using two orifice plates (depending on the air flow rate needed in a particular test run) designed and manufactured according to British Standard (B.S.) 1042 : part 1 : 1964 . The orifices diameter were 17.525 mm and 41.328 mm, inserted into two air pipeline systems of diameters 25.4 mm and 50.8 mm respectively. The high air flow rates were measured using the 50.8 mm pipeline (41.328 mm diameter orifice plate), and the 25.4 mm pipeline (17.525 mm diameter orifice plate) is designed for low air flow rates. In the present set of experimental results, however, a set of four rotameters, which cover the lower 20% of the flow range, which were previously calibrated according to B.S. 1042 [3] were used for low air flow rate measurements. Photographic views of the assemblies are shown in figure 3.3.1. Detailed design and calibration results is given in reference [3]. The following equations were obtained:

For orifice plate diameter 41.328 mm

$$Q \;=\; 2.632\times10^{-4}\, Z_R\,\varepsilon\left[H\frac{T}{P}\right]^{1}/2 \quad m^3/s \tag{3.3.1}$$

And

$$Z_R \;=\; 1.2434 - 0.02784\,[lnR_d] + 0.000739\,[lnR_d]^2 \tag{3.3.2}$$

and

$$\varepsilon \;=\; 1 - 3.9\times10^{-5}\left[\frac{H}{R}\right] \tag{3.3.3}$$

For orifice plate diameter 17.525 mm

$$Q \;=\; 4.0\times10^{-5}\, Z_R\,\varepsilon\left[H\frac{T}{P}\right]^{1}/2 \quad m^3/s \tag{3.3.4}$$

And

$$Z_R = 2.0244 - 0.2414\,[lnR_d] + 0.1969\,[lnR_d]^2 - 0.00055\,[lnR_d]^3 \quad (3.3.5)$$

and

$$\varepsilon = 1 - 3.466 \times 10^{-5}\left[\frac{H}{R}\right] \quad (3.3.6)$$

Where

Z_R = correction factor dependent on Reynolds No. and area contraction ratio m

ε = expansion factor dependent on pressure and head difference across orifice plate

H = head difference across orifice plate mm H_2O

P = upstream pressure bar

T = upstream temperature K

R_d = Reynolds number based on orifice conditions=3.54 M/μd

μ = viscosity poise

M = mass flow rate kg/s

d = orifice diameter mm

3.4 - Temperature Measurements

The temperature of air and water in different stations along the pipeline were measured using copper-constantan thermocouples. Seven temperature measuring stations were used, two at air supply lines (25.40 mm diameter pipeline for low air flow rates, and 50.8 mm pipeline for high air flow rates) located downstream of the orifice plates, one downstream of the water orifice plate, and four in the test section, two at a distance (one on top and one on the bottom) of 9.074 m from the inlet to the test section, and the other two at a distance of 28.429 m from the inlet. All thermocouple stations are shown in figures 3.1.1 and 3.1.2. All the thermocouples were connected to a multi-channel digital thermometer, which is calibrated to give a direct temperature reading in °C.

3.5 - Pressure And Pressure Gradient Measurements

A total of 36 tapping points were used to measure the pressure distribution along the test section (34 meter long), 23 on the bottom of the tube and 13 on the top, distributed initially at 2 m and later at 1 m intervals, diametrically opposite each other. The axial positions are shown in figures 3.1.1 and 3.1.2. These are all connected by means of flexible tubes to two boards of a multi-tube, manometer-piezometer systems, one for the top tappings and the other for the bottom tappings, photographic view for the two boards is shown in figure 3.5.1. The piezometers were made of 4 mm bore glass tubes and connected to the pressure lines through needle valves. The top of the glass tubes were connected to a common header by plastic tubing. Provisions were made for pressurising the header using the main air supply line, and for measuring the pressure inside the header using an air-mercury, U-tube manometer. Valves were also installed at each branch point from the header and these, in conjunction with the valves at the inlet to the piezometers, allowed flexibility and isolation of any of the pressure lines without affecting the whole unit. Pressure pulsations on the manometer-piezometer unit were throttled using clamps on the plastic tubing at the inlet to piezometers. Due to the fluctuation involved, and the time taken to read all pressure readings in all tapping points for each test; a Camera was used to take all points at an instant of time to improve the pressure gradient measurement accuracy, and to minimize the time taken for each test to maintain the steady state condition. All the piezometers reading was kept in view of the Camera by adjusting the air pressure in the common header.

3.6 - Purging System

When measuring pressure, it is important to keep the pressure lines (when filled with liquid) free from bubbles which could cause errors due to gravity, capillary action, etc. This can be difficult with two phase flow were pressure fluctuations or flow instabilities tend to force the lighter phase into the pressure line where it is trapped. It is therefore, necessary to purge all the pressure lines before any readings are taken. All pressure lines were connected to a purging system (from the mains) through a needle valves at the piezometer inlets. In the present number of tests, only the bottom pressure tappings were used, which minimized the need for frequent purging, during each set of tests, because of the fact that the bottom of the tube was always occupied by the liquid (water) phase. Figure 3.1.2 shows the purging lines for the test section pressure tappings, and for water orifice plate.

3.7 - Void Fraction Apparatus

Void fraction measurements were made at a point in the test section 28.067 m from the inlet, the flow conditions being settled at this point. The measurements were made using a traversing vertical γ-ray densitometer apparatus specially designed and constructed for the purpose. Full details are given in chapter 5.

FIG. 3.1.1 ARRANGEMENT OF EXPERIMENTAL TEST RIG LAYOUT

FIG. 3.1.2 AIR SUPPLY SYSTEM & GENERAL INSTRUMENTATION

Figure 3.1.3 Air Water Mixer Arrangement

1 - 5 inch (127 mm) Diameter Tube

2 - Air Water Mixer

3 - 8 inch (203 mm) Diameter P.V.C. Tube

4 - Air Nozzle (Air Inlet To The Mixer)

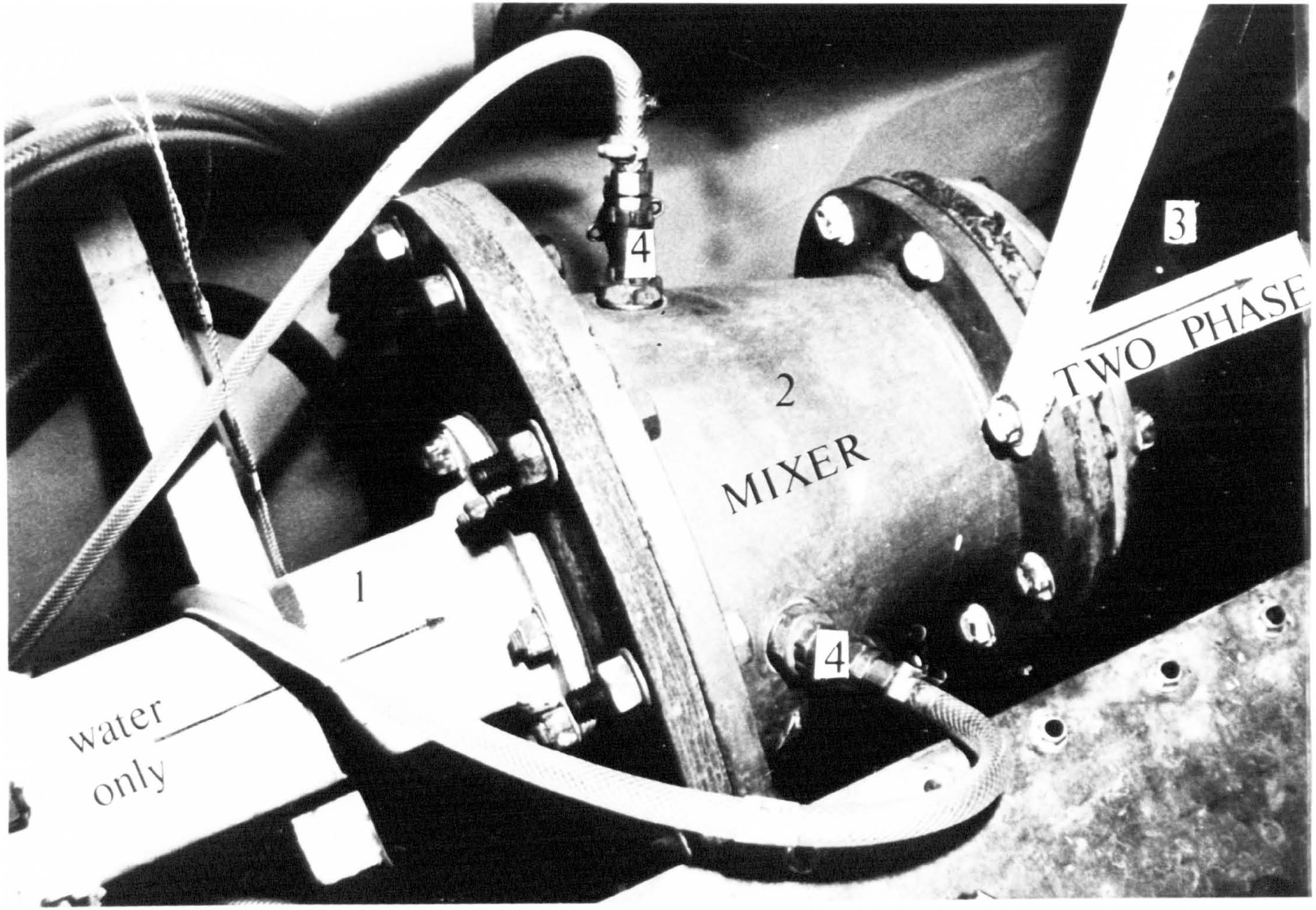


FIG. 3.1.3

Figure 3.1.4 Photographic view of manometer-piezometer system (Board No. 1)

1 - Bottom Valve Manifold

2 - Electronic Capacitance Piezometer (Electronic Circuits In Perspex Box) N/A*

3 - Capacitance Piezometer Bank (C.P.B.)

4 - Top Valves Manifold

5 - Air Manifold

6 - Prespex tube supports (Total Number 4)

7 - C.P.B. Cover (perspex sheet 1900 mm x 900 mm x 10 mm)

* N/A Not applicable (i.e not used)

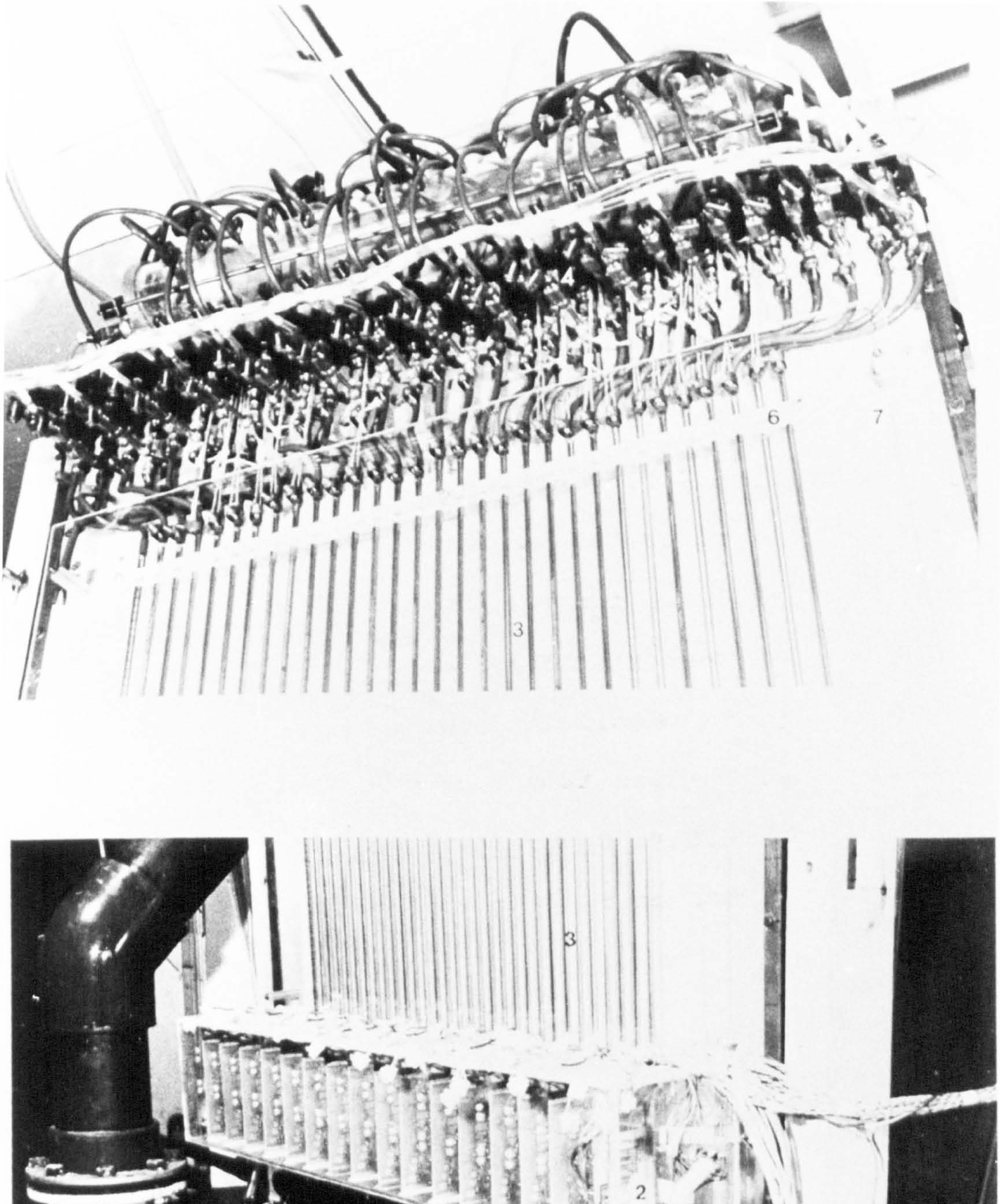


FIG.3.1.4

Figure 3.1.5 Photographic View Of The Electromagnetic Flow Meter

1 - Electromagnetic Flow Meter

2 - Supporting Steel Frame

3 - Pressure Tapping Point (top)

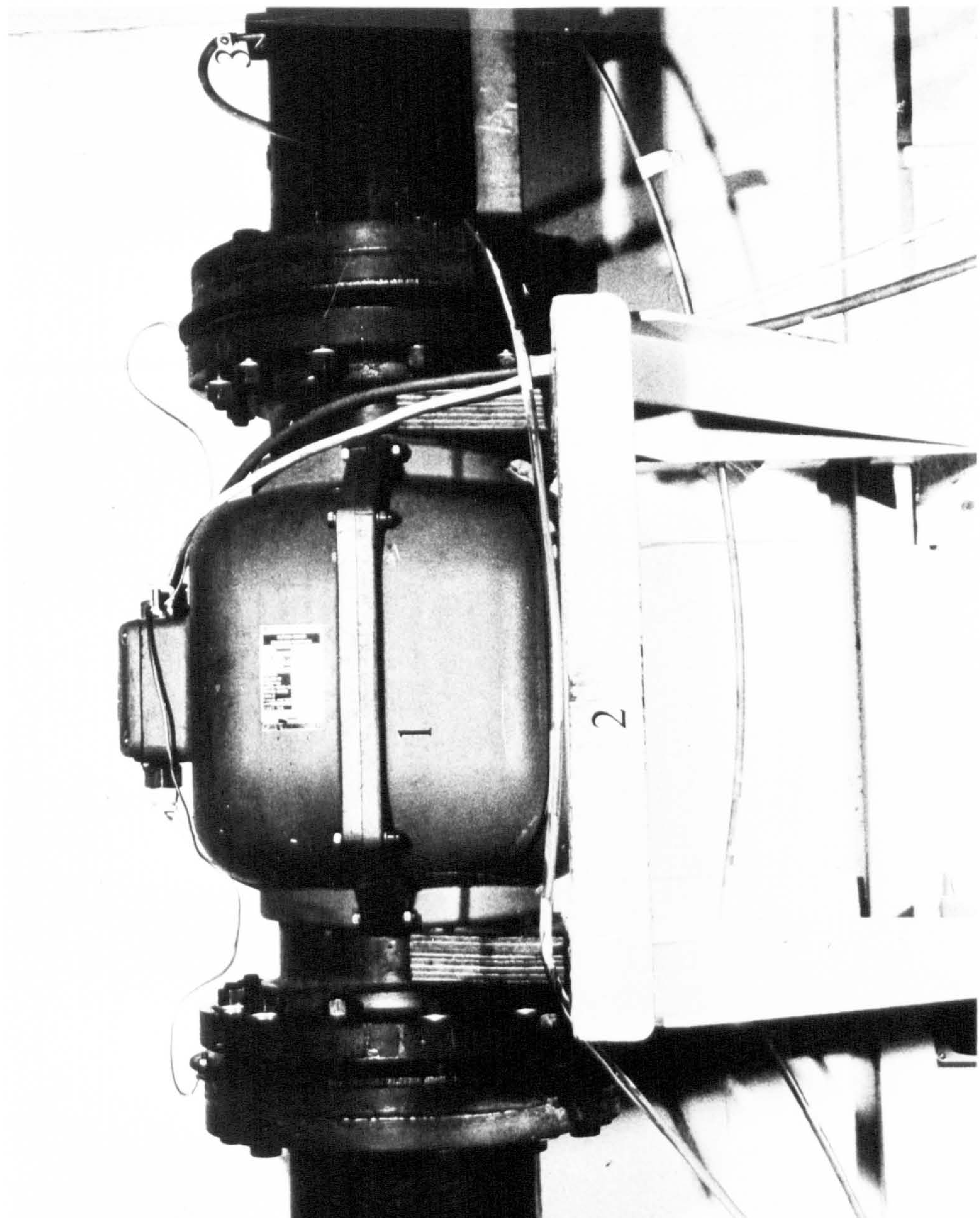


FIG. 3.1.5

Figure 3.2.1 Water Orifice Plate

1 - Water Orifice Plate

2 - 5 inch Diameter Pipeline

3 - Low Pressure Orifice Tapping

4 - Absolute Pressure Transducer N/A

5 - Differential Pressure Transducer N/A

6 - Thermocouple (Temperature Measurement)

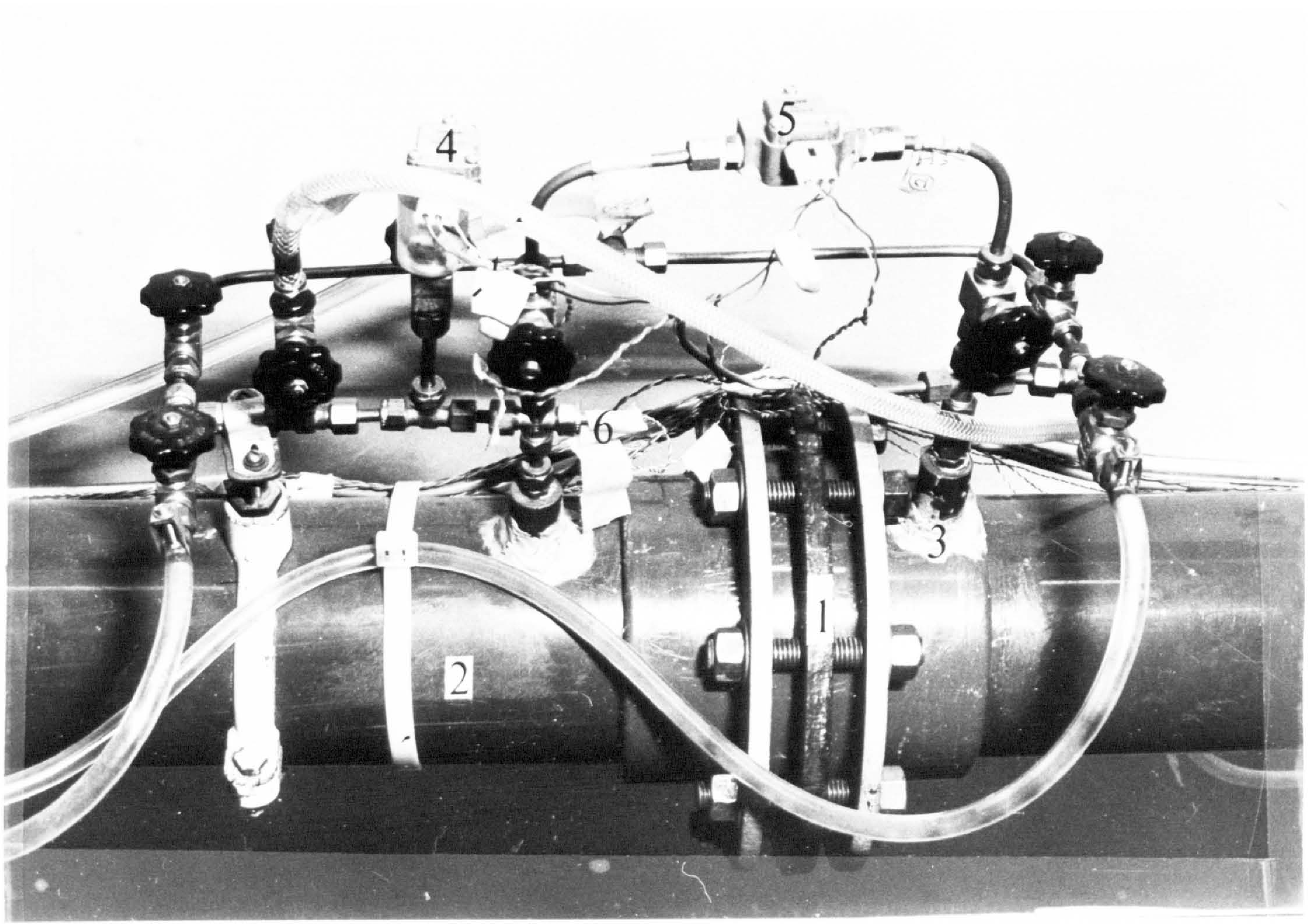


FIG. 3.2.1

Figure 3.3.1a 2 inch Air Orifice Plate

1 - 2 inch Air Pipeline

2 - 2 inch Orifice Plate

3 - Thermocouple (Temperature Measurement)

4 - Absolute Pressure Transducer N/A

5 - Differential Pressure Transducer N/A

Figure 3.3.1b 1 inch Air Orifice Plate

6 - 1 inch Air Pipeline

7 - 1 inch Orifice Plate

8 - Thermocouple

9 - Absolute Pressure Transducer N/A

10 - Differential Pressure Transducer N/A

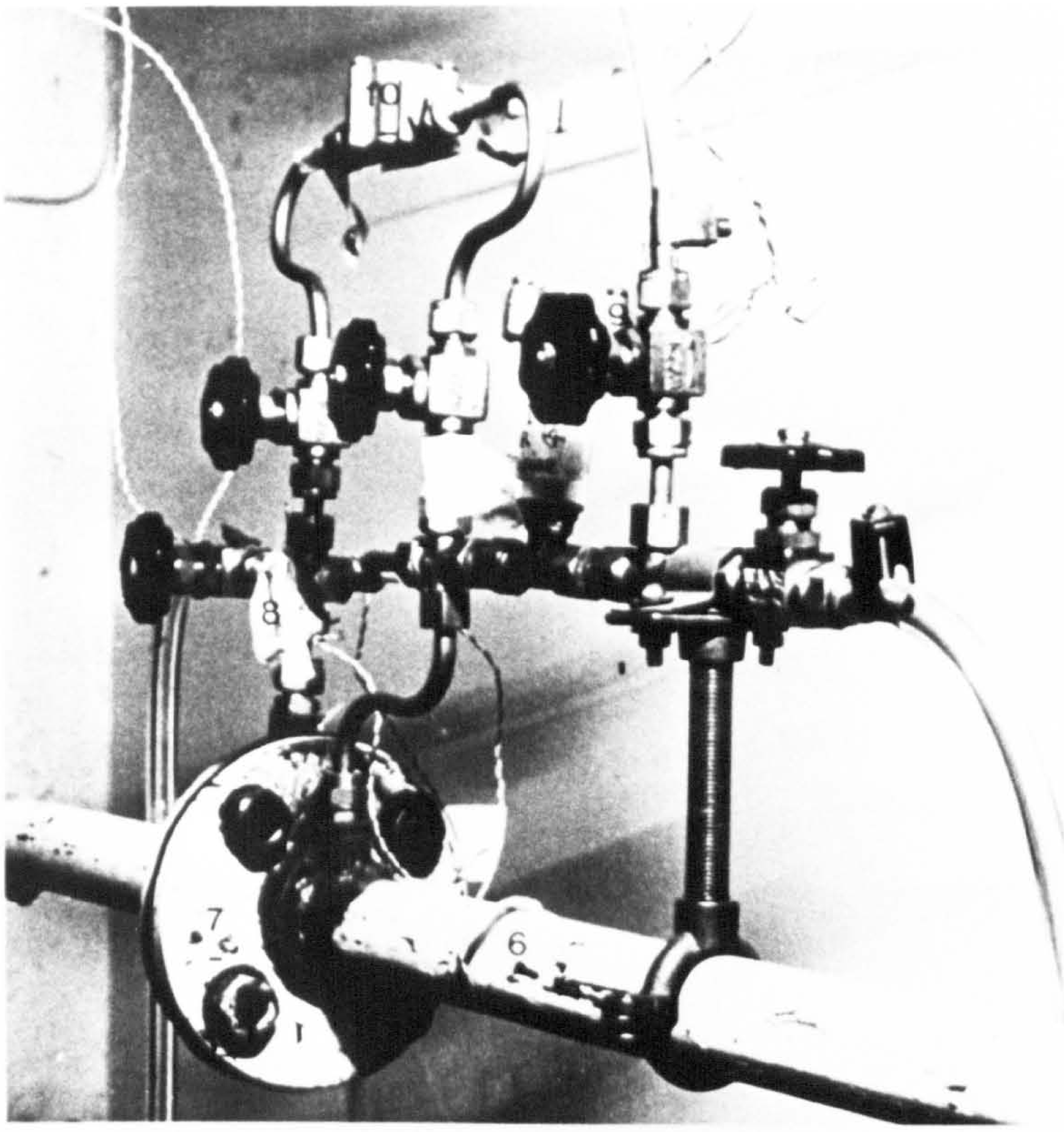


FIG. 3.3.1a

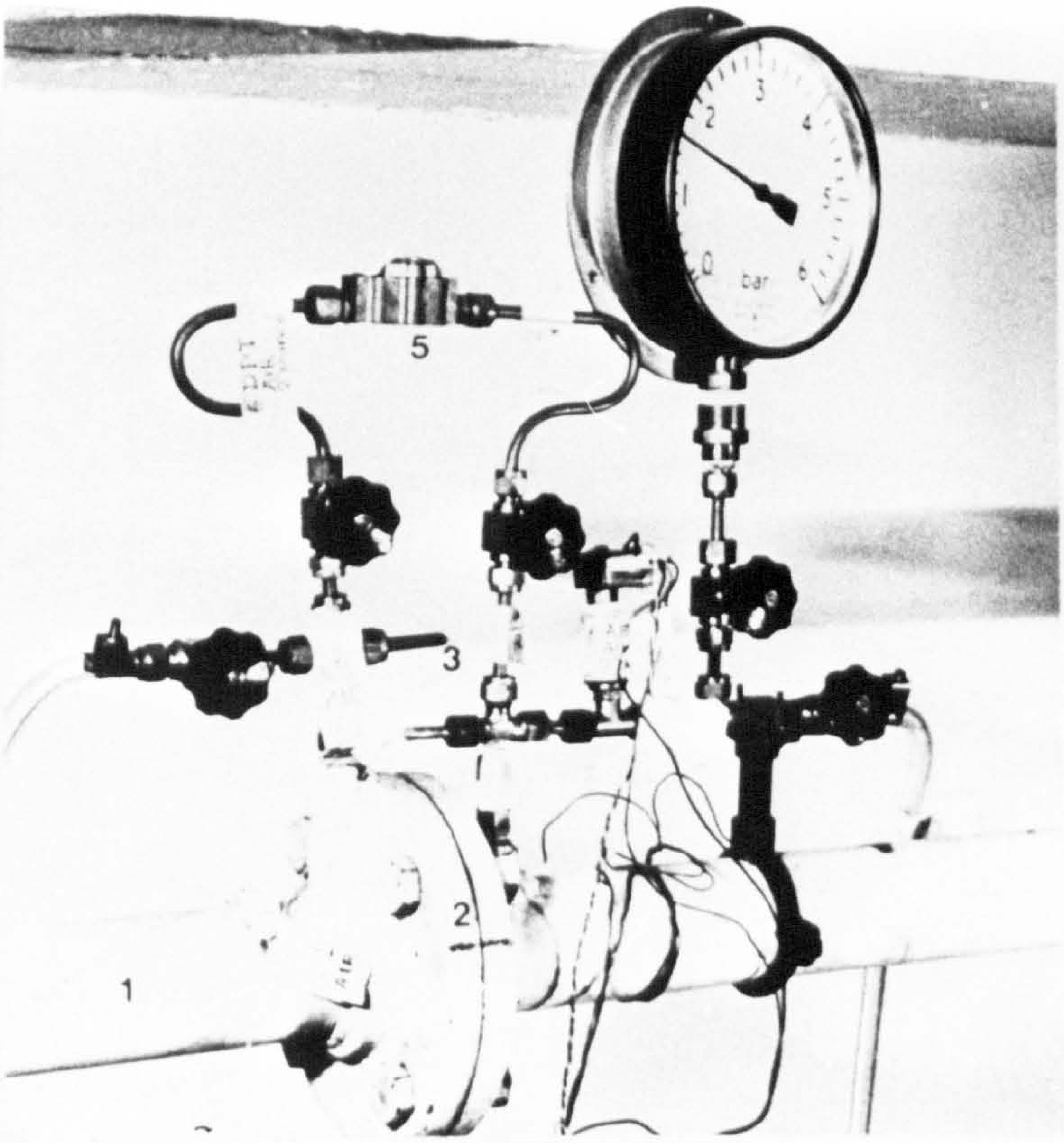


FIG. 3.3.1b

Figure 3.5.1 Manometer-Piezometer Boards

A. Board No. 1, B. Board No. 2

1 - Board Frame

2 - Bottom Valve Manifold

3 - Electronic Capacitance Piezometer (Electronic Circuits In Perspex Box) N/A

4 - Capacitance Piezometer Bank (C.P.B.)

5 - Top Valves Manifold

6 - Air Manifold

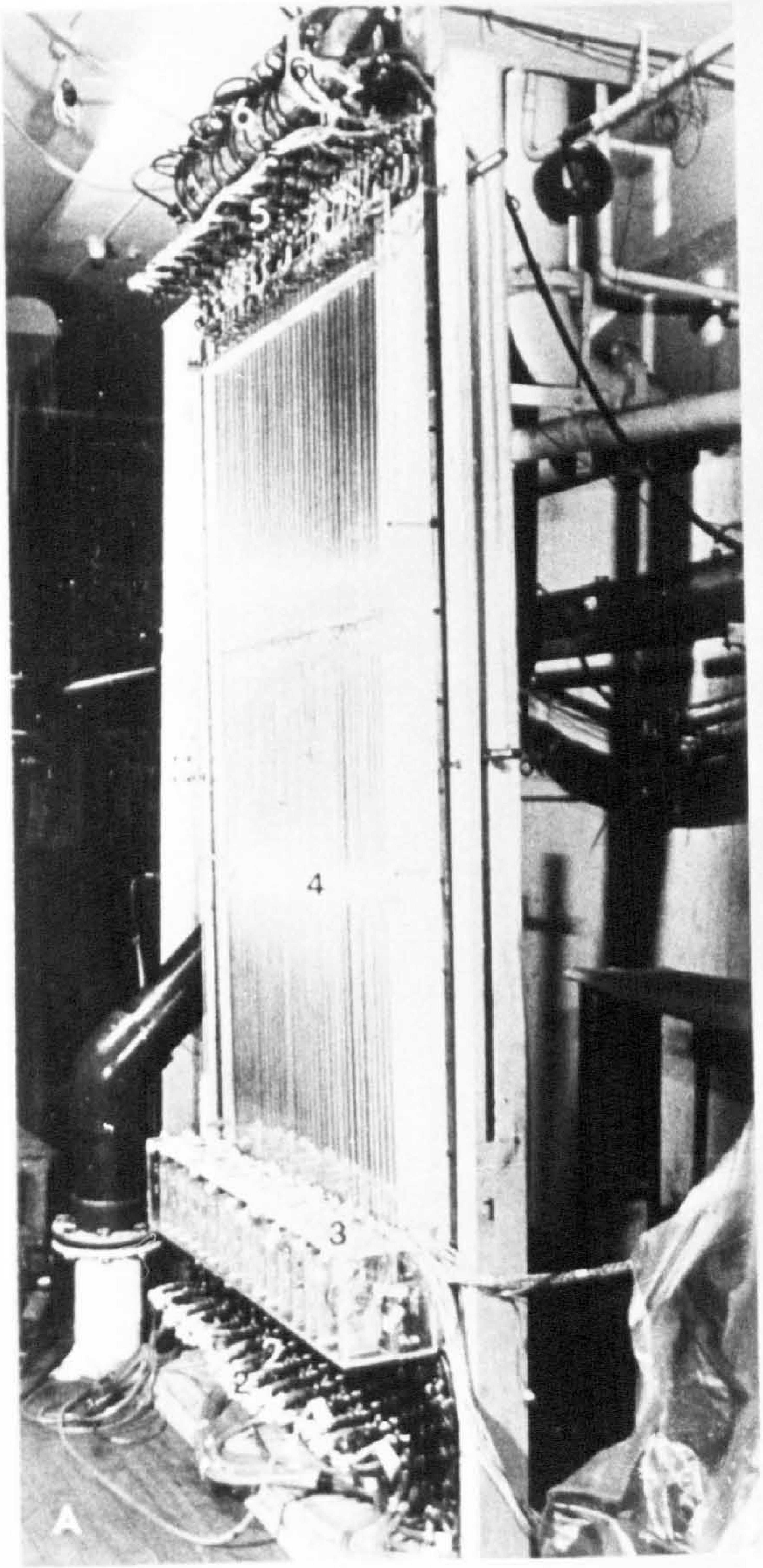


FIG.3.5.1a

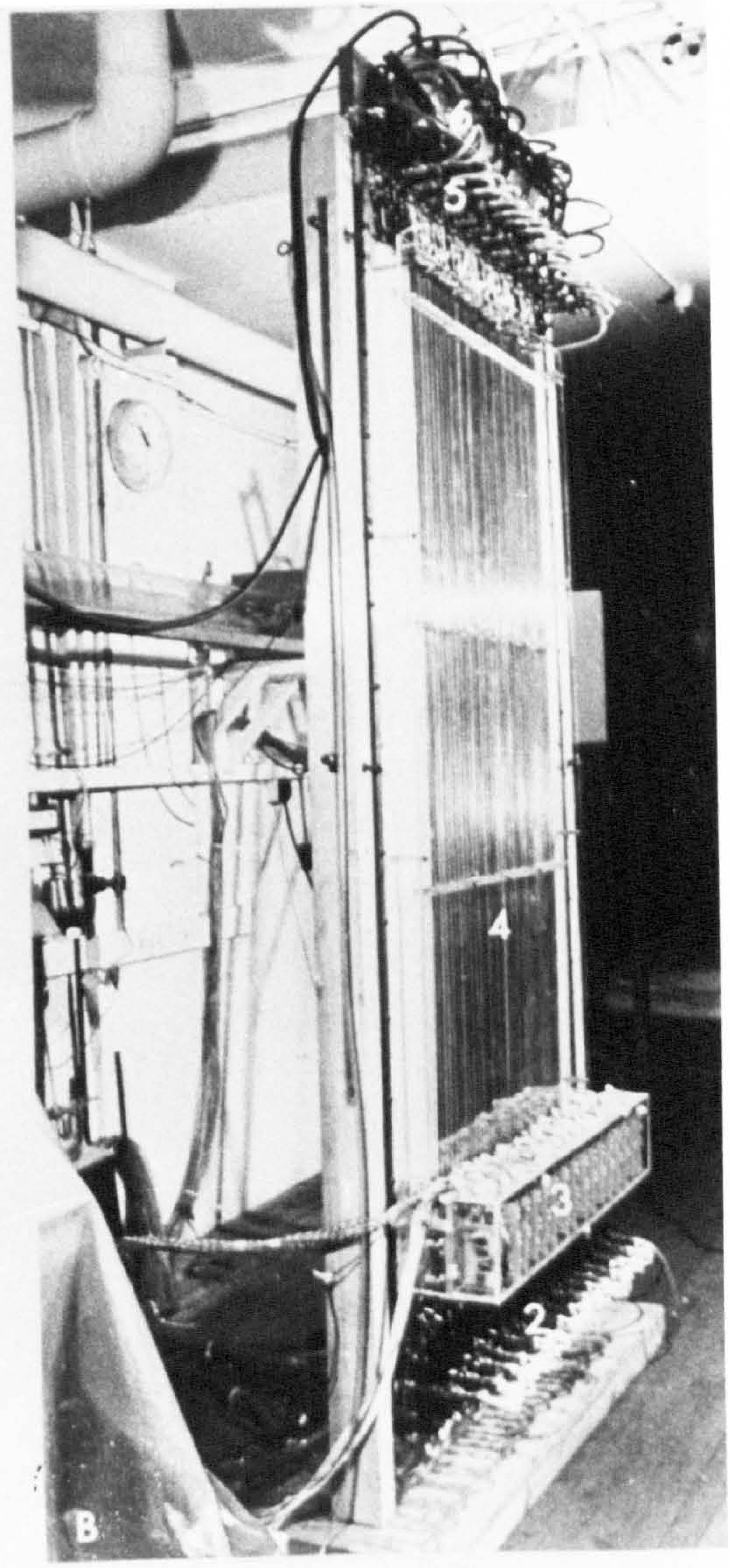


FIG.3.5.1b

CHAPTER (4)

CHAPTER FOUR

WATER LEVEL CHANGE MEASUREMENTS (Hydraulic Gradient)

Two depth gauges, two wave monitors, analog to digital (AI13) card and an Apple computer were the main items of instrumentation used to measure the water level change in a 203 mm diameter tube during stratified flow conditions. The description of each of them is given below.

4.1- Depth Gauge

The standard form of a depth gauge (probe) consists of a pair of parallel stainless steel wires, 1.5 mm in diameter and spaced 12.5 mm apart. However the design of the drive and sensing circuits in the wave monitor enables a very wide variety of probe configuration to be employed. The instrument is a simple and robust device for the measurement and recording of water waves in hydraulic models and ship tanks. It works on the principle of measuring the current flowing in the parallel stainless steel wires. The probe is energised with a high frequency square wave voltage from the wave monitor unit to avoid polarisation effects at the wire surfaces. The wires dip into the water and the current that flows between them is proportional to the depth of immersion. The current is sensed by an electronic circuit which provides an output voltage proportional to the instantaneous depth of immersion i.e water level. The output voltage can be calibrated in terms of water height by varying the depth of immersion of the probe in still water by a measured amount, and noting the change in output signal (see the calibration procedure).

4.1.1- Depth Gauge Design

The design procedure followed to construct a suitable configuration for the purpose required was a lengthy trial and error procedure as may be expected. The first configuration chosen was that of the standard form i.e a pair of parallel stainless steel wires, 1.5 mm in diameter and spaced 12.5 mm apart, with the length of the wires limited by the tube diameter and the minimum length needed for the job. This standard form was constructed and tested, but did not work (no signal was detected); the 12.5 mm spacing is associated with long lengths of wire used in hydraulic models, ship tanks and support structures . The length of wire in this experimental work was limited by the internal diameter of the pipeline (203 mm). It was therefore necessary to determine a wire spacing appropriate to the shorter length design. A trial and error procedure was employed, involving the change of the spacing, wire diameter and to very limited extent the length of the wires (limited by the tube diameter and the minimum length required). Many combination were constructed, tested and calibrated which took a very long time (from the research time) than what was intended. *The best combination found is that of the two parallel stainless steel wires of diameter 2 mm, spaced 6 mm apart, and with wires length of 181.5 mm. The two wires were then fitted into a special plug (figures 4.1.1 and 4.1.2) and fitted into the pipeline.* The spacing between the wires was guarded by the PVC plug at the top and a small piece of perspex at the bottom (figure 4.1.1). The bottom face of the plug was machined in such a way that it coincides with the inside curvature of the tube when positioned in the PVC square block which welded to the tube. The shaping of the plug in situ to the inside curvature of the tube prevents any disturbance to the flow. Also in this design an account was taken to keep the two stainless steel wires in line with each other in the direction of the flow, again to minimize the disturbance of the flow.

4.2- Wave Monitor Unit

This is a standard double wave monitor unit made by Churchhill Controls. The unit is divided into three modules; A.C. Power supply module and two wave monitor modules; one for each probe. All are assembled and rack mounted in special casing. The A.C. power supply is mains operated and provides regulated D.C. output voltages of + and - 15 volts with a sufficient capacity to operate 7 wave monitor modules. The associated wave monitor module carries the energisation and sensing circuits and means for compensating for the resistance of the probe connecting cable. When probes are used in close proximity to each other each of the wave monitor modules can be energised at different frequency to avoid mutual interaction. The wave monitor module is also provided with two other functions; SET DATUM which enables the output signal to be set zero, i.e to earth potential, for any initial depth of probe immersion, and SET OUTPUT which attenuates the output signal and enables it to be set to a value between zero and ± 10 volts.

In the present study the datum (zero signal) was set at the point when the probe is fully immersed in water i.e at tube full (water only). This datum was chosen so that it can be checked and readjusted if needed at any time during the testing. The disadvantage of having zero datum signal at tube full is that the signal received for other depths of liquid will be negative, and had to be converted to positive signal to suit one of the full-scale ranges of the AI13 (computer card) for better accuracy.

4.3- A/D Converter (AI13)

The AI13 analog input system is a high-performance 12-bit data acquisition system for the apple II computer. It plugs directly into one of Apple expansion slots (in slot 3 in the present case) and gives the Apple the ability to make precision voltage measurements. The AI13 is designed to accept analog voltage inputs and to output sampled voltages conditioned for analysis by the computer program. It can select one of 16 input channels, scale the input according to one of 8 full-scale ranges, and return the result in less than 20 micro seconds. The signal was adjusted to a maximum acceptable by the computer of 5 volts.

4.4- Calibration Procedure

An overall calibration from water heights to output voltages was performed by the set-up shown on figures 4.4.1 and 4.4.2. The probe was attached to a Height Gauge Vernier as shown (figure 4.4.2), and the change in output voltage was noted when the probe is raised or lowered by a known amount (20 mm in this calibration) in still water. A computer program was written to enable the apple computer to accept the processed signal from the AI13. The program was designed to take ten readings for each step, each of which is an average of ten readings. Then 8 of the averaged readings were again averaged (the maximum and the minimum readings were rejected) to get the final answer (this did not make any appreciated change to the answer during calibration). The program used for calibration and the program used for actual testing are both given in appendix D. The calibration results are shown in figures 4.4.3 and 4.4.4 for both probes. In situ calibration was also preformed for different water levels (still water levels) in the test section, the readings for both probes were noted and plotted on figure 4.4.5. The recorded height difference between the two probes is zero up to a depth of water in tube equal to 80 mm, thereafter the difference increases to 2.5 mm as the depth increases to 170 mm. Most data were up to 135 mm depth of water with a corresponding difference of ~ 1 mm. All data were corrected accordingly.

Figure 4.1.1 Photograph Of The Depth Gauge (Probe)

1 - Two Stainless Steel Wires

2 - Perspex Piece (Bottom End Holder)

3 - PVC Plug

4 - Perspex Piece With Two Sockets For Connecting Cable

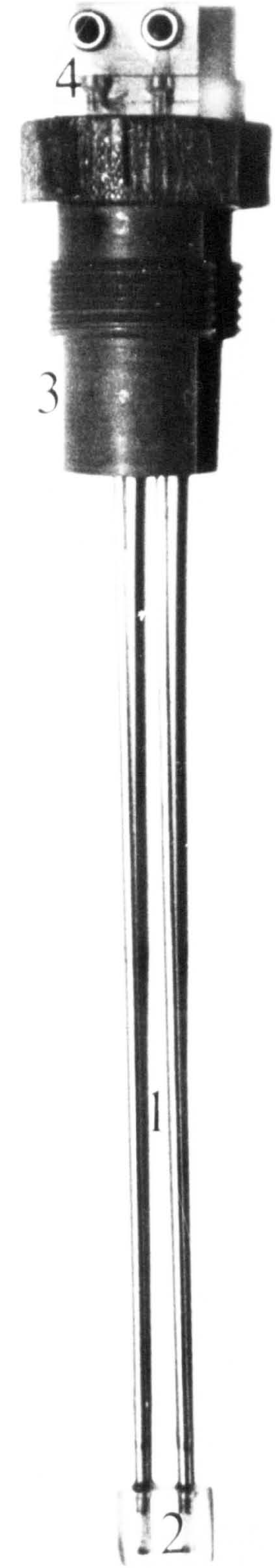


FIG. 4.1.1

Figure 4.1.2 Depth Gauge Arrangement In The Test Section

1 - 8 inch (203 mm) Diameter P.V.C. Tube

2 - PVC Square Block Welded To The 8 inch Diameter Tube

3 - PVC Plug

4 - Connecting Cable

5 - Perspex Piece

6 - Banana Plug

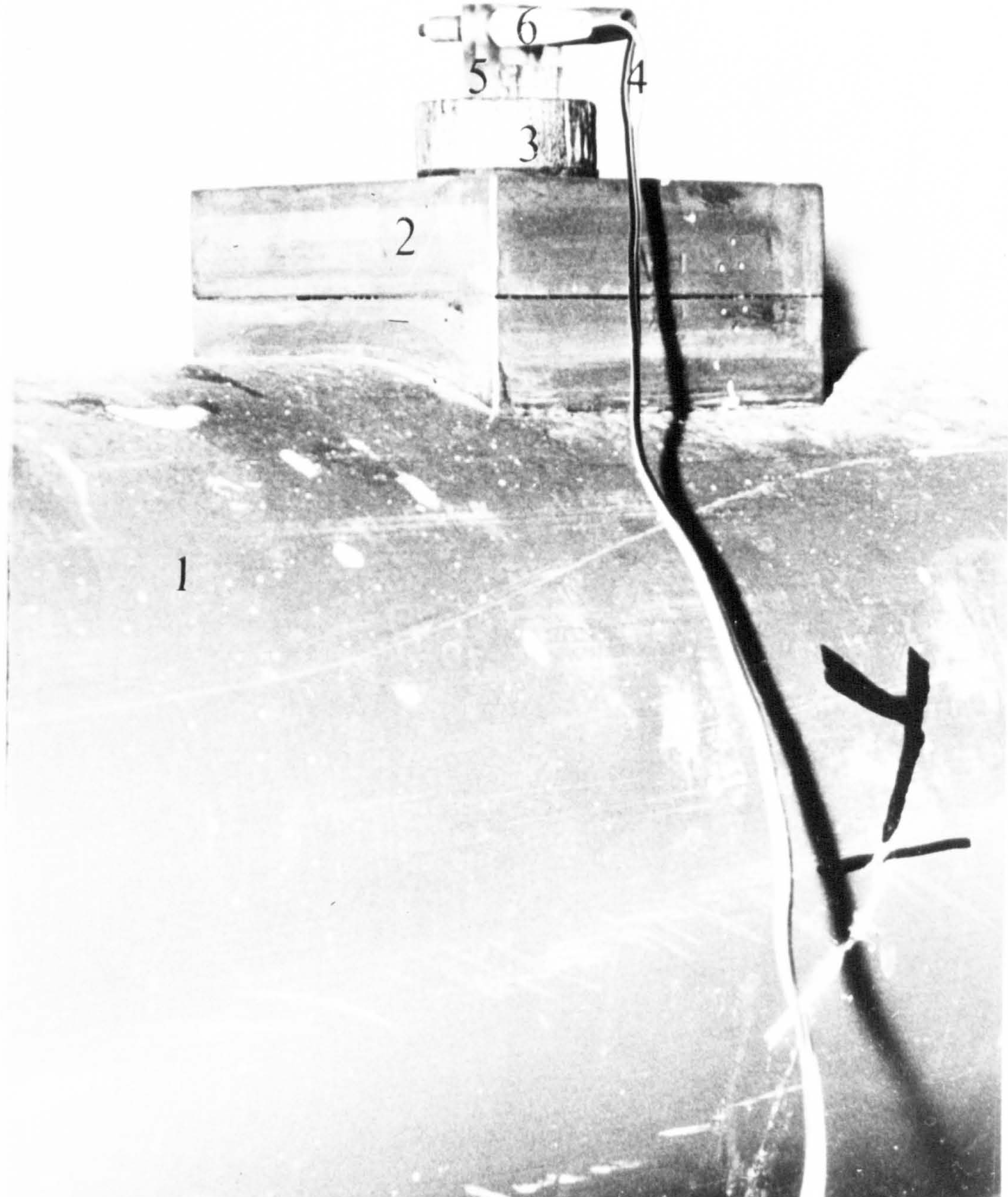


FIG. 4.1.2

Figure 4.4.1 Photogaph Of The Calibration Set-up

1 - Two Stainless Steel Wires

2 - Glass Container Filled With Water

3 - Height Gauge Vernier

4 - Wave Monitor Unit

5 - Digital Volt Meter

6 - Power Supply Filter

7 - Signal Converter (From Negative To Positive Signal)

8 - Apple II Computer

9 - Printer

10 - A/D Converter

11 - Probe Holding Clamp

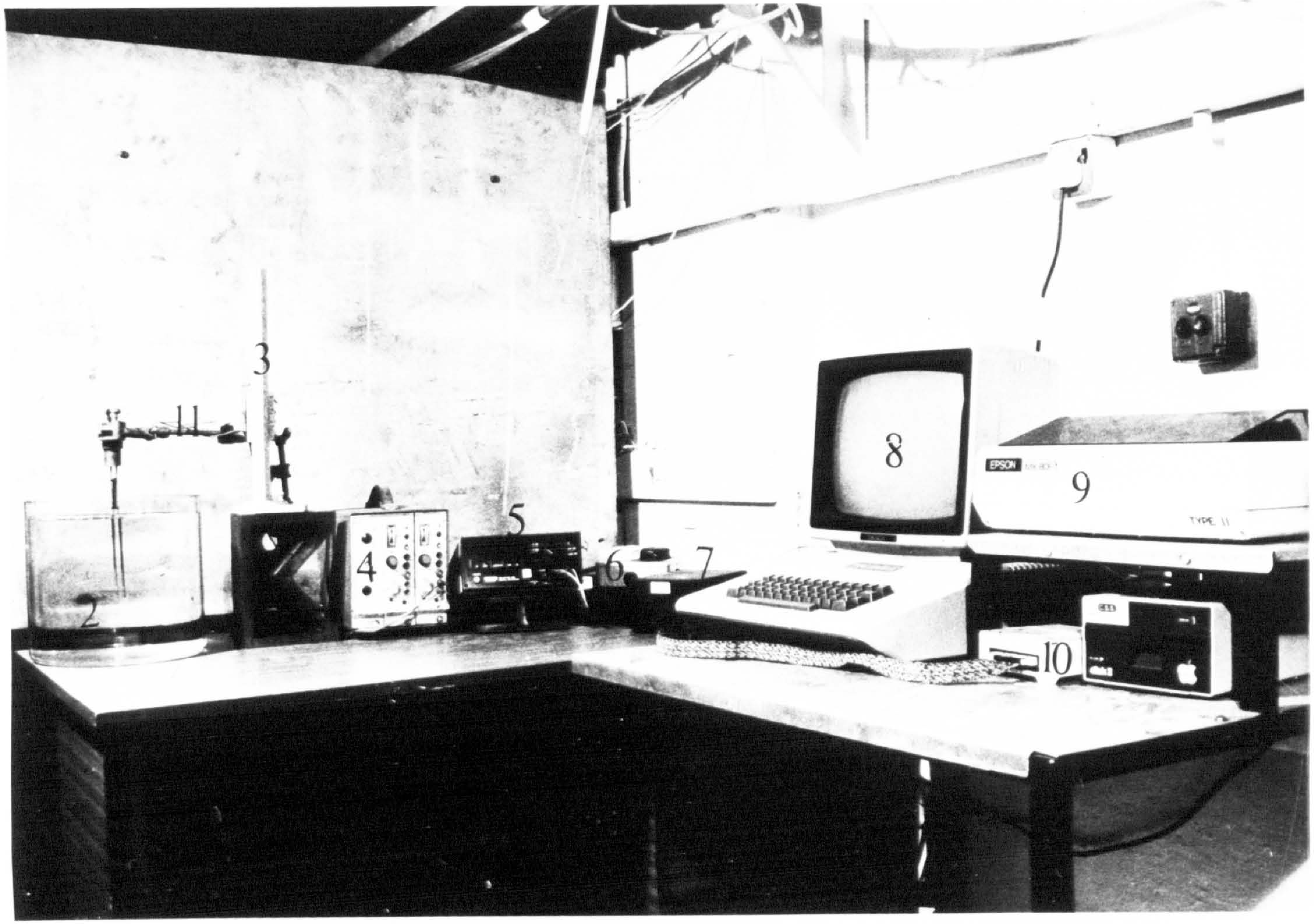


FIG. 4.4.1

Figure 4.4.2 Photogaph Of The Calibration Set-up

1 - Two Stainless Steel Wires

2 - PVC Plug

3 - Glass Container Filled With Water

4 - Probe Holding Clamp

5 - Height Gauge Vernier

6 - A.C. Power Supply Module

7 - Wave Monitor Module For Probe One

8 - Wave Monitor Module For Probe Two

9 - Power Supply Filter

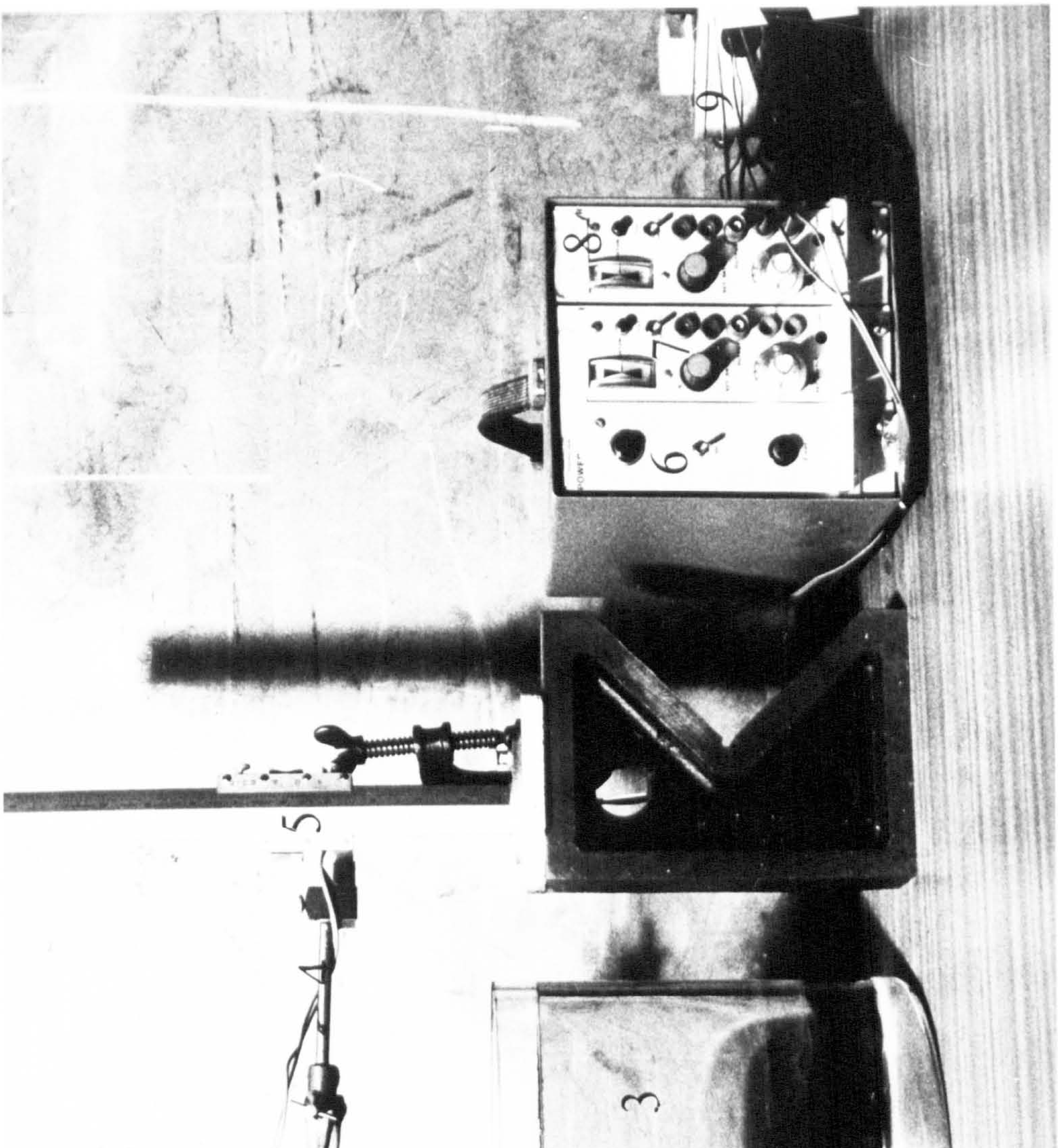


FIG. 4.4.2

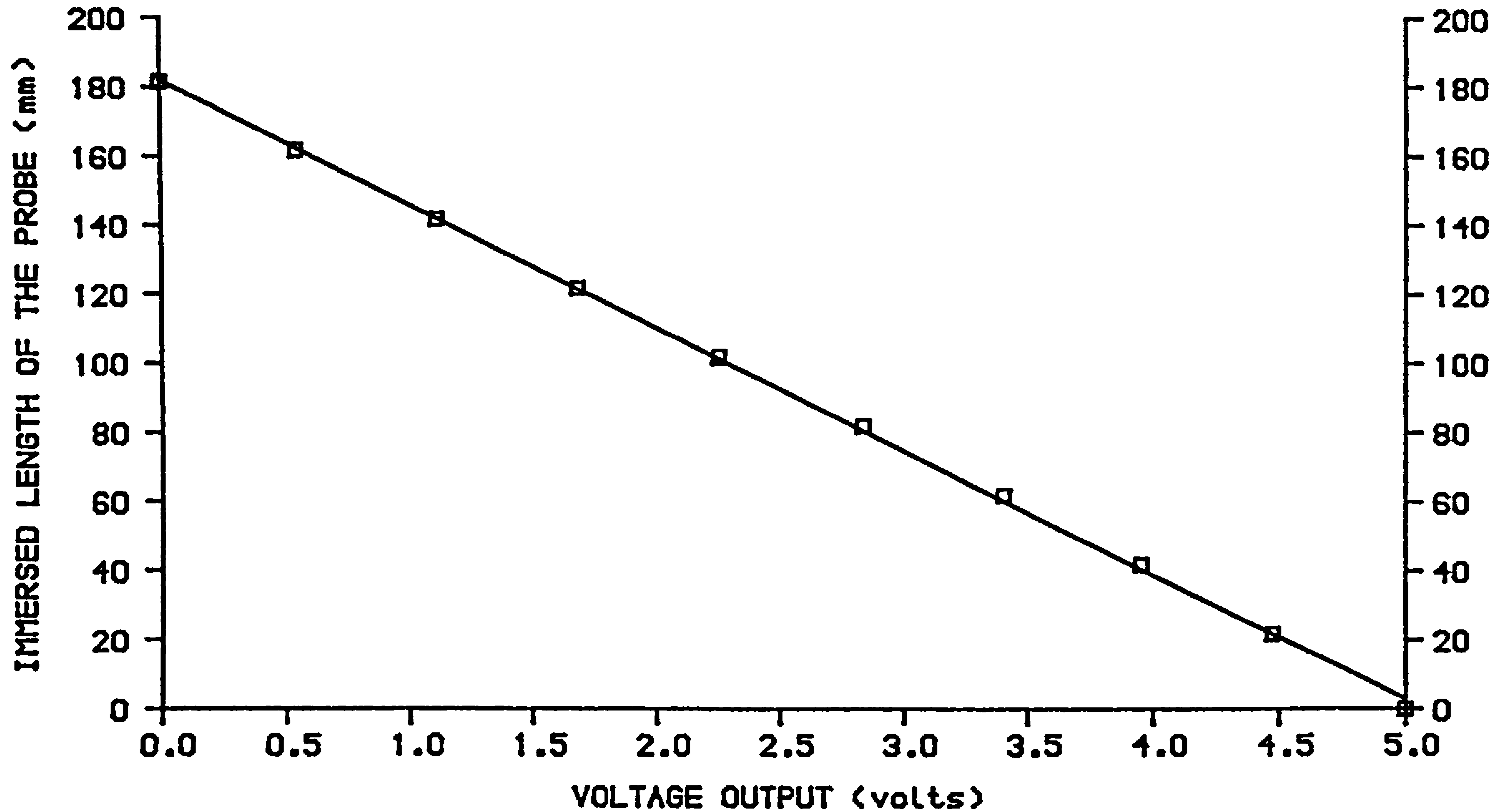


FIG. 4.4.3 PROBE ONE CALIBRATION RESULTS

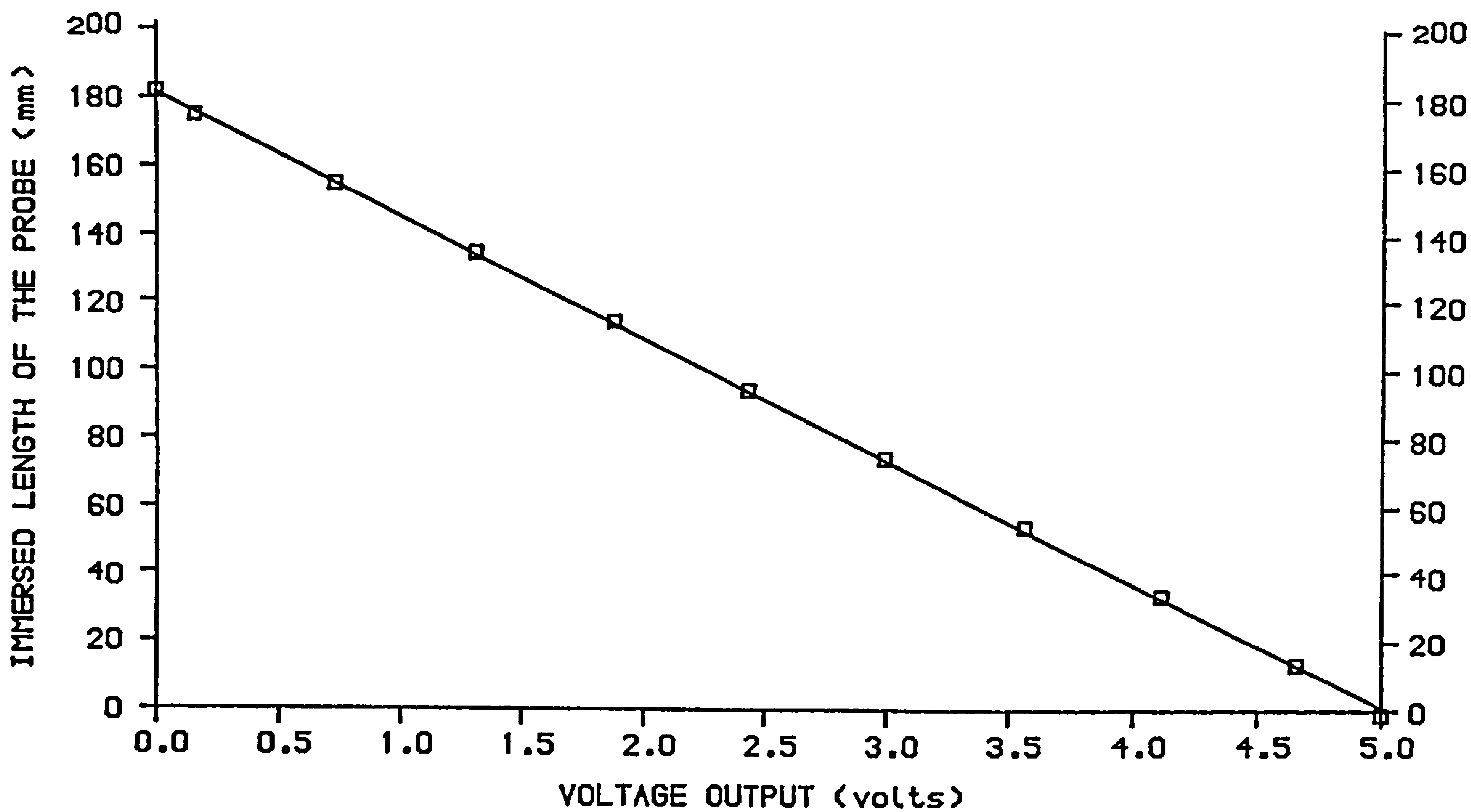


FIG. 4.4.4 PROBE TWO CALIBRATION RESULTS

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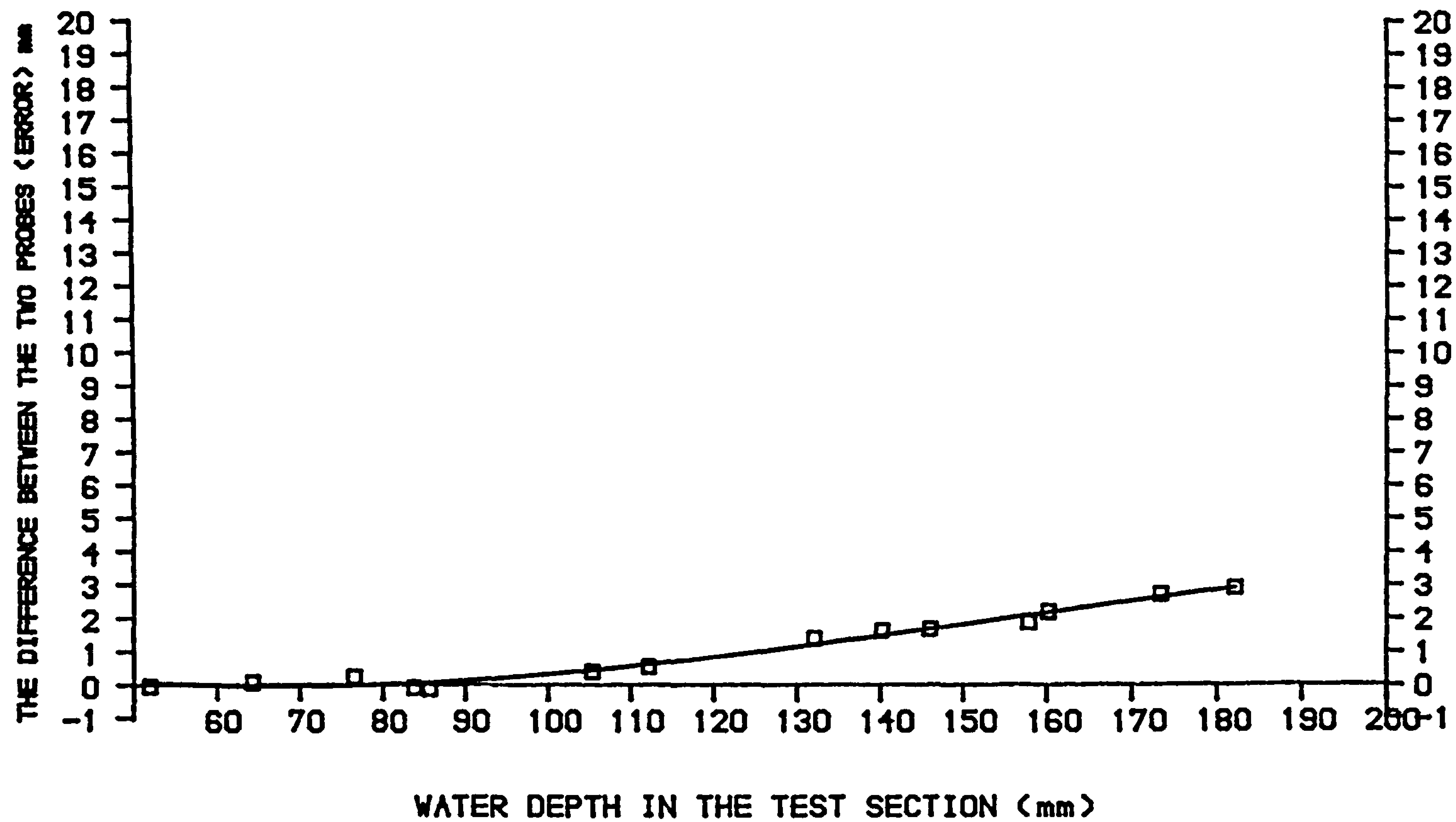


FIG. 4.4.5 IN SITU CALIBRATION RESULTS

CHAPTER (5)

CHAPTER FIVE

VOID FRACTION MEASUREMENT TECHNIQUE, APPARATUS AND CALIBRATION

Void fraction measurements were made at a point in the test section 28.067 m from the inlet. The flow conditions at this point are settled. The measurements were made using a traversing vertical γ-ray densitometer apparatus especially designed and constructed for the purpose.

In this apparatus, a narrow beam of γ-rays (~ 3 mm) was allowed to pass through a chordal section of the tube and attenuated according to the density (and hence the void fraction) of the fluid in the chordal strip. By traversing the beam, in steps across the whole tube cross-section, a distribution of chordal densities or void fraction could be obtained by measuring the degree of attenuation. Integration of the chordal void fraction values over the total cross-section gave the mean void fraction in the tube.

The radioactive source of γ-rays used in this experiment was Caesium 137, half life 33 years and peak energy value 0.662 Mev.

5.1 Principle of γ-Ray Attenuation Technique

A vertical beam of γ-rays emitted from the radioactive source is collimated into a thin strip beam and allowed to pass through the tube. In passing through the tube, the beam is attenuated to a degree dependent on the density of the tube contents. Thus the intensity of the emergent (attenuated) beam is a measure of the tube contents density or voidage.

The intensity of the emergent beam is measured by allowing the γ-rays to impinge on a Sodium-Iodide crystal and produce light flashes or scintillations. The light photons produced impinge on the photo-cathode of a multi-stage photomultiplier tube and releases a photo-electron which passes down the tube. Each stage of the photomultiplier tube gives an electron gain, giving an overall gain in the photomultiplier tube of about 10^6. The signal voltage from the anode of the photomultiplier is fed to an amplifier and hence to a pulse height analyser, the amplitude of the voltage pulses being proportional to the energy of the γ-rays absorbed by the crystal. The function of the pulse height analyser is to impose an upper and lower voltage barrier so that only voltage pulses within a fixed amplitude range are allowed to pass through, this provides a facility for rejecting the effects of lower energy stray or scattered γ-rays on the crystal.

The voltage pulses from the pulse height analyser pass to a counting and timing unit which allows a display of the number of γ-rays absorbed by the crystal to be made. In addition, a D.C. pulse voltage is produced which is proportional to the pulse repetition rate and this voltage, suitably amplified, is coupled to a meter to give a measure of the count rate.

The basic apparatus required for the γ-ray attenuation technique is shown diagrammatically in figure 5.1.2, and photographic view of all the apparatus in position are shown in figure 5.1.1.

5.2 - Measurement of Chordal Void Fraction

Consider the attenuation of a series of γ-rays passing through a medium of thickness x and density ρ as shown in figure 5.2.1, where I_o is initial intensity of the beam and I_x is the intensity of attenuated beam.

The two intensities I_o and I_x are related to each other by the exponential equation;

$$I_x = I_o e^{-\mu \rho x} \tag{5.2.1}$$

where μ is the mass absorption coefficient for γ-rays which depends on the type and wavelength of the radiation employed.

Thus taking the natural log of equation 5.2.1 we get;

$$lnIx = a - b\rho \tag{5.2.2}$$

where a and b are constants.

For the case of multiphase flow the mean density of the mixture must be used. Therefore equation 5.2.2 for the case of multiphase flow takes the form;

$$lnI_x = a - b\rho_m \tag{5.2.3}$$

For a chordal path through a tube as illustrated in figure 5.2.3, the γ-ray beam passes through a composite medium of air, perspex (tube wall) and tube contents. Under these conditions equation 5.2.1 becomes;

$$I_x = I_o e^{-\mu(\rho_a x_a + \rho_p x_p + \rho_m x)} \tag{5.2.4}$$

where a, p, m are the air, perspex and mixture respectively.

Again by taking natural log equation 5.2.4 becomes

$$\begin{aligned} lnI_x &= lnI_o - \mu(\rho_a x_a + \rho_p x_p) - \mu\rho_m x \\ &= A - B\rho_m \end{aligned} \tag{5.2.5}$$

where

$$A = lnI_o - \mu(\rho_a x_a + \rho_p x_p) = constant$$

$$B = \mu x = constant$$

Consider a two-phase mixture flowing in a duct of cross-section area A and length dz as shown in figure 5.2.2. The mean density of the mixture in the element is;

$$\begin{aligned} \rho_m &= \frac{\text{mass of mixture}}{\text{volume of the element}} \\ &= \frac{(\rho_g A_g dz + \rho_f A_f dz)}{(A_g + A_f)dz} \\ &= \left[\frac{\rho_g A_g}{A}\right] + \rho_f \frac{(A - A_g)}{A} \end{aligned}$$

$$\rho_m = \alpha\rho_g + (1-\alpha)\rho_f$$
$$= \rho_f - \alpha(\rho_f - \rho_g) \qquad (5.2.6)$$

where ρ_g, ρ_f are the densities of the gas and the liquid respectively.

Therefore, for a given combination of liquid and gas

$$\rho_m = C - D\alpha \qquad (5.2.7)$$

where C and D are constants

Combining equations 5.2.5 and 5.2.7

$$lnI_x = E + F\alpha \qquad (5.2.8)$$

where E and F are constants.

From equation 5.2.8 it is clear that there is a linear relationship between the natural log of the emergent intensity of the γ-rays beam and the chordal void fraction. Hence for a tube full of liquid $\alpha = 0.0$ and

$$(lnI_x)_{full} = E \qquad (5.2.9)$$

and for tube empty $\alpha = 1.0$ and

$$(lnI_x)_{empty} = E + F \qquad (5.2.10)$$

Combining equations 5.2.8, 5.2.9 and 5.2.10 the following expression for the chordal void fraction is obtained;

$$\alpha = \frac{[lnI_x - (lnI_x)_{full}]}{[(lnI_x)_{empty} - (lnI_x)_{full}]} \qquad (5.2.11)$$

Hence, from equation 5.2.11 it is clear that if the count rate from the scintillation counter, for tube empty, tube full and for tube containing two-phase mixture are known; the chordal void fraction for the two-phase mixture can be obtained.

If the distribution of chordal void fraction is obtained; the mean void fraction for the two-phase mixture can be calculated by integrating the chordal void fraction.

Details of the evaluation of the mean void fraction are given in Appendix C.

5.3 - Void Fraction Apparatus

The main components of the void fraction apparatus included the following

(i) Source holder and integral 1st collimator.

(ii) Shield for scintillating system with integral 2nd collimator.

(iii) Scintillation crystal and photomultiplier tube.

(iv) scaler-Ratemeter.

Items (i), (ii), and (iii) were mounted on a traversing assembly which allowed the unit to be moved across the tube test section and hence chordal void fraction to be obtained. A graduated indicator, actuated by the movement of the traversing gear, identified the chordal position on the tube at which the measurements were taken. The traversing assembly, and the necessary lead shielding surrounding the radioactive source, collimators and scintillation crystal (the total weight being approximately 3/4 Tonne) was supported on a solid steel structure bolted to the walls of the laboratory. Photographs of the traversing assembly are shown in figure 5.1.1, with some details of the layout and support structure in figure 5.3.1.

5.3.1 - Source Holder and Integral 1st Collimator

The radioactive source holder was manufactured in lead and so designed as to isolate the source in a save position when the apparatus was not in use. Details are given in figure 5.3.2 with the three main parts being identified as A - main body, B - source loader and C - 1st collimator and cover.

The main body was made by machining a single piece of lead, 160 mm in diameter and 180 mm long. It had recesses machined as shown to accommodate the top cover and the source loader.

The source loader was 90 mm long with the front 50 mm machined to 25 mm diameter and the rear 40 mm diameter. A 10 mm diameter recess was drilled vertically into the front part, to accommodate the radioactive source, 10 mm from the front face and 12 mm deep. The rear part was lined with a threaded steel bush 20 mm diameter and 30 mm deep to accommodate the insertion of a long rod for remote handling of the source when loading or unloading into or from the holder. The screwed insert was fixed by four small screws and a steel pin acted as a position locate.

The top cover was a stepped cylinder construction 100 mm diameter for a length of 20 mm and 80 mm diameter for a length of 20 mm, these fit into the corresponding recess in the main body. A small rectangular slot 10 mm × 3 mm was machined through the cover offset from the centre line by a distance of 20 mm . Two locating pins ensured that the slot could be fixed in a position of alignment with the hole in the source loader or in a safe position away from source loader hole.

5.3.2 - Shield Scintillation Crystal with Integral 2nd Collimator

The shield from the scintillation crystal was manufactured in lead according to the details given in figure 5.3.3 . The 70 mm internal diameter of the main cylinder was sized such that the scitillation crystal and photomultiplier was a sliding fit inside. A slot of diameter 10 mm × 3 mm, machined into the base, formed the 2nd collimator. During the assembly of the apparatus, this slot was aligned with the corresponding slot in the cover of the source holder allowing a thin rectangular beam of γ-rays to penetrate the test tube.

5.3.3 - Scintillation Crystal and Photomultiplier Tube

The scintillation crystal was a 60 mm diameter and 43 mm long, high quality Sodium Iodide Crystal located in an aluminium assembly which was screwed on the bottom of the photomultiplier tube window to form a demountable assembly. The scintillation detector type DM1-2 (manufactured by Nuclear Interprises Ltd), and comprised of the scintillation crystal and several other items. These being eleven resisters (2.2 mΩ, 10.5 W each) and a chain of anodes and pre-amplifier board and high voltage connector.

5.3.4 - Scaler Ratemeter

The scalar ratemeter was type SR7 manufactured by Nuclear Interprises Ltd, and especially designed for the use with scintillation tube. The scalar ratemeter supplied the high tension voltage required to drive the photomultiplier tube via a high voltage coaxial cable. At the same time the cable was used to transmit the voltage signal out-going from the photomultiplier. The scalar ratemeter consists of the high voltage generator, a linear pulse analyser, a rate meter and a timer. A micro-processor is the over all controlling device and which allowed several modes of operation. Various sub-modes were available in the counting mode such as single cycle and display or continuous counting and display after a pre-selected period of time or a fixed number of counts.

The sampling time used throughout the present testing is 25 seconds, the count rate was displayed in a six digit display, and the following setting for the scalar ratemeter were used throughout tests.

HV FINE	663 (V)
KV RANGE	0-1 (KV)
THRESHOLD	667 (KeV)
± % c	DEPRESSED
WINDOW	20%
MODE	SC1,CR1

5.4 - Void Fraction Calibration

The apparatus was calibrated by traversing the γ-rays beam across the horizontal diameter of the tube. The traverse was in steps of 1 mm when the beam was close to or in perspex tube walls, and in steps of 10 mm when the beam was well within the tube. The traverse was extended beyond the tube outer diameter to obtain a reference readings for the γ-rays beam passing through air only. This reference readings are very useful in the correction of experimental count rate if a drift from calibration conditions occurred; due to drift in amplifiers, slight change in source position or collimator alignment.

At each step the count rate over a presented time period of 25 seconds was obtained. A traverse was carried out first with the tube empty of water (i.e. air only) which corresponded to a void fraction of 1.0 at each chordal station. A second traverse was carried out with the tube full of water which corresponded to a void fraction of 0.0 at each chordal station. In this manner an envelop was obtained as that shown in figure 5.4.1. The axes of the graph are the chordal position versus natural log of counts/second. The top curve on the graph correspond to tube empty (chordal void fraction of 1.0) and the bottom curve correspond to tube full (chordal void fraction of 0.0). This calibration (tube-full and tube-empty) was repeated monthly throughout the test period, to check the consistency of the readings; it was found that the drift from the original envelop was negligible.

A check was also made on the accuracy of the void fraction measurement by carrying out a number of tests, where by the test tube was filled with water to prescribed levels, and the water level height accurately measured using a telescope and cathetometer.

Beam traverse was made at each water level, and using the calibration characteristics, the void fraction indicated by the γ-rays attenuation technique evaluated. This was compared with the void fraction deduced from tube geometry conditions knowing the water level. All these levels are plotted along with the envelop of tube-full and tube-empty graph, and are shown in figure 5.4.2.

The details of the mean void fraction calculation determination, and the comparison between the calculated void fraction using γ-rays attenuation and the geometrical void fraction for partially filled tube (no-flow condition) are given in Appendix C.

5.4.1 - The Effect Of The Number Of Chordal Stations (Steps) Within The Test Tube On The Void Fraction Accuracy

The number of steps on which the γ-rays beam was traversed across the test tube diameter for the first phase of tests was taken as 13 steps. The sampling time at each step was 25 seconds. The 25 seconds with the time taken to record the displayed reading and to manually traverse the assembly to the next step (station) determined the time taken for each step. Therefore, the overall time taken for the full traverse of the γ-rays beam across the tube diameter for each test was considered long; i.e. the time taken can not be ensured to maintain steady state conditions. Hence, a decision was taken to minimize the time consumed per test. The number of steps was reduced to 7 steps, and then to 5 steps (the difference in accuracy between the 7 steps and the 5 steps was negligible).

The decision taken had its effect on the accuracy of the γ-rays attenuation measurements. The error introduced by the 5 steps measurements, compared to the 13 steps was approximately 10%, which was considered to be acceptable.

The comparisons between the 13 steps and 5 steps and the geometrical void fraction for nine water levels (no-flow conditions) are given in table 5.4.1 for the 13 steps and in table 5.4.2 for the 5 steps.

A sample of calculation to obtain the mean void fraction for one level for the two cases (13 steps and 5 steps) are given in Appendix C.

5.5 - Test Procedure

The Following Procedure was followed for both single and two-phase testing.

1. The power supply to all electrical and electronic equipments and instruments were switched on, and given a sufficient time to warm up. Usually they were left on over night.
2. The valves connecting the test section pressure tapping points to the piezometers boards were opened as were the valves connecting the piezometer tubes with the top headers (these are usually left open).
3. The purging valves for the water orifice pressure tappings and the manometer were opened.
4. The purging water was introduced to all the purging lines and each line was visually examined to ensure no air was trapped.
5. The inlet valve (C4), the by-pass valve (C5) and re-circulation valves (C2 and C3) were all opened, while the pump outlet valve (C1) kept shut.
6. The pump was started and being permitted to run for some time; from and to the water tank through the by-pass valve.
7. The water was then introduced gradually to the test section; by gradually opening the valve C1 and gradually closing the by-pass valve C5, until a flow of full bore is reached.
8. The program used to convert the probes signal was loaded and run to make sure that the readings for tube full is the same as that obtained during the calibration. If these readings are not the same the SET OUTPUT on the wave monitor for each probe is used to reset these readings. This step was only for smooth stratified flow tests.
9. The water flow rate was then adjusted to the desired flow rate with the use of the valves C1 and C5.

10. The purging valves on the piezometer and the water orifice tappings were closed as were the purge valves at the manometer.
11. The air supply was introduced into the mixing chamber by opening the regulating valves to the desired air flow rate. This step was only for two-phase flow tests.
12. A suitable air pressure was introduced to the top manifold and adjusted to ensure that the water level in the piezometer tubes were within the height of the glass tube and within the view of the camera. The valves connecting the test section with the piezometer were opened.
13. Once the flow had time to stabilise the following reading were recorded:
    a. Head pressure difference across water orifice plate; taken from water/mercury manometer at high water flowrates or air/water manometer at low water flowrates.
    b. Inlet pressure to the water orifice plate.
    c. Pressure drop along the test section from piezometer board (taken by the camera).
    d. Applied back pressure to the piezometer board.
    e. Readings were taken from the void fraction apparatus as it was traversed across the test section.
    f. The liquid height at each depth gauge was recorded. Usually three sets of readings were taken fo each test.
    g. Air and water temperatures from the digital thermometer.
    h. Head pressure difference across air orifice plate.
    i. Inlet pressure to the air orifice plate.
    j. The flow pattern was visually observed and recorded.

The e, f, h, i, j readings were recorded only for two-phase flow tests.

14. The water and air (if in use) flow rates were changed to a new desired values, and the system allowed to settle before a new set of readings were taken.
15. When the testing was finished, a complete close down of the system was achieved by reversing steps 12 back to 5.

Test No.	Water Height (H) mm	Void Fraction by γ-Ray	Geometrical Void Fraction	Error %
		A	B	$\frac{(A-B)}{(B)} \times 100$
789001	186.91	0.0654	0.0546	19.78
789002	158.61	0.1869	0.1836	1.63
789003	141.20	0.2947	0.2790	5.62
789004	132.90	0.3390	0.3271	3.64
789005	107.20	0.5031	0.4818	4.42
789006	85.02	0.6458	0.6166	4.74
789007	64.95	0.7448	0.7341	1.46
789008	44.74	0.8389	0.8425	-0.43
789009	25.04	0.9169	0.9319	-1.61

Table 5.4.1 Void Fraction Comparison Between γ-Ray and Geometrical Void Fraction Based on 13 Steps (Non-Flow Tests)

Test No.	Water Height (H) mm	Void Fraction by γ-Ray	Geometrical Void Fraction	Error %
		A	B	$\frac{(A-B)}{(B)} \times 100$
789001	186.91	0.0654	0.0546	12.27
789002	158.61	0.1535	0.1836	-16.39
789003	141.20	0.2608	0.2790	-6.52
789004	132.90	0.3019	0.3271	-7.70
789005	107.20	0.5075	0.4818	5.33
789006	85.02	0.7042	0.6166	14.20
789007	64.95	0.8012	0.7341	9.14
789008	44.74	0.8866	0.8425	5.23
789009	25.04	0.9514	0.9319	2.09

Table 5.4.2 Void Fraction Comparison Between γ-Ray and Geometrical Void Fraction Based on 5 Steps (Non-Flow Tests)

Figure 5.1.1 Photographic View Of Void Fraction Apparatus In Position

1 - Gamma-Ray Outer Lead Shield

2 - Traverse Trolley Handle Wheel

3 - Perspex Test Section (Observation Section)

4 - Crystal Scintillator DM1-2 And Photo-multiplier Tube

5 - Steel Support Structure

6 - Graduated Cylinder Indicating Position Of Beam Through Tube

7 - Graduated Plate Attached To The Graduated Cylinder

8 - Crystal Scintillation Lead Shield

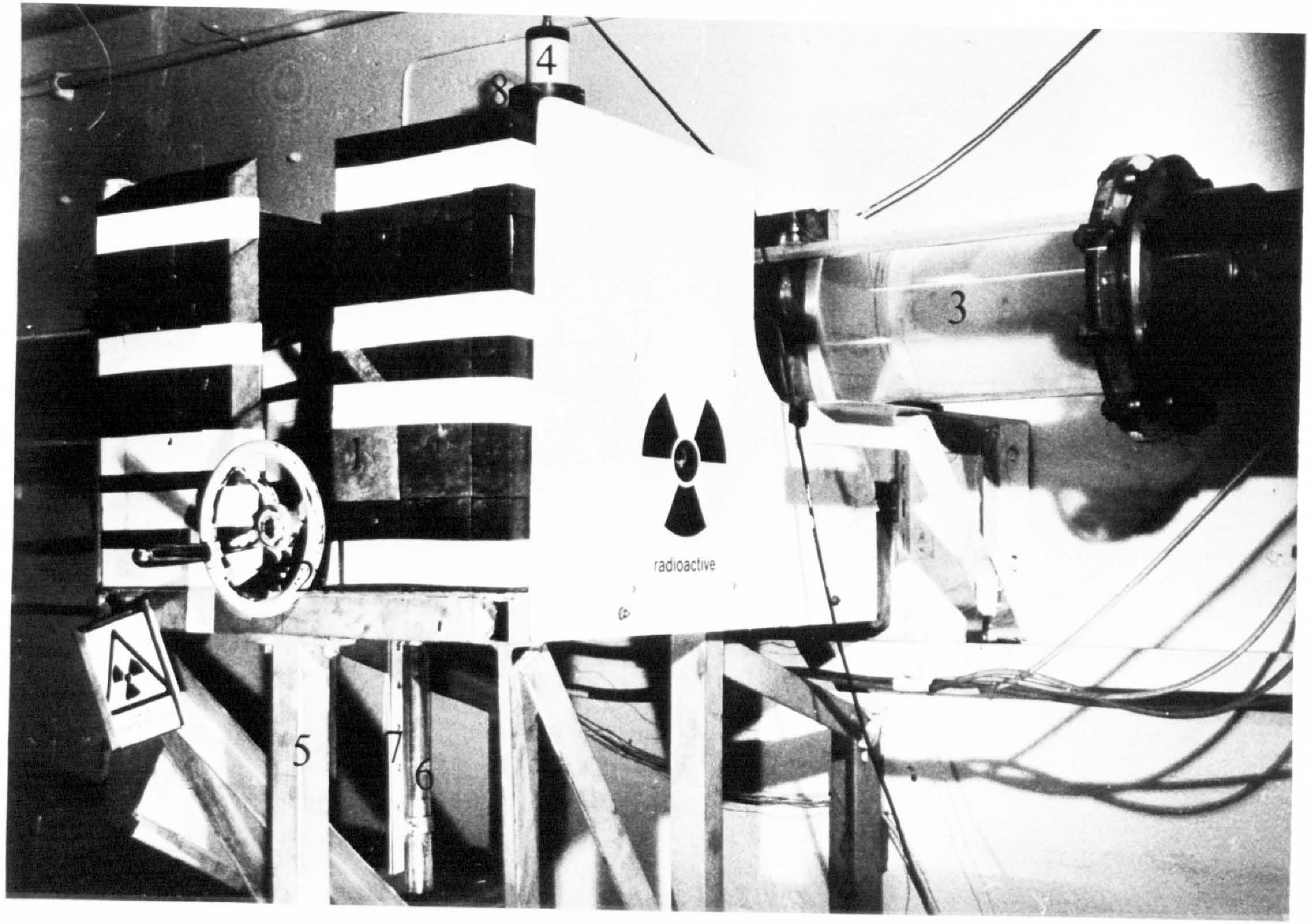


FIG. 5.1.1

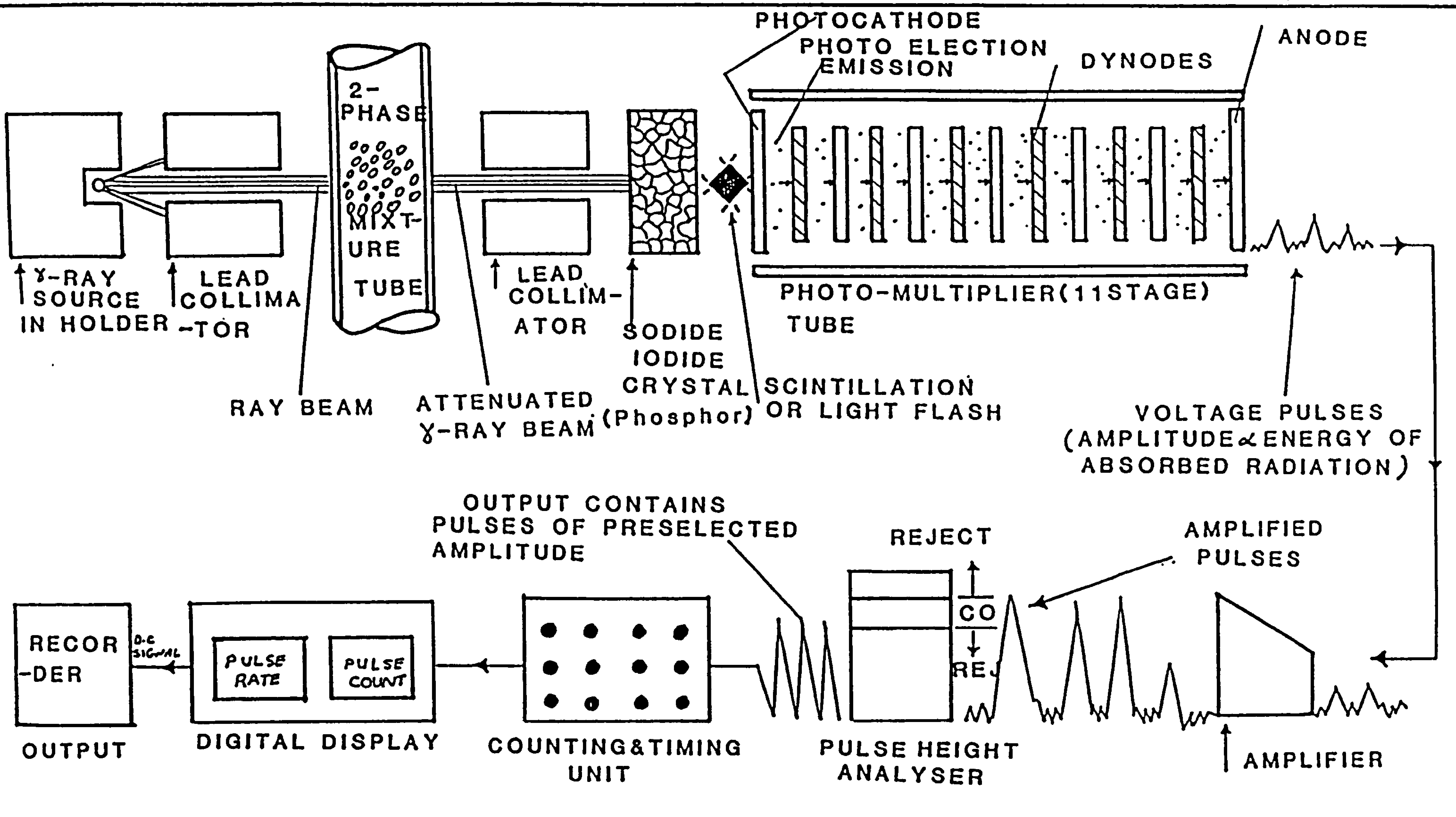


FIG. 5.1.2 Density and Voldage Measurement by Gamma Ray Attenuation Technique Scintillation Counting Method

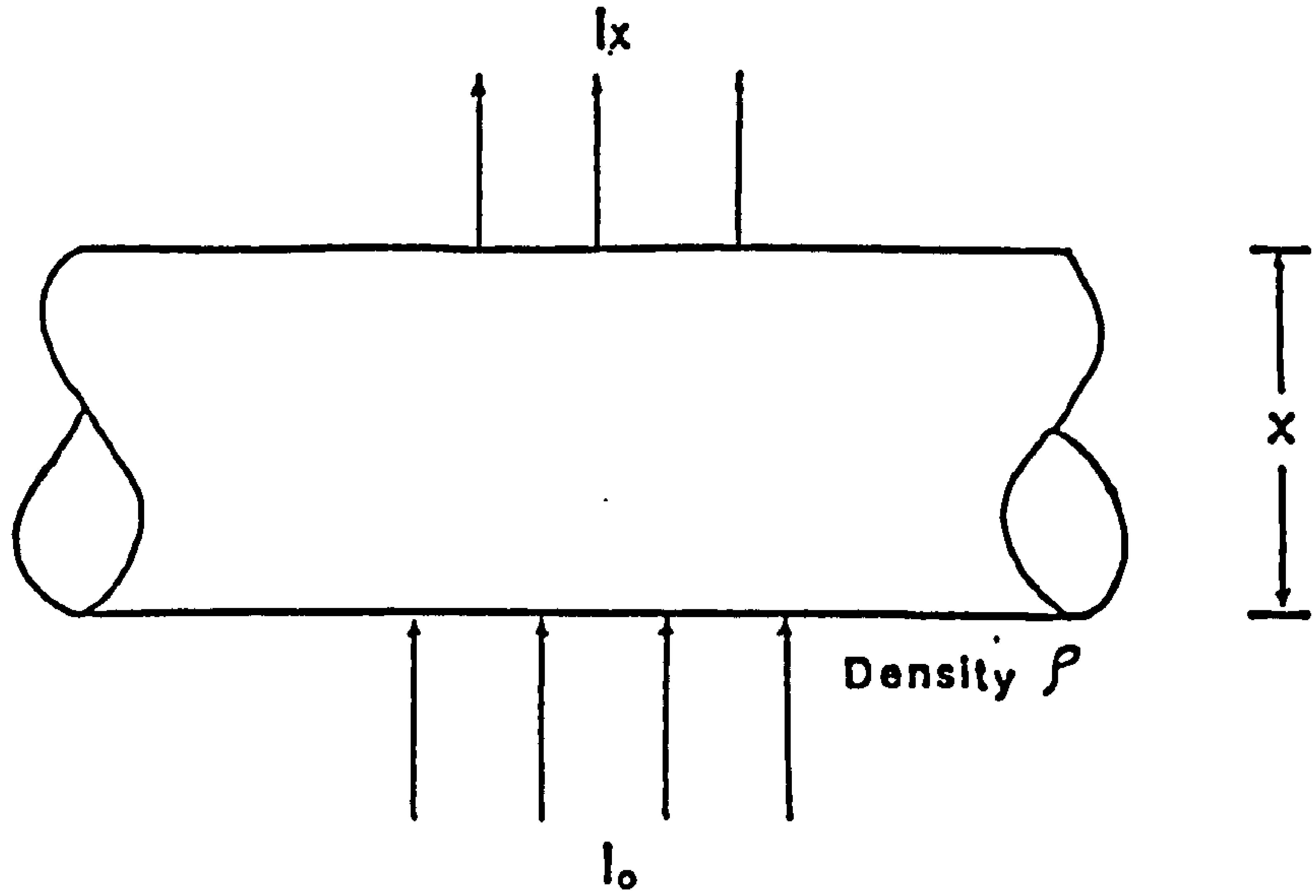


FIG. 5.2.1 γ-RAY BEAM PASSING THROUGH A MEDIUM OF DENSITY (ρ)

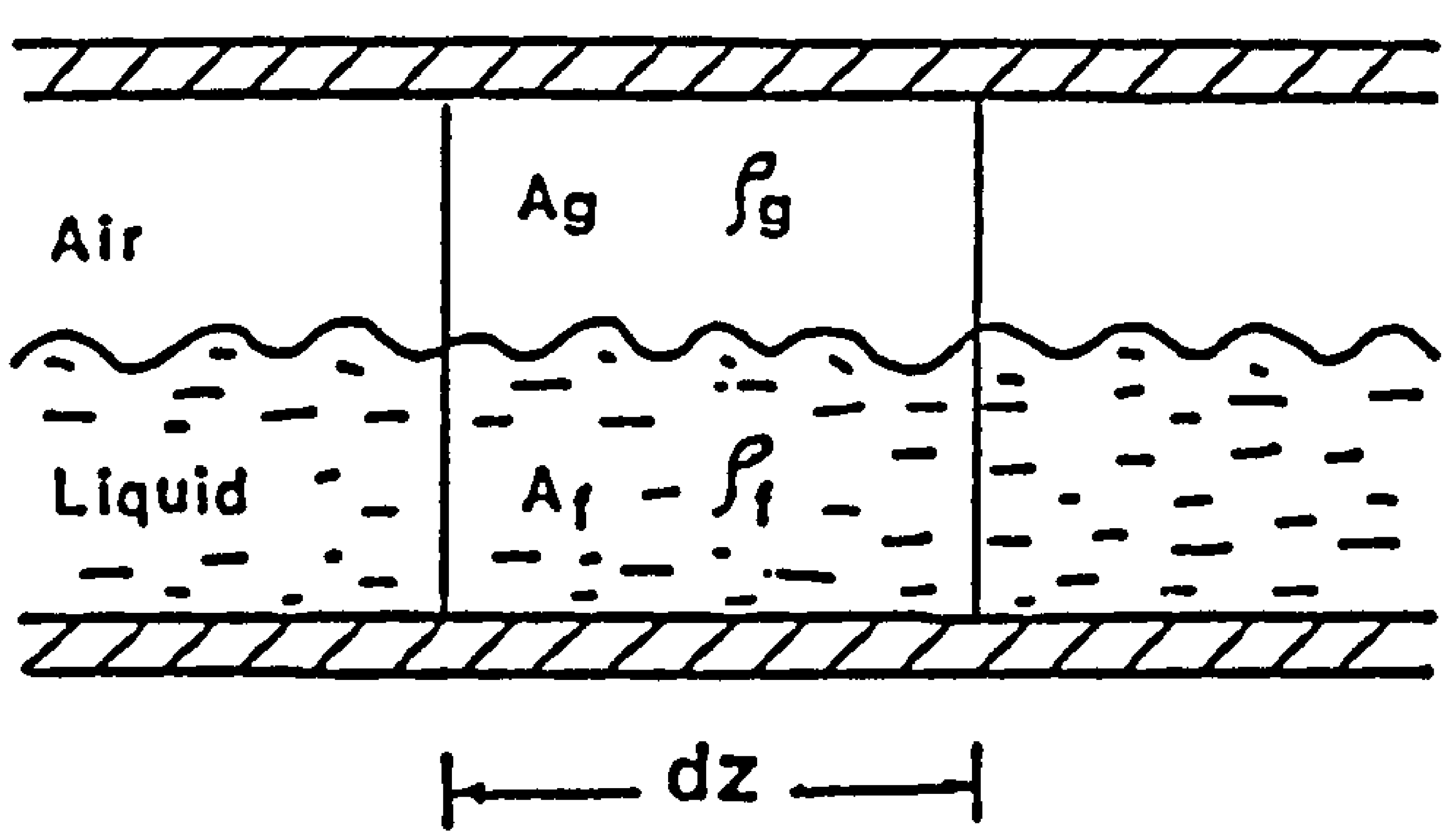


FIG 5.2.2 TWO-PHASE FLOW MIXTURE IN A TUBE OF CROSS-SECTION AREA (A)

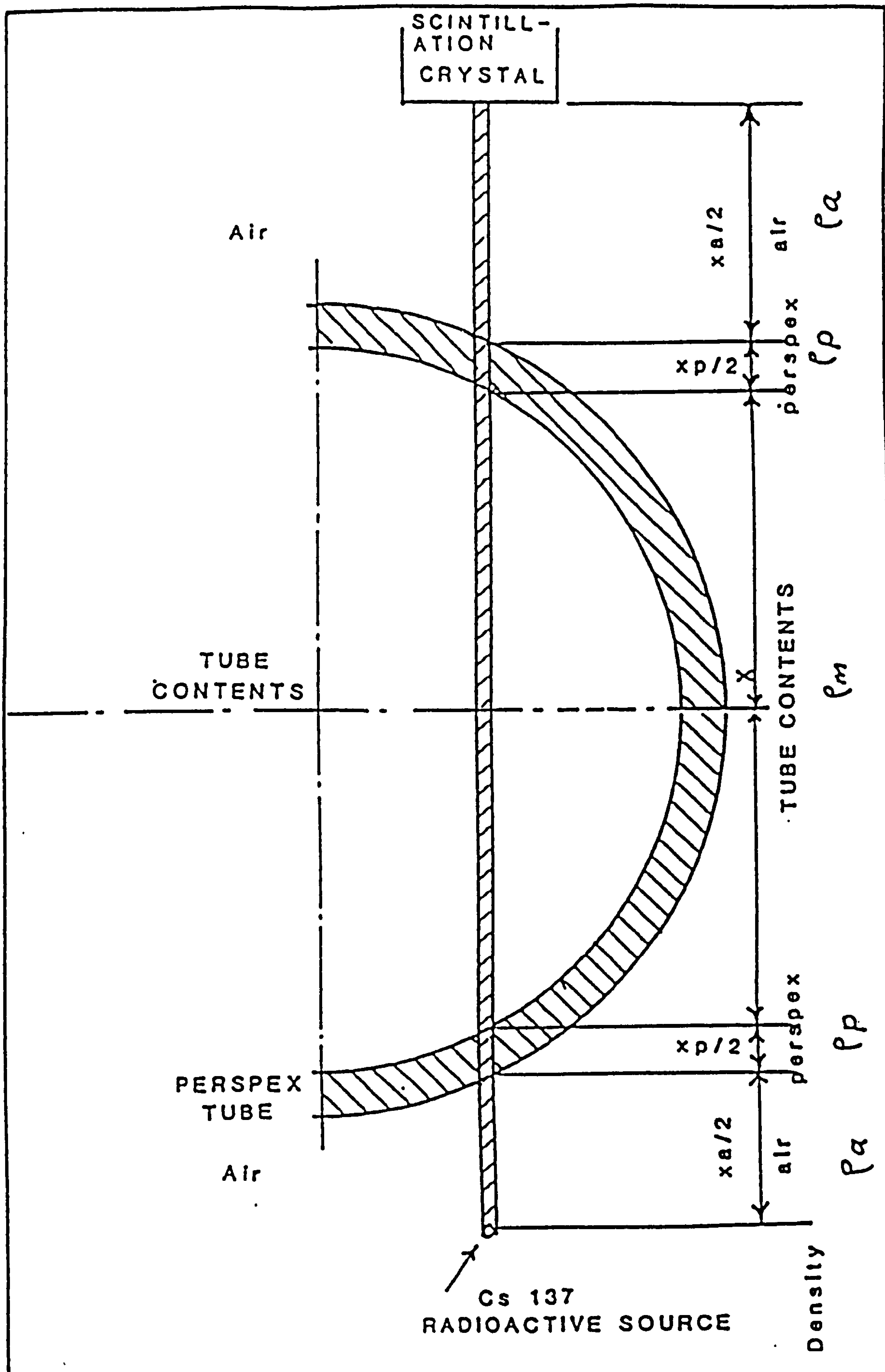
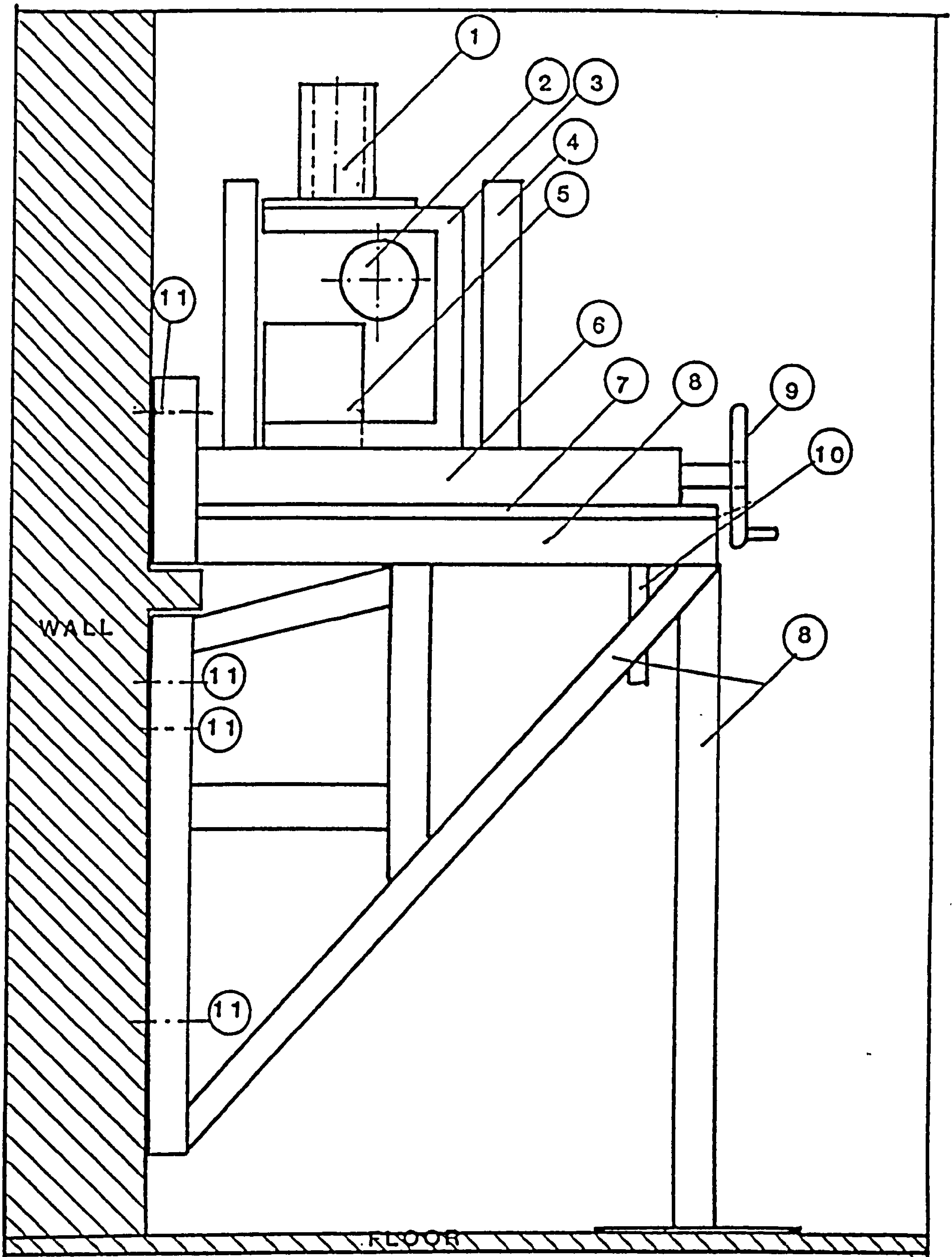


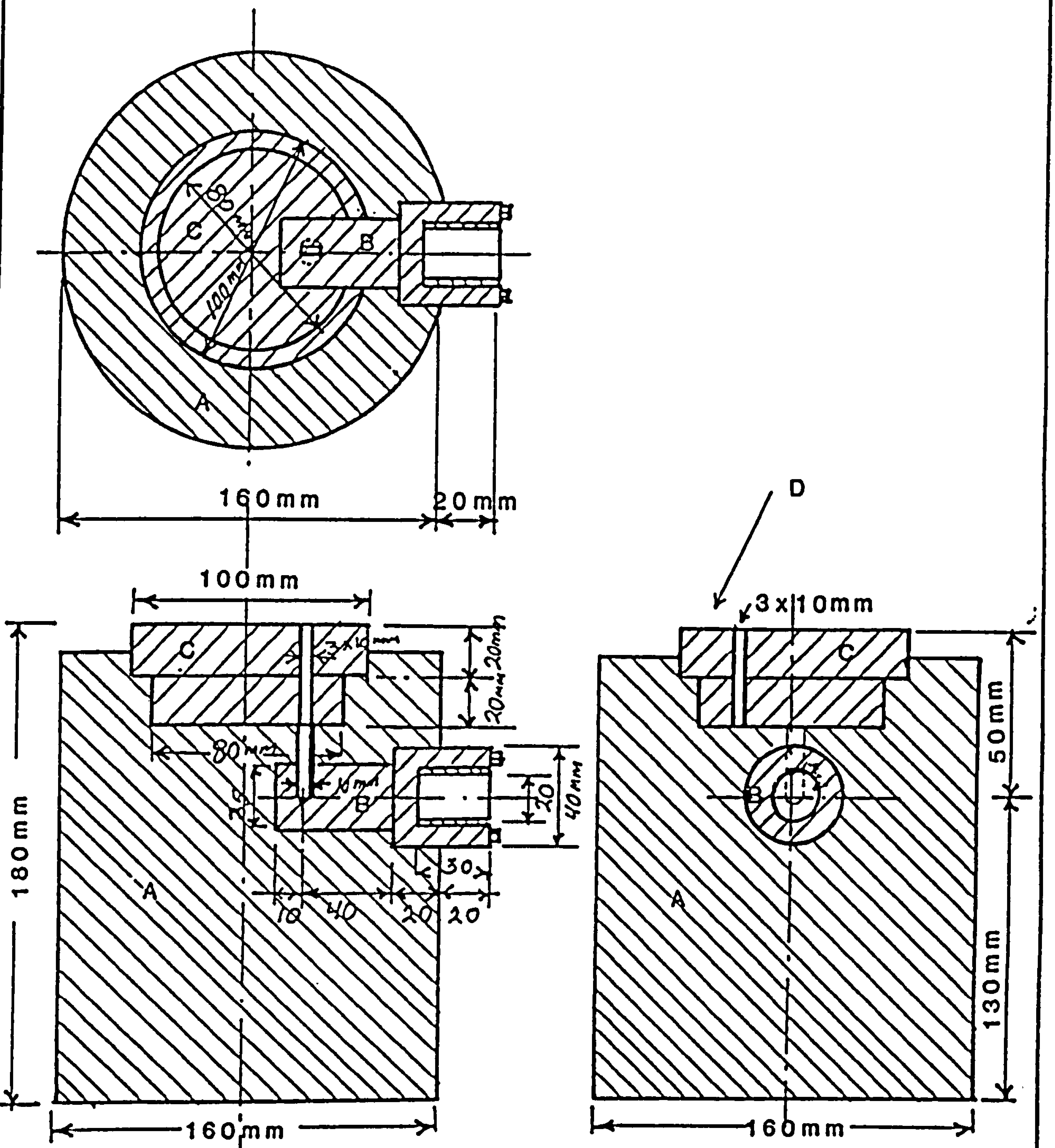
FIG. 5.2.3 γ-RAY ATTENUATION THROUGH CHORDAL LENGTH OF TUBE



CODE

1 . CRYSTAL SHIELD &2nd COLLIMATOR
2. PERSPEX TUBE
3 . STEEL STRUCTURE(CHANNEL1.5")
4 . LEAD SHIELDING
5. SOURCE HOLDER & 1st COLLIMATOR
6. MOVABLE TROLLEY
7. STEEL SHEETING
8. STEEL STRUCTURE(CHANNEL2.0")
9. WHEEL HANDLE
10 . GRADUATED CYLINDER
11. STEEL BOLTS

FIG. 5.3.1 GAMMA RAY SYSTEM APPARATUS LAYOUT



<u>CODE</u>.

A : MAIN BODY — MATERIAL : LEAD

B : SOURCE HOLDER

C : COLLIMATOR AND COVER

D : SAFE POSITION SHOWN COVER ROTATED TO ALIGN SLOTS AND ALLOW EMERGENT γ-RAY BEAM

FIG. 5.3.2 DETAILS OF SOURCE HOLDER AND 1ST COLLIMATOR

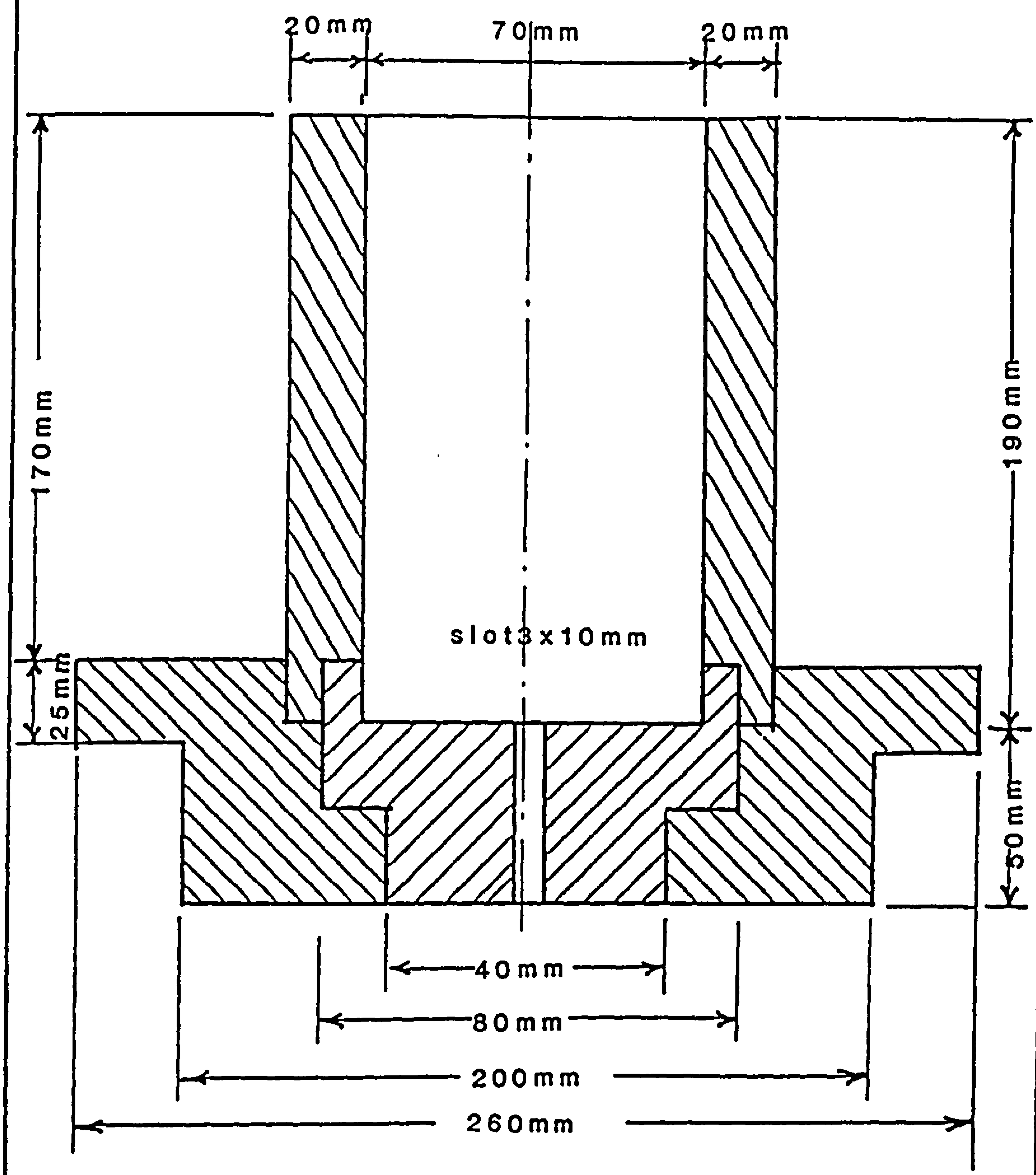


FIG. 5.3.3 DETAILS OF SHIELD FOR CRYSTAL SCINTILLATOR AND 2ND COLLIMATOR

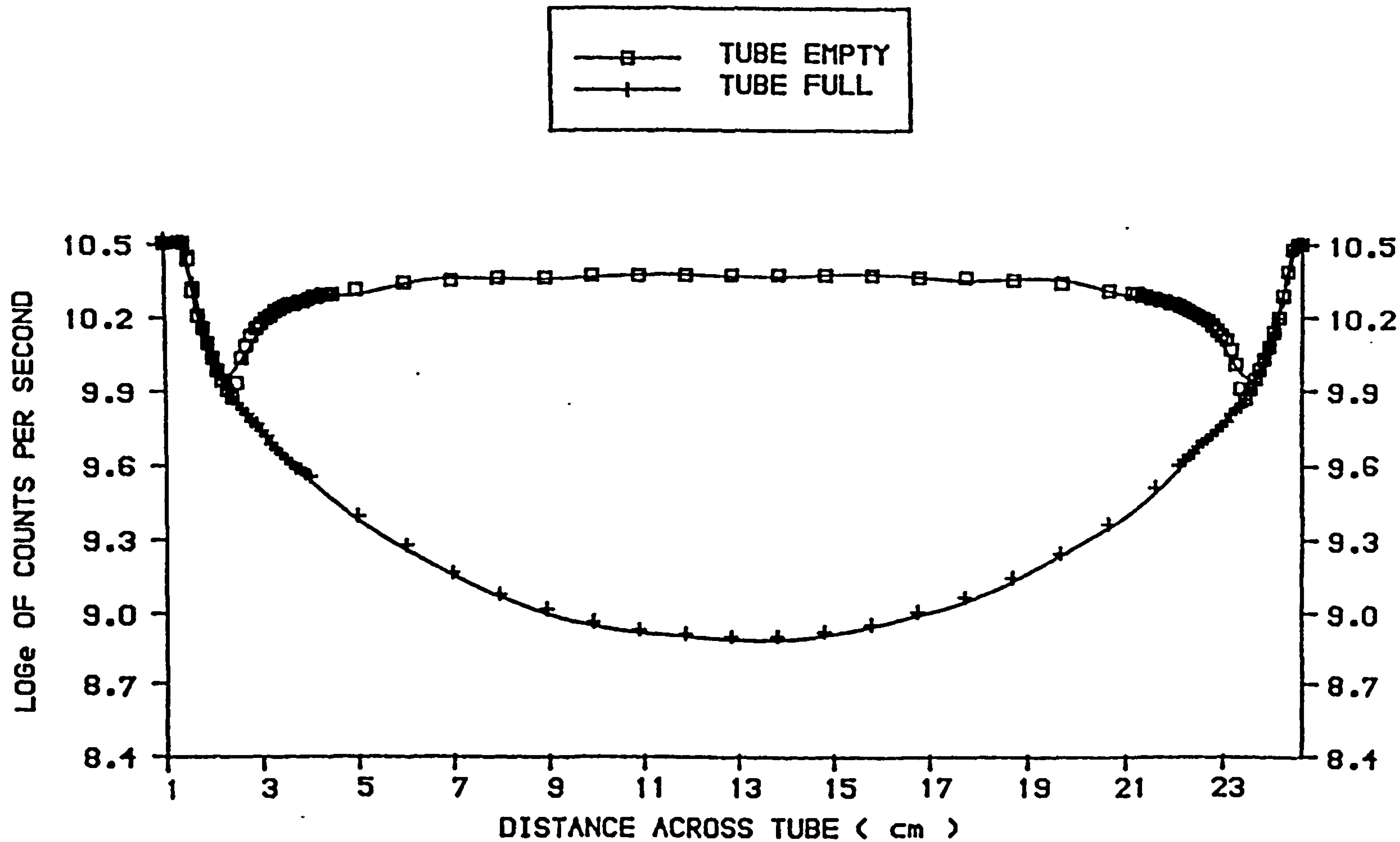


FIG. 5.4.1

EXPERIMENTAL VOID FRACTION CHARACTERISTICS

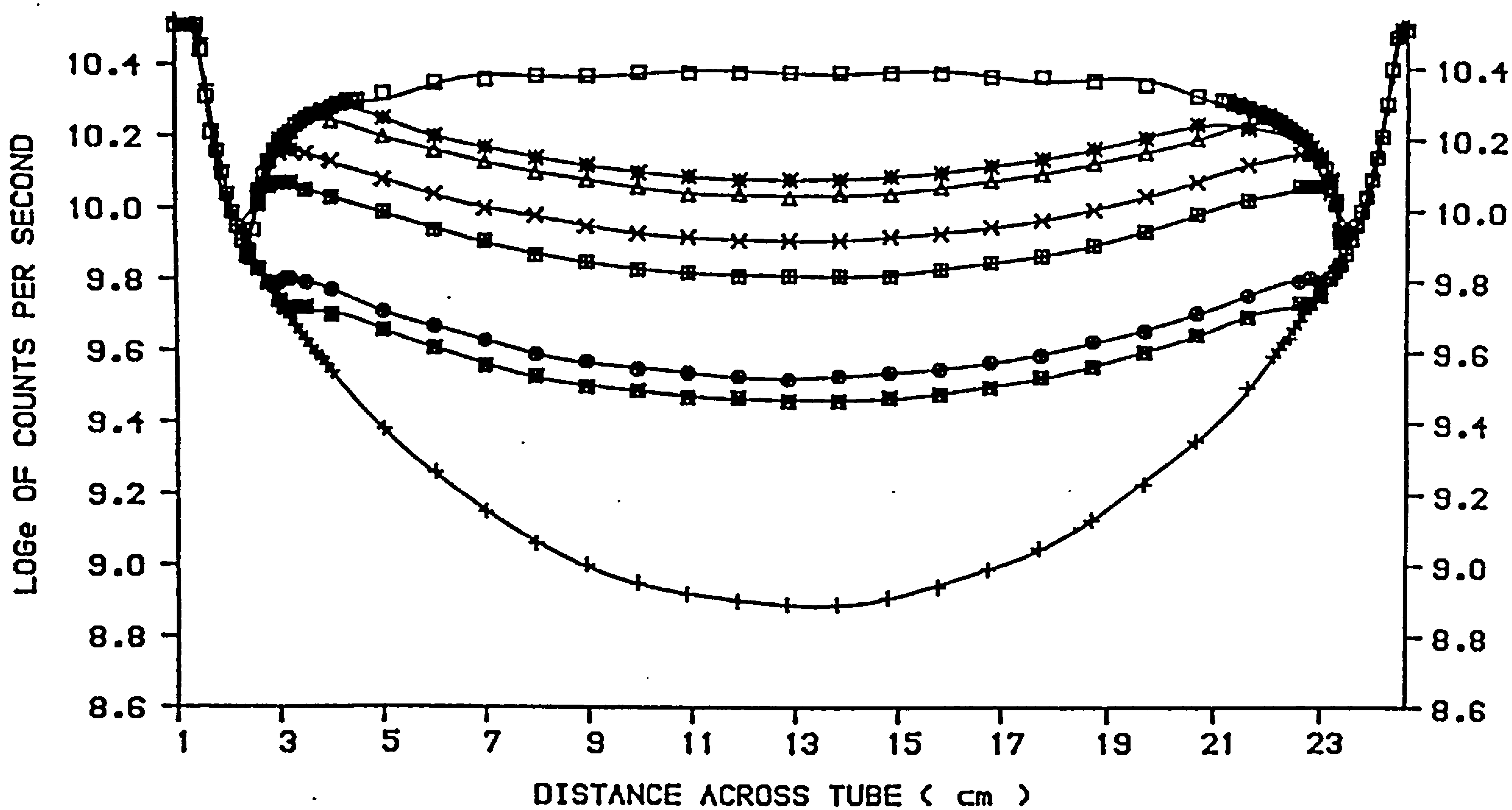


FIG. 5.4.2 EXPERIMENTAL VOID FRACTION CHARACTERISTICS

CHAPTER (6)

CHAPTER SIX

RESULTS, ANALYSIS AND COMPARISONS WITH EXISTING CORRELATIONS

6.1 SINGLE PHASE FLOW

To facilitate comparisons with some existing correlations, the pressure drop data for the two phase flow case need to be converted into the two phase friction multipliers, φ^2_{fo} (the ratio of the two phase friction pressure drop to the corresponding single phase friction pressure drop, calculated on the basis that the total mass flowrate was water). Therefore, the single phase flow pressure drop tests are important in order to determine the test section friction factor characteristics.

A total of 200 single phase (water only) tests where conducted in the study for the above reasons; pressure distribution was measured at each of the bottom tapping points at the 23 axial locations along the test section. Each tapping point is connected to a piezometer tube (each fitted with a piezometer connection at the bottom to expel any bubbles in the line before testing and an air manifold connection at the top to keep the water within the height of the glass column when pressures would exceed this height). A camera was used for both single and two phase flow tests to determine the height of water in the piezometer column and to minimize the effect of the fluctuation nature of the flow (especially in the two phase flow case) on the determination of the pressure gradients; to gain better accuracy in the pressure gradient measurements, and to cut short the time needed for each test to retain the steady state condition. The photos were examined, and all the pressure readings at each accurately known axial point were collected and tabulated, specimen photos are given in figures 6.1.1 to 6.1.4.

A computer program was written which, given the pressure distribution data along the test section, gives the best line through the data (pressure gradient), and the pressure at the mid point in the test section. It became clear after a few tests that a number of tapping points at the inlet and outlet of the test section need to be excluded in the determination of the best line for the pressure gradient i.e. only the linear part of the data was considered in the determination of the pressure gradient in the subsequent analysis, because of the large fluctuations associated with the flow after the inlet and before the exit bends.

6.1.1 Test Section Friction Factor Characteristics

It is convenient to have a simple method of evaluating the single phase pressure gradient for the purpose mentioned in section 6.1. Using a friction factor type expression, the single phase friction pressure gradient can be expressed as:

$$\left[\frac{dp_f}{dz}\right]=\frac{\lambda\, U_f^2\, \rho_f}{2\,d}=\frac{8\,\lambda\, Q_f^2\, \rho_f}{\pi^2 d^5} \tag{6.1.1}$$

In horizontal flow, the friction pressure gradient can be equated to the total pressure (this is not always correct, as will be discussed later in the case of stratified type of flow) or measured pressure gradient dp/dz.

Using the experimental data values of dp/dz

$$\lambda=\frac{\pi^2 d^5}{8\,\rho_f\, Q_f^2}\;\frac{dp}{dz} \tag{6.1.2}$$

The deduced values of λ were plotted against liquid Reynolds number

$$Re_f=\frac{G\,d}{\mu_f}$$

The single phase friction characteristics for the test section (203 ID), was obtained by insitu calibration using water as the flowing fluid. Values of λ and Re_f in the form of tables are given in Appendix A. A specimen Table is shown in Table 6.1.2. The corresponding plot of λ versus log Re_f is shown in figure 6.1.5. As can be seen from figure 6.1.5, that the data cannot be represented over the complete range of Reynolds numbers by a single relationship of the form $\lambda = k\, Re^{-n}$. Hence the data is divided into two regions, as shown in figures 6.1.6 and 6.1.7, and as a result two equations are obtained.

$$\lambda = 0.156772\,Re^{-0.1762848} \quad \text{For} \quad Re > 2.09\times10^{5} \qquad (6.1.3)$$

and for $Re < 2.09\times10^{5}$

$$\lambda = 0.4416447 - 3.715733\times10^{-2}(lnRe) - 2.393404\times10^{-3}(lnRe)^{2} + 2.128791\times10^{-4}(lnRe) \qquad (6.1.4)$$

The test section friction factor characteristics where compared with sixteen equations from the known equations in the literature. The comparisons were in the form of %AVE error, and %RMS error. The equations used along with the results are shown in Table 6.1.1.

Some of these equations were also plotted against present experimental results as shown in figure 6.1.8.

From the Table 6.1.1 and from figure 6.1.8 it is worth noting that all the equations tested gave a lower values of λ than that of the experimental value for this particular pipeline, and also it can be seen although they tend to follow the same trend across the range of Re; their degree of variation considerably defer.

The above difference among the different equations it may be expected since most of the above equations were usually developed for artificially roughened pipes, where as commercial pipes are entirely different and have absolute roughness which varies with age, and production methods for commercial pipes may have its effect also on the friction factor.

Equation 6.1.2 in conjunction with either equation 6.1.3 or equation 6.1.4 (depending on the Reynolds number), was used in subsequent analysis involving single phase pressure gradients.

All data, results and sample of calculation for single phase are included in Appendix A. The computer program used to derive these results is also given in Appendix E.

6.2 GENERAL TWO-PHASE FLOW

A total of 395 two phase tests were carried out during this study. Pressure drop data, void fraction data, flow patterns data, and other test data, were all recorded and transformed into meaningful data, then tabulated in certain format as that given in Appendix B. A specimen Table is shown in Table 6.2.1.

A computer program was written to take this tabulated data, and give all the necessary information, like liquid and gas densities, superficial liquid and gas velocities, two phase friction pressure drop multipliers φ^2_{fo}, liquid and gas flowrates, etc.. A specimen of the computer results is shown in tables 6.2.2 to 6.2.4, and the complete result tables are given in Appendix B.

Six pressure drop correlations, see section 6.2.1, were included in the programme to compare with the experimental data, in the form of two phase friction multipliers, φ^2_{fo}. Nine void fraction correlations were also included in the programme for the comparison with experimental results. Although this part of the study (general two phase flow) is important, it will be discussed here in slightly less detailed manner than the stratified flow part (section 6.3) which is given more attention than other flow patterns in this experimental study.

6.2.1 Two Phase Pressure Drop Results And Comparisons

The first step in the conversion of the pressure drop raw data into useful information was to plot static pressure distribution along the test section. The slope of the linear part of the graph determined the pressure gradient, whilst deviations from linearity were considered as unsettled flows due to the effects of the inlet and outlet bends.

To facilitate comparisons with some of the existing correlations, the pressure drop data were converted into the two phase friction multipliers, φ^2_{fo} (i.e. the ratios of the two phase friction pressure drop to the corresponding single phase friction pressure drop calculated on the basis that the total mass flowrate was water). The total pressure gradient was taken as the friction pressure gradient (this assumption proved incorrect in the case of stratified flow in large diameter pipes, where interfacial hydraulic gradient exists) since the momentum component constitute a very small part of the total pressure drop.

The two phase friction multipliers were predicted using six well known correlations available in the literature, these being

(i) *Homogeneous flow model*- simplest to use.

(ii) *Lockhart-Martinelli*- earliest correlation allowing for slip, widely used.

(iii) *Chenoweth-Martin*- suitable for "large diameter" tubes.

(iv) *Baroczy*- general correlation allowing for property and mass velocity variations.

(v) *Chisholm*- extension of Lockhart-Martinelli and Baroczy, which allows for mass velocity effects and dispenses with graphical procedures.

(vi) *Dukler*- suitable for separated flows but requires a void fraction correlation.

Details of these correlations are given in appendix B, with a sample of calculation. The determination of these two phase friction multipliers involved repetitive calculation and hence a computer program was developed; graphical plots or tables used in the correlations were expressed in polynomial form and included in the programme. The program is listed in appendix E, and a specimen of the results is shown in Table 6.2.5.

The comparisons were made by plotting predicted φ^2_{fo} values against experimental φ^2_{fo} values, and the plots are shown in figures 6.2.1 to 6.2.6 respectively for the six correlations indicated previously. The data points are identified in terms of flow pattern, corresponding to the key shown in each figure, and values of % RMS and % Average error relating to the error between prediction and experiment (% based on experimental value) are quoted on each figure.

In the light of the plots (6.2.1 to 6.2.6) it is worth noting that

(a) None of the correlations give overall prediction with RMS error less than 59% over the data range.

(b) Some of the correlations have very high RMS errors associated with the prediction i.e. > 100%.

(c) The Homogeneous, Lockhart-Martinelli, and Dukler models gave the best relative performance, keeping in mind that less data were examined by the Lockhart-Martinelli correlation, because the evaluation of the Lockhart-Martinelli required evaluation of the parameter χ which in turn required values of the single phase friction factor λ. It was considered unwise to extrapolate the experimental values of λ outwith the turbulent flow range tested.

(d) In spite of the big differences in the values % RMS between some models, all tend to overpredict the two phase pressure gradient.

(e) In general flow pattern has some effect on the accuracy of the prediction (i.e. stratified, wavy, and transition from stratified to wavy).

The results of the comparison cannot be considered satisfactory. The scatter some times is appreciable and suggests that either the existing correlations are inadequate for predicting the friction pressure drop in large diameter tubes or that the comparison is unfair, or perhaps both. However, this conclusion, although rather disturbing, is perhaps not too surprising if one remembers that

(i) Many of the correlations compared were developed from data taken in small diameter tubes and/or for other fluid combinations and sometimes did not include mass velocity effects.

(ii) For a given mass or volume flowrate, the friction pressure drop in large tubes is much less than in smaller tubes, hence large differences do not necessarily constitute large pressure drops in absolute terms, and hence small uncertainties in the correlation could be amplified.

(iii) There is more scope in large diameter tubes for flow separation and stratification, and hence for variations in liquid level along the tube. This mostly applies to stratified and wavy type flows. This stratified effect however, could also affect other flow patterns, e.g. annular (annular flow was not encountered during this study because of the vast amount of air flow required which was in axcess of our available flowrate), where the film thickness at the bottom of the tube is so thick as to give the effect a stratified type flow superimposed on a symmetrical annular flow.

For the case of stratified and wavy flows (where level gradient does exist), therefore, the comparison in terms of two phase friction multipliers φ^2_{fo} *is unfair, since the measured* pressure gradient does not equal the *friction pressure gradient.*

All the data points for stratified, wavy, and the transition between the two were separated from the rest of the data, and plotted separately in figures 6.2.7 to 6.2.12, to see the change in the %RMS. The results for the remaining flow patterns were also replotted for the six models to see the improvement in the %RMS, and are shown in figures 6.2.13 to 6.2.18. A Table showing these results is also given in Table 6.2.6.

All data and results concerning two-phase pressure drop, and other derived results are given in Appendix B.

6.2.2 Observed Flow Patterns And Comparisons

The flow patterns were observed visually in the settled part of the test section, through the clear perspex section. The clear perspex section is 2.55 m long, and installed at distance of 26.5 m from the inlet to the test section. Four flow pattern types and their transitions were observed during this study, namely; plug, slug, stratified and wavy, which are defined in section 2.1.1 (chapter 2), the codes used for the flow patterns and their transitions are given in Table 6.2.7. Flow pattern data are shown in figure 6.2.19, on a nominal co-ordinate system of superficial water velocity versus superficial air velocity. These co-ordinates are used simply as a means of presentation and to facilitate comparison with some of the existing flow pattern maps. In making the comparisons, the author is not recommending the use of the flow pattern maps, nor the map co-ordinates employed for comparison. Indeed, it is difficult to appreciate how a two co-ordinate map can adequately represent the variety of the physical processes and instabilities involved in the different transitions. However, the superficial velocities of the individual phases were used as means of comparison and accordingly the flow pattern boundaries of the maps of other researchers were transferred to these co-ordinates.

The comparisons of the observed flow patterns with the Baker map is shown in figure 6.2.20, with the Hoogendoorn map in figure 6.2.21 and with the Mandhane et al map in figure 6.2.22.

Comparing the experimental data with the boundaries suggested by the three maps considered, it can be seen that on the whole, considering the disagreement between the maps themselves, and remembering that the transition boundaries are not lines but bands of which the lines are representative, the predictions are not too bad.

In all cases the boundaries between stratified and plug, wavy and slug flows are low, and perhaps more disconcerting, the boundary between slug and annular type flows (all the present test conditions did not include any annular flow) is the least adequately represented, the boundary on each map being considerably different. The plug to slug boundary on the Hoogendoorn map shows poor agreement with experiment, and slug to annular boundary on the Baker map appears to have the wrong curvature.

From the experimental results (which did not include any annular flow conditions), the boundaries between stratified and plug, wavy and slug flows occur at much higher water flowrates, and Baker's map suggests that the test should have covered some annular flow points.

The larger diameter used in this study compared to those used by Mandhane et al, Hoogendoorn, and Baker seems to have caused the following effects:

(i) the wavy-slug boundary is shifted to higher water flowrate.

(ii) bubbly flow occurs at higher water flowrates.

(iii) the slug-plug boundary is shifted towards lower air flowrates.

(iv) annular flow occurs at lower air flowrates.

From the above we may also conclude the inadequacy of the co-ordinates U_{sf}, U_{sg} to accommodate the different tube size.

6.2.3 Void Fraction Results And Comparisons

Void fraction measurements were made at a point in the test section 28.067 m from the inlet and 5.709 m from the end of the test section, the flow conditions being settled at this point. The measurements were made using a traversing vertical γ-ray densitometer apparatus specially designed and constructed for the purpose. The details of this apparatus, construction and calibration procedure are all included in chapter 5 of this thesis.

In order to determine the void fraction for two phase flow conditions, the unit was traversed along the horizontal diameter of the pipe and readings were taken at various stations. The chordal void fraction at each station was determined using the readings obtained from the calibration characteristic (tube full-tube empty) as follows:

$$\alpha_{CHORD} = \frac{\ln I - \ln I_{\text{TUBE FULL}}}{\ln I_{\text{TUBE EMPTY}} - \ln I_{\text{TUBE FULL}}} \qquad (6.2.1)$$

Where I is counts/sec measured by the Scalar Ratemeter (the intensity of the gamma-ray beam) at a particular station along the diameter.

The mean void fraction was determined by integrating the chordal void fraction over the length of the horizontal internal diameter of tube.

Simpson's rule was used for the integration. The calculation of the chordal void fraction and the subsequent integration was done by computer. It must be said that there is a fundamental randomness in all radiation measurements. The standard deviation σ on the count rate is given by

$$\sigma = \sqrt{\frac{R}{t}} \tag{6.2.2}$$

where t is the time over which the count rate R is determined.

An effort was made to minimize any other source of error. However, in the subsequent experimental tests the counting time is set at 25 seconds, and a reasonably strong source was used (this was limited by the amount set by the radioactive handling regulation for a given purpose and laboratory) to give high enough count rate, for better accuracy.

The two-phase testing covered 395 tests. The void fraction was measured in all these tests, and the flow patterns encountered during these tests covered four main flow patterns (plug, slug, stratified and wavy) and their transitions.

The measured void fraction results were compared with several correlations existing in the literature. These were:

(i) Hughmark [77]

(ii) Smith [112]

(iii) Chisholm [38]

(iv) Rouhani [104]

(v) Modified Rouhani (3 versions)

(vi) Beggs and Brill [21]

(vii) Eaton [50]

(viii) Mukherjee and Brill [100]

(ix) Guzhov [64]

Details of these correlations along with sample of calculation are given in Appendix C.

The comparisons of the above correlations with the measured void fraction are shown in figures 6.2.23 to 6.2.33 inclusive with the data points being identified in terms of flow pattern, according to the key given in each figure. The % RMS error and the % AVER error associated with the comparisons are also shown in each figure.

In the light of the plots (6.2.23 to 6.2.33) it is worth noting that

(a) The prediction performance of void fraction in large diameter tubes using any of the above void fraction models is even worse than that of the prediction of pressure drop models which discussed in section 6.2.1.

(b) In general, and in terms of the %RMS, all the void fraction models tested here failed to predict satisfactorily the experimental void fraction data i.e RMS > 140%.

(c) The modified Rouhani, Hughmark, and Guzhov models gave the best relative performance, and Rouhani-4 is the most favoured one among all for void fraction predictions.

(d) In contrast to (c), the models widely used in petroleum industry gave the worst performance of all i.e Beggs and Brill model gave % RMS > 750, and Mukherjee and Brill model gave % RMS > 610.

(e) The stratified flow pattern is extremely underpredicted by some of the models (Rouhani-3, Rouhani-4, and to less degree Eaton and Mukherjee and Brill).

(f) For all other flow patterns (i.e except stratified) all the models tested here tend to overpredict the two phase void fraction in varying degrees.

We know from our experimental tests on stratified flows that there exists an interfacial level gradient (ILG) which means that the void fraction is increasing in the direction of the flow and in the test section could be considerably greater than the predicted void fraction. Hence stratified flow is very much underpredicted as seen from graphs. Other flow patterns do not seem to affect the predictability of void fraction.

On the basis of these experiments, the Rouhani correlation must be recommended for use in preference to the other correlations tested, for large diameter tubes and for the range of conditions covered. A value of k should be taken to be about 8, instead of the original value of 1.18.

All comparison results derived by the computer are given in Appendix C.

6.3 STRATIFIED TWO-PHASE FLOW

It may be relevant to mention here why a specific project on stratified two phase flow was envisaged. This was because, in previous two phase studies in large diameter tubes, experimental data from flow patterns other than stratified flow could often be reasonably predicted by existing correlations. Stratified flow however, was a noticeable exception and inevitably yielded large errors between experiment and prediction. In this study, the above behaviour was clearly noticeable in the present results of the pressure drop as discussed in section 6.2.1.

A total of 193 tests were carried out in stratified, wavy, and stratified-wavy transition, as follows:

stratified flow 137 tests

wavy flow 39 tests

stratified-wavy 17 tests

The interfacial level gradient (ILG) was measured in 120 stratified tests; using the two depth gauges described in chapter 4. The results of the ILG, in terms of mm H_2O/m, are shown in Table 6.3.1.

As can be seen in Table 6.3.1, the pressure drop due to hydraulic gradient (level gradient) constitute much more than what was expected of the total pressure drop, i.e the friction pressure gradient is negligible in most of the test points compared to the pressure due to interfacial level change (where a large change in water level along the test section does exist). This conclusion is supported by the discussion in section 6.2.1, (see figures 6.2.1 to 6.2.6), where all the correlations overpredicted the experimental frictional pressure drop; this is a size effect which inadequately accounted for; all the correlations tested here were developed for smaller diameter tubes.

Two models in the field of stratified flows are discussed in this section, and tested for their prediction of the total pressure drop in smooth stratified flow.

(i) Andritsos and Hanratty (1987), allows for $f_i/f_G \neq 1$, gives an expression for the f_i (for wavy flow), and modified Cheremisinoff-Davis (1979) approach for the calculation of wall shear stress in the liquid τ_{WL}.

(ii) A. Bishop and S. D. Deshpande (1986), used the same approach as Taitel and Dukler, and took account of the possible interfacial level gradient (ILG) in the momentum equation of the liquid phase.

6.3.1 Pressure Drop Predicted By Andritsos And Hanratty Model

This model like many others used the same approach as Taitel and Dukler (1976); they considered a momentum balance for fully developed flow in each phase (the gas phase and the liquid phase).

$$-A_G\left(\frac{dp}{dz}\right)-\tau_{WG}\,S_G-\tau_i\,S_i \quad = \quad 0 \qquad (6.3.1)$$

$$-A_L\left(\frac{dp}{dz}\right)-\tau_{WL}\,S_L+\tau_i\,S_i \quad = \quad 0 \qquad (6.3.2)$$

There are two differences in the approaches used by Taitel and Dukler and this model, these being

(i) this model accounts for values of $f_i \neq f_G$, and gives the following expressions for f_i/f_G

$$f_G \quad = \quad 0.046\,Re_G^{-0.2} \qquad \text{for} \qquad Re_G > 2000$$

$$f_G \quad = \quad \frac{16}{Re_G} \qquad \text{for} \qquad Re_G < 2000 \qquad (6.3.3)$$

$$\frac{f_i}{f_G} \quad = \quad 1+15\left(\frac{h}{D}\right)^{0.5}\left[\frac{U_{SG}}{5}\left(\frac{\rho_G}{\rho_{GO}}\right)^{0.5}-1\right] \qquad \text{for} \qquad U_{SG} \geq \left(\frac{\rho_{GO}}{\rho_G}\right)^{0.5}\cdot 5 \quad m/\sec$$

$$\frac{f_i}{f_G} \quad = \quad 1 \qquad \text{for} \qquad U_{SG} \leq \left(\frac{\rho_{GO}}{\rho_G}\right)^{0.5}\cdot 5 \quad m/\sec \qquad (6.3.4)$$

It is perhaps clear from equation 6.3.4 that this model, like Taitel and Dukler model, takes the value of f_i/f_G for smooth stratified flow equal one (f_i/f_G=1).

(ii) A modified Cheremisinoff-Davis (1979) approach is used for the calculation of wall shear stress in the liquid phase (τ_{WL}) instead of the Blasius type of equation used by Taitel and Dukler. In this procedure of calculation two expressions were given; one for the dimensionless liquid height (h^+)

$$h^+ = \left\{(1.082\,Re_L^{0.5})^5 + \left[0.098\,Re_L^{0.85} \;/\; \left(1-\frac{h}{D}\right)^{0.5}\right]^5\right\}^{0.2} \qquad (6.3.5)$$

and the other for characteristic stress, τ_c

$$\tau_c = \rho_L \left(\frac{h^+ \nu_L}{D}\right)^n \left(\frac{h}{D}\right)^m \qquad (6.3.6)$$

where n=2 and m=-2

The expression for τ_{WL} was given as:

$$\tau_{WL} = 1.5\left(\tau_c - \frac{\tau_i}{3}\right) \;/\; \left(1-\frac{h}{D}\right) \qquad (6.3.7)$$

The advantage of this approach (as Andritsos and Hanratty say) is that it better able to account for the changes in the shape of the velocity profile in the liquid caused by gas drag at the interface.

The rest of variables in the equations 6.3.1 and 6.3.2 were calculated in the same way as Taitel and Dukler, i.e

$$\tau_{WG} = f_G\left(\frac{\rho_G U_G^2}{2}\right); \quad Re_G = \frac{D_G U_G}{\nu_G}; \quad D_G = \frac{4A_G}{S_G + S_i}$$

$$\tau_i = f_i\left(\frac{\rho_G U_G^2}{2}\right); \quad Re_L = \frac{D_L U_L}{\nu_L}; \quad D_L = \frac{4A_L}{S_L} \qquad (6.3.8)$$

It perhaps relevant to say here, that this model assumes that the frictional pressure drop in both phases (gas and liquid) are equal as the basis for the iteration procedure used, and there is no interfacial level gradient (ILG) in the liquid phase as shown in equation 6.3.2.

6.3.2 Iteration Procedure For The Calculation Of Pressure Drop And h/D (holdup)

1 - Assume a value of (h/D) and calculate the geometric variables, the actual gas and liquid velocities, and the gas and liquid Reynolds numbers.

2 - The pressure drop in the gas phase is calculated from equation 6.3.1 using the following equations:
Equation 6.3.3 for gas friction factor, and equation 6.3.4 for the interfacial friction factor.

3 - Calculate the dimensionless liquid height (h^+) from equation 6.3.5, and the characteristic stress (τ_c) from equation 6.3.6.

4 - Calculate τ_{WL} from equation 6.3.7.

5 - Calculate the pressure drop in the liquid phase, using equation 6.3.2. If this is not the same as calculated in equation 6.3.1 for the gas phase, a new value of h/D is assumed.

To compare the pressure drop predicted by this model with the experimental pressure drop measured during this study, the above iterative procedure was not employed, because the total pressure drop in the liquid phase $(dp/dz)_L$ was measured along with known water heights (h/D). Therefore, in order to test Andritsos and Hanratty's model, the present experimental values of h/D were used to calculate $(dp/dz)_L$ values from equation 6.3.2, and then compared with experimental values of (dp/dz) obtained from the bottom tapping points (in the liquid). The shear stresses (τ_{WL} and τ_i) were calculated from the above procedure using h/D experimental values.

It is important to note that (dp/dz) in both phases are not assumed equal (which is the basis in the iteration procedure given by Andritsos and Hanratty).

Hand calculation (later transferred to a computer calculation) was carried out, and the results showed that Andritsos & Hanratty model overpredicted the total pressure drop measured experimentally during this study by at least a factor of 2.

6.3.3 Andritsos And Hanratty Model Modified To Predict Results For Large Diameter Pipelines (i.e The Present Study)

It is perhaps important to indicate that the Andritsos and Hanratty experimental work involved pipe diameter of 25.2 mm and 95.3 mm whereas a pipeline diameter of 203 mm was used in the present study. Notable differences between the observations of Andritsos and Hanratty and the present study are

(i) All their results for stratified flow range from 0 < h/D < 0.5, while the present results range from 0.5 < h/D < 0.85.

(ii) Andritsos and Hanratty did not observe turbulent flow for h/D > 0.5, whereas all the stratified flow observed during the present tests was turbulent flow.

An attempt was made to modify the model through the expression for τc, because of the strong dependence of τc on the ratio h/D, see figures 6.3.1. This is an obvious choice as a starting point to modify the model due to the big difference in the test section diameter used.

From equation 6.3.6,

$$\tau_c = \rho_L \left(\frac{h^+ \nu_L}{D} \right)^n \left(\frac{h}{D} \right)^m$$

In the above expression for τ_c all variables have been determined directly from experimental data. It is clear therefore that τ_c can only be changed by changing the indices m and n. Using equation 6.3.2 with the experimental dp/dz and other experimental data τ_{WL} was calculated. Hence values of τ_c was determined via equations 6.3.8 (for τ_i) and 6.3.7. This values of τ_c (i.e from experimental dp/dz) was then compared to values obtained from equation 6.3.6 using indices n and m as variables. First attempt was made using hand calculator for the test run 150814. This attempt was later abandoned because of its time consuming, and lack of accuracy.

A computer package called TSP is later used to calculate the values of n and m which best represent the experimental data. The computer package was given the values of τ_c calculated from experimental data along with all the other variables required in equation 6.3.6 except n and m. The computer then gave the values of n and m which would converge the value of τ_c from 6.3.6 to the experimental value of τ_c (within a range of error which we can specify). Measurement of h/D become progressively less accurate as h/D increases > 0.8 (as discussed in chapter 4). The Andritsos and Hanratty model has a very strong dependence on the value of h/D (model overprediction of the dp/dz increases with the increase of h/D). Therefore the evaluation of n and m (to modify the model) was based on data ranging from $0.5 < h/D < 0.62$ (more than 80% of the experimental data are in this range). Several iterative runs of the TSP program was required to optimize the values of n and m . These indices could be determined for any required degree of agreement between calculated and experimental values of τ_c. Ultimately values of n and m were determined to give agreement within ± 20%.

The values of n and m obtained which best represent the experimental data for large diameter (203 mm) within ± 20% are:

n = 2.4512 and m = -4.2440 (compared with Andritsos and Hanratty values of +2 and -2 respectively). It is perhaps clearer now from these new values of n and m the strong dependence of these indices on the ratio h/D, especially m.

The two new indices were then inserted in equation 6.3.6 and used along with equations 6.3.7 and 6.3.2 to predict (dp/dz) for all experimental data. The modified model predicted 65% of the data within error < 20%, and 79% of the data within error < 35%. The plots of $(dp/dz)_{exp.}$ vs $(dp/dz)_{predicted}$ for both are shown in figures 6.3.2 and 6.3.3 respectively.

6.3.4 Prediction Of Pressure Drop; Bishop's Model

This model uses the same approach as Taitel and Dukler in using a dimensionless form of the mechanical energy equations to predict the liquid holdup and pressure drop, with the addition of three terms in the energy equations; the kinetic energy in each phase and the hydraulic gradient in the liquid phase (ILG).

Three cases of smooth stratified flow were considered and figure 6.3.4 illustrates these three cases.

Case A. represents nearly uniform horizontal flow where the ILG is not steep enough to be observed.

Case B. depicts horizontal stratified flow having an ILG which observable.

Case C. include both ILG and tube inclination.

The objective of their work was to analyze the reported Newtonian liquid-gas stratified flow data for horizontal circular ducts to determine the effect of ILG on liquid holdup, flow pattern transitions, the two-phase pressure drop parameter φ^2_L, and to check the validity of the one-dimentional energy equation for a wide range of liquid-gas stratified flow data. Referring to figure 6.3.4, the one-dimensional energy equation was written as follows:

Case A. Horizontal, stratified, uniform flow; no ILG assumed

$$-\left(\frac{dp}{dx}\right)_{TPL} = \frac{\tau_{WL} S_L}{A_L} - \frac{\tau_{iL} S_i}{A_L} \tag{6.3.9}$$

and

$$-\left(\frac{dp}{dx}\right)_{TPG} = \frac{\tau_{WG} S_G}{A_G} + \frac{\tau_{iG} S_i}{A_G} \tag{6.3.10}$$

where $U_{SG} >> U_{SL}$ and $(dp/dx)_{TPL} = (dp/dx)_{TPG}$

Here, dp/dx is the axial pressure gradient, τ is the shear stress, S is the perimeter, A is the cross-sectional area for flow and U is the fluid velocity. The subscript TP stands for two-phase, W for wall, i for interfacial conditions and S for superficial quantity.

Moreover, subscripts L and G are used to denote the liquid and gas phase, respectively, throughout this analysis.

If the two-phase pressure gradient in the two phases is assumed equal, equations 6.3.9 and 6.3.10 where combined to produce the dimensionless equation

$$\chi^2 F\,(R_L, n, m) \quad - \quad F\left(R_L, \frac{f_{iL}}{f_{WG}}, \frac{f_{iG}}{f_{WG}}\right) \quad = \quad 0 \qquad (6.3.11)$$

Where F is a functional relationship involving the parameters within the brackets; n and m (exponents of the Reynolds number in the friction factor relationship) simply depends on whether the liquid and gas phases are laminar or turbulent, R_L is the liquid holdup, f is the friction factors and χ is the Lockhart-Martinelli parameter.

If values for the interfacial friction factors f_{iG} and f_{iL} are assumed, 6.3.11 can be iterated to obtain holdup R_L. Because 6.3.11 is valid only for smooth or wavy uniform stratified flow, if $f_{iL} = f_{iG}$ is assumed, deviations of experimental holdup values from those predicted by 6.3.11 indicate wavy stratified flow or stratified flow with ILG. Equation 6.3.11 is used by Bishop and Deshpande as a basis for determining the presence of ILG. The procedure followed by Taitel and Dukler (1976) to produce the dimensionless equation 6.3.11 is shown in appendix D.

Case B. Horizontal stratified flow with ILG.

Again referring to figure 6.3.4, the one-dimensional energy equations are

$$-\left(\frac{dp}{dx}\right)_{TPL} \quad - \quad g\,\rho_L \frac{dh}{dx} \quad - \quad \frac{\alpha\,\rho_L}{2}\frac{d(U_L^2)}{dx} \quad = \quad \frac{\tau_{WL}\,S_L}{A_L} - \frac{\tau_{iL}\,S_i}{A_L} \qquad (6.3.12)$$

and

$$-\left(\frac{dp}{dx}\right)_{TPG} \quad - \quad \frac{\alpha\,\rho_G}{2}\frac{d(U_G^2)}{dx} \quad = \quad \frac{\tau_{WG}\,S_G}{A_G} + \frac{\tau_{iG}\,S_i}{A_G} \qquad 6.3.13$$

Where, g is the acceleration due to gravity, ρ is the density and h is the height of liquid in the tube.

The parameter α accounts for radial variation in the velocity profile and is 2 for laminar flow of a Newtonian fluid through a circular tube.

Equations 6.3.12 and 6.3.13 can be put in a dimensionless form similar to 6.3.11. Let

$$I = -\left(\frac{dp}{dx}\right)_{TPL} - g\,\rho_L\left(\frac{dh}{dx}\right) - \frac{\alpha\,\rho_L}{2}\frac{d(U_L^2)}{dx} + \left(\frac{dp}{dx}\right)_{TPG} + \frac{\alpha\,\rho_G}{2}\frac{d(U_G^2)}{dx} \qquad (6.3.14)$$

By combining 6.3.12 and 6.3.13, 6.3.15 is obtained:

$$I - \frac{\tau_{WL}\,S_L}{A_L} + \frac{\tau_{iL}\,S_i}{A_L} + \frac{\tau_{WG}\,S_G}{A_G} + \frac{\tau_{iG}\,S_i}{A_G} = 0 \qquad (6.3.15)$$

Which in dimensionless from gives

$$\chi^2 F\,(R_L, n, m) - F\left(R_L, \frac{f_{iL}}{f_{WG}}, \frac{f_{iG}}{f_{WG}}\right) - Z = 0 \qquad (6.3.16)$$

Where

$$\chi^2 = \frac{-\left(\frac{dp}{dx}\right)_{SL}}{-\left(\frac{dp}{dx}\right)_{SG}} \qquad \textit{Lockhart-Martinelli Parameter}$$

and

$$Z = \frac{4I}{F\,(R_L)\left(\frac{dp}{dx}\right)_{SG}} \qquad (6.3.17)$$

The parameter Z represents the equivalent relative dimensionless force acting on the liquid in the direction of flow due to the ILG and any other difference in the two-phase pressure gradient in each phase.

Case C. Inclined stratified flow with ILG

The one dimensional energy equations are

$$-\left(\frac{dp}{dx}\right)_{TPL} - g\,\rho_L \frac{dh}{dx} - \frac{\alpha\,\rho_L}{2}\frac{d(U_L^2)}{dx} = \frac{\tau_{WL} S_L}{A_L} - \frac{\tau_{iL} S_i}{A_L} - \rho_L\, g \sin\beta \tag{6.3.18}$$

and

$$-\left(\frac{dp}{dx}\right)_{TPG} - \frac{\alpha\,\rho_G}{2}\frac{d(U_G^2)}{dx} = \frac{\tau_{WG} S_G}{A_G} + \frac{\tau_{iG} S_i}{A_G} - \rho_G\, g \sin\beta \tag{6.3.19}$$

Where β is the inclination from the horizontal.

The dimensionless form similar to 6.3.16 is

$$\chi^2 F\,(R_L, n, m) - F\left(R_L, \frac{f_{iL}}{f_{WG}}, \frac{f_{iG}}{f_{WG}}\right) - Z - 4Y = 0 \tag{6.3.20}$$

Where Y is similar to the parameter introduced by Taitel and Dukler (1976) to account for tube inclination.

Equation 6.3.20 is similar to the following equation (as shown in appendix D):

$$\chi^2 \frac{(\tilde{D}_L \tilde{U}_L)^{-n}}{(\tilde{D}_G \tilde{U}_G)^{-m}}\left[\tilde{U}_L^2 \frac{\tilde{S}_L}{\tilde{A}_L}\right] - \tilde{U}_G^2\left[\frac{\tilde{S}_G}{\tilde{A}_G} + \frac{f_{iL}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_L} + \frac{f_{iL}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_G}\right] - Z - 4Y = 0 \tag{6.3.21}$$

Where

$$\chi^2 = \frac{\frac{4C_L}{D}\left(\frac{DU_{SL}}{\nu_L}\right)^{-n} 1/2\rho_L U_{SL}^2}{\frac{4C_G}{D}\left(\frac{DU_{SG}}{\nu_G}\right)^{-m} 1/2\rho_G U_{SG}^2} = \frac{\left(\frac{dp}{dx}\right)_{SL}}{\left(\frac{dp}{dx}\right)_{SG}}$$

$$Z = \frac{4I}{\frac{4C_G}{D}\left(\frac{DU_{SG}}{\nu_G}\right)^{-m} 1/2\rho_G U_{SG}^2\,(\tilde{D}_G \tilde{U}_G)^{-m}} = \frac{4I}{\left(\frac{dp}{dx}\right)_{SG}(\tilde{D}_G \tilde{U}_G)^{-m}}$$

$$Y = \frac{(\rho_L - \rho_G)\, g \sin\beta}{\frac{4C_G}{D}\left(\frac{DU_{SG}}{\nu_G}\right)^{-m} 1/2\rho_G U_{SG}^2\,(\tilde{D}_G \tilde{U}_G)^{-m}} = \frac{(\rho_L - \rho_G)\, g \sin\beta}{\left(\frac{dp}{dx}\right)_{SG}(\tilde{D}_G \tilde{U}_G)^{-m}}$$

and

$$I = -\left(\frac{dp}{dx}\right)_{TPL} - g\,\rho_L\left(\frac{dh}{dx}\right) - \frac{\alpha\,\rho_L}{2}\frac{d(U_L^2)}{dx} + \left(\frac{dp}{dx}\right)_{TPG} + \frac{\alpha\,\rho_G}{2}\frac{d(U_G^2)}{dx}$$

The term Y in equation 6.3.21 is similar to the Y term introduced by Taitel and Dukler (1976) *but in fact these are not equal as Bishop claimed to be. This difference is only important if the flow was not horizontal.*

In order to test the model equation 6.3.21 was programmed on the computer. Only the following which were not measured experimentally i.e f_{iL}/f_G , f_{iG}/f_G , C_L , C_G , n and m were variables in the program (the rest either measured or calculated from experimental data).

As all the stratified data were smooth stratified the following values were assumed for the above variables

$f_{iL}/f_G = f_{iG}/f_G = 1$ (as most of the researchers usually take for the smooth stratified flow), $C_L = C_G = 0.046$ and $n = m = 0.2$ (as given by Taitel and Dukler).

The model (equation 6.3.21) was tested against experimental results; the results were presented in the following form:

As equation 6.3.21 contains four terms in the left hand side; for the left hand side of the expression to converge it should equal the right hand side, i.e zero. The terms in equation 6.3.21 were named for simplicity as follows:

TERM 1 - TERM 2 - TERM Z - TERM Y = 0 (6.3.22)

where,

$$TERM \quad 1 \quad = \quad \chi^2 \frac{(\tilde{D}_L \tilde{U}_L)^{-n}}{(\tilde{D}_G \tilde{U}_G)^{-m}} \cdot \tilde{U}_L^2 \cdot \frac{\tilde{S}_L}{\tilde{A}_L}$$

$$TERM \quad 2 \quad = \quad \tilde{U}_G^2 \left[\frac{\tilde{S}_G}{\tilde{A}_G} + \frac{f_{iL}}{f_G} \frac{\tilde{S}_i}{\tilde{A}_L} + \frac{f_{iL}}{f_G} \frac{\tilde{S}_i}{\tilde{A}_G} \right]$$

$$TERM \quad Z \quad = \quad \frac{4I}{\frac{4C_G}{D}\left(\frac{DU_{SG}}{\nu_G}\right)^{-m} 1/2 \rho_G U_{SG}^2 (\tilde{D}_G \tilde{U}_G)^{-m}} \quad = \quad \frac{4I}{\left(\frac{dp}{dx}\right)_{SG} (\tilde{D}_G \tilde{U}_G)^{-m}}$$

and

$$TERM \quad Y \quad = \quad 4Y \quad = \quad \frac{4(\rho_L - \rho_G)\, g \sin\beta}{\frac{4C_G}{D}\left(\frac{DU_{SG}}{\nu_G}\right)^{-m} 1/2 \rho_G U_{SG}^2 (\tilde{D}_G \tilde{U}_G)^{-m}} \quad = \quad \frac{4(\rho_L - \rho_G)\, g \sin\beta}{\left(\frac{dp}{dx}\right)_{SG} (\tilde{D}_G \tilde{U}_G)^{-m}}$$

In the present case TERM Y = 0 (horizontal flow), and equation 6.3.22 reduces to

TERM 1 - TERM 2 - TERM Z = 0 (6.3.23)

To assess the convergence of equation 6.3.23; the left hand side should always equal zero i.e TERM 1 should equal (TERM 2 + TERM Z). Therefore, the results were plotted on the co-ordinates TERM 1 versus (TERM 2 + TERM Z), and shown on figure 6.3.5 for all values $0.5 < h/D < 0.8$ which include 92% of the total data, and the %RMS error were found to be 14% (based on term one). Although the prediction of the Bishop model was not considered bad, it can be improved for the higher values, of TERM 1 and (TERM 2 + TERM Z) ≥ 1000. A new model has therefore been proposed (section 6.3.5). *This new model follows the same procedure as Bishop's, and a better prediction for the stratified data and perhaps for large diameter stratified data in general where hydraulic gradient does exist was obtained.*

6.3.5 Proposed Model For Prediction Of The Total Change In Pressure In The Direction Of Flow (Including Wall Shear Stress, Interfacial Effects And The Liquid Level Gradient) Based On Bishop's Approach

The present model was an effort by the author to make use of the present set of data for stratified flow not only to test and compare with some of the models available, but also to try and develop a new model based on these data. This model was considered valuable due to the following reasons:

(i) The large diameter test section used in obtaining the present set of data, compared to those available in literature.

(ii) The length of the test section used (34 m), which ensures that settled flows usually obtained within this length, especially for stratified type flows [3], [4], [110], [111].

(iii) The measurements of a new parameters namely the Interfacial Level Gradient (ILG), which has not known to be measured before under these set of conditions.

The present model was developed in the same way as that of Taitel & Dukler, and that of Bishop's. The energy equations for each phase used were like those of Bishop's, i.e. equations 6.3.18 and 6.3.19. All the terms in these two equations were given the same meanings like that given in section 6.3.4.

It perhaps worth mentioning that; although the present data were only for horizontal stratified flow (smooth stratified), the model was developed for both the horizontal and inclined (not tested for inclined flows) flows.

The model is also presented in dimensionless form like that of Bishop's; by following the same procedure as that given in Appendix D. Hence, the model developed is similar to that of Bishop's, i.e. equation 6.3.21.

The difference between the two models being the following:

(i) The value of n in the present model was not assumed 0.2, but was avaluated using the present set of data, i.e by converging model prediction with experimental data.

(ii) The value of m in the present model was not assumed 0.2, but assumed to have the same value as n.

(iii) The values of C_G and C_L in the present model were assumed to be equal, but again their values were left to be decided by the present set of data.

(iv) The parameter Y in Bishop's model was said to be the same as that of Taitel & Dukler; the analysis of equation 6.3.20 (which is the same as that taken from Bishop's paper) would indicate that the Y in 6.3.20 in not that of Taitel and Dukler. Full details are in Appendix D. The parameter Y in the present model was found (as shown in Appendix D) to be;

$$Y = \frac{(\rho_L - \rho_G)\, g \sin\beta}{\frac{4C_G}{D}\left(\frac{DU_{SG}}{\nu_G}\right)^{-m} 1/2\rho_G U_{SG}^2 (\tilde{D}_G \tilde{U}_G)^{-m}} = \frac{(\rho_L - \rho_G)\, g \sin\beta}{\left(\frac{dp}{dx}\right)_{SG} (\tilde{D}_G \tilde{U}_G)^{-m}}$$

The values of m, n, C_G and C_L were all obtained using the present data. The values of f_{iL}/f_G and f_{iG}/f_G were taken the same as the values assumed by Bishop, i.e. $f_{iL}/f_G = f_{iG}/f_G = 1.0$.

The values obtained for m, n, C_G and C_L were as follows;

$m = n = 0.214$ and $C_G = C_L = 0.048$

The new values of m, n, C_G and C_L were used in equation 6.3.21 to predict the present results; in the same way used in section 6.3.4.

The present model predicted 92% of the total data for stratified flow within %RMS of 9%, and 89% of the total data within %RMS of 8%. The results for the 92% of the data are shown in figure 6.3.6 and for 89% of the total data in figure 6.3.7. The axis of these two graphs being (TERM 1) versus (TERM 2 + TERM Z) as explained in section 6.3.4.

From the analysis given in sections 6.3.1 - 6.3.5; it is perhaps fair to say that the model of Andritsos and Hanratty did not take account of tube size effects and the possible ILG effects, and hence the model prediction was not satisfactory. The Bishop model in other hand did take account of ILG, but perhaps its development from small diameters data had its effect on the model; therefore the model preformed in much better way than that of Andritsos & Hanratty. Due to these uncertainties the author recommend the use of the present model in preference to the other two for stratified flows in large diameter tubes in the range of conditions tested.

Correlation	% AVE. Error	% RMS Error
Blasius	19.848	20.023
Konakov	16.986	17.351
Moody	19.945	20.163
Barr	16.929	17.318
Serghides	16.359	16.732
Jain	16.723	17.107
Zingrang & Sylvester	23.349	23.523
Schacham	21.674	21.860
Haaland	16.869	17.247
Chen, J.J.	18.891	19.086
Chen, N.H.	16.212	16.598
2nd Serghides	24.666	24.831
2nd Chen, N.H.	15.953	16.366
2nd Zingrang & Sylvester	15.296	15.719
Jain & Colebrook	16.029	16.437
Haanland & Colebrook	15.953	16.366

Table 6.1.1 Percent Errors of Predicted Single-Phase Friction Compared to Experimental Values (For 50,000 < Re < 500,000)

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
41201	2088.57	0.000000	0.000000	0.0000	1.5848	2.0900	0.0000	0.0000	0.000000	9	0.01617	360004.
41202	2014.10	0.000000	0.000000	0.0000	1.5988	2.0155	0.0000	0.0000	0.000000	9	0.01647	347167.
41203	1923.34	0.000000	0.000000	0.0000	1.5959	1.9247	0.0000	0.0000	0.000000	9	0.01662	332433.
41204	1839.63	0.000000	0.000000	0.0000	1.5749	1.8410	0.0000	0.0000	0.000000	9	0.01657	318834.
41205	1761.16	0.000000	0.000000	0.0000	1.5750	1.7626	0.0000	0.0000	0.000000	9	0.01668	310256.
41206	1639.48	0.000000	0.000000	0.0000	1.5419	1.6409	0.0000	0.0000	0.000000	9	0.01659	291169.
41207	1467.04	0.000000	0.000000	0.0000	1.5351	1.4683	0.0000	0.0000	0.000000	9	0.01699	260194.
41208	1332.77	0.000000	0.000000	0.0000	1.6207	1.3339	0.0000	0.0000	0.000000	9	0.01838	236380.
41209	1105.33	0.000000	0.000000	0.0000	1.0011	1.1063	0.0000	0.0000	0.000000	9	0.01867	196569.
41210	847.91	0.000000	0.000000	0.0000	1.0427	0.8486	0.0000	0.0000	0.000000	9	0.02001	150791.
41211	675.12	0.000000	0.000000	0.0000	0.9167	0.6757	0.0000	0.0000	0.000000	9	0.01854	120547.
41212	454.69	0.000000	0.000000	0.0000	0.9927	0.4551	0.0000	0.0000	0.000000	9	0.02309	81297.
220101	795.53	0.000000	0.000000	0.0000	5.3210	0.7960	0.0000	0.0000	0.000000	9	0.10475	133576.
50201	293.02	0.000000	0.000000	0.0000	1.1083	0.2931	0.0000	0.0000	0.000000	9	0.03338	46506.
50202	305.50	0.000000	0.000000	0.0000	0.9193	0.3056	0.0000	0.0000	0.000000	9	0.02712	48485.
50203	334.65	0.000000	0.000000	0.0000	0.8701	0.3348	0.0000	0.0000	0.000000	9	0.02452	53264.
50204	329.02	0.000000	0.000000	0.0000	1.2965	0.3291	0.0000	0.0000	0.000000	9	0.03676	52593.
50205	376.63	0.000000	0.000000	0.0000	0.8348	0.3768	0.0000	0.0000	0.000000	9	0.02217	60374.
50206	345.62	0.000000	0.000000	0.0000	0.8686	0.3458	0.0000	0.0000	0.000000	9	0.02399	55560.
50207	366.58	0.000000	0.000000	0.0000	0.9388	0.3667	0.0000	0.0000	0.000000	9	0.02519	59013.

TABLE 6.1.2 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	EMF	TEMP	HL	PG	S1	S2	S3	S4	VDF	POT	PE	PRES	ELL	PTT	PATRN
	MV	C	CMH2O	BAR	CM	CM	CM	CM			MMH2O/M	MMH2O			
220102	15.800	12.4	47.9	2.10	20.1	20.1	20.0	20.0	0.3062	0.00	0.92	809.03	0.000	0.0000	42
220103	15.400	12.4	105.8	2.06	20.2	20.1	20.1	20.0	0.3884	0.00	4.59	933.85	0.000	0.0000	2
220104	15.300	12.4	194.0	2.07	20.1	20.0	20.0	20.0	0.4065	0.00	5.18	1118.46	0.000	0.0000	2
220105	15.200	12.4	291.1	2.09	20.0	19.9	19.9	20.0	0.3786	0.00	8.67	1214.82	0.000	0.0000	2
220106	15.200	12.3	370.4	2.10	19.9	19.8	19.8	19.9	0.3700	0.00	8.09	1288.14	0.000	0.0000	2
220107	15.300	12.3	432.2	2.10	19.9	19.8	19.8	19.9	0.3600	0.00	10.80	1416.30	0.000	0.0000	2
220108	15.400	12.3	491.4	2.10	19.9	19.8	19.8	19.8	0.0692	0.00	10.97	1436.77	0.000	0.0000	2
220109	15.400	12.3	478.8	2.12	19.9	19.8	19.8	19.8	0.3390	0.00	13.34	1554.39	0.000	0.0000	2
280101	12.400	10.5	31.0	2.69	19.8	19.8	19.8	19.8	0.2660	0.00	0.76	942.43	0.000	0.0000	34
280102	12.000	10.6	19.0	2.61	19.4	19.4	19.4	19.4	0.3434	0.00	0.65	940.17	0.000	0.0000	3
280103	12.200	10.8	45.0	2.54	19.1	19.1	19.1	19.1	0.3004	0.00	0.93	951.97	0.000	0.0000	34
280104	12.500	11.0	49.0	3.28	4.8	4.9	4.9	4.8	0.1609	0.00	0.75	939.47	0.000	0.0000	3
280105	13.100	11.1	22.0	3.20	4.7	4.8	4.8	4.7	0.3007	0.00	0.65	918.63	0.000	0.0000	3
280106	13.600	11.3	34.0	3.18	4.6	4.7	4.7	4.6	0.1882	0.00	0.80	949.88	0.000	0.0000	3
280107	14.100	11.4	68.0	3.15	4.6	4.7	4.7	4.6	0.0000	0.00	2.14	980.88	0.000	0.0000	42
280108	14.800	11.6	68.0	2.80	14.9	15.0	15.0	15.0	0.2580	0.00	1.01	989.12	0.000	0.0000	42
280109	15.000	11.6	111.0	2.95	15.4	15.4	15.4	15.5	0.3166	0.00	5.93	1266.56	0.000	0.0000	2
280110	14.600	11.1	159.0	3.03	15.7	15.7	15.6	15.7	0.3207	0.00	4.78	1312.48	0.000	0.0000	2
280111	14.200	11.1	212.9	2.89	15.1	15.1	15.0	15.1	0.2937	0.00	5.91	1184.77	0.000	0.0000	2
280112	14.100	11.1	1083.6	2.77	15.2	14.8	14.7	14.6	0.2350	0.00	20.45	2220.64	0.000	0.0000	2
280113	13.900	11.3	957.6	2.74	15.1	14.9	14.9	14.6	0.2489	0.00	20.21	2064.16	0.000	0.0000	2
280114	14.000	11.4	762.3	2.72	15.4	15.1	15.0	14.9	0.2642	0.00	16.43	1814.95	0.000	0.0000	2
280115	14.000	11.6	601.0	2.72	15.5	15.3	15.2	15.0	0.2793	0.00	13.46	1635.83	0.000	0.0000	2
280116	14.100	11.8	461.2	2.72	15.7	15.4	15.4	15.3	0.2960	0.00	9.09	1471.19	0.000	0.0000	2
280117	14.100	11.9	369.2	2.72	15.9	15.6	15.5	15.4	0.3039	0.00	9.26	1425.74	0.000	0.0000	2
280118	14.200	12.1	264.6	2.72	16.1	15.8	15.7	15.6	0.3085	0.00	8.03	1258.99	0.000	0.0000	2
280119	14.100	12.1	258.3	2.04	25.2	25.2	25.1	25.1	0.4640	0.00	10.40	1415.41	0.000	0.0000	2
280120	13.400	12.3	122.2	2.07	25.7	25.7	25.5	25.5	0.5017	0.00	5.71	1233.06	0.000	0.0000	2
290101	15.800	12.8	15.0	2.18	24.6	24.6	24.6	24.6	0.3874	0.00	0.62	167.42	0.000	0.0000	34
290102	15.600	12.9	25.0	2.18	24.6	24.6	24.6	24.6	0.3412	0.00	0.78	175.33	0.000	0.0000	34
290103	15.100	13.1	35.0	2.18	24.7	24.6	24.6	24.6	0.3470	0.00	0.88	151.28	0.000	0.0000	34
290104	15.100	12.3	35.0	2.65	19.6	19.6	19.6	19.6	0.2719	0.00	3.00	187.80	0.000	0.0000	3
290105	15.500	13.4	35.0	3.18	9.8	9.9	9.9	9.9	0.1893	0.00	0.82	151.13	0.000	0.0000	3
290106	15.800	13.6	28.0	3.33	5.0	5.0	4.9	5.0	0.3360	0.00	0.61	166.58	0.000	0.0000	3
70201	14.000	11.0	18.0	3.80	0.5	0.0	0.0	0.0	0.6588	0.00	0.41	844.15	0.000	0.0000	3
70202	14.200	11.2	16.0	3.79	1.0	0.0	0.0	0.0	0.7140	0.00	0.41	910.90	0.000	0.0000	3
70203	14.300	11.4	15.0	3.78	2.0	2.0	0.0	0.0	0.7237	0.00	0.36	919.48	0.000	0.0000	3
70204	14.500	11.5	14.0	3.76	2.0	0.0	1.0	0.0	0.7244	0.00	0.41	950.80	0.000	0.0000	3
70205	14.700	11.7	7.0	3.73	3.0	0.0	3.0	0.0	0.7236	0.00	0.39	957.37	0.000	0.0000	3

TABLE 6.2.1 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
220102	12.4	109.26	0.013688	0.039659	1.3379	999.476	0.05306	0.3062	8.9879	42
220103	12.4	110.48	0.020352	0.039097	1.3532	999.482	0.05291	0.3884	45.0477	2
220104	12.4	112.29	0.027556	0.038396	1.3754	999.482	0.05281	0.4065	50.8051	2
220105	12.4	113.24	0.033749	0.038063	1.3869	999.482	0.05279	0.3786	85.0346	2
220106	12.3	113.96	0.038074	0.037687	1.3962	999.494	0.05262	0.3700	79.3373	2
220107	12.3	115.21	0.041125	0.037269	1.4116	999.494	0.05261	0.3600	105.9231	2
220108	12.3	115.42	0.043852	0.037153	1.4141	999.494	0.05254	0.0692	107.5863	2
220109	12.3	116.57	0.043286	0.036895	1.4282	999.494	0.05269	0.3390	130.7762	2
280101	10.5	110.57	0.011014	0.041990	1.3631	999.678	0.05724	0.2660	7.4293	34
280102	10.6	110.55	0.008623	0.040827	1.3621	999.664	0.05561	0.3434	6.3527	3
280103	10.8	110.66	0.013270	0.039830	1.3628	999.649	0.05428	0.3004	9.1104	34
280104	11.0	110.54	0.013847	0.016072	1.3603	999.629	0.02186	0.1609	7.3550	3
280105	11.1	110.33	0.009279	0.015797	1.3571	999.614	0.02144	0.3007	6.3512	3
280106	11.3	110.64	0.011535	0.015545	1.3604	999.604	0.02115	0.1882	7.8094	3
280107	11.4	110.94	0.016313	0.015448	1.3634	999.588	0.02106	0.0000	20.9904	42
280108	11.6	111.03	0.016313	0.032821	1.3634	999.567	0.04475	0.2580	9.9058	42
280109	11.6	113.75	0.020842	0.033464	1.3966	999.561	0.04674	0.3166	58.1170	2
280110	11.1	114.20	0.024944	0.034084	1.4048	999.619	0.04788	0.3207	46.8786	2
280111	11.1	112.94	0.028867	0.032776	1.3897	999.624	0.04555	0.2937	57.9143	2
280112	11.1	123.10	0.065119	0.029223	1.5144	999.619	0.04426	0.2350	200.5930	2
280113	11.3	121.57	0.061216	0.029602	1.4945	999.599	0.04424	0.2489	198.2217	2
280114	11.4	119.12	0.054618	0.030537	1.4639	999.588	0.04470	0.2642	161.1289	2
280115	11.6	117.37	0.048497	0.031285	1.4413	999.567	0.04509	0.2793	132.0246	2
280116	11.8	115.75	0.042481	0.032098	1.4207	999.550	0.04560	0.2960	89.1305	2
280117	11.9	115.31	0.038010	0.032522	1.4142	999.528	0.04599	0.3039	90.8432	2
280118	12.1	113.67	0.032179	0.033370	1.3937	999.517	0.04651	0.3085	78.7349	2
280119	12.1	115.21	0.031793	0.046448	1.4120	999.506	0.06558	0.4640	101.9788	2
280120	12.3	113.42	0.021870	0.048294	1.3896	999.494	0.06711	0.5017	56.0216	2
290101	12.8	102.97	0.007662	0.051911	1.2593	999.434	0.06537	0.3874	6.0825	34
290102	12.9	103.04	0.009891	0.051918	1.2596	999.416	0.06540	0.3412	7.6429	34
290103	13.1	102.81	0.011703	0.052163	1.2561	999.397	0.06552	0.3470	8.6167	34
290104	12.3	103.17	0.011703	0.044396	1.2640	999.494	0.05612	0.2719	29.4477	3
290105	13.4	102.81	0.011703	0.026627	1.2543	999.346	0.03340	0.1893	8.0730	3
290106	13.6	102.96	0.010468	0.017609	1.2557	999.332	0.02211	0.3360	6.0294	3
70201	11.0	109.60	0.008393	0.002335	1.3488	999.629	0.00315	0.6588	4.0372	3
70202	11.2	110.26	0.007913	0.002534	1.3559	999.609	0.00344	0.7140	3.9833	3
70203	11.4	110.34	0.007662	0.005920	1.3560	999.588	0.00803	0.7237	3.5526	3
70204	11.5	110.65	0.007402	0.005467	1.3593	999.578	0.00743	0.7244	3.9834	3
70205	11.7	110.71	0.005234	0.006735	1.3591	999.556	0.00915	0.7236	3.8225	3

TABLE 6.2.2 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
220102	12.4	109.26	0.3062	0.013688	0.039659	999.48	1.3379	0.00899	42
220103	12.4	110.48	0.3884	0.020352	0.039097	999.48	1.3532	0.04505	2
220104	12.4	112.29	0.4065	0.027556	0.038396	999.48	1.3754	0.05081	2
220105	12.4	113.24	0.3786	0.033749	0.038063	999.48	1.3869	0.08503	2
220106	12.3	113.96	0.3700	0.038074	0.037687	999.49	1.3962	0.07934	2
220107	12.3	115.21	0.3600	0.041125	0.037269	999.49	1.4116	0.10592	2
220108	12.3	115.42	0.0692	0.043852	0.037153	999.49	1.4141	0.10759	2
220109	12.3	116.57	0.3390	0.043286	0.036895	999.49	1.4282	0.13078	2
280101	10.5	110.57	0.2660	0.011014	0.041990	999.68	1.3631	0.00743	34
280102	10.6	110.55	0.3434	0.008623	0.040827	999.66	1.3621	0.00635	3
280103	10.8	110.66	0.3004	0.013270	0.039830	999.65	1.3628	0.00911	34
280104	11.0	110.54	0.1609	0.013847	0.016072	999.63	1.3603	0.00736	3
280105	11.1	110.33	0.3007	0.009279	0.015797	999.61	1.3571	0.00635	3

TABLE 6.2.3 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
280112	2012.59	0.000679	0.003559	1.8901	1.1991	2.0120	0.9029	0.2350	0.309757	2		
280113	1892.01	0.000722	0.003508	1.9219	1.3276	1.8914	0.9146	0.2489	0.325947	2		
280114	1688.23	0.000818	0.003434	1.9887	1.3291	1.6875	0.9435	0.2642	0.358604	2		
280115	1499.17	0.000929	0.003377	2.0606	1.3537	1.4984	0.9666	0.2793	0.392133	2		
280116	1313.37	0.001073	0.003326	2.1857	1.1642	1.3126	0.9917	0.2960	0.430389	2		
280117	1175.25	0.001209	0.003307	2.3901	1.4297	1.1744	1.0048	0.3039	0.461096	2		
280118	995.19	0.001444	0.003257	2.7221	1.7026	0.9942	1.0310	0.3085	0.509086	2		
280119	983.86	0.002060	0.003297	3.3121	2.2536	0.9823	1.4351	0.4640	0.593649	2		
280120	677.44	0.003061	0.003243	4.4562	2.3964	0.6757	1.4922	0.5017	0.688306	2		
290101	238.61	0.008465	0.002930	8.5976	1.3360	0.2367	1.6039	0.3874	0.871390	34		
290102	307.45	0.006572	0.002928	7.3183	1.1481	0.3056	1.6041	0.3412	0.839973	34		
290103	363.40	0.005571	0.002917	6.6094	1.0054	0.3616	1.6117	0.3470	0.816753	34		
290104	363.15	0.004774	0.002950	5.9948	3.4042	0.3616	1.3717	0.2719	0.791383	3		
290105	362.39	0.002848	0.002906	4.4225	0.9508	0.3616	0.8227	0.1893	0.694671	3		
290106	323.89	0.002109	0.002908	3.7384	0.8441	0.3234	0.5441	0.3360	0.627169	3		
70201	259.32	0.000375	0.003172	1.6220	0.7638	0.2593	0.0722	0.6588	0.217670	3		
70202	244.50	0.000434	0.003185	1.6815	0.8255	0.2445	0.0783	0.7140	0.242547	3		
70203	236.87	0.001047	0.003181	2.5406	0.7743	0.2367	0.1829	0.7237	0.435881	3		
70204	228.83	0.001003	0.003187	2.4858	0.9157	0.2287	0.1689	0.7244	0.424810	3		
70205	161.92	0.001747	0.003183	3.3210	1.4815	0.1617	0.2081	0.7236	0.562726	3		

TABLE 6.2.4 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
10403	0.5662	0.12670	3.144	0.009261	2.325	0.006847	3.0077	0.0082	2.428	3.748	2.638	3.740
10404	0.6720	0.11435	4.310	0.012854	3.551	0.010590	4.3198	0.0123	3.839	6.124	4.158	5.455
10405	0.6342	0.09611	2.351	0.007054	3.014	0.009042	3.6984	0.0104	3.192	4.945	3.491	4.778
10406	0.6181	0.15906	2.818	0.008770	2.634	0.008198	3.3035	0.0096	2.805	4.247	3.074	4.355
10407	0.6185	0.17397	2.705	0.008592	2.489	0.007907	3.1610	0.0094	2.670	3.999	2.925	4.233
10408	0.6080	0.17054	2.162	0.006808	2.364	0.007444	2.9726	0.0087	2.465	3.590	2.730	4.102
10409	0.6234	0.09473	2.476	0.007370	2.970	0.008841	3.6624	0.0103	3.141	4.886	3.425	4.645
10410	0.5804	0.14337	2.339	0.007253	2.428	0.007530	3.0877	0.0089	2.587	3.862	2.819	3.885
10411	0.7610	0.16465	8.269	0.025617	5.284	0.016369	6.0518	0.0183	5.971	9.454	6.457	7.555
10412	0.7785	0.15828	7.877	0.024037	5.468	0.016684	6.1920	0.0185	6.173	9.711	6.661	8.091
20401	0.5235	0.13671	1.408	0.004333	1.972	0.006067	2.5472	0.0072	2.044	2.855	2.236	3.176
20402	0.5960	0.19378	2.025	0.006428	2.311	0.007334	2.9021	0.0085	2.406	3.455	2.677	3.958
20403	0.5942	0.19515	2.040	0.006482	2.285	0.007260	2.8775	0.0085	2.379	3.418	2.646	3.923

TABLE 6.2.5 COPARISONS OF FRICTION PRESSURE DROP DATA

Model Used	All Two Phase Data		Stratified and Wavy Data only		All Data except Stratified and Wavy	
	% AVE Err	% RMS Err	% AVE Err	% RMS Err	% AVE Err	% RMS Err
Homogenous	22.924	67.185	51.236	86.927	0.075	50.912
Lockhart-Matinelli	8.187	59.055	40.147	79.266	1.855	54.163
Chenoweth-Martin	51.639	103.589	106.851	140.675	6.497	57.780
Baroczy	124.943	188.381	217.944	258.608	51.097	103.266
Chisholm	95.314	167.458	196.109	240.208	16.153	67.536
Dukler	49.415	77.873	65.130	87.892	36.692	68.237

Table 6.2.6 Percent Errors of Predicted Two-Phase Friction Multipliers Compared to Experimental

Flow Pattern	Computer Code
Bubbel	1
Plug	6
Slug	2
Stratified	3
Wavy	4
Plug-Slug	62
Stratified-Wavy	34
Stratified-Slug	32
Wavy-Slug	42
Bubbel-Plug	16

Table 6.2.7 The Flow Patterns Code Used In The Computer Programs and Throughout This Study.

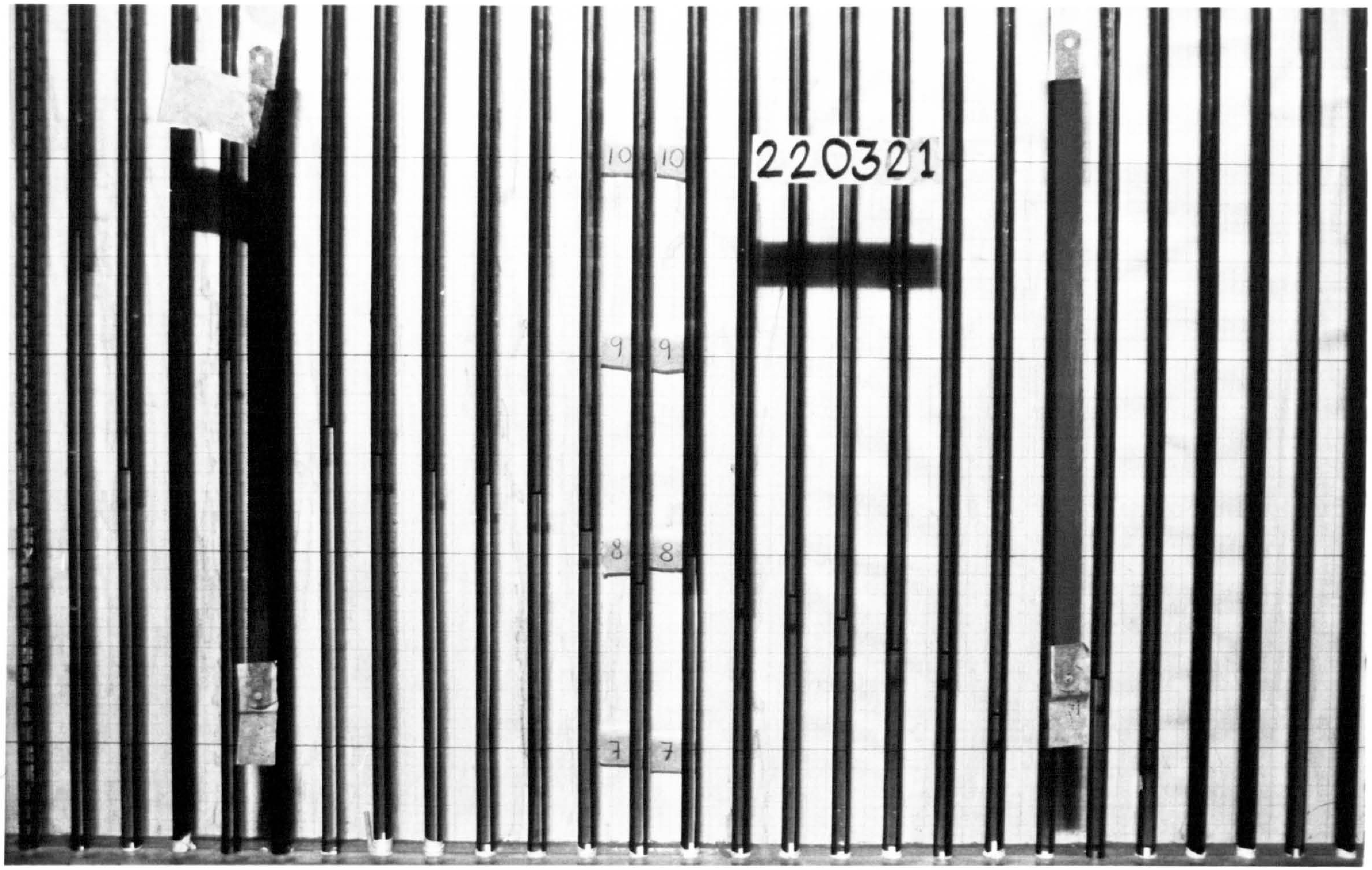


FIG. 6.1.1 AXIAL PRESSURE GRADIENT IN SINGLE PHASE FLOW TAKEN BY CAMERA FOR TEST RUN 220321

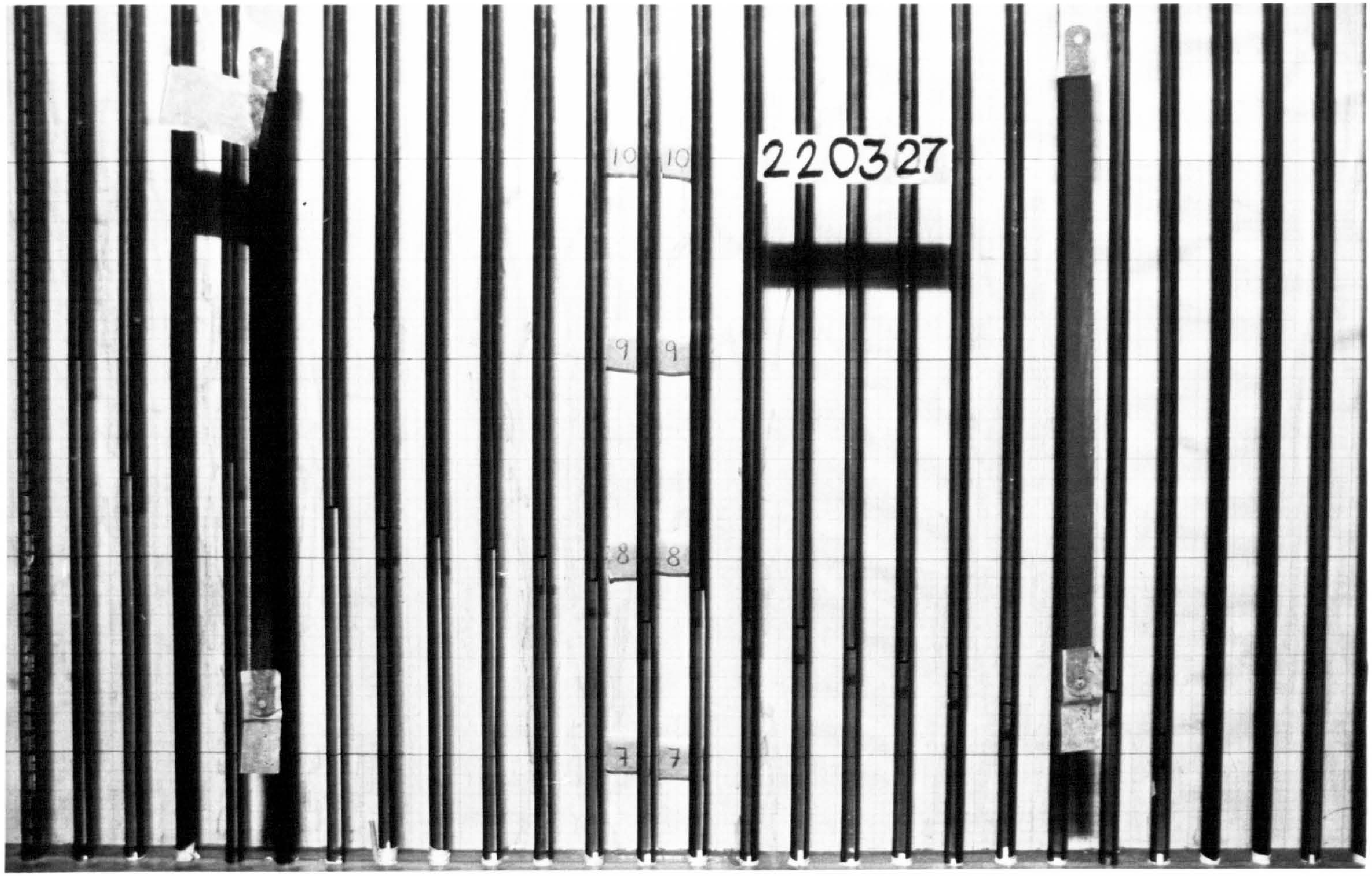


FIG. 6.1.2 AXIAL PRESSURE GRADIENT IN SINGLE PHASE FLOW TAKEN BY CAMERA FOR TEST RUN 220327.

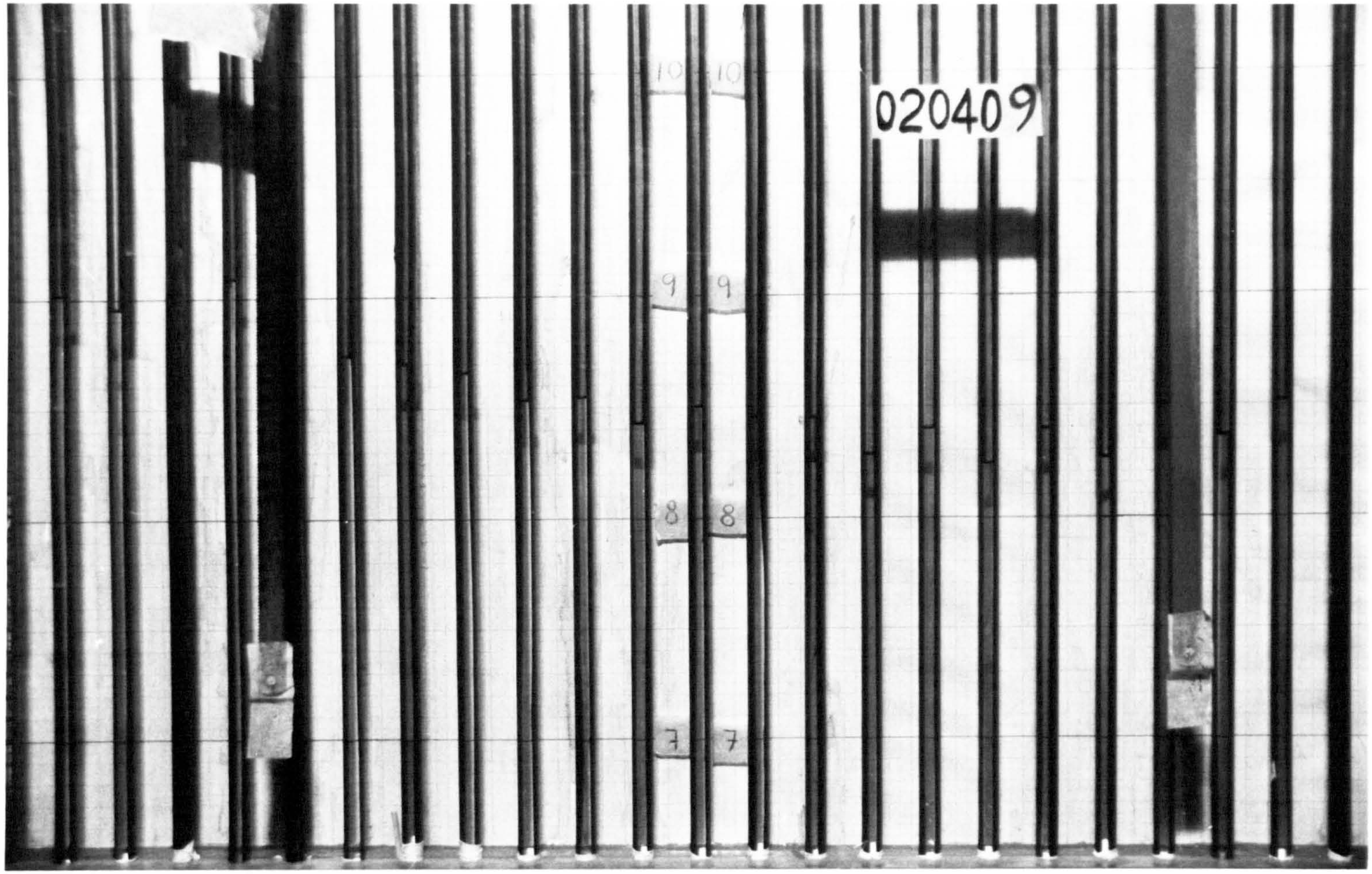


FIG. 6.1.3 AXIAL PRESSURE GRADIENT IN TWO PHASE FLOW (WAVY) TAKEN BY CAMERA FOR TEST RUN 20409.

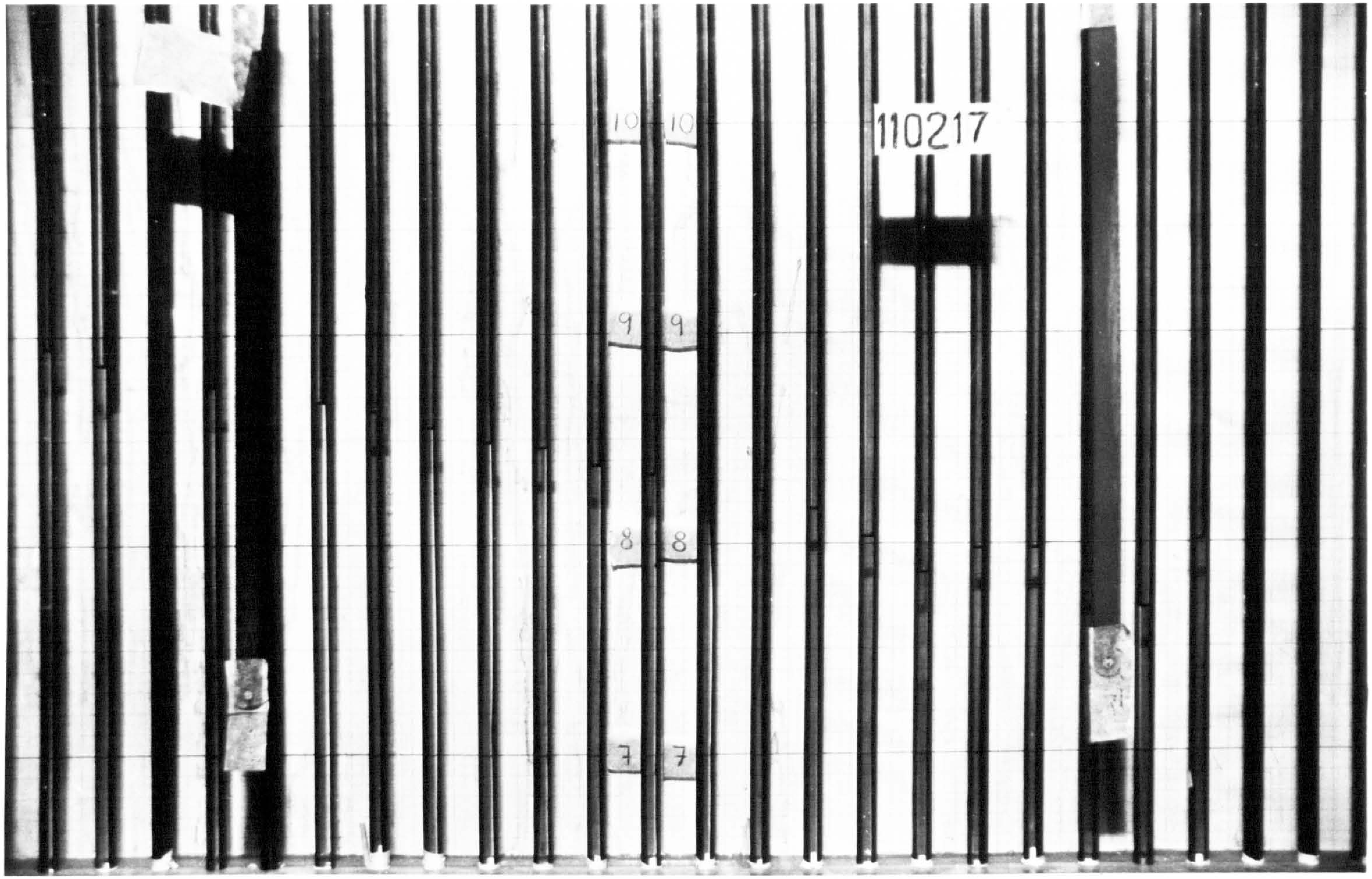


FIG. 6.1.4 AXIAL PRESSURE GRADIENT IN TWO PHASE FLOW (SLUG) TAKEN BY CAMERA FOR TEST RUN 110217.

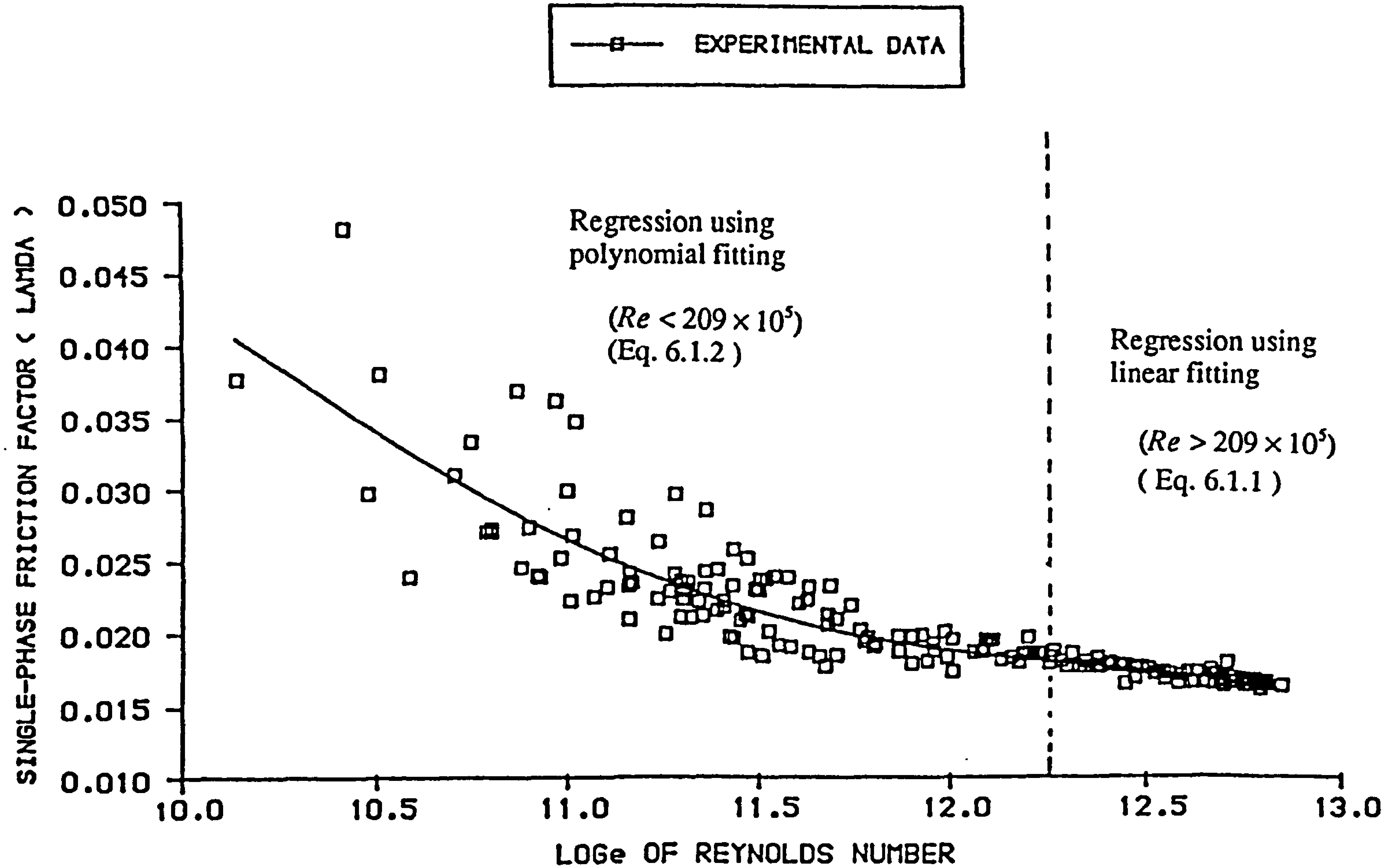


FIG. 6.1.5 EXPERIMENTAL SINGLE-PHASE FRICTION FACTOR CHARACTERISTIC (All Data)

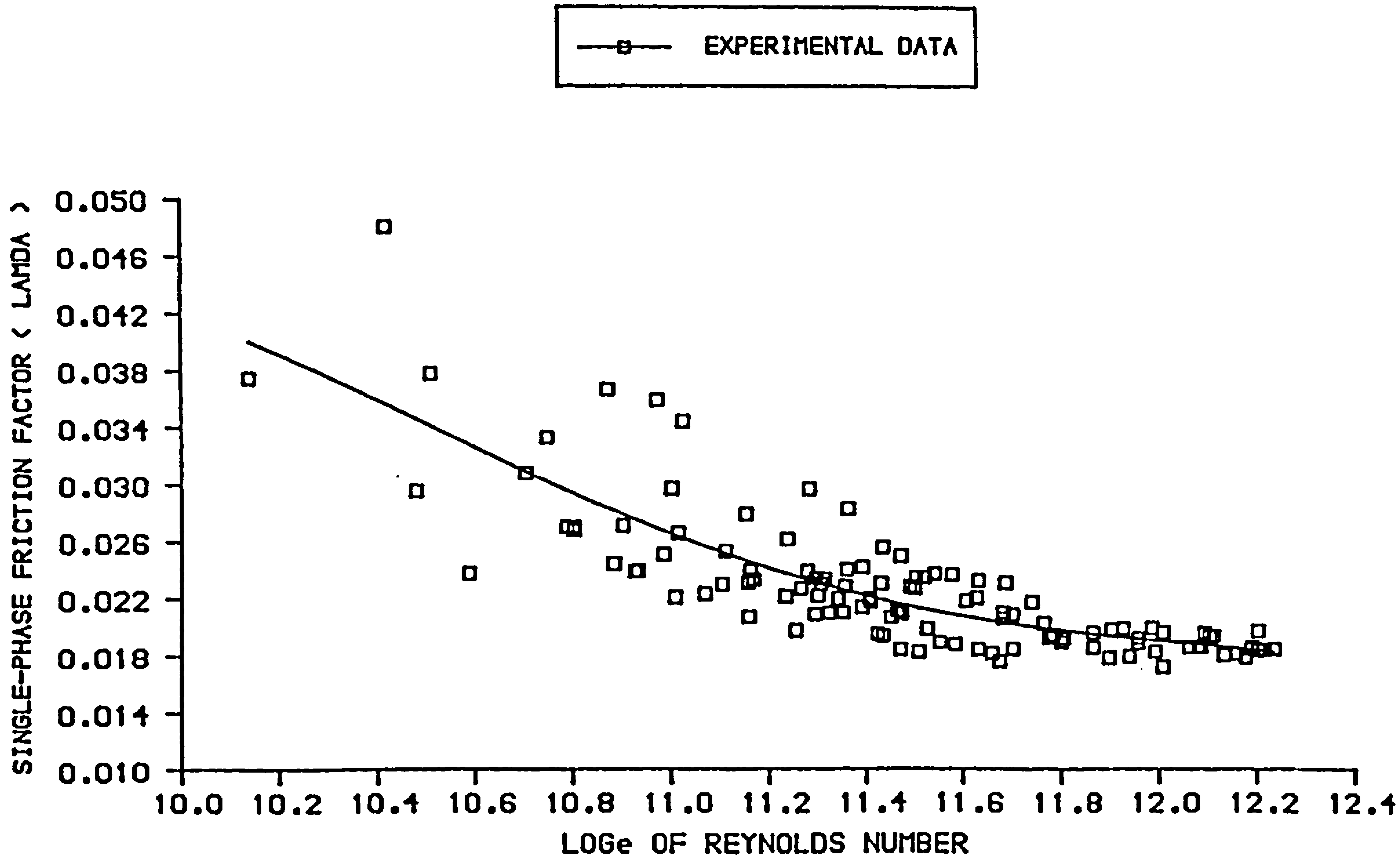


FIG. 6.1.6 EXPERIMENTAL SINGLE-PHASE FRICTION FACTOR CHARACTERISTIC ($Re < 209 \times 10^5$)

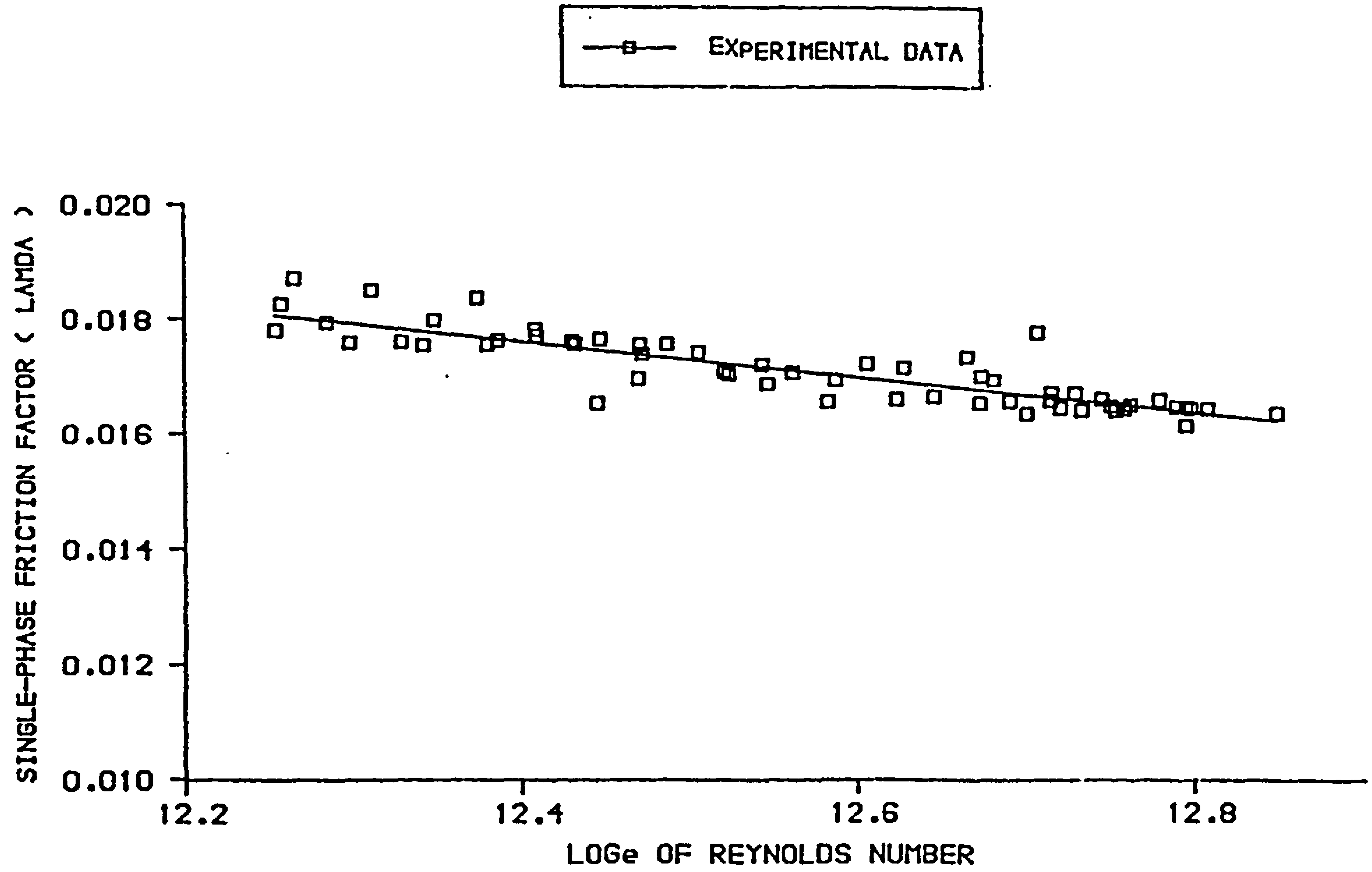


FIG. 6.1.7 EXPERIMENTAL SINGLE-PHASE FRICTION FACTOR CHARACTERISTIC ($Re > 209 \times 10^5$)

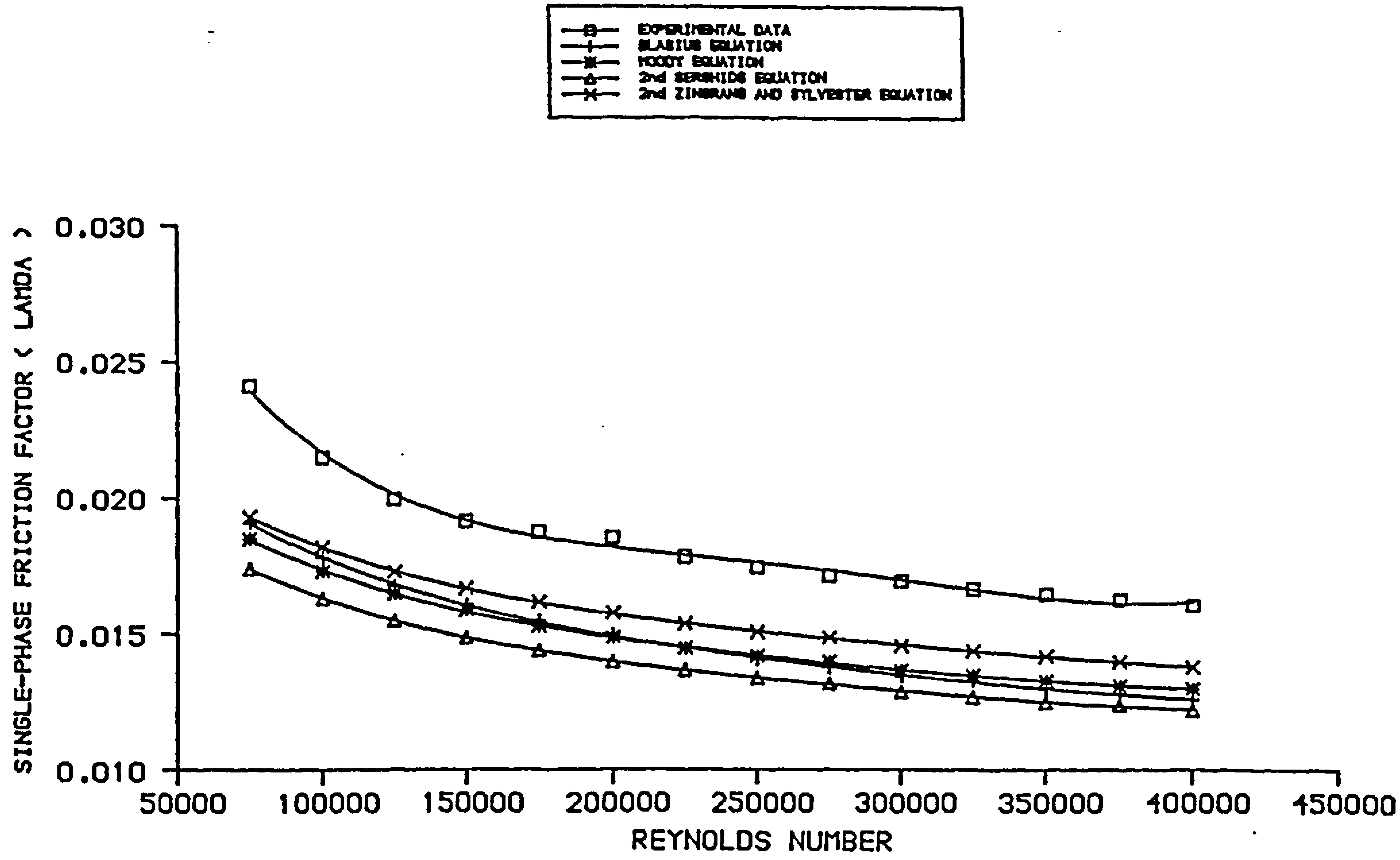


FIG. 6.1.8 COMPARISON BETWEEN EXPERIMENTAL AND PREDICTED SINGLE-PHASE FRICTION FACTORS

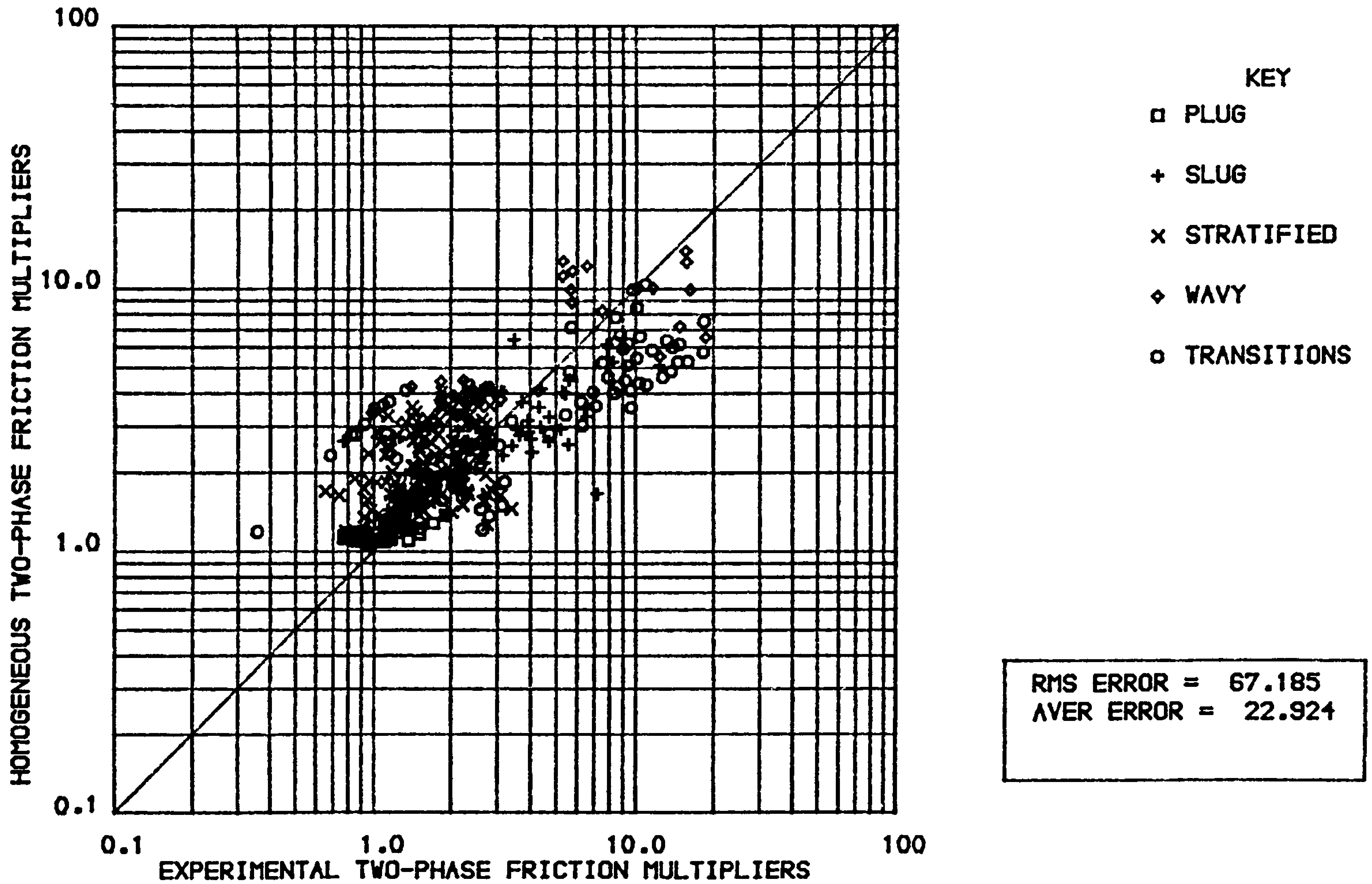


FIG. 6.2.1 COMPARISON BETWEEN EXPERIMENTAL AND HOMOGENEOUS PREDICTIONS (All Data)

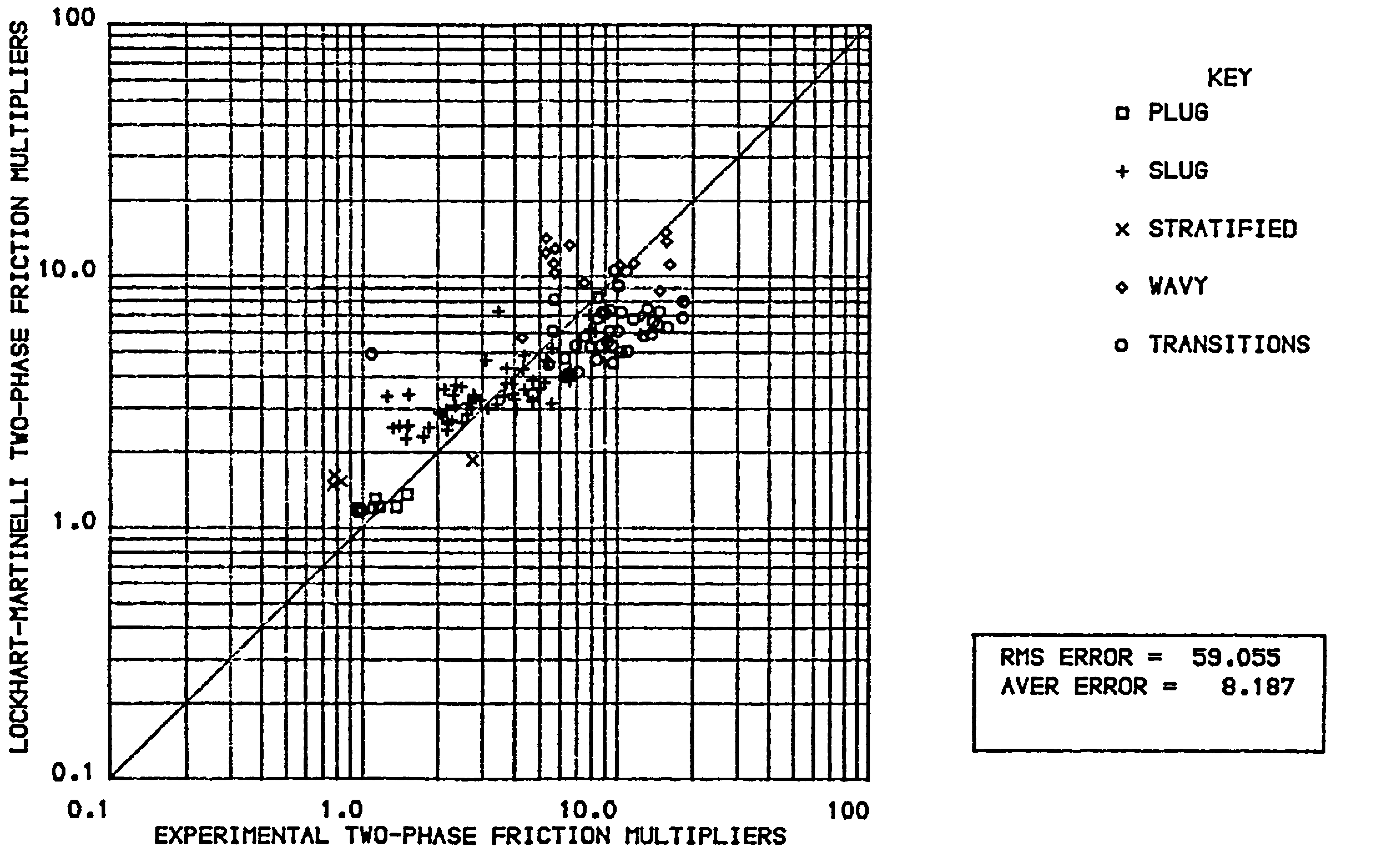


FIG. 6.2.2 COMPARISON BETWEEN EXPERIMENTAL AND LOCKHART-MARTINELLI PREDICTIONS (All Data)

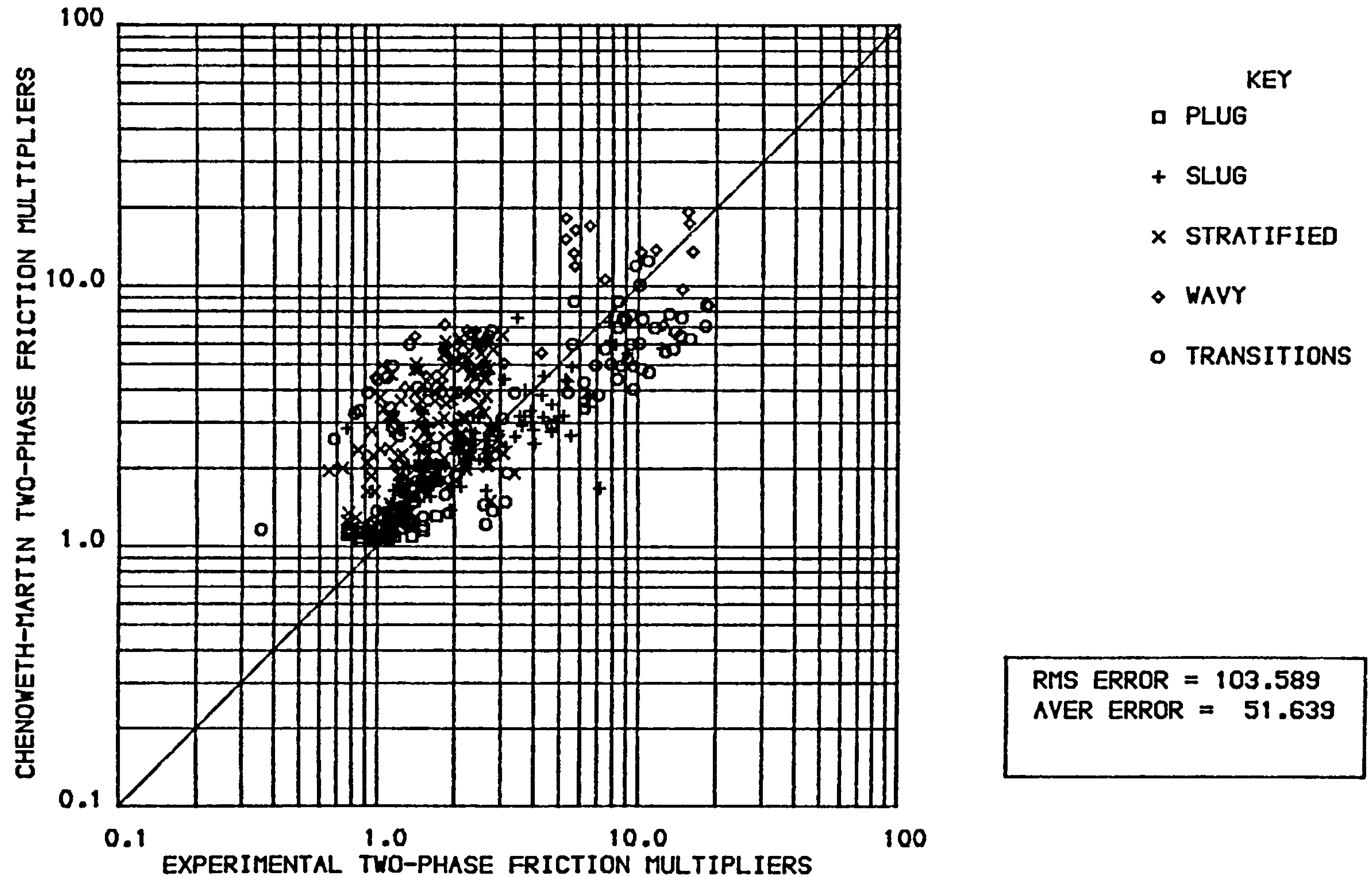


FIG. 6.2.3 COMPARISON BETWEEN EXPERIMENTAL AND CHENOWETH-MARTIN PREDICTIONS (All Data)

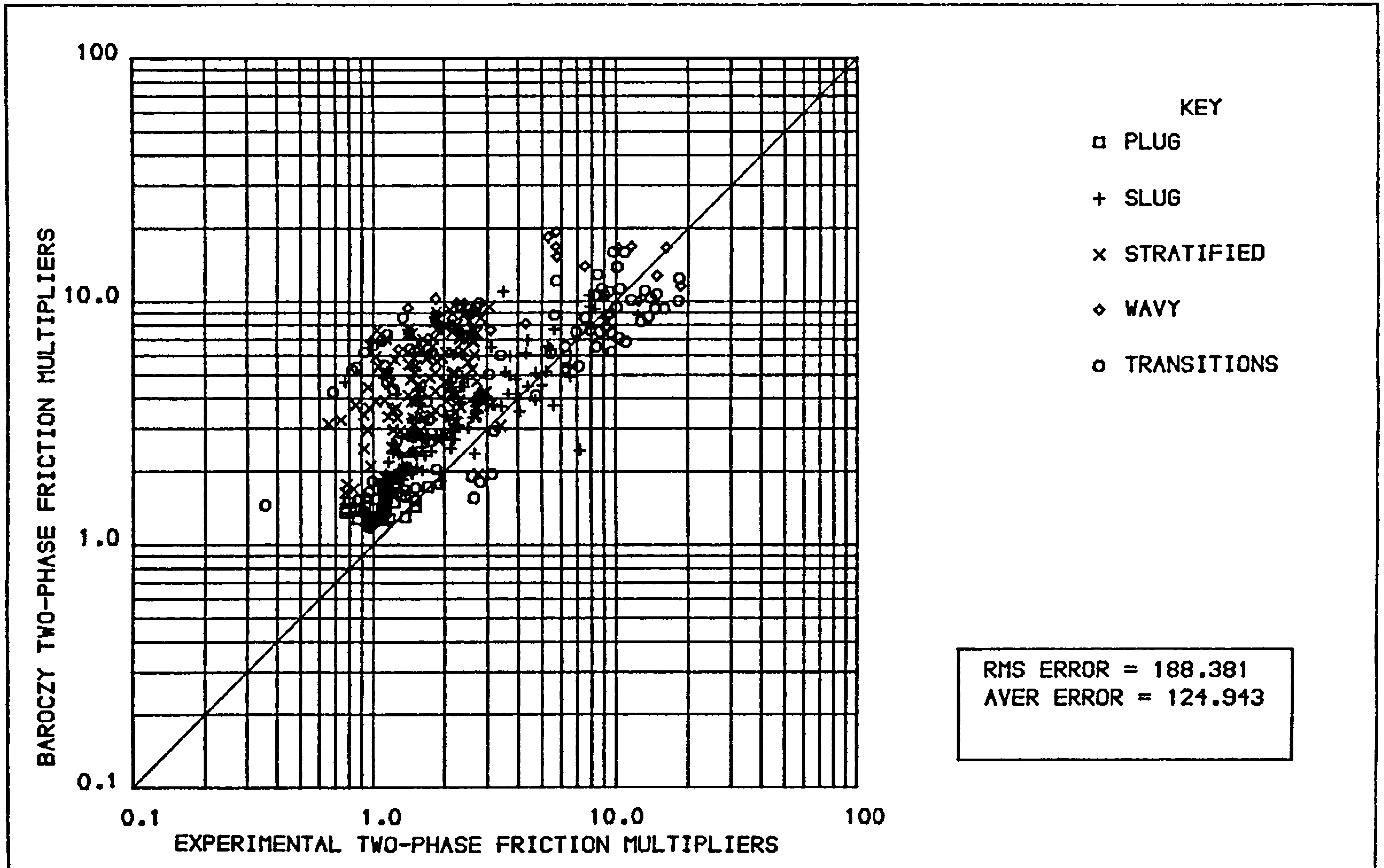


FIG. 6.2.4 COMPARISON BETWEEN EXPERIMENTAL AND BAROCZY PREDICTIONS (All Data)

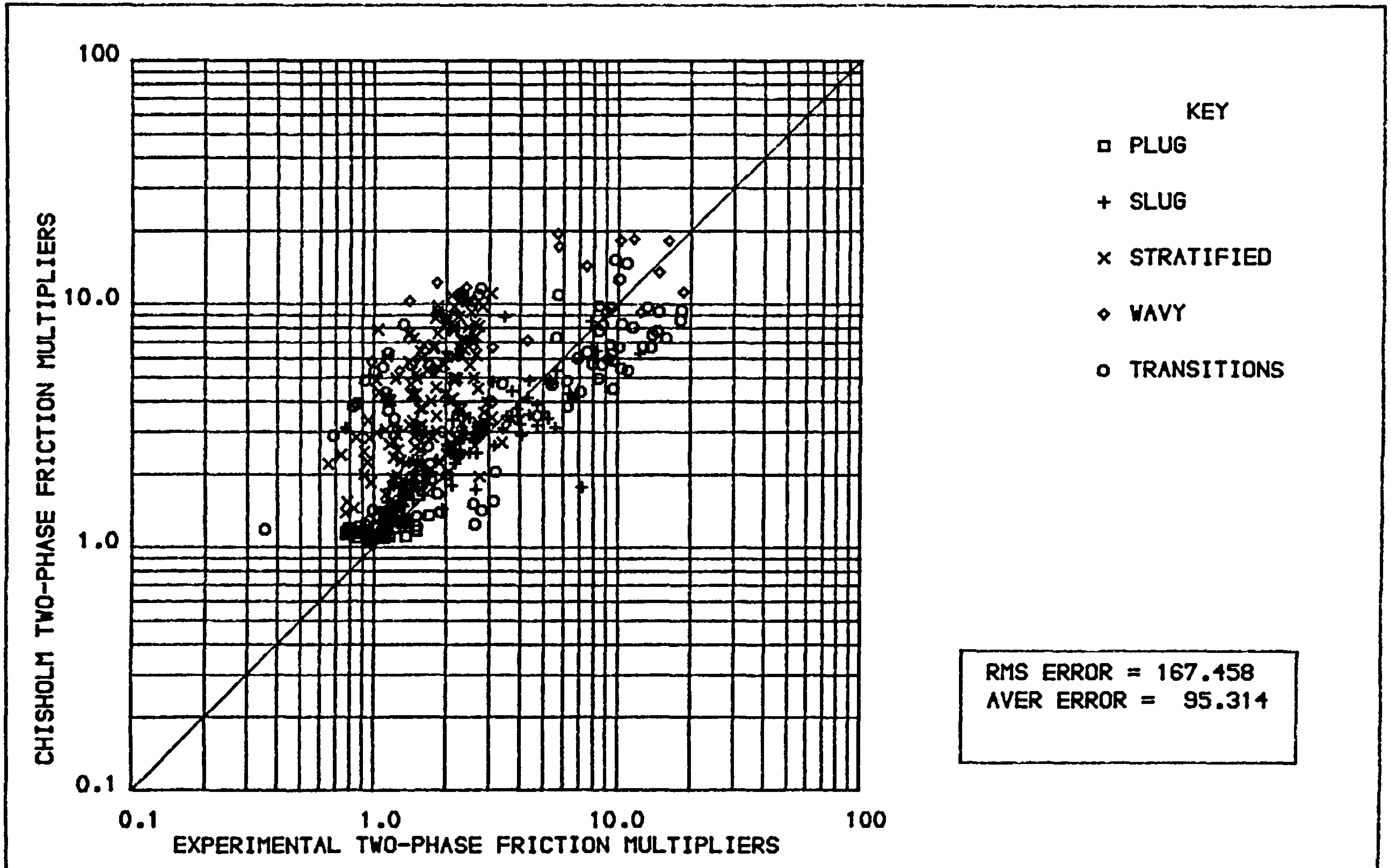


FIG. 6.2.5 COMPARISON BETWEEN EXPERIMENTAL AND CHISHOLM PREDICTIONS (All Data)

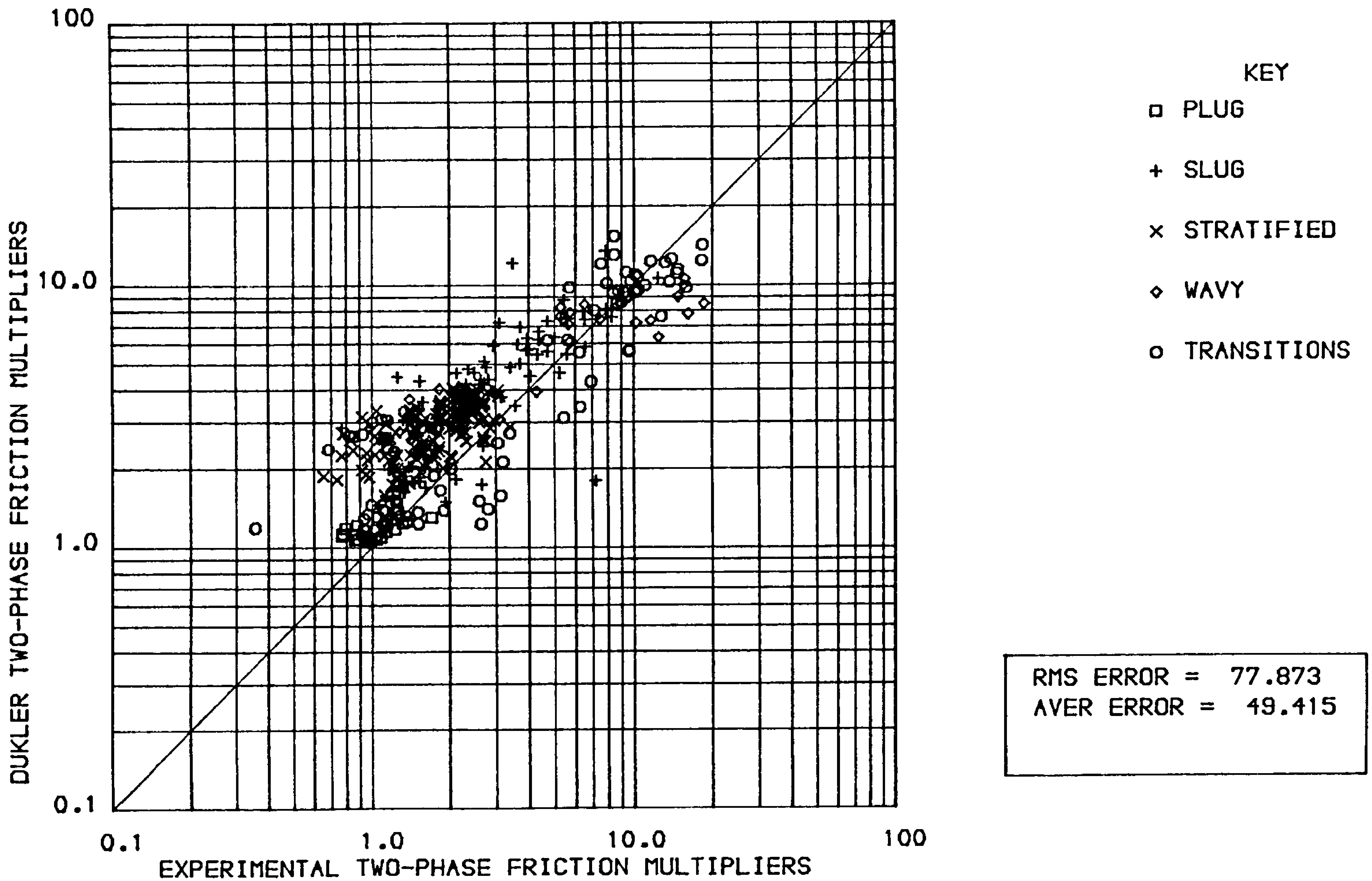


FIG. 6.2.6 COMPARISON BETWEEN EXPERIMENTAL AND DUKLER PREDICTIONS (All Data)

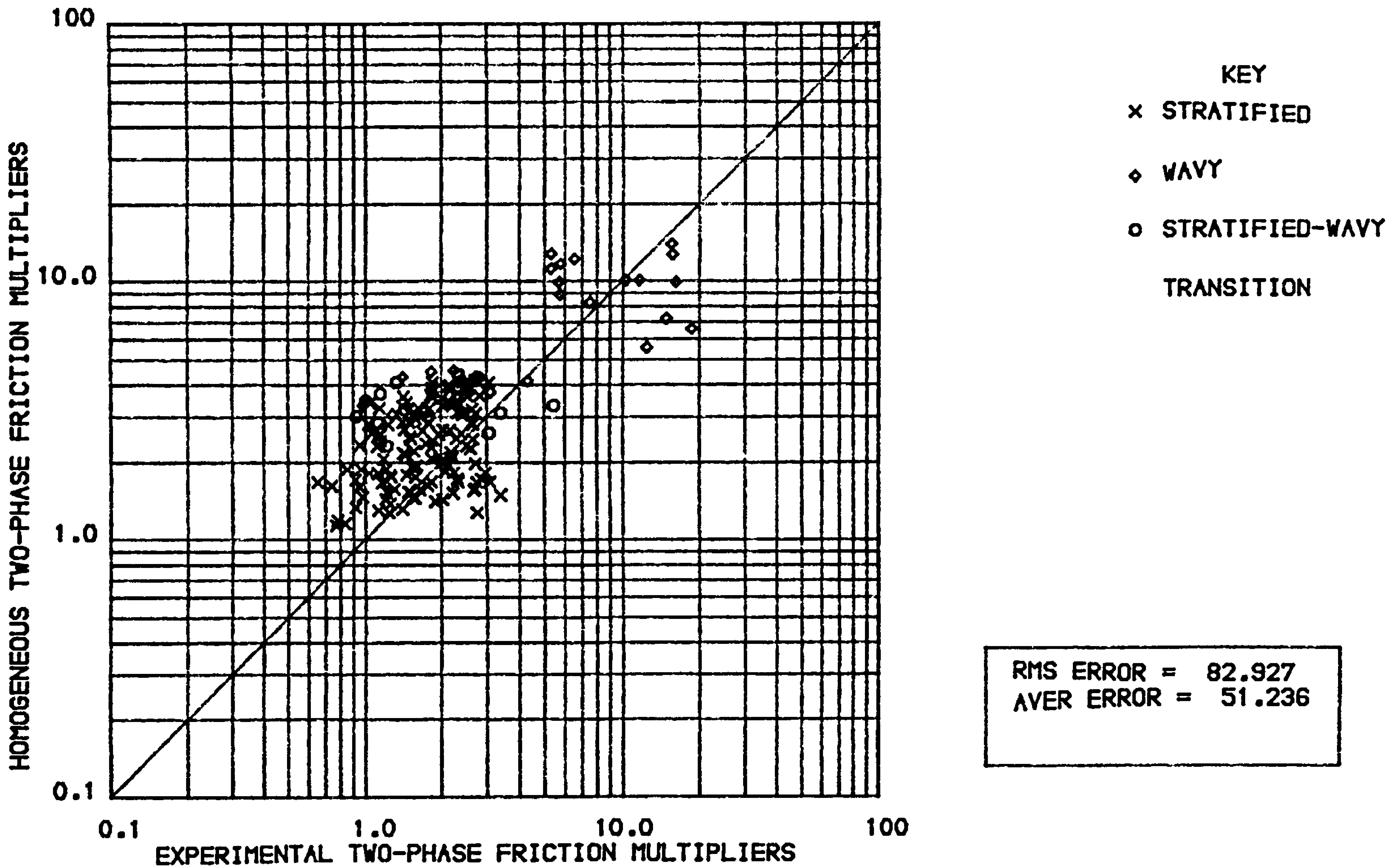


FIG. 6.2.7 COMPARISON BETWEEN EXPERIMENTAL AND HOMOGENEOUS PREDICTIONS (ex. plug & slug)

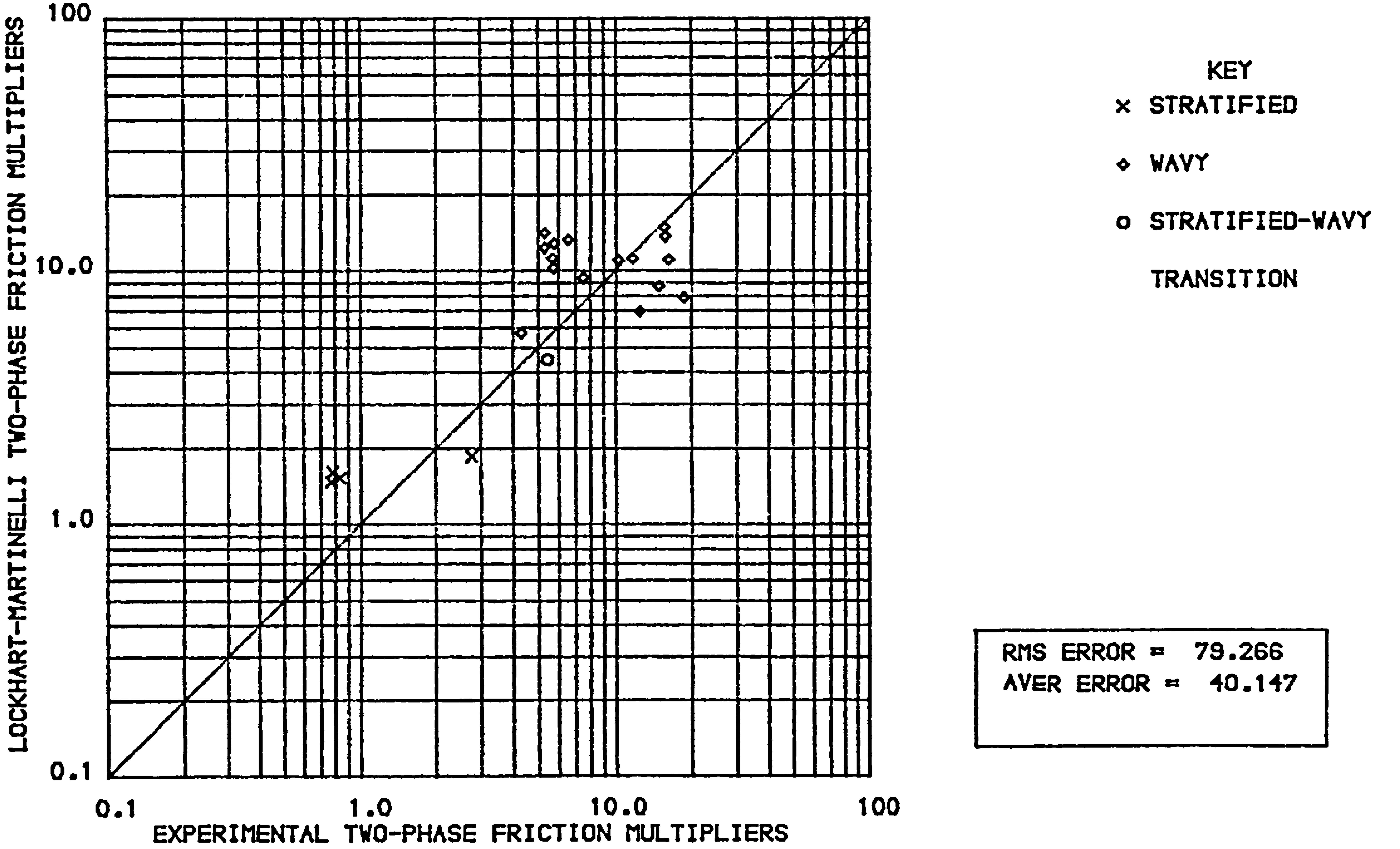


FIG. 6.2.8 COMPARISON BETWEEN EXPERIMENTAL AND LOCKHART-MARTINELLI PREDICTIONS (ex. plug & slug)

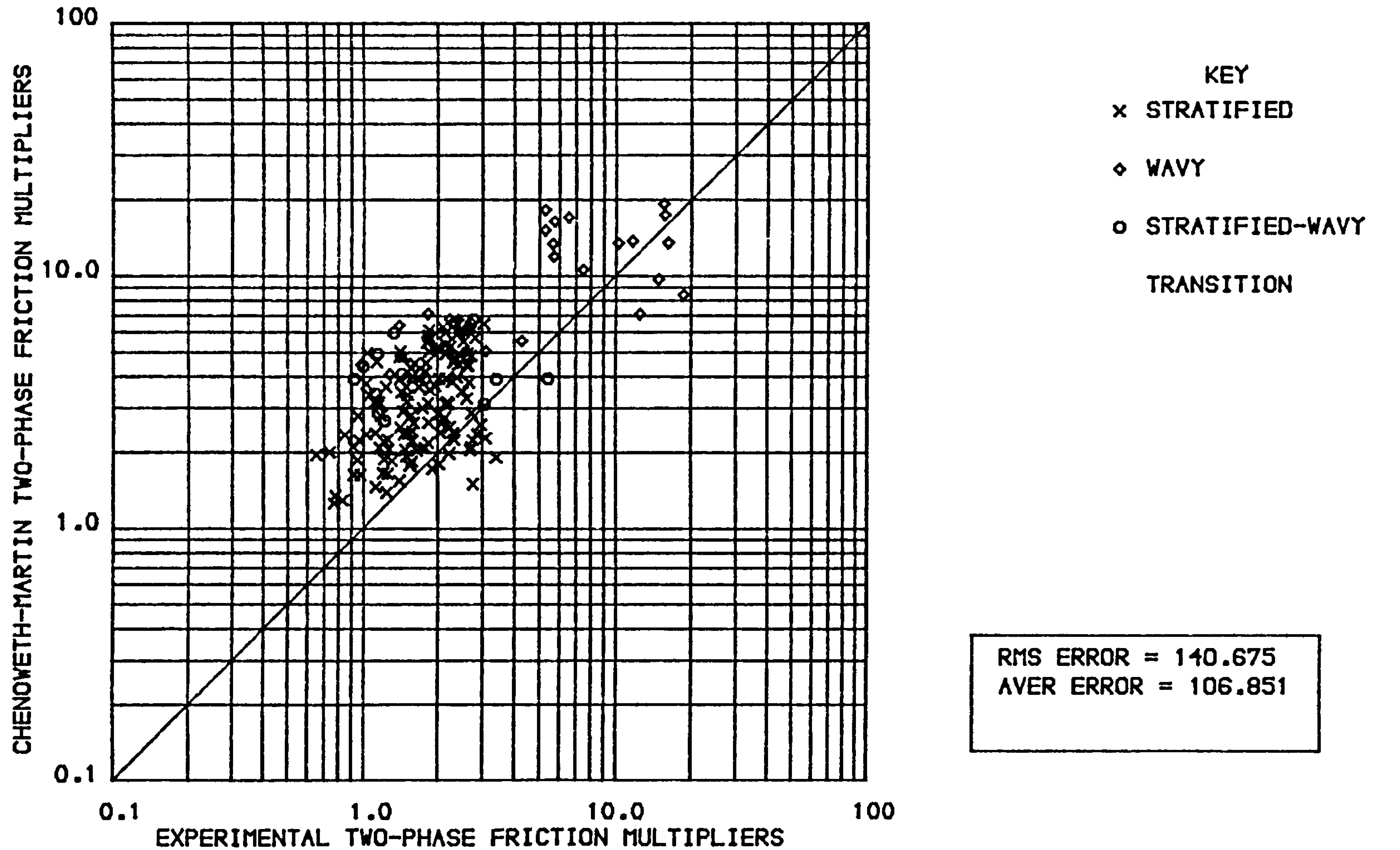


FIG. 6.2.9 COMPARISON BETWEEN EXPERIMENTAL AND CHENOWETH-MARTIN PREDICTIONS(ex.plug & slug)

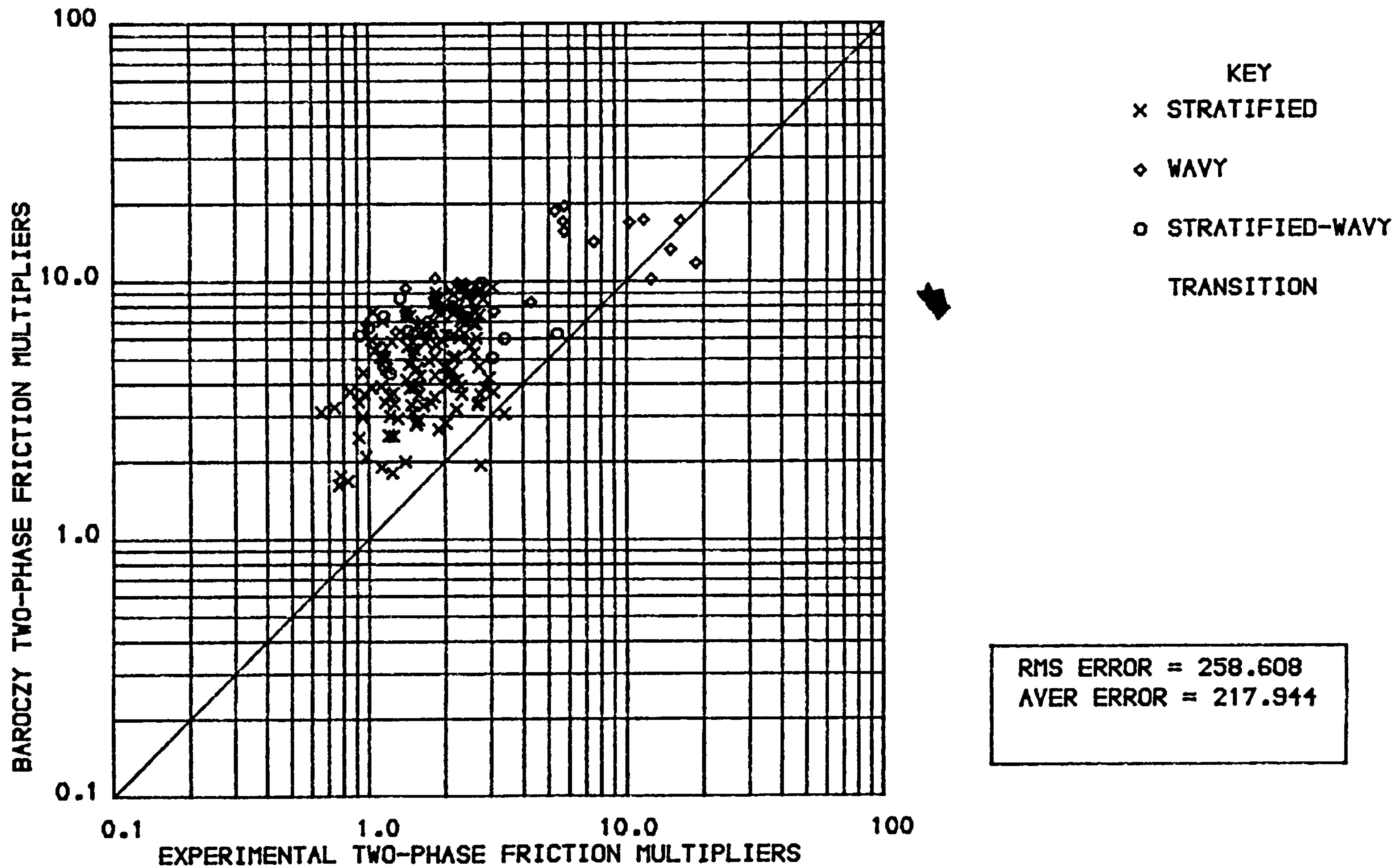


FIG. 6.2.10 COMPARISON BETWEEN EXPERIMENTAL AND BAROCZY PREDICTIONS (ex. plug & slug)

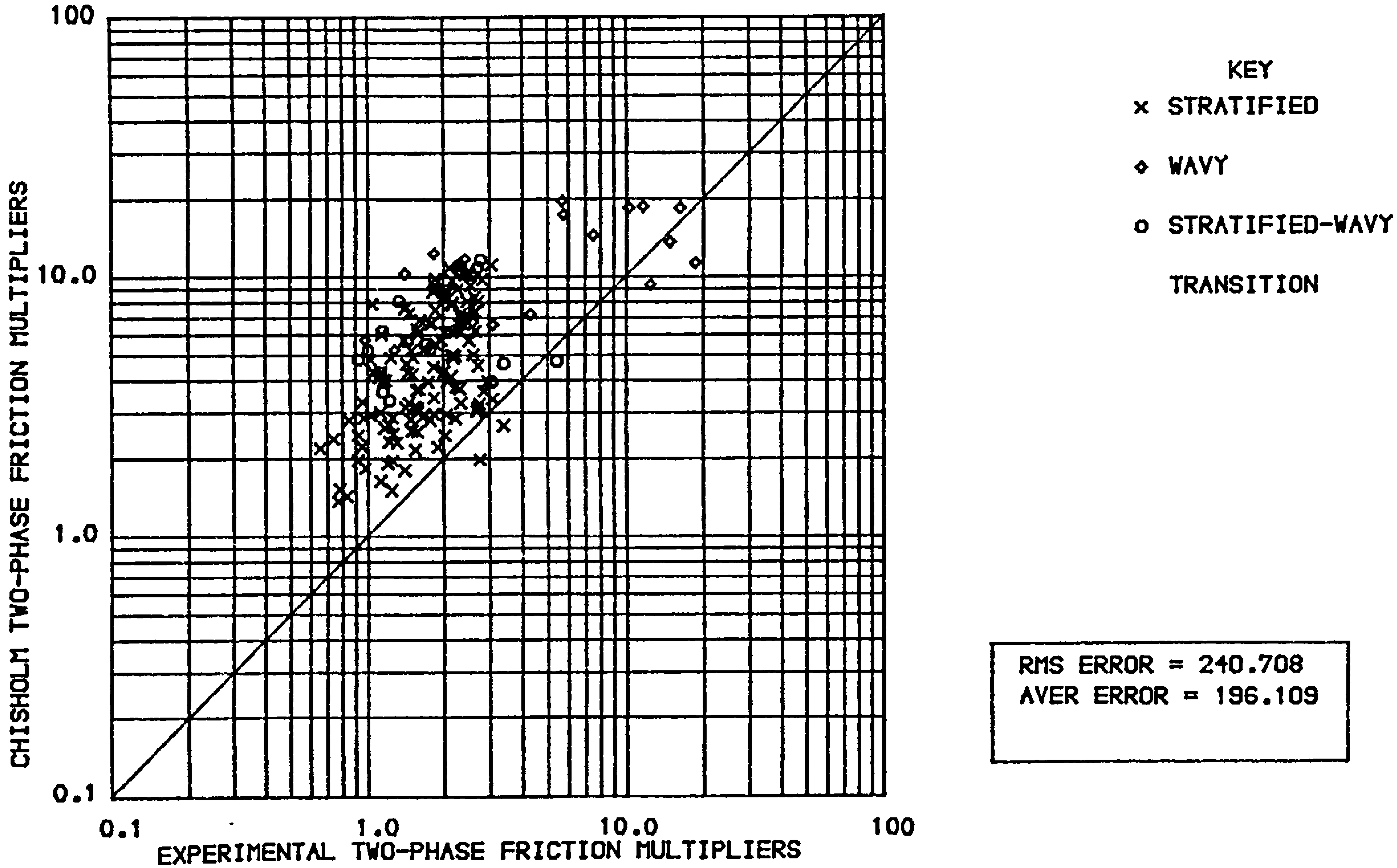


FIG. 6.2.11 COMPARISON BETWEEN EXPERIMENTAL AND CHISHOLM PREDICTIONS (ex. plug & slug)

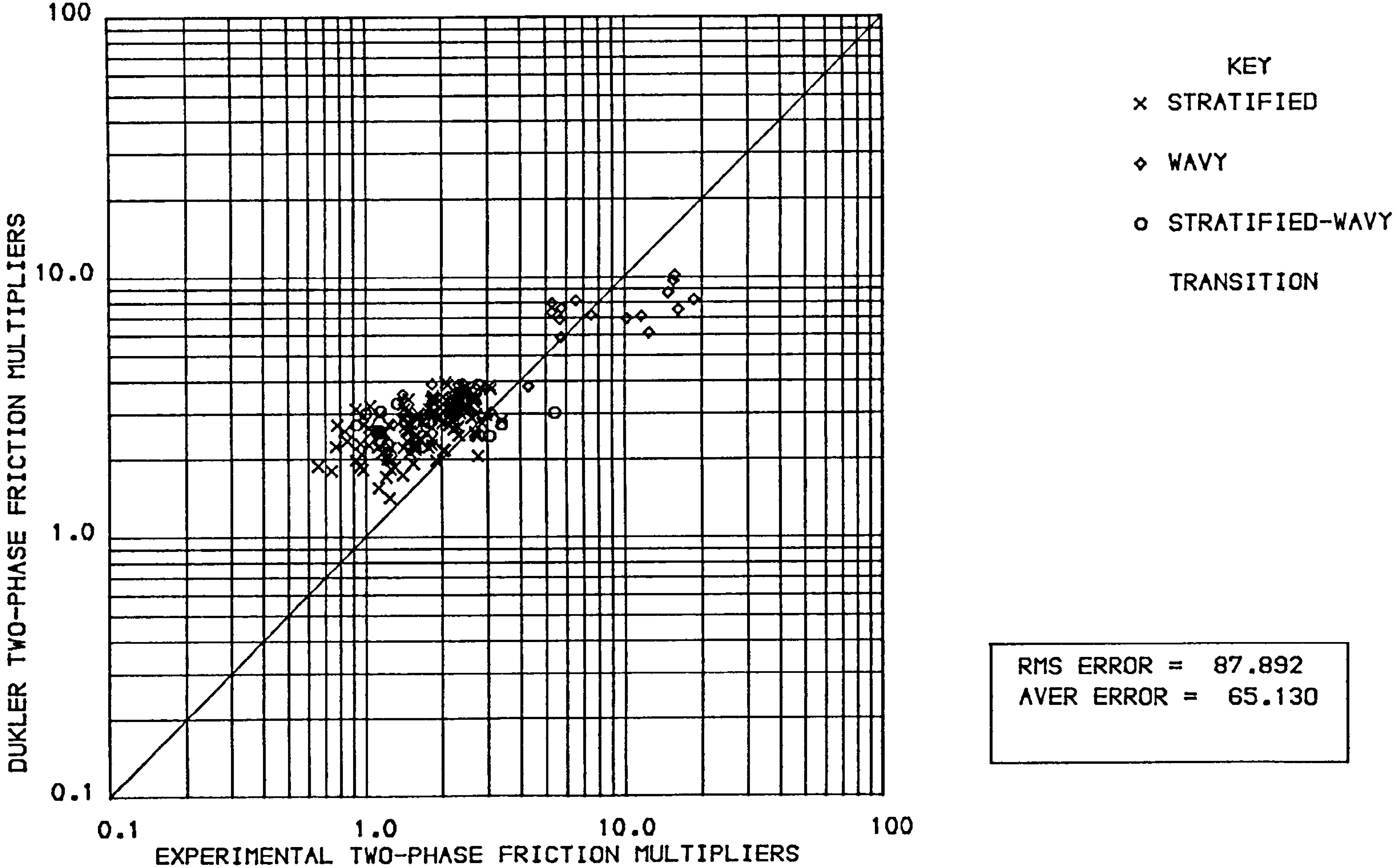


FIG. 6.2.12 COMPARISON BETWEEN EXPERIMENTAL AND DUKLER PREDICTIONS (ex. plug & slug)

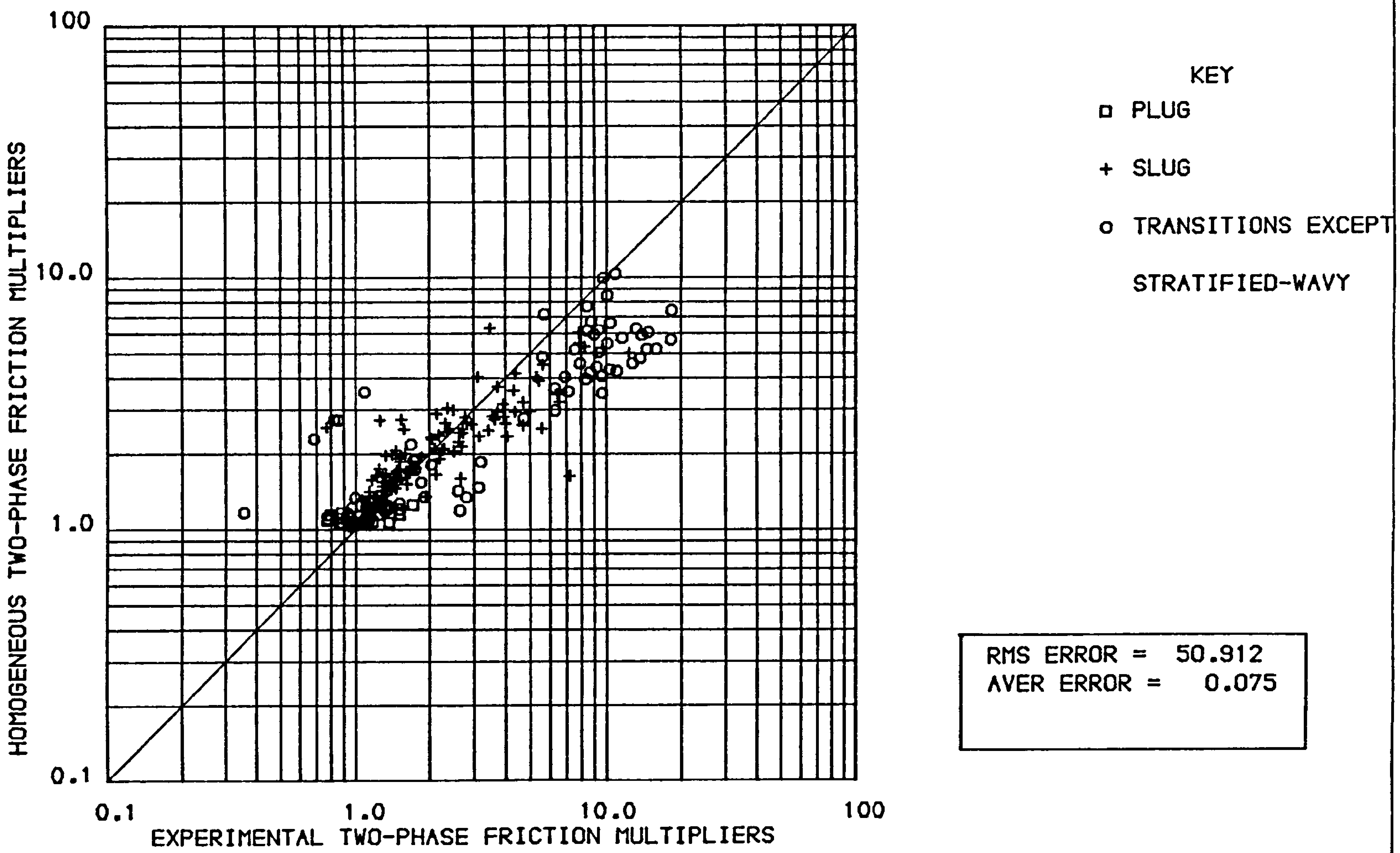


FIG. 6.2.13 COMPARISON BETWEEN EXPERIMENTAL AND HOMOGENEOUS PREDICTIONS (ex. strat. & wavy)

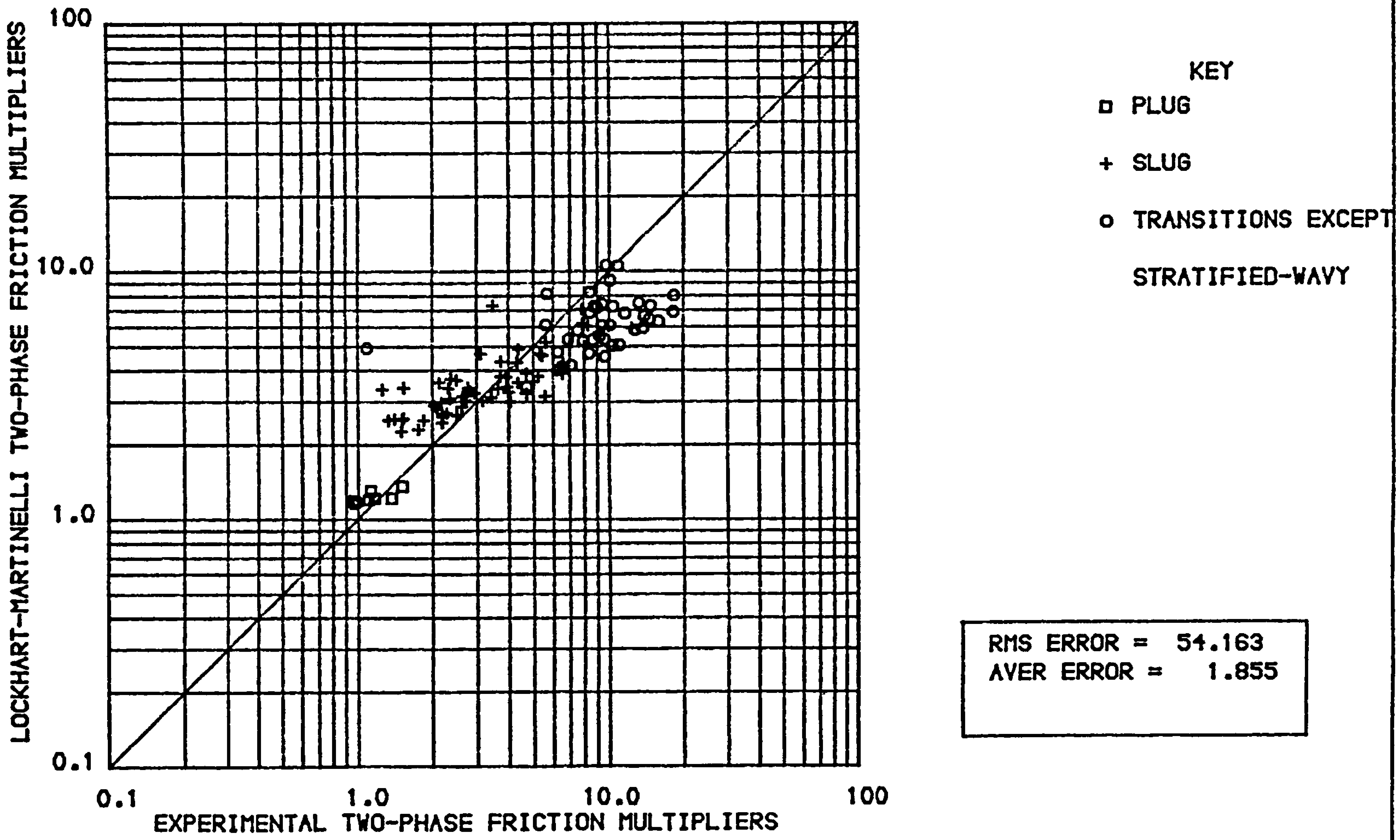


FIG. 6.2.14 COMPARISON BETWEEN EXPERIMENTAL AND LOCKHART-MARTINELLI PREDICTIONS (ex. stra. & wavy)

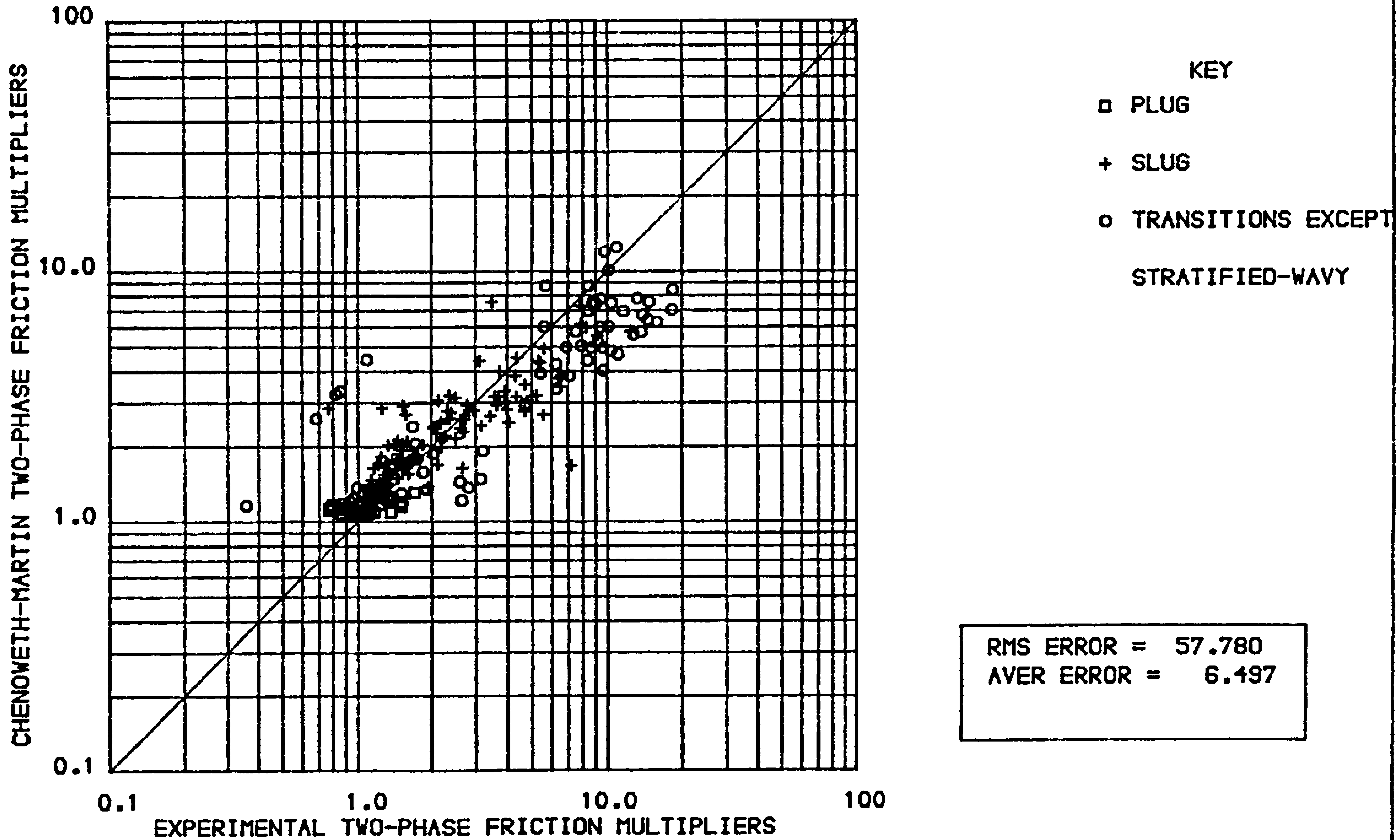


FIG. 6.2.15 COMPARISON BETWEEN EXPERIMENTAL AND CHENOWETH-MARTIN PREDICTIONS(ex.stra.& wavy)

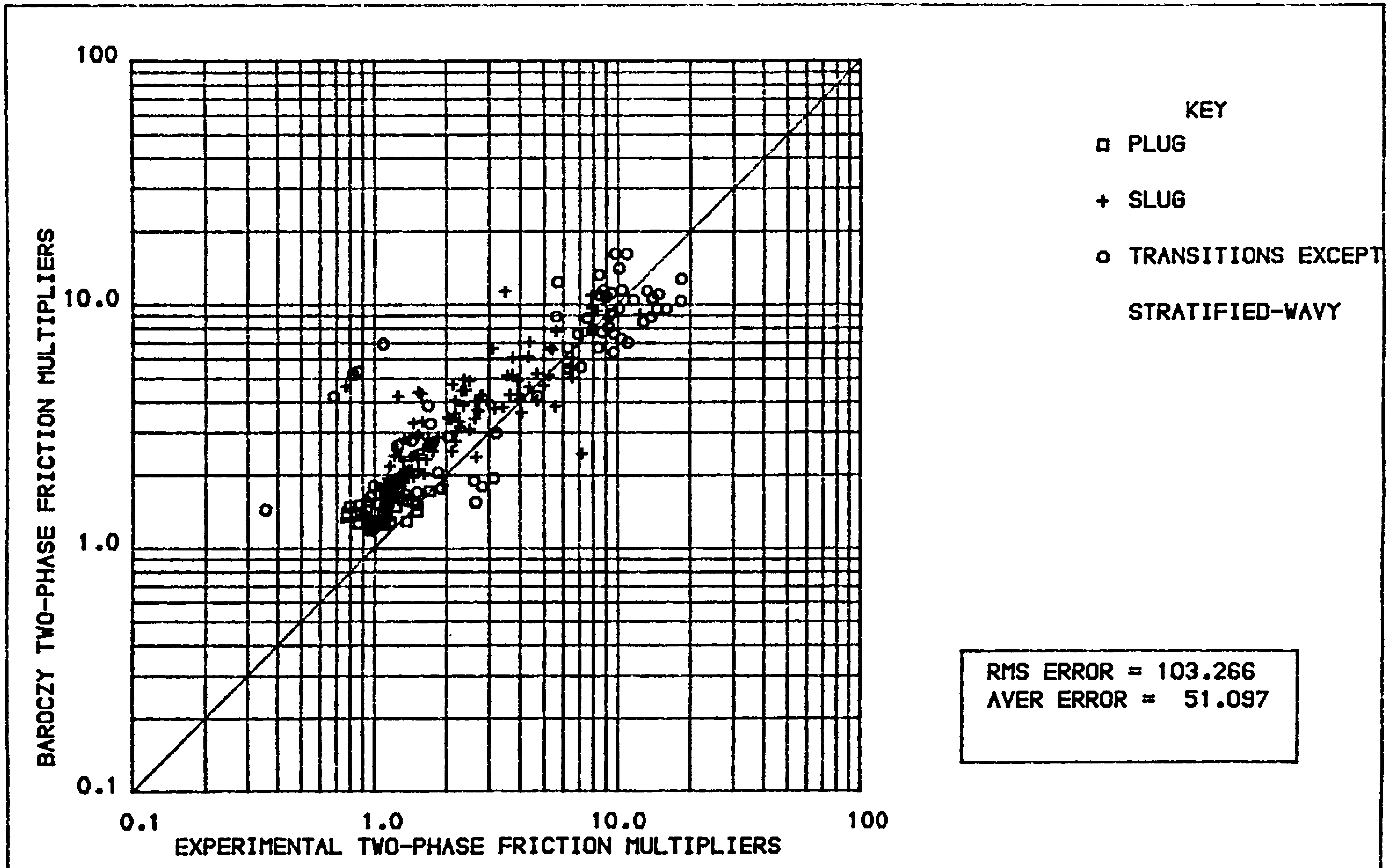


FIG. 6.2.16 COMPARISON BETWEEN EXPERIMENTAL AND BAROCZY PREDICTIONS (ex. strat. & wavy)

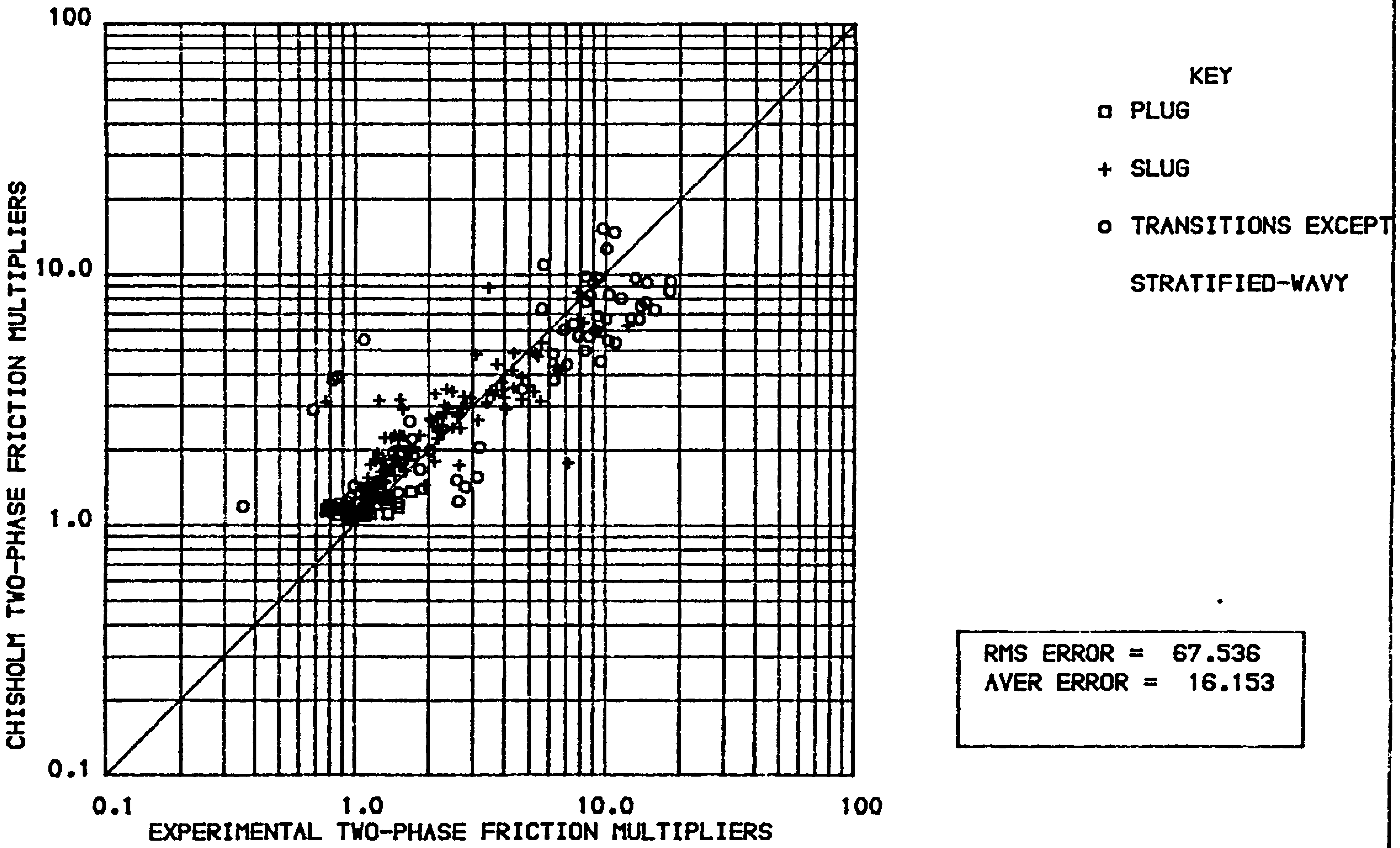


FIG. 6.2.17 COMPARISON BETWEEN EXPERIMENTAL AND CHISHOLM PREDICTIONS (ex. strat. & wavy)

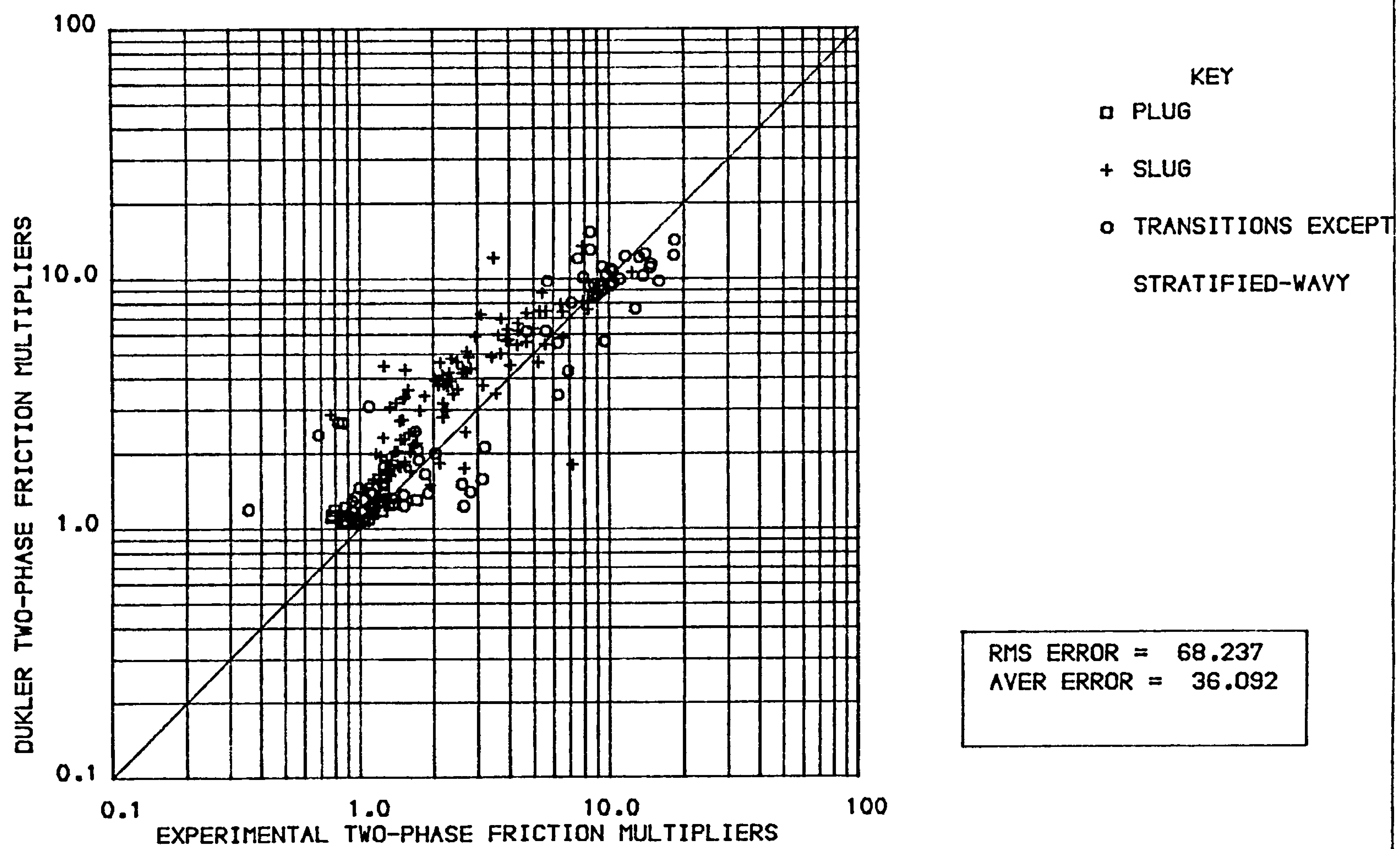


FIG. 6.2.18 COMPARISON BETWEEN EXPERIMENTAL AND DUKLER PREDICTIONS (ex. strat. & wavy)

#1 USER: CLCV03 PLOTFILE: FLOWMAP ENTRY NO. 65563 QUEUED ON 30/05/91 AT 18:16 PLOTTED ON 30/05/91 AT 18:17

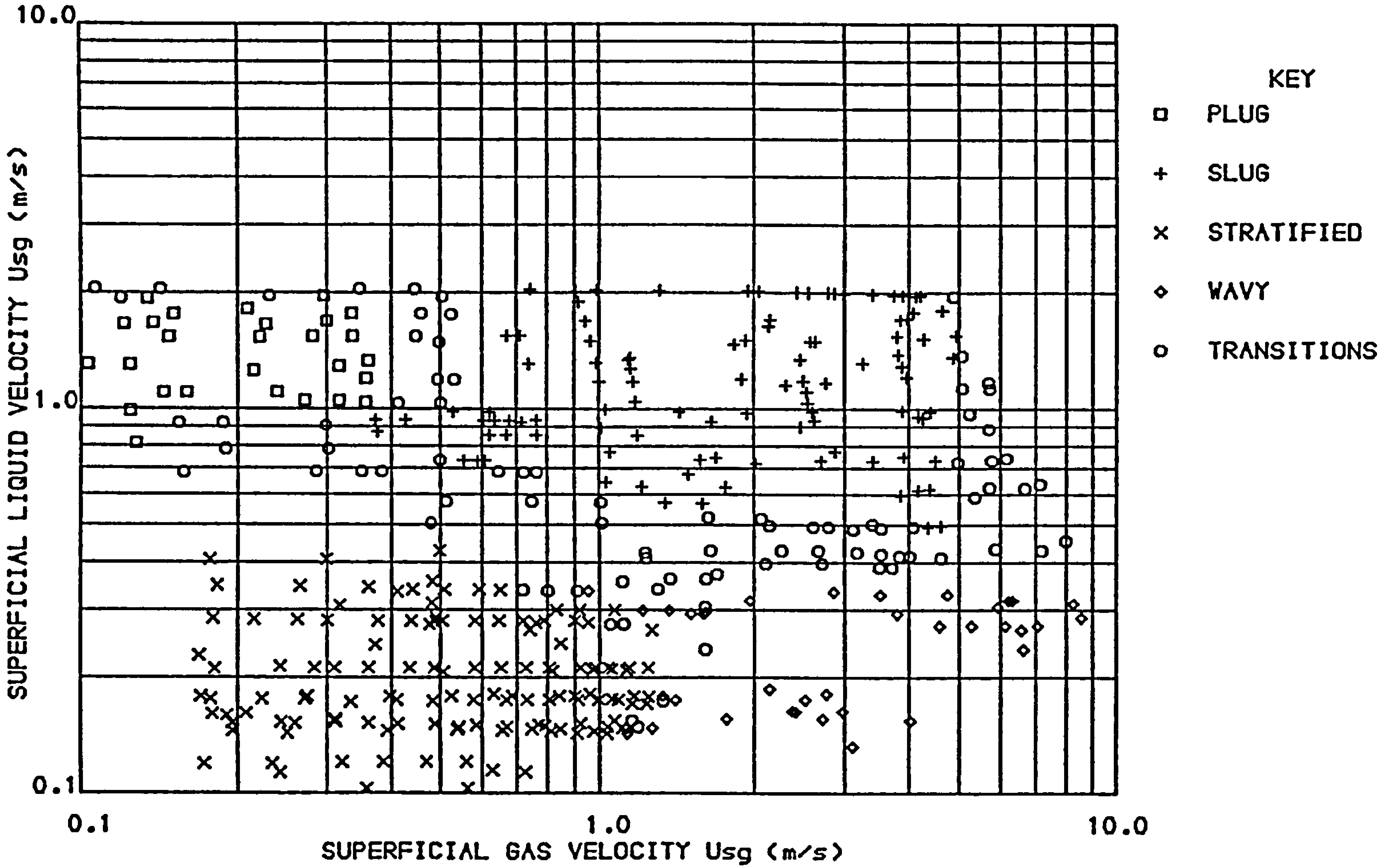


FIG. 6.2.19 EXPERIMENTAL FLOW PATTERN MAP (All Data)

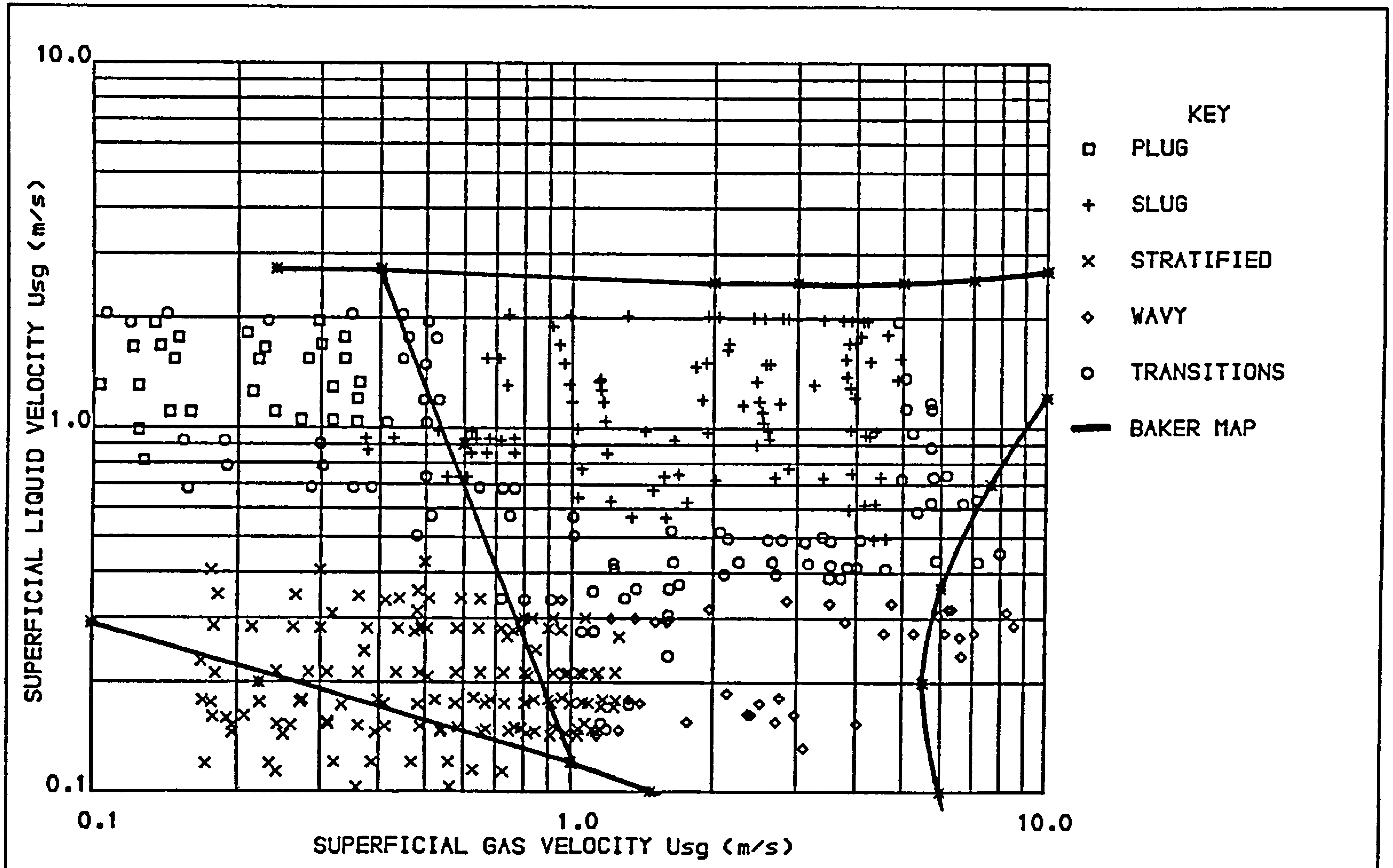


FIG. 6.2.20 COMPARISON BETWEEN EXPERIMENTAL AND BAKER FLOW PATTERN MAPS

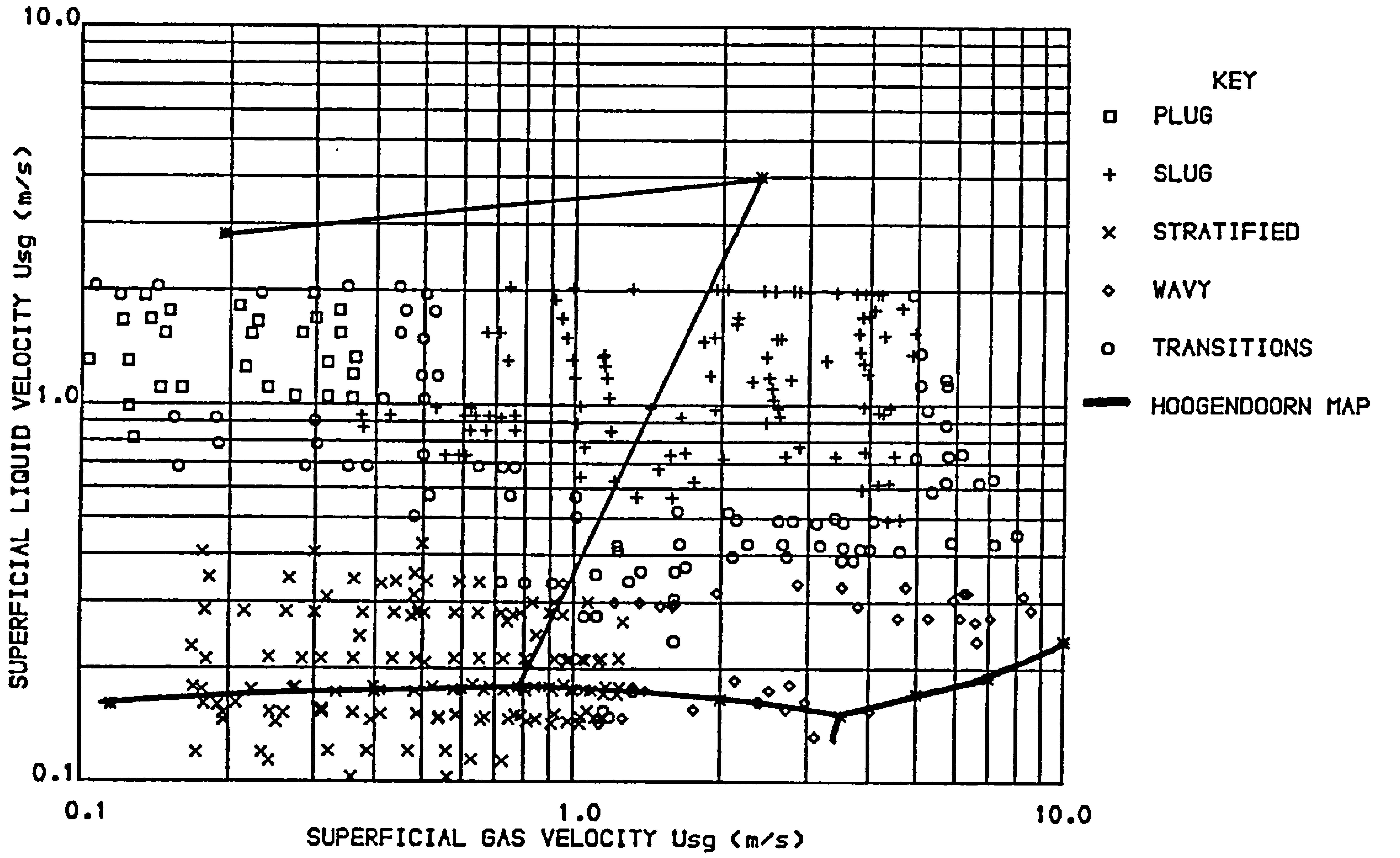


FIG. 6.2.21 COMPARISON BETWEEN EXPERIMENTAL AND HOOGENDOORN FLOW PATTERN MAPS

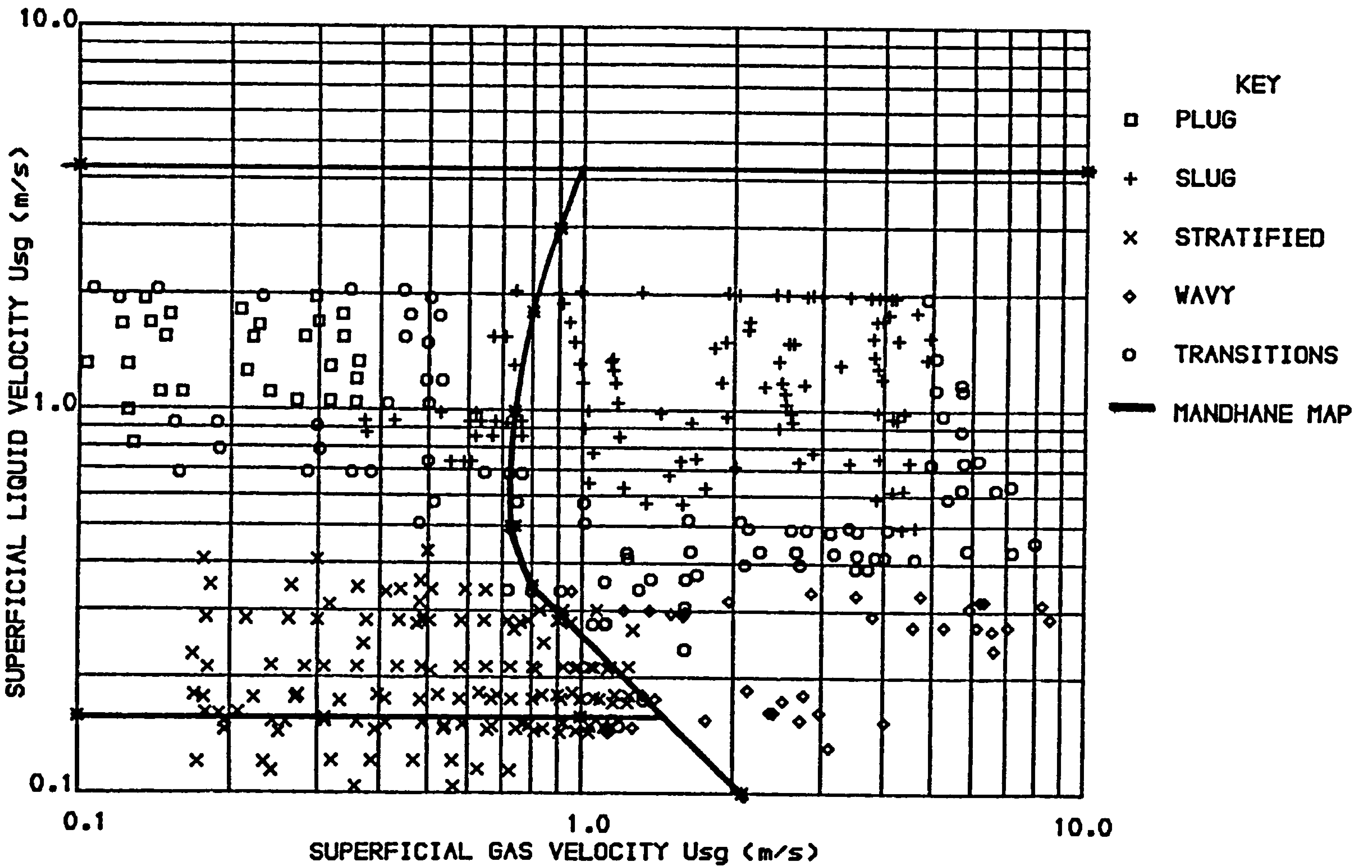


FIG. 6.2.22 COMPARISON BETWEEN EXPERIMENTAL AND MANDHANE FLOW PATTERN MAPS

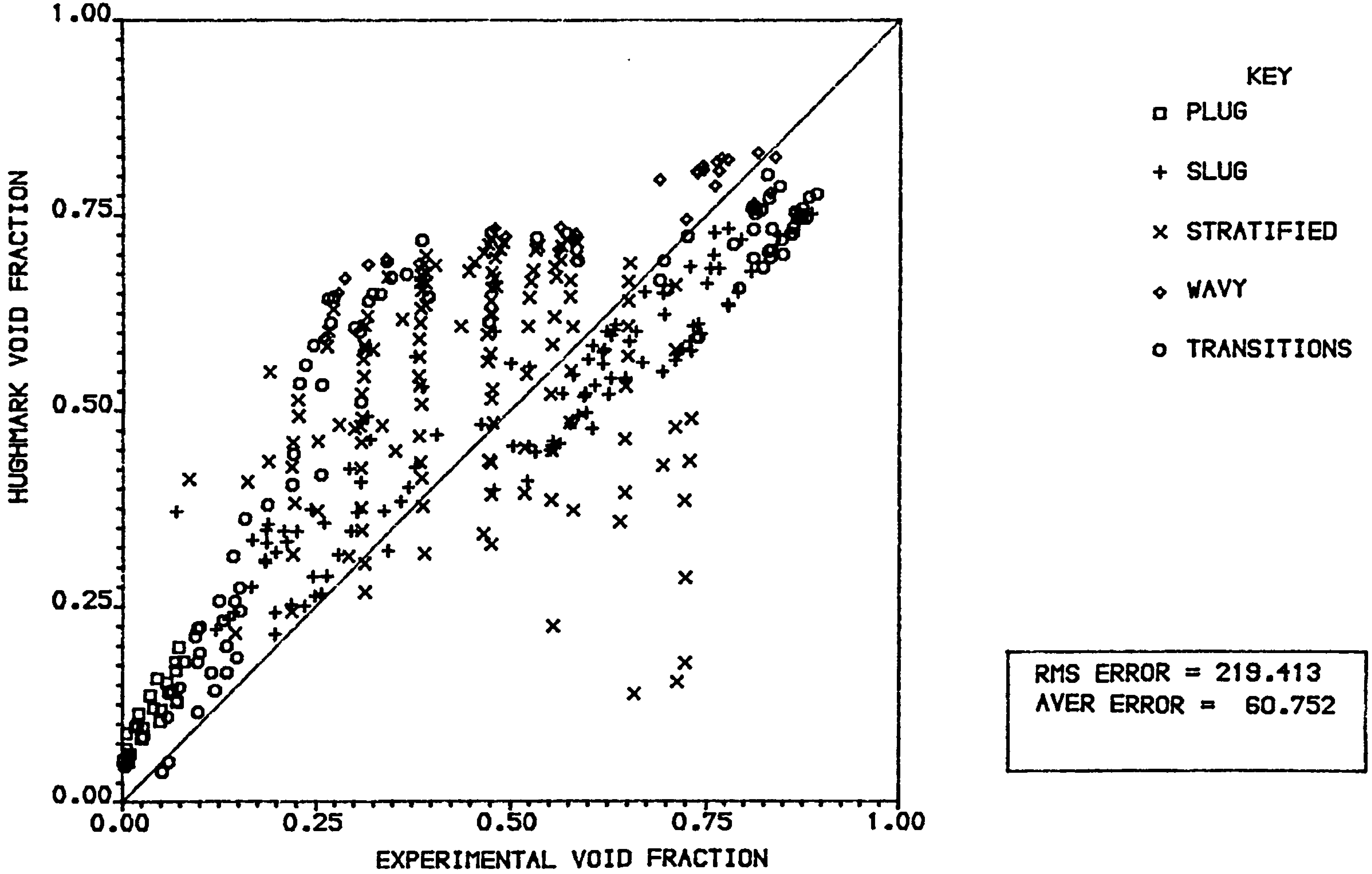


FIG. 6.2.23 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND HUGHMARK PREDICTIONS

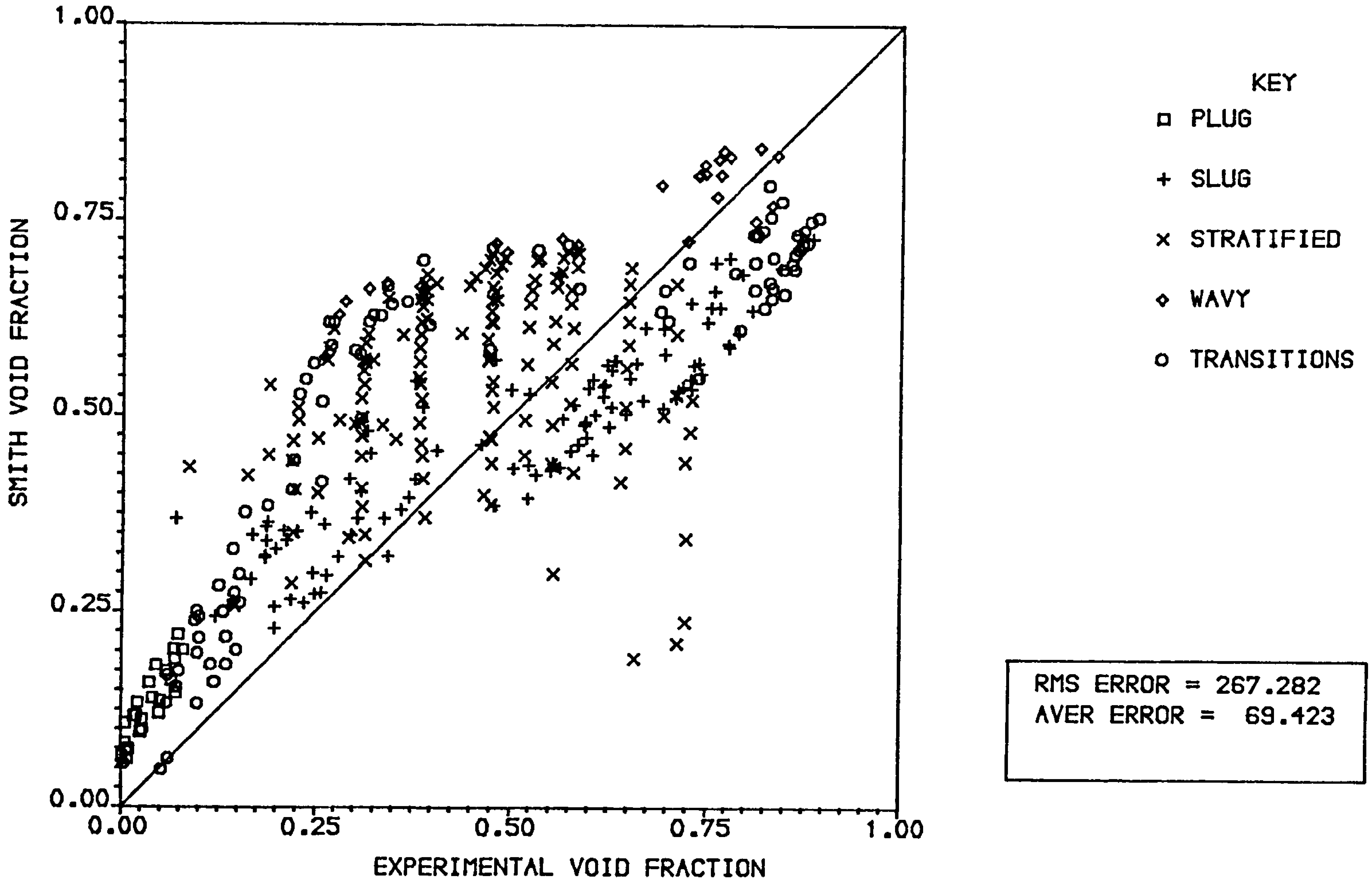


FIG. 6.2.24 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND SMITH PREDICTIONS

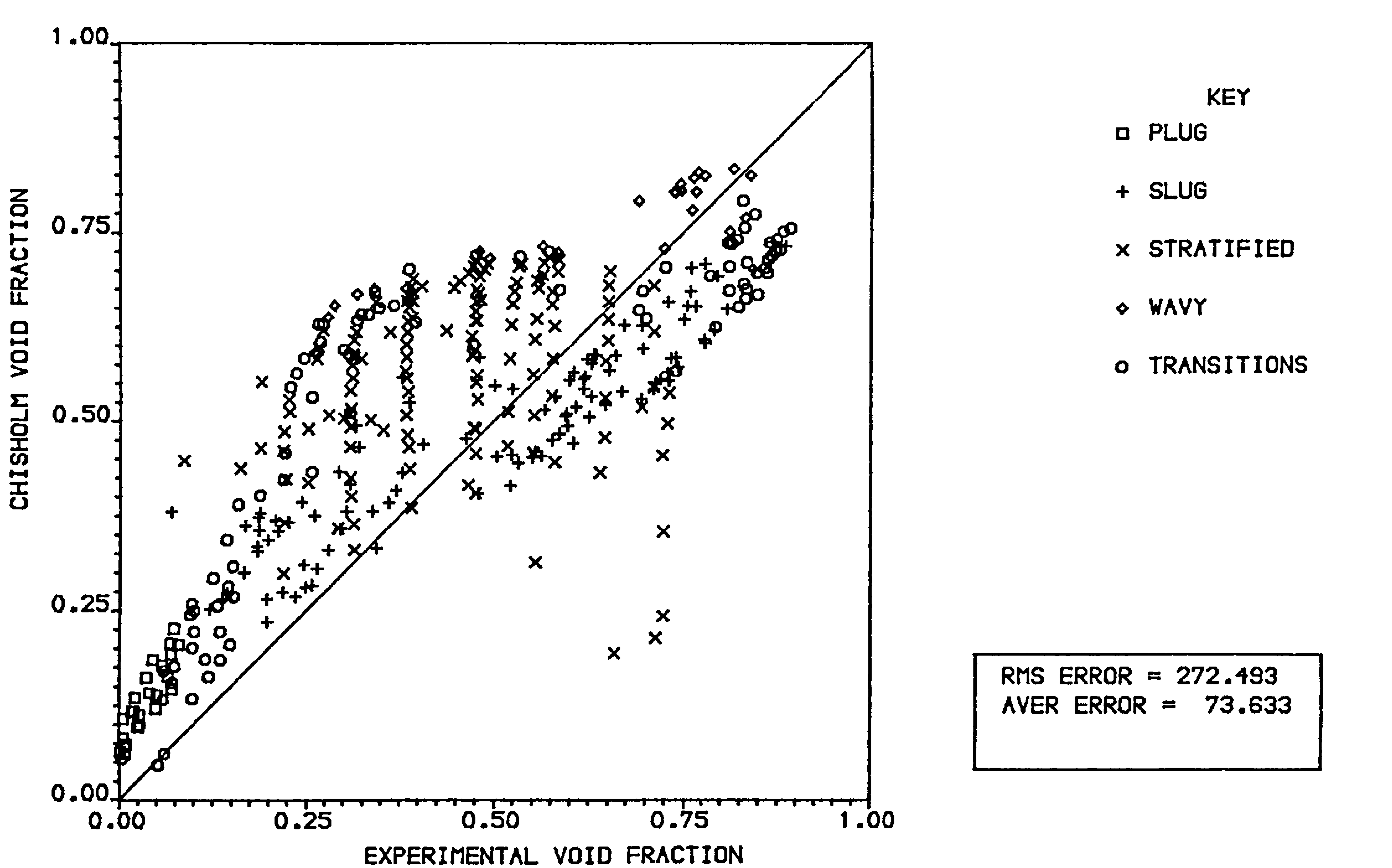


FIG. 6.2.25 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND CHISHOLM PREDICTIONS

#1 USER: CLCR18 PLOTFILE: ROUH-1 ENTRY NO. 10762 QUEUED ON 27/02/92 AT 14:21 PLOTTED ON 27/02/92 AT 14:21

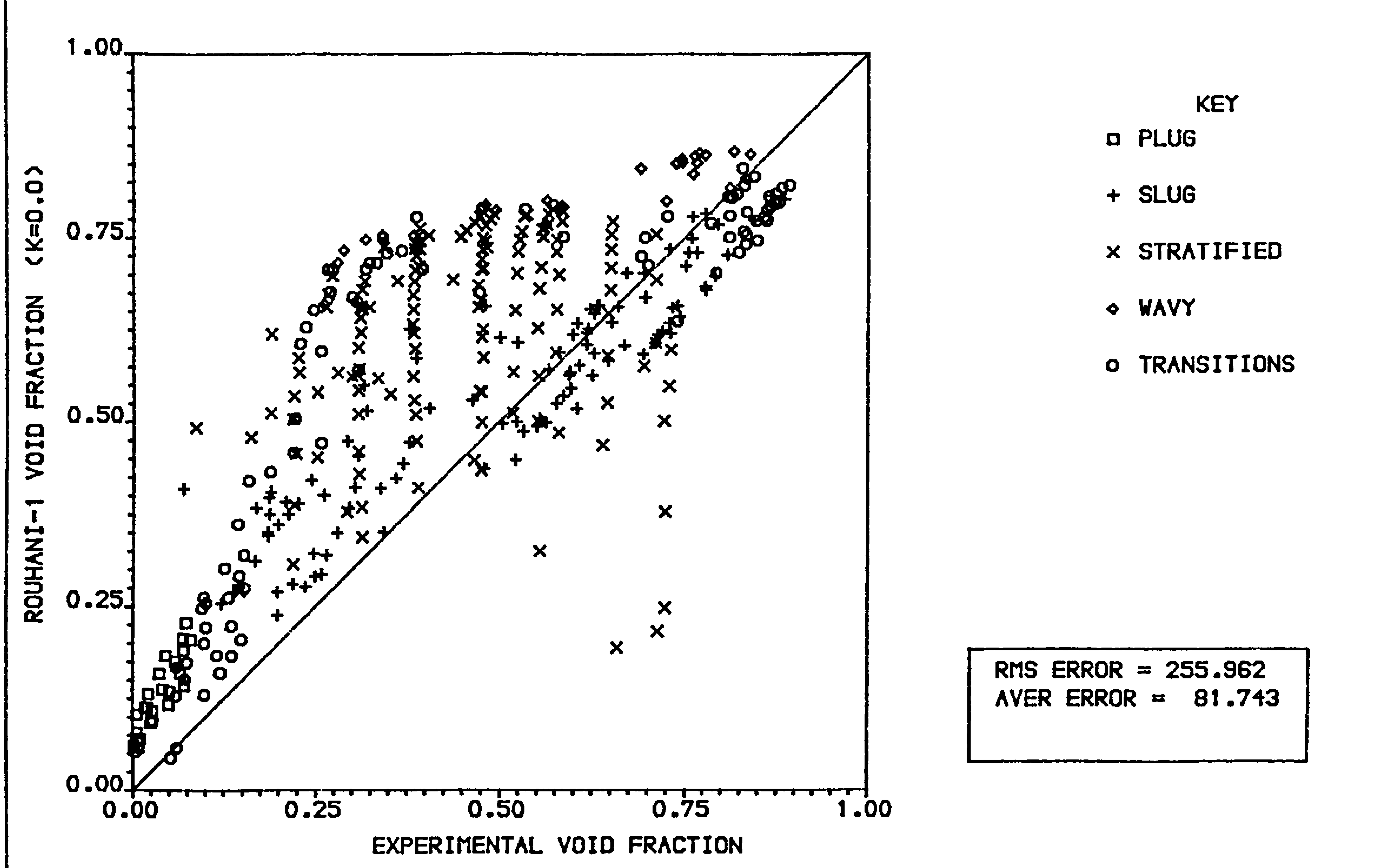


FIG. 6.2.26 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND ROUHANI-1 PREDICTIONS

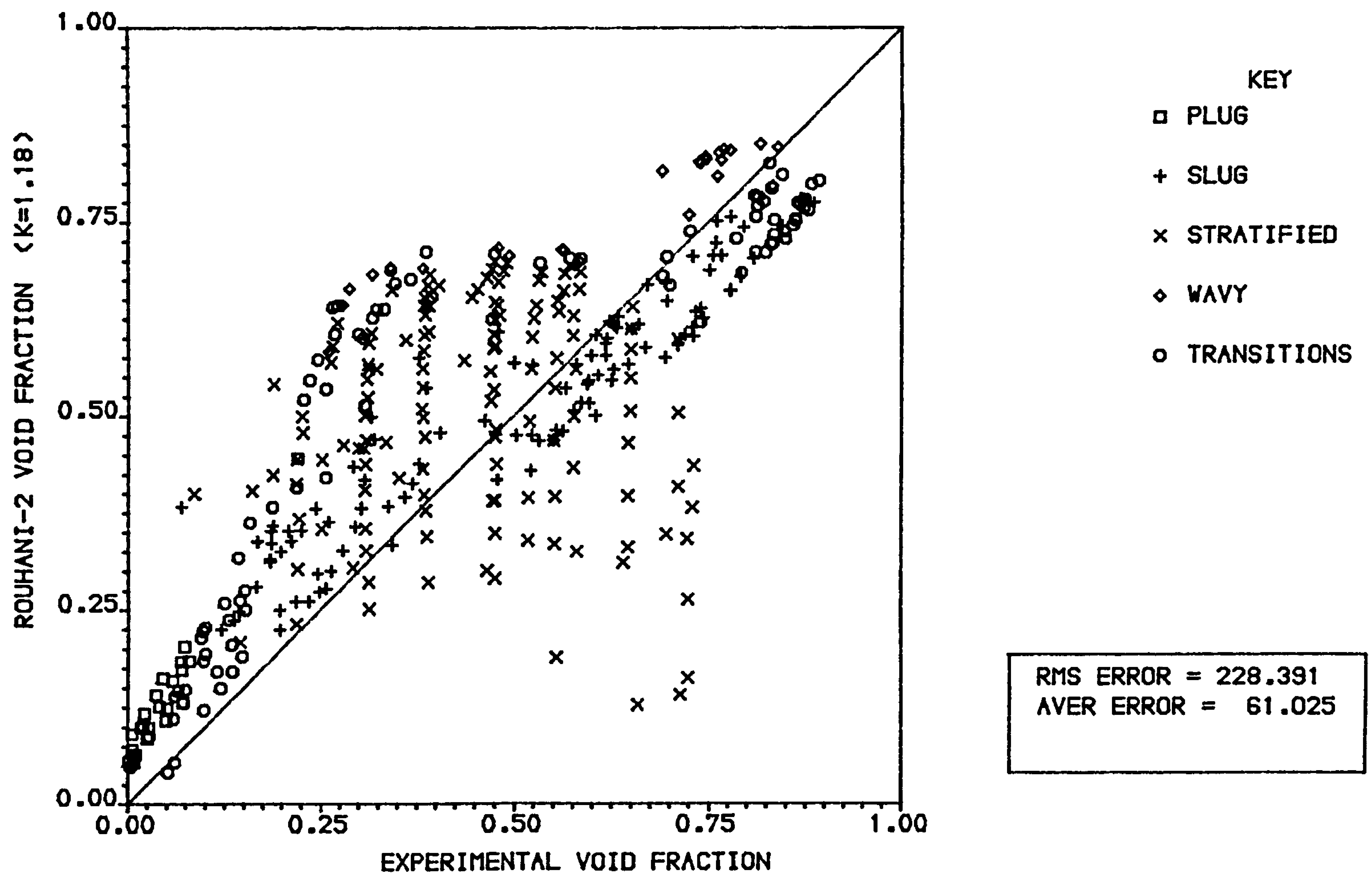


FIG. 6.2.27 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND ROUHANI-2 PREDICTIONS

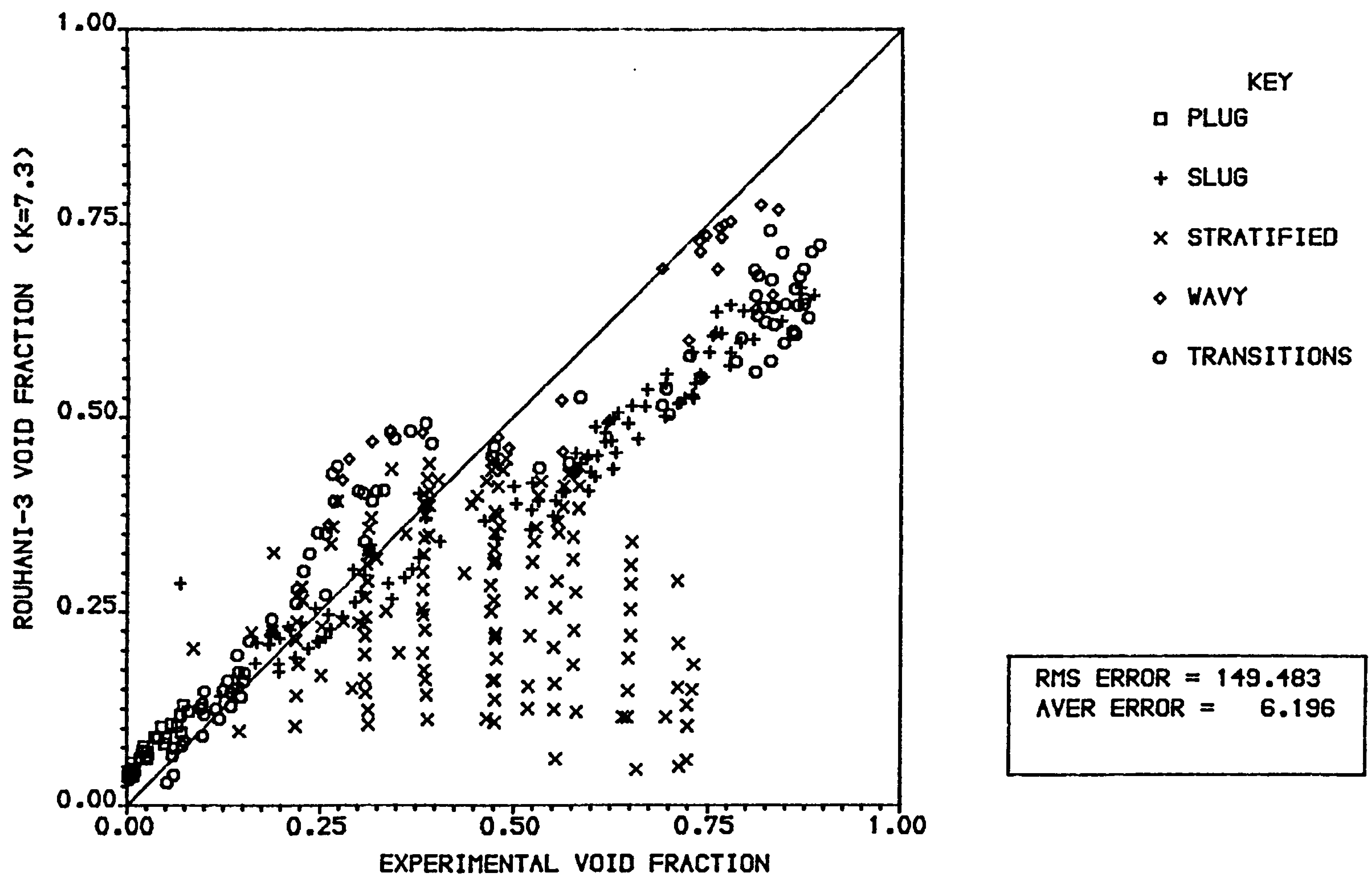


FIG. 6.2.28 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND ROUHANI-3 PREDICTIONS

#1 USER: CLCA12 PLOTFILE: ROUH-4 ENTRY NO. 10768 QUEUED ON 27/02/92 AT 14:29 PLOTTED ON 27/02/92 AT 14:30

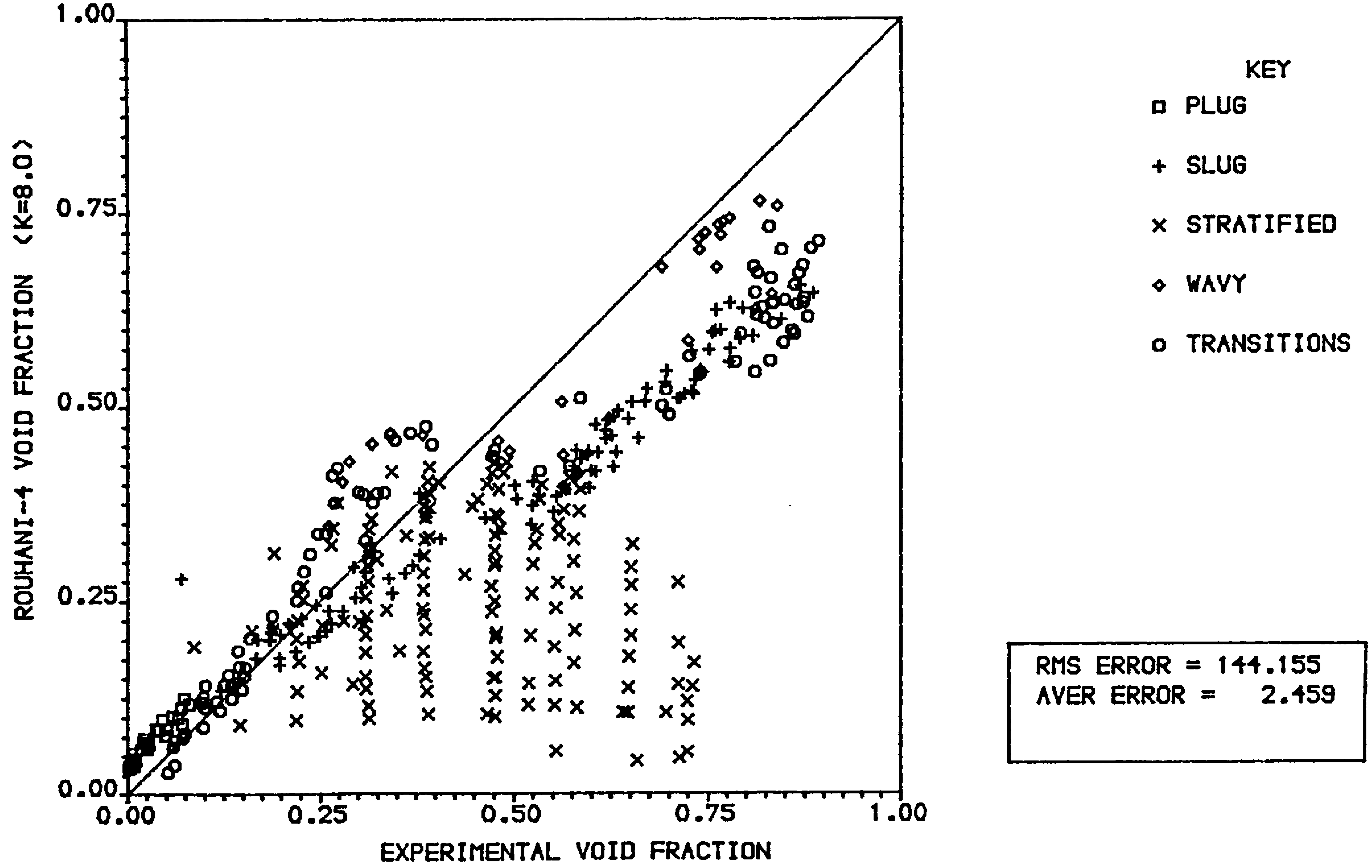


FIG. 6.2.29 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND ROUHANI-4 PREDICTIONS

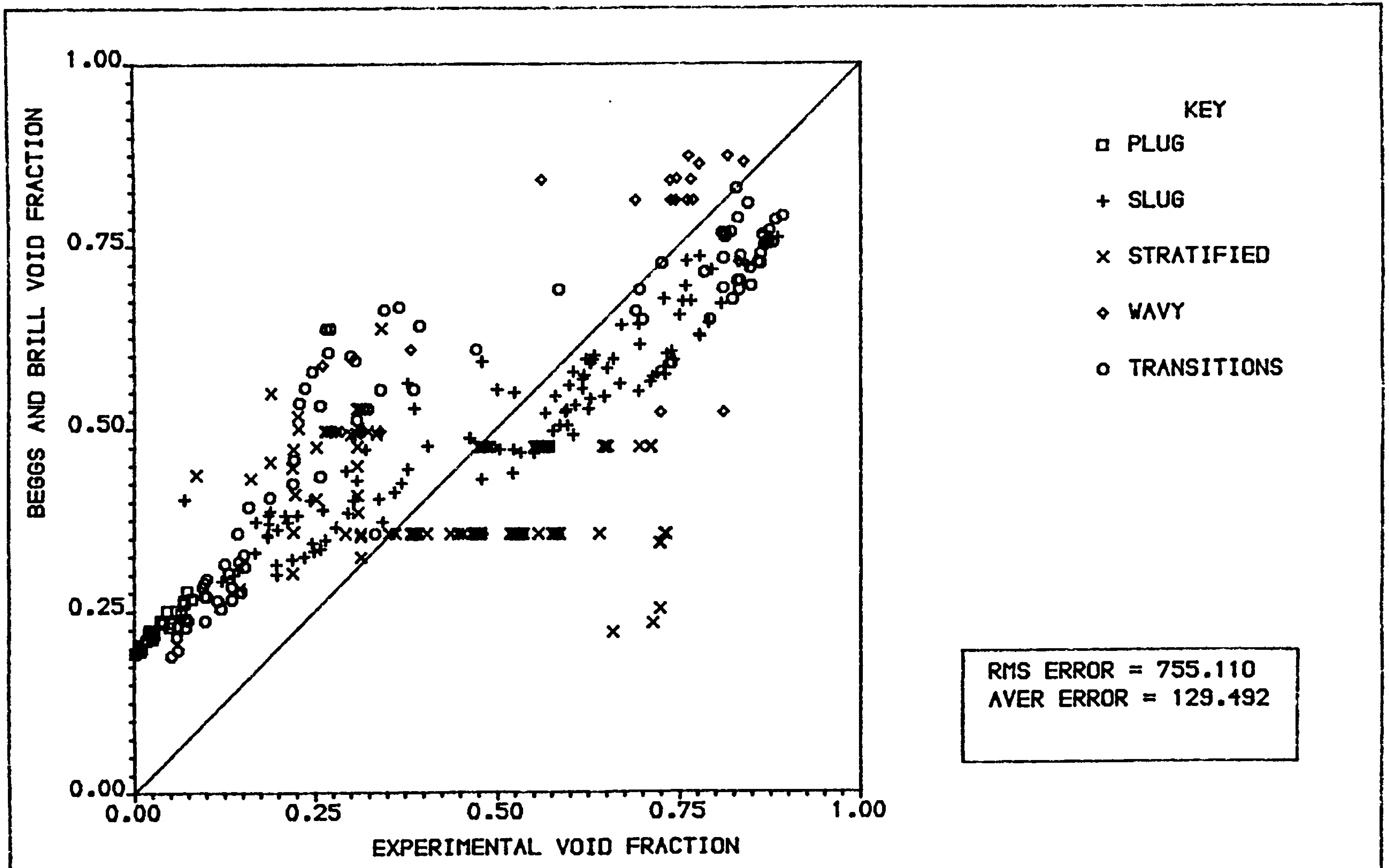


FIG. 6.2.30 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND BEGGS AND BRILL PREDICTIONS

#1 USER: CLOR12 PLOTFILE: EATON ENTRY NO. 10786 QUEUED ON 27/02/92 AT 15:53 PLOTTED ON 27/02/92 AT 15:56

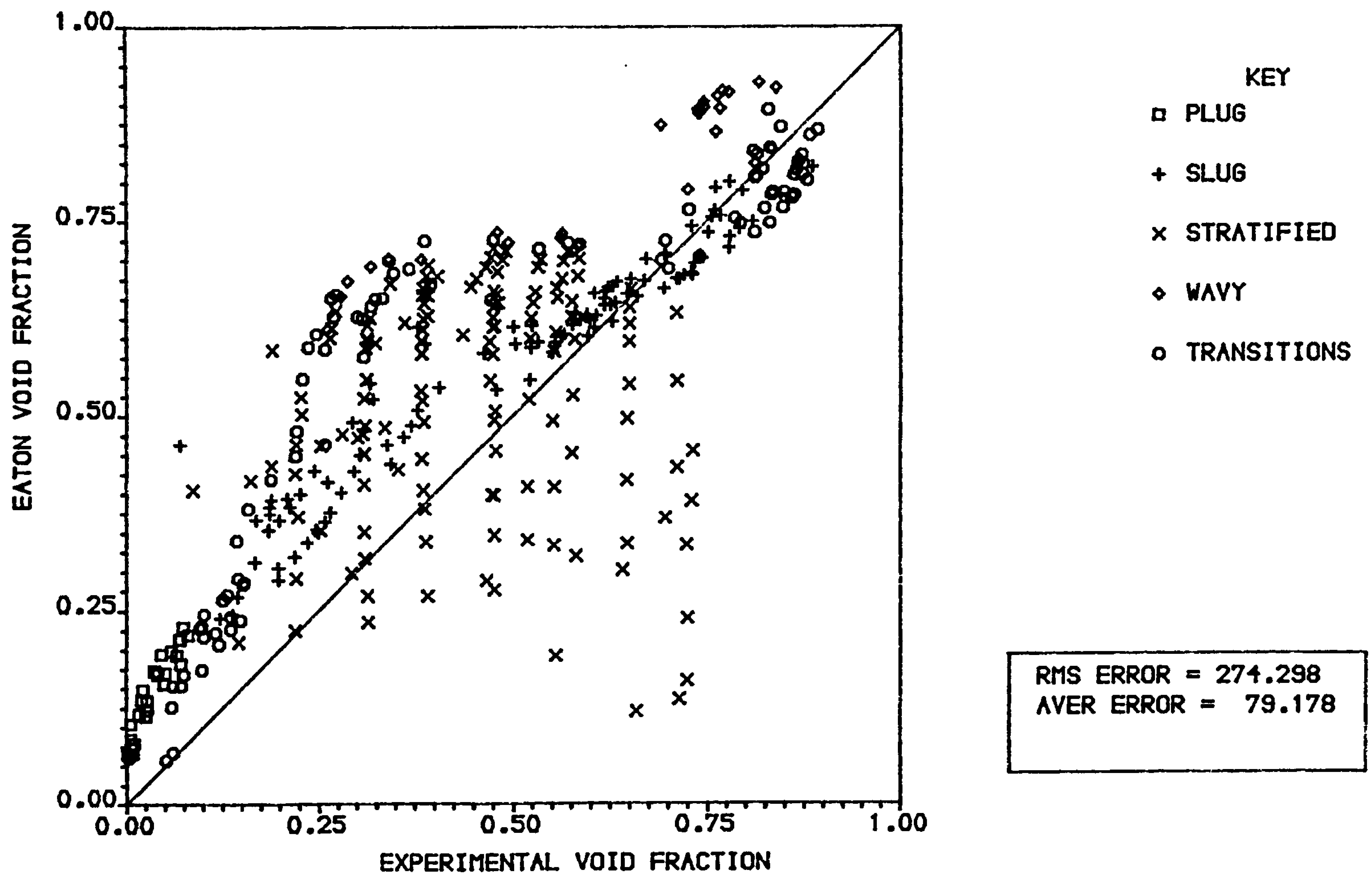


FIG. 6.2.31 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND EATON PREDICTIONS

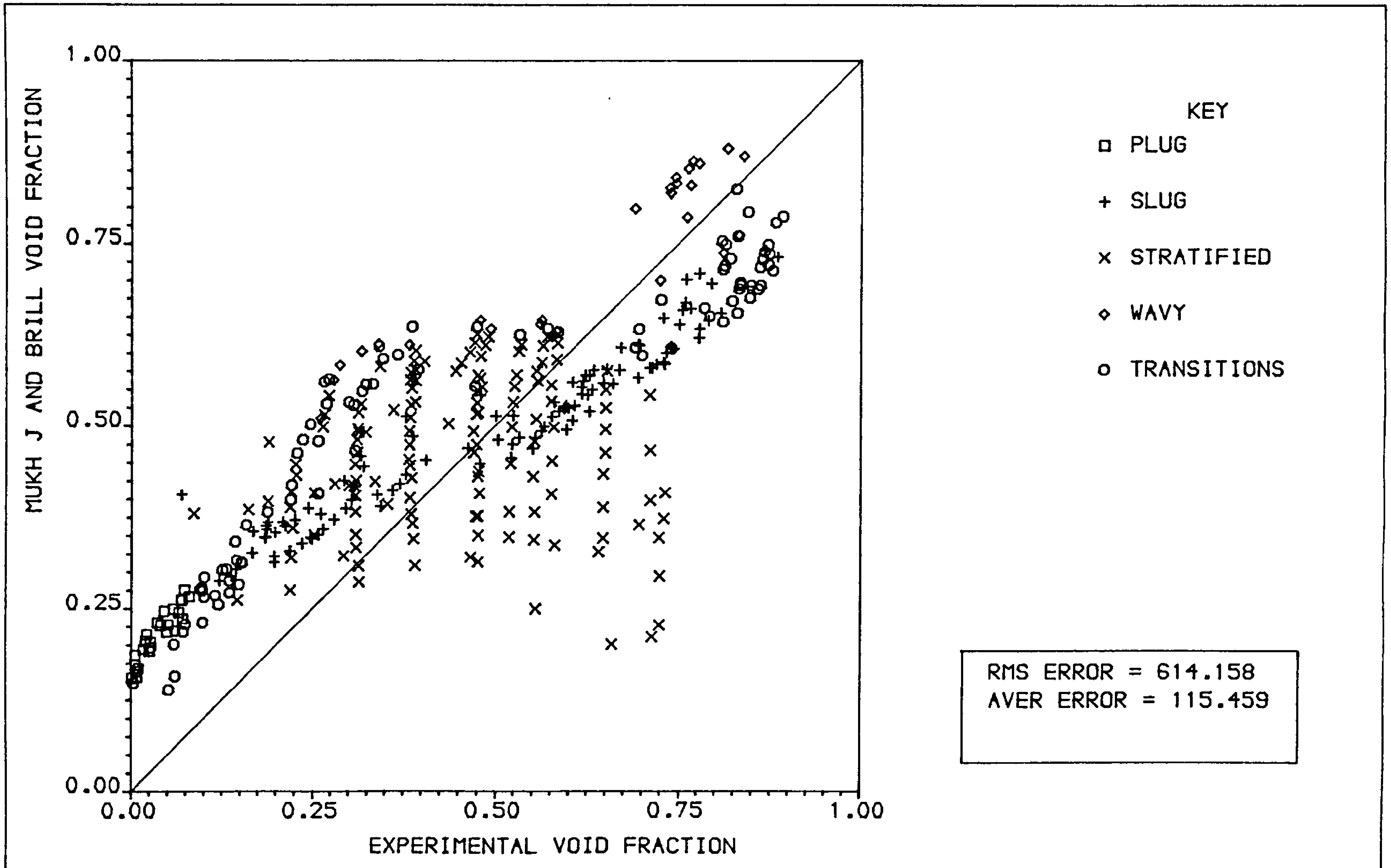


FIG. 6.2.32 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND MUKH J AND BRILL PREDICTIONS

#2 USER: CLCR12 PLOTFILE: GUZHOV ENTRY NO. 10806 QUEUED ON 27/02/82 AT 16:07 PLOTTED ON 27/02/82 AT 16:14

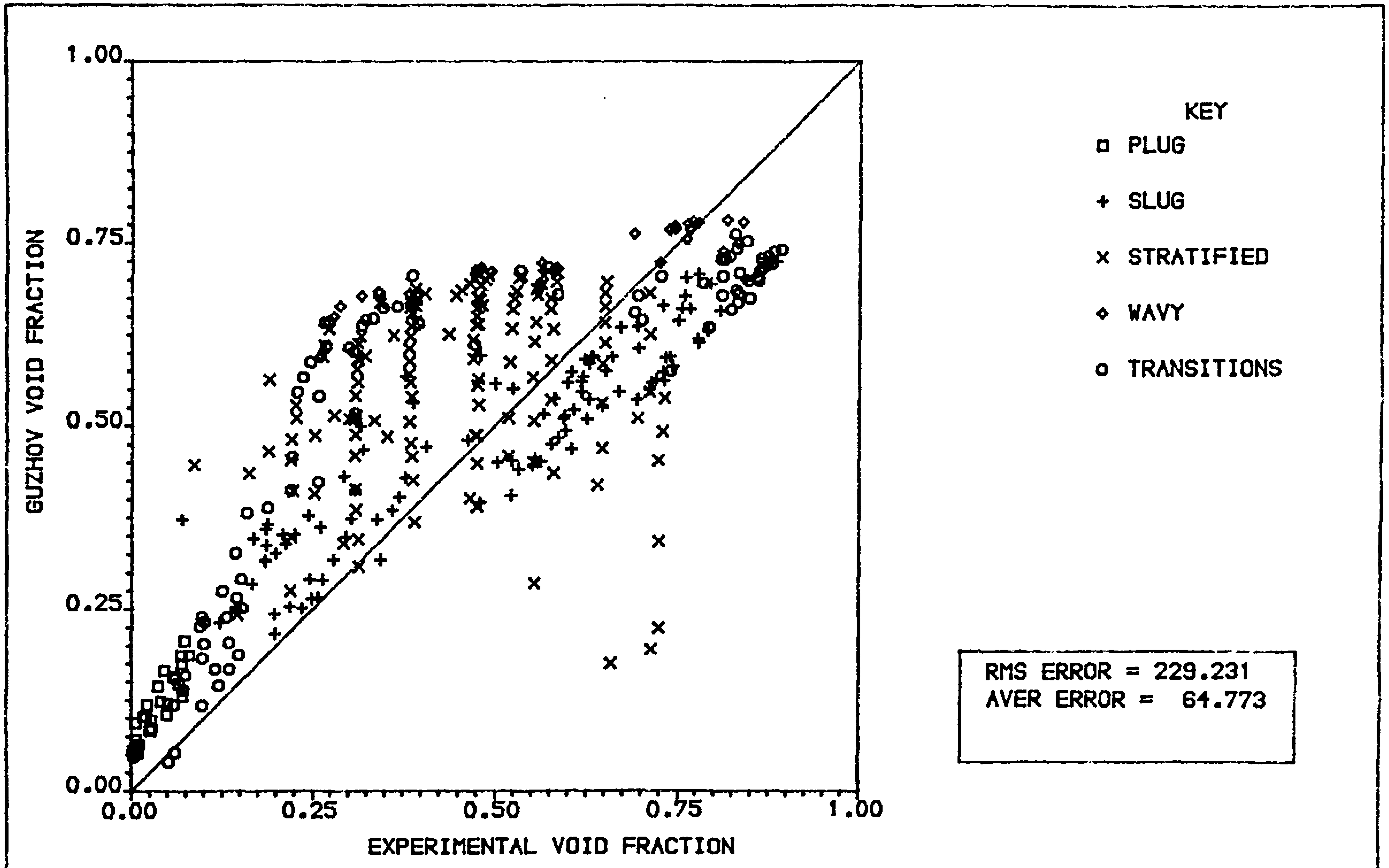


FIG. 6.2.33 COMPARISON BETWEEN EXPERIMENTAL VOID FRACTION AND GUZHOV PREDICTIONS

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
150801	0.011273	0.005917	171.8528	11.6424	0.968	0.86
150802	0.011206	0.008614	171.72558	11.2852	0.939	0.91
150803	0.011139	0.011700	171.0964	11.2092	0.932	0.71
150804	0.010985	0.014251	170.6584	10.5480	0.877	0.93
150805	0.010985	0.016445	169.2434	10.0779	0.838	0.89
150806	0.010985	0.019164	168.1878	9.3757	0.780	1.50
150807	0.010951	0.021022	167.7315	9.4358	0.785	1.03
150808	0.010951	0.023223	166.2264	8.6017	0.715	0.89
150809	0.010882	0.025924	163.9678	8.9453	0.744	0.83
150810	0.010882	0.029459	162.1748	9.7392	0.810	2.21
150811	0.010882	0.030966	159.1792	10.8561	0.903	0.83
150812	0.013156	0.005722	192.8686	12.9072	1.074	1.20
150813	0.013142	0.009692	188.9358	10.8127	0.899	0.94
150814	0.005211	0.005792	102.7146	5.8515	0.487	0.80
150815	0.004951	0.007910	92.9227	5.7005	0.474	0.67
150816	0.004951	0.010087	93.0080	5.9067	0.491	0.45
200801	0.006838	0.005851	134.8468	8.6194	0.717	0.67

Table 6.3.1 Total Pressure Drop and ILG Derived from Experimental Readings

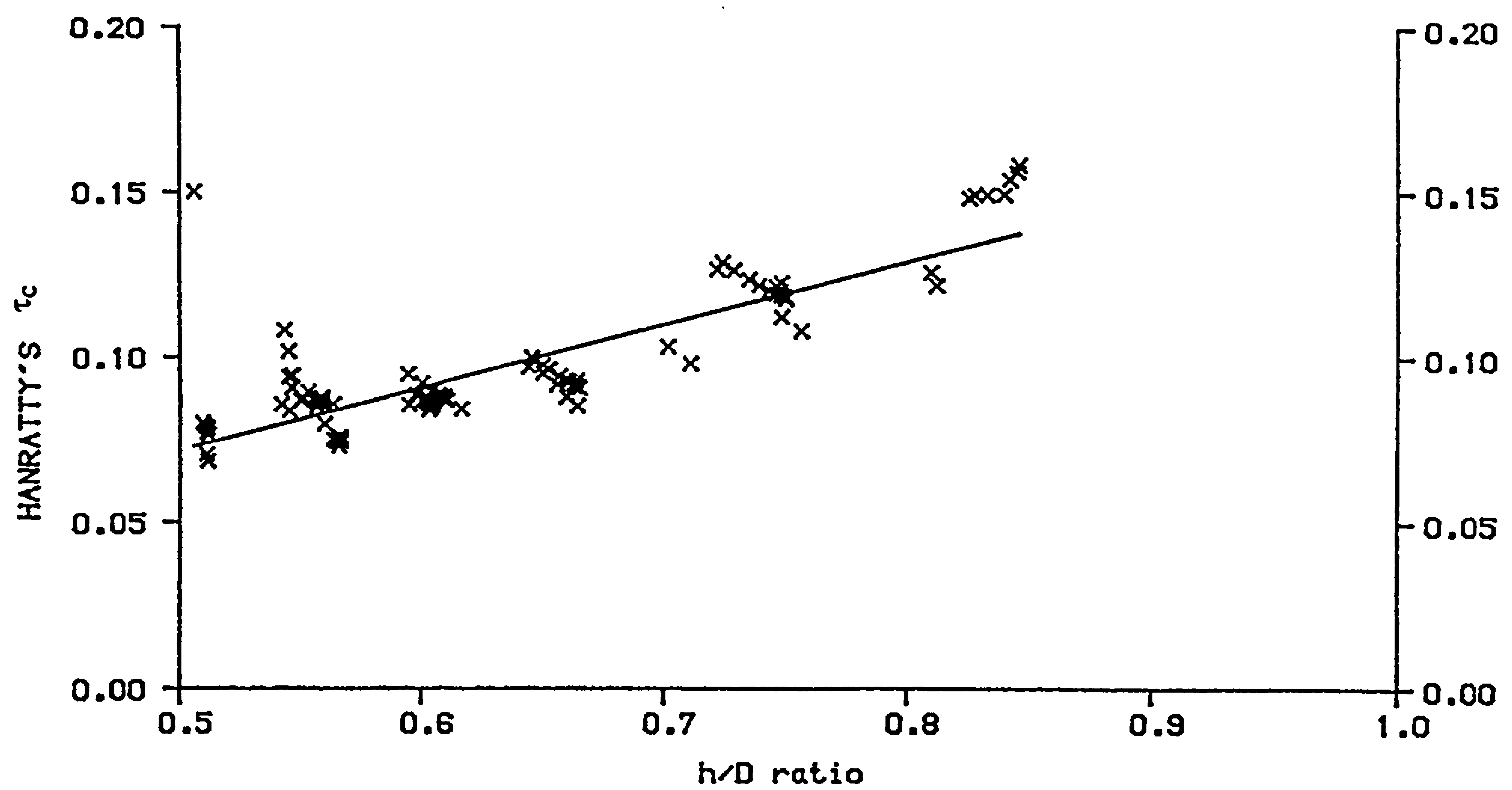


FIG. 6.3.1 A THE DEPENDANCE OF τ_c ON THE h/D RATIO

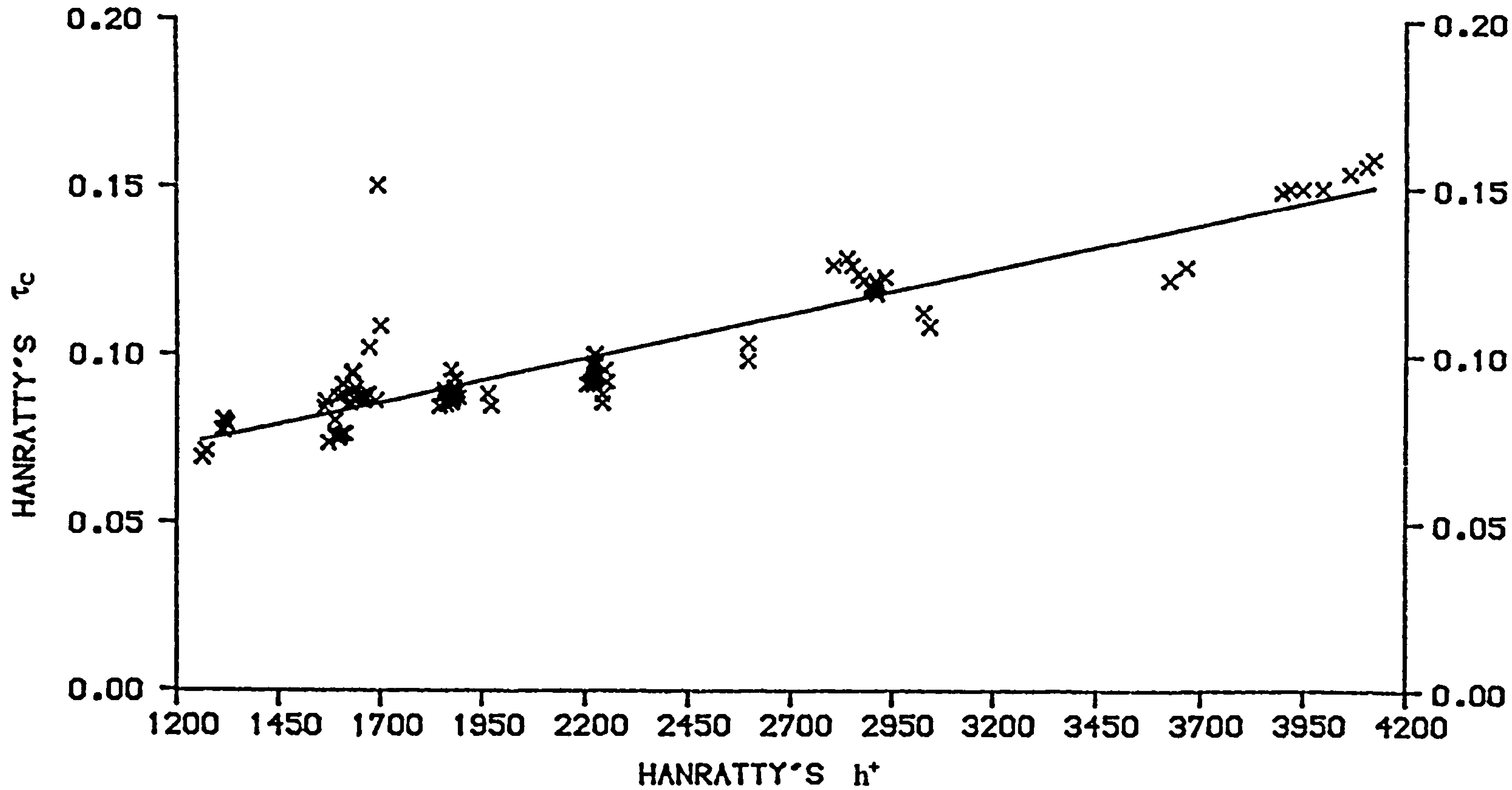


FIG. 6.3.1 B THE DEPENDANCE OF τ_c ON h^+

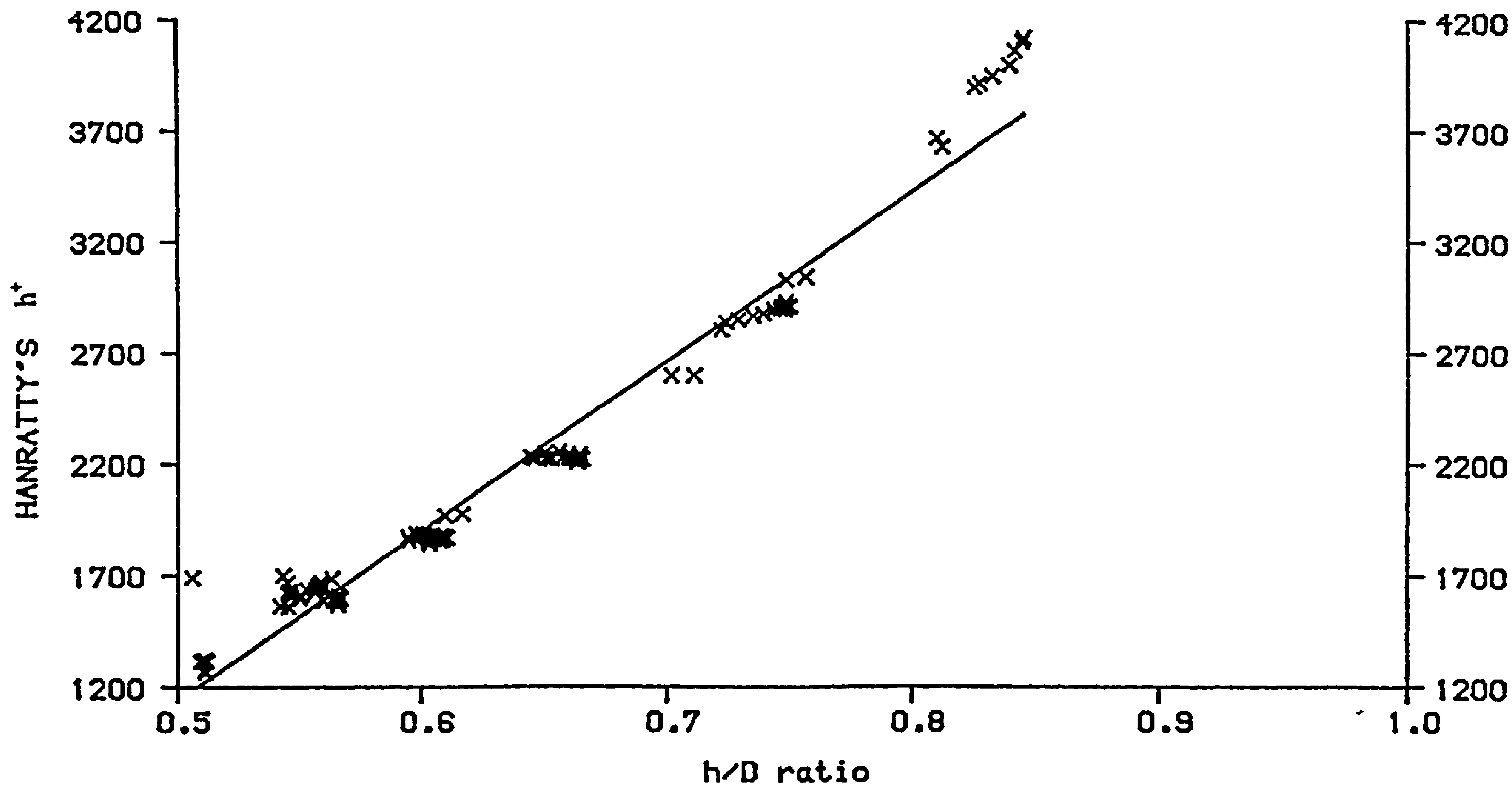


FIG. 6.3.1 C THE DEPENDANCE OF h^+ ON THE h/D RATIO

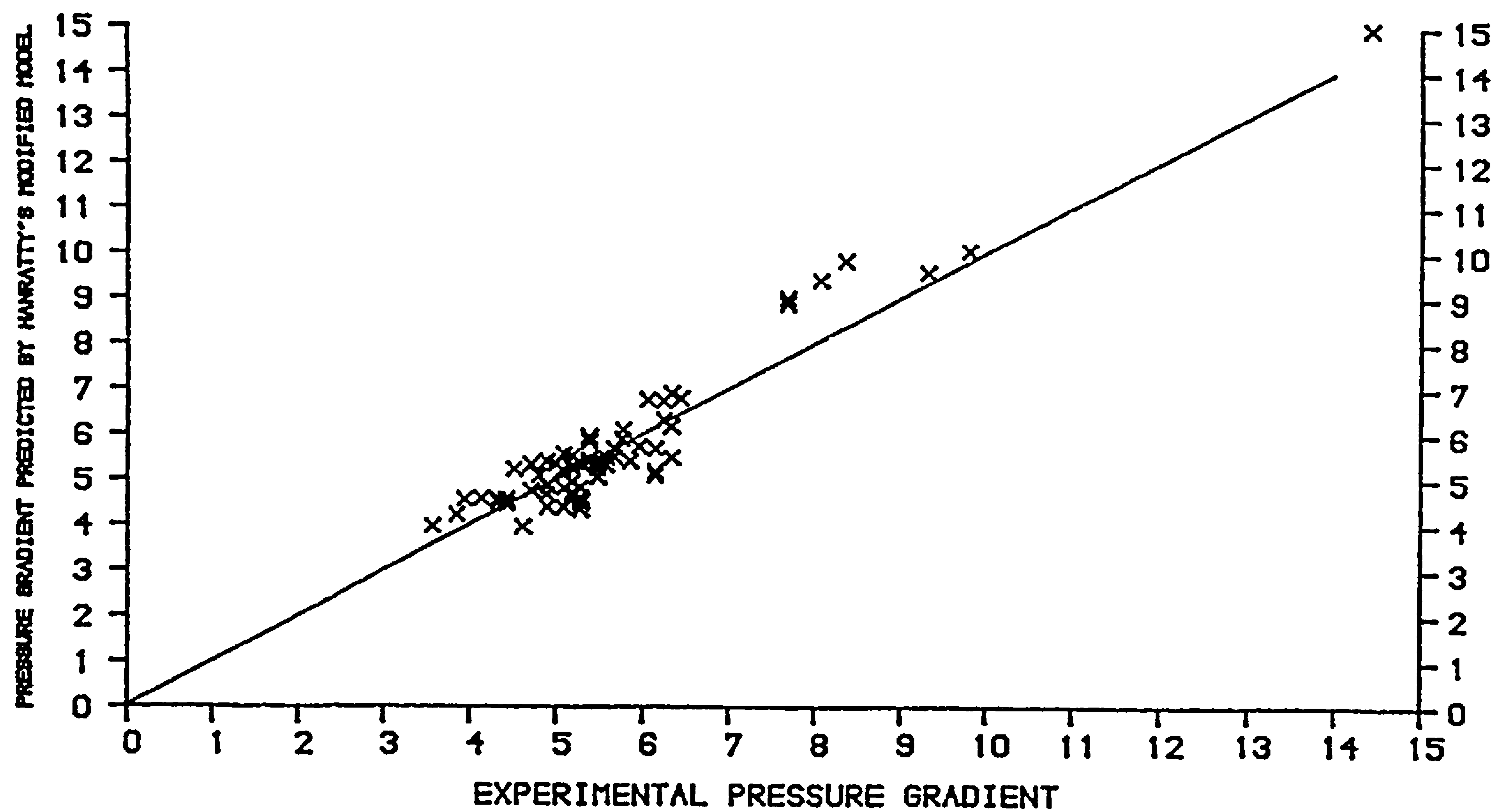


FIG. 6.3.2

COMPARISON OF PRESSURE GRADIENT PREDICTED BY HANRATTY'S MODIFIED MODEL WITH EXPERIMENTAL FOR 65% OF THE TOTAL STRATIFIED DATA (within ±20% diff.)

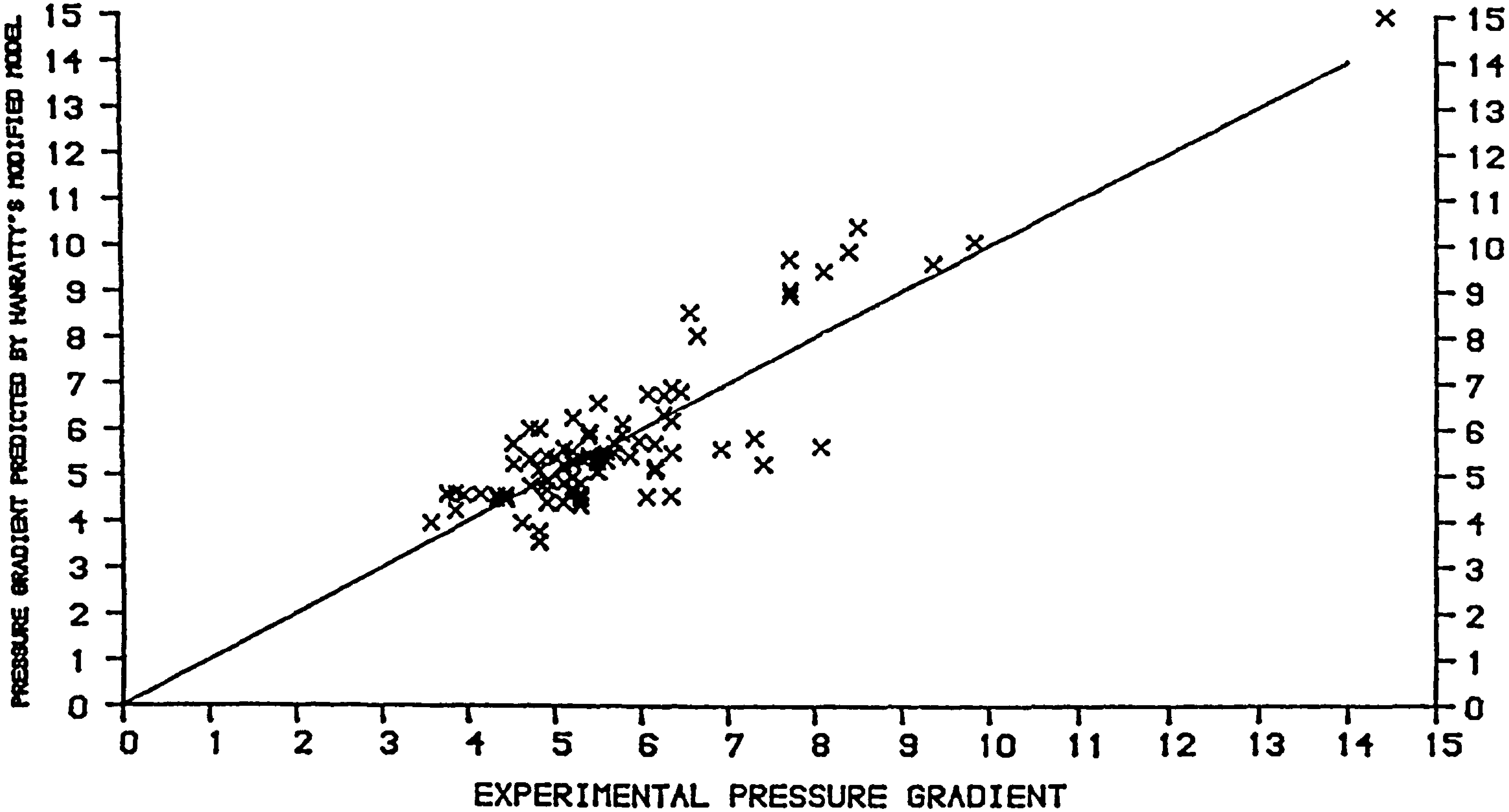
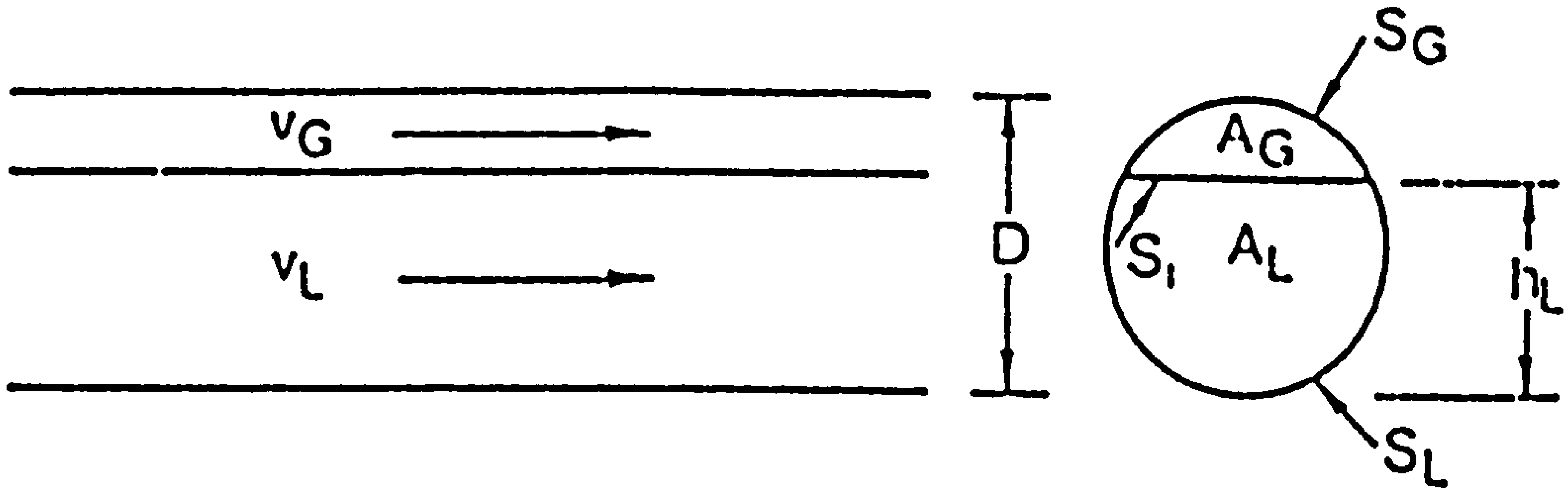
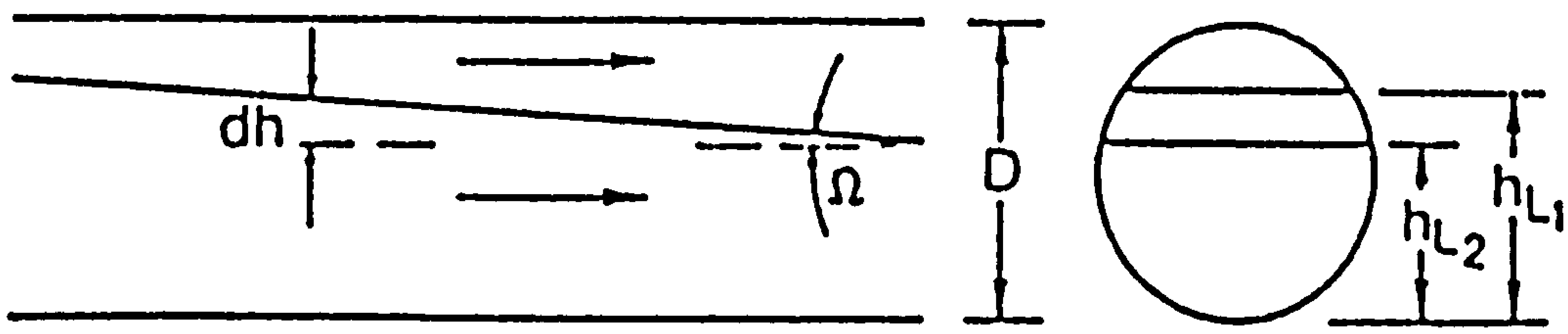


FIG. 6.3.3

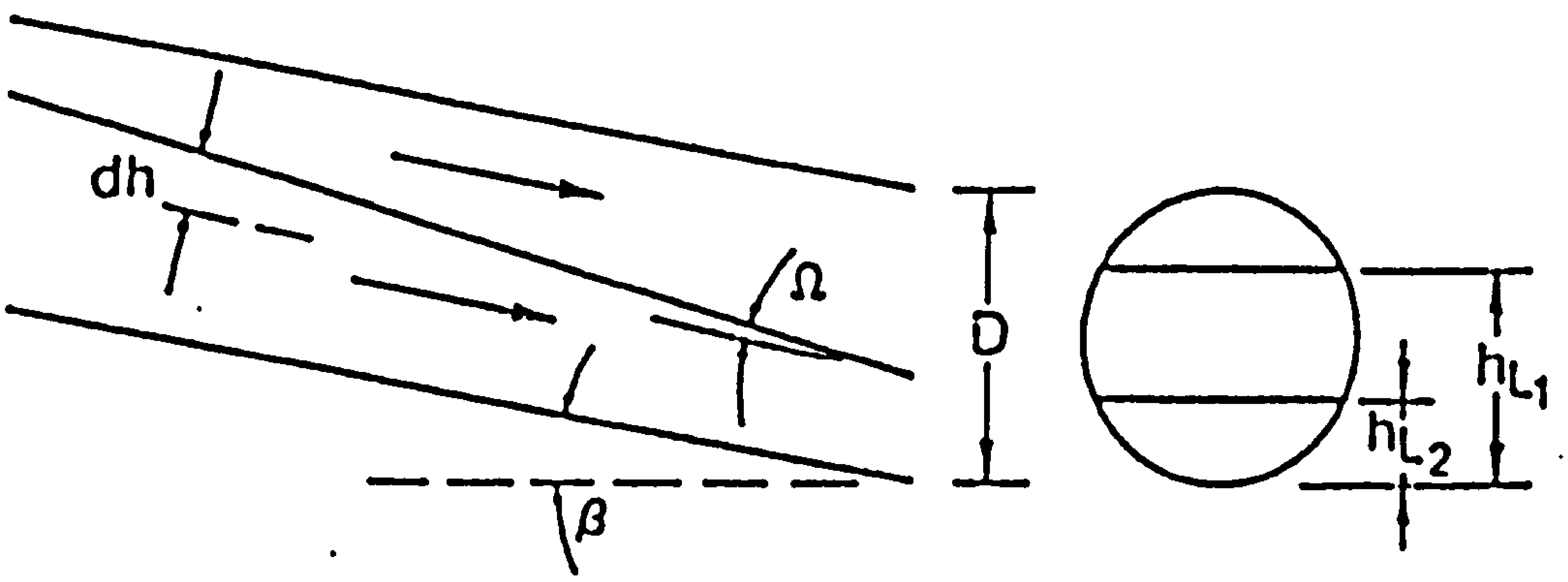
COMPARISON OF PRESSURE GRADIENT PREDICTED BY HANRATTY'S MODIFIED MODEL WITH EXPERIMENTAL FOR 79% OF THE TOTAL STRATIFIED DATA (within ±35% diff.)



Case A. Horizontal, Smooth Stratified Flow with no visible Interfacial Level Gradient (ILG): Uniform Flow



Case B. Horizontal, Smooth Stratified Flow with a visible Interfacial Level Gradient (ILG): Non-Uniform Flow



Case C. Inclined, Smooth Stratified Flow with a visible Interfacial Level Gradient: Non-Uniform Flow

FIG. 6.3.4 UNIFORM AND NON-UNIFORM SMOOTH STRATIFIED FLOW. (Ref.)

USER: CLCR12 PLOTFILE: PLOTLIB ENTRY NO. 74521 QUEUED ON 14/08/91 AT 13:09 PLOTTED ON 14/08/91 AT 13:13

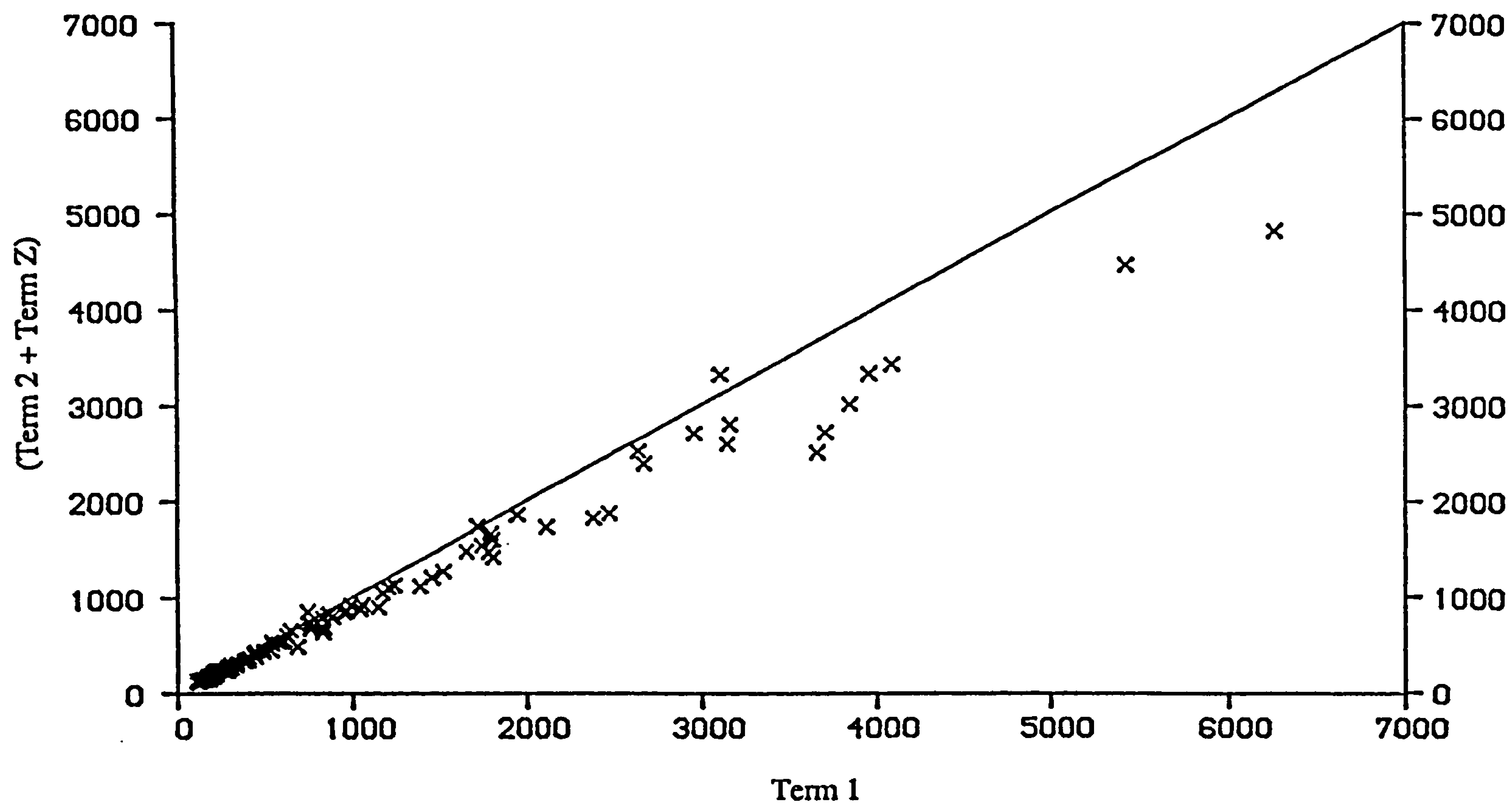


FIG. 6.3.5 BISHOP'S MODEL PREDICTION OF THE EXPERIMENTAL RESULTS (STRATIFIED ONLY)

USER: CLCR12 PLOTFILE: PLOTLIB ENTRY NO. 74519 QUEUED ON 14/08/91 AT 13:03 PLOTTED ON 14/08/91 AT 13:12

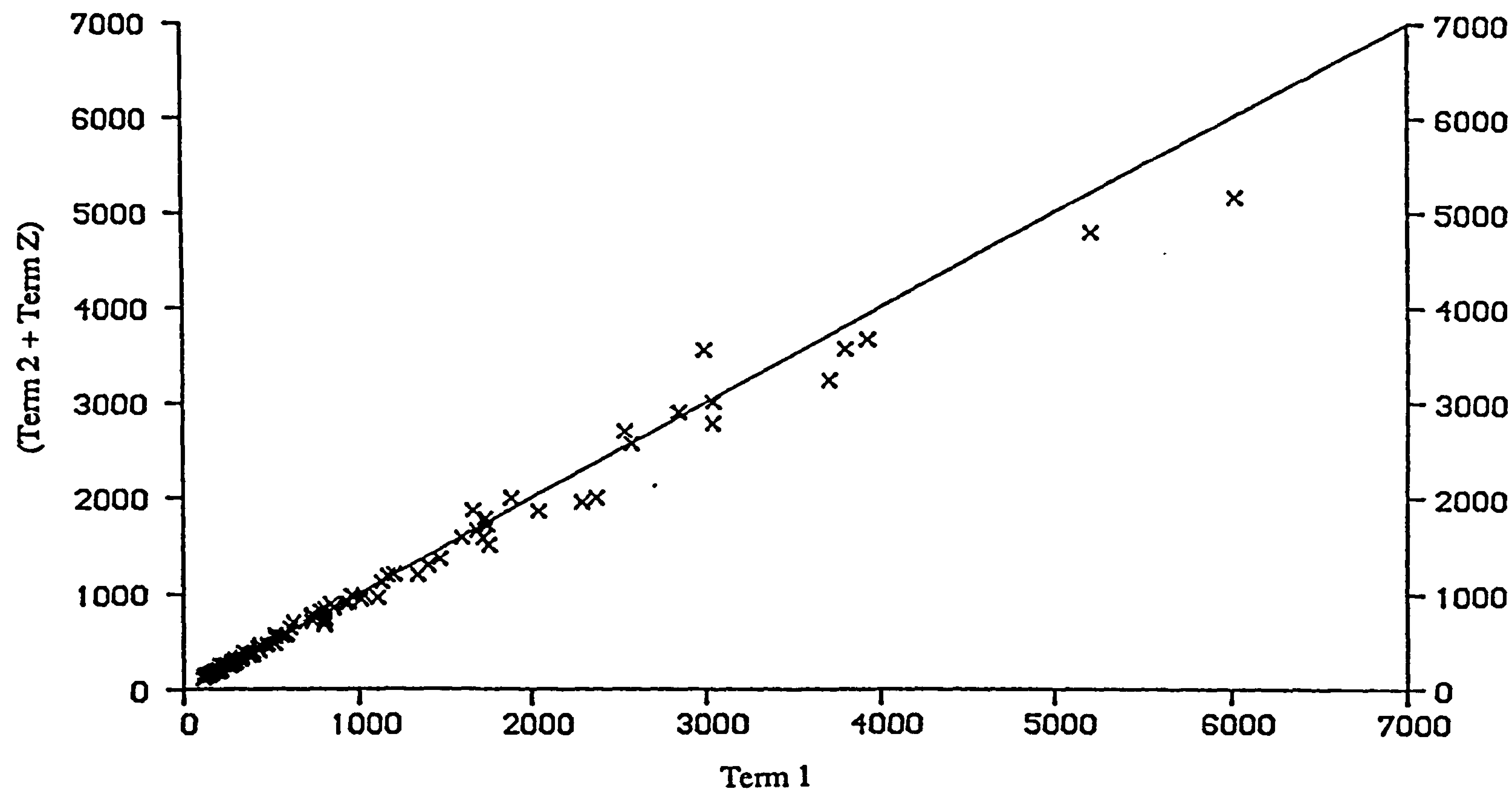


FIG. 6.3.6 PRESENT MODEL PREDICTION OF THE EXPERIMENTAL RESULTS (STRATIFIED ONLY)

USER: CLCR12 PLOTFILE: PLOTLIB ENTRY NO. 74512 QUEUED ON 14/08/91 AT 12:50 PLOTTED ON 14/08/91 AT 12:50

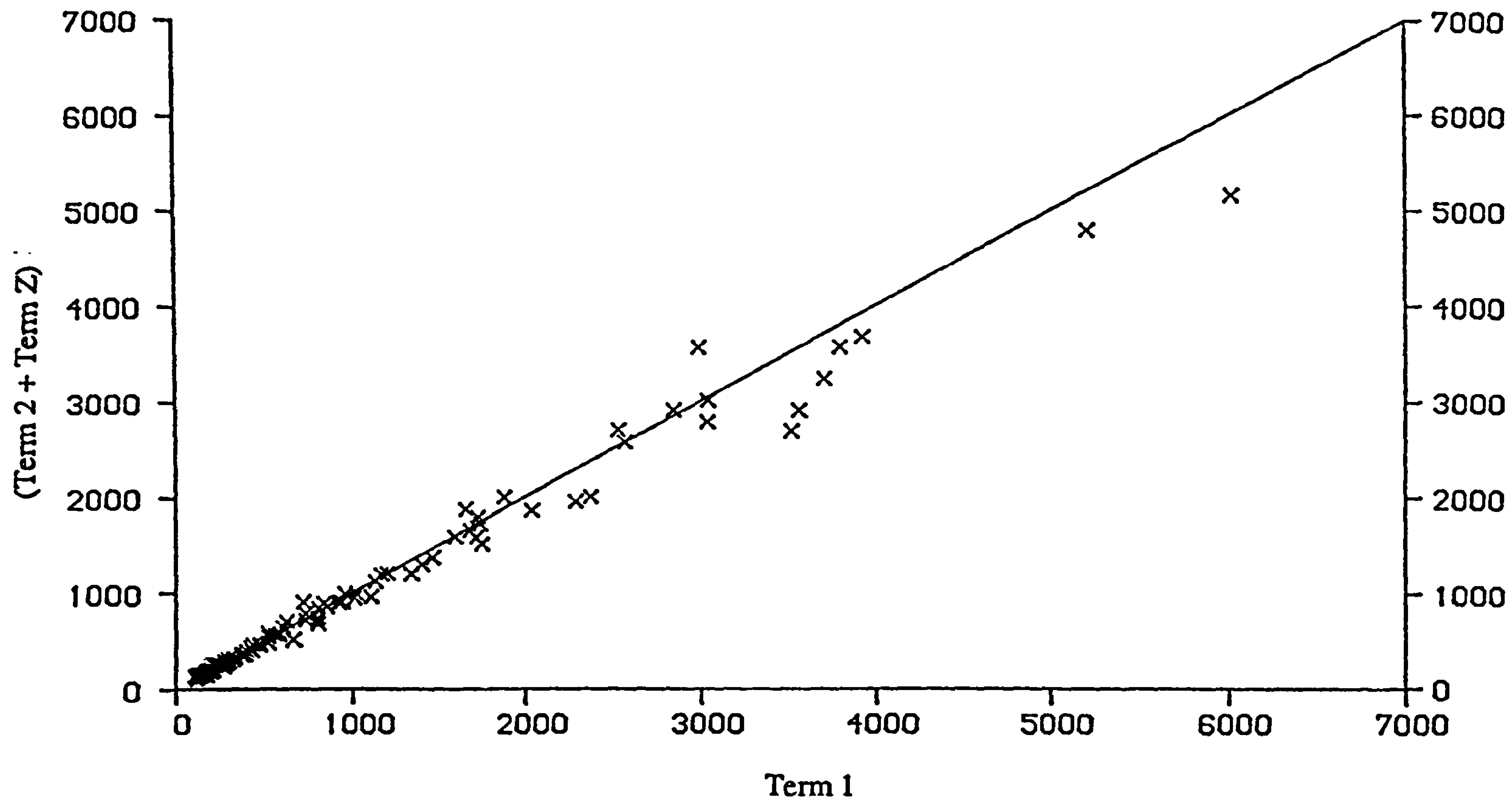


FIG. 6.3.7 PRESENT MODEL PREDICTION OF THE EXPERIMENTAL RESULTS (STRATIFIED ONLY)

CHAPTER (7)

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

(i) A test rig was reconstructed to increase the test section diameter size and length. The diameter size was increased to 203 mm (8"), and the length to 34 m long.

(ii) A gamma-ray attenuation type densitometer was designed and built for void fraction measurements, and involved a tube traversing apparatus. This allowed the measurements of the mean chordal void fraction distributions across the tube cross section in addition to overall mean void fraction.

(iii) Two depth gauges were designed, constructed and calibrated for the measurements of the water level change (ILG) in smooth stratified flow conditions, and placed 12 m apart in the test section.

(iv) A data acquisition system was designed, developed and constructed to condition and analyze the two depth gauge signals and to convert these signals to a meaningful readings.

(v) A programme of tests was carried out involving single and two phase flows. A series of 200 single phase and 400 two phase flow tests were carried out. The working fluids were air and water at pressures close to atmospheric. The tests covered a range of air and water flowrates, and four of the flow patterns and their transitions, namely, plug, slug, stratified and wavy. In addition to flowrates, temperatures and pressures, measurement of pressure gradients or pressure drop, void fraction and interfacial level gradients (ILG) or water level change were obtained.

(vi) Pressure drop prediction of six pressure drop correlations existing in the literature were compared with experimental pressure drop. The agreement was genrally poor (RMS error > 60% with some well over 100%), and the need to include the effect of tube size and flow pattern seem necessary. These correlations are mainly for fully developed flows; however comparrison may be misleading as the flow conditions being studied are considered to be subcritical i.e not fully developed.

(vii) Eight void fraction correlations were tested against the experimental void fraction data. In general, and terms of %RMS, all the void fraction correlations tested here failed to predict satisfactorily the experimental void fraction (RMS > 140% with some over 600%), with stratified flow beeing underpredicted by some of the models due perhaps to the existance of ILG.

(viii) The ILG was measured in smooth stratified conditions, and was found to constitute most of (if not all) the total pressure gradient when the water flowrates are low. The accuracy of the measurement was very good, i.e within error of less than 1%.

(ix) If interfacial level gradient exists in the stratified flow, the void fraction increases in the direction of the flow. This would indicate the importance of ILG term to be taken into account for flow of stratified in large diameter pipelines.

(x) Two models were tested for their ability to predict total pressure drop in the case of smooth stratified flow with ILG. Andritsos & Hanratty model overpredicted the total pressure drop measured experimentally by at least a factor of 2. This model was modified through its characteristic stress (τ_C expression, where a new values of n = 2.4512 and m = -4.2440 were recommended. The modified model predicted the present experimental total pressure within error of < 20%.

The Bishop's model did include the effect of ILG, and therefore, it predicted the present total pressure drop data within RMS of 14%.

(xi) A new model was developed in the same way as that of Bishop's, and this model predicted the present measured total pressure drop data within RMS of 8%.

(xii) Flow pattern maps tested in general seem to have a limited value due perhaps to the inadequacy of the two co-ordinate system normally used. However, the data presented here do indicate that, the effect of tube size is to move the boundaries to lower superficial gas velocities and higher superficial liquid velocities, and the transitions are not sharp, but are fairly gradual.

(xiii) The use of gamma-ray attenuation technique for the measurements of void fraction gave a very good accuracy when compared with geometrical void fraction. The number of chordal stations (steps) does have some effect on the accuracy of measurement, but to acceptable degree.

7.2 Recommendations

On the assumption that the project is to be continued, the following recommendations are made to improve the test facility operation, and to ask for further analysis of the stratified flow data.

(i) The void fraction traversing apparatus should be motorised in order to eliminate the time consuming manual operation.

(ii) The pressure drop measurement should be measured with more sensitive and accurate devices, especially for the stratified flow testing, where the pressure gradients are very small.

(iii) Further analysis are needed for the stratified flow data, to clarify the mechanisms of the ILG.

(iv) If the present pressure drop apparatus have to be used for future testing, the depth gauges are recommended for the measurements of the total pressure drop for the case of smooth stratified flow at low water flowrates.

(v) The present model developed for stratified flow (Eq. 6.3.21 with n = m = 0.214, $C_G = C_L = 0.048$ and $f_{iL}/f_G = f_{iG}/f_G = 1.0$) is recommended for the prediction of total pressure drop in stratified flow for large diameter pipes.

(vi) The results obtained in the stratified flow regime may be dependent on the test section exit geometry; the flow is considered to be subcritical i.e not fully developed; the results are considered valid for the geometry above.

(vii) Further studies of the subcritical stratified flows in this test facility would be worthwhile to improve the characteristics of the exit boundary conditions, so that detailed theoretical modelling of the intire flow could be attempted.

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APPENDICES

APPENDIX (A)

APPENDIX A

A.1 EXPERIMENTAL DATA; SINGLE PHASE FLOW.

A.2 PRESSURE DROP AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

A.3 REYNOLDS NUMBER, FRICTION FACTOR AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

A.4 SINGLE PHASE FRICTION FACTOR SPECIMEN CALCULATION.

SYMBOLS USED IN APPENDIX A

Code		
No.	Test number	
EMF	Air temperature	°C
Temp	Water temperature	°C
HL	Head difference across water orifice	cm H_2O
PG	Air pressure	bar
S1,S2,S3,S4	Air rotameter readings (head across 1" air orifice)	cm H_2O
S1	Head across 2" air orifice	cm H_2O
ELE	Void fraction readings	
PE	Pressure gradient	mm H_2O
PRES	Pressure at the middle of the test section	mm H_2O
PATRN	Flow pattern	
HOR	Identification of water and air orifices plate used	
GTOTL	Total mass velocity	kg/m^2s
FFSP	Single phase friction factor	
RE	Single phase Reynolds Number	
USF	Superficial liquid velocity	m/s
USG	Superficial air velocity	m/s
QALITY	Mass dryness fraction	

SYMBOLS USED IN APPENDIX A

Code		
BETA	Volume fraction	
TME	Experimental two-phase multiplier	
VDF	Experimental void fraction	
TMBE	Not used	
PINDX	Not used	
PR-GRAD	Pressure gradient	kn/m^3
POT	Not used	
EL	Not used	
PT	Not used	

APPENDIX A

A.1 EXPERIMENTAL DATA; SINGLE PHASE FLOW.

FROM **Table A.1.1** TO **Table A.1.5.**

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	EL	PT	PATRN
230803	0.000	19.3	976.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	15.00	965.98	0.0	0.00	9
230804	0.000	19.3	883.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	13.64	939.46	0.0	0.00	9
230805	0.000	19.4	803.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	12.38	818.72	0.0	0.00	9
230806	0.000	19.5	720.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	11.06	736.06	0.0	0.00	9
230807	0.000	19.5	617.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.63	652.47	0.0	0.00	9
230808	0.000	19.5	526.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	8.34	569.08	0.0	0.00	9
230809	0.000	19.6	428.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.65	492.83	0.0	0.00	9
230810	0.000	19.6	262.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.86	256.66	0.0	0.00	9
230811	0.000	19.8	160.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.84	202.33	0.0	0.00	9
230812	0.000	19.8	41.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.16	96.01	0.0	0.00	9
230813	0.000	20.3	173.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.19	280.31	0.0	0.00	9
230814	0.000	20.3	140.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.61	251.31	0.0	0.00	9
230815	0.000	20.3	106.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.02	231.40	0.0	0.00	9
230816	0.000	20.4	81.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.77	196.73	0.0	0.00	9
230817	0.000	20.4	52.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.07	138.48	0.0	0.00	9
230818	0.000	20.4	20.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.45	99.69	0.0	0.00	9
230819	0.000	20.5	89.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.73	176.65	0.0	0.00	9
230820	0.000	20.5	202.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.74	304.21	0.0	0.00	9
41201	0.000	13.8	1169.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	17.73	569.66	0.0	0.00	9
41202	0.000	13.8	1087.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	16.79	502.46	0.0	0.00	9
41203	0.000	13.9	991.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	15.45	319.31	0.0	0.00	9
41204	0.000	13.9	907.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	14.09	249.40	0.0	0.00	9
41205	0.000	14.6	831.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	13.01	319.36	0.0	0.00	9
41206	0.000	14.9	720.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	11.21	193.92	0.0	0.00	9
41207	0.000	14.8	577.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.19	62.42	0.0	0.00	9
41208	0.000	14.8	476.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	8.20	54.86	0.0	0.00	9
41209	0.000	14.9	327.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.74	-77.14	0.0	0.00	9
41210	0.000	14.9	192.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.62	-117.65	0.0	0.00	9
41211	0.000	15.1	122.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.12	-188.07	0.0	0.00	9
41212	0.000	15.1	55.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.20	-263.73	0.0	0.00	9
220101	0.000	12.8	169.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	16.66	866.63	0.0	0.00	9
50201	0.000	10.8	23.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.72	178.32	0.0	0.00	9
50202	0.000	10.8	25.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.64	198.82	0.0	0.00	9
50203	0.000	10.9	30.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.69	184.17	0.0	0.00	9
50204	0.000	11.1	29.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.00	172.80	0.0	0.00	9
50205	0.000	11.1	38.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.79	181.56	0.0	0.00	9
50206	0.000	11.3	32.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.72	177.77	0.0	0.00	9

TABLE A.1.1 OBTAINED EXPERIMENTAL READINGS FOR SINGLE PHASE FLOW

NO	EMF	TEMP	HL	PG	S1	S2	S3	S4	VDF	POT	PE	PRES	EL	PT	PATRN
	MV	C	CMH2O	BAR	CM	CM	CM	CM			MMH2O/M	MMH2O			
50207	0.000	11.3	36.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.85	195.50	0.0	0.00	9
50208	0.000	11.4	46.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.75	200.98	0.0	0.00	9
50209	0.000	11.5	57.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.88	213.90	0.0	0.00	9
50210	0.000	11.5	67.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.40	221.81	0.0	0.00	9
50211	0.000	11.6	74.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.47	229.23	0.0	0.00	9
50212	0.000	11.6	80.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.61	245.32	0.0	0.00	9
50213	0.000	11.6	90.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.76	279.33	0.0	0.00	9
50214	0.000	11.6	92.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.83	273.50	0.0	0.00	9
50215	0.000	11.8	100.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.72	280.38	0.0	0.00	9
50216	0.000	11.9	176.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.14	370.81	0.0	0.00	9
50217	0.000	11.9	267.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.33	502.45	0.0	0.00	9
50218	0.000	11.9	323.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.91	509.49	0.0	0.00	9
50219	0.000	12.0	383.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.65	546.39	0.0	0.00	9
50220	0.000	12.1	438.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	7.51	608.18	0.0	0.00	9
100201	0.000	12.1	1130.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	17.42	1009.83	0.0	0.00	9
100202	0.000	12.1	1102.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	17.04	981.99	0.0	0.00	9
100203	0.000	12.3	1033.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	16.09	920.23	0.0	0.00	9
100204	0.000	12.4	730.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	11.72	663.70	0.0	0.00	9
100205	0.000	12.4	301.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.27	257.83	0.0	0.00	9
100206	0.000	12.5	225.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.81	185.45	0.0	0.00	9
100207	0.000	12.7	6.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.12	-52.93	0.0	0.00	9
100208	0.000	12.7	15.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.34	345.17	0.0	0.00	9
100209	0.000	12.7	19.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.55	-30.78	0.0	0.00	9
100210	0.000	12.8	23.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.58	-27.50	0.0	0.00	9
100211	0.000	12.9	28.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.50	-28.00	0.0	0.00	9
100212	0.000	12.9	32.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.08	-17.49	0.0	0.00	9
100213	0.000	12.9	34.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.95	-16.23	0.0	0.00	9
100214	0.000	13.1	42.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.00	-6.99	0.0	0.00	9
100215	0.000	13.1	46.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.00	10.01	0.0	0.00	9
100216	0.000	13.1	54.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.33	9.02	0.0	0.00	9
100217	0.000	13.1	60.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.00	11.01	0.0	0.00	9
100218	0.000	13.1	91.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.95	58.23	0.0	0.00	9
100219	0.000	13.3	68.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.30	27.19	0.0	0.00	9
100220	0.000	13.3	187.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.45	155.24	0.0	0.00	9
210301	0.000	13.6	618.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	10.10	515.27	0.0	0.00	9
210302	0.000	13.6	588.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.74	484.19	0.0	0.00	9
210303	0.000	13.7	568.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.36	470.77	0.0	0.00	9
210304	0.000	13.8	540.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.03	446.44	0.0	0.00	9
210305	0.000	13.8	515.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	8.52	419.52	0.0	0.00	9
210306	0.000	13.9	468.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	7.71	399.29	0.0	0.00	9
210307	0.000	13.9	439.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	7.62	386.71	0.0	0.00	9

TABLE A.1.2 OBTAINED EXPERIMENTAL READINGS FOR SINGLE PHASE FLOW

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	EL	PT	PATRN
210308	0.000	14.0	427.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	7.04	376.38	0.0	0.00	9
210309	0.000	14.0	415.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.99	373.04	0.0	0.00	9
210310	0.000	14.1	389.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.50	351.13	0.0	0.00	9
210311	0.000	14.1	357.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.20	339.04	0.0	0.00	9
210312	0.000	14.2	347.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.00	328.79	0.0	0.00	9
210313	0.000	14.2	318.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.44	299.38	0.0	0.00	9
210314	0.000	14.3	288.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.26	284.04	0.0	0.00	9
210315	0.000	14.4	273.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.79	284.29	0.0	0.00	9
210316	0.000	14.4	223.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.19	237.85	0.0	0.00	9
210317	0.000	14.4	146.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.65	152.10	0.0	0.00	9
210318	0.000	14.6	93.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.66	106.85	0.0	0.00	9
210319	0.000	14.6	35.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.74	60.73	0.0	0.00	9
210320	0.000	14.6	79.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.57	144.33	0.0	0.00	9
220301	0.000	14.4	1155.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	17.83	1137.80	0.0	0.00	9
220302	0.000	14.4	1126.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	17.42	1128.00	0.0	0.00	9
220303	0.000	14.6	1107.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	17.13	1111.50	0.0	0.00	9
220304	0.000	14.6	1084.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	16.91	1098.70	0.0	0.00	9
220305	0.000	14.6	1048.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	16.25	1065.30	0.0	0.00	9
220306	0.000	14.6	1019.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	15.78	1006.40	0.0	0.00	9
220307	0.000	14.7	1005.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	15.67	1026.80	0.0	0.00	9
220308	0.000	14.8	971.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	15.25	1010.40	0.0	0.00	9
220309	0.000	14.9	940.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	14.75	962.07	0.0	0.00	9
220310	0.000	14.9	924.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	15.42	953.40	0.0	0.00	9
220311	0.000	14.9	878.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	13.95	926.65	0.0	0.00	9
220312	0.000	14.9	846.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	13.75	903.07	0.0	0.00	9
220313	0.000	15.9	816.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	13.00	860.67	0.0	0.00	9
220314	0.000	15.1	781.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	12.53	842.84	0.0	0.00	9
220315	0.000	15.1	747.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	12.04	803.39	0.0	0.00	9
220316	0.000	15.1	715.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	11.34	785.39	0.0	0.00	9
220317	0.000	15.1	680.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	10.87	743.97	0.0	0.00	9
220318	0.000	15.1	656.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	10.56	730.52	0.0	0.00	9
220319	0.000	15.3	627.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	10.00	703.94	0.0	0.00	9
220320	0.000	15.3	604.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.86	682.36	0.0	0.00	9
220321	0.000	15.4	579.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.52	666.27	0.0	0.00	9
220322	0.000	15.4	558.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	9.16	646.36	0.0	0.00	9
220323	0.000	15.4	515.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	8.49	597.79	0.0	0.00	9
220324	0.000	15.6	491.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	8.15	586.04	0.0	0.00	9
220325	0.000	15.6	463.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	7.61	552.02	0.0	0.00	9
220326	0.000	15.6	432.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	7.27	526.44	0.0	0.00	9
220327	0.000	15.6	415.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.84	508.28	0.0	0.00	9
220328	0.000	15.8	364.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	6.37	466.11	0.0	0.00	9

TABLE A.1.3 OBTAINED EXPERIMENTAL READINGS FOR SINGLE PHASE FLOW

NO	EMF	TEMP	HL	PG	S1	S2	S3	S4	VDF	POT	PE	PRES	EL	PT	PATRN
	MV	C	CMH2O	BAR	CM	CM	CM	CM			MMH2O/M	MMH2O			
220329	0.000	15.8	341.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.92	451.78	0.0	0.00	9
220330	0.000	15.9	302.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	5.08	411.33	0.0	0.00	9
220331	0.000	15.9	277.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.70	394.49	0.0	0.00	9
220332	0.000	15.9	239.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.19	370.79	0.0	0.00	9
220333	0.000	15.9	207.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.57	300.22	0.0	0.00	9
220334	0.000	15.9	194.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.51	287.45	0.0	0.00	9
220335	0.000	16.0	171.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.88	274.55	0.0	0.00	9
220336	0.000	16.0	142.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.57	258.36	0.0	0.00	9
220337	0.000	16.0	115.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.28	232.20	0.0	0.00	9
220338	0.000	16.0	109.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.82	230.45	0.0	0.00	9
220339	0.000	16.1	54.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.07	172.03	0.0	0.00	9
220340	0.000	16.1	17.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.35	132.20	0.0	0.00	9
180501	0.000	15.4	29.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.05	248.75	0.0	0.00	9
180502	0.000	15.4	35.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.91	289.93	0.0	0.00	9
180503	0.000	15.4	40.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.05	230.35	0.0	0.00	9
180504	0.000	15.4	52.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.76	310.97	0.0	0.00	9
180505	0.000	15.3	47.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.99	314.43	0.0	0.00	9
180506	0.000	15.3	54.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.19	313.02	0.0	0.00	9
180507	0.000	15.2	61.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.31	330.78	0.0	0.00	9
180508	0.000	15.1	62.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.65	297.18	0.0	0.00	9
180509	0.000	15.1	71.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.54	308.10	0.0	0.00	9
180510	0.000	15.1	77.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.81	296.18	0.0	0.00	9
180511	0.000	15.1	85.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.88	308.68	0.0	0.00	9
180512	0.000	15.1	73.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.98	293.18	0.0	0.00	9
180513	0.000	15.1	80.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.72	310.97	0.0	0.00	9
180514	0.000	15.1	91.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.67	322.35	0.0	0.00	9
180515	0.000	15.1	105.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.18	331.72	0.0	0.00	9
180516	0.000	15.2	96.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.70	327.43	0.0	0.00	9
180517	0.000	15.3	71.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.71	298.60	0.0	0.00	9
180518	0.000	15.3	45.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.29	257.43	0.0	0.00	9
180519	0.000	15.3	59.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.22	264.97	0.0	0.00	9
180520	0.000	15.3	52.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.17	295.24	0.0	0.00	9
180521	0.000	15.4	61.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.38	286.80	0.0	0.00	9
180522	0.000	15.4	65.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.48	285.70	0.0	0.00	9
180523	0.000	15.4	81.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.79	305.32	0.0	0.00	9
180524	0.000	15.4	69.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.27	294.68	0.0	0.00	9
180525	0.000	15.4	72.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.29	315.20	0.0	0.00	9
180526	0.000	15.4	99.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.61	320.45	0.0	0.00	9
180527	0.000	15.4	78.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.17	290.95	0.0	0.00	9
180528	0.000	15.5	110.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.88	337.82	0.0	0.00	9
180529	0.000	15.6	70.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.28	293.07	0.0	0.00	9

TABLE A.1.4 OBTAINED EXPERIMENTAL READINGS FOR SINGLE PHASE FLOW

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	EL	PT	PATRN
180530	0.000	15.6	41.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.90	251.25	0.0	0.00	9
180531	0.000	15.6	143.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	4.28	358.62	0.0	0.00	9
180532	0.000	15.6	165.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.88	387.72	0.0	0.00	9
180533	0.000	15.6	131.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	3.07	339.38	0.0	0.00	9
180534	0.000	15.6	115.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.50	341.50	0.0	0.00	9
180535	0.000	15.6	30.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.75	252.08	0.0	0.00	9
180536	0.000	15.7	40.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.78	250.15	0.0	0.00	9
210601	0.000	17.3	1677.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.35	409.22	0.0	0.00	9
210602	0.000	17.3	1539.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.41	421.82	0.0	0.00	9
210603	0.000	17.3	1367.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	2.07	349.72	0.0	0.00	9
210604	0.000	17.3	1234.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.64	340.60	0.0	0.00	9
210605	0.000	17.4	1169.3	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.84	322.07	0.0	0.00	9
210606	0.000	17.4	1103.8	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.88	309.82	0.0	0.00	9
210607	0.000	17.5	1024.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.75	294.03	0.0	0.00	9
210608	0.000	17.5	991.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.42	258.98	0.0	0.00	9
210609	0.000	17.6	882.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.17	254.13	0.0	0.00	9
210610	0.000	17.6	776.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.23	244.48	0.0	0.00	9
210611	0.000	17.6	700.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.15	231.40	0.0	0.00	9
210612	0.000	17.7	618.7	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.93	215.07	0.0	0.00	9
210613	0.000	17.8	582.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.95	201.73	0.0	0.00	9
270601	0.000	15.9	708.1	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	1.19	249.80	0.0	0.00	9
270602	0.000	15.9	626.2	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.89	244.72	0.0	0.00	9
270603	0.000	16.0	516.6	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.89	236.63	0.0	0.00	9
270604	0.000	16.0	459.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.76	205.43	0.0	0.00	9
270605	0.000	16.0	391.9	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.97	197.93	0.0	0.00	9
270606	0.000	16.0	307.4	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.60	204.58	0.0	0.00	9
270607	0.000	16.0	252.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.49	201.50	0.0	0.00	9
270608	0.000	16.0	146.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.58	180.65	0.0	0.00	9
270609	0.000	16.0	140.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.38	183.32	0.0	0.00	9
270610	0.000	16.0	132.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.28	182.40	0.0	0.00	9
270611	0.000	16.0	116.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.40	189.18	0.0	0.00	9
270612	0.000	16.0	88.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.40	186.93	0.0	0.00	9
270613	0.000	16.0	75.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.31	184.43	0.0	0.00	9
270614	0.000	16.0	67.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.18	185.10	0.0	0.00	9
270615	0.000	16.0	56.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.20	181.10	0.0	0.00	9
270616	0.000	16.1	41.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.15	179.77	0.0	0.00	9
270617	0.000	16.1	26.5	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.16	181.27	0.0	0.00	9
270618	0.000	16.1	36.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.37	182.77	0.0	0.00	9
270619	0.000	16.1	90.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.37	194.18	0.0	0.00	9
270620	0.000	16.1	101.0	0.00	0.0	0.0	0.0	0.0	0.0000	0.00	0.41	192.52	0.0	0.00	9

TABLE A.1.5 OBTAINED EXPERIMENTAL READINGS FOR SINGLE PHASE FLOW

APPENDIX A

A.2 PRESSURE DROP AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

FROM **Table A.2.1** TO **Table A.2.16.**

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
230803	19.3	110.80	0.0000	0.061817	0.000000	998.39	1.3249	0.14709	9
230804	19.3	110.54	0.0000	0.058792	0.000000	998.39	1.3218	0.13374	9
230805	19.4	109.35	0.0000	0.056088	0.000000	998.37	1.3072	0.12143	9
230806	19.5	108.54	0.0000	0.053108	0.000000	998.35	1.2971	0.10850	9
230807	19.5	107.72	0.0000	0.049154	0.000000	998.35	1.2873	0.09440	9
230808	19.5	106.91	0.0000	0.045399	0.000000	998.33	1.2771	0.08176	9
230809	19.6	106.16	0.0000	0.040945	0.000000	998.31	1.2677	0.06518	9
230810	19.6	103.84	0.0000	0.032025	0.000000	998.31	1.2401	0.04768	9
230811	19.8	103.31	0.0000	0.025024	0.000000	998.29	1.2333	0.02782	9
230812	19.8	102.27	0.0000	0.012756	0.000000	998.28	1.2206	0.01138	9
230813	20.3	104.07	0.0000	0.026019	0.000000	998.18	1.2403	0.03132	9
230814	20.3	103.79	0.0000	0.023407	0.000000	998.18	1.2369	0.02562	9
230815	20.3	103.59	0.0000	0.020367	0.000000	998.17	1.2344	0.01981	9

TABLE A.2.1 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
230816	20.4	103.25	0.0000	0.017804	0.000000	998.16	1.2301	0.01736	9
230817	20.4	102.68	0.0000	0.014265	0.000000	998.16	1.2233	0.01044	9
230818	20.4	102.30	0.0000	0.008847	0.000000	998.15	1.2185	0.00441	9
230819	20.5	103.06	0.0000	0.018711	0.000000	998.14	1.2273	0.01700	9
230820	20.5	104.31	0.0000	0.028175	0.000000	998.13	1.2420	0.03665	9
41201	13.8	106.91	0.0000	0.067645	0.000000	999.31	1.3030	0.17390	9
41202	13.8	106.25	0.0000	0.065232	0.000000	999.31	1.2950	0.16464	9
41203	13.9	104.46	0.0000	0.062294	0.000000	999.29	1.2727	0.15150	9
41204	13.9	103.77	0.0000	0.059583	0.000000	999.28	1.2639	0.13822	9
41205	14.6	104.46	0.0000	0.057047	0.000000	999.19	1.2696	0.12756	9
41206	14.9	103.23	0.0000	0.053108	0.000000	999.15	1.2533	0.10995	9
41207	14.8	101.94	0.0000	0.047522	0.000000	999.16	1.2379	0.09015	9
41208	14.8	101.86	0.0000	0.043172	0.000000	999.16	1.2370	0.08046	9

TABLE A.2.2 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
41209	14.9	100.57	0.0000	0.035805	0.000000	999.14	1.2208	0.05624	9
41210	14.9	100.17	0.0000	0.027467	0.000000	999.14	1.2160	0.03547	9
41211	15.1	99.48	0.0000	0.021870	0.000000	999.12	1.2070	0.02083	9
41212	15.1	98.74	0.0000	0.014729	0.000000	999.11	1.1978	0.01177	9
220101	12.8	109.82	0.0000	0.025762	0.000000	999.43	1.3430	0.16338	9
50201	10.8	103.07	0.0000	0.009487	0.000000	999.65	1.2693	0.00706	9
50202	10.8	103.27	0.0000	0.009891	0.000000	999.65	1.2718	0.00624	9
50203	10.9	103.13	0.0000	0.010835	0.000000	999.64	1.2696	0.00677	9
50204	11.1	103.02	0.0000	0.010653	0.000000	999.62	1.2675	0.00981	9
50205	11.1	103.11	0.0000	0.012195	0.000000	999.61	1.2682	0.00775	9
50206	11.3	103.07	0.0000	0.011190	0.000000	999.60	1.2673	0.00706	9
50207	11.3	103.24	0.0000	0.011869	0.000000	999.60	1.2692	0.00834	9
50208	11.4	103.30	0.0000	0.013417	0.000000	999.59	1.2694	0.00736	9

TABLE A.2.3 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
50209	11.5	103.42	0.0000	0.014935	0.000000	999.58	1.2705	0.00858	9
50210	11.5	103.50	0.0000	0.016192	0.000000	999.58	1.2714	0.01373	9
50211	11.6	103.57	0.0000	0.017017	0.000000	999.57	1.2721	0.01437	9
50212	11.6	103.73	0.0000	0.017694	0.000000	999.57	1.2741	0.01582	9
50213	11.6	104.06	0.0000	0.018767	0.000000	999.57	1.2779	0.01722	9
50214	11.6	104.01	0.0000	0.018974	0.000000	999.56	1.2770	0.01798	9
50215	11.8	104.07	0.0000	0.019782	0.000000	999.55	1.2774	0.01687	9
50216	11.9	104.96	0.0000	0.026274	0.000000	999.53	1.2874	0.03084	9
50217	11.9	106.25	0.0000	0.032332	0.000000	999.53	1.3032	0.04246	9
50218	11.9	106.32	0.0000	0.035598	0.000000	999.53	1.3040	0.05791	9
50219	12.0	106.68	0.0000	0.038716	0.000000	999.52	1.3082	0.06523	9
50220	12.1	107.29	0.0000	0.041424	0.000000	999.52	1.3154	0.07363	9
100201	12.1	111.23	0.0000	0.066505	0.000000	999.51	1.3633	0.17088	9

TABLE A.2.4 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
100202	12.1	110.96	0.0000	0.065684	0.000000	999.51	1.3599	0.16707	9
100203	12.3	110.35	0.0000	0.063587	0.000000	999.49	1.3520	0.15775	9
100204	12.4	107.83	0.0000	0.053478	0.000000	999.48	1.3207	0.11496	9
100205	12.4	103.85	0.0000	0.034329	0.000000	999.48	1.2718	0.05171	9
100206	12.5	103.14	0.0000	0.029709	0.000000	999.46	1.2626	0.03735	9
100207	12.7	100.81	0.0000	0.004846	0.000000	999.44	1.2331	0.00114	9
100208	12.7	104.71	0.0000	0.007662	0.000000	999.44	1.2809	0.00329	9
100209	12.7	101.02	0.0000	0.008623	0.000000	999.44	1.2358	0.00539	9
100210	12.8	101.06	0.0000	0.009487	0.000000	999.43	1.2358	0.00569	9
100211	12.9	101.05	0.0000	0.010468	0.000000	999.42	1.2353	0.00490	9
100212	12.9	101.15	0.0000	0.011190	0.000000	999.42	1.2365	0.01059	9
100213	12.9	101.17	0.0000	0.011535	0.000000	999.42	1.2367	0.00932	9
100214	13.1	101.26	0.0000	0.012820	0.000000	999.40	1.2371	0.00981	9

TABLE A.2.5 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
100215	13.1	101.42	0.0000	0.013417	0.000000	999.39	1.2389	0.00981	9
100216	13.1	101.41	0.0000	0.014537	0.000000	999.39	1.2388	0.01304	9
100217	13.1	101.43	0.0000	0.015323	0.000000	999.38	1.2389	0.00981	9
100218	13.1	101.90	0.0000	0.018871	0.000000	999.38	1.2445	0.01912	9
100219	13.3	101.59	0.0000	0.016313	0.000000	999.37	1.2404	0.03236	9
100220	13.3	102.85	0.0000	0.027052	0.000000	999.37	1.2557	0.03383	9
210301	13.6	106.38	0.0000	0.049204	0.000000	999.33	1.2972	0.09904	9
210302	13.6	106.07	0.0000	0.047986	0.000000	999.33	1.2935	0.09554	9
210303	13.7	105.94	0.0000	0.047157	0.000000	999.31	1.2914	0.09182	9
210304	13.8	105.70	0.0000	0.045993	0.000000	999.31	1.2883	0.08854	9
210305	13.8	105.44	0.0000	0.044908	0.000000	999.30	1.2849	0.08353	9
210306	13.9	105.24	0.0000	0.042828	0.000000	999.29	1.2820	0.07562	9
210307	13.9	105.12	0.0000	0.041483	0.000000	999.28	1.2803	0.07476	9

TABLE A.2.6 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
210308	14.0	105.02	0.0000	0.040884	0.000000	999.27	1.2788	0.06900	9
210309	14.0	104.98	0.0000	0.040338	0.000000	999.27	1.2784	0.06857	9
210310	14.1	104.77	0.0000	0.039034	0.000000	999.26	1.2753	0.06373	9
210311	14.1	104.65	0.0000	0.037421	0.000000	999.25	1.2737	0.06082	9
210312	14.2	104.55	0.0000	0.036890	0.000000	999.24	1.2722	0.05883	9
210313	14.2	104.26	0.0000	0.035320	0.000000	999.24	1.2687	0.05334	9
210314	14.3	104.11	0.0000	0.033603	0.000000	999.23	1.2665	0.05161	9
210315	14.4	104.11	0.0000	0.032711	0.000000	999.22	1.2660	0.04693	9
210316	14.4	103.66	0.0000	0.029542	0.000000	999.22	1.2605	0.04112	9
210317	14.4	102.82	0.0000	0.023916	0.000000	999.21	1.2501	0.02595	9
210318	14.6	102.37	0.0000	0.019102	0.000000	999.19	1.2442	0.01631	9
210319	14.6	101.92	0.0000	0.011750	0.000000	999.18	1.2383	0.00727	9
210320	14.6	102.74	0.0000	0.017625	0.000000	999.18	1.2483	0.01535	9

TABLE A.2.7 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
220301	14.4	112.48	0.0000	0.067242	0.000000	999.21	1.3676	0.17487	9
220302	14.4	112.39	0.0000	0.066394	0.000000	999.21	1.3664	0.17088	9
220303	14.6	112.23	0.0000	0.065834	0.000000	999.19	1.3640	0.16798	9
220304	14.6	112.10	0.0000	0.065157	0.000000	999.19	1.3625	0.16582	9
220305	14.6	111.77	0.0000	0.064050	0.000000	999.19	1.3585	0.15931	9
220306	14.6	111.19	0.0000	0.063159	0.000000	999.18	1.3510	0.15474	9
220307	14.7	111.39	0.0000	0.062728	0.000000	999.17	1.3532	0.15371	9
220308	14.8	111.23	0.0000	0.061657	0.000000	999.16	1.3510	0.14951	9
220309	14.9	110.76	0.0000	0.060650	0.000000	999.15	1.3448	0.14467	9
220310	14.9	110.67	0.0000	0.060160	0.000000	999.15	1.3437	0.15123	9
220311	14.9	110.41	0.0000	0.058624	0.000000	999.15	1.3405	0.13681	9
220312	14.9	110.18	0.0000	0.057563	0.000000	999.14	1.3373	0.13488	9
220313	15.9	109.77	0.0000	0.056526	0.000000	998.98	1.3276	0.12745	9

TABLE A.2.8 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
220314	15.1	109.59	0.0000	0.055291	0.000000	999.12	1.3296	0.12293	9
220315	15.1	109.20	0.0000	0.054074	0.000000	999.12	1.3249	0.11803	9
220316	15.1	109.03	0.0000	0.052922	0.000000	999.11	1.3223	0.11123	9
220317	15.1	108.62	0.0000	0.051601	0.000000	999.11	1.3174	0.10657	9
220318	15.1	108.49	0.0000	0.050685	0.000000	999.11	1.3158	0.10361	9
220319	15.3	108.23	0.0000	0.049553	0.000000	999.09	1.3122	0.09806	9
220320	15.3	108.02	0.0000	0.048650	0.000000	999.09	1.3096	0.09666	9
220321	15.4	107.86	0.0000	0.047625	0.000000	999.07	1.3073	0.09338	9
220322	15.4	107.66	0.0000	0.046737	0.000000	999.06	1.3044	0.08988	9
220323	15.4	107.19	0.0000	0.044908	0.000000	999.06	1.2987	0.08327	9
220324	15.6	107.07	0.0000	0.043852	0.000000	999.04	1.2968	0.07988	9
220325	15.6	106.74	0.0000	0.042597	0.000000	999.04	1.2928	0.07466	9
220326	15.6	106.49	0.0000	0.041125	0.000000	999.03	1.2893	0.07127	9

TABLE A.2.9 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
220327	15.6	106.31	0.0000	0.040338	0.000000	999.03	1.2871	0.06712	9
220328	15.8	105.90	0.0000	0.037749	0.000000	999.01	1.2817	0.06243	9
220329	15.8	105.76	0.0000	0.036555	0.000000	999.01	1.2800	0.05808	9
220330	15.9	105.36	0.0000	0.034400	0.000000	999.00	1.2748	0.04984	9
220331	15.9	105.19	0.0000	0.032936	0.000000	999.00	1.2728	0.04613	9
220332	15.9	104.96	0.0000	0.030608	0.000000	998.98	1.2695	0.04107	9
220333	15.9	104.27	0.0000	0.028523	0.000000	998.98	1.2611	0.03504	9
220334	15.9	104.14	0.0000	0.027556	0.000000	998.98	1.2596	0.03445	9
220335	16.0	104.02	0.0000	0.025896	0.000000	998.96	1.2576	0.02820	9
220336	16.0	103.86	0.0000	0.023605	0.000000	998.96	1.2557	0.02524	9
220337	16.0	103.60	0.0000	0.021299	0.000000	998.96	1.2526	0.02234	9
220338	16.0	103.59	0.0000	0.020712	0.000000	998.96	1.2524	0.01782	9
220339	16.1	103.01	0.0000	0.014561	0.000000	998.95	1.2451	0.01049	9

TABLE A.2.10 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
220340	16.1	102.62	0.0000	0.008308	0.000000	998.95	1.2403	0.00344	9
180501	15.4	103.76	0.0000	0.010653	0.000000	999.06	1.2572	0.02010	9
180502	15.4	104.17	0.0000	0.011787	0.000000	999.06	1.2621	0.01873	9
180503	15.4	103.58	0.0000	0.012511	0.000000	999.06	1.2550	0.01030	9
180504	15.4	104.37	0.0000	0.014265	0.000000	999.07	1.2648	0.01726	9
180505	15.3	104.41	0.0000	0.013634	0.000000	999.08	1.2657	0.00971	9
180506	15.3	104.39	0.0000	0.014537	0.000000	999.09	1.2657	0.01167	9
180507	15.2	104.57	0.0000	0.015450	0.000000	999.10	1.2681	0.01285	9
180508	15.1	104.24	0.0000	0.015576	0.000000	999.11	1.2643	0.01618	9
180509	15.1	104.35	0.0000	0.016669	0.000000	999.11	1.2656	0.01510	9
180510	15.1	104.23	0.0000	0.017359	0.000000	999.11	1.2642	0.01775	9
180511	15.1	104.35	0.0000	0.018238	0.000000	999.11	1.2656	0.01844	9
180512	15.1	104.20	0.0000	0.016902	0.000000	999.11	1.2638	0.01942	9

TABLE A.2.11 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
180513	15.1	104.37	0.0000	0.017694	0.000000	999.11	1.2659	0.01687	9
180514	15.1	104.49	0.0000	0.018871	0.000000	999.11	1.2673	0.02618	9
180515	15.1	104.58	0.0000	0.020271	0.000000	999.11	1.2684	0.02138	9
180516	15.2	104.54	0.0000	0.019382	0.000000	999.10	1.2677	0.01667	9
180517	15.3	104.25	0.0000	0.016669	0.000000	999.09	1.2640	0.01677	9
180518	15.3	103.85	0.0000	0.013270	0.000000	999.09	1.2591	0.02246	9
180519	15.3	103.92	0.0000	0.015195	0.000000	999.09	1.2600	0.01196	9
180520	15.3	104.22	0.0000	0.014265	0.000000	999.08	1.2634	0.01147	9
180521	15.4	104.14	0.0000	0.015450	0.000000	999.07	1.2622	0.01353	9
180522	15.4	104.13	0.0000	0.015949	0.000000	999.07	1.2620	0.01451	9
180523	15.4	104.32	0.0000	0.017804	0.000000	999.07	1.2641	0.01755	9
180524	15.4	104.21	0.0000	0.016432	0.000000	999.07	1.2629	0.01245	9
180525	15.4	104.42	0.0000	0.016786	0.000000	999.06	1.2651	0.04207	9

TABLE A.2.12 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
180526	15.4	104.47	0.0000	0.019683	0.000000	999.06	1.2657	0.01579	9
180527	15.4	104.18	0.0000	0.017471	0.000000	999.06	1.2622	0.01147	9
180528	15.5	104.64	0.0000	0.020748	0.000000	999.05	1.2676	0.01844	9
180529	15.6	104.20	0.0000	0.016551	0.000000	999.04	1.2620	0.01255	9
180530	15.6	103.79	0.0000	0.012667	0.000000	999.04	1.2571	0.00883	9
180531	15.6	104.84	0.0000	0.023656	0.000000	999.04	1.2698	0.04197	9
180532	15.6	105.13	0.0000	0.025411	0.000000	999.04	1.2731	0.02824	9
180533	15.6	104.65	0.0000	0.022642	0.000000	999.03	1.2671	0.03011	9
180534	15.6	104.67	0.0000	0.021214	0.000000	999.03	1.2673	0.02452	9
180535	15.6	103.80	0.0000	0.010835	0.000000	999.03	1.2567	0.00736	9
180536	15.7	103.78	0.0000	0.012511	0.000000	999.02	1.2563	0.00765	9
210601	17.3	105.34	0.0000	0.022404	0.000000	998.75	1.2681	0.02305	9
210602	17.3	105.46	0.0000	0.021467	0.000000	998.76	1.2698	0.02363	9

TABLE A.2.13 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
210603	17.3	104.75	0.0000	0.020228	0.000000	998.75	1.2611	0.02030	9
210604	17.3	104.67	0.0000	0.019224	0.000000	998.75	1.2600	0.01608	9
210605	17.4	104.48	0.0000	0.018707	0.000000	998.73	1.2574	0.01804	9
210606	17.4	104.36	0.0000	0.018175	0.000000	998.73	1.2560	0.01844	9
210607	17.5	104.21	0.0000	0.017510	0.000000	998.73	1.2539	0.01716	9
210608	17.5	103.86	0.0000	0.017227	0.000000	998.72	1.2495	0.01393	9
210609	17.6	103.82	0.0000	0.016247	0.000000	998.70	1.2485	0.01147	9
210610	17.6	103.72	0.0000	0.015241	0.000000	998.70	1.2474	0.01206	9
210611	17.6	103.59	0.0000	0.014480	0.000000	998.69	1.2456	0.01128	9
210612	17.7	103.43	0.0000	0.013607	0.000000	998.68	1.2435	0.00912	9
210613	17.8	103.30	0.0000	0.013199	0.000000	998.67	1.2417	0.00932	9
270601	15.9	103.77	0.0000	0.014558	0.000000	999.00	1.2556	0.01167	9
270602	15.9	103.72	0.0000	0.013690	0.000000	998.99	1.2548	0.00873	9

TABLE A.2.14 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
270603	16.0	103.65	0.0000	0.012434	0.000000	998.97	1.2534	0.00873	9
270604	16.0	103.34	0.0000	0.011732	0.000000	998.97	1.2497	0.00745	9
270605	16.0	103.27	0.0000	0.010830	0.000000	998.97	1.2488	0.00951	9
270606	16.0	103.33	0.0000	0.009592	0.000000	998.97	1.2496	0.00588	9
270607	16.0	103.30	0.0000	0.008685	0.000000	998.97	1.2492	0.00481	9
270608	16.0	103.10	0.0000	0.006610	0.000000	998.97	1.2467	0.00569	9
270609	16.0	103.12	0.0000	0.006473	0.000000	998.97	1.2470	0.00373	9
270610	16.0	103.11	0.0000	0.006285	0.000000	998.97	1.2469	0.00275	9
270611	16.0	103.18	0.0000	0.005892	0.000000	998.97	1.2477	0.00392	9
270612	16.0	103.16	0.0000	0.005132	0.000000	998.97	1.2475	0.00392	9
270613	16.0	103.13	0.0000	0.004754	0.000000	998.97	1.2472	0.00304	9
270614	16.0	103.14	0.0000	0.004478	0.000000	998.97	1.2473	0.00177	9
270615	16.0	103.10	0.0000	0.004094	0.000000	998.97	1.2468	0.00196	9

TABLE A.2.15 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
270616	16.1	103.09	0.0000	0.003503	0.000000	998.96	1.2462	0.00147	9
270617	16.1	103.10	0.0000	0.002816	0.000000	998.96	1.2464	0.00157	9
270618	16.1	103.12	0.0000	0.003282	0.000000	998.96	1.2466	0.00363	9
270619	16.1	103.23	0.0000	0.005190	0.000000	998.96	1.2479	0.00363	9
270620	16.1	103.21	0.0000	0.005498	0.000000	998.96	1.2477	0.00402	9

TABLE A.2.16 PRESSURE DROP, WATER FLOW RATE AND OTHER DATA DERIVED FROM SINGLE PHASE EXPERIMENTAL READINGS

APPENDIX A

A.3 REYNOLDS NUMBER, FRICTION FACTOR AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS. FROM **Table A.3.1** TO **Table A.3.10.**

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
230803	1906.89	0.000000	0.000000	0.0000	1.6281	1.9100	0.0000	0.0000	0.000000	9	0.01640	379689.
230804	1813.57	0.000000	0.000000	0.0000	1.6162	1.8165	0.0000	0.0000	0.000000	9	0.01648	361107.
230805	1730.12	0.000000	0.000000	0.0000	1.5944	1.7330	0.0000	0.0000	0.000000	9	0.01644	345354.
230806	1638.16	0.000000	0.000000	0.0000	1.5685	1.6409	0.0000	0.0000	0.000000	9	0.01639	327813.
230807	1516.20	0.000000	0.000000	0.0000	1.5625	1.5187	0.0000	0.0000	0.000000	9	0.01664	303408.
230808	1400.35	0.000000	0.000000	0.0000	1.5562	1.4027	0.0000	0.0000	0.000000	9	0.01690	280925.
230809	1262.93	0.000000	0.000000	0.0000	1.4872	1.2651	0.0000	0.0000	0.000000	9	0.01656	253987.
230810	987.81	0.000000	0.000000	0.0000	1.0621	0.9895	0.0000	0.0000	0.000000	9	0.01981	198657.
230811	771.85	0.000000	0.000000	0.0000	0.9915	0.7732	0.0000	0.0000	0.000000	9	0.01893	155612.
230812	393.44	0.000000	0.000000	0.0000	1.2681	0.3941	0.0000	0.0000	0.000000	9	0.02978	79420.
230813	802.46	0.000000	0.000000	0.0000	1.0405	0.8039	0.0000	0.0000	0.000000	9	0.01971	163792.
230814	721.88	0.000000	0.000000	0.0000	1.0335	0.7232	0.0000	0.0000	0.000000	9	0.01992	147345.
230815	628.13	0.000000	0.000000	0.0000	1.0234	0.6293	0.0000	0.0000	0.000000	9	0.02035	128367.
230816	549.08	0.000000	0.000000	0.0000	1.1298	0.5501	0.0000	0.0000	0.000000	9	0.02333	112349.
230817	439.94	0.000000	0.000000	0.0000	0.9795	0.4408	0.0000	0.0000	0.000000	9	0.02187	90018.
230818	272.84	0.000000	0.000000	0.0000	0.8724	0.2733	0.0000	0.0000	0.000000	9	0.02402	55895.
230819	577.03	0.000000	0.000000	0.0000	1.0181	0.5781	0.0000	0.0000	0.000000	9	0.02070	118358.
230820	868.91	0.000000	0.000000	0.0000	1.0483	0.8705	0.0000	0.0000	0.000000	9	0.01967	178446.

TABLE A.3.1 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
41201	2088.57	0.000000	0.000000	0.0000	1.5848	2.0900	0.0000	0.0000	0.000000	9	0.01617	360004.
41202	2014.10	0.000000	0.000000	0.0000	1.5988	2.0155	0.0000	0.0000	0.000000	9	0.01647	347167.
41203	1923.34	0.000000	0.000000	0.0000	1.5959	1.9247	0.0000	0.0000	0.000000	9	0.01662	332433.
41204	1839.63	0.000000	0.000000	0.0000	1.5749	1.8410	0.0000	0.0000	0.000000	9	0.01657	318834.
41205	1761.16	0.000000	0.000000	0.0000	1.5750	1.7626	0.0000	0.0000	0.000000	9	0.01668	310256.
41206	1639.48	0.000000	0.000000	0.0000	1.5419	1.6409	0.0000	0.0000	0.000000	9	0.01659	291169.
41207	1467.04	0.000000	0.000000	0.0000	1.5351	1.4683	0.0000	0.0000	0.000000	9	0.01699	260194.
41208	1332.77	0.000000	0.000000	0.0000	1.6207	1.3339	0.0000	0.0000	0.000000	9	0.01838	236380.
41209	1105.33	0.000000	0.000000	0.0000	1.0011	1.1063	0.0000	0.0000	0.000000	9	0.01867	196569.
41210	847.91	0.000000	0.000000	0.0000	1.0427	0.8486	0.0000	0.0000	0.000000	9	0.02001	150791.
41211	675.12	0.000000	0.000000	0.0000	0.9167	0.6757	0.0000	0.0000	0.000000	9	0.01854	120547.
41212	454.69	0.000000	0.000000	0.0000	0.9927	0.4551	0.0000	0.0000	0.000000	9	0.02309	81297.
220101	795.53	0.000000	0.000000	0.0000	5.3210	0.7960	0.0000	0.0000	0.000000	9	0.10475	133576.
50201	293.02	0.000000	0.000000	0.0000	1.1083	0.2931	0.0000	0.0000	0.000000	9	0.03338	46506.
50202	305.50	0.000000	0.000000	0.0000	0.9193	0.3056	0.0000	0.0000	0.000000	9	0.02712	48485.
50203	334.65	0.000000	0.000000	0.0000	0.8701	0.3348	0.0000	0.0000	0.000000	9	0.02452	53264.
50204	329.02	0.000000	0.000000	0.0000	1.2965	0.3291	0.0000	0.0000	0.000000	9	0.03676	52593.
50205	376.63	0.000000	0.000000	0.0000	0.8348	0.3768	0.0000	0.0000	0.000000	9	0.02217	60374.
50206	345.62	0.000000	0.000000	0.0000	0.8686	0.3458	0.0000	0.0000	0.000000	9	0.02399	55560.
50207	366.58	0.000000	0.000000	0.0000	0.9388	0.3667	0.0000	0.0000	0.000000	9	0.02519	59013.

TABLE A.3.2 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
50208	414.37	0.000000	0.000000	0.0000	0.6865	0.4145	0.0000	0.0000	0.000000	9	0.01738	66897.
50209	461.26	0.000000	0.000000	0.0000	0.6788	0.4615	0.0000	0.0000	0.000000	9	0.01637	74677.
50210	500.09	0.000000	0.000000	0.0000	0.9562	0.5003	0.0000	0.0000	0.000000	9	0.02228	80963.
50211	525.56	0.000000	0.000000	0.0000	0.9254	0.5258	0.0000	0.0000	0.000000	9	0.02111	85207.
50212	546.45	0.000000	0.000000	0.0000	0.9572	0.5467	0.0000	0.0000	0.000000	9	0.02150	88595.
50213	579.59	0.000000	0.000000	0.0000	0.9478	0.5798	0.0000	0.0000	0.000000	9	0.02081	94101.
50214	586.00	0.000000	0.000000	0.0000	0.9723	0.5863	0.0000	0.0000	0.000000	9	0.02124	95275.
50215	610.94	0.000000	0.000000	0.0000	0.8530	0.6112	0.0000	0.0000	0.000000	9	0.01834	99610.
50216	811.40	0.000000	0.000000	0.0000	0.9647	0.8118	0.0000	0.0000	0.000000	9	0.01901	133042.
50217	998.48	0.000000	0.000000	0.0000	0.9123	0.9990	0.0000	0.0000	0.000000	9	0.01728	163717.
50218	1099.36	0.000000	0.000000	0.0000	1.0372	1.0999	0.0000	0.0000	0.000000	9	0.01945	180257.
50219	1195.66	0.000000	0.000000	0.0000	0.9926	1.1962	0.0000	0.0000	0.000000	9	0.01852	196323.
50220	1279.25	0.000000	0.000000	0.0000	1.5641	1.2799	0.0000	0.0000	0.000000	9	0.01826	210345.
100201	2053.80	0.000000	0.000000	0.0000	1.5863	2.0548	0.0000	0.0000	0.000000	9	0.01644	338650.
100202	2028.46	0.000000	0.000000	0.0000	1.5850	2.0295	0.0000	0.0000	0.000000	9	0.01648	334472.
100203	1963.65	0.000000	0.000000	0.0000	1.5852	1.9646	0.0000	0.0000	0.000000	9	0.01660	324694.
100204	1651.45	0.000000	0.000000	0.0000	1.5652	1.6523	0.0000	0.0000	0.000000	9	0.01711	273837.
100205	1060.10	0.000000	0.000000	0.0000	0.9938	1.0607	0.0000	0.0000	0.000000	9	0.01867	176028.
100206	917.42	0.000000	0.000000	0.0000	0.9404	0.9179	0.0000	0.0000	0.000000	9	0.01801	152762.
100207	149.63	0.000000	0.000000	0.0000	0.5034	0.1497	0.0000	0.0000	0.000000	9	0.02062	25055.
100208	236.59	0.000000	0.000000	0.0000	0.7304	0.2367	0.0000	0.0000	0.000000	9	0.02382	39615.

TABLE A.3.3 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
100209	266.27	0.000000	0.000000	0.0000	1.0039	0.2664	0.0000	0.0000	0.000000	9	0.03087	44585.
100210	292.96	0.000000	0.000000	0.0000	0.9179	0.2931	0.0000	0.0000	0.000000	9	0.02689	49190.
100211	323.23	0.000000	0.000000	0.0000	0.6827	0.3234	0.0000	0.0000	0.000000	9	0.01904	54425.
100212	345.55	0.000000	0.000000	0.0000	1.3321	0.3458	0.0000	0.0000	0.000000	9	0.03599	58182.
100213	356.19	0.000000	0.000000	0.0000	1.1188	0.3564	0.0000	0.0000	0.000000	9	0.02980	59973.
100214	395.87	0.000000	0.000000	0.0000	1.0030	0.3961	0.0000	0.0000	0.000000	9	0.02539	66933.
100215	414.29	0.000000	0.000000	0.0000	0.9353	0.4145	0.0000	0.0000	0.000000	9	0.02318	70144.
100216	448.87	0.000000	0.000000	0.0000	1.0976	0.4491	0.0000	0.0000	0.000000	9	0.02627	75999.
100217	473.15	0.000000	0.000000	0.0000	0.7599	0.4734	0.0000	0.0000	0.000000	9	0.01777	80221.
100218	582.70	0.000000	0.000000	0.0000	1.0597	0.5831	0.0000	0.0000	0.000000	9	0.02285	98794.
100219	503.70	0.000000	0.000000	0.0000	2.2728	0.5040	0.0000	0.0000	0.000000	9	0.05175	85636.
100220	835.29	0.000000	0.000000	0.0000	1.0132	0.8358	0.0000	0.0000	0.000000	9	0.01968	142012.
210301	1519.23	0.000000	0.000000	0.0000	1.5737	1.5203	0.0000	0.0000	0.000000	9	0.01741	260793.
210302	1481.64	0.000000	0.000000	0.0000	1.5861	1.4826	0.0000	0.0000	0.000000	9	0.01766	254339.
210303	1456.02	0.000000	0.000000	0.0000	1.5727	1.4570	0.0000	0.0000	0.000000	9	0.01757	250628.
210304	1420.05	0.000000	0.000000	0.0000	1.5850	1.4210	0.0000	0.0000	0.000000	9	0.01781	244772.
210305	1386.54	0.000000	0.000000	0.0000	1.5596	1.3875	0.0000	0.0000	0.000000	9	0.01763	239324.
210306	1322.32	0.000000	0.000000	0.0000	1.5351	1.3233	0.0000	0.0000	0.000000	9	0.01755	228865.
210307	1280.78	0.000000	0.000000	0.0000	1.6053	1.2817	0.0000	0.0000	0.000000	9	0.01849	221978.
210308	1262.29	0.000000	0.000000	0.0000	1.5204	1.2632	0.0000	0.0000	0.000000	9	0.01757	219072.

TABLE A.3.4 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
210309	1245.42	0.000000	0.000000	0.0000	1.5468	1.2463	0.0000	0.0000	0.000000	9	0.01793	216145.
210310	1205.13	0.000000	0.000000	0.0000	1.5240	1.2060	0.0000	0.0000	0.000000	9	0.01780	209723.
210311	1155.34	0.000000	0.000000	0.0000	0.9916	1.1562	0.0000	0.0000	0.000000	9	0.01849	201333.
210312	1138.94	0.000000	0.000000	0.0000	0.9867	1.1398	0.0000	0.0000	0.000000	9	0.01840	198746.
210313	1090.46	0.000000	0.000000	0.0000	0.9742	1.0913	0.0000	0.0000	0.000000	9	0.01820	190285.
210314	1037.43	0.000000	0.000000	0.0000	1.0383	1.0382	0.0000	0.0000	0.000000	9	0.01945	181525.
210315	1009.87	0.000000	0.000000	0.0000	0.9944	1.0107	0.0000	0.0000	0.000000	9	0.01867	177183.
210316	912.06	0.000000	0.000000	0.0000	1.0550	0.9128	0.0000	0.0000	0.000000	9	0.02005	160021.
210317	738.35	0.000000	0.000000	0.0000	0.9738	0.7389	0.0000	0.0000	0.000000	9	0.01931	129720.
210318	589.72	0.000000	0.000000	0.0000	0.8979	0.5902	0.0000	0.0000	0.000000	9	0.01902	103888.
210319	362.74	0.000000	0.000000	0.0000	0.8675	0.3630	0.0000	0.0000	0.000000	9	0.02240	64076.
210320	544.11	0.000000	0.000000	0.0000	0.9655	0.5446	0.0000	0.0000	0.000000	9	0.02103	96114.
220301	2075.95	0.000000	0.000000	0.0000	1.6182	2.0776	0.0000	0.0000	0.000000	9	0.01646	364722.
220302	2049.75	0.000000	0.000000	0.0000	1.6168	2.0514	0.0000	0.0000	0.000000	9	0.01650	360119.
220303	2032.45	0.000000	0.000000	0.0000	1.6141	2.0341	0.0000	0.0000	0.000000	9	0.01650	358049.
220304	2011.54	0.000000	0.000000	0.0000	1.6225	2.0132	0.0000	0.0000	0.000000	9	0.01662	354364.
220305	1977.37	0.000000	0.000000	0.0000	1.6062	1.9790	0.0000	0.0000	0.000000	9	0.01653	348345.
220306	1949.82	0.000000	0.000000	0.0000	1.6000	1.9514	0.0000	0.0000	0.000000	9	0.01651	344422.
220307	1936.50	0.000000	0.000000	0.0000	1.6090	1.9381	0.0000	0.0000	0.000000	9	0.01663	342532.
220308	1903.45	0.000000	0.000000	0.0000	1.6135	1.9050	0.0000	0.0000	0.000000	9	0.01674	337140.
220309	1872.31	0.000000	0.000000	0.0000	1.6080	1.8739	0.0000	0.0000	0.000000	9	0.01674	332519.

TABLE A.3.5 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
220310	1857.19	0.000000	0.000000	0.0000	1.7050	1.8588	0.0000	0.0000	0.000000	9	0.01779	329834.
220311	1809.77	0.000000	0.000000	0.0000	1.6138	1.8113	0.0000	0.0000	0.000000	9	0.01694	321413.
220312	1776.99	0.000000	0.000000	0.0000	1.6439	1.7785	0.0000	0.0000	0.000000	9	0.01733	316442.
220313	1744.70	0.000000	0.000000	0.0000	1.6144	1.7465	0.0000	0.0000	0.000000	9	0.01698	319095.
220314	1706.83	0.000000	0.000000	0.0000	1.6087	1.7083	0.0000	0.0000	0.000000	9	0.01712	304766.
220315	1669.25	0.000000	0.000000	0.0000	1.6060	1.6707	0.0000	0.0000	0.000000	9	0.01718	298056.
220316	1633.66	0.000000	0.000000	0.0000	1.5726	1.6351	0.0000	0.0000	0.000000	9	0.01691	292485.
220317	1592.89	0.000000	0.000000	0.0000	1.5749	1.5943	0.0000	0.0000	0.000000	9	0.01704	285185.
220318	1564.61	0.000000	0.000000	0.0000	1.5798	1.5660	0.0000	0.0000	0.000000	9	0.01717	280123.
220319	1529.66	0.000000	0.000000	0.0000	1.5565	1.5311	0.0000	0.0000	0.000000	9	0.01700	274601.
220320	1501.76	0.000000	0.000000	0.0000	1.5846	1.5031	0.0000	0.0000	0.000000	9	0.01739	269592.
220321	1470.12	0.000000	0.000000	0.0000	1.5899	1.4715	0.0000	0.0000	0.000000	9	0.01753	264619.
220322	1442.68	0.000000	0.000000	0.0000	1.5827	1.4440	0.0000	0.0000	0.000000	9	0.01752	260374.
220323	1386.21	0.000000	0.000000	0.0000	1.5724	1.3875	0.0000	0.0000	0.000000	9	0.01758	250182.
220324	1353.61	0.000000	0.000000	0.0000	1.5735	1.3549	0.0000	0.0000	0.000000	9	0.01768	244951.
220325	1314.88	0.000000	0.000000	0.0000	1.5474	1.3161	0.0000	0.0000	0.000000	9	0.01752	237942.
220326	1269.41	0.000000	0.000000	0.0000	1.5719	1.2706	0.0000	0.0000	0.000000	9	0.01794	230326.
220327	1245.12	0.000000	0.000000	0.0000	1.5313	1.2463	0.0000	0.0000	0.000000	9	0.01756	225919.
220328	1165.19	0.000000	0.000000	0.0000	1.6008	1.1663	0.0000	0.0000	0.000000	9	0.01865	211979.
220329	1128.32	0.000000	0.000000	0.0000	0.9928	1.1294	0.0000	0.0000	0.000000	9	0.01850	205271.

TABLE A.3.6 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
220330	1061.81	0.000000	0.000000	0.0000	0.9606	1.0629	0.0000	0.0000	0.000000	9	0.01793	193685.
220331	1016.60	0.000000	0.000000	0.0000	0.9677	1.0176	0.0000	0.0000	0.000000	9	0.01810	185439.
220332	944.74	0.000000	0.000000	0.0000	0.9915	0.9457	0.0000	0.0000	0.000000	9	0.01866	172786.
220333	880.39	0.000000	0.000000	0.0000	0.9655	0.8813	0.0000	0.0000	0.000000	9	0.01834	161018.
220334	850.54	0.000000	0.000000	0.0000	1.0117	0.8514	0.0000	0.0000	0.000000	9	0.01932	155558.
220335	799.27	0.000000	0.000000	0.0000	0.9280	0.8001	0.0000	0.0000	0.000000	9	0.01791	146570.
220336	728.56	0.000000	0.000000	0.0000	0.9798	0.7293	0.0000	0.0000	0.000000	9	0.01929	133602.
220337	657.39	0.000000	0.000000	0.0000	1.0368	0.6581	0.0000	0.0000	0.000000	9	0.02097	120550.
220338	639.27	0.000000	0.000000	0.0000	0.8675	0.6399	0.0000	0.0000	0.000000	9	0.01768	117229.
220339	449.42	0.000000	0.000000	0.0000	0.9120	0.4499	0.0000	0.0000	0.000000	9	0.02107	82632.
220340	256.44	0.000000	0.000000	0.0000	0.7097	0.2567	0.0000	0.0000	0.000000	9	0.02123	47150.
180501	328.84	0.000000	0.000000	0.0000	2.8175	0.3291	0.0000	0.0000	0.000000	9	0.07541	59348.
180502	363.83	0.000000	0.000000	0.0000	2.2476	0.3642	0.0000	0.0000	0.000000	9	0.05740	65664.
180503	386.20	0.000000	0.000000	0.0000	1.1266	0.3866	0.0000	0.0000	0.000000	9	0.02800	69701.
180504	440.34	0.000000	0.000000	0.0000	1.5368	0.4408	0.0000	0.0000	0.000000	9	0.03611	79366.
180505	420.86	0.000000	0.000000	0.0000	0.9273	0.4212	0.0000	0.0000	0.000000	9	0.02223	75653.
180506	448.74	0.000000	0.000000	0.0000	1.0069	0.4491	0.0000	0.0000	0.000000	9	0.02351	80556.
180507	476.94	0.000000	0.000000	0.0000	1.0054	0.4774	0.0000	0.0000	0.000000	9	0.02291	85504.
180508	480.84	0.000000	0.000000	0.0000	1.2494	0.4813	0.0000	0.0000	0.000000	9	0.02839	86088.
180509	514.55	0.000000	0.000000	0.0000	1.0456	0.5150	0.0000	0.0000	0.000000	9	0.02314	92124.
180510	535.86	0.000000	0.000000	0.0000	1.1505	0.5363	0.0000	0.0000	0.000000	9	0.02508	95938.

TABLE A.3.7 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
180511	563.00	0.000000	0.000000	0.0000	1.1020	0.5635	0.0000	0.0000	0.000000	9	0.02359	100798.
180512	521.75	0.000000	0.000000	0.0000	1.3144	0.5222	0.0000	0.0000	0.000000	9	0.02893	93413.
180513	546.19	0.000000	0.000000	0.0000	1.0596	0.5467	0.0000	0.0000	0.000000	9	0.02293	97789.
180514	582.54	0.000000	0.000000	0.0000	1.4792	0.5831	0.0000	0.0000	0.000000	9	0.03130	104295.
180515	625.74	0.000000	0.000000	0.0000	1.0715	0.6263	0.0000	0.0000	0.000000	9	0.02215	112031.
180516	598.32	0.000000	0.000000	0.0000	0.9012	0.5989	0.0000	0.0000	0.000000	9	0.01889	107265.
180517	514.55	0.000000	0.000000	0.0000	1.1622	0.5150	0.0000	0.0000	0.000000	9	0.02569	92370.
180518	409.64	0.000000	0.000000	0.0000	2.2363	0.4100	0.0000	0.0000	0.000000	9	0.05429	73537.
180519	469.05	0.000000	0.000000	0.0000	0.9621	0.4695	0.0000	0.0000	0.000000	9	0.02206	84203.
180520	440.35	0.000000	0.000000	0.0000	1.0205	0.4408	0.0000	0.0000	0.000000	9	0.02400	79156.
180521	476.93	0.000000	0.000000	0.0000	1.0609	0.4774	0.0000	0.0000	0.000000	9	0.02413	85846.
180522	492.32	0.000000	0.000000	0.0000	1.0813	0.4928	0.0000	0.0000	0.000000	9	0.02429	88616.
180523	549.58	0.000000	0.000000	0.0000	1.0943	0.5501	0.0000	0.0000	0.000000	9	0.02357	99055.
180524	507.24	0.000000	0.000000	0.0000	0.8847	0.5077	0.0000	0.0000	0.000000	9	0.01963	91424.
180525	518.14	0.000000	0.000000	0.0000	2.8887	0.5186	0.0000	0.0000	0.000000	9	0.06356	93514.
180526	607.58	0.000000	0.000000	0.0000	0.8336	0.6081	0.0000	0.0000	0.000000	9	0.01735	109655.
180527	539.30	0.000000	0.000000	0.0000	0.7381	0.5398	0.0000	0.0000	0.000000	9	0.01600	97332.
180528	640.44	0.000000	0.000000	0.0000	0.8909	0.6410	0.0000	0.0000	0.000000	9	0.01823	115740.
180529	510.89	0.000000	0.000000	0.0000	0.8827	0.5114	0.0000	0.0000	0.000000	9	0.01951	92451.
180530	390.99	0.000000	0.000000	0.0000	0.9484	0.3914	0.0000	0.0000	0.000000	9	0.02342	70754.

TABLE A.3.8 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
180531	730.20	0.000000	0.000000	0.0000	1.6177	0.7309	0.0000	0.0000	0.000000	9	0.03193	132139.
180532	784.36	0.000000	0.000000	0.0000	0.9591	0.7851	0.0000	0.0000	0.000000	9	0.01862	142128.
180533	698.88	0.000000	0.000000	0.0000	1.2535	0.6996	0.0000	0.0000	0.000000	9	0.02500	126808.
180534	654.81	0.000000	0.000000	0.0000	1.1421	0.6555	0.0000	0.0000	0.000000	9	0.02319	118812.
180535	334.45	0.000000	0.000000	0.0000	1.0069	0.3348	0.0000	0.0000	0.000000	9	0.02667	60684.
180536	386.19	0.000000	0.000000	0.0000	0.8394	0.3866	0.0000	0.0000	0.000000	9	0.02080	70164.
210601	691.35	0.000000	0.000000	0.0000	0.9884	0.6922	0.0000	0.0000	0.000000	9	0.01955	130992.
210602	662.44	0.000000	0.000000	0.0000	1.0917	0.6633	0.0000	0.0000	0.000000	9	0.02184	125353.
210603	624.20	0.000000	0.000000	0.0000	1.0390	0.6250	0.0000	0.0000	0.000000	9	0.02113	118269.
210604	593.23	0.000000	0.000000	0.0000	0.8975	0.5940	0.0000	0.0000	0.000000	9	0.01853	112401.
210605	577.26	0.000000	0.000000	0.0000	1.0551	0.5780	0.0000	0.0000	0.000000	9	0.02196	109659.
210606	560.86	0.000000	0.000000	0.0000	1.1313	0.5616	0.0000	0.0000	0.000000	9	0.02377	106543.
210607	540.31	0.000000	0.000000	0.0000	1.1209	0.5410	0.0000	0.0000	0.000000	9	0.02384	102772.
210608	531.59	0.000000	0.000000	0.0000	0.9347	0.5323	0.0000	0.0000	0.000000	9	0.01998	101245.
210609	501.34	0.000000	0.000000	0.0000	0.8486	0.5020	0.0000	0.0000	0.000000	9	0.01851	95729.
210610	470.30	0.000000	0.000000	0.0000	0.9895	0.4709	0.0000	0.0000	0.000000	9	0.02211	89802.
210611	446.81	0.000000	0.000000	0.0000	1.0049	0.4474	0.0000	0.0000	0.000000	9	0.02291	85426.
210612	419.87	0.000000	0.000000	0.0000	0.8976	0.4204	0.0000	0.0000	0.000000	9	0.02098	80380.
210613	407.28	0.000000	0.000000	0.0000	0.9626	0.4078	0.0000	0.0000	0.000000	9	0.02277	78069.
270601	449.35	0.000000	0.000000	0.0000	1.0113	0.4498	0.0000	0.0000	0.000000	9	0.02344	81965.
270602	422.56	0.000000	0.000000	0.0000	0.8339	0.4230	0.0000	0.0000	0.000000	9	0.01983	77182.

TABLE A.3.9 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
270603	383.79	0.000000	0.000000	0.0000	0.9705	0.3842	0.0000	0.0000	0.000000	9	0.02403	70286.
270604	362.12	0.000000	0.000000	0.0000	0.9068	0.3625	0.0000	0.0000	0.000000	9	0.02305	66317.
270605	334.26	0.000000	0.000000	0.0000	1.3090	0.3346	0.0000	0.0000	0.000000	9	0.03453	61215.
270606	296.07	0.000000	0.000000	0.0000	0.9743	0.2964	0.0000	0.0000	0.000000	9	0.02722	54222.
270607	268.05	0.000000	0.000000	0.0000	0.9250	0.2683	0.0000	0.0000	0.000000	9	0.02712	49090.
270608	204.03	0.000000	0.000000	0.0000	1.6506	0.2042	0.0000	0.0000	0.000000	9	0.05542	37365.
270609	199.79	0.000000	0.000000	0.0000	1.1160	0.2000	0.0000	0.0000	0.000000	9	0.03786	36590.
270610	194.00	0.000000	0.000000	0.0000	0.8595	0.1942	0.0000	0.0000	0.000000	9	0.02959	35529.
270611	181.86	0.000000	0.000000	0.0000	1.3528	0.1821	0.0000	0.0000	0.000000	9	0.04810	33306.
270612	158.40	0.000000	0.000000	0.0000	1.6647	0.1586	0.0000	0.0000	0.000000	9	0.06341	29009.
270613	146.72	0.000000	0.000000	0.0000	1.4477	0.1469	0.0000	0.0000	0.000000	9	0.05728	26870.
270614	138.22	0.000000	0.000000	0.0000	0.9198	0.1384	0.0000	0.0000	0.000000	9	0.03748	25312.
270615	126.36	0.000000	0.000000	0.0000	0.0000	0.1265	0.0000	0.0000	0.000000	9	0.04982	23141.
270616	108.12	0.000000	0.000000	0.0000	0.0000	0.1082	0.0000	0.0000	0.000000	9	0.05104	19853.
270617	86.92	0.000000	0.000000	0.0000	0.0000	0.0870	0.0000	0.0000	0.000000	9	0.08423	15961.
270618	101.31	0.000000	0.000000	0.0000	0.0000	0.1014	0.0000	0.0000	0.000000	9	0.14337	18603.
270619	160.19	0.000000	0.000000	0.0000	1.5160	0.1604	0.0000	0.0000	0.000000	9	0.05735	29414.
270620	169.70	0.000000	0.000000	0.0000	1.5405	0.1699	0.0000	0.0000	0.000000	9	0.05663	31160.

TABLE A.3.10 REYNOLDS NUMBER (Re) , LAMBDA AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

APPENDIX A

A.4 SINGLE PHASE FRICTION FACTOR SPECIMEN CALCULATION.

FOR TEST No. 230803.

A.4 Single Phase Friction Factor Specimen Calculation

Consider Test No. 230803

Water flowrate = 0.061817 m^3/s

Pipe diameter = 0.203 m

Water density = 998.386 kg/m

Reynolds number = 379689

Cross sectional area = $\frac{\pi \times (0.203)^2}{4}$ = 0.032365472 m^2

Pressure gradient

$$\left(\frac{\Delta P}{\Delta Z}\right) = 147.09\ N/m^3$$

$$water\ velocity = \frac{Q_f}{CSA}$$

$$= \frac{0.061817}{0.032365472} = 1.909967457\ m/s$$

The friction factor obtained using

$$h_f = \frac{\lambda L U^2}{2gd}$$

where h_f is the head loss due to friction.Therefore

$$\lambda = \frac{\Delta P}{\Delta Z} x \frac{2dA^2}{\rho Q_f^2}$$

$$\lambda = \frac{147.09\ x\ 2\ x\ 0.203\ x\ (0.032365472)^2}{998.386\ x\ (0.061817)^2}$$

λ = 0.016396787, By Computer λ = 0.01640

APPENDIX (B)

APPENDIX B

B.1 EXPERIMENTAL DATA; TWO-PHASE FLOW.

B.2 PRESSURE DROP AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

B.3 WATER AND GAS FLOW RATES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

B.4 COMPARISON OF FRICTION PRESSURE DROP DATA.

B.5 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

B.6 PRESSURE DROP CORRELATIONS USED IN COMPARISON AND SPECIMEN CALCULATIONS.

APPENDIX B

B.1 EXPERIMENTAL DATA; TWO-PHASE FLOW.

FROM **Table B.1.1** TO **Table B.1.10**

SYMBOLS USED IN APPENDIX B

Code		
No.	Test number	
E.M.F.	Air temperature	°C
Temp.	Water temperature	°C
HL	Head difference across water orifice	cm H_2O
PG	Air pressure	bar
S_1,S_2,S_3,S_4	Air rotameter readings (head across 1" air orifice	cm H_2O
S_1	Head across 2" air orifice	cm H_2O
ELE	Void fraction readings	
PE	Pressure gradient	mm H_2O/m
PRES	Pressure at the middle of the test section	mm H_2O
PATRN	Flow pattern	
HOR	Identification of water and air orifices plate used	
G_{total}	Total mass velocity	kg/m^{2}s
QALTY	Mass dryness fraction	
USF	Superficial water velocity	m/s
USg	Superficial air velocity	m/s
BETA	Volume fraction	
TME	Experimental two-phase multiplier	
VDF	Experimental void fraction	

SYMBOLS USED IN APPENDIX B

Pattern	Test Code
Slug flow	2
Stratified flow	3
Wavy flow	4
Plug flow	6
Plug-slug transition	62
Slug-annular transition	44
Slug-wavy transition	42
Stratified-wavy transition	34
Bubble-plug transition	16

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
220102	15.800	12.4	47.9	2.10	20.1	20.1	20.0	20.0	0.3062	0.00	0.92	809.03	0.000	0.0000	42
220103	15.400	12.4	105.8	2.06	20.2	20.1	20.1	20.0	0.3884	0.00	4.59	933.85	0.000	0.0000	2
220104	15.300	12.4	194.0	2.07	20.1	20.0	20.0	20.0	0.4065	0.00	5.18	1118.46	0.000	0.0000	2
220105	15.200	12.4	291.1	2.09	20.0	19.9	19.9	20.0	0.3786	0.00	8.67	1214.82	0.000	0.0000	2
220106	15.200	12.3	370.4	2.10	19.9	19.8	19.8	19.9	0.3700	0.00	8.09	1288.14	0.000	0.0000	2
220107	15.300	12.3	432.2	2.10	19.9	19.8	19.8	19.9	0.3600	0.00	10.80	1416.30	0.000	0.0000	2
220108	15.400	12.3	491.4	2.10	19.9	19.8	19.8	19.8	0.0692	0.00	10.97	1436.77	0.000	0.0000	2
220109	15.400	12.3	478.8	2.12	19.9	19.8	19.8	19.8	0.3390	0.00	13.34	1554.39	0.000	0.0000	2
280101	12.400	10.5	31.0	2.69	19.8	19.8	19.8	19.8	0.2660	0.00	0.76	942.43	0.000	0.0000	34
280102	12.000	10.6	19.0	2.61	19.4	19.4	19.4	19.4	0.3434	0.00	0.65	940.17	0.000	0.0000	3
280103	12.200	10.8	45.0	2.54	19.1	19.1	19.1	19.1	0.3004	0.00	0.93	951.97	0.000	0.0000	34
280104	12.500	11.0	49.0	3.28	4.8	4.9	4.9	4.8	0.1609	0.00	0.75	939.47	0.000	0.0000	3
280105	13.100	11.1	22.0	3.20	4.7	4.8	4.8	4.7	0.3007	0.00	0.65	918.63	0.000	0.0000	3
280106	13.600	11.3	34.0	3.18	4.6	4.7	4.7	4.6	0.1882	0.00	0.80	949.88	0.000	0.0000	3
280107	14.100	11.4	68.0	3.15	4.6	4.7	4.7	4.6	0.0000	0.00	2.14	980.88	0.000	0.0000	42
280108	14.800	11.6	68.0	2.80	14.9	15.0	15.0	15.0	0.2580	0.00	1.01	989.12	0.000	0.0000	42
280109	15.000	11.6	111.0	2.95	15.4	15.4	15.4	15.5	0.3166	0.00	5.93	1266.56	0.000	0.0000	2
280110	14.600	11.1	159.0	3.03	15.7	15.7	15.6	15.7	0.3207	0.00	4.78	1312.48	0.000	0.0000	2
280111	14.200	11.1	212.9	2.89	15.1	15.1	15.0	15.1	0.2937	0.00	5.91	1184.77	0.000	0.0000	2
280112	14.100	11.1	1083.6	2.77	15.2	14.8	14.7	14.6	0.2350	0.00	20.45	2220.64	0.000	0.0000	2
280113	13.900	11.3	957.6	2.74	15.1	14.9	14.9	14.6	0.2489	0.00	20.21	2064.16	0.000	0.0000	2
280114	14.000	11.4	762.3	2.72	15.4	15.1	15.0	14.9	0.2642	0.00	16.43	1814.95	0.000	0.0000	2
280115	14.000	11.6	601.0	2.72	15.5	15.3	15.2	15.0	0.2793	0.00	13.46	1635.83	0.000	0.0000	2
280116	14.100	11.8	461.2	2.72	15.7	15.4	15.4	15.3	0.2960	0.00	9.09	1471.19	0.000	0.0000	2
280117	14.100	11.9	369.2	2.72	15.9	15.6	15.5	15.4	0.3039	0.00	9.26	1425.74	0.000	0.0000	2
280118	14.200	12.1	264.6	2.72	16.1	15.8	15.7	15.6	0.3085	0.00	8.03	1258.99	0.000	0.0000	2
280119	14.100	12.1	258.3	2.04	25.2	25.2	25.1	25.1	0.4640	0.00	10.40	1415.41	0.000	0.0000	2
280120	13.400	12.3	122.2	2.07	25.7	25.7	25.5	25.5	0.5017	0.00	5.71	1233.06	0.000	0.0000	2
290101	15.800	12.8	15.0	2.18	24.6	24.6	24.6	24.6	0.3874	0.00	0.62	167.42	0.000	0.0000	34
290102	15.600	12.9	25.0	2.18	24.6	24.6	24.6	24.6	0.3412	0.00	0.78	175.33	0.000	0.0000	34
290103	15.100	13.1	35.0	2.18	24.7	24.6	24.6	24.6	0.3470	0.00	0.88	151.28	0.000	0.0000	34
290104	15.100	12.3	35.0	2.65	19.6	19.6	19.6	19.6	0.2719	0.00	3.00	187.80	0.000	0.0000	3
290105	15.500	13.4	35.0	3.18	9.8	9.9	9.9	9.9	0.1893	0.00	0.82	151.13	0.000	0.0000	3
290106	15.800	13.6	28.0	3.33	5.0	5.0	4.9	5.0	0.3360	0.00	0.61	166.58	0.000	0.0000	3
70201	14.000	11.0	18.0	3.80	0.5	0.0	0.0	0.0	0.6588	0.00	0.41	844.15	0.000	0.0000	3
70202	14.200	11.2	16.0	3.79	1.0	0.0	0.0	0.0	0.7140	0.00	0.41	910.90	0.000	0.0000	3
70203	14.300	11.4	15.0	3.78	2.0	2.0	0.0	0.0	0.7237	0.00	0.36	919.48	0.000	0.0000	3
70204	14.500	11.5	14.0	3.76	2.0	0.0	1.0	0.0	0.7244	0.00	0.41	950.80	0.000	0.0000	3
70205	14.700	11.7	7.0	3.73	3.0	0.0	3.0	0.0	0.7236	0.00	0.39	957.37	0.000	0.0000	3

TABLE B.1.1 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF	TEMP	HL	PG	S1	S2	S3	S4	VDF	POT	PE	PRES	ELL	PTT	PATRN
	MV	C	CMH2O	BAR	CM	CM	CM	CM			MMH2O/M	MMH2O			
70206	15.200	11.9	30.0	3.65	3.0	3.1	3.0	2.9	0.0856	0.00	0.58	1003.77	0.000	0.0000	3
70207	15.800	12.2	21.0	3.61	4.0	4.0	5.0	4.9	0.2804	0.00	0.67	1009.02	0.000	0.0000	3
110201	13.000	12.4	19.0	3.49	8.0	10.1	7.8	9.6	0.3237	0.00	0.61	837.72	0.000	0.0000	3
110202	12.600	12.6	24.0	3.41	10.0	11.1	10.0	11.0	0.2642	0.00	0.76	858.05	0.000	0.0000	3
110203	12.400	12.8	24.0	3.32	12.1	12.2	12.2	12.1	0.2665	0.00	0.70	876.38	0.000	0.0000	3
110204	12.200	12.9	24.0	3.19	15.1	15.0	14.7	14.6	0.2723	0.00	0.68	881.78	0.000	0.0000	34
110205	12.000	13.1	24.0	3.07	19.2	15.5	19.1	15.2	0.2792	0.00	0.84	869.20	0.000	0.0000	4
110206	11.800	13.2	24.0	2.89	20.0	20.1	20.1	20.0	0.2878	0.00	0.64	880.20	0.000	0.0000	4
110207	11.500	13.4	23.0	2.70	23.4	22.4	22.9	22.4	0.3179	0.00	1.45	906.28	0.000	0.0000	4
110208	11.200	13.5	23.5	2.55	25.4	24.4	24.1	25.0	0.3414	0.00	1.99	871.63	0.000	0.0000	4
110210	10.800	13.8	37.0	2.51	26.7	26.6	27.0	26.8	0.3676	0.00	0.99	1122.30	0.000	0.0000	42
110213	14.000	12.8	88.0	3.55	4.0	6.5	3.7	4.8	0.1577	0.00	2.26	839.28	0.000	0.0000	42
110214	13.600	12.9	88.0	3.37	10.0	11.1	8.2	7.3	0.2212	0.00	3.09	863.71	0.000	0.0000	42
110215	13.000	13.1	87.0	3.15	14.0	14.5	13.6	13.6	0.3087	0.00	2.99	878.55	0.000	0.0000	42
110216	12.200	13.3	87.0	2.79	20.3	21.0	20.3	20.3	0.3796	0.00	1.36	1151.38	0.000	0.0000	2
110217	11.700	13.4	86.0	2.33	25.4	26.0	26.0	25.7	0.4811	0.00	6.27	1113.96	0.000	0.0000	2
110218	11.100	13.4	145.0	2.34	25.2	25.9	25.8	25.6	0.5253	0.00	4.30	1188.70	0.000	0.0000	2
110219	11.900	13.6	1123.9	3.78	3.2	0.0	0.0	0.0	0.0515	0.00	16.64	1181.28	0.000	0.0000	16
110220	13.100	13.8	1118.9	3.71	6.0	0.0	0.0	0.0	0.0604	0.00	16.19	1250.51	0.000	0.0000	16
110221	13.800	13.9	1118.9	3.62	2.8	1.9	2.1	2.1	0.0980	0.00	19.11	1836.15	0.000	0.0000	16
110222	14.000	14.1	1112.6	3.54	2.8	5.5	3.0	5.9	0.1200	0.00	15.98	1923.29	0.000	0.0000	62
110223	14.000	14.1	1112.6	3.26	13.6	6.7	15.4	6.6	0.1978	0.00	19.43	2195.38	0.000	0.0000	2
110224	13.200	14.4	1102.5	3.02	15.1	16.6	16.7	15.0	0.2577	0.00	21.77	2294.13	0.000	0.0000	2
110225	12.600	14.5	1096.2	2.53	21.5	24.6	24.0	22.7	0.3440	0.00	23.58	2544.13	0.000	0.0000	2
300501	17.700	16.4	269.6	2.30	3.1	0.0	0.0	0.0	0.0000	0.00	5.53	709.00	0.000	0.0000	6
300502	17.700	16.4	262.1	2.18	6.0	0.0	0.0	0.0	0.0000	0.00	5.18	872.70	0.000	0.0000	6
300503	17.900	16.5	454.9	2.28	4.0	0.0	0.0	0.0	0.0000	0.00	8.30	856.77	0.000	0.0000	6
300504	18.100	16.5	453.6	2.14	6.1	0.0	0.0	0.0	0.0000	0.00	10.24	921.96	0.000	0.0000	6
300505	18.200	16.5	739.6	2.13	6.0	0.0	0.0	0.0	0.0016	0.00	11.24	1112.82	0.000	0.0000	6
300506	18.200	16.6	740.9	2.29	3.1	0.0	0.0	0.0	0.0000	0.00	11.35	1095.40	0.000	0.0000	16
300507	18.300	16.8	1004.2	2.12	6.1	0.0	0.0	0.0	0.0036	0.00	15.40	1367.65	0.000	0.0000	16
300508	18.400	16.8	1004.2	2.05	7.6	0.0	0.0	0.0	0.0086	0.00	15.10	1407.12	0.000	0.0000	6
300509	18.600	16.9	831.6	2.01	9.0	0.0	0.0	0.0	0.0104	0.00	12.88	1301.98	0.000	0.0000	6
300510	18.700	16.9	748.4	2.10	7.6	0.0	0.0	0.0	0.0080	0.00	10.15	1193.53	0.000	0.0000	6
300511	18.800	16.9	633.8	2.02	8.5	0.0	0.0	0.0	0.0060	0.00	10.60	1106.18	0.000	0.0000	6
300512	18.800	17.0	326.3	1.99	9.5	0.0	0.0	0.0	0.0171	0.00	6.19	1024.08	0.000	0.0000	6
300513	18.700	17.0	326.3	2.07	8.0	0.0	0.0	0.0	0.0058	0.00	5.01	1001.58	0.000	0.0000	6
300514	18.800	17.1	327.6	1.98	6.2	0.0	6.3	0.0	0.0369	0.00	5.95	1265.70	0.000	0.0000	6
300515	18.700	17.1	422.1	2.00	5.1	0.0	5.1	0.0	0.0216	0.00	7.93	1264.45	0.000	0.0000	6
300516	18.700	17.3	632.5	1.96	5.5	0.0	5.5	0.0	0.0201	0.00	8.51	1334.53	0.000	0.0000	6
300517	18.700	17.3	733.3	1.90	6.1	0.0	6.1	0.0	0.0271	0.00	8.87	1553.13	0.000	0.0000	6

TABLE B.1.2 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
300518	18.700	17.4	885.8	1.95	5.0	0.0	5.3	0.0	0.0254	0.00	10.53	1588.13	0.000	0.0000	6
300519	18.200	17.0	1033.2	2.11	6.1	0.0	6.0	0.0	0.0275	0.00	14.48	1656.03	0.000	0.0000	16
300520	18.300	17.1	1034.5	1.79	9.8	0.0	9.5	0.0	0.0493	0.00	14.73	2041.71	0.000	0.0000	6
300521	18.400	17.3	763.6	1.95	10.0	0.0	9.0	0.0	0.0505	0.00	9.48	1738.28	0.000	0.0000	6
300522	18.500	17.3	637.6	2.00	9.0	0.0	7.8	0.0	0.0407	0.00	12.56	1569.67	0.000	0.0000	6
300523	18.600	17.4	446.0	1.89	10.0	0.0	10.1	0.0	0.0582	0.00	9.72	1451.00	0.000	0.0000	6
300524	18.600	17.5	294.8	1.90	10.1	0.0	9.6	0.0	0.0692	0.00	5.85	1312.47	0.000	0.0000	62
300525	18.700	17.5	296.1	1.99	7.2	0.0	8.1	0.0	0.0451	0.00	5.78	1272.98	0.000	0.0000	6
300526	18.700	17.6	289.8	1.80	11.4	0.0	12.1	0.0	0.0737	0.00	8.64	1282.45	0.000	0.0000	62
300527	18.500	17.6	386.8	1.79	11.9	0.0	12.0	0.0	0.0798	0.00	6.79	1399.62	0.000	0.0000	62
300528	18.900	17.8	473.8	1.75	12.1	0.0	12.5	0.0	0.0696	0.00	9.24	1466.72	0.000	0.0000	62
300529	18.900	17.9	638.8	1.80	12.3	0.0	10.1	0.0	0.0652	0.00	11.64	1554.60	0.000	0.0000	62
300530	18.600	17.9	837.9	1.73	11.6	0.0	11.7	0.0	0.0706	0.00	11.40	1820.25	0.000	0.0000	6
310501	18.100	17.5	286.0	1.94	12.5	0.0	15.1	0.0	0.1007	0.00	5.66	1363.85	0.000	0.0000	62
310502	18.200	17.5	286.0	1.77	17.5	0.0	18.1	0.0	0.1451	0.00	6.26	1401.18	0.000	0.0000	62
310503	18.200	17.5	380.5	1.77	17.4	0.0	18.0	0.0	0.1306	0.00	6.32	1498.67	0.000	0.0000	62
310504	18.300	17.5	638.8	1.81	15.0	0.0	17.0	0.0	0.0978	0.00	13.87	1706.63	0.000	0.0000	62
310505	18.400	17.6	835.4	1.70	16.5	0.0	17.9	0.0	0.1157	0.00	16.59	1971.47	0.000	0.0000	62
310506	18.500	17.6	826.6	1.55	20.6	0.0	20.4	0.0	0.1482	0.00	14.25	1975.35	0.000	0.0000	62
310507	18.600	17.8	1023.1	1.54	20.2	0.0	20.0	0.0	0.1349	0.00	15.07	2223.91	0.000	0.0000	62
310508	18.600	17.8	592.2	1.64	19.0	0.0	18.2	0.0	0.1347	0.00	11.99	1723.63	0.000	0.0000	62
310509	18.700	17.9	379.3	1.54	19.9	0.0	20.0	0.0	0.1528	0.00	7.86	1483.15	0.000	0.0000	62
310510	18.700	17.9	258.3	1.58	19.0	0.0	20.0	0.0	0.1669	0.00	5.14	1389.80	0.000	0.0000	2
310511	18.700	18.0	257.0	1.58	14.5	14.8	15.3	0.0	0.1849	0.00	5.79	1396.10	0.000	0.0000	2
50601	17.600	16.1	176.4	2.12	6.4	0.0	0.0	0.0	0.0000	0.00	4.81	919.22	0.000	0.0000	6
50602	17.700	16.2	124.7	2.02	9.1	0.0	0.0	0.0	0.0599	0.00	6.16	894.72	0.000	0.0000	63
50603	17.700	16.2	226.8	2.02	8.9	0.0	0.0	0.0	0.0585	0.00	1.42	973.88	0.000	0.0000	63
50604	17.700	16.2	226.8	1.91	12.1	0.0	0.0	0.0	0.0713	0.00	6.09	1109.85	0.000	0.0000	63
50605	17.800	16.3	165.1	1.91	12.2	0.0	0.0	0.0	0.0743	0.00	4.12	1054.93	0.000	0.0000	63
50606	17.900	16.3	165.1	1.91	9.1	0.0	9.1	0.0	0.0947	0.00	5.69	1194.00	0.000	0.0000	63
50607	18.000	16.4	219.2	1.90	9.0	0.0	9.0	0.0	0.1004	0.00	5.87	1232.63	0.000	0.0000	63
50608	18.100	16.5	126.0	1.90	8.5	0.0	8.1	0.0	0.0970	0.00	6.61	1116.55	0.000	0.0000	63
50609	18.200	16.5	126.0	1.75	12.0	0.0	11.0	0.0	0.1255	0.00	6.10	1179.80	0.000	0.0000	42
50610	18.200	16.6	126.0	1.69	13.2	0.0	12.7	0.0	0.1516	0.00	7.37	1127.05	0.000	0.0000	42
50611	18.300	16.6	202.9	1.69	13.1	0.0	12.6	0.0	0.1373	0.00	6.97	1275.60	0.000	0.0000	2
50612	18.400	16.7	234.4	1.68	13.0	0.0	12.5	0.0	0.1212	0.00	4.39	1291.51	0.000	0.0000	2
50613	18.400	16.8	234.4	1.58	15.4	0.0	15.3	0.0	0.1438	0.00	5.03	1317.10	0.000	0.0000	2
60601	17.900	16.4	143.6	1.84	10.4	10.1	10.3	0.0	0.1430	0.00	4.88	967.65	0.000	0.0000	62
60602	17.800	16.3	143.6	1.70	12.0	12.2	12.1	0.0	0.1685	0.00	7.02	966.28	0.000	0.0000	2
60603	17.800	16.3	143.6	1.60	13.6	13.4	13.1	0.0	0.1862	0.00	19.08	975.56	0.000	0.0000	2
60604	17.900	16.3	143.6	1.55	14.0	13.9	14.5	0.0	0.1884	0.00	5.58	1033.30	0.000	0.0000	2

TABLE B.1.3 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
60605	17.900	16.4	233.1	1.52	14.3	14.1	14.3	0.0	0.1845	0.00	6.63	1126.67	0.000	0.0000	2
60606	17.900	16.4	233.1	1.43	15.1	15.6	15.6	0.0	0.1989	0.00	5.47	1156.58	0.000	0.0000	2
60607	17.900	16.4	233.1	1.40	15.8	16.9	17.5	0.0	0.2128	0.00	5.91	1153.22	0.000	0.0000	2
60608	17.900	16.4	228.1	1.30	18.2	18.2	18.2	0.0	0.2257	0.00	6.16	1184.15	0.000	0.0000	2
60609	17.900	16.4	234.4	1.20	20.2	19.7	19.9	0.0	0.2614	0.00	5.02	1175.07	0.000	0.0000	2
60610	17.900	16.4	457.4	1.23	19.8	19.3	19.6	0.0	0.2466	0.00	11.03	1452.30	0.000	0.0000	2
60611	17.900	16.4	641.3	1.23	19.4	18.9	19.2	0.0	0.2184	0.00	13.76	1680.36	0.000	0.0000	2
60612	17.900	16.5	641.3	1.38	17.7	17.2	17.1	0.0	0.1973	0.00	11.70	1623.91	0.000	0.0000	2
60613	18.000	16.6	124.7	1.22	19.3	20.0	19.6	0.0	0.2578	0.00	7.47	1044.18	0.000	0.0000	42
60614	17.900	16.6	124.7	1.42	17.8	18.0	17.0	0.0	0.2196	0.00	4.73	1020.58	0.000	0.0000	42
60615	17.900	16.6	126.0	1.51	14.5	15.7	15.3	0.0	0.1876	0.00	4.09	987.75	0.000	0.0000	42
60616	18.000	16.6	195.3	1.49	14.1	15.2	14.8	0.0	0.1862	0.00	5.34	1090.50	0.000	0.0000	2
60617	18.000	16.7	195.3	1.39	16.4	16.7	16.2	0.0	0.2093	0.00	4.48	1112.50	0.000	0.0000	2
60618	18.000	16.7	195.3	1.23	18.6	20.1	20.6	0.0	0.2444	0.00	5.60	1140.08	0.000	0.0000	2
140801	20.700	17.6	286.0	2.93	3.9	0.0	0.9	0.0	0.3141	0.00	0.80	1015.83	152.014	-0.0263	3
140802	20.800	17.6	282.2	2.85	4.9	0.0	3.1	0.0	0.3133	0.00	0.71	1067.60	151.607	-0.1031	3
140803	20.900	17.7	281.0	2.80	7.0	0.0	5.0	0.0	0.3098	0.00	0.87	1096.95	151.963	0.0204	3
140804	21.100	17.7	278.5	2.64	10.1	0.0	5.0	0.0	0.3089	0.00	0.68	1111.58	152.309	-0.1652	3
140805	21.600	17.7	277.2	2.64	15.0	0.0	6.0	0.0	0.3087	0.00	0.65	1120.92	151.962	-0.1730	3
140806	21.800	17.8	277.2	2.59	15.1	0.0	10.8	0.0	0.3092	0.00	0.70	1098.62	152.388	-0.1677	3
140807	22.200	17.8	277.2	2.50	20.2	0.0	10.6	0.0	0.3100	0.00	0.88	1123.87	151.554	0.0506	3
140808	22.300	17.9	277.2	2.40	26.1	0.0	10.2	0.0	0.3087	0.00	1.02	1105.53	151.031	0.2112	3
140809	22.100	17.8	277.2	2.34	26.4	0.0	15.1	0.0	0.3121	0.00	0.87	1106.45	150.161	0.0655	3
140810	22.400	17.8	277.2	2.27	26.1	0.0	21.1	0.0	0.3112	0.00	0.97	1121.70	149.302	0.2146	3
140811	22.700	17.8	277.2	2.15	26.4	0.0	26.5	0.0	0.3128	0.00	0.84	1139.20	148.051	0.1123	3
140812	22.800	17.8	277.2	2.28	26.1	4.6	26.2	0.0	0.3135	0.00	0.80	1144.53	147.083	0.1413	3
140813	21.800	17.8	270.9	2.10	26.5	10.4	26.5	0.0	0.3170	0.00	0.68	1135.10	146.647	-0.0233	3
140814	21.600	17.8	264.6	1.89	26.5	20.3	26.5	0.0	0.3183	0.00	0.96	1132.93	145.305	0.2604	34
140815	22.100	17.8	264.6	1.78	26.7	26.6	25.9	0.0	0.3239	0.00	0.92	1126.18	143.697	0.2945	34
140816	22.000	17.7	442.3	1.78	26.7	26.6	25.9	0.0	0.2690	0.00	0.90	1140.93	154.161	0.4063	34
150801	20.200	18.5	424.6	2.99	4.0	0.0	1.0	0.0	0.2189	0.00	0.86	1072.50	171.853	0.1070	3
150802	20.200	18.6	419.6	2.81	7.1	0.0	5.0	0.0	0.2200	0.00	0.91	1086.60	171.726	0.1863	3
150803	20.300	18.7	414.5	2.71	9.8	0.0	10.0	0.0	0.2225	0.00	0.71	1103.50	171.096	-0.0091	3
150804	20.300	18.7	403.2	2.64	15.2	0.0	10.5	0.0	0.2190	0.00	0.93	1098.60	170.658	0.2647	3
150805	20.400	18.8	403.2	2.56	20.2	0.0	10.3	0.0	0.2202	0.00	0.89	1097.38	169.243	0.2599	3
150806	20.500	18.9	403.2	2.43	26.6	0.0	9.9	0.0	0.2274	0.00	1.50	1088.69	168.188	0.9253	3
150807	20.600	19.0	400.7	2.39	26.2	0.0	15.0	0.0	0.2265	0.00	1.03	1123.00	167.732	0.4490	3
150808	20.600	19.1	400.7	2.30	26.2	0.0	20.1	0.0	0.2287	0.00	0.89	1078.60	166.226	0.3742	34
150809	20.600	19.1	395.6	2.16	26.7	0.0	26.4	0.0	0.2366	0.00	0.83	1099.00	163.968	0.2792	34
150810	20.600	19.1	395.6	2.21	25.9	5.8	25.9	0.0	0.2472	0.00	2.21	1080.93	162.175	1.5880	34
150811	20.600	19.2	395.6	2.04	26.4	10.6	26.3	0.0	0.2613	0.00	0.83	1081.87	159.179	0.1065	4

TABLE B.1.4 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
150812	20.500	19.3	578.3	2.94	3.1	0.0	1.4	0.0	0.1450	0.00	1.20	1022.42	192.869	0.3950	3
150813	20.600	19.4	577.1	2.70	10.0	0.0	4.9	0.0	0.2928	0.00	0.94	1103.20	188.936	0.3001	3
150814	20.800	19.4	90.7	2.91	4.0	0.0	0.7	0.0	0.6409	0.00	0.80	1018.15	102.715	0.3457	3
150815	20.900	19.6	81.9	2.72	5.2	0.0	5.2	0.0	0.7301	0.00	0.67	1010.15	92.923	0.2117	3
150816	20.900	19.6	81.9	2.62	8.2	0.0	7.8	0.0	0.7320	0.00	0.45	1007.78	93.008	-0.0253	3
200801	22.100	19.4	156.2	3.07	3.9	0.0	0.8	0.0	0.3907	0.00	0.67	1047.53	134.847	0.0627	3
200802	22.100	19.4	160.0	2.91	5.0	0.0	5.0	0.0	0.3885	0.00	0.54	1045.42	134.960	0.0000	3
200803	22.100	19.4	157.5	2.87	8.2	0.0	5.1	0.0	0.3873	0.00	0.63	1067.96	134.836	0.0140	3
200804	22.300	19.5	157.5	2.83	10.1	0.0	5.3	0.0	0.3855	0.00	0.65	1066.29	134.751	0.0390	3
200805	22.200	19.5	157.5	2.78	10.7	0.0	8.8	0.0	0.3836	0.00	0.52	1071.51	135.185	-0.1079	3
200806	22.200	19.6	157.5	2.70	15.0	0.0	10.0	0.0	0.3864	0.00	0.57	1076.73	134.993	-0.0596	3
200807	22.100	19.6	157.5	2.63	18.7	0.0	10.0	0.0	0.3843	0.00	0.42	1081.84	134.346	-0.1777	3
200808	22.100	19.6	157.5	2.51	25.4	0.0	9.9	0.0	0.3838	0.00	0.65	1086.51	134.824	0.0152	3
200809	21.900	19.7	157.5	2.43	26.6	0.0	14.2	0.0	0.3833	0.00	0.54	1068.53	134.290	-0.0936	3
200810	21.800	19.7	157.5	2.34	26.3	0.0	20.4	0.0	0.3849	0.00	0.60	1079.90	134.101	0.0464	3
200811	21.900	19.8	157.5	2.22	26.4	0.0	26.4	0.0	0.3858	0.00	0.50	1074.40	133.560	0.0000	3
200812	21.800	19.8	157.5	2.32	25.8	5.6	25.9	0.0	0.3871	0.00	0.56	1060.27	132.684	-0.0183	3
200813	21.900	19.9	157.5	2.14	26.3	11.9	26.2	0.0	0.3848	0.00	0.64	1058.71	132.634	0.0288	3
200814	22.000	19.9	157.5	1.99	26.2	18.0	26.2	0.0	0.3856	0.00	0.84	1055.04	132.187	0.2531	3
200815	22.100	20.0	157.5	1.78	26.7	26.9	26.8	0.0	0.3898	0.00	0.66	1076.49	131.317	0.0776	3
200816	21.900	20.1	157.5	1.70	26.4	26.2	26.2	7.9	0.3922	0.00	0.77	1073.93	131.174	0.1767	3
210801	20.700	19.9	108.4	3.03	3.8	0.0	0.6	0.0	0.4663	0.00	0.42	1034.76	122.870	-0.1817	3
210802	20.800	20.0	108.4	2.90	4.1	0.0	4.3	0.0	0.4764	0.00	0.44	1035.76	122.402	-0.1825	3
210803	20.900	20.1	108.4	2.82	6.0	0.0	6.4	0.0	0.4734	0.00	0.62	1038.31	122.418	0.0022	3
210804	21.200	20.1	104.6	2.75	10.1	0.0	7.2	0.0	0.4786	0.00	0.58	1041.98	122.452	-0.0395	3
210805	21.500	20.2	107.1	2.67	13.1	0.0	10.1	0.0	0.4777	0.00	0.53	1031.38	122.365	-0.0739	3
210806	21.800	20.3	105.8	2.60	15.3	0.0	13.4	0.0	0.4712	0.00	0.57	1034.93	122.635	-0.0404	3
210807	21.800	20.4	107.1	2.50	22.3	0.0	13.1	0.0	0.4705	0.00	0.49	1041.49	122.726	-0.1415	3
210808	21.800	20.4	107.1	2.40	21.8	0.0	20.3	0.0	0.4750	0.00	0.57	1046.82	122.529	-0.0534	3
210809	21.900	20.5	107.1	2.32	26.4	0.0	20.4	0.0	0.4753	0.00	0.47	1050.82	122.119	-0.1307	3
210810	21.900	20.6	107.1	2.21	26.3	0.0	26.3	0.0	0.4764	0.00	0.64	1053.49	122.241	0.0125	3
210811	21.900	20.7	107.1	2.20	26.1	5.3	26.1	0.0	0.4766	0.00	0.57	1061.93	121.406	-0.0091	3
210812	22.000	20.9	107.1	2.10	26.4	13.1	26.1	0.0	0.4542	0.00	0.53	1042.38	121.941	-0.1943	3
210813	22.300	20.9	107.1	1.98	26.6	20.3	26.6	0.0	0.4662	0.00	0.49	1029.29	121.355	-0.2355	3
210814	22.500	21.0	102.1	1.87	26.6	26.5	26.5	0.0	0.4725	0.00	0.55	1010.73	120.548	-0.1224	3
210815	22.900	21.1	102.1	1.80	26.3	26.2	25.8	5.2	0.4758	0.00	0.69	1008.73	120.771	-0.0110	3
210816	22.900	21.2	105.8	1.64	26.6	26.6	26.4	14.9	0.4758	0.00	0.61	1023.84	119.695	-0.0535	34
210817	22.900	21.2	107.1	1.35	26.6	26.6	26.4	26.4	0.4806	0.00	0.59	1015.96	118.127	-0.0404	4
290801	21.600	20.3	74.0	3.10	3.6	0.0	2.2	0.0	0.5187	0.00	0.54	1029.33	114.901	-0.0629	3
290802	21.800	20.4	72.0	2.87	6.9	0.0	3.7	0.0	0.5191	0.00	0.45	1027.73	114.856	-0.1382	3
290803	21.900	20.6	74.0	2.70	13.0	0.0	8.8	0.0	0.5213	0.00	0.43	1031.95	115.069	-0.1706	3

TABLE B.1.5 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
290804	21.900	20.6	75.0	2.57	20.2	0.0	12.1	0.0	0.5231	0.00	0.46	1018.95	115.011	-0.1553	3
290805	22.000	20.7	74.0	2.42	26.3	0.0	14.6	0.0	0.5246	0.00	0.53	1021.04	114.801	-0.0632	3
290806	21.900	20.8	75.0	2.30	26.4	0.0	21.5	0.0	0.5268	0.00	0.55	1026.22	114.885	-0.0377	3
290807	21.800	20.8	73.0	2.20	26.5	0.0	26.5	0.0	0.5295	0.00	0.40	1034.85	114.376	-0.1575	3
290808	21.900	20.9	73.0	2.05	26.5	3.9	26.5	2.9	0.5329	0.00	0.48	1032.25	114.629	-0.1376	3
290809	21.800	21.0	83.0	1.93	26.7	13.5	26.4	2.6	0.5362	0.00	0.55	1037.50	114.366	-0.0654	3
290810	21.800	21.1	83.0	1.80	26.4	14.0	26.4	12.1	0.5340	0.00	0.59	1037.98	113.799	0.0177	34
290811	21.700	21.2	115.0	2.35	13.4	14.7	15.5	15.5	0.4472	0.00	0.29	1046.44	123.806	0.0000	3
290812	21.600	21.3	115.0	2.70	7.4	7.7	7.5	9.3	0.4372	0.00	0.54	1031.78	125.236	-0.0930	3
40901	21.700	20.0	89.0	3.10	2.8	0.0	2.6	0.0	0.5811	0.00	0.51	1013.00	110.301	-0.0720	3
40902	22.000	20.1	85.0	2.91	8.0	0.0	7.2	0.0	0.5767	0.00	0.66	1021.00	110.641	0.0689	3
40903	22.000	20.2	80.0	2.79	14.0	0.0	8.8	0.0	0.5776	0.00	0.47	1012.18	110.931	-0.1222	3
40904	22.200	20.2	77.0	2.67	16.8	0.0	15.5	0.0	0.5799	0.00	0.55	1017.64	110.951	-0.0526	3
40905	22.300	20.3	77.0	2.50	26.7	0.0	14.7	0.0	0.5765	0.00	0.54	1021.73	110.897	-0.0581	3
40906	22.200	20.4	79.0	2.38	26.1	0.0	22.7	0.0	0.5767	0.00	0.52	1012.80	110.664	-0.0854	3
40907	22.100	20.5	71.0	2.32	20.3	20.0	17.2	0.0	0.5842	0.00	0.55	1007.44	110.710	-0.0613	3
40908	22.100	20.6	71.0	2.05	26.0	20.9	22.0	0.0	0.5854	0.00	0.41	1023.50	110.069	-0.1775	3
40909	22.000	20.7	71.0	1.83	25.9	25.8	26.8	0.0	0.5836	0.00	0.47	1027.20	109.739	-0.1278	4
40910	21.800	20.8	153.0	1.82	25.8	25.7	26.7	0.0	0.4039	0.00	0.49	1026.35	130.971	-0.1128	3
40911	21.400	20.8	155.0	2.05	26.3	24.7	19.4	0.0	0.3926	0.00	0.51	1035.25	132.188	-0.1195	3
40912	21.300	20.9	154.0	2.20	17.4	25.5	20.1	0.0	0.3921	0.00	0.56	1054.44	133.359	-0.1312	3
40913	21.500	21.0	151.0	2.38	15.4	17.5	17.9	0.0	0.3916	0.00	0.54	1072.80	134.145	-0.1514	3
40914	21.800	21.0	150.0	2.69	4.0	8.6	13.6	0.0	0.3827	0.00	0.49	1073.89	135.040	-0.2170	3
50901	21.000	19.9	207.9	2.95	5.5	5.5	4.3	0.0	0.3526	0.00	0.69	1064.69	144.475	-0.0787	3
50902	21.000	20.0	210.4	2.45	15.0	18.0	19.4	0.0	0.3614	0.00	0.66	1052.00	142.565	-0.1163	3
50903	20.800	20.1	75.0	2.44	15.0	17.9	19.3	0.0	0.5569	0.00	0.46	1023.89	113.670	-0.1886	3
50904	20.800	20.1	76.0	1.92	25.3	26.2	25.1	0.0	0.5807	0.00	0.48	1014.16	110.666	-0.1305	4
50905	20.700	20.2	267.1	1.91	25.2	26.1	25.0	0.0	0.3327	0.00	0.76	1037.58	146.069	0.2018	34
50906	20.400	20.3	269.6	2.61	14.4	15.2	15.6	0.0	0.3134	0.00	0.60	1031.95	152.080	-0.1312	3
50907	20.500	20.4	265.9	2.80	3.7	4.0	15.1	0.0	0.3067	0.00	0.80	1017.80	153.722	0.0146	3
50908	20.800	20.5	332.6	2.90	3.7	3.8	3.5	0.0	0.2515	0.00	0.81	1045.22	165.027	-0.0583	3
50909	20.900	20.6	342.7	2.69	9.8	8.9	6.0	0.0	0.2522	0.00	0.61	1068.22	164.557	-0.2467	3
100901	20.500	19.0	112.0	3.08	2.0	0.0	1.8	0.0	0.4764	0.00	0.56	1026.00	123.302	-0.0798	3
100902	20.800	19.1	112.0	2.99	4.0	0.0	2.0	0.0	0.4719	0.00	0.60	1028.96	123.573	0.0000	3
100903	21.000	19.3	112.0	2.83	8.0	0.0	4.6	0.0	0.4764	0.00	0.76	1039.40	123.789	0.0915	3
100904	21.000	19.3	112.0	2.71	14.3	0.0	7.8	0.0	0.4767	0.00	0.59	1042.00	123.939	-0.0606	3
100905	21.100	19.4	112.0	2.60	15.5	0.0	16.1	0.0	0.4753	0.00	0.72	1045.20	123.827	0.0807	3
100906	21.000	19.5	112.0	2.40	26.6	0.0	16.6	0.0	0.4777	0.00	0.56	1042.36	123.311	-0.0676	3
100907	21.000	19.6	112.0	2.38	20.0	9.5	10.1	10.1	0.4830	0.00	0.64	1041.78	123.519	-0.0060	3
100908	21.100	19.7	112.0	2.22	26.7	8.9	9.6	9.5	0.4803	0.00	0.39	1046.00	122.729	-0.2224	3
100909	20.900	19.7	108.0	2.00	24.6	26.3	9.0	8.7	0.4813	0.00	0.49	1049.00	122.376	-0.1234	3

TABLE B.1.6 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
100910	20.900	19.8	112.0	1.82	26.3	26.5	18.7	7.8	0.4876	0.00	0.51	1049.90	121.882	-0.0749	3
100911	21.100	19.8	111.0	1.66	25.6	26.1	26.1	9.9	0.4918	0.00	0.51	1052.30	120.683	-0.0281	3
100912	21.300	19.9	112.0	1.51	23.6	24.1	24.6	25.4	0.4946	0.00	0.39	1093.40	120.115	-0.1760	4
120901	19.900	18.7	30.0	3.06	1.8	0.0	1.9	0.0	0.6963	0.00	0.50	999.40	97.078	-0.0541	3
120902	20.000	18.8	45.0	2.87	6.4	0.0	3.5	0.0	0.7120	0.00	0.37	1009.35	95.880	-0.1277	3
120903	20.200	18.9	37.0	2.75	12.3	0.0	6.7	0.0	0.7120	0.00	0.45	1007.58	96.367	-0.1202	3
120904	20.200	19.0	37.0	2.55	18.0	0.0	16.2	0.0	0.7115	0.00	0.51	988.29	96.334	-0.0336	3
120905	20.300	19.1	51.0	2.55	17.9	0.0	16.1	0.0	0.6507	0.00	0.39	998.00	103.432	-0.1829	3
120906	20.400	19.1	51.0	2.69	11.6	0.0	15.6	0.0	0.6502	0.00	0.39	1002.20	103.521	-0.1680	3
120907	20.400	19.3	51.0	2.73	5.8	0.0	15.0	0.0	0.6502	0.00	0.54	1008.56	103.702	-0.0241	3
120908	20.500	19.4	51.0	2.83	5.8	0.0	10.2	0.0	0.6474	0.00	0.40	1012.29	103.870	-0.1587	3
120909	20.600	19.4	50.0	2.90	5.5	0.0	3.7	0.0	0.6466	0.00	0.46	1012.02	103.800	-0.0848	3
120910	20.600	19.5	50.0	2.95	2.1	0.0	2.0	0.0	0.6465	0.00	0.66	1002.89	103.969	0.1047	3
120911	20.700	19.6	46.0	2.40	19.8	0.0	19.6	0.0	0.6506	0.00	0.37	1017.50	103.804	-0.1955	3
120912	20.800	19.7	45.0	2.30	26.4	0.0	20.1	0.0	0.6525	0.00	0.50	1028.47	103.893	-0.0827	3
120913	21.200	20.1	76.0	1.90	10.5	24.1	25.1	25.8	0.5630	0.00	0.38	1044.75	110.207	-0.2172	4
120914	21.300	20.2	77.0	2.03	11.2	15.5	25.7	25.6	0.5714	0.00	0.58	1022.33	111.172	-0.0369	34
120915	21.300	20.2	76.0	2.22	12.2	16.7	16.2	25.5	0.5710	0.00	0.63	1029.90	111.712	-0.0136	3
120916	21.300	20.3	77.0	2.33	12.7	17.3	16.8	18.0	0.5649	0.00	0.51	1026.60	111.831	-0.1040	3
120917	21.200	20.4	80.0	2.45	13.2	16.5	15.9	9.6	0.5634	0.00	0.54	1028.75	112.313	-0.0968	3
120918	21.200	20.5	78.0	2.59	13.8	5.7	15.0	9.8	0.5576	0.00	0.55	1038.84	113.032	-0.0919	3
120919	21.300	20.6	79.0	2.71	11.1	0.0	11.5	9.7	0.5552	0.00	0.50	1038.30	112.987	-0.1372	3
120920	21.200	20.6	80.0	2.78	10.7	0.0	10.1	3.7	0.5529	0.00	0.53	1035.33	113.142	-0.1124	3
120921	21.200	20.7	81.0	2.84	9.6	0.0	9.4	0.0	0.5511	0.00	0.58	1035.80	113.429	-0.0606	3
120922	21.300	20.7	81.0	2.90	8.0	0.0	3.1	0.0	0.5526	0.00	0.61	1040.93	113.257	-0.0228	3
120923	21.400	20.8	81.0	2.94	2.9	0.0	3.1	0.0	0.5516	0.00	0.57	1030.02	113.483	-0.0850	3
120924	21.400	20.8	82.0	3.03	2.1	0.0	0.0	0.0	0.5537	0.00	0.59	991.70	113.461	-0.0516	3
10401	16.000	13.4	104.6	0.90				10.5	0.6323	0.00	10.84	1054.84	0.000	0.0000	42
10402	15.200	13.6	148.7	0.85				10.0	0.5992	0.00	6.43	1155.60	0.000	0.0000	42
10403	14.300	13.7	229.3	0.85				10.0	0.5662	0.00	12.92	1402.10	0.000	0.0000	2
10404	13.600	13.1	142.4	1.22				22.5	0.6720	0.00	11.66	1386.80	0.000	0.0000	42
10405	12.700	13.4	231.8	1.20				22.0	0.6342	0.00	9.80	1586.30	0.000	0.0000	42
10406	11.900	13.4	326.3	1.20				21.5	0.6181	0.00	16.22	1886.00	0.000	0.0000	2
10407	15.500	13.6	373.0	1.21				21.5	0.6185	0.00	17.74	2031.15	0.000	0.0000	2
10408	14.600	13.8	480.1	1.22				21.5	0.6080	0.00	17.39	2246.69	0.000	0.0000	2
10409	13.500	13.1	215.5	1.80				15.0	0.6234	0.00	9.66	1467.87	0.000	0.0000	42
10410	12.800	13.2	355.3	1.65				14.5	0.5804	0.00	14.62	1760.90	0.000	0.0000	2
10411	12.100	13.4	100.8	2.75				33.0	0.7610	0.00	16.79	1610.96	0.000	0.0000	2
10412	11.300	13.6	102.1	1.85				47.0	0.7785	0.00	16.14	1474.36	0.000	0.0000	2
20401	16.200	14.8	607.3	1.16				13.0	0.5235	0.00	13.94	2069.44	0.000	0.0000	2
20402	15.800	14.9	597.2	1.09				27.0	0.5960	0.00	19.76	2476.90	0.000	0.0000	2

TABLE B.1.7 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
20403	15.300	14.9	597.2	1.40				22.5	0.5942	0.00	19.90	2494.40	0.000	0.0000	2
20404	14.500	16.0	30.0	1.30				22.0	0.7252	0.00	9.44	888.60	0.000	0.0000	42
20405	16.000	16.0	29.0	1.20				36.0	0.8114	0.00	13.79	989.55	0.000	0.0000	42
20406	15.900	15.9	29.0	1.20				67.5	0.7611	0.00	5.55	1051.70	0.000	0.0000	4
20407	14.800	15.9	15.0	1.39				118.0	0.7695	0.00	2.44	811.87	0.000	0.0000	4
20408	15.000	16.9	20.0	1.20				61.0	0.6898	0.00	3.18	977.22	0.000	0.0000	4
20409	14.200	16.9	20.0	1.18				83.5	0.7388	0.00	3.16	1024.36	0.000	0.0000	4
20410	13.600	16.9	20.0	1.42				103.0	0.7456	0.00	2.96	1105.76	0.000	0.0000	4
40401	15.700	13.9	42.0	1.40				11.5	0.5850	0.00	6.90	889.90	0.000	0.0000	42
40402	14.000	13.9	42.0	1.30				20.0	0.7266	0.00	5.61	889.48	0.000	0.0000	42
40403	13.300	13.9	40.0	1.40				34.0	0.8133	0.00	8.73	1175.93	0.000	0.0000	42
40404	14.500	13.9	40.0	1.13				43.5	0.8208	0.00	9.13	1208.95	0.000	0.0000	42
40405	13.800	14.9	45.0	1.66				54.0	0.8306	0.00	5.98	1233.91	0.000	0.0000	42
40406	13.100	14.9	93.0	1.63				82.5	0.8141	0.00	19.69	1830.33	0.000	0.0000	44
40407	14.200	14.9	104.0	1.75				87.0	0.8092	0.00	18.09	1618.38	0.000	0.0000	44
40408	13.400	15.9	50.0	1.40				102.0	0.8446	0.00	11.54	1467.33	0.000	0.0000	44
40409	12.800	15.8	49.0	2.00				129.0	0.8282	0.00	11.04	1754.22	0.000	0.0000	44
40410	12.000	15.9	258.3	0.58				30.0	0.6284	0.00	9.69	1675.98	0.000	0.0000	42
50401	17.000	14.1	160.0	1.42				23.5	0.6951	0.00	19.58	1378.73	0.000	0.0000	42
50402	16.300	13.9	150.0	1.30				49.0	0.7598	0.00	15.83	1693.90	0.000	0.0000	2
50403	15.800	13.9	140.0	1.65				73.0	0.8112	0.00	27.22	1994.20	0.000	0.0000	44
50404	15.000	13.9	773.6	1.09				18.0	0.5036	0.00	16.42	2500.20	0.000	0.0000	2
60401	16.900	14.4	286.0	0.75				25.0	0.6053	0.00	7.77	1310.00	0.000	0.0000	2
60402	16.200	14.4	260.8	1.55				44.5	0.7515	0.00	17.36	1841.80	0.000	0.0000	2
60403	15.700	14.4	258.3	1.42				63.5	0.7670	0.00	24.53	2147.60	0.000	0.0000	2
60404	13.800	14.3	25.0	1.73				76.5	0.7376	0.00	7.04	439.80	0.000	0.0000	4
60405	15.000	15.9	364.1	1.84				19.0	0.6199	0.00	7.77	1689.70	0.000	0.0000	2
60406	14.300	15.9	459.9	1.62				31.0	0.6520	0.00	21.22	2136.20	0.000	0.0000	2
60407	13.700	15.9	443.5	1.55				48.5	0.6971	0.00	29.14	2510.38	0.000	0.0000	2
90401	12.900	13.6	22.0	2.45				140.0	0.8167	0.00	9.98	912.30	0.000	0.0000	4
90402	16.800	13.7	19.0	1.63				103.5	0.7631	0.00	3.24	644.20	0.000	0.0000	4
90403	16.000	13.6	20.0	1.68				119.0	0.7776	0.00	3.85	711.71	0.000	0.0000	4
90404	16.500	13.5	55.0	1.79				136.0	0.0000	0.00	13.83	263.80	0.000	0.0000	42
90405	15.800	14.6	142.0	1.83				26.5	0.7296	0.00	11.65	1066.90	0.000	0.0000	2
90406	16.400	14.6	143.0	1.74				53.5	0.7954	0.00	24.75	1623.00	0.000	0.0000	2
90407	15.600	14.6	240.7	0.97				67.0	0.7556	0.00	13.31	1639.20	0.000	0.0000	2
150401	14.500	12.4	1092.4	2.15				11.0	0.4792	0.00	25.61	3234.27	0.000	0.0000	2
150402	16.000	12.6	1074.8	2.02				19.0	0.5328	0.00	36.68	3587.70	0.000	0.0000	2
150403	15.300	12.6	1068.5	1.87				23.0	0.5626	0.00	31.65	3864.90	0.000	0.0000	2
150404	14.600	12.8	1053.4	2.15				30.5	0.5870	0.00	37.52	4242.50	0.000	0.0000	2
150405	15.800	12.3	1064.7	1.88				30.5	0.5772	0.00	41.63	4154.55	0.000	0.0000	2

TABLE B.1.8 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF MV	TEMP C	HL CMH2O	PG BAR	S1 CM	S2 CM	S3 CM	S4 CM	VDF	POT	PE MMH2O/M	PRES MMH2O	ELL	PTT	PATRN
150406	14.900	12.4	1048.3	1.32				47.0	0.6265	0.00	42.95	4617.67	0.000	0.0000	2
150407	14.000	12.4	1039.5	1.93				58.5	0.6476	0.00	66.46	5124.87	0.000	0.0000	2
150408	15.500	11.9	1026.9	1.93				69.0	0.6697	0.00	55.39	4798.20	0.000	0.0000	2
150409	14.700	11.7	26.0	1.93				167.0	0.8386	0.00	11.67	1215.87	0.000	0.0000	4
150410	13.900	11.3	27.0	1.02				140.5	0.7463	0.00	8.84	1135.05	0.000	0.0000	4
150411	14.900	11.3	27.0	1.20				124.0	0.7664	0.00	12.29	1155.51	0.000	0.0000	4
150412	14.000	11.4	27.0	0.97				12.5	0.5607	0.00	3.14	1005.33	0.000	0.0000	4
180401	14.400	11.1	243.2	1.19				60.5	0.8084	0.00	23.94	1783.95	0.000	0.0000	2
180402	12.700	11.1	390.6	1.10				62.0	0.7779	0.00	32.35	2346.43	0.000	0.0000	2
180403	11.600	11.1	509.0	1.12				60.0	0.7337	0.00	37.47	2704.09	0.000	0.0000	2
180404	9.900	11.1	636.3	1.22				61.0	0.7298	0.00	38.28	3225.74	0.000	0.0000	2
180405	9.100	11.1	783.7	1.40				67.0	0.7201	0.00	51.09	3792.97	0.000	0.0000	2
180406	13.500	11.6	849.2	1.84				62.5	0.7311	0.00	40.20	4063.00	0.000	0.0000	2
180407	13.000	11.6	1038.2	1.81				61.0	0.6946	0.00	44.45	4492.50	0.000	0.0000	2
180408	11.700	11.6	1031.9	1.80				75.0	0.7114	0.00	91.22	4843.80	0.000	0.0000	2
180409	10.500	11.6	865.6	1.88				79.0	0.7435	0.00	54.99	3986.00	0.000	0.0000	2
180410	9.300	11.6	774.9	1.40				63.5	0.7143	0.00	59.16	3870.13	0.000	0.0000	2
180411	9.100	11.6	617.4	1.43				74.0	0.7401	0.00	51.29	3570.00	0.000	0.0000	2
180412	13.200	12.3	492.7	2.41				71.0	0.7915	0.00	53.66	3736.80	0.000	0.0000	2
180413	11.700	12.2	341.5	2.42				71.0	0.8236	0.00	50.89	3229.97	0.000	0.0000	42
180414	10.000	12.2	252.0	2.60				69.0	0.8340	0.00	36.11	2987.02	0.000	0.0000	42
180415	9.100	12.3	143.6	2.79				74.0	0.8672	0.00	38.95	2516.02	0.000	0.0000	42
180416	8.500	12.3	147.4	2.78				84.0	0.8719	0.00	23.92	2486.20	0.000	0.0000	42
190401	14.100	13.4	210.4	2.42				75.0	0.8615	0.00	28.98	2054.06	0.000	0.0000	42
190402	11.400	13.4	340.2	2.61				86.0	0.8488	0.00	63.02	3293.27	0.000	0.0000	42
190403	9.900	13.4	502.7	2.15				78.0	0.7924	0.00	59.89	3432.40	0.000	0.0000	42
190404	9.300	13.5	642.6	2.21				79.0	0.7785	0.00	68.86	4038.40	0.000	0.0000	2
190405	14.800	15.0	1021.9	2.78				78.5	0.7398	0.00	74.95	5336.20	0.000	0.0000	42
190406	12.800	14.9	365.4	2.85				82.0	0.8325	0.00	69.70	3516.67	0.000	0.0000	42
190407	10.900	14.9	103.3	3.05				83.0	0.8826	0.00	37.88	1918.02	0.000	0.0000	44
190408	10.100	14.9	108.4	3.08				99.0	0.8922	0.00	18.07	2209.18	0.000	0.0000	44
210401	16.400	14.1	49.0	1.95				6.0	0.3954	0.00	6.06	1213.22	0.000	0.0000	34
210402	15.800	14.1	49.0	2.13				10.5	0.6966	0.00	10.82	1069.58	0.000	0.0000	42
210403	15.200	14.1	49.0	2.00				15.5	0.7857	0.00	14.41	1138.40	0.000	0.0000	42
210404	14.400	14.1	48.0	1.96				22.5	0.8620	0.00	16.24	1200.50	0.000	0.0000	42
210405	13.600	14.2	47.0	1.97				28.0	0.8786	0.00	19.93	1218.67	0.000	0.0000	42
210406	12.600	14.3	46.0	2.00				33.5	0.8644	0.00	15.87	1372.11	0.000	0.0000	42
210407	12.000	14.3	46.0	1.85				40.0	0.8738	0.00	14.24	1583.44	0.000	0.0000	42
210408	14.400	13.1	66.0	2.00				52.5	0.8685	0.00	5.01	1696.05	0.000	0.0000	2
210409	13.600	13.1	65.0	1.93				46.0	0.8855	0.00	11.19	1540.25	0.000	0.0000	2
210410	12.600	13.1	65.0	2.01				38.5	0.8725	0.00	16.65	1447.10	0.000	0.0000	42

TABLE B.1.9 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

NO	EMF	TEMP	HL	PG	S1	S2	S3	S4	VDF	POT	PE	PRES	ELL	PTT	PATRN
	MV	C	CMH2O	BAR	CM	CM	CM	CM			MMH2O/M	MMH2O			
210411	11.800	13.3	64.0	2.10				28.0	0.8339	0.00	22.38	1486.60	0.000	0.0000	42
210412	11.600	13.3	63.0	2.22				21.0	0.8475	0.00	19.07	1524.05	0.000	0.0000	42
210413	12.100	13.4	72.0	0.88				14.5	0.7003	0.00	14.79	1095.87	0.000	0.0000	42
210414	12.600	13.4	73.0	1.10				8.0	0.4725	0.00	9.67	1080.31	0.000	0.0000	42
10501	17.500	13.8	23.0	1.85				5.5	0.3832	0.00	1.62	856.44	0.000	0.0000	4
10502	17.800	13.9	66.0	1.78				10.5	0.6915	0.00	8.87	952.62	0.000	0.0000	42
10503	17.700	13.9	65.0	1.70				17.0	0.8112	0.00	12.19	1264.58	0.000	0.0000	42
10504	17.200	13.9	65.0	1.62				20.0	0.8303	0.00	12.96	1237.15	0.000	0.0000	42
10505	16.600	13.9	67.0	1.62				30.0	0.8588	0.00	13.58	1264.71	0.000	0.0000	42
10506	15.500	14.0	23.0	1.87				33.5	0.8318	0.00	9.48	1153.87	0.000	0.0000	4
10507	15.000	14.1	95.0	1.89				36.5	0.8442	0.00	23.82	1715.60	0.000	0.0000	2
10508	17.300	13.3	138.6	2.34				8.5	0.6601	0.00	9.75	1502.22	0.000	0.0000	42
10509	17.800	13.4	253.3	2.27				8.5	0.6283	0.00	11.79	1838.36	0.000	0.0000	2
10510	18.200	13.4	381.8	2.24				8.5	0.5967	0.00	13.98	2078.69	0.000	0.0000	2
10511	18.300	13.4	578.3	2.22				8.5	0.5506	0.00	14.38	2444.96	0.000	0.0000	2
10512	18.200	13.4	716.9	2.18				12.5	0.5541	0.00	17.68	2834.90	0.000	0.0000	2
10513	17.900	13.5	1088.6	2.18				12.5	0.5218	0.00	29.69	3427.40	0.000	0.0000	2
10514	17.600	13.6	1071.0	2.10				26.5	0.6051	0.00	36.60	4099.17	0.000	0.0000	2

TABLE B.1.10 OBTAINED EXPERIMENTAL READINGS FOR TWO-PHASE TESTS

APPENDIX B

B.2 PRESSURE DROP AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

FROM **Table B.2.1** TO **Table B.2.10**

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
220102	12.4	109.26	0.013688	0.039659	1.3379	999.476	0.05306	0.3062	8.9879	42
220103	12.4	110.48	0.020352	0.039097	1.3532	999.482	0.05291	0.3884	45.0477	2
220104	12.4	112.29	0.027556	0.038396	1.3754	999.482	0.05281	0.4065	50.8051	2
220105	12.4	113.24	0.033749	0.038063	1.3869	999.482	0.05279	0.3786	85.0346	2
220106	12.3	113.96	0.038074	0.037687	1.3962	999.494	0.05262	0.3700	79.3373	2
220107	12.3	115.21	0.041125	0.037269	1.4116	999.494	0.05261	0.3600	105.9231	2
220108	12.3	115.42	0.043852	0.037153	1.4141	999.494	0.05254	0.0692	107.5863	2
220109	12.3	116.57	0.043286	0.036895	1.4282	999.494	0.05269	0.3390	130.7762	2
280101	10.5	110.57	0.011014	0.041990	1.3631	999.678	0.05724	0.2660	7.4293	34
280102	10.6	110.55	0.008623	0.040827	1.3621	999.664	0.05561	0.3434	6.3527	3
280103	10.8	110.66	0.013270	0.039830	1.3628	999.649	0.05428	0.3004	9.1104	34
280104	11.0	110.54	0.013847	0.016072	1.3603	999.629	0.02186	0.1609	7.3550	3
280105	11.1	110.33	0.009279	0.015797	1.3571	999.614	0.02144	0.3007	6.3512	3
280106	11.3	110.64	0.011535	0.015545	1.3604	999.604	0.02115	0.1882	7.8094	3
280107	11.4	110.94	0.016313	0.015448	1.3634	999.588	0.02106	0.0000	20.9904	42
280108	11.6	111.03	0.016313	0.032821	1.3634	999.567	0.04475	0.2580	9.9058	42
280109	11.6	113.75	0.020842	0.033464	1.3966	999.561	0.04674	0.3166	58.1170	2
280110	11.1	114.20	0.024944	0.034084	1.4048	999.619	0.04788	0.3207	46.8786	2
280111	11.1	112.94	0.028867	0.032776	1.3897	999.624	0.04555	0.2937	57.9143	2
280112	11.1	123.10	0.065119	0.029223	1.5144	999.619	0.04426	0.2350	200.5930	2
280113	11.3	121.57	0.061216	0.029602	1.4945	999.599	0.04424	0.2489	198.2217	2
280114	11.4	119.12	0.054618	0.030537	1.4639	999.588	0.04470	0.2642	161.1289	2
280115	11.6	117.37	0.048497	0.031285	1.4413	999.567	0.04509	0.2793	132.0246	2
280116	11.8	115.75	0.042481	0.032098	1.4207	999.550	0.04560	0.2960	89.1305	2
280117	11.9	115.31	0.038010	0.032522	1.4142	999.528	0.04599	0.3039	90.8432	2
280118	12.1	113.67	0.032179	0.033370	1.3937	999.517	0.04651	0.3085	78.7349	2
280119	12.1	115.21	0.031793	0.046448	1.4120	999.506	0.06558	0.4640	101.9788	2
280120	12.3	113.42	0.021870	0.048294	1.3896	999.494	0.06711	0.5017	56.0216	2
290101	12.8	102.97	0.007662	0.051911	1.2593	999.434	0.06537	0.3874	6.0825	34
290102	12.9	103.04	0.009891	0.051918	1.2596	999.416	0.06540	0.3412	7.6429	34
290103	13.1	102.81	0.011703	0.052163	1.2561	999.397	0.06552	0.3470	8.6167	34
290104	12.3	103.17	0.011703	0.044396	1.2640	999.494	0.05612	0.2719	29.4477	3
290105	13.4	102.81	0.011703	0.026627	1.2543	999.346	0.03340	0.1893	8.0730	3
290106	13.6	102.96	0.010468	0.017609	1.2557	999.332	0.02211	0.3360	6.0294	3
70201	11.0	109.60	0.008393	0.002335	1.3488	999.629	0.00315	0.6588	4.0372	3
70202	11.2	110.26	0.007913	0.002534	1.3559	999.609	0.00344	0.7140	3.9833	3
70203	11.4	110.34	0.007662	0.005920	1.3560	999.588	0.00803	0.7237	3.5526	3
70204	11.5	110.65	0.007402	0.005467	1.3593	999.578	0.00743	0.7244	3.9834	3
70205	11.7	110.71	0.005234	0.006735	1.3591	999.556	0.00915	0.7236	3.8225	3

TABLE B.2.1 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
70206	11.9	111.17	0.010835	0.013319	1.3637	999.534	0.01816	0.0856	5.6523	3
70207	12.2	111.22	0.009065	0.015793	1.3629	999.500	0.02152	0.2804	6.5670	3
110201	12.4	109.54	0.008623	0.023949	1.3412	999.470	0.03212	0.3237	6.0295	3
110202	12.6	109.74	0.009691	0.026874	1.3427	999.447	0.03608	0.2642	7.4815	3
110203	12.8	109.92	0.009691	0.029757	1.3442	999.428	0.04000	0.2665	6.8363	3
110204	12.9	109.97	0.009691	0.034741	1.3441	999.410	0.04669	0.2723	6.6209	34
110205	13.1	109.85	0.009691	0.039329	1.3419	999.391	0.05277	0.2792	8.2352	4
110206	13.2	109.96	0.009691	0.044268	1.3427	999.378	0.05944	0.2878	6.2982	4
110207	13.4	110.21	0.009487	0.048826	1.3451	999.359	0.06568	0.3179	14.2636	4
110208	13.5	109.87	0.009590	0.052069	1.3403	999.339	0.06979	0.3414	19.5372	4
110210	13.8	112.33	0.012033	0.054787	1.3691	999.306	0.07501	0.3676	9.6927	42
110213	12.8	109.56	0.018557	0.016531	1.3399	999.434	0.02215	0.1577	22.1824	42
110214	12.9	109.80	0.018557	0.024157	1.3419	999.410	0.03242	0.2212	30.3079	42
110215	13.1	109.94	0.018452	0.032708	1.3428	999.384	0.04392	0.3087	29.2960	42
110216	13.3	112.62	0.018452	0.043538	1.3750	999.372	0.05986	0.3796	13.3510	2
110217	13.4	112.25	0.018345	0.051400	1.3700	999.359	0.07042	0.4811	61.5165	2
110218	13.4	112.98	0.023821	0.050926	1.3785	999.346	0.07020	0.5253	42.1967	2
110219	13.6	112.91	0.066319	0.003444	1.3769	999.326	0.00474	0.0515	163.1912	16
110220	13.8	113.59	0.066171	0.004611	1.3842	999.299	0.00638	0.0604	158.7243	16
110221	13.9	119.33	0.066171	0.011267	1.4536	999.285	0.01638	0.0980	187.4432	16
110222	14.1	120.19	0.065984	0.014409	1.4633	999.265	0.02108	0.1200	156.6698	62
110223	14.1	122.86	0.065984	0.024037	1.4953	999.251	0.03594	0.1978	190.5205	2
110224	14.4	123.82	0.065684	0.032167	1.5060	999.223	0.04844	0.2577	213.5044	2
110225	14.5	126.28	0.065497	0.042519	1.5350	999.201	0.06527	0.3440	231.2546	2
300501	16.4	108.28	0.032484	0.003052	1.3078	998.915	0.00399	0.0000	54.2310	6
300502	16.4	109.88	0.032025	0.004034	1.3270	998.907	0.00535	0.0000	50.7987	6
300503	16.5	109.73	0.042190	0.003336	1.3248	998.898	0.00442	0.0000	81.3956	6
300504	16.5	110.37	0.042132	0.004031	1.3321	998.881	0.00537	0.0000	100.4205	6
300505	16.5	112.24	0.053799	0.003921	1.3547	998.881	0.00531	0.0016	110.2272	6
300506	16.6	112.07	0.053845	0.002945	1.3522	998.865	0.00398	0.0000	111.3060	16
300507	16.8	114.74	0.062688	0.003868	1.3839	998.848	0.00535	0.0036	151.0231	16
300508	16.8	115.12	0.062688	0.004355	1.3886	998.848	0.00605	0.0086	148.0811	6
300509	16.9	114.09	0.057047	0.004886	1.3757	998.831	0.00672	0.0104	126.3102	6
300510	16.9	113.03	0.054119	0.004466	1.3628	998.831	0.00609	0.0080	99.5379	6
300511	16.9	112.17	0.049802	0.004787	1.3523	998.822	0.00647	0.0060	103.9509	6
300512	17.0	111.37	0.035736	0.005184	1.3421	998.805	0.00696	0.0171	60.7034	6
300513	17.0	111.15	0.035736	0.004677	1.3392	998.796	0.00626	0.0058	49.1315	6
300514	17.1	113.74	0.035805	0.007764	1.3702	998.787	0.01064	0.0369	58.3498	6
300515	17.1	113.73	0.040643	0.006979	1.3698	998.779	0.00956	0.0216	77.7671	6

TABLE B.2.2 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
300516	17.3	114.41	0.049752	0.007178	1.3776	998.761	0.00989	0.0201	83.4550	6
300517	17.3	116.56	0.053570	0.007394	1.4034	998.761	0.01038	0.0271	86.9854	6
300518	17.4	116.90	0.058876	0.006781	1.4071	998.743	0.00954	0.0254	103.2645	6
300519	17.0	117.57	0.063587	0.007515	1.4165	998.796	0.01064	0.0275	142.0009	16
300520	17.1	121.35	0.063625	0.009350	1.4616	998.779	0.01367	0.0493	144.4526	6
300521	17.3	118.37	0.054663	0.009715	1.4253	998.761	0.01385	0.0505	92.9674	6
300522	17.3	116.72	0.049950	0.009121	1.4054	998.761	0.01282	0.0407	123.1721	6
300523	17.4	115.55	0.041779	0.010266	1.3909	998.743	0.01428	0.0582	95.3211	6
300524	17.5	114.20	0.033968	0.010258	1.3741	998.725	0.01410	0.0692	57.3692	62
300525	17.5	113.81	0.034040	0.008794	1.3689	998.708	0.01204	0.0451	56.6827	6
300526	17.6	113.90	0.033676	0.011560	1.3698	998.699	0.01583	0.0737	84.7298	62
300527	17.6	115.05	0.038907	0.011583	1.3834	998.690	0.01602	0.0798	66.5874	62
300528	17.8	115.71	0.043058	0.011702	1.3908	998.672	0.01628	0.0696	90.6138	62
300529	17.9	116.57	0.049999	0.010899	1.4007	998.653	0.01527	0.0652	114.1499	62
300530	17.9	119.18	0.057262	0.010863	1.4320	998.653	0.01556	0.0706	111.7963	6
310501	17.5	114.70	0.033456	0.013379	1.3801	998.725	0.01846	0.1007	55.5059	62
310502	17.5	115.07	0.033456	0.016207	1.3845	998.725	0.02244	0.1451	61.3899	62
310503	17.5	116.02	0.038589	0.015994	1.3958	998.717	0.02232	0.1306	61.9783	62
310504	17.5	118.06	0.049999	0.014454	1.4201	998.708	0.02053	0.0978	136.0188	62
310505	17.6	120.66	0.057176	0.014813	1.4508	998.690	0.02149	0.1157	162.6930	62
310506	17.6	120.70	0.056874	0.016966	1.4513	998.690	0.02462	0.1482	139.7454	62
310507	17.8	123.13	0.063276	0.016297	1.4801	998.672	0.02412	0.1349	147.7869	62
310508	17.8	118.23	0.048140	0.016071	1.4211	998.672	0.02284	0.1347	117.5823	62
310509	17.9	115.87	0.038525	0.017200	1.3923	998.653	0.02395	0.1528	77.0806	62
310510	17.9	114.95	0.031793	0.017096	1.3810	998.644	0.02361	0.1669	50.4064	2
310511	18.0	115.02	0.031716	0.020091	1.3813	998.626	0.02775	0.1849	56.7808	2
50601	16.1	110.34	0.026274	0.004132	1.3336	998.948	0.00551	0.0000	47.1702	6
50602	16.2	110.10	0.022094	0.005107	1.3305	998.940	0.00680	0.0599	60.4092	63
50603	16.2	110.88	0.029792	0.004994	1.3399	998.940	0.00669	0.0585	13.9255	63
50604	16.2	112.21	0.029792	0.006089	1.3560	998.940	0.00826	0.0713	59.7228	63
50605	16.3	111.67	0.025415	0.006158	1.3492	998.931	0.00831	0.0743	40.4036	63
50606	16.3	113.03	0.025415	0.009788	1.3657	998.931	0.01337	0.0947	55.8001	63
50607	16.4	113.41	0.029291	0.009668	1.3698	998.915	0.01324	0.1004	57.5653	63
50608	16.5	112.28	0.022205	0.009250	1.3556	998.898	0.01254	0.0970	64.8222	63
50609	16.5	112.90	0.022205	0.011349	1.3626	998.881	0.01547	0.1255	59.8208	42
50610	16.6	112.38	0.022205	0.012402	1.3561	998.873	0.01682	0.1516	72.2753	42
50611	16.6	113.83	0.028175	0.012166	1.3735	998.865	0.01671	0.1373	68.3526	2
50612	16.7	113.99	0.030284	0.012053	1.3751	998.856	0.01657	0.1212	43.0514	2
50613	16.8	114.24	0.030284	0.013809	1.3779	998.848	0.01903	0.1438	49.3277	2
60601	16.4	110.81	0.023709	0.016151	1.3384	998.915	0.02162	0.1430	47.8567	62
60602	16.3	110.80	0.023709	0.017895	1.3385	998.923	0.02395	0.1685	68.8430	2

TABLE B.2.3 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
60603	16.3	110.89	0.023709	0.019047	1.3396	998.923	0.02552	0.1862	187.1117	2
60604	16.3	111.46	0.023709	0.019672	1.3465	998.923	0.02649	0.1884	54.7213	2
60605	16.4	112.37	0.030203	0.019526	1.3573	998.915	0.02650	0.1845	65.0184	2
60606	16.4	112.67	0.030203	0.020529	1.3608	998.915	0.02794	0.1989	53.6426	2
60607	16.4	112.63	0.030203	0.021929	1.3604	998.915	0.02983	0.2128	57.9576	2
60608	16.4	112.94	0.029874	0.023141	1.3638	998.907	0.03156	0.2257	60.4092	2
60609	16.4	112.85	0.030284	0.024687	1.3628	998.907	0.03364	0.2614	49.2296	2
60610	16.4	115.57	0.042307	0.023840	1.3956	998.907	0.03327	0.2466	108.1678	2
60611	16.4	117.80	0.050098	0.022942	1.4226	998.907	0.03264	0.2184	134.9401	2
60612	16.5	117.25	0.050098	0.021667	1.4154	998.890	0.03067	0.1973	114.7383	2
60613	16.6	111.57	0.022094	0.024735	1.3463	998.873	0.03330	0.2578	73.2560	42
60614	16.6	111.33	0.022094	0.023321	1.3435	998.873	0.03133	0.2196	46.3857	42
60615	16.6	111.01	0.022205	0.020847	1.3397	998.873	0.02793	0.1876	40.1094	42
60616	16.6	112.02	0.027645	0.020040	1.3516	998.865	0.02709	0.1862	52.3677	2
60617	16.7	112.24	0.027645	0.021633	1.3540	998.856	0.02929	0.2093	43.9340	2
60618	16.7	112.51	0.027645	0.024747	1.3572	998.856	0.03359	0.2444	54.9175	2
140801	17.6	111.29	0.009252	0.005808	1.3384	998.699	0.00777	0.3141	7.8454	3
140802	17.6	111.79	0.009191	0.006980	1.3445	998.699	0.00938	0.3133	6.9628	3
140803	17.7	112.08	0.009170	0.008517	1.3475	998.681	0.01148	0.3098	8.5318	3
140804	17.7	112.23	0.009129	0.009633	1.3492	998.681	0.01300	0.3089	6.6686	3
140805	17.7	112.32	0.009108	0.012196	1.3503	998.681	0.01647	0.3087	6.3744	3
140806	17.8	112.10	0.009108	0.014161	1.3472	998.662	0.01908	0.3092	6.8647	3
140807	17.8	112.35	0.009108	0.016296	1.3502	998.662	0.02200	0.3100	8.6299	3
140808	17.9	112.17	0.009108	0.018813	1.3475	998.644	0.02535	0.3087	10.0028	3
140809	17.8	112.18	0.009108	0.020904	1.3481	998.662	0.02818	0.3121	8.5318	3
140810	17.8	112.33	0.009108	0.023286	1.3499	998.662	0.03143	0.3112	9.5125	3
140811	17.8	112.50	0.009108	0.025491	1.3520	998.662	0.03446	0.3128	8.2376	3
140812	17.8	112.55	0.009108	0.029138	1.3526	998.662	0.03941	0.3135	7.8454	3
140813	17.8	112.46	0.009004	0.030947	1.3515	998.662	0.04182	0.3170	6.6686	3
140814	17.8	112.44	0.008899	0.034092	1.3512	998.662	0.04607	0.3183	9.4144	34
140815	17.8	112.37	0.008899	0.036057	1.3504	998.662	0.04869	0.3239	9.0222	34
140816	17.7	112.51	0.011505	0.036004	1.3526	998.681	0.04870	0.2690	8.8260	34
150801	18.5	111.84	0.011273	0.005917	1.3409	998.532	0.00793	0.2189	8.4338	3
150802	18.6	111.98	0.011206	0.008614	1.3421	998.513	0.01156	0.2200	8.9241	3
150803	18.7	112.15	0.011139	0.011700	1.3436	998.494	0.01572	0.2225	6.9628	3
150804	18.7	112.10	0.010985	0.014251	1.3430	998.494	0.01914	0.2190	9.1202	3
150805	18.8	112.09	0.010985	0.016445	1.3424	998.474	0.02208	0.2202	8.7280	3
150806	18.9	112.00	0.010985	0.019164	1.3409	998.455	0.02570	0.2274	14.7100	3
150807	19.0	112.34	0.010951	0.021022	1.3445	998.436	0.02826	0.2265	10.1009	3
150808	19.1	111.90	0.010951	0.023223	1.3388	998.416	0.03109	0.2287	8.7280	34
150809	19.1	112.10	0.010882	0.025924	1.3412	998.416	0.03477	0.2366	8.1396	34

TABLE B.2.4 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
150810	19.1	111.93	0.010882	0.029459	1.3391	998.416	0.03945	0.2472	21.6728	34
150811	19.2	111.93	0.010882	0.030966	1.3388	998.396	0.04146	0.2613	8.1396	4
150812	19.3	111.35	0.013156	0.005722	1.3313	998.376	0.00762	0.1450	11.7680	3
150813	19.4	112.14	0.013142	0.009692	1.3403	998.356	0.01299	0.2928	9.2183	3
150814	19.4	111.31	0.005211	0.005792	1.3304	998.356	0.00771	0.6409	7.8454	3
150815	19.6	111.23	0.004951	0.007910	1.3285	998.316	0.01051	0.7301	6.5705	3
150816	19.6	111.21	0.004951	0.010087	1.3282	998.316	0.01340	0.7320	4.4130	3
200801	19.4	111.60	0.006838	0.005851	1.3338	998.356	0.00780	0.3907	6.5705	3
200802	19.4	111.58	0.006920	0.007864	1.3336	998.356	0.01049	0.3885	5.2956	3
200803	19.4	111.80	0.006866	0.009183	1.3362	998.356	0.01227	0.3873	6.1782	3
200804	19.5	111.78	0.006866	0.010046	1.3356	998.336	0.01342	0.3855	6.3744	3
200805	19.5	111.83	0.006866	0.011697	1.3362	998.336	0.01563	0.3836	5.0995	3
200806	19.6	111.88	0.006866	0.014066	1.3363	998.316	0.01880	0.3864	5.5898	3
200807	19.6	111.93	0.006866	0.015731	1.3369	998.316	0.02103	0.3843	4.1188	3
200808	19.6	111.98	0.006866	0.018771	1.3375	998.316	0.02511	0.3838	6.3744	3
200809	19.7	111.80	0.006866	0.021071	1.3349	998.296	0.02813	0.3833	5.2956	3
200810	19.7	111.92	0.006866	0.023543	1.3362	998.296	0.03146	0.3849	5.8840	3
200811	19.8	111.86	0.006866	0.026073	1.3351	998.275	0.03481	0.3858	4.9033	3
200812	19.8	111.72	0.006866	0.029862	1.3335	998.275	0.03982	0.3871	5.4917	3
200813	19.9	111.71	0.006866	0.031943	1.3328	998.255	0.04257	0.3848	6.2763	3
200814	19.9	111.67	0.006866	0.033789	1.3324	998.255	0.04502	0.3856	8.2376	3
200815	20.0	111.88	0.006866	0.037016	1.3345	998.234	0.04940	0.3898	6.4724	3
200816	20.1	111.86	0.006866	0.040232	1.3337	998.214	0.05366	0.3922	7.5512	3
210801	19.9	111.47	0.005695	0.005742	1.3300	998.255	0.00764	0.4663	4.1188	3
210802	20.0	111.48	0.005695	0.007251	1.3297	998.234	0.00964	0.4764	4.3149	3
210803	20.1	111.51	0.005695	0.008809	1.3295	998.214	0.01171	0.4734	6.0802	3
210804	20.1	111.54	0.005595	0.010793	1.3300	998.214	0.01435	0.4786	5.6879	3
210805	20.2	111.44	0.005662	0.013269	1.3283	998.193	0.01762	0.4777	5.1975	3
210806	20.3	111.47	0.005628	0.015640	1.3282	998.172	0.02077	0.4712	5.5898	3
210807	20.4	111.54	0.005662	0.018722	1.3286	998.151	0.02487	0.4705	4.8053	3
210808	20.4	111.59	0.005662	0.021596	1.3292	998.151	0.02870	0.4750	5.5898	3
210809	20.5	111.63	0.005662	0.023645	1.3292	998.130	0.03143	0.4753	4.6091	3
210810	20.6	111.66	0.005662	0.026058	1.3291	998.108	0.03463	0.4764	6.2763	3
210811	20.7	111.74	0.005662	0.029561	1.3296	998.087	0.03930	0.4766	5.5898	3
210812	20.9	111.55	0.005662	0.032404	1.3264	998.044	0.04298	0.4542	5.1975	3
210813	20.9	111.42	0.005662	0.035323	1.3249	998.044	0.04680	0.4662	4.8053	3
210814	21.0	111.24	0.005527	0.037538	1.3223	998.022	0.04963	0.4725	5.3937	3
210815	21.1	111.22	0.005527	0.040037	1.3216	998.001	0.05291	0.4758	6.7666	3
210816	21.2	111.37	0.005628	0.043068	1.3229	997.979	0.05697	0.4758	5.9821	34
210817	21.2	111.29	0.005662	0.045476	1.3220	997.979	0.06012	0.4806	5.7859	4
290801	20.3	111.42	0.004706	0.006340	1.3276	998.172	0.00842	0.5187	5.2956	3

TABLE B.2.5 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
290802	20.4	111.40	0.004642	0.008136	1.3270	998.151	0.01080	0.5191	4.4130	3
290803	20.6	111.45	0.004706	0.012718	1.3265	998.108	0.01687	0.5213	4.2169	3
290804	20.6	111.32	0.004738	0.017427	1.3250	998.108	0.02309	0.5231	4.5111	3
290805	20.7	111.34	0.004706	0.021234	1.3248	998.087	0.02813	0.5246	5.1975	3
290806	20.8	111.39	0.004738	0.024188	1.3250	998.066	0.03205	0.5268	5.3937	3
290807	20.8	111.47	0.004674	0.026275	1.3260	998.066	0.03484	0.5295	3.9227	3
290808	20.9	111.45	0.004674	0.031697	1.3252	998.044	0.04201	0.5329	4.7072	3
290809	21.0	111.50	0.004984	0.034712	1.3254	998.022	0.04601	0.5362	5.3937	3
290810	21.1	111.50	0.004984	0.037519	1.3250	998.001	0.04971	0.5340	5.7859	34
290811	21.2	111.59	0.005867	0.031103	1.3255	997.979	0.04123	0.4472	2.8439	3
290812	21.3	111.44	0.005867	0.020381	1.3234	997.957	0.02697	0.4372	5.2956	3
40901	20.0	111.26	0.005161	0.006176	1.3270	998.234	0.00820	0.5811	5.0014	3
40902	20.1	111.34	0.005044	0.010073	1.3275	998.214	0.01337	0.5767	6.4724	3
40903	20.2	111.25	0.004893	0.013331	1.3260	998.193	0.01768	0.5776	4.6091	3
40904	20.2	111.31	0.004801	0.017505	1.3267	998.193	0.02322	0.5799	5.3937	3
40905	20.3	111.35	0.004801	0.021667	1.3267	998.172	0.02875	0.5765	5.2956	3
40906	20.4	111.26	0.004863	0.024892	1.3252	998.151	0.03299	0.5767	5.0995	3
40907	20.5	111.20	0.004610	0.029411	1.3241	998.130	0.03894	0.5842	5.3937	3
40908	20.6	111.36	0.004610	0.033551	1.3256	998.108	0.04447	0.5854	4.0207	3
40909	20.7	111.40	0.004610	0.036738	1.3255	998.087	0.04870	0.5836	4.6091	4
40910	20.8	111.39	0.006767	0.036571	1.3250	998.066	0.04846	0.4039	4.8053	3
40911	20.8	111.48	0.006811	0.034294	1.3260	998.066	0.04547	0.3926	5.0014	3
40912	20.9	111.67	0.006789	0.031511	1.3278	998.044	0.04184	0.3921	5.4917	3
40913	21.0	111.85	0.006723	0.026366	1.3295	998.022	0.03505	0.3916	5.2956	3
40914	21.0	111.86	0.006700	0.016328	1.3296	998.022	0.02171	0.3827	4.8053	3
50901	19.9	111.77	0.007888	0.011999	1.3335	998.255	0.01600	0.3526	6.7666	3
50902	20.0	111.64	0.007936	0.027383	1.3316	998.234	0.03646	0.3614	6.4724	3
50903	20.1	111.37	0.004738	0.027336	1.3279	998.214	0.03630	0.5569	4.5111	3
50904	20.1	111.27	0.004769	0.036464	1.3267	998.214	0.04838	0.5807	4.7072	4
50905	20.2	111.50	0.008941	0.036212	1.3290	998.193	0.04813	0.3327	7.4531	34
50906	20.3	111.45	0.008983	0.024563	1.3279	998.172	0.03262	0.3134	5.8840	3
50907	20.4	111.31	0.008920	0.015331	1.3258	998.151	0.02033	0.3067	7.8454	3
50908	20.5	111.58	0.009978	0.010243	1.3285	998.130	0.01361	0.2515	7.9434	3
50909	20.6	111.80	0.010128	0.015552	1.3308	998.108	0.02070	0.2522	5.9821	3
100901	19.0	111.39	0.005790	0.005509	1.3331	998.436	0.00734	0.4764	5.4917	3
100902	19.1	111.42	0.005790	0.006338	1.3330	998.416	0.00845	0.4719	5.8840	3
100903	19.3	111.52	0.005790	0.008895	1.3333	998.376	0.01186	0.4764	7.4531	3
100904	19.3	111.54	0.005790	0.012873	1.3336	998.376	0.01717	0.4767	5.7859	3
100905	19.4	111.58	0.005790	0.016958	1.3335	998.356	0.02261	0.4753	7.0608	3
100906	19.5	111.55	0.005790	0.022158	1.3328	998.336	0.02953	0.4777	5.4917	3
100907	19.6	111.54	0.005790	0.027206	1.3322	998.316	0.03624	0.4830	6.2763	3

TABLE B.2.6 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP	PRESS	QF	QG	DG	DF	WG	VDF	PE	PATERN
	C	KN/M2	M3/SEC	M3/SEC	KG/M3	KG/M3	KG/SEC		N/M3	
100908	19.7	111.58	0.005790	0.029139	1.3323	998.296	0.03882	0.4803	3.8246	3
100909	19.7	111.61	0.005685	0.034344	1.3326	998.296	0.04577	0.4813	4.8053	3
100910	19.8	111.62	0.005790	0.037867	1.3323	998.275	0.05045	0.4876	5.0014	3
100911	19.8	111.64	0.005764	0.040334	1.3326	998.275	0.05375	0.4918	5.0014	3
100912	19.9	112.05	0.005790	0.043020	1.3369	998.255	0.05751	0.4946	3.8246	4
120901	18.7	111.13	0.002996	0.005473	1.3314	998.494	0.00729	0.6963	4.9033	3
120902	18.8	111.22	0.003670	0.007845	1.3321	998.474	0.01045	0.7120	3.6285	3
120903	18.9	111.21	0.003328	0.011583	1.3314	998.455	0.01542	0.7120	4.4130	3
120904	19.0	111.02	0.003328	0.018193	1.3287	998.436	0.02417	0.7115	5.0014	3
120905	19.1	111.11	0.003907	0.018084	1.3294	998.416	0.02404	0.6507	3.8246	3
120906	19.1	111.15	0.003907	0.015160	1.3299	998.416	0.02016	0.6502	3.8246	3
120907	19.3	111.22	0.003907	0.012468	1.3297	998.376	0.01658	0.6502	5.2956	3
120908	19.4	111.25	0.003907	0.010374	1.3297	998.356	0.01379	0.6474	3.9227	3
120909	19.4	111.25	0.003868	0.007582	1.3297	998.356	0.01008	0.6466	4.5111	3
120910	19.5	111.16	0.003868	0.005579	1.3281	998.336	0.00741	0.6465	6.4724	3
120911	19.6	111.30	0.003710	0.020308	1.3294	998.316	0.02700	0.6506	3.6285	3
120912	19.7	111.41	0.003670	0.023462	1.3302	998.296	0.03121	0.6525	4.9033	3
120913	20.1	111.57	0.004769	0.041016	1.3303	998.214	0.05456	0.5630	3.7265	4
120914	20.2	111.35	0.004801	0.038475	1.3272	998.193	0.05107	0.5714	5.6879	34
120915	20.2	111.43	0.004769	0.035954	1.3281	998.193	0.04775	0.5710	6.1782	3
120916	20.3	111.39	0.004801	0.033664	1.3273	998.172	0.04468	0.5649	5.0014	3
120917	20.4	111.41	0.004893	0.029842	1.3271	998.151	0.03960	0.5634	5.2956	3
120918	20.5	111.51	0.004832	0.025560	1.3278	998.130	0.03394	0.5576	5.3937	3
120919	20.6	111.51	0.004863	0.018883	1.3273	998.108	0.02506	0.5552	4.9033	3
120920	20.6	111.48	0.004893	0.015755	1.3269	998.108	0.02091	0.5529	5.1975	3
120921	20.7	111.48	0.004924	0.011659	1.3265	998.087	0.01547	0.5511	5.6879	3
120922	20.7	111.53	0.004924	0.008399	1.3271	998.087	0.01115	0.5526	5.9821	3
120923	20.8	111.43	0.004924	0.006330	1.3254	998.066	0.00839	0.5516	5.5898	3
120924	20.8	111.05	0.004954	0.002842	1.3209	998.066	0.00375	0.5537	5.7859	3
10401	13.4	111.67	0.020230	0.056970	1.3627	999.352	0.07763	0.6323	106.3046	42
10402	13.6	112.66	0.024121	0.054511	1.3740	999.332	0.07490	0.5992	63.0570	42
10403	13.7	115.08	0.029957	0.053477	1.4028	999.312	0.07502	0.5662	126.7025	2
10404	13.1	114.93	0.023605	0.087276	1.4036	999.384	0.12250	0.6720	114.3460	42
10405	13.4	116.88	0.030121	0.084684	1.4265	999.359	0.12080	0.6342	96.1056	42
10406	13.4	119.82	0.035736	0.081821	1.4619	999.346	0.11961	0.6181	159.0645	2
10407	13.6	121.24	0.038204	0.080583	1.4785	999.326	0.11914	0.6185	173.9707	2
10408	13.8	123.36	0.043343	0.079544	1.5035	999.306	0.11959	0.6080	170.5384	2
10409	13.1	115.72	0.029037	0.079632	1.4138	999.397	0.11259	0.6234	94.7327	42
10410	13.2	118.59	0.037289	0.074490	1.4482	999.378	0.10788	0.5804	143.3739	2
10411	13.4	117.12	0.019861	0.134577	1.4295	999.359	0.19238	0.7610	164.6544	2
10412	13.6	115.78	0.019985	0.141532	1.4122	999.332	0.19987	0.7785	158.2800	2

TABLE B.2.7 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP	PRESS	QF	QG	DG	DF	WG	VDF	PE	PATERN
	C	KN/M2	M3/SEC	M3/SEC	KG/M3	KG/M3	KG/SEC		N/M3	
20401	14.8	121.62	0.048751	0.062185	1.4771	999.165	0.09186	0.5235	136.7053	2
20402	14.9	125.62	0.048345	0.084942	1.5249	999.143	0.12952	0.5960	193.7803	2
20403	14.9	125.79	0.048345	0.083163	1.5267	999.135	0.12696	0.5942	195.1532	2
20404	16.0	110.04	0.010835	0.092536	1.3305	998.964	0.12312	0.7252	92.5752	42
20405	16.0	111.03	0.010653	0.113894	1.3427	998.972	0.15292	0.8114	135.2343	42
20406	15.9	111.64	0.010653	0.153797	1.3503	998.980	0.20767	0.7611	54.4272	4
20407	15.9	109.29	0.007662	0.214601	1.3223	998.996	0.28376	0.7695	23.9283	4
20408	16.9	110.91	0.008847	0.148093	1.3373	998.831	0.19804	0.6898	31.1853	4
20409	16.9	111.37	0.008847	0.171058	1.3428	998.831	0.22970	0.7388	30.9891	4
20410	16.9	112.17	0.008847	0.198288	1.3525	998.831	0.26818	0.7456	29.0278	4
40401	13.9	110.05	0.012820	0.067994	1.3408	999.292	0.09117	0.5850	67.6662	42
40402	13.9	110.05	0.012820	0.087695	1.3408	999.292	0.11758	0.7266	55.0155	42
40403	13.9	112.86	0.012511	0.113465	1.3750	999.292	0.15602	0.8133	85.6124	42
40404	13.9	113.18	0.012511	0.119990	1.3790	999.292	0.16546	0.8208	89.5351	42
40405	14.9	113.43	0.013270	0.149395	1.3771	999.150	0.20574	0.8306	58.6440	42
40406	14.9	119.28	0.019077	0.173754	1.4481	999.150	0.25162	0.8141	193.0938	44
40407	14.9	117.20	0.020174	0.185221	1.4229	999.150	0.26355	0.8092	177.4031	44
40408	15.9	115.72	0.013988	0.189981	1.3996	998.980	0.26589	0.8446	113.1692	44
40409	15.8	118.53	0.013847	0.232656	1.4346	999.012	0.33377	0.8282	108.2659	44
40410	15.9	117.76	0.031793	0.083836	1.4246	998.988	0.11943	0.6284	95.0268	42
50401	14.1	114.85	0.025023	0.092875	1.3983	999.265	0.12986	0.6951	192.0150	42
50402	13.9	117.94	0.024228	0.126464	1.4364	999.279	0.18165	0.7598	155.2400	2
50403	13.9	120.88	0.023407	0.160946	1.4723	999.279	0.23696	0.8112	266.9382	44
50404	13.9	125.84	0.055023	0.069322	1.5332	999.292	0.10629	0.5036	161.0259	2
60401	14.4	114.17	0.033456	0.082084	1.3886	999.223	0.11398	0.6053	76.1980	2
60402	14.4	119.39	0.031948	0.125703	1.4520	999.223	0.18253	0.7515	170.2442	2
60403	14.4	122.39	0.031793	0.142156	1.4885	999.223	0.21160	0.7670	240.5582	2
60404	14.3	105.64	0.009891	0.192106	1.2853	999.237	0.24691	0.7376	69.0391	4
60405	15.9	117.90	0.037749	0.089076	1.4264	998.996	0.12706	0.6199	76.1980	2
60406	15.9	122.27	0.042423	0.105104	1.4794	998.996	0.15549	0.6520	208.0980	2
60407	15.9	125.94	0.041661	0.125506	1.5233	998.980	0.19118	0.6971	285.7670	2
90401	13.6	110.27	0.009279	0.277178	1.3447	999.326	0.37272	0.8167	97.8708	4
90402	13.7	107.64	0.008623	0.212547	1.3122	999.312	0.27890	0.7631	31.7737	4
90403	13.6	108.30	0.008847	0.228232	1.3209	999.332	0.30148	0.7776	37.7558	4
90404	13.5	103.91	0.014671	0.258547	1.2676	999.339	0.32773	0.0000	135.6266	42
90405	14.6	111.79	0.023573	0.109815	1.3587	999.194	0.14920	0.7296	114.2480	2
90406	14.6	117.24	0.023656	0.145252	1.4247	999.187	0.20694	0.7954	242.7157	2
90407	14.6	117.40	0.030688	0.137270	1.4264	999.180	0.19580	0.7556	130.5271	2
150401	12.4	133.04	0.065383	0.062760	1.6289	999.470	0.10223	0.4792	251.1494	2
150402	12.6	136.51	0.064853	0.078281	1.6705	999.453	0.13077	0.5328	359.7095	2
150403	12.6	139.23	0.064663	0.082335	1.7034	999.447	0.14025	0.5626	310.3818	2

TABLE B.2.8 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
150404	12.8	142.93	0.064204	0.096656	1.7481	999.434	0.16897	0.5870	367.9471	2
150405	12.3	142.07	0.064549	0.092651	1.7406	999.494	0.16127	0.5772	408.2527	2
150406	12.4	146.61	0.064050	0.099816	1.7953	999.476	0.17920	0.6265	421.1975	2
150407	12.4	151.58	0.063780	0.120946	1.8559	999.470	0.22447	0.6476	651.7528	2
150408	11.9	148.38	0.063392	0.133278	1.8205	999.539	0.24264	0.6697	543.1927	2
150409	11.7	113.25	0.010087	0.267344	1.3902	999.556	0.37167	0.8386	114.4441	4
150410	11.3	112.46	0.010279	0.204653	1.3827	999.604	0.28297	0.7463	86.6912	4
150411	11.3	112.66	0.010279	0.200970	1.3852	999.604	0.27837	0.7664	120.5243	4
150412	11.4	111.18	0.010279	0.063258	1.3661	999.583	0.08642	0.5607	30.7930	4
180401	11.1	118.82	0.030849	0.134799	1.4614	999.614	0.19700	0.8084	234.7722	2
180402	11.1	124.34	0.039097	0.128005	1.5293	999.614	0.19576	0.7779	317.2465	2
180403	11.1	127.84	0.044632	0.123354	1.5724	999.614	0.19397	0.7337	367.4568	2
180404	11.1	132.96	0.049900	0.122710	1.6356	999.619	0.20071	0.7298	375.4002	2
180405	11.1	138.52	0.055380	0.128377	1.7041	999.619	0.21876	0.7201	501.0239	2
180406	11.6	141.17	0.057649	0.131784	1.7333	999.561	0.22842	0.7311	394.2291	2
180407	11.6	145.38	0.063741	0.125897	1.7850	999.561	0.22473	0.6946	435.9075	2
180408	11.6	148.83	0.063548	0.135994	1.8280	999.572	0.24859	0.7114	894.5665	2
180409	11.6	140.42	0.058202	0.150248	1.7246	999.572	0.25912	0.7435	539.2700	2
180410	11.6	139.28	0.055068	0.124554	1.7107	999.572	0.21307	0.7143	580.1639	2
180411	11.6	136.34	0.049154	0.137943	1.6745	999.572	0.23099	0.7401	502.9853	2
180412	12.3	137.97	0.043908	0.157694	1.6904	999.494	0.26657	0.7915	526.2271	2
180413	12.2	133.00	0.036555	0.164225	1.6298	999.500	0.26766	0.8236	499.0626	42
180414	12.2	130.62	0.031403	0.169707	1.6006	999.500	0.27164	0.8340	354.1197	42
180415	12.3	126.00	0.023709	0.187125	1.5438	999.494	0.28888	0.8672	381.9707	42
180416	12.3	125.71	0.024019	0.199465	1.5402	999.494	0.30721	0.8719	234.5761	42
190401	13.4	121.47	0.028696	0.184726	1.4820	999.346	0.27377	0.8615	284.1980	42
190402	13.4	133.62	0.036487	0.185307	1.6303	999.346	0.30210	0.8488	618.0178	42
190403	13.4	134.99	0.044355	0.163758	1.6469	999.346	0.26970	0.7924	587.3228	42
190404	13.5	140.93	0.050147	0.159528	1.7191	999.339	0.27425	0.7785	675.2889	2
190405	15.0	153.66	0.063237	0.157672	1.8646	999.128	0.29400	0.7398	735.0116	42
190406	14.9	135.81	0.037814	0.184514	1.6484	999.135	0.30415	0.8325	683.5265	42
190407	14.9	120.14	0.020108	0.215949	1.4581	999.135	0.31487	0.8826	371.4775	44
190408	14.9	122.99	0.020592	0.231026	1.4927	999.135	0.34486	0.8922	177.2069	44
210401	14.1	113.22	0.013847	0.053049	1.3785	999.265	0.07313	0.3954	59.4286	34
210402	14.1	111.81	0.013847	0.073009	1.3611	999.258	0.09937	0.6966	106.1084	42
210403	14.1	112.49	0.013847	0.086226	1.3691	999.251	0.11805	0.7857	141.3144	42
210404	14.1	113.10	0.013705	0.102508	1.3765	999.251	0.14110	0.8620	159.2607	42
210405	14.2	113.28	0.013562	0.114342	1.3784	999.244	0.15761	0.8786	195.4474	42
210406	14.3	114.78	0.013417	0.124092	1.3965	999.237	0.17329	0.8644	155.6322	42
210407	14.3	116.85	0.013417	0.129773	1.4215	999.230	0.18447	0.8738	139.6473	42
210408	13.1	117.96	0.016071	0.149390	1.4412	999.397	0.21530	0.8685	49.1315	2

TABLE B.2.9 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	TEMP C	PRESS KN/M2	QF M3/SEC	QG M3/SEC	DG KG/M3	DF KG/M3	WG KG/SEC	VDF	PE N/M3	PATERN
210409	13.1	116.43	0.015949	0.140454	1.4220	999.384	0.19973	0.8855	109.7369	2
210410	13.1	115.52	0.015949	0.131726	1.4109	999.384	0.18585	0.8725	163.2814	42
210411	13.3	115.90	0.015826	0.114130	1.4151	999.372	0.16151	0.8339	219.4738	42
210412	13.3	116.27	0.015702	0.100659	1.4196	999.372	0.14289	0.8475	187.0136	42
210413	13.4	112.07	0.016786	0.066643	1.3676	999.352	0.09114	0.7003	145.0410	42
210414	13.4	111.92	0.016902	0.052542	1.3655	999.346	0.07175	0.4725	94.8307	42
10501	13.8	109.72	0.009487	0.051411	1.3371	999.299	0.06874	0.3832	15.8868	4
10502	13.9	110.67	0.016071	0.069269	1.3483	999.292	0.09340	0.6915	86.9854	42
10503	13.9	113.73	0.015949	0.084304	1.3851	999.279	0.11677	0.8112	119.5436	42
10504	13.9	113.46	0.015949	0.090269	1.3818	999.279	0.12474	0.8303	127.0947	42
10505	13.9	113.73	0.016192	0.110031	1.3851	999.279	0.15241	0.8588	133.1749	42
10506	14.0	112.64	0.009487	0.122968	1.3717	999.272	0.16867	0.8318	92.9674	4
10507	14.1	118.15	0.019281	0.122824	1.4385	999.265	0.17668	0.8442	233.5954	2
10508	13.3	116.06	0.023289	0.065086	1.4167	999.365	0.09221	0.6601	95.6153	42
10509	13.4	119.35	0.031482	0.062587	1.4567	999.359	0.09117	0.6283	115.6209	2
10510	13.4	121.71	0.038653	0.061055	1.4855	999.359	0.09070	0.5967	137.0976	2
10511	13.4	125.30	0.047573	0.059124	1.5290	999.352	0.09040	0.5506	141.0202	2
10512	13.4	129.13	0.052968	0.069004	1.5754	999.346	0.10871	0.5541	173.3823	2
10513	13.5	134.94	0.065270	0.066078	1.6460	999.339	0.10877	0.5218	291.1607	2
10514	13.6	141.53	0.064739	0.090162	1.7261	999.332	0.15563	0.6051	358.9249	2

TABLE B.2.10 PRESSURE GRADIENT AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

APPENDIX B

B.3 WATER AND GAS FLOW RATES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

FROM **Table B.3.1** TO **Table B.3.30**

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
220102	12.4	109.26	0.3062	0.013688	0.039659	999.48	1.3379	0.00899	42
220103	12.4	110.48	0.3884	0.020352	0.039097	999.48	1.3532	0.04505	2
220104	12.4	112.29	0.4065	0.027556	0.038396	999.48	1.3754	0.05081	2
220105	12.4	113.24	0.3786	0.033749	0.038063	999.48	1.3869	0.08503	2
220106	12.3	113.96	0.3700	0.038074	0.037687	999.49	1.3962	0.07934	2
220107	12.3	115.21	0.3600	0.041125	0.037269	999.49	1.4116	0.10592	2
220108	12.3	115.42	0.0692	0.043852	0.037153	999.49	1.4141	0.10759	2
220109	12.3	116.57	0.3390	0.043286	0.036895	999.49	1.4282	0.13078	2
280101	10.5	110.57	0.2660	0.011014	0.041990	999.68	1.3631	0.00743	34
280102	10.6	110.55	0.3434	0.008623	0.040827	999.66	1.3621	0.00635	3
280103	10.8	110.66	0.3004	0.013270	0.039830	999.65	1.3628	0.00911	34
280104	11.0	110.54	0.1609	0.013847	0.016072	999.63	1.3603	0.00736	3
280105	11.1	110.33	0.3007	0.009279	0.015797	999.61	1.3571	0.00635	3

TABLE B.3.1 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
280106	11.3	110.64	0.1882	0.011535	0.015545	999.60	1.3604	0.00781	3
280107	11.4	110.94	0.0000	0.016313	0.015448	999.59	1.3634	0.02099	42
280108	11.6	111.03	0.2580	0.016313	0.032821	999.57	1.3634	0.00991	42
280109	11.6	113.75	0.3166	0.020842	0.033464	999.56	1.3966	0.05812	2
280110	11.1	114.20	0.3207	0.024944	0.034084	999.62	1.4048	0.04688	2
280111	11.1	112.94	0.2937	0.028867	0.032776	999.62	1.3897	0.05791	2
280112	11.1	123.10	0.2350	0.065119	0.029223	999.62	1.5144	0.20059	2
280113	11.3	121.57	0.2489	0.061216	0.029602	999.60	1.4945	0.19822	2
280114	11.4	119.12	0.2642	0.054618	0.030537	999.59	1.4639	0.16113	2
280115	11.6	117.37	0.2793	0.048497	0.031285	999.57	1.4413	0.13202	2
280116	11.8	115.75	0.2960	0.042481	0.032098	999.55	1.4207	0.08913	2
280117	11.9	115.31	0.3039	0.038010	0.032522	999.53	1.4142	0.09084	2
280118	12.1	113.67	0.3085	0.032179	0.033370	999.52	1.3937	0.07873	2

TABLE B.3.2 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
280119	12.1	115.21	0.4640	0.031793	0.046448	999.51	1.4120	0.10198	2
280120	12.3	113.42	0.5017	0.021870	0.048294	999.49	1.3896	0.05602	2
290101	12.8	102.97	0.3874	0.007662	0.051911	999.43	1.2593	0.00608	34
290102	12.9	103.04	0.3412	0.009891	0.051918	999.42	1.2596	0.00764	34
290103	13.1	102.81	0.3470	0.011703	0.052163	999.40	1.2561	0.00862	34
290104	12.3	103.17	0.2719	0.011703	0.044396	999.49	1.2640	0.02945	3
290105	13.4	102.81	0.1893	0.011703	0.026627	999.35	1.2543	0.00807	3
290106	13.6	102.96	0.3360	0.010468	0.017609	999.33	1.2557	0.00603	3
70201	11.0	109.60	0.6588	0.008393	0.002335	999.63	1.3488	0.00404	3
70202	11.2	110.26	0.7140	0.007913	0.002534	999.61	1.3559	0.00398	3
70203	11.4	110.34	0.7237	0.007662	0.005920	999.59	1.3560	0.00355	3
70204	11.5	110.65	0.7244	0.007402	0.005467	999.58	1.3593	0.00398	3
70205	11.7	110.71	0.7236	0.005234	0.006735	999.56	1.3591	0.00382	3

TABLE B.3.3 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
70206	11.9	111.17	0.0856	0.010835	0.013319	999.53	1.3637	0.00565	3
70207	12.2	111.22	0.2804	0.009065	0.015793	999.50	1.3629	0.00657	3
110201	12.4	109.54	0.3237	0.008623	0.023949	999.47	1.3412	0.00603	3
110202	12.6	109.74	0.2642	0.009691	0.026874	999.45	1.3427	0.00748	3
110203	12.8	109.92	0.2665	0.009691	0.029757	999.43	1.3442	0.00684	3
110204	12.9	109.97	0.2723	0.009691	0.034741	999.41	1.3441	0.00662	34
110205	13.1	109.85	0.2792	0.009691	0.039329	999.39	1.3419	0.00824	4
110206	13.2	109.96	0.2878	0.009691	0.044268	999.38	1.3427	0.00630	4
110207	13.4	110.21	0.3179	0.009487	0.048826	999.36	1.3451	0.01426	4
110208	13.5	109.87	0.3414	0.009590	0.052069	999.34	1.3403	0.01954	4
110210	13.8	112.33	0.3676	0.012033	0.054787	999.31	1.3691	0.00969	42
110213	12.8	109.56	0.1577	0.018557	0.016531	999.43	1.3399	0.02218	42
110214	12.9	109.80	0.2212	0.018557	0.024157	999.41	1.3419	0.03031	42

TABLE B.3.4 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
110215	13.1	109.94	0.3087	0.018452	0.032708	999.38	1.3428	0.02930	42
110216	13.3	112.62	0.3796	0.018452	0.043538	999.37	1.3750	0.01335	2
110217	13.4	112.25	0.4811	0.018345	0.051400	999.36	1.3700	0.06152	2
110218	13.4	112.98	0.5253	0.023821	0.050926	999.35	1.3785	0.04220	2
110219	13.6	112.91	0.0515	0.066319	0.003444	999.33	1.3769	0.16319	16
110220	13.8	113.59	0.0604	0.066171	0.004611	999.30	1.3842	0.15872	16
110221	13.9	119.33	0.0980	0.066171	0.011267	999.29	1.4536	0.18744	16
110222	14.1	120.19	0.1200	0.065984	0.014409	999.26	1.4633	0.15667	62
110223	14.1	122.86	0.1978	0.065984	0.024037	999.25	1.4953	0.19052	2
110224	14.4	123.82	0.2577	0.065684	0.032167	999.22	1.5060	0.21350	2
110225	14.5	126.28	0.3440	0.065497	0.042519	999.20	1.5350	0.23125	2
300501	16.4	108.28	0.0000	0.032484	0.003052	998.91	1.3078	0.05423	6
300502	16.4	109.88	0.0000	0.032025	0.004034	998.91	1.3270	0.05080	6

TABLE B.3.5 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
300503	16.5	109.73	0.0000	0.042190	0.003336	998.90	1.3248	0.08140	6
300504	16.5	110.37	0.0000	0.042132	0.004031	998.88	1.3321	0.10042	6
300505	16.5	112.24	0.0016	0.053799	0.003921	998.88	1.3547	0.11023	6
300506	16.6	112.07	0.0000	0.053845	0.002945	998.86	1.3522	0.11131	16
300507	16.8	114.74	0.0036	0.062688	0.003868	998.85	1.3839	0.15102	16
300508	16.8	115.12	0.0086	0.062688	0.004355	998.85	1.3886	0.14808	6
300509	16.9	114.09	0.0104	0.057047	0.004886	998.83	1.3757	0.12631	6
300510	16.9	113.03	0.0080	0.054119	0.004466	998.83	1.3628	0.09954	6
300511	16.9	112.17	0.0060	0.049802	0.004787	998.82	1.3523	0.10395	6
300512	17.0	111.37	0.0171	0.035736	0.005184	998.80	1.3421	0.06070	6
300513	17.0	111.15	0.0058	0.035736	0.004677	998.80	1.3392	0.04913	6
300514	17.1	113.74	0.0369	0.035805	0.007764	998.79	1.3702	0.05835	6
300515	17.1	113.73	0.0216	0.040643	0.006979	998.78	1.3698	0.07777	6

TABLE B.3.6 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
300516	17.3	114.41	0.0201	0.049752	0.007178	998.76	1.3776	0.08345	6
300517	17.3	116.56	0.0271	0.053570	0.007394	998.76	1.4034	0.08699	6
300518	17.4	116.90	0.0254	0.058876	0.006781	998.74	1.4071	0.10326	6
300519	17.0	117.57	0.0275	0.063587	0.007515	998.80	1.4165	0.14200	16
300520	17.1	121.35	0.0493	0.063625	0.009350	998.78	1.4616	0.14445	6
300521	17.3	118.37	0.0505	0.054663	0.009715	998.76	1.4253	0.09297	6
300522	17.3	116.72	0.0407	0.049950	0.009121	998.76	1.4054	0.12317	6
300523	17.4	115.55	0.0582	0.041779	0.010266	998.74	1.3909	0.09532	6
300524	17.5	114.20	0.0692	0.033968	0.010258	998.73	1.3741	0.05737	62
300525	17.5	113.81	0.0451	0.034040	0.008794	998.71	1.3689	0.05668	6
300526	17.6	113.90	0.0737	0.033676	0.011560	998.70	1.3698	0.08473	62
300527	17.6	115.05	0.0798	0.038907	0.011583	998.69	1.3834	0.06659	62
300528	17.8	115.71	0.0696	0.043058	0.011702	998.67	1.3908	0.09061	62

TABLE B.3.7 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
300529	17.9	116.57	0.0652	0.049999	0.010899	998.65	1.4007	0.11415	62
300530	17.9	119.18	0.0706	0.057262	0.010863	998.65	1.4320	0.11180	6
310501	17.5	114.70	0.1007	0.033456	0.013379	998.73	1.3801	0.05551	62
310502	17.5	115.07	0.1451	0.033456	0.016207	998.73	1.3845	0.06139	62
310503	17.5	116.02	0.1306	0.038589	0.015994	998.72	1.3958	0.06198	62
310504	17.5	118.06	0.0978	0.049999	0.014454	998.71	1.4201	0.13602	62
310505	17.6	120.66	0.1157	0.057176	0.014813	998.69	1.4508	0.16269	62
310506	17.6	120.70	0.1482	0.056874	0.016966	998.69	1.4513	0.13975	62
310507	17.8	123.13	0.1349	0.063276	0.016297	998.67	1.4801	0.14779	62
310508	17.8	118.23	0.1347	0.048140	0.016071	998.67	1.4211	0.11758	62
310509	17.9	115.87	0.1528	0.038525	0.017200	998.65	1.3923	0.07708	62
310510	17.9	114.95	0.1669	0.031793	0.017096	998.64	1.3810	0.05041	2
310511	18.0	115.02	0.1849	0.031716	0.020091	998.63	1.3813	0.05678	2

TABLE B.3.8 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
50601	16.1	110.34	0.0000	0.026274	0.004132	998.95	1.3336	0.04717	6
50602	16.2	110.10	0.0599	0.022094	0.005107	998.94	1.3305	0.06041	63
50603	16.2	110.88	0.0585	0.029792	0.004994	998.94	1.3399	0.01393	63
50604	16.2	112.21	0.0713	0.029792	0.006089	998.94	1.3560	0.05972	63
50605	16.3	111.67	0.0743	0.025415	0.006158	998.93	1.3492	0.04040	63
50606	16.3	113.03	0.0947	0.025415	0.009788	998.93	1.3657	0.05580	63
50607	16.4	113.41	0.1004	0.029291	0.009668	998.91	1.3698	0.05757	63
50608	16.5	112.28	0.0970	0.022205	0.009250	998.90	1.3556	0.06482	63
50609	16.5	112.90	0.1255	0.022205	0.011349	998.88	1.3626	0.05982	42
50610	16.6	112.38	0.1516	0.022205	0.012402	998.87	1.3561	0.07228	42
50611	16.6	113.83	0.1373	0.028175	0.012166	998.86	1.3735	0.06835	2
50612	16.7	113.99	0.1212	0.030284	0.012053	998.86	1.3751	0.04305	2
50613	16.8	114.24	0.1438	0.030284	0.013809	998.85	1.3779	0.04933	2

TABLE B.3.9 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
60601	16.4	110.81	0.1430	0.023709	0.016151	998.91	1.3384	0.04786	62
60602	16.3	110.80	0.1685	0.023709	0.017895	998.92	1.3385	0.06884	2
60603	16.3	110.89	0.1862	0.023709	0.019047	998.92	1.3396	0.18711	2
60604	16.3	111.46	0.1884	0.023709	0.019672	998.92	1.3465	0.05472	2
60605	16.4	112.37	0.1845	0.030203	0.019526	998.91	1.3573	0.06502	2
60606	16.4	112.67	0.1989	0.030203	0.020529	998.91	1.3608	0.05364	2
60607	16.4	112.63	0.2128	0.030203	0.021929	998.91	1.3604	0.05796	2
60608	16.4	112.94	0.2257	0.029874	0.023141	998.91	1.3638	0.06041	2
60609	16.4	112.85	0.2614	0.030284	0.024687	998.91	1.3628	0.04923	2
60610	16.4	115.57	0.2466	0.042307	0.023840	998.91	1.3956	0.10817	2
60611	16.4	117.80	0.2184	0.050098	0.022942	998.91	1.4226	0.13494	2
60612	16.5	117.25	0.1973	0.050098	0.021667	998.89	1.4154	0.11474	2
60613	16.6	111.57	0.2578	0.022094	0.024735	998.87	1.3463	0.07326	42

TABLE B.3.10 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
60614	16.6	111.33	0.2196	0.022094	0.023321	998.87	1.3435	0.04639	42
60615	16.6	111.01	0.1876	0.022205	0.020847	998.87	1.3397	0.04011	42
60616	16.6	112.02	0.1862	0.027645	0.020040	998.86	1.3516	0.05237	2
60617	16.7	112.24	0.2093	0.027645	0.021633	998.86	1.3540	0.04393	2
60618	16.7	112.51	0.2444	0.027645	0.024747	998.86	1.3572	0.05492	2
140801	17.6	111.29	0.3141	0.009252	0.005808	998.70	1.3384	0.00785	3
140802	17.6	111.79	0.3133	0.009191	0.006980	998.70	1.3445	0.00696	3
140803	17.7	112.08	0.3098	0.009170	0.008517	998.68	1.3475	0.00853	3
140804	17.7	112.23	0.3089	0.009129	0.009633	998.68	1.3492	0.00667	3
140805	17.7	112.32	0.3087	0.009108	0.012196	998.68	1.3503	0.00637	3
140806	17.8	112.10	0.3092	0.009108	0.014161	998.66	1.3472	0.00686	3
140807	17.8	112.35	0.3100	0.009108	0.016296	998.66	1.3502	0.00863	3
140808	17.9	112.17	0.3087	0.009108	0.018813	998.64	1.3475	0.01000	3

TABLE B.3.11 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
140809	17.8	112.18	0.3121	0.009108	0.020904	998.66	1.3481	0.00853	3
140810	17.8	112.33	0.3112	0.009108	0.023286	998.66	1.3499	0.00951	3
140811	17.8	112.50	0.3128	0.009108	0.025491	998.66	1.3520	0.00824	3
140812	17.8	112.55	0.3135	0.009108	0.029138	998.66	1.3526	0.00785	3
140813	17.8	112.46	0.3170	0.009004	0.030947	998.66	1.3515	0.00667	3
140814	17.8	112.44	0.3183	0.008899	0.034092	998.66	1.3512	0.00941	34
140815	17.8	112.37	0.3239	0.008899	0.036057	998.66	1.3504	0.00902	34
140816	17.7	112.51	0.2690	0.011505	0.036004	998.68	1.3526	0.00883	34
150801	18.5	111.84	0.2189	0.011273	0.005917	998.53	1.3409	0.00843	3
150802	18.6	111.98	0.2200	0.011206	0.008614	998.51	1.3421	0.00892	3
150803	18.7	112.15	0.2225	0.011139	0.011700	998.49	1.3436	0.00696	3
150804	18.7	112.10	0.2190	0.010985	0.014251	998.49	1.3430	0.00912	3
150805	18.8	112.09	0.2202	0.010985	0.016445	998.47	1.3424	0.00873	3

TABLE B.3.12 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
150806	18.9	112.00	0.2274	0.010985	0.019164	998.46	1.3409	0.01471	3
150807	19.0	112.34	0.2265	0.010951	0.021022	998.44	1.3445	0.01010	3
150808	19.1	111.90	0.2287	0.010951	0.023223	998.42	1.3388	0.00873	34
150809	19.1	112.10	0.2366	0.010882	0.025924	998.42	1.3412	0.00814	34
150810	19.1	111.93	0.2472	0.010882	0.029459	998.42	1.3391	0.02167	34
150811	19.2	111.93	0.2613	0.010882	0.030966	998.40	1.3388	0.00814	4
150812	19.3	111.35	0.1450	0.013156	0.005722	998.38	1.3313	0.01177	3
150813	19.4	112.14	0.2928	0.013142	0.009692	998.36	1.3403	0.00922	3
150814	19.4	111.31	0.6409	0.005211	0.005792	998.36	1.3304	0.00785	3
150815	19.6	111.23	0.7301	0.004951	0.007910	998.32	1.3285	0.00657	3
150816	19.6	111.21	0.7320	0.004951	0.010087	998.32	1.3282	0.00441	3
200801	19.4	111.60	0.3907	0.006838	0.005851	998.36	1.3338	0.00657	3
200802	19.4	111.58	0.3885	0.006920	0.007864	998.36	1.3336	0.00530	3

TABLE B.3.13 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
200803	19.4	111.80	0.3873	0.006866	0.009183	998.36	1.3362	0.00618	3
200804	19.5	111.78	0.3855	0.006866	0.010046	998.34	1.3356	0.00637	3
200805	19.5	111.83	0.3836	0.006866	0.011697	998.34	1.3362	0.00510	3
200806	19.6	111.88	0.3864	0.006866	0.014066	998.32	1.3363	0.00559	3
200807	19.6	111.93	0.3843	0.006866	0.015731	998.32	1.3369	0.00412	3
200808	19.6	111.98	0.3838	0.006866	0.018771	998.32	1.3375	0.00637	3
200809	19.7	111.80	0.3833	0.006866	0.021071	998.30	1.3349	0.00530	3
200810	19.7	111.92	0.3849	0.006866	0.023543	998.30	1.3362	0.00588	3
200811	19.8	111.86	0.3858	0.006866	0.026073	998.28	1.3351	0.00490	3
200812	19.8	111.72	0.3871	0.006866	0.029862	998.28	1.3335	0.00549	3
200813	19.9	111.71	0.3848	0.006866	0.031943	998.26	1.3328	0.00628	3
200814	19.9	111.67	0.3856	0.006866	0.033789	998.26	1.3324	0.00824	3
200815	20.0	111.88	0.3898	0.006866	0.037016	998.23	1.3345	0.00647	3

TABLE B.3.14 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
200816	20.1	111.86	0.3922	0.006866	0.040232	998.21	1.3337	0.00755	3
210801	19.9	111.47	0.4663	0.005695	0.005742	998.26	1.3300	0.00412	3
210802	20.0	111.48	0.4764	0.005695	0.007251	998.23	1.3297	0.00431	3
210803	20.1	111.51	0.4734	0.005695	0.008809	998.21	1.3295	0.00608	3
210804	20.1	111.54	0.4786	0.005595	0.010793	998.21	1.3300	0.00569	3
210805	20.2	111.44	0.4777	0.005662	0.013269	998.19	1.3283	0.00520	3
210806	20.3	111.47	0.4712	0.005628	0.015640	998.17	1.3282	0.00559	3
210807	20.4	111.54	0.4705	0.005662	0.018722	998.15	1.3286	0.00481	3
210808	20.4	111.59	0.4750	0.005662	0.021596	998.15	1.3292	0.00559	3
210809	20.5	111.63	0.4753	0.005662	0.023645	998.13	1.3292	0.00461	3
210810	20.6	111.66	0.4764	0.005662	0.026058	998.11	1.3291	0.00628	3
210811	20.7	111.74	0.4766	0.005662	0.029561	998.09	1.3296	0.00559	3
210812	20.9	111.55	0.4542	0.005662	0.032404	998.04	1.3264	0.00520	3

TABLE B.3.15 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

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TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
290809	21.0	111.50	0.5362	0.004984	0.034712	998.02	1.3254	0.00539	3
290810	21.1	111.50	0.5340	0.004984	0.037519	998.00	1.3250	0.00579	34
290811	21.2	111.59	0.4472	0.005867	0.031103	997.98	1.3255	0.00284	3
290812	21.3	111.44	0.4372	0.005867	0.020381	997.96	1.3234	0.00530	3
40901	20.0	111.26	0.5811	0.005161	0.006176	998.23	1.3270	0.00500	3
40902	20.1	111.34	0.5767	0.005044	0.010073	998.21	1.3275	0.00647	3
40903	20.2	111.25	0.5776	0.004893	0.013331	998.19	1.3260	0.00461	3
40904	20.2	111.31	0.5799	0.004801	0.017505	998.19	1.3267	0.00539	3
40905	20.3	111.35	0.5765	0.004801	0.021667	998.17	1.3267	0.00530	3
40906	20.4	111.26	0.5767	0.004863	0.024892	998.15	1.3252	0.00510	3
40907	20.5	111.20	0.5842	0.004610	0.029411	998.13	1.3241	0.00539	3
40908	20.6	111.36	0.5854	0.004610	0.033551	998.11	1.3256	0.00402	3
40909	20.7	111.40	0.5836	0.004610	0.036738	998.09	1.3255	0.00461	4

TABLE B.3.17 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
40910	20.8	111.39	0.4039	0.006767	0.036571	998.07	1.3250	0.00481	3
40911	20.8	111.48	0.3926	0.006811	0.034294	998.07	1.3260	0.00500	3
40912	20.9	111.67	0.3921	0.006789	0.031511	998.04	1.3278	0.00549	3
40913	21.0	111.85	0.3916	0.006723	0.026366	998.02	1.3295	0.00530	3
40914	21.0	111.86	0.3827	0.006700	0.016328	998.02	1.3296	0.00481	3
50901	19.9	111.77	0.3526	0.007888	0.011999	998.26	1.3335	0.00677	3
50902	20.0	111.64	0.3614	0.007936	0.027383	998.23	1.3316	0.00647	3
50903	20.1	111.37	0.5569	0.004738	0.027336	998.21	1.3279	0.00451	3
50904	20.1	111.27	0.5807	0.004769	0.036464	998.21	1.3267	0.00471	4
50905	20.2	111.50	0.3327	0.008941	0.036212	998.19	1.3290	0.00745	34
50906	20.3	111.45	0.3134	0.008983	0.024563	998.17	1.3279	0.00588	3
50907	20.4	111.31	0.3067	0.008920	0.015331	998.15	1.3258	0.00785	3
50908	20.5	111.58	0.2515	0.009978	0.010243	998.13	1.3285	0.00794	3

TABLE B.3.18 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
50909	20.6	111.80	0.2522	0.010128	0.015552	998.11	1.3308	0.00598	3
100901	19.0	111.39	0.4764	0.005790	0.005509	998.44	1.3331	0.00549	3
100902	19.1	111.42	0.4719	0.005790	0.006338	998.42	1.3330	0.00588	3
100903	19.3	111.52	0.4764	0.005790	0.008895	998.38	1.3333	0.00745	3
100904	19.3	111.54	0.4767	0.005790	0.012873	998.38	1.3336	0.00579	3
100905	19.4	111.58	0.4753	0.005790	0.016958	998.36	1.3335	0.00706	3
100906	19.5	111.55	0.4777	0.005790	0.022158	998.34	1.3328	0.00549	3
100907	19.6	111.54	0.4830	0.005790	0.027206	998.32	1.3322	0.00628	3
100908	19.7	111.58	0.4803	0.005790	0.029139	998.30	1.3323	0.00382	3
100909	19.7	111.61	0.4813	0.005685	0.034344	998.30	1.3326	0.00481	3
100910	19.8	111.62	0.4876	0.005790	0.037867	998.28	1.3323	0.00500	3
100911	19.8	111.64	0.4918	0.005764	0.040334	998.28	1.3326	0.00500	3
100912	19.9	112.05	0.4946	0.005790	0.043020	998.26	1.3369	0.00382	4

TABLE B.3.19 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
120901	18.7	111.13	0.6963	0.002996	0.005473	998.49	1.3314	0.00490	3
120902	18.8	111.22	0.7120	0.003670	0.007845	998.47	1.3321	0.00363	3
120903	18.9	111.21	0.7120	0.003328	0.011583	998.46	1.3314	0.00441	3
120904	19.0	111.02	0.7115	0.003328	0.018193	998.44	1.3287	0.00500	3
120905	19.1	111.11	0.6507	0.003907	0.018084	998.42	1.3294	0.00382	3
120906	19.1	111.15	0.6502	0.003907	0.015160	998.42	1.3299	0.00382	3
120907	19.3	111.22	0.6502	0.003907	0.012468	998.38	1.3297	0.00530	3
120908	19.4	111.25	0.6474	0.003907	0.010374	998.36	1.3297	0.00392	3
120909	19.4	111.25	0.6466	0.003868	0.007582	998.36	1.3297	0.00451	3
120910	19.5	111.16	0.6465	0.003868	0.005579	998.34	1.3281	0.00647	3
120911	19.6	111.30	0.6506	0.003710	0.020308	998.32	1.3294	0.00363	3
120912	19.7	111.41	0.6525	0.003670	0.023462	998.30	1.3302	0.00490	3
120913	20.1	111.57	0.5630	0.004769	0.041016	998.21	1.3303	0.00373	4

TABLE B.3.20 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
120914	20.2	111.35	0.5714	0.004801	0.038475	998.19	1.3272	0.00569	34
120915	20.2	111.43	0.5710	0.004769	0.035954	998.19	1.3281	0.00618	3
120916	20.3	111.39	0.5649	0.004801	0.033664	998.17	1.3273	0.00500	3
120917	20.4	111.41	0.5634	0.004893	0.029842	998.15	1.3271	0.00530	3
120918	20.5	111.51	0.5576	0.004832	0.025560	998.13	1.3278	0.00539	3
120919	20.6	111.51	0.5552	0.004863	0.018883	998.11	1.3273	0.00490	3
120920	20.6	111.48	0.5529	0.004893	0.015755	998.11	1.3269	0.00520	3
120921	20.7	111.48	0.5511	0.004924	0.011659	998.09	1.3265	0.00569	3
120922	20.7	111.53	0.5526	0.004924	0.008399	998.09	1.3271	0.00598	3
120923	20.8	111.43	0.5516	0.004924	0.006330	998.07	1.3254	0.00559	3
120924	20.8	111.05	0.5537	0.004954	0.002842	998.07	1.3209	0.00579	3
10401	13.4	111.67	0.6323	0.020230	0.056970	999.35	1.3627	0.10630	42
10402	13.6	112.66	0.5992	0.024121	0.054511	999.33	1.3740	0.06306	42

TABLE B.3.21 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
10403	13.7	115.08	0.5662	0.029957	0.053477	999.31	1.4028	0.12670	2
10404	13.1	114.93	0.6720	0.023605	0.087276	999.38	1.4036	0.11435	42
10405	13.4	116.88	0.6342	0.030121	0.084684	999.36	1.4265	0.09611	42
10406	13.4	119.82	0.6181	0.035736	0.081821	999.35	1.4619	0.15906	2
10407	13.6	121.24	0.6185	0.038204	0.080583	999.33	1.4785	0.17397	2
10408	13.8	123.36	0.6080	0.043343	0.079544	999.31	1.5035	0.17054	2
10409	13.1	115.72	0.6234	0.029037	0.079632	999.40	1.4138	0.09473	42
10410	13.2	118.59	0.5804	0.037289	0.074490	999.38	1.4482	0.14337	2
10411	13.4	117.12	0.7610	0.019861	0.134577	999.36	1.4295	0.16465	2
10412	13.6	115.78	0.7785	0.019985	0.141532	999.33	1.4122	0.15828	2
20401	14.8	121.62	0.5235	0.048751	0.062185	999.16	1.4771	0.13671	2
20402	14.9	125.62	0.5960	0.048345	0.084942	999.14	1.5249	0.19378	2
20403	14.9	125.79	0.5942	0.048345	0.083163	999.14	1.5267	0.19515	2

TABLE B.3.22 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
20404	16.0	110.04	0.7252	0.010835	0.092536	998.96	1.3305	0.09258	42
20405	16.0	111.03	0.8114	0.010653	0.113894	998.97	1.3427	0.13523	42
20406	15.9	111.64	0.7611	0.010653	0.153797	998.98	1.3503	0.05443	4
20407	15.9	109.29	0.7695	0.007662	0.214601	999.00	1.3223	0.02393	4
20408	16.9	110.91	0.6898	0.008847	0.148093	998.83	1.3373	0.03119	4
20409	16.9	111.37	0.7388	0.008847	0.171058	998.83	1.3428	0.03099	4
20410	16.9	112.17	0.7456	0.008847	0.198288	998.83	1.3525	0.02903	4
40401	13.9	110.05	0.5850	0.012820	0.067994	999.29	1.3408	0.06767	42
40402	13.9	110.05	0.7266	0.012820	0.087695	999.29	1.3408	0.05502	42
40403	13.9	112.86	0.8133	0.012511	0.113465	999.29	1.3750	0.08561	42
40404	13.9	113.18	0.8208	0.012511	0.119990	999.29	1.3790	0.08954	42
40405	14.9	113.43	0.8306	0.013270	0.149395	999.15	1.3771	0.05864	42
40406	14.9	119.28	0.8141	0.019077	0.173754	999.15	1.4481	0.19309	44

TABLE B.3.23 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
40407	14.9	117.20	0.8092	0.020174	0.185221	999.15	1.4229	0.17740	44
40408	15.9	115.72	0.8446	0.013988	0.189981	998.98	1.3996	0.11317	44
40409	15.8	118.53	0.8282	0.013847	0.232656	999.01	1.4346	0.10827	44
40410	15.9	117.76	0.6284	0.031793	0.083836	998.99	1.4246	0.09503	42
50401	14.1	114.85	0.6951	0.025023	0.092875	999.26	1.3983	0.19202	42
50402	13.9	117.94	0.7598	0.024228	0.126464	999.28	1.4364	0.15524	2
50403	13.9	120.88	0.8112	0.023407	0.160946	999.28	1.4723	0.26694	44
50404	13.9	125.84	0.5036	0.055023	0.069322	999.29	1.5332	0.16103	2
60401	14.4	114.17	0.6053	0.033456	0.082084	999.22	1.3886	0.07620	2
60402	14.4	119.39	0.7515	0.031948	0.125703	999.22	1.4520	0.17024	2
60403	14.4	122.39	0.7670	0.031793	0.142156	999.22	1.4885	0.24056	2
60404	14.3	105.64	0.7376	0.009891	0.192106	999.24	1.2853	0.06904	4
60405	15.9	117.90	0.6199	0.037749	0.089076	999.00	1.4264	0.07620	2

TABLE B.3.24 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
60406	15.9	122.27	0.6520	0.042423	0.105104	999.00	1.4794	0.20810	2
60407	15.9	125.94	0.6971	0.041661	0.125506	998.98	1.5233	0.28577	2
90401	13.6	110.27	0.8167	0.009279	0.277178	999.33	1.3447	0.09787	4
90402	13.7	107.64	0.7631	0.008623	0.212547	999.31	1.3122	0.03177	4
90403	13.6	108.30	0.7776	0.008847	0.228232	999.33	1.3209	0.03776	4
90404	13.5	103.91	0.0000	0.014671	0.258547	999.34	1.2676	0.13563	42
90405	14.6	111.79	0.7296	0.023573	0.109815	999.19	1.3587	0.11425	2
90406	14.6	117.24	0.7954	0.023656	0.145252	999.19	1.4247	0.24272	2
90407	14.6	117.40	0.7556	0.030688	0.137270	999.18	1.4264	0.13053	2
150401	12.4	133.04	0.4792	0.065383	0.062760	999.47	1.6289	0.25115	2
150402	12.6	136.51	0.5328	0.064853	0.078281	999.45	1.6705	0.35971	2
150403	12.6	139.23	0.5626	0.064663	0.082335	999.45	1.7034	0.31038	2
150404	12.8	142.93	0.5870	0.064204	0.096656	999.43	1.7481	0.36795	2

TABLE B.3.25 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
150405	12.3	142.07	0.5772	0.064549	0.092651	999.49	1.7406	0.40825	2
150406	12.4	146.61	0.6265	0.064050	0.099816	999.48	1.7953	0.42120	2
150407	12.4	151.58	0.6476	0.063780	0.120946	999.47	1.8559	0.65175	2
150408	11.9	148.38	0.6697	0.063392	0.133278	999.54	1.8205	0.54319	2
150409	11.7	113.25	0.8386	0.010087	0.267344	999.56	1.3902	0.11444	4
150410	11.3	112.46	0.7463	0.010279	0.204653	999.60	1.3827	0.08669	4
150411	11.3	112.66	0.7664	0.010279	0.200970	999.60	1.3852	0.12052	4
150412	11.4	111.18	0.5607	0.010279	0.063258	999.58	1.3661	0.03079	4
180401	11.1	118.82	0.8084	0.030849	0.134799	999.61	1.4614	0.23477	2
180402	11.1	124.34	0.7779	0.039097	0.128005	999.61	1.5293	0.31725	2
180403	11.1	127.84	0.7337	0.044632	0.123354	999.61	1.5724	0.36746	2
180404	11.1	132.96	0.7298	0.049900	0.122710	999.62	1.6356	0.37540	2
180405	11.1	138.52	0.7201	0.055380	0.128377	999.62	1.7041	0.50102	2

TABLE B.3.26 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
180406	11.6	141.17	0.7311	0.057649	0.131784	999.56	1.7333	0.39423	2
180407	11.6	145.38	0.6946	0.063741	0.125897	999.56	1.7850	0.43591	2
180408	11.6	148.83	0.7114	0.063548	0.135994	999.57	1.8280	0.89457	2
180409	11.6	140.42	0.7435	0.058202	0.150248	999.57	1.7246	0.53927	2
180410	11.6	139.28	0.7143	0.055068	0.124554	999.57	1.7107	0.58016	2
180411	11.6	136.34	0.7401	0.049154	0.137943	999.57	1.6745	0.50299	2
180412	12.3	137.97	0.7915	0.043908	0.157694	999.49	1.6904	0.52623	2
180413	12.2	133.00	0.8236	0.036555	0.164225	999.50	1.6298	0.49906	42
180414	12.2	130.62	0.8340	0.031403	0.169707	999.50	1.6006	0.35412	42
180415	12.3	126.00	0.8672	0.023709	0.187125	999.49	1.5438	0.38197	42
180416	12.3	125.71	0.8719	0.024019	0.199465	999.49	1.5402	0.23458	42
190401	13.4	121.47	0.8615	0.028696	0.184726	999.35	1.4820	0.28420	42
190402	13.4	133.62	0.8488	0.036487	0.185307	999.35	1.6303	0.61802	42

TABLE B.3.27 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
190403	13.4	134.99	0.7924	0.044355	0.163758	999.35	1.6469	0.58732	42
190404	13.5	140.93	0.7785	0.050147	0.159528	999.34	1.7191	0.67529	2
190405	15.0	153.66	0.7398	0.063237	0.157672	999.13	1.8646	0.73501	42
190406	14.9	135.81	0.8325	0.037814	0.184514	999.14	1.6484	0.68353	42
190407	14.9	120.14	0.8826	0.020108	0.215949	999.14	1.4581	0.37148	44
190408	14.9	122.99	0.8922	0.020592	0.231026	999.14	1.4927	0.17721	44
210401	14.1	113.22	0.3954	0.013847	0.053049	999.26	1.3785	0.05943	34
210402	14.1	111.81	0.6966	0.013847	0.073009	999.26	1.3611	0.10611	42
210403	14.1	112.49	0.7857	0.013847	0.086226	999.25	1.3691	0.14131	42
210404	14.1	113.10	0.8620	0.013705	0.102508	999.25	1.3765	0.15926	42
210405	14.2	113.28	0.8786	0.013562	0.114342	999.24	1.3784	0.19545	42
210406	14.3	114.78	0.8644	0.013417	0.124092	999.24	1.3965	0.15563	42
210407	14.3	116.85	0.8738	0.013417	0.129773	999.23	1.4215	0.13965	42

TABLE B.3.28 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
210408	13.1	117.96	0.8685	0.016071	0.149390	999.40	1.4412	0.04913	2
210409	13.1	116.43	0.8855	0.015949	0.140454	999.38	1.4220	0.10974	2
210410	13.1	115.52	0.8725	0.015949	0.131726	999.38	1.4109	0.16328	42
210411	13.3	115.90	0.8339	0.015826	0.114130	999.37	1.4151	0.21947	42
210412	13.3	116.27	0.8475	0.015702	0.100659	999.37	1.4196	0.18701	42
210413	13.4	112.07	0.7003	0.016786	0.066643	999.35	1.3676	0.14504	42
210414	13.4	111.92	0.4725	0.016902	0.052542	999.35	1.3655	0.09483	42
10501	13.8	109.72	0.3832	0.009487	0.051411	999.30	1.3371	0.01589	4
10502	13.9	110.67	0.6915	0.016071	0.069269	999.29	1.3483	0.08699	42
10503	13.9	113.73	0.8112	0.015949	0.084304	999.28	1.3851	0.11954	42
10504	13.9	113.46	0.8303	0.015949	0.090269	999.28	1.3818	0.12709	42
10505	13.9	113.73	0.8588	0.016192	0.110031	999.28	1.3851	0.13317	42
10506	14.0	112.64	0.8318	0.009487	0.122968	999.27	1.3717	0.09297	4

TABLE B.3.29 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

TEST RUN NO	TEMP C	P MEAN KN/M2	VOID FRCTN	WATER FLOW RATE M3/SEC	AIR FLOW RATE M3/SEC	DENSITY WATER KG/M3	DENSITY AIR KG/M3	PR-GRAD KN/M3	FLOW PATTERN
10507	14.1	118.15	0.8442	0.019281	0.122824	999.26	1.4385	0.23360	2
10508	13.3	116.06	0.6601	0.023289	0.065086	999.37	1.4167	0.09562	42
10509	13.4	119.35	0.6283	0.031482	0.062587	999.36	1.4567	0.11562	2
10510	13.4	121.71	0.5967	0.038653	0.061055	999.36	1.4855	0.13710	2
10511	13.4	125.30	0.5506	0.047573	0.059124	999.35	1.5290	0.14102	2
10512	13.4	129.13	0.5541	0.052968	0.069004	999.35	1.5754	0.17338	2
10513	13.5	134.94	0.5218	0.065270	0.066078	999.34	1.6460	0.29116	2
10514	13.6	141.53	0.6051	0.064739	0.090162	999.33	1.7261	0.35892	2

TABLE B.3.30 WATER AND GAS FLOW RATES AND DENSITIES DERIVED FROM EXPERIMENTAL READINGS

APPENDIX B

B.4 COMPARISON OF FRICTION PRESSURE DROP DATA.

FROM **Table B.4.1** TO **Table B.4.30**

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER: EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
220102	0.3062	0.00899	0.819	0.002608	2.725	0.008682	--	--	3.255	5.207	3.813	2.669
220103	0.3884	0.04505	2.177	0.006430	2.343	0.006919	--	--	2.529	4.060	2.692	2.802
220104	0.4065	0.05081	1.459	0.004246	2.049	0.005964	--	--	2.133	3.272	2.291	2.710
220105	0.3786	0.08503	1.683	0.004955	1.853	0.005457	--	--	1.931	2.814	2.067	2.454
220106	0.3700	0.07934	1.245	0.003736	1.732	0.005200	--	--	1.826	2.562	1.944	2.312
220107	0.3600	0.10592	1.471	0.004383	1.703	0.005074	--	--	1.762	2.413	1.883	2.270
220108	0.0692	0.10759	1.329	0.003967	1.659	0.004953	--	--	1.716	2.292	1.831	1.653
220109	0.3390	0.13078	1.654	0.004987	1.663	0.005014	--	--	1.720	2.319	1.839	2.174
280101	0.2660	0.00743	0.919	0.003259	3.000	0.010636	--	--	3.922	6.172	4.871	2.711
280102	0.3434	0.00635	1.138	0.004342	3.218	0.012281	--	--	4.578	7.042	6.120	2.963
280103	0.3004	0.00911	0.853	0.002850	2.727	0.009113	--	--	3.331	5.349	3.927	2.660
280104	0.1609	0.00736	0.649	0.002135	1.663	0.005471	--	--	1.956	3.115	2.216	1.872
280105	0.3007	0.00635	1.032	0.003812	1.798	0.006637	--	--	2.366	3.866	2.981	2.265

TABLE B.4.1 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER: EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
280106	0.1882	0.00781	0.915	0.003162	1.700	0.005877	--	--	2.098	3.399	2.489	1.977
280107	0.0000	0.02099	1.440	0.004531	1.596	0.005020	--	--	1.793	2.778	1.955	0.000
280108	0.2580	0.00991	0.680	0.002132	2.288	0.007178	--	--	2.597	4.215	2.898	2.371
280109	0.3166	0.05812	2.683	0.008205	2.133	0.006520	--	--	2.293	3.706	2.453	2.440
280110	0.3207	0.04688	1.590	0.004801	2.012	0.006075	--	--	2.112	3.320	2.269	2.415
280111	0.2937	0.05791	1.520	0.004498	1.865	0.005522	--	--	1.937	2.911	2.072	2.273
280112	0.2350	0.20059	1.199	0.003857	1.358	0.004367	--	--	1.401	1.890	1.477	1.646
280113	0.2489	0.19822	1.328	0.004209	1.385	0.004390	--	--	1.430	1.922	1.508	1.699
280114	0.2642	0.16113	1.329	0.004126	1.443	0.004478	--	--	1.491	1.989	1.576	1.787
280115	0.2793	0.13202	1.354	0.004133	1.508	0.004603	--	--	1.559	2.061	1.652	1.883
280116	0.2960	0.08913	1.164	0.003500	1.591	0.004784	--	--	1.645	2.186	1.749	1.999
280117	0.3039	0.09084	1.430	0.004349	1.637	0.004980	--	--	1.723	2.390	1.830	2.051
280118	0.3085	0.07873	1.703	0.005030	1.793	0.005298	--	--	1.862	2.722	1.991	2.204

TABLE B.4.2 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
280119	0.4640	0.10198	2.254	0.006740	2.097	0.006271	--	--	2.184	3.312	2.362	2.983
280120	0.5017	0.05602	2.396	0.007196	2.558	0.007681	--	--	2.744	4.456	2.951	3.446
290101	0.3874	0.00608	1.336	0.004747	4.075	0.014478	--	--	5.971	8.598	8.245	3.287
290102	0.3412	0.00764	1.148	0.003758	3.687	0.012066	--	--	4.937	7.318	6.288	3.053
290103	0.3470	0.00862	1.005	0.003114	3.469	0.010743	--	--	4.383	6.609	5.304	2.999
290104	0.2719	0.02945	3.404	0.010727	3.093	0.009747	--	--	3.908	5.995	4.708	2.732
290105	0.1893	0.00807	0.951	0.002927	2.322	0.007151	--	--	2.794	4.422	3.344	2.292
290106	0.3360	0.00603	0.844	0.002686	1.873	0.005960	--	--	2.350	3.738	2.854	2.346
70201	0.6588	0.00404	0.764	0.002902	1.135	0.004311	1.3572	0.0052	1.258	1.622	1.393	2.238
70202	0.7140	0.00398	0.826	0.003204	1.153	0.004476	1.3766	0.0054	1.294	1.681	1.457	2.580
70203	0.7237	0.00355	0.774	0.003028	1.350	0.005277	--	--	1.659	2.541	2.032	3.205
70204	0.7244	0.00398	0.916	0.003624	1.334	0.005278	--	--	1.632	2.486	2.003	3.147
70205	0.7236	0.00382	1.481	0.006533	1.532	0.006755	--	--	2.052	3.321	2.872	3.430

TABLE B.4.3 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
70206	0.0856	0.00565	0.735	0.002571	1.621	0.005672	--	--	2.008	3.245	2.408	1.817
70207	0.2804	0.00657	1.122	0.004128	1.820	0.006696	--	--	2.395	3.927	3.059	2.247
110201	0.3237	0.00603	1.112	0.004075	2.320	0.008501	--	--	3.166	5.096	4.183	2.606
110202	0.2642	0.00748	1.160	0.004091	2.428	0.008562	--	--	3.163	5.094	4.060	2.509
110203	0.2665	0.00684	1.062	0.003739	2.613	0.009204	--	--	3.382	5.412	4.362	2.575
110204	0.2723	0.00662	1.029	0.003617	2.832	0.009951	--	--	3.757	5.937	4.872	2.681
110205	0.2792	0.00824	1.282	0.004486	3.077	0.010770	--	--	4.098	6.397	5.334	2.771
110206	0.2878	0.00630	0.980	0.003428	3.336	0.011664	--	--	4.461	6.880	5.828	2.862
110207	0.3179	0.01426	2.295	0.008074	3.603	0.012676	--	--	4.866	7.413	6.426	2.994
110208	0.3414	0.01954	3.098	0.010798	3.758	0.013102	--	--	5.062	7.657	6.671	3.080
110210	0.3676	0.00969	1.092	0.003624	3.567	0.011834	4.9382	0.0157	4.450	6.934	5.518	3.087
110213	0.1577	0.02218	1.256	0.003719	1.627	0.004817	--	--	1.750	2.652	1.859	1.760
110214	0.2212	0.03031	1.718	0.005083	1.898	0.005617	--	--	2.063	3.256	2.216	2.068

TABLE B.4.4 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
110215	0.3087	0.02930	1.678	0.004962	2.214	0.006548	--	--	2.418	3.879	2.617	2.454
110216	0.3796	0.01335	0.764	0.002312	2.597	0.007856	--	--	2.857	4.640	3.118	2.871
110217	0.4811	0.06152	3.555	0.010714	2.876	0.008667	--	--	3.184	5.143	3.479	3.473
110218	0.5253	0.04220	1.575	0.004600	2.546	0.007435	--	--	2.692	4.303	2.908	3.606
110219	0.0515	0.16319	0.957	0.002760	1.043	0.003009	1.1026	0.0025	1.051	1.186	1.065	1.087
110220	0.0604	0.15872	0.935	0.002710	1.057	0.003063	--	--	1.068	1.237	1.085	1.109
110221	0.0980	0.18744	1.105	0.003360	1.139	0.003463	--	--	1.163	1.473	1.195	1.230
110222	0.1200	0.15667	0.929	0.002841	1.177	0.003601	--	--	1.206	1.561	1.246	1.294
110223	0.1978	0.19052	1.129	0.003528	1.292	0.004038	--	--	1.331	1.782	1.396	1.518
110224	0.2577	0.21350	1.277	0.004014	1.389	0.004368	--	--	1.435	1.933	1.520	1.721
110225	0.3440	0.23125	1.391	0.004453	1.511	0.004839	--	--	1.562	2.101	1.678	2.037
300501	0.0000	0.05423	1.169	0.003200	1.090	0.002982	1.1635	0.0028	1.092	1.285	1.109	0.000
300502	0.0000	0.05080	1.126	0.003121	1.120	0.003106	1.1797	0.0030	1.122	1.359	1.143	0.000

TABLE B.4.5 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
300503	0.0000	0.08140	1.104	0.003020	1.065	0.002914	1.1440	0.0026	1.077	1.252	1.094	0.000
300504	0.0000	0.10042	1.366	0.003756	1.078	0.002966	1.1540	0.0027	1.093	1.293	1.112	0.000
300505	0.0016	0.11023	0.960	0.002685	1.060	0.002964	1.1295	0.0026	1.071	1.241	1.088	1.062
300506	0.0000	0.11131	0.968	0.002702	1.045	0.002916	1.1150	0.0025	1.054	1.191	1.068	0.000
300507	0.0036	0.15102	0.996	0.002843	1.051	0.002999	1.1148	0.0025	1.060	1.215	1.077	1.052
300508	0.0086	0.14808	0.977	0.002797	1.057	0.003027	--	--	1.068	1.237	1.085	1.062
300509	0.0104	0.12631	0.990	0.002807	1.070	0.003035	--	--	1.084	1.276	1.103	1.076
300510	0.0080	0.09954	0.859	0.002412	1.068	0.002999	--	--	1.081	1.267	1.099	1.072
300511	0.0060	0.10395	1.044	0.002909	1.079	0.003006	--	--	1.094	1.298	1.114	1.081
300512	0.0171	0.06070	1.086	0.003088	1.087	0.003092	--	--	1.140	1.401	1.163	1.097
300513	0.0058	0.04913	0.879	0.002494	1.076	0.003053	--	--	1.126	1.372	1.148	1.078
300514	0.0369	0.05835	1.039	0.003019	1.142	0.003317	--	--	1.205	1.535	1.236	1.167
300515	0.0216	0.07777	1.132	0.003193	1.140	0.003214	--	--	1.164	1.457	1.194	1.153

TABLE B.4.6 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
300516	0.0201	0.08345	0.841	0.002383	1.118	0.003168	--	--	1.139	1.406	1.166	1.130
300517	0.0271	0.08699	0.766	0.002211	1.113	0.003213	--	--	1.133	1.399	1.161	1.132
300518	0.0254	0.10326	0.766	0.002216	1.094	0.003166	--	--	1.112	1.351	1.136	1.112
300519	0.0275	0.14200	0.914	0.002666	1.097	0.003199	--	--	1.115	1.359	1.140	1.117
300520	0.0493	0.14445	0.929	0.002794	1.120	0.003369	--	--	1.141	1.429	1.173	1.160
300521	0.0505	0.09297	0.789	0.002313	1.145	0.003356	--	--	1.169	1.481	1.203	1.185
300522	0.0407	0.12317	1.232	0.003562	1.148	0.003321	--	--	1.174	1.485	1.207	1.179
300523	0.0582	0.09532	1.321	0.003778	1.199	0.003429	--	--	1.230	1.586	1.271	1.245
300524	0.0692	0.05737	1.135	0.003276	1.216	0.003512	--	--	1.279	1.663	1.322	1.271
300525	0.0451	0.05668	1.117	0.003212	1.182	0.003400	--	--	1.241	1.599	1.278	1.213
300526	0.0737	0.08473	1.705	0.004899	1.249	0.003590	--	--	1.314	1.716	1.361	1.307
300527	0.0798	0.06659	1.052	0.002988	1.240	0.003522	--	--	1.275	1.660	1.322	1.308
300528	0.0696	0.09061	1.191	0.003399	1.220	0.003481	--	--	1.253	1.625	1.297	1.277

TABLE B.4.7 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
300529	0.0652	0.11415	1.143	0.003283	1.177	0.003381	--	--	1.206	1.545	1.244	1.231
300530	0.0706	0.11180	0.874	0.002567	1.154	0.003391	--	--	1.180	1.504	1.217	1.215
310501	0.1007	0.05551	1.131	0.003272	1.294	0.003745	--	--	1.361	1.789	1.417	1.381
310502	0.1451	0.06139	1.250	0.003630	1.358	0.003943	--	--	1.430	1.884	1.497	1.499
310503	0.1306	0.06198	0.993	0.002848	1.331	0.003819	--	--	1.373	1.811	1.437	1.458
310504	0.0978	0.13602	1.359	0.003966	1.233	0.003598	--	--	1.268	1.659	1.317	1.323
310505	0.1157	0.16269	1.274	0.003795	1.209	0.003603	--	--	1.242	1.623	1.289	1.321
310506	0.1482	0.13975	1.105	0.003292	1.240	0.003697	--	--	1.276	1.681	1.329	1.394
310507	0.1349	0.14779	0.962	0.002923	1.208	0.003670	--	--	1.240	1.629	1.290	1.344
310508	0.1347	0.11758	1.260	0.003676	1.268	0.003700	--	--	1.306	1.720	1.362	1.403
310509	0.1528	0.07708	1.241	0.003543	1.356	0.003874	--	--	1.399	1.846	1.467	1.513
310510	0.1669	0.05041	1.135	0.003262	1.406	0.004041	--	--	1.473	1.937	1.548	1.577
310511	0.1849	0.05678	1.284	0.003690	1.478	0.004246	--	--	1.550	2.026	1.636	1.671

TABLE B.4.8 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
50601	0.0000	0.04717	1.512	0.004179	1.133	0.003131	1.2008	0.0031	1.151	1.422	1.176	0.000
50602	0.0599	0.06041	2.633	0.007321	1.177	0.003273	--	--	1.217	1.547	1.249	1.230
50603	0.0585	0.01393	0.354	0.000986	1.154	0.003214	--	--	1.160	1.443	1.187	1.191
50604	0.0713	0.05972	1.518	0.004277	1.190	0.003352	--	--	1.193	1.511	1.225	1.234
50605	0.0743	0.04040	1.376	0.003846	1.204	0.003367	--	--	1.227	1.570	1.263	1.259
50606	0.0947	0.05580	1.899	0.005375	1.334	0.003776	--	--	1.349	1.766	1.403	1.390
50607	0.1004	0.05757	1.510	0.004294	1.260	0.003582	--	--	1.303	1.699	1.350	1.368
50608	0.0970	0.06482	2.805	0.007927	1.332	0.003766	--	--	1.375	1.799	1.430	1.407
50609	0.1255	0.05982	2.590	0.007352	1.416	0.004019	--	--	1.452	1.903	1.520	1.510
50610	0.1516	0.07228	3.130	0.008839	1.459	0.004120	--	--	1.490	1.947	1.563	1.579
50611	0.1373	0.06835	1.930	0.005486	1.341	0.003812	--	--	1.387	1.823	1.449	1.496
50612	0.1212	0.04305	1.062	0.003033	1.310	0.003741	--	--	1.360	1.785	1.416	1.453
50613	0.1438	0.04933	1.216	0.003481	1.354	0.003875	--	--	1.407	1.851	1.471	1.534

TABLE B.4.9 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER: EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
60601	0.1430	0.04786	1.844	0.005125	1.528	0.004248	--	--	1.587	2.050	1.672	1.654
60602	0.1685	0.06884	2.651	0.007371	1.583	0.004402	--	--	1.645	2.381	1.738	1.742
60603	0.1862	0.18711	7.204	0.020048	1.619	0.004506	--	--	1.683	2.460	1.781	1.804
60604	0.1884	0.05472	2.107	0.005893	1.639	0.004584	--	--	1.703	2.508	1.806	1.824
60605	0.1845	0.06502	1.609	0.004541	1.500	0.004234	--	--	1.560	2.028	1.644	1.693
60606	0.1989	0.05364	1.327	0.003756	1.525	0.004315	--	--	1.586	2.058	1.675	1.740
60607	0.2128	0.05796	1.434	0.004056	1.560	0.004412	--	--	1.622	2.096	1.716	1.796
60608	0.2257	0.06041	1.526	0.004323	1.597	0.004525	--	--	1.660	2.348	1.761	1.853
60609	0.2614	0.04923	1.212	0.003433	1.626	0.004606	--	--	1.692	2.404	1.797	1.950
60610	0.2466	0.10817	1.457	0.004201	1.446	0.004170	--	--	1.494	1.967	1.576	1.757
60611	0.2184	0.13494	1.336	0.003927	1.365	0.004012	--	--	1.409	1.869	1.481	1.625
60612	0.1973	0.11474	1.137	0.003322	1.345	0.003932	--	--	1.388	1.838	1.456	1.571
60613	0.2578	0.07326	3.196	0.008964	1.843	0.005168	--	--	1.925	2.974	2.057	2.124

TABLE B.4.10 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
60614	0.2196	0.04639	2.024	0.005665	1.796	0.005028	--	--	1.876	2.877	2.001	2.002
60615	0.1876	0.04011	1.735	0.004841	1.712	0.004777	--	--	1.787	2.695	1.899	1.875
60616	0.1862	0.05237	1.531	0.004278	1.565	0.004375	--	--	1.621	2.092	1.715	1.785
60617	0.2093	0.04393	1.284	0.003595	1.608	0.004502	--	--	1.666	2.384	1.768	1.873
60618	0.2444	0.05492	1.605	0.004503	1.692	0.004747	--	--	1.753	2.560	1.869	2.030
140801	0.3141	0.00785	1.399	0.004673	1.316	0.004396	--	--	1.545	2.004	1.832	1.758
140802	0.3133	0.00696	1.253	0.004215	1.380	0.004642	--	--	1.648	2.523	1.994	1.846
140803	0.3098	0.00853	1.543	0.005196	1.465	0.004935	--	--	1.779	2.801	2.197	1.944
140804	0.3089	0.00667	1.214	0.004098	1.528	0.005161	--	--	1.876	2.996	2.347	2.013
140805	0.3087	0.00637	1.163	0.003934	1.674	0.005662	--	--	2.092	3.405	2.675	2.152
140806	0.3092	0.00686	1.254	0.004225	1.790	0.006032	--	--	2.254	3.692	2.918	2.245
140807	0.3100	0.00863	1.576	0.005320	1.919	0.006480	--	--	2.431	3.996	3.181	2.334
140808	0.3087	0.01000	1.828	0.006150	2.079	0.006995	--	--	2.638	4.331	3.485	2.422

TABLE B.4.11 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
140809	0.3121	0.00853	1.556	0.005245	2.212	0.007457	--	--	2.809	4.601	3.733	2.494
140810	0.3112	0.00951	1.734	0.005852	2.372	0.008004	--	--	3.003	4.900	4.016	2.560
140811	0.3128	0.00824	1.501	0.005072	2.525	0.008532	--	--	3.182	5.170	4.276	2.620
140812	0.3135	0.00785	1.428	0.004828	2.691	0.009095	--	--	3.476	5.596	4.699	2.704
140813	0.3170	0.00667	1.235	0.004185	2.807	0.009513	--	--	3.650	5.840	4.961	2.755
140814	0.3183	0.00941	1.773	0.006029	3.002	0.010208	--	--	3.935	6.235	5.387	2.824
140815	0.3239	0.00902	1.699	0.005772	3.116	0.010588	--	--	4.094	6.450	5.615	2.871
140816	0.2690	0.00883	1.122	0.003548	2.838	0.008975	--	--	3.425	5.521	4.338	2.639
150801	0.2189	0.00843	1.123	0.003510	1.289	0.004030	--	--	1.463	1.909	1.664	1.580
150802	0.2200	0.00892	1.200	0.003756	1.427	0.004467	--	--	1.656	2.537	1.943	1.741
150803	0.2225	0.00696	0.946	0.002964	1.592	0.004991	--	--	1.872	2.985	2.257	1.902
150804	0.2190	0.00912	1.265	0.003978	1.738	0.005465	--	--	2.060	3.343	2.530	2.013
150805	0.2202	0.00873	1.211	0.003804	1.866	0.005858	--	--	2.211	3.615	2.744	2.098

TABLE B.4.12 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
150806	0.2274	0.01471	2.043	0.006399	2.031	0.006362	--	--	2.397	3.934	3.005	2.201
150807	0.2265	0.01010	1.411	0.004429	2.151	0.006752	--	--	2.528	4.156	3.193	2.258
150808	0.2287	0.00873	1.220	0.003809	2.296	0.007168	--	--	2.679	4.392	3.398	2.323
150809	0.2366	0.00814	1.148	0.003598	2.392	0.007493	--	--	2.874	4.699	3.673	2.408
150810	0.2472	0.02167	3.055	0.009557	2.581	0.008073	--	--	3.115	5.060	4.000	2.506
150811	0.2613	0.00814	1.149	0.003587	2.663	0.008316	--	--	3.217	5.210	4.140	2.564
150812	0.1450	0.01177	1.242	0.003670	1.261	0.003727	--	--	1.390	1.811	1.529	1.445
150813	0.2928	0.00922	0.975	0.002898	1.454	0.004323	--	--	1.631	2.097	1.859	1.858
150814	0.6409	0.00785	3.392	0.013215	1.479	0.005760	--	--	1.919	3.068	2.718	2.872
150815	0.7301	0.00657	3.073	0.012118	1.661	0.006551	--	--	2.287	3.735	3.432	3.784
150816	0.7320	0.00441	2.062	0.008129	1.827	0.007204	--	--	2.616	4.282	4.033	4.046
200801	0.3907	0.00657	1.890	0.006764	1.395	0.004992	--	--	1.723	2.678	2.237	2.012
200802	0.3885	0.00530	1.495	0.005329	1.520	0.005417	--	--	1.938	3.107	2.594	2.175

TABLE B.4.13 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
200803	0.3873	0.00618	1.765	0.006317	1.608	0.005756	--	--	2.090	3.395	2.855	2.273
200804	0.3855	0.00637	1.823	0.006513	1.665	0.005948	--	--	2.185	3.565	3.014	2.328
200805	0.3836	0.00510	1.457	0.005209	1.774	0.006340	--	--	2.366	3.879	3.313	2.422
200806	0.3864	0.00559	1.599	0.005706	1.935	0.006907	--	--	2.625	4.305	3.737	2.549
200807	0.3843	0.00412	1.177	0.004204	2.051	0.007323	--	--	2.806	4.591	4.030	2.618
200808	0.3838	0.00637	1.820	0.006502	2.270	0.008107	--	--	3.134	5.090	4.558	2.731
200809	0.3833	0.00530	1.513	0.005387	2.445	0.008702	--	--	3.381	5.446	4.950	2.803
200810	0.3849	0.00588	1.680	0.005986	2.637	0.009397	--	--	3.644	5.822	5.369	2.877
200811	0.3858	0.00490	1.401	0.004980	2.845	0.010114	--	--	3.911	6.191	5.793	2.944
200812	0.3871	0.00549	1.567	0.005563	3.062	0.010870	--	--	4.306	6.724	6.416	3.033
200813	0.3848	0.00628	1.792	0.006350	3.209	0.011370	--	--	4.521	7.009	6.759	3.071
200814	0.3856	0.00824	2.351	0.008326	3.336	0.011815	--	--	4.709	7.257	7.057	3.109
200815	0.3898	0.00647	1.848	0.006544	3.559	0.012606	--	--	5.036	7.689	7.585	3.180

TABLE B.4.14 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
200816	0.3922	0.00755	2.156	0.007622	3.779	0.013359	--	--	5.356	8.103	8.101	3.244
210801	0.4663	0.00412	1.569	0.005900	1.445	0.005434	--	--	1.840	2.916	2.531	2.247
210802	0.4764	0.00431	1.645	0.006175	1.553	0.005830	--	--	2.042	3.302	2.893	2.424
210803	0.4734	0.00608	2.319	0.008695	1.664	0.006239	--	--	2.248	3.672	3.261	2.550
210804	0.4786	0.00569	2.226	0.008396	1.816	0.006849	--	--	2.535	4.155	3.780	2.717
210805	0.4777	0.00520	1.999	0.007491	1.993	0.007467	--	--	2.845	4.643	4.305	2.852
210806	0.4712	0.00559	2.170	0.008135	2.178	0.008164	--	--	3.167	5.129	4.867	2.949
210807	0.4705	0.00481	1.849	0.006911	2.419	0.009038	--	--	3.555	5.688	5.521	3.064
210808	0.4750	0.00559	2.149	0.008033	2.656	0.009928	--	--	3.923	6.202	6.145	3.171
210809	0.4753	0.00461	1.773	0.006618	2.834	0.010579	--	--	4.183	6.556	6.588	3.231
210810	0.4764	0.00628	2.415	0.009001	3.051	0.011372	--	--	4.485	6.961	7.105	3.298
210811	0.4766	0.00559	2.151	0.008008	3.380	0.012581	--	--	4.918	7.533	7.846	3.381
210812	0.4542	0.00520	2.003	0.007419	3.516	0.013022	--	--	5.263	7.976	8.438	3.374

TABLE B.4.15 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER: EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
210813	0.4662	0.00481	1.850	0.006843	3.741	0.013836	--	--	5.613	8.421	9.035	3.468
210814	0.4725	0.00539	2.153	0.008000	3.951	0.014679	--	--	5.982	8.886	9.740	3.545
210815	0.4758	0.00677	2.702	0.010020	4.146	0.015374	--	--	6.279	9.263	10.265	3.604
210816	0.4758	0.00598	2.326	0.008569	4.347	0.016018	--	--	6.543	9.602	10.683	3.649
210817	0.4806	0.00579	2.228	0.008186	4.516	0.016594	--	--	6.787	9.894	11.090	3.703
290801	0.5187	0.00530	2.697	0.010712	1.564	0.006211	--	--	2.098	3.403	3.128	2.559
290802	0.5191	0.00441	2.295	0.009139	1.714	0.006824	--	--	2.403	3.935	3.716	2.749
290803	0.5213	0.00422	2.150	0.008495	2.074	0.008194	--	--	3.111	5.045	5.010	3.070
290804	0.5231	0.00451	2.272	0.008946	2.461	0.009689	--	--	3.825	6.061	6.286	3.288
290805	0.5246	0.00520	2.643	0.010411	2.805	0.011049	--	--	4.421	6.868	7.375	3.429
290806	0.5268	0.00539	2.716	0.010659	3.075	0.012068	--	--	4.838	7.418	8.115	3.519
290807	0.5295	0.00392	2.014	0.007941	3.292	0.012982	--	--	5.194	7.884	8.797	3.591
290808	0.5329	0.00471	2.414	0.009498	3.847	0.015136	--	--	5.974	8.884	10.232	3.733

TABLE B.4.16 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
290809	0.5362	0.00539	2.514	0.009677	3.892	0.014985	--	--	6.095	9.039	10.262	3.773
290810	0.5340	0.00579	2.697	0.010364	4.126	0.015856	--	--	6.463	9.505	10.936	3.822
290811	0.4472	0.00284	1.044	0.003806	3.377	0.012314	--	--	4.974	7.602	7.872	3.309
290812	0.4372	0.00530	1.953	0.007106	2.545	0.009261	--	--	3.677	5.857	5.692	3.009
40901	0.5811	0.00500	2.210	0.008549	1.512	0.005851	--	--	1.984	3.191	2.848	2.681
40902	0.5767	0.00647	2.959	0.011519	1.819	0.007079	--	--	2.586	4.235	3.969	3.056
40903	0.5776	0.00461	2.205	0.008645	2.092	0.008201	--	--	3.127	5.066	4.976	3.291
40904	0.5799	0.00539	2.651	0.010457	2.450	0.009664	--	--	3.802	6.029	6.210	3.508
40905	0.5765	0.00530	2.601	0.010245	2.815	0.011087	--	--	4.422	6.870	7.322	3.640
40906	0.5767	0.00510	2.457	0.009613	3.100	0.012129	--	--	4.847	7.427	8.053	3.728
40907	0.5842	0.00539	2.813	0.011164	3.612	0.014337	--	--	5.708	8.536	9.756	3.905
40908	0.5854	0.00402	2.095	0.008313	3.908	0.015504	--	--	6.301	9.294	10.864	4.004
40909	0.5836	0.00461	2.402	0.009514	4.184	0.016574	--	--	6.747	9.847	11.706	4.064

TABLE B.4.17 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
40910	0.4039	0.00481	1.416	0.004953	3.572	0.012496	--	--	5.044	7.688	7.647	3.220
40911	0.3926	0.00500	1.460	0.005103	3.406	0.011902	--	--	4.789	7.357	7.225	3.146
40912	0.3921	0.00549	1.615	0.005650	3.219	0.011262	--	--	4.513	6.998	6.797	3.092
40913	0.3916	0.00530	1.584	0.005563	2.927	0.010279	--	--	4.001	6.313	6.001	2.982
40914	0.3827	0.00481	1.449	0.005097	2.128	0.007486	--	--	2.914	4.756	4.254	2.657
50901	0.3526	0.00677	1.577	0.005358	1.737	0.005901	--	--	2.229	3.642	2.995	2.304
50902	0.3614	0.00647	1.491	0.005038	2.837	0.009587	--	--	3.660	5.838	5.186	2.848
50903	0.5569	0.00451	2.249	0.008920	3.355	0.013305	--	--	5.295	8.011	8.914	3.715
50904	0.5807	0.00471	2.315	0.009147	4.081	0.016124	--	--	6.539	9.589	11.163	4.018
50905	0.3327	0.00745	1.435	0.004651	3.179	0.010309	--	--	4.092	6.431	5.648	2.905
50906	0.3134	0.00588	1.129	0.003649	2.538	0.008206	--	--	3.135	5.080	4.252	2.617
50907	0.3067	0.00785	1.526	0.004933	1.905	0.006156	--	--	2.378	3.891	3.138	2.310
50908	0.2515	0.00794	1.305	0.004087	1.557	0.004875	--	--	1.854	2.944	2.288	1.926

TABLE B.4.18 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
50909	0.2522	0.00598	0.961	0.002996	1.869	0.005830	--	--	2.240	3.661	2.851	2.161
100901	0.4764	0.00549	2.018	0.007653	1.421	0.005389	--	--	1.797	2.828	2.436	2.232
100902	0.4719	0.00588	2.164	0.008196	1.479	0.005603	--	--	1.906	3.045	2.633	2.311
100903	0.4764	0.00745	2.746	0.010372	1.659	0.006267	--	--	2.241	3.659	3.225	2.552
100904	0.4767	0.00579	2.128	0.008040	1.942	0.007335	--	--	2.755	4.507	4.114	2.812
100905	0.4753	0.00706	2.597	0.009795	2.247	0.008473	--	--	3.278	5.293	5.000	2.996
100906	0.4777	0.00549	2.019	0.007597	2.662	0.010016	--	--	3.932	6.214	6.097	3.179
100907	0.4830	0.00628	2.306	0.008660	3.098	0.011633	--	--	4.553	7.048	7.139	3.329
100908	0.4803	0.00382	1.406	0.005273	3.276	0.012284	--	--	4.787	7.357	7.535	3.365
100909	0.4813	0.00481	1.812	0.006834	3.623	0.013664	--	--	5.479	8.253	8.750	3.486
100910	0.4876	0.00500	1.836	0.006871	3.863	0.014459	--	--	5.815	8.682	9.278	3.565
100911	0.4918	0.00500	1.846	0.006921	4.053	0.015192	--	--	6.117	9.068	9.810	3.626
100912	0.4946	0.00382	1.403	0.005261	4.246	0.015920	--	--	6.400	9.438	10.301	3.682

TABLE B.4.19 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER: EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
120901	0.6963	--	--	--	0.000	0.008026	--	--	0.000	4.024	0.000	0.000
120902	0.7120	--	--	--	0.000	0.007996	--	--	0.000	4.402	0.000	0.000
120903	0.7120	--	--	--	0.000	0.010106	--	--	0.000	5.860	0.000	0.000
120904	0.7115	--	--	--	0.000	0.012913	--	--	0.000	7.732	0.000	0.000
120905	0.6507	--	--	--	0.000	0.011462	--	--	0.000	6.972	0.000	0.000
120906	0.6502	--	--	--	0.000	0.010343	--	--	0.000	6.258	0.000	0.000
120907	0.6502	--	--	--	0.000	0.009320	--	--	0.000	5.563	0.000	0.000
120908	0.6474	--	--	--	0.000	0.008540	--	--	0.000	4.991	0.000	0.000
120909	0.6466	--	--	--	0.000	0.007560	--	--	0.000	4.189	0.000	0.000
120910	0.6465	--	--	--	0.000	0.006782	--	--	0.000	3.530	0.000	0.000
120911	0.6506	--	--	--	0.000	0.012770	--	--	0.000	7.746	0.000	0.000
120912	0.6525	--	--	--	0.000	0.014231	--	--	0.000	8.551	0.000	0.000
120913	0.5630	0.00373	1.829	0.007244	4.456	0.017648	--	--	7.146	10.328	12.302	4.028

TABLE B.4.20 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
120914	0.5714	0.00569	2.771	0.010916	4.239	0.016698	--	--	6.776	9.878	11.586	4.013
120915	0.5710	0.00618	3.043	0.012021	4.042	0.015967	--	--	6.470	9.509	11.046	3.964
120916	0.5649	0.00500	2.445	0.009622	3.843	0.015124	--	--	6.127	9.074	10.399	3.887
120917	0.5634	0.00530	2.523	0.009859	3.572	0.013960	--	--	5.518	8.299	9.243	3.787
120918	0.5576	0.00539	2.626	0.010302	3.174	0.012449	--	--	4.966	7.588	8.290	3.665
120919	0.5552	0.00490	2.374	0.009285	2.564	0.010024	--	--	3.973	6.268	6.507	3.450
120920	0.5529	0.00520	2.496	0.009743	2.293	0.008951	--	--	3.491	5.597	5.638	3.312
120921	0.5511	0.00569	2.715	0.010560	1.960	0.007624	--	--	2.863	4.671	4.506	3.085
120922	0.5526	0.00598	2.859	0.011129	1.706	0.006640	--	--	2.368	3.877	3.604	2.844
120923	0.5516	0.00559	2.677	0.010396	1.545	0.006001	--	--	2.051	3.318	3.014	2.630
120924	0.5537	0.00579	2.749	0.010624	1.262	0.004876	1.5490	0.0060	1.502	1.948	1.963	2.122
10401	0.6323	0.10630	5.230	0.015408	2.935	0.008645	3.7989	0.0106	3.195	5.140	3.415	4.630
10402	0.5992	0.06306	2.304	0.006695	2.631	0.007645	3.3912	0.0092	2.783	4.433	3.006	4.200

TABLE B.4.21 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
10403	0.5662	0.12670	3.144	0.009261	2.325	0.006847	3.0077	0.0082	2.428	3.748	2.638	3.740
10404	0.6720	0.11435	4.310	0.012854	3.551	0.010590	4.3198	0.0123	3.839	6.124	4.158	5.455
10405	0.6342	0.09611	2.351	0.007054	3.014	0.009042	3.6984	0.0104	3.192	4.945	3.491	4.778
10406	0.6181	0.15906	2.818	0.008770	2.634	0.008198	3.3035	0.0096	2.805	4.247	3.074	4.355
10407	0.6185	0.17397	2.705	0.008592	2.489	0.007907	3.1610	0.0094	2.670	3.999	2.925	4.233
10408	0.6080	0.17054	2.162	0.006808	2.364	0.007444	2.9726	0.0087	2.465	3.590	2.730	4.102
10409	0.6234	0.09473	2.476	0.007370	2.970	0.008841	3.6624	0.0103	3.141	4.886	3.425	4.645
10410	0.5804	0.14337	2.339	0.007253	2.428	0.007530	3.0877	0.0089	2.587	3.862	2.819	3.885
10411	0.7610	0.16465	8.269	0.025617	5.284	0.016369	6.0518	0.0183	5.971	9.454	6.457	7.555
10412	0.7785	0.15828	7.877	0.024037	5.468	0.016684	6.1920	0.0185	6.173	9.711	6.661	8.091
20401	0.5235	0.13671	1.408	0.004333	1.972	0.006067	2.5472	0.0072	2.044	2.855	2.236	3.176
20402	0.5960	0.19378	2.025	0.006428	2.311	0.007334	2.9021	0.0085	2.406	3.455	2.677	3.958
20403	0.5942	0.19515	2.040	0.006482	2.285	0.007260	2.8775	0.0085	2.379	3.418	2.646	3.923

TABLE B.4.22 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
20404	0.7252	0.09258	12.518	0.040328	5.543	0.017857	6.9920	0.0221	7.108	10.210	9.295	6.316
20405	0.8114	0.13523	18.672	0.060989	6.540	0.021361	7.9403	0.0256	8.419	11.778	11.234	8.483
20406	0.7611	0.05443	7.452	0.024459	8.262	0.027118	9.4617	0.0309	10.606	14.235	14.392	7.392
20407	0.7695	0.02393	5.256	0.018620	12.760	0.045199	14.2536	0.0507	18.254	21.357	27.432	8.226
20408	0.6898	0.03119	5.707	0.019372	8.862	0.030084	10.3532	0.0350	11.950	15.609	17.291	6.078
20409	0.7388	0.03099	5.641	0.019208	9.951	0.033886	11.3264	0.0385	13.439	17.096	19.516	7.121
20410	0.7456	0.02903	5.250	0.017982	11.218	0.038424	12.4812	0.0428	15.174	18.761	22.116	7.606
40401	0.5850	0.06767	6.914	0.022038	4.038	0.012872	5.3316	0.0164	4.975	7.586	6.032	4.282
40402	0.7266	0.05502	5.604	0.017851	4.844	0.015432	6.1130	0.0190	6.014	8.944	7.331	6.182
40403	0.8133	0.08561	9.010	0.029607	5.931	0.019488	7.1752	0.0232	7.438	10.764	9.308	8.624
40404	0.8208	0.08954	9.412	0.031010	6.187	0.020383	7.4082	0.0241	7.758	11.155	9.744	8.969
40405	0.8306	0.05864	5.674	0.018139	7.163	0.022898	8.1581	0.0258	8.751	12.399	10.942	9.782
40406	0.8141	0.19309	10.453	0.032533	6.582	0.020484	7.2413	0.0222	7.462	11.427	8.296	9.583

TABLE B.4.23 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
40407	0.8092	0.17740	8.747	0.026528	6.678	0.020254	7.2378	0.0216	7.507	11.482	8.232	9.473
40408	0.8446	0.11317	10.151	0.032105	8.467	0.026778	9.2128	0.0290	10.099	14.099	12.677	10.937
40409	0.8282	0.10827	9.769	0.031779	9.976	0.032454	10.6105	0.0344	11.985	16.184	15.261	10.402
40410	0.6284	0.09503	2.119	0.006310	2.880	0.008577	3.5767	0.0100	3.063	4.705	3.356	4.623
50401	0.6951	0.19202	6.578	0.019327	3.583	0.010529	4.3153	0.0121	3.849	6.068	4.182	5.831
50402	0.7598	0.15524	5.602	0.016954	4.501	0.013623	5.1951	0.0152	4.917	7.780	5.379	7.453
50403	0.8112	0.26694	10.184	0.031671	5.462	0.016986	6.0985	0.0185	6.037	9.652	6.669	9.361
50404	0.5036	0.16103	1.324	0.004249	1.960	0.006290	2.5190	0.0074	2.032	2.822	2.238	3.060
60401	0.6053	0.07620	1.536	0.004499	2.756	0.008072	3.4164	0.0094	2.927	4.390	3.174	4.327
60402	0.7515	0.17024	3.731	0.011385	3.717	0.011342	4.3602	0.0127	4.010	6.077	4.407	6.947
60403	0.7670	0.24056	5.311	0.016610	4.050	0.012665	4.6881	0.0140	4.393	6.688	4.865	7.474
60404	0.7376	0.06904	10.274	0.033496	10.094	0.032910	11.1190	0.0362	13.490	16.873	18.312	7.184
60405	0.6199	0.07620	1.254	0.003707	2.722	0.008045	3.3506	0.0093	2.857	4.216	3.141	4.470

TABLE B.4.24 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
60406	0.6520	0.20810	2.767	0.008482	2.801	0.008584	3.4068	0.0098	2.944	4.261	3.271	4.857
60407	0.6971	0.28577	3.923	0.012375	3.153	0.009945	3.7661	0.0112	3.340	4.876	3.746	5.668
90401	0.8167	0.09787	15.557	0.054352	13.965	0.048789	15.0298	0.0527	19.264	22.121	26.975	9.994
90402	0.7631	0.03177	5.715	0.019954	11.673	0.040759	12.9383	0.0453	16.414	19.617	23.374	7.851
90403	0.7776	0.03776	6.503	0.022710	12.195	0.042586	13.3798	0.0469	17.047	20.189	24.107	8.416
90404	0.0000	0.13563	10.916	0.031777	10.353	0.030138	10.5247	0.0306	12.462	16.126	14.724	0.000
90405	0.7296	0.11425	4.352	0.012431	4.160	0.011883	4.8613	0.0133	4.525	7.039	4.867	6.655
90406	0.7954	0.24272	9.154	0.027396	5.048	0.015109	5.6915	0.0165	5.546	8.736	6.065	8.674
90407	0.7556	0.13053	3.085	0.009216	4.060	0.012125	4.6742	0.0134	4.394	6.618	4.808	7.204
150401	0.4792	0.25115	1.498	0.005145	1.742	0.005984	2.2735	0.0071	1.803	2.433	1.987	2.730
150402	0.5328	0.35971	2.178	0.007664	1.922	0.006763	2.4688	0.0080	1.992	2.770	2.229	3.178
150403	0.5626	0.31038	1.889	0.006778	1.969	0.007065	2.5240	0.0083	2.042	2.874	2.300	3.404
150404	0.5870	0.36795	2.268	0.008346	2.134	0.007852	2.7017	0.0092	2.217	3.167	2.531	3.732

TABLE B.4.25 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
150405	0.5772	0.40825	2.486	0.009134	2.084	0.007657	2.6468	0.0090	2.164	3.080	2.461	3.615
150406	0.6265	0.42120	2.602	0.009853	2.170	0.008218	2.7482	0.0096	2.257	3.250	2.595	4.089
150407	0.6476	0.65175	4.053	0.015861	2.404	0.009409	3.0027	0.0109	2.511	3.633	2.933	4.509
150408	0.6697	0.54319	3.404	0.013107	2.545	0.009799	3.1349	0.0112	2.665	3.815	3.104	4.875
150409	0.8386	0.11444	15.698	0.056788	12.730	0.046052	13.8210	0.0502	17.429	20.584	23.751	10.547
150410	0.7463	0.08669	11.643	0.042029	10.108	0.036489	11.2945	0.0407	13.761	17.275	18.550	7.328
150411	0.7664	0.12052	16.197	0.058583	9.961	0.036028	11.1659	0.0403	13.558	17.090	18.284	7.769
150412	0.5607	0.03079	4.267	0.015263	4.120	0.014738	5.7325	0.0199	5.556	8.311	7.156	3.942
180401	0.8084	0.23477	5.417	0.016840	4.002	0.012441	4.6043	0.0137	4.320	6.560	4.733	8.768
180402	0.7779	0.31725	4.685	0.015496	3.258	0.010775	3.8869	0.0121	3.531	5.221	3.900	7.279
180403	0.7337	0.36746	4.347	0.014513	2.987	0.009972	3.5728	0.0112	3.156	4.588	3.538	6.181
180404	0.7298	0.37540	3.624	0.012591	2.785	0.009674	3.3685	0.0109	2.931	4.263	3.318	5.957
180405	0.7201	0.50102	4.001	0.014479	2.690	0.009737	3.2714	0.0111	2.826	4.093	3.234	5.711

TABLE B.4.26 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER: EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
180406	0.7311	0.39423	2.934	0.010768	2.669	0.009796	3.2531	0.0111	2.802	4.042	3.224	5.883
180407	0.6946	0.43591	2.703	0.010217	2.458	0.009292	3.0346	0.0107	2.570	3.667	2.971	5.121
180408	0.7114	0.89457	5.571	0.021577	2.570	0.009953	3.1608	0.0114	2.693	3.850	3.139	5.467
180409	0.7435	0.53927	3.938	0.014391	2.866	0.010471	3.4440	0.0118	3.022	4.295	3.478	6.281
180410	0.7143	0.58016	4.692	0.017006	2.653	0.009614	3.2404	0.0110	2.784	4.052	3.191	5.585
180411	0.7401	0.50299	4.997	0.017728	3.014	0.010693	3.6134	0.0120	3.188	4.657	3.642	6.324
180412	0.7915	0.52623	6.429	0.022939	3.520	0.012559	4.1537	0.0141	3.762	5.546	4.325	7.935
180413	0.8236	0.49906	8.378	0.029235	4.027	0.014051	4.6953	0.0157	4.408	6.685	4.986	9.302
180414	0.8340	0.35412	7.912	0.026811	4.625	0.015673	5.2713	0.0173	5.044	7.848	5.705	10.143
180415	0.8672	0.38197	14.021	0.046271	6.015	0.019851	6.6394	0.0215	6.698	10.627	7.502	12.580
180416	0.8719	0.23458	8.411	0.027656	6.254	0.020564	6.8412	0.0221	6.960	10.921	7.806	13.037
190401	0.8615	0.28420	7.527	0.023436	5.248	0.016341	5.7928	0.0175	5.746	8.774	6.369	12.037
190402	0.8488	0.61802	10.413	0.036259	4.363	0.015192	5.0409	0.0169	4.819	7.246	5.461	10.693

TABLE B.4.27 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
190403	0.7924	0.58732	7.086	0.024478	3.585	0.012384	4.2017	0.0138	3.835	5.567	4.385	8.005
190404	0.7785	0.67529	6.523	0.023512	3.258	0.011745	3.8825	0.0132	3.463	5.037	4.009	7.390
190405	0.7398	0.73501	4.692	0.018204	2.808	0.010894	3.4407	0.0125	2.956	4.219	3.502	6.164
190406	0.8325	0.68353	11.074	0.037990	4.324	0.014834	5.0718	0.0167	4.680	7.020	5.379	9.966
190407	0.8826	0.37148	18.353	0.056996	7.520	0.023354	8.0131	0.0246	8.447	12.768	9.414	14.202
190408	0.8922	0.17721	8.394	0.026600	7.798	0.024713	8.2859	0.0260	8.729	13.264	9.847	15.317
210401	0.3954	0.05943	5.413	0.017346	3.308	0.010599	4.5147	0.0138	3.935	6.262	4.692	3.118
210402	0.6966	0.10611	9.643	0.030475	4.112	0.012996	5.3261	0.0163	4.953	7.625	5.905	5.605
210403	0.7857	0.14131	12.823	0.040725	4.629	0.014701	5.8295	0.0180	5.605	8.519	6.715	7.597
210404	0.8620	0.15926	14.646	0.046871	5.276	0.016883	6.4489	0.0202	6.431	9.627	7.780	11.063
210405	0.8786	0.19545	18.246	0.058576	5.753	0.018469	6.8958	0.0218	7.040	10.364	8.586	12.402
210406	0.8644	0.15563	14.755	0.048078	6.152	0.020046	7.2839	0.0234	7.549	11.015	9.319	11.419
210407	0.8738	0.13965	13.230	0.043845	6.366	0.021096	7.4977	0.0245	7.808	11.390	9.721	12.159

TABLE B.4.28 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
210408	0.8685	0.04913	3.452	0.011264	6.396	0.020872	7.2879	0.0234	7.578	11.315	8.855	12.131
210409	0.8855	0.10974	7.824	0.025211	6.135	0.019771	7.0509	0.0224	7.275	10.888	8.471	13.483
210410	0.8725	0.16328	11.657	0.037276	5.848	0.018702	6.7888	0.0213	6.931	10.437	8.032	12.279
210411	0.8339	0.21947	15.918	0.051102	5.285	0.016966	6.3018	0.0198	6.257	9.605	7.254	9.755
210412	0.8475	0.18701	13.759	0.044402	4.842	0.015627	5.9129	0.0186	5.728	8.877	6.648	10.294
210413	0.7003	0.14504	9.662	0.029567	3.529	0.010800	4.5531	0.0133	4.035	6.393	4.521	5.637
210414	0.4725	0.09483	6.263	0.019101	3.019	0.009207	4.0220	0.0116	3.410	5.480	3.812	3.426
10501	0.3832	0.01589	2.571	0.008933	3.751	0.013034	--	--	5.055	7.644	6.689	3.176
10502	0.6915	0.08699	6.240	0.018911	3.704	0.011225	4.7562	0.0138	4.278	6.696	4.846	5.545
10503	0.8112	0.11954	8.670	0.026997	4.257	0.013257	5.3224	0.0160	4.963	7.736	5.692	8.512
10504	0.8303	0.12709	9.211	0.028609	4.467	0.013876	5.5178	0.0166	5.220	8.087	5.986	9.370
10505	0.8588	0.13317	9.396	0.029146	5.111	0.015854	6.0911	0.0184	5.984	9.170	6.851	11.165
10506	0.8318	0.09297	14.847	0.052615	7.202	0.025524	8.8025	0.0310	9.722	13.307	13.563	9.016

TABLE B.4.29 COPARISONS OF FRICTION PRESSURE DROP DATA

TEST RUN NO	VOID FRCTN	TWO-PHASE FRICTION PRES-GRAD KN/M3	VALUES OF TWO-PHASE FRICTION MULTIPLIER									
			EXPERIMENTAL		HOMOG MODEL		LOCK-MART		CH-MRT	BAROCZY	CHLSM	DUCKLR
10507	0.8442	0.23360	12.414	0.038631	5.046	0.015701	5.8792	0.0178	5.701	9.056	6.179	10.582
10508	0.6601	0.09562	3.701	0.011143	2.972	0.008949	3.7728	0.0107	3.179	5.156	3.457	5.016
10509	0.6283	0.11562	2.610	0.008011	2.460	0.007548	3.1496	0.0090	2.580	4.021	2.831	4.353
10510	0.5967	0.13710	2.085	0.006669	2.131	0.006816	2.7963	0.0083	2.273	3.391	2.481	3.758
10511	0.5506	0.14102	1.508	0.004839	1.948	0.006248	2.5330	0.0075	2.019	2.875	2.220	3.308
10512	0.5541	0.17338	1.525	0.005038	1.991	0.006577	2.5648	0.0078	2.064	2.932	2.289	3.372
10513	0.5218	0.29116	1.751	0.006044	1.781	0.006146	2.3206	0.0073	1.843	2.513	2.043	2.971
10514	0.6051	0.35892	2.189	0.007919	2.054	0.007433	2.6183	0.0087	2.132	3.027	2.422	3.793

TABLE B.4.30 COPARISONS OF FRICTION PRESSURE DROP DATA

APPENDIX B

B.5 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS.

FROM **Table B.5.1** TO **Table B.5.19**

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
220102	424.35	0.003863	0.003120	5.2074	0.8188	0.4229	1.2254	0.3062	0.743411	42		
220103	630.11	0.002594	0.003156	4.0605	2.1772	0.6288	1.2080	0.3884	0.657663	2		
220104	852.60	0.001914	0.003208	3.2721	1.4591	0.8514	1.1863	0.4065	0.582182	2		
220105	1043.85	0.001563	0.003235	2.8137	1.6827	1.0428	1.1760	0.3786	0.530033	2		
220106	1177.42	0.001381	0.003258	2.5622	1.2446	1.1764	1.1644	0.3700	0.497441	2		
220107	1271.63	0.001278	0.003294	2.4126	1.4710	1.2706	1.1515	0.3600	0.475403	2		
220108	1355.84	0.001197	0.003300	2.2919	1.3292	1.3549	1.1479	0.0692	0.458647	2		
220109	1338.37	0.001216	0.003333	2.3188	1.6544	1.3374	1.1400	0.3390	0.460146	2		
280101	341.97	0.005171	0.003216	6.1716	0.9194	0.3403	1.2974	0.2660	0.792203	34		
280102	268.05	0.006410	0.003210	7.0416	1.1378	0.2664	1.2614	0.3434	0.825623	3		
280103	411.55	0.004075	0.003209	5.3488	0.8528	0.4100	1.2306	0.3004	0.750089	34		
280104	428.36	0.001577	0.003199	3.1149	0.6488	0.4278	0.4966	0.1609	0.537180	3		
280105	287.24	0.002306	0.003189	3.8657	1.0324	0.2867	0.4881	0.3007	0.629972	3		
280106	356.91	0.001831	0.003194	3.3991	0.9148	0.3564	0.4803	0.1882	0.574043	3		
280107	504.46	0.001290	0.003198	2.7777	1.4403	0.5040	0.4773	0.0000	0.486393	42		
280108	505.18	0.002737	0.003195	4.2148	0.6797	0.5040	1.0141	0.2580	0.667989	42		
280109	645.11	0.002238	0.003271	3.7064	2.6835	0.6440	1.0339	0.3166	0.616215	2		
280110	771.89	0.001917	0.003302	3.3195	1.5900	0.7707	1.0531	0.3207	0.577421	2		
280111	892.98	0.001576	0.003267	2.9114	1.5195	0.8919	1.0127	0.2937	0.531706	2		

TABLE B.5.1 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
280112	2012.59	0.000679	0.003559	1.8901	1.1991	2.0120	0.9029	0.2350	0.309757	2		
280113	1892.01	0.000722	0.003508	1.9219	1.3276	1.8914	0.9146	0.2489	0.325947	2		
280114	1688.23	0.000818	0.003434	1.9887	1.3291	1.6875	0.9435	0.2642	0.358604	2		
280115	1499.17	0.000929	0.003377	2.0606	1.3537	1.4984	0.9666	0.2793	0.392133	2		
280116	1313.37	0.001073	0.003326	2.1857	1.1642	1.3126	0.9917	0.2960	0.430389	2		
280117	1175.25	0.001209	0.003307	2.3901	1.4297	1.1744	1.0048	0.3039	0.461096	2		
280118	995.19	0.001444	0.003257	2.7221	1.7026	0.9942	1.0310	0.3085	0.509086	2		
280119	983.86	0.002060	0.003297	3.3121	2.2536	0.9823	1.4351	0.4640	0.593649	2		
280120	677.44	0.003061	0.003243	4.4562	2.3964	0.6757	1.4922	0.5017	0.688306	2		
290101	238.61	0.008465	0.002930	8.5976	1.3360	0.2367	1.6039	0.3874	0.871390	34		
290102	307.45	0.006572	0.002928	7.3183	1.1481	0.3056	1.6041	0.3412	0.839973	34		
290103	363.40	0.005571	0.002917	6.6094	1.0054	0.3616	1.6117	0.3470	0.816753	34		
290104	363.15	0.004774	0.002950	5.9948	3.4042	0.3616	1.3717	0.2719	0.791383	3		
290105	362.39	0.002848	0.002906	4.4225	0.9508	0.3616	0.8227	0.1893	0.694671	3		
290106	323.89	0.002109	0.002908	3.7384	0.8441	0.3234	0.5441	0.3360	0.627169	3		
70201	259.32	0.000375	0.003172	1.6220	0.7638	0.2593	0.0722	0.6588	0.217670	3		
70202	244.50	0.000434	0.003185	1.6815	0.8255	0.2445	0.0783	0.7140	0.242547	3		
70203	236.87	0.001047	0.003181	2.5406	0.7743	0.2367	0.1829	0.7237	0.435881	3		
70204	228.83	0.001003	0.003187	2.4858	0.9157	0.2287	0.1689	0.7244	0.424810	3		
70205	161.92	0.001747	0.003183	3.3210	1.4815	0.1617	0.2081	0.7236	0.562726	3		

TABLE B.5.2 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
70206	335.18	0.001674	0.003189	3.2452	0.7349	0.3348	0.4115	0.0856	0.551420	3		
70207	280.62	0.002370	0.003182	3.9266	1.1217	0.2801	0.4880	0.2804	0.635319	3		
110201	267.27	0.003713	0.003126	5.0955	1.1122	0.2664	0.7400	0.3237	0.735270	3		
110202	300.38	0.003711	0.003126	5.0943	1.1603	0.2994	0.8303	0.2642	0.734960	3		
110203	300.50	0.004113	0.003127	5.4124	1.0617	0.2994	0.9194	0.2665	0.754328	3		
110204	300.70	0.004798	0.003124	5.9371	1.0293	0.2994	1.0734	0.2723	0.781886	34		
110205	300.88	0.005419	0.003116	6.3969	1.2816	0.2994	1.2151	0.2792	0.802301	4		
110206	301.08	0.006100	0.003116	6.8797	0.9805	0.2994	1.3678	0.2878	0.820398	4		
110207	294.97	0.006880	0.003119	7.4132	2.2951	0.2931	1.5086	0.3179	0.837307	4		
110208	298.26	0.007229	0.003105	7.6568	3.0975	0.2963	1.6088	0.3414	0.844471	4		
110210	373.84	0.006199	0.003166	6.9343	1.0924	0.3718	1.6928	0.3676	0.819920	42		
110213	573.73	0.001193	0.003118	2.6520	1.2559	0.5734	0.5108	0.1577	0.471128	42		
110214	574.03	0.001745	0.003119	3.2564	1.7179	0.5734	0.7464	0.2212	0.565550	42		
110215	571.11	0.002376	0.003117	3.8795	1.6778	0.5701	1.0106	0.3087	0.639330	42		
110216	571.59	0.003236	0.003190	4.6401	0.7643	0.5701	1.3452	0.3796	0.702346	2		
110217	568.63	0.003826	0.003176	5.1431	3.5553	0.5668	1.5881	0.4811	0.736968	2		
110218	737.68	0.002940	0.003194	4.3026	1.5752	0.7360	1.5735	0.5253	0.681315	2		
110219	2047.85	0.000072	0.003187	1.1862	0.9566	2.0491	0.1064	0.0515	0.049369	1		
110220	2043.25	0.000097	0.003200	1.2366	0.9351	2.0445	0.1425	0.0604	0.065146	1		
110221	2043.53	0.000248	0.003359	1.4731	1.1045	2.0445	0.3481	0.0980	0.145498	16		
110222	2037.87	0.000320	0.003378	1.5610	0.9285	2.0387	0.4452	0.1200	0.179234	62		

TABLE B.5.3 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
110223	2038.30	0.000545	0.003450	1.7823	1.1292	2.0387	0.7427	0.1978	0.267017	2		
110224	2029.38	0.000738	0.003471	1.9328	1.2768	2.0295	0.9939	0.2577	0.328733	2		
110225	2024.05	0.000996	0.003535	2.1014	1.3906	2.0237	1.3137	0.3440	0.393639	2		
300501	1002.69	0.000123	0.002979	1.2854	1.1693	1.0037	0.0943	0.0000	0.085876	6		
300502	988.57	0.000167	0.003022	1.3589	1.1258	0.9895	0.1246	0.0000	0.111862	6		
300503	1302.26	0.000105	0.003017	1.2524	1.1037	1.3036	0.1031	0.0000	0.073285	6		
300504	1300.46	0.000128	0.003031	1.2935	1.3657	1.3018	0.1245	0.0000	0.087321	6		
300505	1660.55	0.000099	0.003083	1.2410	0.9599	1.6622	0.1211	0.0016	0.067931	6		
300506	1661.90	0.000074	0.003075	1.1914	0.9683	1.6637	0.0910	0.0000	0.051856	16		
300507	1934.83	0.000085	0.003146	1.2149	0.9961	1.9369	0.1195	0.0036	0.058119	16		
300508	1934.85	0.000097	0.003156	1.2367	0.9766	1.9369	0.1346	0.0086	0.064962	6		
300509	1760.73	0.000118	0.003125	1.2765	0.9898	1.7626	0.1510	0.0104	0.078899	6		
300510	1670.36	0.000113	0.003096	1.2667	0.8587	1.6721	0.1380	0.0080	0.076229	6		
300511	1537.11	0.000130	0.003071	1.2979	1.0438	1.5387	0.1479	0.0060	0.087685	6		
300512	1103.04	0.000195	0.003046	1.4005	1.0857	1.1041	0.1602	0.0171	0.126691	6		
300513	1103.01	0.000175	0.003039	1.3716	0.8787	1.1041	0.1445	0.0058	0.115739	6		
300514	1105.26	0.000297	0.003108	1.5350	1.0394	1.1063	0.2399	0.0369	0.178200	6		
300515	1254.50	0.000235	0.003107	1.4571	1.1323	1.2557	0.2156	0.0216	0.146547	6		
300516	1535.59	0.000199	0.003123	1.4064	0.8408	1.5372	0.2218	0.0201	0.126085	6		
300517	1653.42	0.000194	0.003181	1.3991	0.7658	1.6552	0.2284	0.0271	0.121280	6		

TABLE B.5.4 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
300518	1817.10	0.000162	0.003188	1.3510	0.7657	1.8191	0.2095	0.0254	0.103283	6		
300519	1962.61	0.000168	0.003215	1.3594	0.9137	1.9646	0.2322	0.0275	0.105688	16		
300520	1963.86	0.000215	0.003315	1.4292	0.9288	1.9658	0.2889	0.0493	0.128122	6		
300521	1687.27	0.000254	0.003231	1.4808	0.7888	1.6889	0.3002	0.0505	0.150911	6		
300522	1541.79	0.000257	0.003186	1.4851	1.2319	1.5433	0.2818	0.0407	0.154402	6		
300523	1289.68	0.000342	0.003151	1.5862	1.3208	1.2909	0.3172	0.0582	0.197258	6		
300524	1048.60	0.000415	0.003111	1.6630	1.1346	1.0495	0.3170	0.0692	0.231954	62		
300525	1050.76	0.000354	0.003098	1.5992	1.1166	1.0517	0.2717	0.0451	0.205297	6		
300526	1039.63	0.000471	0.003099	1.7161	1.7046	1.0405	0.3572	0.0737	0.255542	62		
300527	1201.03	0.000412	0.003129	1.6599	1.0520	1.2021	0.3579	0.0798	0.229413	62		
300528	1329.10	0.000378	0.003144	1.6252	1.1906	1.3304	0.3616	0.0696	0.213702	62		
300529	1543.22	0.000306	0.003165	1.5447	1.1427	1.5448	0.3367	0.0652	0.178970	62		
300530	1767.34	0.000272	0.003235	1.5041	0.8739	1.7692	0.3356	0.0706	0.159456	6		
310501	1032.94	0.000552	0.003125	1.7886	1.1308	1.0337	0.4134	0.1007	0.285657	62		
310502	1033.06	0.000671	0.003135	1.8838	1.2504	1.0337	0.5008	0.1451	0.326347	62		
310503	1191.44	0.000579	0.003160	1.8109	0.9930	1.1923	0.4942	0.1306	0.293023	62		
310504	1543.47	0.000411	0.003214	1.6585	1.3594	1.5448	0.4466	0.0978	0.224252	62		
310505	1764.93	0.000376	0.003281	1.6230	1.2739	1.7666	0.4577	0.1157	0.205769	62		
310506	1755.69	0.000433	0.003282	1.6807	1.1047	1.7572	0.5242	0.1482	0.229773	62		
310507	1953.18	0.000382	0.003346	1.6286	0.9623	1.9550	0.5035	0.1349	0.204806	62		
310508	1486.12	0.000475	0.003212	1.7200	1.2603	1.4874	0.4966	0.1347	0.250285	62		

TABLE B.5.5 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
310509	1189.45	0.000622	0.003145	1.8458	1.2406	1.1903	0.5314	0.1528	0.308655	62		
310510	981.72	0.000743	0.003119	1.9367	1.1348	0.9823	0.5282	0.1669	0.349689	2		
310511	979.43	0.000875	0.003118	2.0265	1.2843	0.9799	0.6208	0.1849	0.387809	2		
50601	811.10	0.000210	0.003042	1.4220	1.5120	0.8118	0.1277	0.0000	0.135887	6		
50602	682.13	0.000308	0.003034	1.5472	2.6333	0.6826	0.1578	0.0599	0.187760	63		
50603	919.71	0.000225	0.003055	1.4427	0.3539	0.9205	0.1543	0.0585	0.143577	63		
50604	919.76	0.000277	0.003092	1.5108	1.5177	0.9205	0.1881	0.0713	0.169703	63		
50605	784.68	0.000327	0.003076	1.5695	1.3757	0.7853	0.1903	0.0743	0.195046	63		
50606	784.83	0.000526	0.003113	1.7662	1.8993	0.7853	0.3024	0.0947	0.278045	63		
50607	904.43	0.000452	0.003121	1.6991	1.5105	0.9050	0.2987	0.1004	0.248167	63		
50608	685.71	0.000565	0.003087	1.7993	2.8048	0.6861	0.2858	0.0970	0.294056	63		
50609	685.79	0.000697	0.003101	1.9030	2.5896	0.6861	0.3507	0.1255	0.338237	42		
50610	685.83	0.000758	0.003085	1.9471	3.1295	0.6861	0.3832	0.1516	0.358355	42		
50611	870.07	0.000593	0.003124	1.8228	1.9300	0.8705	0.3759	0.1373	0.301577	2		
50612	935.13	0.000548	0.003127	1.7847	1.0617	0.9357	0.3724	0.1212	0.284689	2		
50613	935.20	0.000629	0.003132	1.8510	1.2165	0.9357	0.4267	0.1438	0.313183	2		
60601	732.41	0.000912	0.003049	2.0498	1.8437	0.7325	0.4990	0.1430	0.405201	62		
60602	732.49	0.001010	0.003050	2.3810	2.6509	0.7325	0.5529	0.1685	0.430133	2		
60603	732.54	0.001076	0.003053	2.4604	7.2042	0.7325	0.5885	0.1862	0.445480	2		
60604	732.57	0.001117	0.003068	2.5081	2.1067	0.7325	0.6078	0.1884	0.453467	2		

TABLE B.5.6 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
60605	932.98	0.000878	0.003092	2.0279	1.6090	0.9332	0.6033	0.1845	0.392650	2		
60606	933.02	0.000925	0.003100	2.0580	1.3274	0.9332	0.6343	0.1989	0.404665	2		
60607	933.08	0.000988	0.003099	2.0964	1.4340	0.9332	0.6775	0.2128	0.420645	2		
60608	923.00	0.001057	0.003106	2.3477	1.5259	0.9230	0.7150	0.2257	0.436501	2		
60609	935.71	0.001111	0.003104	2.4038	1.2118	0.9357	0.7628	0.2614	0.449090	2		
60610	1306.76	0.000787	0.003179	1.9673	1.4572	1.3072	0.7366	0.2466	0.360406	2		
60611	1547.19	0.000652	0.003240	1.8690	1.3359	1.5479	0.7088	0.2184	0.314106	2		
60612	1547.10	0.000612	0.003222	1.8382	1.1366	1.5479	0.6694	0.1973	0.301917	2		
60613	682.90	0.001507	0.003063	2.9738	3.1957	0.6826	0.7642	0.2578	0.528197	42		
60614	682.84	0.001418	0.003057	2.8770	2.0238	0.6826	0.7206	0.2196	0.513511	42		
60615	686.17	0.001258	0.003048	2.6954	1.7352	0.6861	0.6441	0.1876	0.484220	42		
60616	854.03	0.000980	0.003074	2.0916	1.5305	0.8542	0.6192	0.1862	0.420258	2		
60617	854.09	0.001060	0.003079	2.3837	1.2841	0.8542	0.6684	0.2093	0.438996	2		
60618	854.23	0.001215	0.003086	2.5604	1.6047	0.8542	0.7646	0.2444	0.472334	2		
140801	285.73	0.000841	0.003028	2.0036	1.3985	0.2859	0.1794	0.3141	0.385645	3		
140802	283.89	0.001021	0.003042	2.5229	1.2535	0.2840	0.2157	0.3133	0.431632	3		
140803	283.32	0.001252	0.003047	2.8006	1.5426	0.2833	0.2632	0.3098	0.481539	3		
140804	282.09	0.001423	0.003051	2.9959	1.2136	0.2821	0.2976	0.3089	0.513425	3		
140805	281.56	0.001807	0.003053	3.4047	1.1634	0.2814	0.3768	0.3087	0.572470	3		
140806	281.64	0.002093	0.003044	3.6920	1.2539	0.2814	0.4375	0.3092	0.608559	3		
140807	281.73	0.002413	0.003051	3.9956	1.5756	0.2814	0.5035	0.3100	0.641460	3		

TABLE B.5.7 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
140808	281.83	0.002779	0.003044	4.3309	1.8275	0.2814	0.5813	0.3087	0.673788	3		
140809	281.92	0.003089	0.003047	4.6007	1.5561	0.2814	0.6459	0.3121	0.696512	3		
140810	282.02	0.003444	0.003051	4.9000	1.7340	0.2814	0.7195	0.3112	0.718829	3		
140811	282.11	0.003774	0.003055	5.1695	1.5009	0.2814	0.7876	0.3128	0.736747	3		
140812	282.27	0.004314	0.003057	5.5965	1.4282	0.2814	0.9003	0.3135	0.761849	3		
140813	279.13	0.004630	0.003054	5.8401	1.2348	0.2782	0.9562	0.3170	0.774618	3		
140814	276.01	0.005157	0.003054	6.2352	1.7732	0.2750	1.0533	0.3183	0.793002	34		
140815	276.09	0.005449	0.003052	6.4501	1.6985	0.2750	1.1141	0.3239	0.802050	34		
140816	356.51	0.004221	0.003058	5.5214	1.1221	0.3555	1.1124	0.2690	0.757838	34		
150801	348.04	0.000704	0.003019	1.9086	1.1230	0.3483	0.1828	0.2189	0.344196	3		
150802	346.08	0.001032	0.003020	2.5367	1.2001	0.3462	0.2662	0.2200	0.434613	3		
150803	344.12	0.001411	0.003021	2.9849	0.9457	0.3442	0.3615	0.2225	0.512282	3		
150804	339.49	0.001742	0.003020	3.3431	1.2649	0.3394	0.4403	0.2190	0.564700	3		
150805	339.57	0.002009	0.003017	3.6146	1.2114	0.3394	0.5081	0.2202	0.599519	3		
150806	339.68	0.002337	0.003012	3.9338	2.0430	0.3394	0.5921	0.2274	0.635642	3		
150807	338.69	0.002578	0.003019	4.1561	1.4108	0.3383	0.6495	0.2265	0.657492	3		
150808	338.77	0.002836	0.003004	4.3917	1.2200	0.3383	0.7175	0.2287	0.679557	34		
150809	336.76	0.003190	0.003010	4.6990	1.1483	0.3362	0.8010	0.2366	0.704345	34		
150810	336.90	0.003618	0.003005	5.0595	3.0554	0.3362	0.9102	0.2472	0.730256	34		
150811	336.96	0.003801	0.003003	5.2103	1.1485	0.3362	0.9568	0.2613	0.739967	4		

TABLE B.5.8 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
150812	406.07	0.000580	0.002984	1.8115	1.2416	0.4065	0.1768	0.1450	0.303092	3		
150813	405.79	0.000989	0.003003	2.0972	0.9746	0.4061	0.2995	0.2928	0.424455	3		
150814	160.97	0.001479	0.002981	3.0685	3.3923	0.1610	0.1790	0.6409	0.526422	3		
150815	153.04	0.002122	0.002973	3.7354	3.0725	0.1530	0.2444	0.7301	0.615037	3		
150816	153.13	0.002703	0.002973	4.2817	2.0618	0.1530	0.3117	0.7320	0.670763	3		
200801	211.18	0.001142	0.002988	2.6781	1.8902	0.2113	0.1808	0.3907	0.461110	3		
200802	213.79	0.001516	0.002988	3.1075	1.4954	0.2138	0.2430	0.3885	0.531925	3		
200803	212.16	0.001787	0.002994	3.3947	1.7649	0.2121	0.2837	0.3873	0.572189	3		
200804	212.19	0.001954	0.002991	3.5653	1.8227	0.2121	0.3104	0.3855	0.594033	3		
200805	212.26	0.002275	0.002992	3.8793	1.4575	0.2121	0.3614	0.3836	0.630142	3		
200806	212.36	0.002735	0.002991	4.3052	1.5985	0.2121	0.4346	0.3864	0.671987	3		
200807	212.42	0.003059	0.002992	4.5913	1.1773	0.2121	0.4861	0.3843	0.696166	3		
200808	212.55	0.003650	0.002993	5.0896	1.8204	0.2121	0.5800	0.3838	0.732196	3		
200809	212.64	0.004087	0.002986	5.4459	1.5132	0.2121	0.6510	0.3833	0.754236	3		
200810	212.74	0.004569	0.002989	5.8218	1.6801	0.2121	0.7274	0.3849	0.774221	3		
200811	212.84	0.005053	0.002985	6.1909	1.4008	0.2121	0.8056	0.3858	0.791558	3		
200812	213.00	0.005776	0.002981	6.7235	1.5672	0.2121	0.9227	0.3871	0.813066	3		
200813	213.08	0.006174	0.002978	7.0087	1.7922	0.2121	0.9869	0.3848	0.823088	3		
200814	213.15	0.006526	0.002977	7.2568	2.3510	0.2121	1.0440	0.3856	0.831120	3		
200815	213.28	0.007156	0.002980	7.6886	1.8477	0.2121	1.1437	0.3898	0.843539	3		
200816	213.41	0.007768	0.002977	8.1029	2.1563	0.2121	1.2430	0.3922	0.854223	3		

TABLE B.5.9 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
210801	175.88	0.001342	0.002972	2.9157	1.5687	0.1760	0.1774	0.4663	0.502082	3		
210802	175.94	0.001693	0.002970	3.3015	1.6446	0.1760	0.2240	0.4764	0.560099	3		
210803	176.00	0.002056	0.002968	3.6721	2.3190	0.1760	0.2722	0.4734	0.607351	3		
210804	172.99	0.002564	0.002969	4.1554	2.2263	0.1729	0.3335	0.4786	0.658599	3		
210805	175.16	0.003109	0.002963	4.6432	1.9992	0.1749	0.4100	0.4777	0.700927	3		
210806	174.22	0.003684	0.002962	5.1289	2.1701	0.1739	0.4832	0.4712	0.735370	3		
210807	175.37	0.004382	0.002961	5.6884	1.8493	0.1749	0.5785	0.4705	0.767810	3		
210808	175.49	0.005054	0.002962	6.2017	2.1491	0.1749	0.6672	0.4750	0.792289	3		
210809	175.57	0.005531	0.002961	6.5558	1.7730	0.1749	0.7306	0.4753	0.806816	3		
210810	175.67	0.006091	0.002959	6.9611	2.4152	0.1749	0.8051	0.4764	0.821512	3		
210811	175.81	0.006908	0.002958	7.5326	2.1510	0.1749	0.9134	0.4766	0.839264	3		
210812	175.91	0.007549	0.002948	7.9758	2.0030	0.1749	1.0012	0.4542	0.851265	3		
210813	176.03	0.008214	0.002945	8.4213	1.8500	0.1749	1.0914	0.4662	0.861860	3		
210814	171.96	0.008918	0.002938	8.8865	2.1533	0.1708	1.1598	0.4725	0.871662	3		
210815	172.06	0.009502	0.002935	9.2632	2.7024	0.1708	1.2370	0.4758	0.878703	3		
210816	175.30	0.010042	0.002936	9.6019	2.3257	0.1739	1.3307	0.4758	0.884422	34		
210817	176.43	0.010528	0.002934	9.8943	2.2279	0.1749	1.4051	0.4806	0.889287	4		
290801	145.40	0.001788	0.002960	3.4031	2.6971	0.1454	0.1959	0.5187	0.573940	3		
290802	143.50	0.002325	0.002957	3.9348	2.2953	0.1434	0.2514	0.5191	0.636714	3		
290803	145.65	0.003579	0.002953	5.0448	2.1498	0.1454	0.3930	0.5213	0.729909	3		

TABLE B.5.10 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
290804	146.82	0.004859	0.002950	6.0607	2.2723	0.1464	0.5385	0.5231	0.786249	3		
290805	146.00	0.005953	0.002948	6.8684	2.6435	0.1454	0.6561	0.5246	0.818575	3		
290806	147.09	0.006732	0.002947	7.4185	2.7158	0.1464	0.7473	0.5268	0.836210	3		
290807	145.22	0.007413	0.002949	7.8835	2.0136	0.1444	0.8118	0.5295	0.848972	3		
290808	145.44	0.008924	0.002946	8.8835	2.4137	0.1444	0.9793	0.5329	0.871486	3		
290809	155.11	0.009164	0.002945	9.0391	2.5137	0.1540	1.0725	0.5362	0.874444	3		
290810	155.22	0.009895	0.002942	9.5054	2.6968	0.1540	1.1592	0.5340	0.882737	34		
290811	182.17	0.006992	0.002942	7.6015	1.0437	0.1813	0.9610	0.4472	0.841312	3		
290812	181.73	0.004586	0.002936	5.8572	1.9529	0.1813	0.6297	0.4372	0.776490	3		
40901	159.43	0.001588	0.002964	3.1909	2.2100	0.1595	0.1908	0.5811	0.544775	3		
40902	155.97	0.002649	0.002963	4.2350	2.9594	0.1558	0.3112	0.5767	0.666353	3		
40903	151.46	0.003606	0.002958	5.0657	2.2051	0.1512	0.4119	0.5776	0.731499	3		
40904	148.77	0.004823	0.002960	6.0287	2.6508	0.1483	0.5409	0.5799	0.784782	3		
40905	148.94	0.005963	0.002958	6.8699	2.6013	0.1483	0.6695	0.5765	0.818626	3		
40906	150.98	0.006751	0.002953	7.4274	2.4573	0.1502	0.7691	0.5767	0.836581	3		
40907	143.36	0.008393	0.002949	8.5355	2.8126	0.1424	0.9087	0.5842	0.864503	3		
40908	143.53	0.009574	0.002951	9.2943	2.0954	0.1424	1.0366	0.5854	0.879202	3		
40909	143.66	0.010473	0.002949	9.8468	2.4018	0.1424	1.1351	0.5836	0.888512	4		
40910	210.17	0.007123	0.002947	7.6882	1.4159	0.2091	1.1299	0.4039	0.843855	3		
40911	211.44	0.006645	0.002949	7.3567	1.4604	0.2104	1.0596	0.3926	0.834303	3		
40912	210.64	0.006137	0.002951	6.9978	1.6146	0.2098	0.9736	0.3921	0.822741	3		

TABLE B.5.11 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
40913	208.38	0.005198	0.002954	6.3132	1.5844	0.2077	0.8146	0.3916	0.796833	3		
40914	207.28	0.003236	0.002954	4.7555	1.4491	0.2070	0.5045	0.3827	0.709042	3		
50901	243.79	0.002028	0.002980	3.6417	1.5773	0.2437	0.3707	0.3526	0.603354	3		
50902	245.89	0.004582	0.002974	5.8380	1.4911	0.2452	0.8461	0.3614	0.775310	3		
50903	147.24	0.007617	0.002964	8.0106	2.2490	0.1464	0.8446	0.5569	0.852284	3		
50904	148.59	0.010059	0.002961	9.5891	2.3149	0.1474	1.1266	0.5807	0.884333	4		
50905	277.25	0.005363	0.002965	6.4306	1.4345	0.2763	1.1188	0.3327	0.801979	34		
50906	278.06	0.003624	0.002961	5.0798	1.1288	0.2776	0.7589	0.3134	0.732209	3		
50907	275.73	0.002278	0.002955	3.8906	1.5263	0.2756	0.4737	0.3067	0.632176	3		
50908	308.13	0.001365	0.002959	2.9440	1.3053	0.3083	0.3165	0.2515	0.506567	3		
50909	312.97	0.002043	0.002963	3.6606	0.9608	0.3129	0.4805	0.2522	0.605619	3		
100901	178.83	0.001269	0.002993	2.8280	2.0178	0.1789	0.1702	0.4764	0.487575	3		
100902	178.86	0.001460	0.002991	3.0450	2.1640	0.1789	0.1958	0.4719	0.522623	3		
100903	178.96	0.002048	0.002989	3.6592	2.7456	0.1789	0.2748	0.4764	0.605736	3		
100904	179.13	0.002961	0.002989	4.5068	2.1285	0.1789	0.3977	0.4767	0.689777	3		
100905	179.29	0.003897	0.002988	5.2932	2.5971	0.1789	0.5240	0.4753	0.745485	3		
100906	179.50	0.005083	0.002984	6.2136	2.0189	0.1789	0.6846	0.4777	0.792839	3		
100907	179.70	0.006232	0.002982	7.0480	2.3062	0.1789	0.8406	0.4830	0.824533	3		
100908	179.78	0.006672	0.002980	7.3566	1.4062	0.1789	0.9003	0.4803	0.834243	3		
100909	176.78	0.007999	0.002981	8.2532	1.8119	0.1757	1.0611	0.4813	0.857970	3		

TABLE B.5.12 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
100910	180.14	0.008653	0.002978	8.6824	1.8356	0.1789	1.1700	0.4876	0.867382	3		
100911	179.44	0.009255	0.002979	9.0679	1.8463	0.1781	1.2462	0.4918	0.874967	3		
100912	180.35	0.009853	0.002987	9.4383	1.4029	0.1789	1.3292	0.4946	0.881383	4		
120901	92.67	0.002429	0.002994	4.0245	0.0000	0.0926	0.1691	0.6963	0.646193	3		
120902	113.54	0.002844	0.002994	4.4018	0.0000	0.1134	0.2424	0.7120	0.681293	3		
120903	103.13	0.004620	0.002991	5.8604	0.0000	0.1028	0.3579	0.7120	0.776830	3		
120904	103.40	0.007223	0.002983	7.7324	0.0000	0.1028	0.5621	0.7115	0.845373	3		
120905	121.26	0.006125	0.002983	6.9718	0.0000	0.1207	0.5587	0.6507	0.822338	3		
120906	121.14	0.005142	0.002984	6.2575	0.0000	0.1207	0.4684	0.6502	0.795100	3		
120907	121.03	0.004233	0.002981	5.5631	0.0000	0.1207	0.3852	0.6502	0.761415	3		
120908	120.94	0.003524	0.002979	4.9906	0.0000	0.1207	0.3205	0.6474	0.726425	3		
120909	119.64	0.002604	0.002979	4.1894	0.0000	0.1195	0.2343	0.6466	0.662169	3		
120910	119.55	0.001915	0.002974	3.5297	0.0000	0.1195	0.1724	0.6465	0.590529	3		
120911	115.28	0.007235	0.002975	7.7460	0.0000	0.1146	0.6275	0.6506	0.845516	3		
120912	114.16	0.008447	0.002975	8.5506	0.0000	0.1134	0.7249	0.6525	0.864737	3		
120913	148.78	0.011331	0.002969	10.3277	1.8291	0.1474	1.2673	0.5630	0.895833	4		
120914	149.63	0.010544	0.002961	9.8776	2.7713	0.1483	1.1888	0.5714	0.889071	34		
120915	148.57	0.009931	0.002963	9.5087	3.0427	0.1474	1.1109	0.5710	0.882886	3		
120916	149.43	0.009238	0.002959	9.0739	2.4446	0.1483	1.0401	0.5649	0.875195	3		
120917	152.13	0.008043	0.002957	8.2992	2.5229	0.1512	0.9220	0.5634	0.859130	3		
120918	150.05	0.006988	0.002958	7.5885	2.6263	0.1493	0.7897	0.5576	0.841018	3		

TABLE B.5.13 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
120919	150.73	0.005138	0.002955	6.2679	2.3744	0.1502	0.5834	0.5552	0.795226	3		
120920	151.55	0.004262	0.002954	5.5969	2.4965	0.1512	0.4868	0.5529	0.763015	3		
120921	152.31	0.003137	0.002952	4.6712	2.7145	0.1521	0.3602	0.5511	0.703082	3		
120922	152.18	0.002263	0.002953	3.8770	2.8587	0.1521	0.2595	0.5526	0.630426	3		
120923	152.09	0.001704	0.002948	3.3178	2.6768	0.1521	0.1956	0.5516	0.562500	3		
120924	152.88	0.000759	0.002938	1.9477	2.7492	0.1531	0.0878	0.5537	0.364524	3		
10401	627.04	0.003825	0.003158	5.1400	5.2299	0.6251	1.7602	0.6323	0.737952	42		
10402	747.09	0.003098	0.003182	4.4334	2.3042	0.7453	1.6842	0.5992	0.693241	42		
10403	927.26	0.002500	0.003245	3.7481	3.1442	0.9256	1.6523	0.5662	0.640951	2		
10404	732.65	0.005166	0.003258	6.1240	4.3100	0.7293	2.6966	0.6720	0.787117	42		
10405	933.78	0.003997	0.003307	4.9451	2.3509	0.9306	2.6165	0.6342	0.737634	42		
10406	1107.12	0.003338	0.003387	4.2468	2.8180	1.1041	2.5280	0.6181	0.696010	2		
10407	1183.27	0.003111	0.003423	3.9995	2.7047	1.1804	2.4898	0.6185	0.678384	2		
10408	1341.95	0.002754	0.003477	3.5903	2.1623	1.3392	2.4577	0.6080	0.647293	2		
10409	900.11	0.003865	0.003284	4.8862	2.4759	0.8972	2.4604	0.6234	0.732792	42		
10410	1154.75	0.002886	0.003360	3.8616	2.3386	1.1521	2.3015	0.5804	0.666403	2		
10411	619.20	0.009599	0.003314	9.4536	8.2686	0.6137	4.1580	0.7610	0.871397	2		
10412	623.24	0.009908	0.003270	9.7106	7.8771	0.6175	4.3729	0.7785	0.876268	2		
20401	1507.84	0.001882	0.003396	2.8553	1.4079	1.5063	1.9213	0.5235	0.560549	2		
20402	1496.43	0.002674	0.003503	3.4554	2.0250	1.4937	2.6245	0.5960	0.637288	2		

TABLE B.5.14 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
20403	1496.34	0.002622	0.003506	3.4175	2.0400	1.4937	2.5695	0.5942	0.632383	2		
20404	338.23	0.011246	0.003036	10.2102	12.5184	0.3348	2.8591	0.7252	0.895182	42		
20405	333.53	0.014166	0.003065	11.7778	18.6719	0.3291	3.5190	0.8114	0.914466	42		
20406	335.23	0.019140	0.003083	14.2351	7.4521	0.3291	4.7519	0.7611	0.935220	4		
20407	245.25	0.035749	0.003021	21.3569	5.2564	0.2367	6.6306	0.7695	0.965529	4		
20408	279.14	0.021920	0.003038	15.6092	5.7066	0.2733	4.5756	0.6898	0.943629	4		
20409	280.12	0.025336	0.003051	17.0958	5.6408	0.2733	5.2852	0.7388	0.950825	4		
20410	281.31	0.029455	0.003073	18.7610	5.2499	0.2733	6.1265	0.7456	0.957289	4		
40401	398.65	0.007066	0.003099	7.5857	6.9140	0.3961	2.1008	0.5850	0.841361	42		
40402	399.46	0.009094	0.003099	8.9436	5.6036	0.3961	2.7095	0.7266	0.872455	42		
40403	391.11	0.012325	0.003178	10.7642	9.0102	0.3866	3.5057	0.8133	0.900685	42		
40404	391.40	0.013061	0.003187	11.1547	9.4121	0.3866	3.7073	0.8208	0.905576	42		
40405	416.02	0.015280	0.003165	12.3989	5.6740	0.4100	4.6159	0.8306	0.918420	42		
40406	596.70	0.013029	0.003328	11.4265	10.4531	0.5894	5.3685	0.8141	0.901068	44		
40407	630.93	0.012906	0.003270	11.4822	8.7467	0.6233	5.7228	0.8092	0.901780	44		
40408	439.97	0.018673	0.003196	14.0990	10.1515	0.4322	5.8699	0.8446	0.931421	44		
40409	437.74	0.023558	0.003280	16.1838	9.7685	0.4278	7.1884	0.8282	0.943824	44		
40410	985.02	0.003746	0.003254	4.7046	2.1185	0.9823	2.5903	0.6284	0.725041	42		
50401	776.57	0.005167	0.003228	6.0678	6.5776	0.7731	2.8696	0.6951	0.787759	42		
50402	753.65	0.007447	0.003318	7.7799	5.6020	0.7486	3.9074	0.7598	0.839221	2		
50403	729.99	0.010029	0.003401	9.6521	10.1837	0.7232	4.9728	0.8112	0.873034	44		

TABLE B.5.15 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
50404	1702.13	0.001929	0.003544	2.8221	1.3240	1.7000	2.1419	0.5036	0.557499	2		
60401	1036.41	0.003398	0.003200	4.3901	1.5360	1.0337	2.5362	0.6053	0.710439	2		
60402	991.97	0.005685	0.003346	6.0768	3.7311	0.9871	3.8839	0.7515	0.797350	2		
60403	988.10	0.006617	0.003431	6.6879	5.3115	0.9823	4.3922	0.7670	0.817226	2		
60404	313.00	0.024373	0.002964	16.8733	10.2739	0.3056	5.9355	0.7376	0.951034	4		
60405	1169.10	0.003358	0.003259	4.2163	1.2544	1.1663	2.7522	0.6199	0.702354	2		
60406	1314.25	0.003656	0.003380	4.2613	2.7674	1.3108	3.2474	0.6520	0.712438	2		
60407	1291.80	0.004573	0.003478	4.8762	3.9234	1.2872	3.8778	0.6971	0.750782	2		
90401	298.01	0.038643	0.003113	22.1207	15.5573	0.2867	8.5640	0.8167	0.967609	4		
90402	274.85	0.031352	0.003036	19.6173	5.7146	0.2664	6.5671	0.7631	0.961013	4		
90403	282.47	0.032976	0.003059	20.1885	6.5030	0.2733	7.0517	0.7776	0.962684	4		
90404	463.11	0.021865	0.002936	16.1257	10.9160	0.4533	7.9884	0.0000	0.946304	42		
90405	732.37	0.006295	0.003128	7.0394	4.3520	0.7283	3.3930	0.7296	0.823274	2		
90406	736.70	0.008679	0.003279	8.7358	9.1538	0.7309	4.4879	0.7954	0.859948	2		
90407	953.46	0.006345	0.003282	6.6175	3.0855	0.9482	4.2413	0.7556	0.817286	2		
150401	2022.25	0.001562	0.003797	2.4326	1.4981	2.0202	1.9391	0.4792	0.489763	2		
150402	2006.73	0.002013	0.003890	2.7697	2.1776	2.0038	2.4186	0.5328	0.546904	2		
150403	2001.13	0.002165	0.003966	2.8743	1.8890	1.9979	2.5439	0.5626	0.560108	2		
150404	1987.82	0.002626	0.004067	3.1668	2.2679	1.9837	2.9864	0.5870	0.600869	2		
150405	1998.34	0.002493	0.004062	3.0798	2.4862	1.9944	2.8627	0.5772	0.589385	2		

TABLE B.5.16 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
150406	1983.47	0.002792	0.004186	3.2495	2.6021	1.9790	3.0840	0.6265	0.609132	2		
150407	1976.52	0.003509	0.004326	3.6327	4.0533	1.9706	3.7369	0.6476	0.654732	2		
150408	1965.24	0.003815	0.004259	3.8154	3.4037	1.9586	4.1179	0.6697	0.677672	2		
150409	323.00	0.035552	0.003255	20.5841	15.6978	0.3117	8.2602	0.8386	0.963642	4		
150410	326.21	0.026802	0.003247	17.2753	11.6427	0.3176	6.3232	0.7463	0.952175	4		
150411	326.07	0.026378	0.003253	17.0904	16.1972	0.3176	6.2094	0.7664	0.951341	4		
150412	320.13	0.008340	0.003204	8.3112	4.2667	0.3176	1.9545	0.5607	0.860219	4		
180401	958.86	0.006348	0.003434	6.5597	5.4174	0.9531	4.1649	0.8084	0.813769	2		
180402	1213.56	0.004984	0.003593	5.2211	4.6850	1.2080	3.9550	0.7779	0.766031	2		
180403	1384.47	0.004329	0.003695	4.5883	4.3468	1.3790	3.8113	0.7337	0.734310	2		
180404	1547.39	0.004008	0.003844	4.2628	3.6243	1.5418	3.7914	0.7298	0.710907	2		
180405	1717.19	0.003936	0.004005	4.0928	4.0006	1.7111	3.9665	0.7201	0.698623	2		
180406	1787.45	0.003948	0.004060	4.0421	2.9338	1.7812	4.0717	0.7311	0.695677	2		
180407	1975.51	0.003515	0.004181	3.6668	2.7030	1.9694	3.8899	0.6946	0.663879	2		
180408	1970.28	0.003898	0.004284	3.8499	5.5712	1.9634	4.2018	0.7114	0.681531	2		
180409	1805.51	0.004434	0.004042	4.2953	3.9383	1.7983	4.6422	0.7435	0.720787	2		
180410	1707.29	0.003856	0.004009	4.0523	4.6920	1.7014	3.8484	0.7143	0.693424	2		
180411	1525.20	0.004679	0.003925	4.6568	4.9968	1.5187	4.2621	0.7401	0.737282	2		
180412	1364.19	0.006038	0.003945	5.5456	6.4290	1.3566	4.8723	0.7915	0.782203	2		
180413	1137.14	0.007273	0.003805	6.6851	8.3782	1.1294	5.0741	0.8236	0.817937	42		
180414	978.18	0.008580	0.003737	7.8484	7.9119	0.9703	5.2435	0.8340	0.843851	42		

TABLE B.5.17 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
180415	741.09	0.012044	0.003603	10.6269	14.0207	0.7325	5.7816	0.8672	0.887547	42		
180416	751.23	0.012635	0.003594	10.9208	8.4108	0.7421	6.1629	0.8719	0.892525	42		
190401	894.49	0.009456	0.003434	8.7738	7.5270	0.8866	5.7075	0.8615	0.865545	42		
190402	1135.95	0.008217	0.003777	7.2463	10.4130	1.1273	5.7255	0.8488	0.835491	42		
190403	1377.89	0.006048	0.003816	5.5673	7.0863	1.3704	5.0597	0.7924	0.786870	42		
190404	1556.84	0.005443	0.003982	5.0370	6.5226	1.5494	4.9290	0.7785	0.760835	2		
190405	1961.21	0.004632	0.004281	4.2194	4.6922	1.9538	4.8716	0.7398	0.713742	42		
190406	1176.74	0.007986	0.003786	7.0202	11.0743	1.1684	5.7009	0.8325	0.829916	42		
190407	630.47	0.015431	0.003349	12.7683	18.3533	0.6213	6.6722	0.8826	0.914818	44		
190408	646.35	0.016485	0.003428	13.2636	8.3941	0.6362	7.1380	0.8922	0.918160	44		
210401	429.79	0.005257	0.003183	6.2624	5.4135	0.4278	1.6391	0.3954	0.793001	34		
210402	430.60	0.007130	0.003142	7.6249	9.6429	0.4278	2.2558	0.6966	0.840570	42		
210403	431.17	0.008459	0.003159	8.5186	12.8230	0.4278	2.6641	0.7857	0.861627	42		
210404	427.50	0.010198	0.003176	9.6268	14.6464	0.4235	3.1672	0.8620	0.882066	42		
210405	423.58	0.011497	0.003180	10.3641	18.2462	0.4190	3.5328	0.8786	0.893967	42		
210406	419.58	0.012761	0.003220	11.0155	14.7548	0.4145	3.8341	0.8644	0.902429	42		
210407	419.92	0.013573	0.003277	11.3905	13.2303	0.4145	4.0096	0.8738	0.906300	42		
210408	502.90	0.013227	0.003347	11.3150	3.4517	0.4966	4.6157	0.8685	0.902871	2		
210409	498.64	0.012376	0.003301	10.8881	7.8236	0.4928	4.3396	0.8855	0.898027	2		
210410	498.21	0.011525	0.003275	10.4365	11.6571	0.4928	4.0699	0.8725	0.892000	42		

TABLE B.5.18 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

NO	GTOTL	QALTY	PINDX	TMBE	TME	USF	USG	VDF	BETA	PATERN	FFSP	RE
210411	493.65	0.010108	0.003283	9.6054	15.9178	0.4890	3.5263	0.8339	0.878222	42		
210412	489.24	0.009024	0.003293	8.8769	13.7587	0.4851	3.1101	0.8475	0.865061	42		
210413	521.11	0.005404	0.003170	6.3935	9.6619	0.5186	2.0591	0.7003	0.798801	42		
210414	524.09	0.004230	0.003164	5.4798	6.2626	0.5222	1.6234	0.4725	0.756611	42		
10501	295.05	0.007199	0.003092	7.6445	2.5706	0.2931	1.5885	0.3832	0.844213	4		
10502	499.08	0.005782	0.003117	6.6958	6.2403	0.4966	2.1402	0.6915	0.811683	42		
10503	496.03	0.007274	0.003200	7.7362	8.6702	0.4928	2.6048	0.8112	0.840914	42		
10504	496.27	0.007766	0.003192	8.0866	9.2106	0.4928	2.7890	0.8303	0.849847	42		
10505	504.65	0.009331	0.003200	9.1695	9.3959	0.5003	3.3996	0.8588	0.871716	42		
10506	298.12	0.017481	0.003168	13.3075	14.8470	0.2931	3.7994	0.8318	0.928375	4		
10507	600.76	0.009087	0.003321	9.0562	12.4144	0.5957	3.7949	0.8442	0.864317	2		
10508	721.96	0.003946	0.003285	5.1556	3.7007	0.7196	2.0110	0.6601	0.736473	42		
10509	974.88	0.002889	0.003377	4.0206	2.6105	0.9727	1.9338	0.6283	0.665334	2		
10510	1196.29	0.002342	0.003444	3.3911	2.0855	1.1943	1.8864	0.5967	0.612339	2		
10511	1471.72	0.001898	0.003544	2.8751	1.5085	1.4699	1.8268	0.5506	0.554126	2		
10512	1638.85	0.002050	0.003650	2.9323	1.5247	1.6366	2.1320	0.5541	0.565736	2		
10513	2018.69	0.001665	0.003813	2.5128	1.7511	2.0167	2.0416	0.5218	0.503075	2		
10514	2003.73	0.002400	0.003997	3.0274	2.1886	2.0003	2.7858	0.6051	0.582062	2		

TABLE B.5.19 SUPERFICIAL LIQUID AND GAS VELOCITIES AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS

APPENDIX B

B.6 PRESSURE DROP CORRELATIONS USED IN COMPARISON AND SPECIMEN CALCULATIONS.

B.6 Pressure Drop Correlations Used in Comparison and Specimen Calculations

Consider Test No. 150401

The corresponding computer answers are given alongside, with hand calculation, for easy comparison. Obviously hand calculation can not be accurate, because a lot of coefficients have to be obtained; however, these hand calculations clearly show the method followed by the computer.

Water volume flowrate	$Q_f = 0.065383\ m^3/s$
Air volume flowrate	$Q_g = 0.062760\ m^3/s$
Water density	$\rho_f = 999.470$ kg/m
Air density	$\rho_g = 1.6289$ kg/m
Water temperature	$t_f = 12.4°C$
Air temperature	$t_g = 14.5°C$
Pressure gradient	PE = 25.61 x 9.81
	$= 251.2341\ N/m^3$
Tube diameter	D = 0.203 m
Cross sectional area	$A = 0.032365472\ m^2$
Void fraction	$\alpha = 0.4792$
Flow pattern	Slug

Water dynamic viscosity

$$\mu_f = 1.77226 - 0.0557784 \times t_f + 0.001026\ (t_f)^2$$

$$-0.0000083\ (t_f)^3$$

$$\mu_f = 938.675059 \times 10^{-6}$$

Air dynamic viscosity

$$\mu_g = 1.70744 + 0.00612487 \times t_g - 0.000031396 \times (t_g)^2$$

$$\mu_g = 1.789649606 \times 10^{-5}$$

Mass flow of water

$$m_f = \rho_f \times Q_f = 999.470 \times 0.065383$$

$$m_f = 65.34834701$$

Mass flow of air

$$m_g = \rho_g \times Q_g = 1.6289 \times 0.062760$$

$$m_g = 0.102229764$$

$$M_{tot} = m_g + m_f = 0.102229764 + 65.34834701$$

$$M_{tot} = 65.45057677$$

Quality

$$X = \frac{m_g}{M_{tot}} = \frac{0.102229764}{65.45057677}$$

$X = 0.001561938321$ By computer $X = 0.001562$

Total mass velocity

$$G_{tot} = \frac{M_{tot}}{CSA}$$

$$G_{tot} = \frac{65.45057677}{0.032365472}$$

$G_{tot} = 2022.234583$ kg/sm^2 By computer $G_{tot} = 2022.25$ kg/Sm^2

B.6.1 Experimental Two-Phase Multipliers

$$\left(\frac{\Delta P}{\Delta Z}\right)_{fo} = \frac{\lambda_{fo}(G_{tot})^2}{2d\rho_f}$$

$$Re_{fo} = \frac{G_{tot}d}{\mu_f}$$

$$Re_{fo} = \frac{2022.234583 \ x \ 0.203}{938.675059 \ x \ 10^{-6}}$$

$$Re_{fo} = 437{,}333.0434$$

From the equation developed using single phase

$$Re_{fo} > 2.09 \text{ x } 10^5$$

$$\lambda_{fo} = 0.156772 \text{ x } Re^{-0.17628}$$

$$\lambda_{fo} = 0.015882033$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{fo} = \frac{\lambda_{fo}(G_{tot})^2}{2d\rho_f}$$

$$= \frac{0.015882033 \ x \ (2022.234583)^2}{2 \ x \ 0.203 \ x \ 999.470}$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{fo} = 160.0565228$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{exp} = PE \ x \ 9.81$$

$$= 25.61 \times 9.81$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{exp} = 251.2341$$

$$\Phi^2_{fo}\ exp = \frac{\left(\frac{\Delta P}{\Delta Z}\right)_{measured}}{\left(\frac{\Delta P}{\Delta Z}\right)_{fo}}$$

$$\Phi^2_{fo}\ exp = \frac{251.2341}{160.2881556}$$

Φ^2_{fo} exp = 1.5696586 Φ_{fo}^2 by computer = 1.498

$$\left(\frac{\Delta P}{\Delta Z}\right)_{go} = \frac{\lambda_{go}(G_{tot})^2}{2\ x\ d\ x\ \rho_g}$$

$$Re_{go} = \frac{G_{tot}d}{\mu_g}$$

$$Re_{go} = \frac{2022.234583\ x\ 0.203}{1.789649606\ x\ 10^{-5}}$$

$$Re_{go} = 22{,}938{,}211.98$$

From single phase

$$Re_{go} > 209 \times 10^5$$

$$\lambda_{go} = 0.156772 \times Re^{-0.17628}$$

$$\lambda_{go} = 0.007902218961$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{go} = \frac{\lambda_{go}(G_{tot})^2}{2d\rho_g}$$

$$= \frac{0.007902218961 \ x \ (2022.234583)^2}{2 \ x \ 0.203 \ x \ 1.6289}$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{go} = 48864.29$$

$$\Phi^2_{go} = \frac{\left(\frac{\Delta P}{\Delta Z}\right)_{measured}}{\left(\frac{\Delta P}{\Delta Z}\right)_{go}}$$

$$\Phi^2_{go} = \frac{251.2341}{48864.29}$$

$\Phi^2_{go} = 0.005141466294$ By computer $\Phi_{go}^2 = 0.005145$

B.6.2 Homogeneous Model

Gas volume fraction

$$\beta = \frac{Q_g}{Q_g + Q_f}$$

$$= \frac{0.062760}{0.062760 + 0.065383}$$

$$\beta = 0.48976534$$

liquid volume fraction

$$1\text{-}\beta = 1\text{-}0.48976534$$

$$1\text{-}\beta = 0.510234659$$

mixture viscosity

$$\mu_H = \beta \times \mu_g + (1\text{-}\beta)\mu_f$$

$$\mu_H = 0.48976534 \times 1.7896496606 \times 10^{-5} + (0.510234659) \times 938.675059 \times 10^{-6}$$

$$\mu_H = 8.765083478 \times 10^{-6} + 4.789445493 \times 10^{-4}$$

$$\mu_H = 4.877096328 \times 10^{-4}$$

$$Re_H = \frac{Gtot \ x \ d}{\mu_H}$$

$$= \frac{2022.234583 \ x \ 0.203}{4.877096328 \ x \ 10^{-4}}$$

$$Re_H = 841{,}717.2694$$

$$Re_H > 2.09 \times 10^5$$

Using the eqn. $\lambda_H = 0.156772 \times Re^{-0.17628}$

$$\lambda_H = 0.014150773$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_H = \frac{\lambda_H (G_{tot})^2}{2d}\left[\frac{x}{\rho_g} + \frac{1-x}{\rho_f}\right]$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_H = \left[\frac{0.014150773\ (2022.234583)^2}{2\ x\ 0.203}\right] X$$

$$\left[\frac{1.561938321\ x\ 10^{-3}}{1.6289} + \frac{1-1.56193832\ x\ 10^{-3}}{999.470}\right]$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_H = 279.0606529$$

$$\phi^2_{foH} = \frac{\left(\frac{\Delta P}{\Delta Z}\right)_H}{\left(\frac{\Delta P}{\Delta Z}\right)_{fo}}$$

$$= \frac{279.0606529}{160.2881556}$$

$\Phi^2_{foH} = 1.740993599$ By computer $\Phi^2_{foH} = 1.742$

$$\Phi^2_{goH} = \frac{\left(\frac{\Delta P}{\Delta Z}\right)_H}{\left(\frac{\Delta P}{\Delta Z}\right)_{go}}$$

$$\Phi^2_{goH} = \frac{279.0606529}{48864.29}$$

$\Phi^2_{goH} = 0.005710932317$ By computer $\Phi^2_{goH} = 0.005984$

B.6.3 Lockhart-Martinelli Correlation

$$\left(\frac{\Delta P}{\Delta Z}\right)_f = \frac{\lambda_f G_{tot}^2}{2d\rho_f}(1-x)^2$$

$$Re = \frac{(1-x)G_{tot}d}{\mu_f}$$

$$1\text{-}x = 1\text{-}0.001561938321 = 0.998438062$$

$$Re = \frac{(1-0.001561938321)\ x\ 2022.25\ x\ 0.203}{938.675059\ x\ 10^{-6}}$$

Re = 436,650.0293

Re > 2.09×10^5

Using the equation

$$\lambda_f = 0.156722 \times Re^{-0.17628}$$

$$\lambda_f = 0.015886409$$

$$\left(\frac{\Delta P_f}{\Delta Z}\right)_f = \frac{0.015886409\ x\ (2022.25)^2\ x\ (0.998438062)^2}{2\ x\ 0.203\ x\ 999.470}$$

$$\left(\frac{\Delta P_f}{\Delta Z}\right)_f = 159.6033179$$

$$Re = \frac{x\ G_{tot}d}{\mu_g} \qquad Re_{go}\ from\ \text{exp} = 22938211.98$$

$$Re = \frac{0.001561938321\ x\ 2022.25\ x\ 0.203}{1.789649606\ x\ 10^{-5}}$$

Re_g = 35828.33809 $\qquad Re_g < 2.09 \times 10^5$

Using the equation

$$\lambda_g = 0.4416447 - 3.715733 \times 10^{-2} (\ln Re) -$$

$$2.393404 \times 10^{-3} (\ln Re)^2 + 2.128791 \times 10^{-4} (\ln Re)^3$$

$$\lambda_g = 0.034284616$$

$$\left(\frac{\Delta P_f}{\Delta Z}\right)_g = \frac{\lambda_g\, x^2\, G_{tot}^2}{2D\rho_g}$$

$$= \frac{0.034284616 \times (0.001561938321)^2\ (2022.25)^2}{2 \times 0.203 \times 1.6289}$$

$$\left(\frac{\Delta P_F}{\Delta Z}\right)_g = 0.517220944$$

$$X_{L\text{-}M}\ parameter = \left(\frac{(\Delta P/\Delta Z)_f}{\left(\frac{\Delta P}{\Delta Z}\right)_g}\right)^{1/2} = \left(\frac{159.603107}{0.517220944}\right)^{1/2}$$

$X_{L\text{-}M}$ parameter = 17.566394

From Figure 2.1.4 and for turbulent-turbulent

Martinelli Parameter

X	Φ_{ftt}	Φ_{gtt}
10	1.75	17.5
17.566394	α	β
20	1.48	29.5

By linear interpolation

$$\alpha = \Phi_{ftt} = \Phi_{fL\text{-}M} = 1.545707362$$

$$\beta = \Phi_{gtt} = \Phi 2_{gL\text{-}M} = 26.5796728$$

$$\phi^2_{fL\text{-}M} = \frac{(\Delta P/\Delta Z)_{TP}}{(\Delta P/\Delta Z)_f}$$

$$\phi^2_{foL\text{-}M} = \frac{(\Delta P/\Delta Z)_{TP}}{(\Delta P/\Delta Z)_{fo}}$$

$$\phi^2_{foL\text{-}M} = \phi^2_{fL\text{-}M}\,\frac{(\Delta P/\Delta Z)_f}{(\Delta P/\Delta Z)_{fo}} = \phi^2_{fL\text{-}M}\,(1-x)^2\,\frac{\lambda_f}{\lambda_{fo}}$$

$$\phi^2_{foL\text{-}M} = (1.545707362)^2\,(1-0.001561938321)^2\,x\,\frac{0.015886389}{0.015882033}$$

$\Phi^2_{foL\text{-}M} = 2.3824$ By computer = 2.2735

B.6.4 Chenoweth and Martin Correlation

Liquid volume fraction

$$1-\beta = 1 - 0.48976534$$

$$1-\beta = 0.51023466$$

$$Z = \frac{\left(\frac{\Delta P}{\Delta Z}\right)_{go}}{\left(\frac{\Delta P}{\Delta Z}\right)_{fo}} = \frac{\lambda_{go}}{\lambda_{fo}} x \frac{\rho_f}{\rho_g}$$

From previous

$$Re_f = \frac{G_{tot}d}{\mu_f}$$

λ_{fo} = 0.015882033 as for experimental calculation

$$Re_g = \frac{G_{tot}d}{\mu_g}$$

λ_{go} = 0.007902218961 as for experimental calculation

$$\therefore Z = \frac{0.0079022218961}{0.015882033} x \frac{999.470}{1.6289}$$

Z = 305.293988 from table (2.1.4) (Z = 200 to Z = 500)

$1-\beta$	Φ^2_{fo}
0.4	2.22
0.51023466	α
0.7	1.38

$\alpha = \Phi^2_{fo} = 1.911$

By computer $\Phi^2_{fo} = 1.803$

B.6.5 Baroczy Correlation

$$Property\ Index = \left(\frac{\mu_f}{\mu_g}\right)^{0.2}\left(\frac{\rho_g}{\rho_f}\right)$$

$$= \left(\frac{938.675059\ x\ 10^{-6}}{1.789649606\ x\ 10^{-5}}\right)^{0.2}\left(\frac{1.6289}{999.470}\right)$$

x = 0.003598107332 By computer x = 0.003797

Mass dryness fraction

X = 0.001561938321

From table 2.1.2

Mass dryness fraction x	Property index
0.001	2.15
0.001561938321	A
0.005	5.6
Mass dryness fraction x	Property index
0.001	2.08
0.001561938321	B
0.005	4.9

By linear interpolation A = 2.634671525 , B = 2.476616629

Property Index	Φ^2_{fo}
0.001	2.634671525
0.003598107332	α
0.004	2.47616629

$\alpha = \Phi^2_{fo} = 2.497400338$ by computer $\Phi^2_{fo} = 2.433$

B.6.6 Chisholm Correlation

$$\Gamma = \left(\frac{\left(\frac{\Delta P}{\Delta Z}\right)_{go}}{\left(\frac{\Delta P}{\Delta Z}\right)_{fo}} \right)^{1/2}$$

$$= \left(\frac{48864.29}{160.28815561} \right)^{1/2}$$

$$= \sqrt{304.852781}$$

$$= 17.46003382$$

From single-phase

$$\lambda = 0.15677 \text{ x Re}^{-0.17628}$$

$$\lambda = \text{k Re}^{-n}$$

Hence n = 0.17628

and 1-n = 0.82372

$\frac{2-n}{2}$ = 0.91186 and x = 1.561938321 x 10^{-3}

$$\phi_{fo}^2 = 1 + (\Gamma^2 - 1)\left[B\,(x)^{\frac{2-n}{2}}\,(1-x)^{\frac{2-n}{2}} + (x)^{2-n}\right]$$

From Table 2.1.3 for Γ in the range 9.5 to 28

and $G_{tot} > 600$

$$B = \frac{21}{\Gamma} = \frac{21}{17.46003382} = 1.202746811$$

$$(\Gamma^2\text{-}1) = 303.852781$$

$$(x)^{\frac{2-n}{2}} = 2.760669046 \times 10^{-3}$$

$$(1-x)^{\frac{2-n}{2}} = 0.998575632$$

$(x)^{2-n} = 7.621293581 \times 10^{-6}$

$\therefore \Phi^2_{fo} = 2.009787181$ By computer $\Phi^2_{fo} = 1.987$

B.6.7 Duckler Case II

$$\left(\frac{\Delta P}{\Delta Z}\right)_{D2} = \frac{\lambda_2 \, G_{tot}^2}{2d\rho_{HOM}} \; x \; \psi$$

$\rho_{NS} = \beta \, \rho_g + (1\text{-}\beta)\rho_f$

$\rho_{NS} = 0.48976534 \text{ x } 1.6289 + 0.510234659 \text{ x } 999.470$

$\rho_{NS} = 510.7620134$

$$\psi = \frac{\rho_f}{\rho_{HOM}} \frac{(1-\beta)^2}{1-\alpha} + \frac{\rho_g}{\rho_{HOM}} \frac{\beta^2}{\alpha}$$

$$\psi = \frac{999.470}{510.7620134} \; x \; \frac{(0.510234659)^2}{(1-0.4792)}$$

$$+ \frac{1.6289}{510.7620134} \; x \; \frac{(0.48976534)^2}{0.4792}$$

$\Psi = 0.979779385$

$$Re_{D_2} = \frac{G_{tot} d}{\mu_{HOM}} \; x \; \psi$$

$\mu_{HOM} = \beta \text{ x } \mu_g + (1\text{-}\beta)\mu_f$

From homogeneous calculation

$\mu_{HOM} = 4.877096328 \text{ x } 10^{-4}$

$$Re_{D_2} = \frac{(2022.234583) \; x \; 0.203}{4.877096328 \; x \; 10^{-4}} \; x \; 0.979779385$$

$$Re_{D2} = 824697.2285$$

$$Re > 2.09 \text{ x } 10^5$$

Using $\lambda = 0.15677 \, Re^{-0.17628}$

$$\lambda_1 = 0.014201641$$

$$\lambda_2 = \lambda_1 \left[1 + \frac{N}{1.281 - 0.478\,N + 0.444\,N^2 - 0.094 N^3 + 0.00843 N^4}\right]$$

Where N = -ln (1-β)

N = 0.672884543

$$\lambda_2 = 0.022632353$$

$$\left(\frac{\Delta P}{\Delta Z}\right)_{D2} = \frac{\lambda_2\, G_{tot}^2\, \psi}{2 d \rho_{NS}}$$

$$= \frac{0.022632353 \ x \ (2022.234583)^2}{2 \ x \ 0.203 \ x \ 510.7620134} \ x \ 0.981442465$$

= 437.2969672

$$\phi_{fo}^2 = \frac{437.2969672}{160.2881556} = 2.728192645$$

$\Phi^2_{fo} = 2.728192645$ By Computer $\Phi^2_{fo} = 2.730$

APPENDIX (C)

APPENDIX C

C.1 MEAN VOID FRACTION CALCULATION.

C.2 GEOMETRICAL VOID FRACTION CALCULATION.

C.3 GEOMETRICAL VOID FRACTION; SAMPLE OF CALCULATION.

C.4 γ-RAYS MEAN VOID FRACTION; SAMPLE OF CALCULATION.

C.5 EXPERIMENTAL AND PREDICTED VOID FRACTION COMPARISONS.

C.6 VOID FRACTION CORRELATIONS; SAMPLE OF CALCULATION.

APPENDIX C

C.1 MEAN VOID FRACTION CALCULATION.

C.2 GEOMETRICAL VOID FRACTION CALCULATION.

C.3 GEOMETRICAL VOID FRACTION; SAMPLE OF CALCULATION.

C.4 γ-RAYS MEAN VOID FRACTION; SAMPLE OF CALCULATION.

APPENDIX C

C.1 Mean Void Fraction Calculation

Referring to figure C.1

$$\frac{L}{2} = \{(R^2 - X^2)\}^{1/2}$$

$$= R\left\{1 - \left(\frac{X}{R}\right)^2\right\}^{1/2}$$

therefore,

$$\frac{L}{2R} = \left\{1 - \left(\frac{X}{R}\right)^2\right\}^{1/2} \qquad (C.1)$$

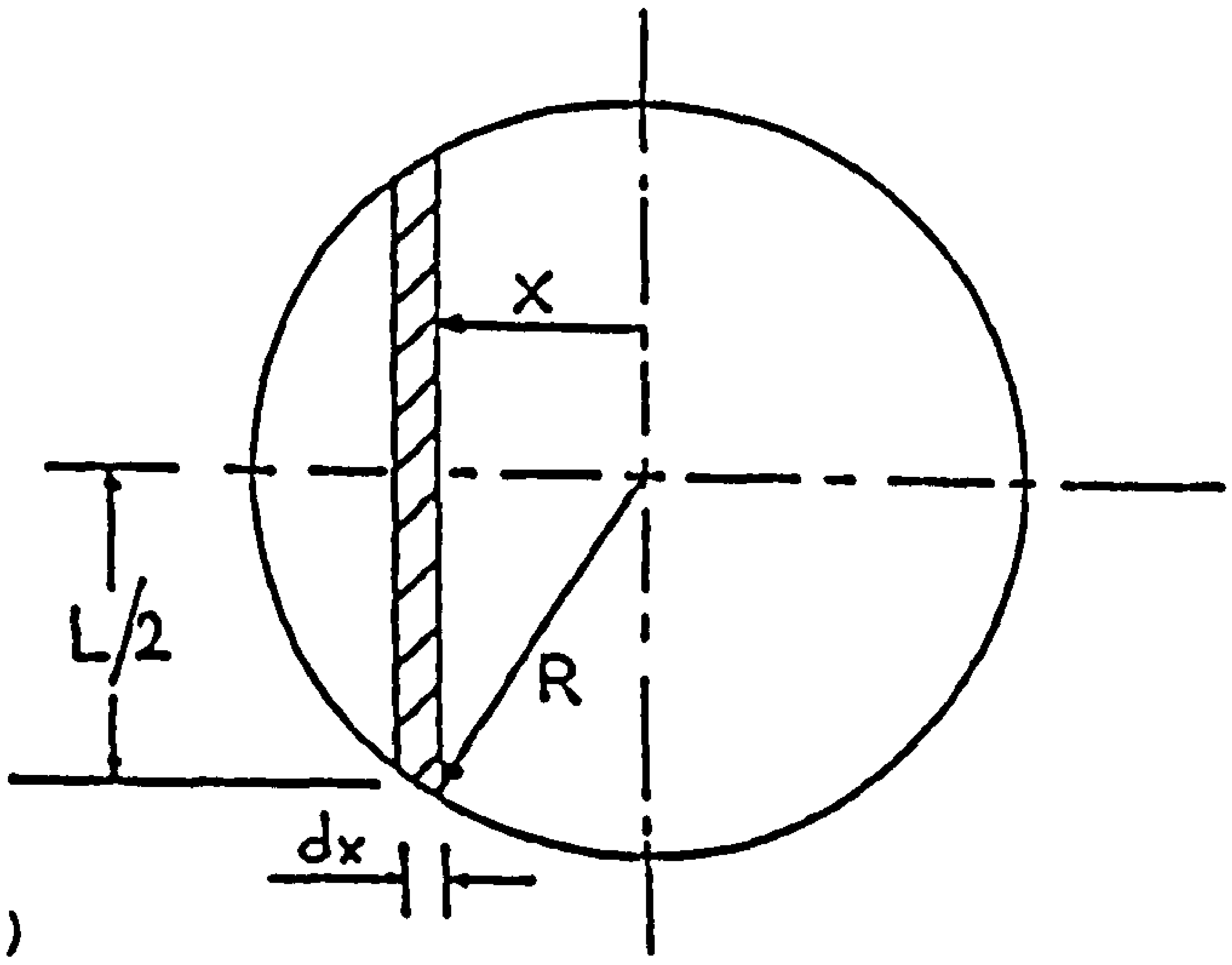

Fig.C.1

where X/R is the fractional radius.

The values for X/R and the corresponding L/R values from equation C.1 for any size of tube are shown below;

X/R	0.0	0.15	0.30	0.45	0.6	0.75	0.90	1.0
L/R	2.0	1.9774	1.9078	1.7861	1.6000	1.3229	0.8718	0.0

Consider the element L dx. The area of the gas is given by:

$$A_{gas} = \int_{-R}^{R} \alpha_{CHORD} L dx$$

where α_{CHORD} is the chordal void fraction obtained from equation 5.2.11 (section 5.2).

The mean void fraction can be written as,

$$\alpha_m = \frac{A_{gas}}{A_{pipe}}$$

$$= \frac{1}{\pi R^2}\int_{-R}^{R} \alpha_{CHORD} L dx$$

$$x = \frac{X}{R}$$

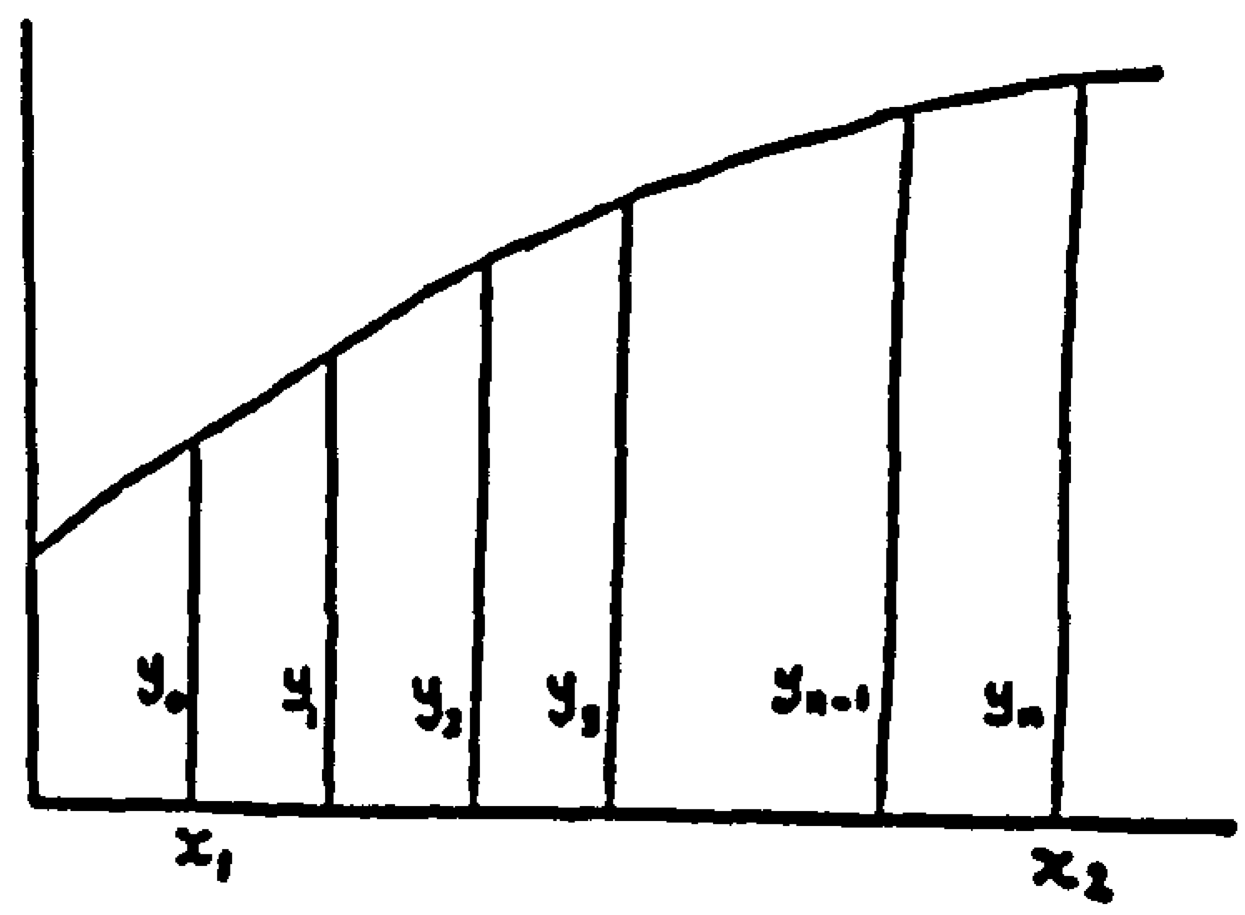

Fig.C.2

and limit change from -R to R to -1 to +1

$$= \frac{1}{\pi}\int_{-1}^{+1} \alpha_{CHORD} \frac{L}{R} d\left(\frac{X}{R}\right)$$

According to Simpson's Rule in figure C.2

$$\int_{x_1}^{x_2} y dx = \left(\frac{h}{3}\right)(y_0 + 4y_1 + 2y_2 + \ldots + 2y_{n-2} + 4y_{n-1} + y_n)$$

Hence,

$$\alpha_m = \frac{1}{\pi}\int_{-1}^{+1} y dx$$

$$= \left(\frac{h}{3\pi}\right)(y_0 + 4y_1 + 2y_2 + \ldots + 2y_{n-2} + 4y_{n-1} + y_n) \qquad (C.2)$$

where,

$h = 0.15$

$$y = \alpha_{CHORD}\left(\frac{L}{R}\right)$$

C.2 Geometrical Void Fraction Calculation

Consider a level of water in a pipe of diameter R at still conditions or at a smooth stratified flow where the height of water is h (see fig. C.3). The void fraction can be determined geometrically knowing the value of h in the tube.

Referring to figure C.3

$$\cos\theta = \frac{R-h}{R}$$

$$= 1 - \frac{h}{R}$$

Hence,

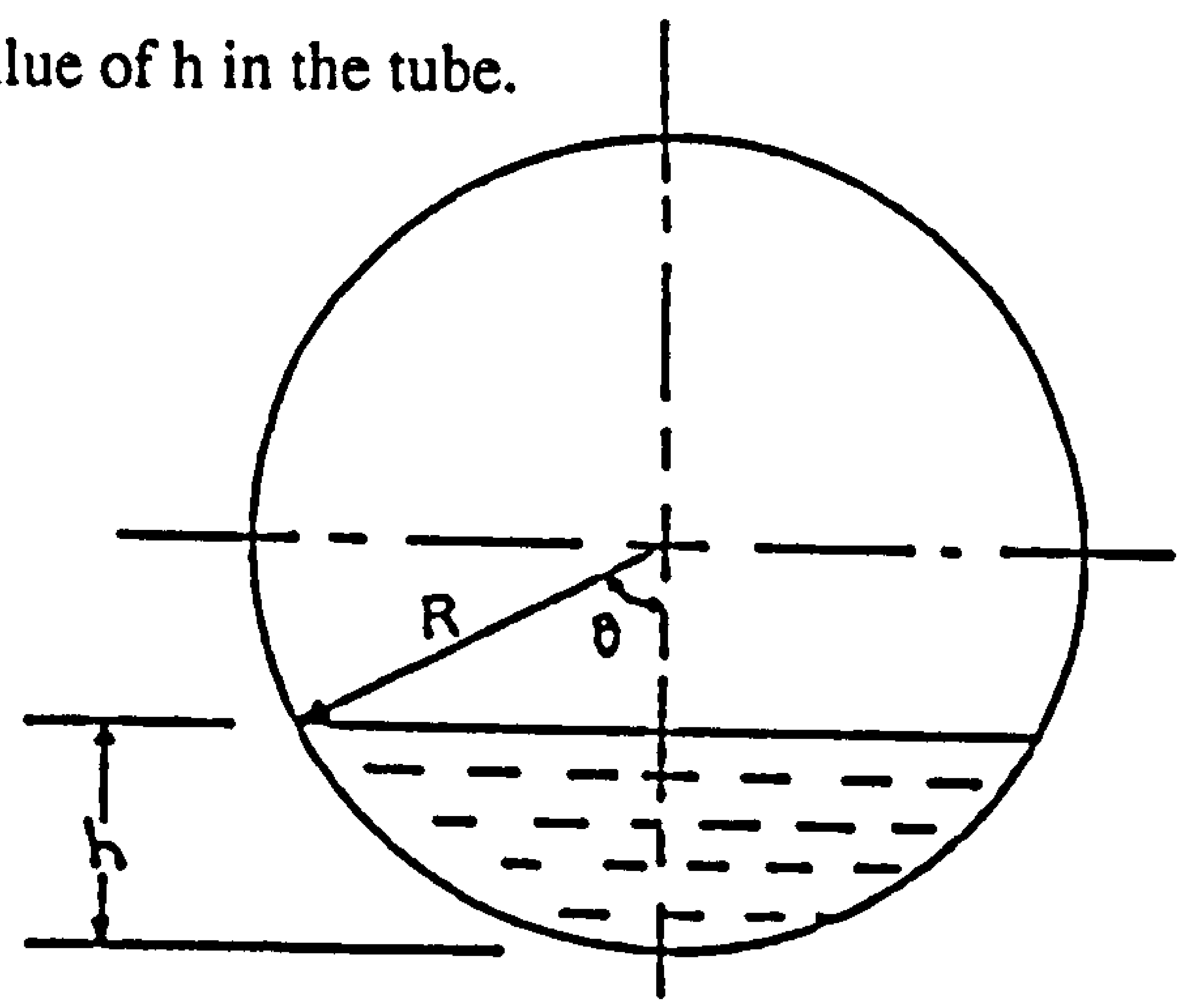

Fig.C.3

$$\theta = \cos^{-1}\left(1-\frac{h}{R}\right) \tag{C.3}$$

and void fraction

$$\alpha = \frac{A_{gas}}{A_{pipe}}$$

$$= \frac{\left(1-\frac{2\theta}{360}\right)\pi R^2 + R^2 \sin\theta\cos\theta}{\pi R^2}$$

$$= \left\{1-\frac{2\theta}{360}\right\} + \frac{\sin\theta\cos\theta}{\pi} \tag{C.4}$$

C.3 Geometrical Void Fraction; Sample of Calculation

The calculation of the geometrical void fraction is as follows:

Consider Test No. 789007 from table 5.4.1

The level of water in the tube h = 64.95 mm

The void fraction obtained by γ-rays α = 0.7748

The tube diameter D = 208.45 mm.

from equation C.3,

$$\theta = \cos^{-1}\left(1-\frac{h}{R}\right)$$

$$= \cos^{-1}\left(1-\frac{64.95}{104.225}\right)$$

$$\theta = 67.8626001$$

and from equation C.4,

$$\alpha = \left[1-\frac{2\theta}{360}\right] + \frac{\sin\theta\cos\theta}{\pi}$$

$$= \left[1-\frac{2\times 67.8626001}{360}\right] + \frac{\sin 67.8626 \cos 67.8626}{\pi}$$

$$= 0.622985555 + 0.111106135$$

$$\alpha = 0.73409 \qquad \gamma\text{-}rays \quad value \quad \alpha = 0.7448$$

C.4 γ-Rays Mean Void Fraction; Sample of Calculation

The void fraction was determined using 13 steps (chordal positions) and 5 steps. A check calculation was made for each case, and both are detailed below;

From the calibration characteristics shown in figure 5.4.2 and using equation 5.2.11 the chordal void fraction at fractional radiuses was determined for liquid height H = 64.95 mm (non-flow), as shown in table C.4.1.

The mean void fraction then calculated where Simpson's Rule equation (C.2) was used and the results of the calculation are shown in table C.4.2 for the 13 steps, and in table C.4.3 for the 5 steps.

Fractional Radius	Log$_e$ of Counts Per Second			
	Values at H = 64.95mm	Tube Empty	Tube Full	Chordal Void Fraction α_{CH}
	A	B	C	$\frac{A-C}{B-C}$
-1.0	-	-	-	-
-0.90	9.7188	9.8451	9.1158	0.8268
-0.75	9.6477	9.9025	8.8769	0.7516
-0.60	9.5886	9.9238	8.7060	0.7247
-0.45	9.5424	9.9359	8.5765	0.7105
-0.30	9.5180	9.9426	8.4987	0.7059
-0.15	9.4952	9.9430	8.4563	0.6988
0.0	9.4997	9.9420	8.4539	0.7028
0.15	9.5167	9.9446	8.4922	0.7054
0.30	9.5445	9.9362	8.5586	0.7157
0.45	9.5838	9.9255	8.6776	0.7262
0.60	9.6395	9.9021	8.8346	0.7540
0.75	9.7093	9.8555	9.0545	0.8175
0.90	9.5843	9.6073	9.3746	0.9012
1.0	-	-	-	-

Table C.4.1 Void Fraction Data and Chordal

Void Fraction (13 Steps) for H = 64.95 mm

Fractional Radius X/R	Chordal Void-Fraction α_{CII}	Fractional Chordal Length L/R	Product $\alpha_{CII}(L/R)$	Multplr. A	Weighted Value α_{CII} (L/R)A
-1	1	0	0	1	0
-0.90	0.8268	0.8718	0.7208	4	2.8832
-0.75	0.7516	1.3229	0.9943	2	1.9886
-0.60	0.7247	1.6000	1.1595	4	4.6381
-0.45	0.7105	1.7861	1.2690	2	2.5380
-0.30	0.7059	1.9078	1.3467	4	5.3869
-0.15	0.6988	1.9774	1.3818	2	2.7636
0.0	0.7028	2.000	1.4056	4	5.6224
0.15	0.7054	1.9774	1.3949	2	2.7897
0.30	0.7157	1.9078	1.3654	4	5.4616
0.45	0.7262	1.7861	1.2971	2	2.5941
0.60	0.7540	1.6000	1.2064	4	4.8256
0.75	0.8175	1.3229	1.0815	2	2.1629
0.90	0.9012	0.8718	0.7857	4	3.1427
1.0	-	0	0	1	0
					Σ = 46.7974

Table C.4.2 The Mean Void Fraction Using 13 steps

The mean void fraction $\alpha_{mean} = \frac{0.15}{3 \times \pi} \times \Sigma$

$$\alpha_{mean} = \frac{0.15 \times 46.7974}{3\pi}$$

α_{mean} = 0.74480 By computer α = 0.7448

Fract-ional Radius (X/R)	Chordal Void-Fraction α_{CII}	Fract-ional Chordal Length (L/R)	Product $\alpha_{CII}(L/R)$	Multplr. (A)	Weighted Value $\alpha_{CII}(L/R)A$
-1	1	0	0	1	0
-0.90	0.8268	0.8718	0.7208	4	2.8832
-0.45	0.7105	1.7861	1.2690	2	2.5380
0.0	0.7028	2.000	1.4056	4	5.6224
0.45	0.7262	1.7861	1.2971	2	2.5941
0.90	0.9012	0.8718	0.7857	4	3.1427
1.0	-	0	0	1	0
					Σ = 16.7804

Table C.4.3 The Mean Void Fraction Using 5 steps

$$\text{Mean void fraction } \alpha_{mean} = \frac{0.45}{3\pi}\Sigma$$

$$\alpha_{mean} = \frac{0.45 \times 16.7804}{3\pi}$$

α_{mean} = 0.801205082 By computer α_{mean} = 0.7448

APPENDIX C

C.5 EXPERIMENTAL AND PREDICTED VOID FRACTION COMPARISONS.

FROM **Table C.5.1** TO **Table C.5.38**

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
220102	0.3062	0.5931	0.6640	0.6010	0.4027	0.3881	0.5781	0.6012
220103	0.3884	0.5280	0.5874	0.5368	0.3712	0.3586	0.5107	0.5304
220104	0.4065	0.4730	0.5199	0.4793	0.3410	0.3301	0.4552	0.4693
220105	0.3786	0.4353	0.4733	0.4391	0.3194	0.3097	0.4180	0.4275
220106	0.3700	0.4117	0.4442	0.4137	0.3049	0.2960	0.3949	0.4015
220107	0.3600	0.3957	0.4245	0.3962	0.2945	0.2861	0.3794	0.3839
220108	0.0692	0.3834	0.4096	0.3831	0.2870	0.2790	0.3675	0.3706
220109	0.3390	0.3845	0.4109	0.3841	0.2870	0.2790	0.3686	0.3716
280101	0.2660	0.6327	0.7077	0.6401	0.4279	0.4123	0.6202	0.6433
280102	0.3434	0.6617	0.7377	0.6626	0.4337	0.4172	0.6515	0.6714
280103	0.3004	0.5984	0.6700	0.6061	0.4055	0.3907	0.5837	0.6065
280104	0.1609	0.4405	0.4797	0.4041	0.2223	0.2115	0.4231	0.4087
280105	0.3007	0.5077	0.5626	0.4599	0.2363	0.2238	0.4900	0.4774
280106	0.1882	0.4671	0.5126	0.4248	0.2250	0.2135	0.4494	0.4348
280107	0.0000	0.4037	0.4343	0.3693	0.2078	0.1979	0.3871	0.3701
280108	0.2580	0.5356	0.5966	0.5356	0.3500	0.3366	0.5185	0.5339
280109	0.3166	0.4976	0.5503	0.4989	0.3361	0.3240	0.4800	0.4929
280110	0.3207	0.4695	0.5157	0.4710	0.3250	0.3139	0.4518	0.4624
280111	0.2937	0.4365	0.4748	0.4353	0.3040	0.2939	0.4192	0.4254
280112	0.2350	0.2713	0.2766	0.2611	0.2023	0.1973	0.2606	0.2502

TABLE C.5.1 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
280113	0.2489	0.2839	0.2910	0.2742	0.2107	0.2053	0.2725	0.2630
280114	0.2642	0.3089	0.3202	0.3005	0.2277	0.2215	0.2963	0.2889
280115	0.2793	0.3342	0.3502	0.3272	0.2442	0.2373	0.3203	0.3155
280116	0.2960	0.3626	0.3843	0.3575	0.2625	0.2547	0.3475	0.3458
280117	0.3039	0.3852	0.4117	0.3815	0.2762	0.2677	0.3693	0.3701
280118	0.3085	0.4201	0.4546	0.4189	0.2975	0.2880	0.4032	0.4082
280119	0.4640	0.4812	0.5302	0.4948	0.3676	0.3571	0.4635	0.4824
280120	0.5017	0.5508	0.6148	0.5694	0.4117	0.3990	0.5341	0.5604
290101	0.3874	0.7056	0.7787	0.7118	0.4925	0.4757	0.6992	0.7181
290102	0.3412	0.6750	0.7505	0.6882	0.4811	0.4651	0.6657	0.6904
290103	0.3470	0.6540	0.7297	0.6709	0.4732	0.4578	0.6428	0.6704
290104	0.2719	0.6322	0.7070	0.6428	0.4372	0.4217	0.6194	0.6446
290105	0.1893	0.5557	0.6204	0.5414	0.3261	0.3119	0.5390	0.5494
290106	0.3360	0.5057	0.5601	0.4671	0.2509	0.2383	0.4879	0.4809
70201	0.6588	0.1974	0.1944	0.1277	0.0460	0.0428	0.1907	0.1375
70202	0.7140	0.2178	0.2166	0.1410	0.0502	0.0468	0.2100	0.1531
70203	0.7237	0.3667	0.3892	0.2756	0.1097	0.1026	0.3514	0.2974
70204	0.7244	0.3585	0.3793	0.2644	0.1028	0.0961	0.3436	0.2869
70205	0.7236	0.4589	0.5025	0.3424	0.1291	0.1205	0.4413	0.3855
70206	0.0856	0.4507	0.4924	0.3998	0.2024	0.1916	0.4332	0.4122

TABLE C.5.2 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
70207	0.2804	0.5116	0.5674	0.4631	0.2372	0.2246	0.4940	0.4820
110201	0.3237	0.5867	0.6568	0.5605	0.3184	0.3034	0.5714	0.5782
110202	0.2642	0.5865	0.6565	0.5694	0.3373	0.3222	0.5712	0.5823
110203	0.2665	0.6018	0.6738	0.5901	0.3589	0.3435	0.5872	0.6018
110204	0.2723	0.6241	0.6985	0.6204	0.3926	0.3768	0.6110	0.6299
110205	0.2792	0.6413	0.7168	0.6433	0.4201	0.4041	0.6294	0.6509
110206	0.2878	0.6571	0.7330	0.6641	0.4466	0.4304	0.6464	0.6697
110207	0.3179	0.6724	0.7481	0.6827	0.4695	0.4533	0.6631	0.6868
110208	0.3414	0.6791	0.7546	0.6918	0.4833	0.4672	0.6704	0.6945
110210	0.3676	0.6566	0.7326	0.6760	0.4826	0.4673	0.6460	0.6743
110213	0.1577	0.3926	0.4207	0.3629	0.2118	0.2022	0.3763	0.3615
110214	0.2212	0.4610	0.5051	0.4466	0.2790	0.2676	0.4433	0.4443
110215	0.3087	0.5145	0.5710	0.5147	0.3406	0.3279	0.4970	0.5112
110216	0.3796	0.5614	0.6273	0.5754	0.4026	0.3892	0.5450	0.5698
110217	0.4811	0.5880	0.6583	0.6094	0.4400	0.4264	0.5728	0.6024
110218	0.5253	0.5455	0.6085	0.5662	0.4160	0.4037	0.5287	0.5561
110219	0.0515	0.0482	0.0441	0.0408	0.0295	0.0286	0.0477	0.0389
110220	0.0604	0.0631	0.0582	0.0539	0.0391	0.0379	0.0622	0.0514
110221	0.0980	0.1359	0.1299	0.1212	0.0898	0.0872	0.1324	0.1158
110222	0.1200	0.1651	0.1600	0.1496	0.1119	0.1088	0.1601	0.1431
110223	0.1978	0.2375	0.2384	0.2245	0.1723	0.1678	0.2287	0.2152

TABLE C.5.3 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
110224	0.2577	0.2860	0.2935	0.2777	0.2169	0.2116	0.2745	0.2666
110225	0.3440	0.3353	0.3515	0.3342	0.2663	0.2602	0.3214	0.3213
300501	0.0000	0.0824	0.0767	0.0663	0.0389	0.0371	0.0809	0.0643
300502	0.0000	0.1061	0.0999	0.0865	0.0510	0.0487	0.1038	0.0840
300503	0.0000	0.0707	0.0654	0.0583	0.0372	0.0357	0.0696	0.0561
300504	0.0000	0.0837	0.0780	0.0696	0.0446	0.0428	0.0822	0.0670
300505	0.0016	0.0657	0.0607	0.0553	0.0379	0.0366	0.0648	0.0530
300506	0.0000	0.0506	0.0463	0.0422	0.0288	0.0278	0.0500	0.0404
300507	0.0036	0.0565	0.0519	0.0479	0.0342	0.0331	0.0558	0.0457
300508	0.0086	0.0629	0.0580	0.0535	0.0383	0.0371	0.0621	0.0512
300509	0.0104	0.0759	0.0704	0.0646	0.0452	0.0437	0.0747	0.0619
300510	0.0080	0.0735	0.0681	0.0621	0.0428	0.0414	0.0723	0.0595
300511	0.0060	0.0841	0.0783	0.0710	0.0480	0.0462	0.0826	0.0682
300512	0.0171	0.1193	0.1131	0.0995	0.0614	0.0588	0.1165	0.0964
300513	0.0058	0.1096	0.1033	0.0908	0.0557	0.0534	0.1071	0.0879
300514	0.0369	0.1642	0.1591	0.1410	0.0888	0.0852	0.1592	0.1368
300515	0.0216	0.1368	0.1308	0.1171	0.0759	0.0729	0.1332	0.1131
300516	0.0201	0.1188	0.1126	0.1025	0.0701	0.0676	0.1160	0.0985
300517	0.0271	0.1145	0.1083	0.0992	0.0691	0.0668	0.1119	0.0952
300518	0.0254	0.0983	0.0922	0.0850	0.0604	0.0585	0.0963	0.0814

TABLE C.5.4 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
300519	0.0275	0.1005	0.0944	0.0875	0.0635	0.0616	0.0984	0.0837
300520	0.0493	0.1206	0.1144	0.1063	0.0777	0.0753	0.1177	0.1017
300521	0.0505	0.1407	0.1347	0.1240	0.0877	0.0849	0.1369	0.1190
300522	0.0407	0.1437	0.1379	0.1260	0.0870	0.0840	0.1398	0.1211
300523	0.0582	0.1803	0.1761	0.1591	0.1059	0.1020	0.1746	0.1537
300524	0.0692	0.2091	0.2071	0.1839	0.1163	0.1116	0.2018	0.1789
300525	0.0451	0.1871	0.1833	0.1622	0.1015	0.0973	0.1809	0.1577
300526	0.0737	0.2283	0.2282	0.2031	0.1294	0.1243	0.2199	0.1977
300527	0.0798	0.2070	0.2048	0.1845	0.1217	0.1171	0.1998	0.1787
300528	0.0696	0.1941	0.1908	0.1732	0.1170	0.1129	0.1876	0.1673
300529	0.0652	0.1648	0.1598	0.1464	0.1020	0.0986	0.1599	0.1409
300530	0.0706	0.1481	0.1424	0.1316	0.0945	0.0916	0.1439	0.1263
310501	0.1007	0.2524	0.2551	0.2279	0.1468	0.1411	0.2427	0.2220
310502	0.1451	0.2842	0.2914	0.2620	0.1719	0.1654	0.2728	0.2553
310503	0.1306	0.2582	0.2616	0.2374	0.1603	0.1545	0.2482	0.2303
310504	0.0978	0.2028	0.2002	0.1843	0.1304	0.1262	0.1958	0.1775
310505	0.1157	0.1874	0.1837	0.1705	0.1242	0.1204	0.1813	0.1638
310506	0.1482	0.2073	0.2052	0.1908	0.1398	0.1357	0.2001	0.1834
310507	0.1349	0.1866	0.1829	0.1709	0.1275	0.1240	0.1806	0.1640
310508	0.1347	0.2241	0.2235	0.2056	0.1454	0.1406	0.2159	0.1984
310509	0.1528	0.2705	0.2756	0.2505	0.1702	0.1642	0.2598	0.2432

TABLE C.5.5 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
310510	0.1669	0.3021	0.3122	0.2803	0.1830	0.1761	0.2898	0.2738
310511	0.1849	0.3310	0.3463	0.3126	0.2078	0.2002	0.3172	0.3056
50601	0.0000	0.1275	0.1213	0.1025	0.0568	0.0540	0.1243	0.1004
50602	0.0599	0.1723	0.1676	0.1391	0.0739	0.0701	0.1670	0.1376
50603	0.0585	0.1342	0.1282	0.1105	0.0643	0.0614	0.1307	0.1076
50604	0.0713	0.1569	0.1515	0.1311	0.0772	0.0737	0.1523	0.1278
50605	0.0743	0.1785	0.1742	0.1480	0.0832	0.0792	0.1728	0.1453
50606	0.0947	0.2463	0.2483	0.2143	0.1253	0.1196	0.2370	0.2107
50607	0.1004	0.2223	0.2216	0.1938	0.1175	0.1124	0.2143	0.1894
50608	0.0970	0.2590	0.2626	0.2230	0.1252	0.1192	0.2490	0.2208
50609	0.1255	0.2934	0.3020	0.2589	0.1488	0.1419	0.2815	0.2565
50610	0.1516	0.3087	0.3200	0.2755	0.1602	0.1528	0.2961	0.2729
50611	0.1373	0.2649	0.2693	0.2366	0.1451	0.1389	0.2545	0.2317
50612	0.1212	0.2516	0.2542	0.2246	0.1400	0.1342	0.2420	0.2194
50613	0.1438	0.2740	0.2796	0.2482	0.1568	0.1505	0.2631	0.2426
60601	0.1430	0.3440	0.3618	0.3174	0.1939	0.1856	0.3296	0.3134
60602	0.1685	0.3625	0.3841	0.3386	0.2099	0.2011	0.3474	0.3344
60603	0.1862	0.3738	0.3978	0.3518	0.2200	0.2110	0.3582	0.3474
60604	0.1884	0.3796	0.4049	0.3588	0.2254	0.2162	0.3639	0.3542
60605	0.1845	0.3346	0.3506	0.3152	0.2069	0.1991	0.3207	0.3083

TABLE C.5.6 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
60606	0.1989	0.3436	0.3613	0.3255	0.2150	0.2069	0.3293	0.3184
60607	0.2128	0.3555	0.3756	0.3393	0.2259	0.2176	0.3406	0.3319
60608	0.2257	0.3672	0.3898	0.3526	0.2360	0.2274	0.3519	0.3452
60609	0.2614	0.3764	0.4010	0.3640	0.2463	0.2375	0.3608	0.3562
60610	0.2466	0.3103	0.3218	0.2968	0.2114	0.2047	0.2975	0.2874
60611	0.2184	0.2747	0.2805	0.2606	0.1904	0.1847	0.2638	0.2513
60612	0.1973	0.2652	0.2696	0.2501	0.1820	0.1765	0.2548	0.2412
60613	0.2578	0.4340	0.4717	0.4214	0.2715	0.2609	0.4167	0.4172
60614	0.2196	0.4234	0.4586	0.4084	0.2605	0.2501	0.4063	0.4043
60615	0.1876	0.4021	0.4324	0.3828	0.2399	0.2301	0.3856	0.3790
60616	0.1862	0.3552	0.3753	0.3359	0.2176	0.2092	0.3404	0.3297
60617	0.2093	0.3690	0.3920	0.3521	0.2305	0.2217	0.3536	0.3456
60618	0.2444	0.3934	0.4218	0.3812	0.2542	0.2449	0.3772	0.3742
140801	0.3141	0.3294	0.3444	0.2513	0.1046	0.0981	0.3157	0.2679
140802	0.3133	0.3636	0.3854	0.2866	0.1230	0.1154	0.3484	0.3048
140803	0.3098	0.4001	0.4300	0.3269	0.1457	0.1370	0.3837	0.3466
140804	0.3089	0.4233	0.4585	0.3534	0.1614	0.1520	0.4062	0.3739
140805	0.3087	0.4659	0.5112	0.4051	0.1951	0.1842	0.4482	0.4263
140806	0.3092	0.4921	0.5435	0.4384	0.2188	0.2070	0.4743	0.4595
140807	0.3100	0.5161	0.5729	0.4697	0.2429	0.2302	0.4986	0.4905
140808	0.3087	0.5400	0.6018	0.5015	0.2691	0.2555	0.5229	0.5216

TABLE C.5.7 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
140809	0.3121	0.5570	0.6221	0.5246	0.2893	0.2752	0.5405	0.5437
140810	0.3112	0.5740	0.6420	0.5477	0.3108	0.2962	0.5581	0.5658
140811	0.3128	0.5879	0.6581	0.5667	0.3294	0.3143	0.5726	0.5837
140812	0.3135	0.6078	0.6805	0.5939	0.3577	0.3421	0.5936	0.6091
140813	0.3170	0.6181	0.6920	0.6071	0.3712	0.3554	0.6046	0.6217
140814	0.3183	0.6334	0.7084	0.6270	0.3929	0.3768	0.6209	0.6402
140815	0.3239	0.6411	0.7165	0.6374	0.4052	0.3890	0.6292	0.6496
140816	0.2690	0.6045	0.6769	0.6058	0.3920	0.3768	0.5902	0.6121
150801	0.2189	0.2979	0.3073	0.2321	0.1022	0.0961	0.2858	0.2426
150802	0.2200	0.3658	0.3881	0.3029	0.1416	0.1335	0.3505	0.3156
150803	0.2225	0.4225	0.4575	0.3677	0.1822	0.1723	0.4054	0.3816
150804	0.2190	0.4603	0.5043	0.4130	0.2130	0.2018	0.4427	0.4275
150805	0.2202	0.4855	0.5354	0.4449	0.2371	0.2251	0.4678	0.4593
150806	0.2274	0.5118	0.5677	0.4791	0.2647	0.2518	0.4942	0.4929
150807	0.2265	0.5279	0.5872	0.5000	0.2824	0.2690	0.5106	0.5134
150808	0.2287	0.5443	0.6069	0.5218	0.3020	0.2881	0.5273	0.5345
150809	0.2366	0.5629	0.6291	0.5463	0.3247	0.3103	0.5466	0.5583
150810	0.2472	0.5828	0.6523	0.5730	0.3516	0.3367	0.5673	0.5836
150811	0.2613	0.5904	0.6610	0.5832	0.3623	0.3472	0.5753	0.5932
150812	0.1450	0.2661	0.2706	0.2089	0.0957	0.0901	0.2557	0.2155

TABLE C.5.8 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
150813	0.2928	0.3583	0.3790	0.3046	0.1510	0.1427	0.3433	0.3131
150814	0.6409	0.4327	0.4701	0.3120	0.1137	0.1060	0.4154	0.3578
150815	0.7301	0.4968	0.5493	0.3832	0.1492	0.1394	0.4791	0.4355
150816	0.7320	0.5377	0.5991	0.4370	0.1819	0.1705	0.5206	0.4899
200801	0.3907	0.3852	0.4118	0.2861	0.1107	0.1035	0.3693	0.3167
200802	0.3885	0.4367	0.4750	0.3449	0.1425	0.1336	0.4193	0.3778
200803	0.3873	0.4658	0.5110	0.3792	0.1623	0.1523	0.4480	0.4135
200804	0.3855	0.4816	0.5305	0.3990	0.1745	0.1640	0.4638	0.4336
200805	0.3836	0.5078	0.5628	0.4328	0.1969	0.1853	0.4902	0.4675
200806	0.3864	0.5386	0.6002	0.4739	0.2267	0.2139	0.5215	0.5081
200807	0.3843	0.5567	0.6218	0.4987	0.2461	0.2326	0.5402	0.5322
200808	0.3838	0.5843	0.6540	0.5372	0.2788	0.2643	0.5689	0.5687
200809	0.3833	0.6017	0.6737	0.5616	0.3015	0.2863	0.5871	0.5916
200810	0.3849	0.6178	0.6916	0.5844	0.3240	0.3083	0.6043	0.6125
200811	0.3858	0.6322	0.7071	0.6047	0.3454	0.3292	0.6196	0.6309
200812	0.3871	0.6506	0.7264	0.6306	0.3746	0.3579	0.6394	0.6539
200813	0.3848	0.6595	0.7354	0.6430	0.3893	0.3725	0.6490	0.6647
200814	0.3856	0.6667	0.7426	0.6530	0.4017	0.3848	0.6569	0.6734
200815	0.3898	0.6782	0.7537	0.6687	0.4220	0.4049	0.6694	0.6869
200816	0.3922	0.6884	0.7633	0.6825	0.4406	0.4234	0.6805	0.6985
210801	0.4663	0.4151	0.4484	0.3014	0.1117	0.1042	0.3982	0.3420

TABLE C.5.9 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
210802	0.4764	0.4570	0.5002	0.3496	0.1365	0.1276	0.4394	0.3929
210803	0.4734	0.4912	0.5424	0.3918	0.1606	0.1504	0.4735	0.4364
210804	0.4786	0.5287	0.5882	0.4389	0.1895	0.1779	0.5114	0.4848
210805	0.4777	0.5604	0.6260	0.4836	0.2219	0.2089	0.5439	0.5279
210806	0.4712	0.5868	0.6568	0.5204	0.2506	0.2365	0.5715	0.5634
210807	0.4705	0.6126	0.6859	0.5582	0.2841	0.2690	0.5987	0.5981
210808	0.4750	0.6328	0.7078	0.5876	0.3124	0.2966	0.6203	0.6246
210809	0.4753	0.6452	0.7208	0.6056	0.3311	0.3148	0.6336	0.6406
210810	0.4764	0.6581	0.7340	0.6243	0.3516	0.3349	0.6475	0.6569
210811	0.4766	0.6742	0.7499	0.6474	0.3789	0.3617	0.6650	0.6767
210812	0.4542	0.6855	0.7607	0.6635	0.3991	0.3817	0.6774	0.6901
210813	0.4662	0.6959	0.7702	0.6780	0.4182	0.4007	0.6887	0.7020
210814	0.4725	0.7057	0.7790	0.6897	0.4326	0.4149	0.6996	0.7125
210815	0.4758	0.7130	0.7854	0.6997	0.4470	0.4292	0.7077	0.7205
210816	0.4758	0.7191	0.7905	0.7093	0.4627	0.4450	0.7144	0.7274
210817	0.4806	0.7243	0.7949	0.7168	0.4747	0.4570	0.7203	0.7330
290801	0.5187	0.4670	0.5125	0.3407	0.1244	0.1159	0.4493	0.3946
290802	0.5191	0.5126	0.5686	0.3959	0.1538	0.1437	0.4950	0.4529
290803	0.5213	0.5826	0.6520	0.4940	0.2189	0.2058	0.5670	0.5487
290804	0.5231	0.6278	0.7024	0.5612	0.2748	0.2597	0.6148	0.6104

TABLE C.5.10 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
290805	0.5246	0.6555	0.7313	0.6020	0.3139	0.2977	0.6447	0.6466
290806	0.5268	0.6714	0.7472	0.6264	0.3408	0.3239	0.6619	0.6671
290807	0.5295	0.6833	0.7586	0.6428	0.3588	0.3415	0.6750	0.6813
290808	0.5329	0.7055	0.7789	0.6753	0.3997	0.3819	0.6994	0.7076
290809	0.5362	0.7086	0.7815	0.6853	0.4182	0.4003	0.7028	0.7129
290810	0.5340	0.7173	0.7890	0.6975	0.4355	0.4176	0.7124	0.7225
290811	0.4472	0.6761	0.7517	0.6532	0.3890	0.3718	0.6671	0.6802
290812	0.4372	0.6197	0.6936	0.5722	0.2998	0.2844	0.6062	0.6093
40901	0.5811	0.4460	0.4865	0.3261	0.1204	0.1123	0.4285	0.3737
40902	0.5767	0.5345	0.5951	0.4348	0.1814	0.1700	0.5172	0.4868
40903	0.5776	0.5838	0.6534	0.5003	0.2259	0.2126	0.5683	0.5522
40904	0.5799	0.6265	0.7011	0.5609	0.2753	0.2602	0.6135	0.6092
40905	0.5765	0.6555	0.7314	0.6041	0.3175	0.3012	0.6447	0.6473
40906	0.5767	0.6717	0.7475	0.6295	0.3462	0.3292	0.6623	0.6683
40907	0.5842	0.6985	0.7726	0.6638	0.3836	0.3659	0.6916	0.6989
40908	0.5854	0.7135	0.7858	0.6856	0.4127	0.3947	0.7083	0.7162
40909	0.5836	0.7235	0.7942	0.6998	0.4329	0.4148	0.7194	0.7271
40910	0.4039	0.6785	0.7540	0.6681	0.4199	0.4028	0.6697	0.6870
40911	0.3926	0.6696	0.7454	0.6564	0.4054	0.3884	0.6600	0.6768
40912	0.3921	0.6592	0.7351	0.6417	0.3868	0.3700	0.6487	0.6643
40913	0.3916	0.6367	0.7119	0.6092	0.3486	0.3323	0.6244	0.6362

TABLE C.5.11 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
40914	0.3827	0.5665	0.6333	0.5099	0.2536	0.2398	0.5503	0.5446
50901	0.3526	0.4883	0.5388	0.4209	0.1971	0.1858	0.4705	0.4491
50902	0.3614	0.6187	0.6926	0.5982	0.3504	0.3345	0.6052	0.6190
50903	0.5569	0.6865	0.7616	0.6488	0.3669	0.3495	0.6785	0.6854
50904	0.5807	0.7190	0.7904	0.6962	0.4303	0.4123	0.7143	0.7230
50905	0.3327	0.6410	0.7165	0.6377	0.4062	0.3900	0.6291	0.6503
50906	0.3134	0.5844	0.6540	0.5608	0.3225	0.3075	0.5689	0.5795
50907	0.3067	0.5093	0.5646	0.4591	0.2331	0.2207	0.4917	0.4819
50908	0.2515	0.4183	0.4524	0.3546	0.1672	0.1577	0.4014	0.3729
50909	0.2522	0.4900	0.5408	0.4444	0.2309	0.2189	0.4722	0.4624
100901	0.4764	0.4045	0.4354	0.2915	0.1074	0.1002	0.3880	0.3301
100902	0.4719	0.4299	0.4667	0.3197	0.1214	0.1134	0.4127	0.3602
100903	0.4764	0.4900	0.5410	0.3921	0.1615	0.1513	0.4723	0.4354
100904	0.4767	0.5519	0.6161	0.4743	0.2163	0.2036	0.5352	0.5173
100905	0.4753	0.5948	0.6659	0.5348	0.2646	0.2501	0.5798	0.5749
100906	0.4777	0.6333	0.7083	0.5904	0.3170	0.3010	0.6208	0.6258
100907	0.4830	0.6608	0.7367	0.6302	0.3601	0.3433	0.6504	0.6607
100908	0.4803	0.6696	0.7454	0.6428	0.3750	0.3579	0.6600	0.6715
100909	0.4813	0.6920	0.7667	0.6729	0.4117	0.3942	0.6845	0.6975
100910	0.4876	0.7014	0.7752	0.6873	0.4329	0.4153	0.6948	0.7086

TABLE C.5.12 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
100911	0.4918	0.7091	0.7820	0.6976	0.4472	0.4296	0.7034	0.7170
100912	0.4946	0.7158	0.7878	0.7070	0.4615	0.4438	0.7109	0.7244
120901	0.6963	0.5196	0.5771	0.3480	0.1137	0.1056	0.5021	0.4322
120902	0.7120	0.5456	0.6085	0.4099	0.1522	0.1420	0.5287	0.4818
120903	0.7120	0.6200	0.6939	0.5050	0.2094	0.1962	0.6065	0.5804
120904	0.7115	0.6799	0.7554	0.5999	0.2901	0.2739	0.6713	0.6629
120905	0.6507	0.6588	0.7347	0.5860	0.2859	0.2701	0.6483	0.6423
120906	0.6502	0.6352	0.7103	0.5495	0.2528	0.2381	0.6228	0.6105
120907	0.6502	0.6074	0.6801	0.5073	0.2189	0.2055	0.5932	0.5722
120908	0.6474	0.5799	0.6488	0.4666	0.1900	0.1779	0.5642	0.5338
120909	0.6466	0.5314	0.5914	0.3977	0.1474	0.1375	0.5141	0.4662
120910	0.6465	0.4790	0.5274	0.3316	0.1134	0.1055	0.4612	0.3971
120911	0.6506	0.6801	0.7555	0.6131	0.3100	0.2935	0.6714	0.6680
120912	0.6525	0.6987	0.7728	0.6410	0.3401	0.3228	0.6919	0.6911
120913	0.5630	0.7316	0.8008	0.7138	0.4566	0.4385	0.7284	0.7365
120914	0.5714	0.7241	0.7947	0.7040	0.4421	0.4241	0.7201	0.7287
120915	0.5710	0.7174	0.7891	0.6941	0.4272	0.4092	0.7126	0.7213
120916	0.5649	0.7093	0.7822	0.6831	0.4123	0.3944	0.7037	0.7126
120917	0.5634	0.6932	0.7677	0.6615	0.3852	0.3676	0.6858	0.6945
120918	0.5576	0.6758	0.7515	0.6350	0.3520	0.3349	0.6668	0.6732
120919	0.5552	0.6353	0.7104	0.5753	0.2897	0.2741	0.6229	0.6216

TABLE C.5.13 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
120920	0.5529	0.6087	0.6816	0.5367	0.2553	0.2408	0.5946	0.5863
120921	0.5511	0.5620	0.6280	0.4700	0.2039	0.1915	0.5456	0.5231
120922	0.5526	0.5080	0.5630	0.3970	0.1569	0.1468	0.4904	0.4505
120923	0.5516	0.4588	0.5023	0.3360	0.1236	0.1153	0.4411	0.3872
120924	0.5537	0.3134	0.3255	0.1898	0.0600	0.0557	0.3005	0.2259
10401	0.6323	0.5888	0.6592	0.6146	0.4552	0.4420	0.5736	0.6054
10402	0.5992	0.5545	0.6192	0.5781	0.4300	0.4178	0.5379	0.5673
10403	0.5662	0.5157	0.5724	0.5365	0.4047	0.3936	0.4982	0.5240
10404	0.6720	0.6284	0.7032	0.6694	0.5359	0.5240	0.6157	0.6545
10405	0.6342	0.5885	0.6589	0.6283	0.5063	0.4953	0.5734	0.6121
10406	0.6181	0.5565	0.6217	0.5934	0.4803	0.4701	0.5401	0.5767
10407	0.6185	0.5433	0.6059	0.5787	0.4693	0.4593	0.5265	0.5618
10408	0.6080	0.5202	0.5781	0.5530	0.4511	0.4418	0.5030	0.5358
10409	0.6234	0.5847	0.6545	0.6225	0.4965	0.4852	0.5694	0.6071
10410	0.5804	0.5344	0.5952	0.5668	0.4545	0.4444	0.5173	0.5506
10411	0.7610	0.7052	0.7788	0.7516	0.6362	0.6252	0.6995	0.7335
10412	0.7785	0.7103	0.7832	0.7570	0.6450	0.6342	0.7050	0.7384
20401	0.5235	0.4573	0.5006	0.4766	0.3817	0.3732	0.4397	0.4610
20402	0.5960	0.5129	0.5692	0.5463	0.4520	0.4432	0.4955	0.5286
20403	0.5942	0.5093	0.5648	0.5418	0.4472	0.4385	0.4919	0.5242

TABLE C.5.14 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
20404	0.7252	0.7309	0.8002	0.7592	0.5996	0.5856	0.7276	0.7500
20405	0.8114	0.7535	0.8177	0.7826	0.6400	0.6269	0.7531	0.7702
20406	0.7611	0.7810	0.8367	0.8092	0.6912	0.6799	0.7844	0.7932
20407	0.7695	0.8312	0.8654	0.8441	0.7486	0.7390	0.8425	0.8282
20408	0.6898	0.7935	0.8445	0.8154	0.6919	0.6801	0.7986	0.8008
20409	0.7388	0.8048	0.8513	0.8256	0.7139	0.7030	0.8118	0.8097
20410	0.7456	0.8157	0.8574	0.8349	0.7346	0.7246	0.8246	0.8184
40401	0.5850	0.6761	0.7518	0.7031	0.5264	0.5117	0.6672	0.6972
40402	0.7266	0.7065	0.7797	0.7386	0.5800	0.5661	0.7005	0.7287
40403	0.8133	0.7370	0.8052	0.7710	0.6316	0.6189	0.7347	0.7574
40404	0.8208	0.7427	0.8097	0.7769	0.6419	0.6294	0.7411	0.7626
40405	0.8306	0.7584	0.8214	0.7940	0.6772	0.6660	0.7588	0.7771
40406	0.8141	0.7372	0.8056	0.7829	0.6831	0.6732	0.7353	0.7633
40407	0.8092	0.7381	0.8063	0.7849	0.6900	0.6806	0.7362	0.7647
40408	0.8446	0.7755	0.8333	0.8110	0.7124	0.7026	0.7784	0.7925
40409	0.8282	0.7934	0.8448	0.8261	0.7408	0.7321	0.7992	0.8073
40410	0.6284	0.5787	0.6476	0.6178	0.4986	0.4878	0.5631	0.6018
50401	0.6951	0.6289	0.7037	0.6719	0.5441	0.5325	0.6163	0.6561
50402	0.7598	0.6740	0.7499	0.7231	0.6099	0.5991	0.6651	0.7046
50403	0.8112	0.7068	0.7803	0.7573	0.6570	0.6472	0.7014	0.7372
50404	0.5036	0.4550	0.4979	0.4765	0.3895	0.3816	0.4376	0.4599

TABLE C.5.15 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
60401	0.6053	0.5675	0.6346	0.6053	0.4884	0.4778	0.5514	0.5890
60402	0.7515	0.6369	0.7124	0.6880	0.5842	0.5743	0.6250	0.6685
60403	0.7670	0.6540	0.7302	0.7074	0.6091	0.5995	0.6435	0.6871
60404	0.7376	0.8054	0.8514	0.8284	0.7267	0.7166	0.8120	0.8113
60405	0.6199	0.5613	0.6273	0.6009	0.4930	0.4831	0.5451	0.5836
60406	0.6520	0.5689	0.6364	0.6131	0.5156	0.5064	0.5531	0.5943
60407	0.6971	0.5987	0.6707	0.6490	0.5558	0.5468	0.5844	0.6289
90401	0.8167	0.8352	0.8675	0.8509	0.7737	0.7658	0.8475	0.8349
90402	0.7631	0.8227	0.8609	0.8396	0.7442	0.7346	0.8323	0.8230
90403	0.7776	0.8257	0.8626	0.8426	0.7524	0.7433	0.8360	0.8259
90404	0.0000	0.7979	0.8469	0.8299	0.7515	0.7435	0.8031	0.8111
90405	0.7296	0.6596	0.7356	0.7060	0.5841	0.5728	0.6492	0.6891
90406	0.7954	0.6938	0.7685	0.7439	0.6379	0.6276	0.6868	0.7245
90407	0.7556	0.6542	0.7302	0.7067	0.6055	0.5958	0.6435	0.6867
150401	0.4792	0.4060	0.4374	0.4191	0.3444	0.3375	0.3896	0.4032
150402	0.5328	0.4473	0.4884	0.4700	0.3933	0.3861	0.4301	0.4526
150403	0.5626	0.4568	0.5002	0.4819	0.4049	0.3976	0.4395	0.4641
150404	0.5870	0.4862	0.5366	0.5186	0.4416	0.4343	0.4689	0.4997
150405	0.5772	0.4779	0.5264	0.5083	0.4314	0.4241	0.4606	0.4896
150406	0.6265	0.4922	0.5440	0.5261	0.4492	0.4418	0.4749	0.5069

TABLE C.5.16 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
150407	0.6476	0.5254	0.5848	0.5676	0.4925	0.4852	0.5087	0.5471
150408	0.6697	0.5424	0.6053	0.5886	0.5147	0.5074	0.5261	0.5673
150409	0.8386	0.8272	0.8637	0.8465	0.7676	0.7595	0.8384	0.8295
150410	0.7463	0.8069	0.8526	0.8309	0.7340	0.7244	0.8145	0.8130
150411	0.7664	0.8055	0.8518	0.8298	0.7316	0.7218	0.8129	0.8119
150412	0.5607	0.6942	0.7687	0.7143	0.5225	0.5070	0.6870	0.7120
180401	0.8084	0.6510	0.7271	0.7033	0.6013	0.5915	0.6402	0.6830
180402	0.7779	0.6109	0.6843	0.6621	0.5668	0.5576	0.5973	0.6415
180403	0.7337	0.5857	0.6559	0.6348	0.5438	0.5350	0.5708	0.6141
180404	0.7298	0.5676	0.6350	0.6151	0.5289	0.5205	0.5520	0.5943
180405	0.7201	0.5582	0.6240	0.6056	0.5251	0.5172	0.5423	0.5845
180406	0.7311	0.5560	0.6214	0.6036	0.5254	0.5177	0.5400	0.5823
180407	0.6946	0.5322	0.5930	0.5760	0.5014	0.4941	0.5156	0.5551
180408	0.7114	0.5453	0.6088	0.5922	0.5187	0.5115	0.5291	0.5708
180409	0.7435	0.5751	0.6439	0.6270	0.5521	0.5447	0.5599	0.6050
180410	0.7143	0.5543	0.6194	0.6007	0.5193	0.5114	0.5383	0.5798
180411	0.7401	0.5879	0.6586	0.6395	0.5558	0.5476	0.5733	0.6180
180412	0.7915	0.6239	0.6988	0.6800	0.5964	0.5882	0.6116	0.6579
180413	0.8236	0.6544	0.7309	0.7110	0.6234	0.6147	0.6444	0.6891
180414	0.8340	0.6780	0.7541	0.7337	0.6433	0.6344	0.6700	0.7120
180415	0.8672	0.7219	0.7935	0.7729	0.6815	0.6724	0.7186	0.7517

TABLE C.5.17 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
180416	0.8719	0.7274	0.7980	0.7785	0.6909	0.6821	0.7247	0.7570
190401	0.8615	0.6992	0.7736	0.7538	0.6656	0.6568	0.6930	0.7322
190402	0.8488	0.6702	0.7466	0.7283	0.6458	0.6376	0.6616	0.7059
190403	0.7924	0.6278	0.7030	0.6846	0.6028	0.5947	0.6157	0.6625
190404	0.7785	0.6065	0.6797	0.6621	0.5834	0.5756	0.5930	0.6399
190405	0.7398	0.5695	0.6376	0.6219	0.5513	0.5442	0.5544	0.5999
190406	0.8325	0.6651	0.7416	0.7234	0.6418	0.6336	0.6560	0.7012
190407	0.8826	0.7536	0.8182	0.7992	0.7135	0.7049	0.7539	0.7786
190408	0.8922	0.7577	0.8212	0.8034	0.7219	0.7136	0.7587	0.7826
210401	0.3954	0.6334	0.7084	0.6538	0.4670	0.4522	0.6209	0.6506
210402	0.6966	0.6754	0.7511	0.7056	0.5371	0.5228	0.6664	0.6978
210403	0.7857	0.6955	0.7700	0.7292	0.5722	0.5584	0.6886	0.7189
210404	0.8620	0.7164	0.7884	0.7522	0.6075	0.5944	0.7117	0.7395
210405	0.8786	0.7294	0.7992	0.7657	0.6290	0.6164	0.7262	0.7516
210406	0.8644	0.7390	0.8068	0.7753	0.6446	0.6324	0.7370	0.7602
210407	0.8738	0.7434	0.8104	0.7799	0.6526	0.6406	0.7422	0.7643
210408	0.8685	0.7393	0.8073	0.7809	0.6675	0.6566	0.7377	0.7628
210409	0.8855	0.7338	0.8029	0.7751	0.6573	0.6461	0.7314	0.7577
210410	0.8725	0.7271	0.7974	0.7683	0.6459	0.6344	0.7238	0.7515
210411	0.8339	0.7123	0.7850	0.7526	0.6198	0.6076	0.7073	0.7374

TABLE C.5.18 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VCHISH	VROHN1	VROHN2	VROHN3	VROHN4	VSMITH	VHUMA
210412	0.8475	0.6988	0.7731	0.7376	0.5958	0.5830	0.6924	0.7241
210413	0.7003	0.6383	0.7136	0.6688	0.5044	0.4906	0.6262	0.6600
210414	0.4725	0.6035	0.6759	0.6255	0.4511	0.4372	0.5892	0.6194
10501	0.3832	0.6788	0.7543	0.6909	0.4810	0.4649	0.6701	0.6941
10502	0.6915	0.6494	0.7252	0.6806	0.5160	0.5021	0.6381	0.6719
10503	0.8112	0.6756	0.7514	0.7117	0.5586	0.5452	0.6668	0.7004
10504	0.8303	0.6841	0.7594	0.7214	0.5728	0.5596	0.6760	0.7093
10505	0.8588	0.7056	0.7791	0.7460	0.6114	0.5991	0.6998	0.7313
10506	0.8318	0.7714	0.8305	0.7968	0.6583	0.6455	0.7736	0.7837
10507	0.8442	0.6981	0.7725	0.7432	0.6212	0.6097	0.6916	0.7262
10508	0.6601	0.5876	0.6578	0.6187	0.4728	0.4603	0.5724	0.6068
10509	0.6283	0.5336	0.5942	0.5609	0.4345	0.4235	0.5165	0.5468
10510	0.5967	0.4947	0.5469	0.5178	0.4060	0.3962	0.4771	0.5028
10511	0.5506	0.4526	0.4949	0.4702	0.3737	0.3651	0.4352	0.4548
10512	0.5541	0.4609	0.5052	0.4831	0.3936	0.3854	0.4435	0.4665
10513	0.5218	0.4156	0.4493	0.4309	0.3556	0.3486	0.3990	0.4148
10514	0.6051	0.4726	0.5198	0.5017	0.4249	0.4176	0.4553	0.4834

TABLE C.5.19 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
220102	0.3062	0.6254	0.5941	0.5289	0.6022	42
220103	0.3884	0.5932	0.5282	0.4866	0.5327	2
220104	0.4065	0.5372	0.4770	0.4542	0.4716	2
220105	0.3786	0.5075	0.4446	0.4338	0.4293	2
220106	0.3700	0.4878	0.4254	0.4212	0.4029	2
220107	0.3600	0.4736	0.4128	0.4125	0.3851	2
220108	0.0692	0.4633	0.4035	0.4063	0.3715	2
220109	0.3390	0.4633	0.4041	0.4064	0.3727	2
280101	0.2660	0.6515	0.6374	0.5610	0.6417	34
280102	0.3434	0.6698	0.6374	0.5818	0.6688	3
280103	0.3004	0.6277	0.5997	0.5327	0.6076	34
280104	0.1609	0.4167	0.4322	0.3862	0.4351	3
280105	0.3007	0.4728	0.4932	0.4192	0.5103	3
280106	0.1882	0.4360	0.4550	0.3973	0.4650	3
280107	0.0000	0.3811	0.4009	0.3667	0.3940	42
280108	0.2580	0.5864	0.5328	0.4799	0.5411	42
280109	0.3166	0.5418	0.4968	0.4593	0.4991	2
280110	0.3207	0.5217	0.4718	0.4450	0.4677	2
280111	0.2937	0.4919	0.4428	0.4254	0.4307	2
280112	0.2350	0.3375	0.3242	0.3396	0.2509	2

TABLE C.5.20 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
280113	0.2489	0.3505	0.3319	0.3462	0.2640	2
280114	0.2642	0.3765	0.3479	0.3596	0.2905	2
280115	0.2793	0.4018	0.3650	0.3729	0.3176	2
280116	0.2960	0.4293	0.3853	0.3878	0.3486	2
280117	0.3039	0.4499	0.4021	0.3995	0.3735	2
280118	0.3085	0.4814	0.4297	0.4182	0.4124	2
280119	0.4640	0.5811	0.4877	0.4707	0.4809	2
280120	0.5017	0.6152	0.5538	0.5142	0.5575	2
290101	0.3874	0.7251	0.5538	0.6363	0.7058	34
290102	0.3412	0.6993	0.5538	0.6092	0.6804	34
290103	0.3470	0.6834	0.6631	0.5923	0.6616	34
290104	0.2719	0.6561	0.6373	0.5643	0.6410	3
290105	0.1893	0.5851	0.5494	0.4788	0.5627	3
290106	0.3360	0.4854	0.4931	0.4246	0.5080	3
70201	0.6588	0.1201	0.2209	0.2017	0.1752	3
70202	0.7140	0.1359	0.2336	0.2120	0.1951	3
70203	0.7237	0.2533	0.3513	0.3023	0.3525	3
70204	0.7244	0.2406	0.3433	0.2954	0.3433	3
70205	0.7236	0.3347	0.3433	0.3478	0.4542	3
70206	0.0856	0.4048	0.4375	0.3807	0.4466	3

TABLE C.5.21 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
70207	0.2804	0.4768	0.4970	0.4213	0.5146	3
110201	0.3237	0.5938	0.4970	0.4916	0.5956	3
110202	0.2642	0.6001	0.4970	0.4989	0.5953	3
110203	0.2665	0.6134	0.4970	0.5158	0.6110	3
110204	0.2723	0.6350	0.4970	0.5419	0.6333	34
110205	0.2792	0.6540	0.4970	0.5632	0.6499	4
110206	0.2878	0.6734	0.4970	0.5836	0.6645	4
110207	0.3179	0.6924	0.4970	0.6029	0.6782	4
110208	0.3414	0.7026	0.4970	0.6130	0.6840	4
110210	0.3676	0.6887	0.6668	0.5979	0.6641	42
110213	0.1577	0.3806	0.3936	0.3653	0.3816	42
110214	0.2212	0.4808	0.4578	0.4199	0.4581	42
110215	0.3087	0.5762	0.5123	0.4674	0.5179	42
110216	0.3796	0.6148	0.5628	0.5141	0.5689	2
110217	0.4811	0.6387	0.5925	0.5427	0.5969	2
110218	0.5253	0.6162	0.5495	0.5144	0.5519	2
110219	0.0515	0.0573	0.1896	0.1387	0.0400	1
110220	0.0604	0.0671	0.1972	0.1577	0.0528	1
110221	0.0980	0.1742	0.2373	0.2309	0.1179	16
110222	0.1200	0.2069	0.2545	0.2557	0.1452	62
110223	0.1978	0.2894	0.3010	0.3139	0.2163	2

TABLE C.5.22 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
110224	0.2577	0.3638	0.3351	0.3516	0.2663	2
110225	0.3440	0.4388	0.3724	0.3906	0.3188	2
300501	0.0000	0.0675	0.1876	0.1590	0.0696	6
300502	0.0000	0.0940	0.2005	0.1801	0.0906	6
300503	0.0000	0.0639	0.1886	0.1543	0.0594	6
300504	0.0000	0.0776	0.1956	0.1676	0.0707	6
300505	0.0016	0.0650	0.1928	0.1552	0.0550	6
300506	0.0000	0.0571	0.1849	0.1369	0.0420	16
300507	0.0036	0.0604	0.1922	0.1482	0.0471	16
300508	0.0086	0.0660	0.1956	0.1561	0.0526	6
300509	0.0104	0.0792	0.1998	0.1682	0.0639	6
300510	0.0080	0.0739	0.1971	0.1640	0.0617	6
300511	0.0060	0.0849	0.2004	0.1728	0.0710	6
300512	0.0171	0.1175	0.2111	0.1949	0.1026	6
300513	0.0058	0.1043	0.2055	0.1865	0.0937	6
300514	0.0369	0.1731	0.2380	0.2310	0.1443	6
300515	0.0216	0.1481	0.2248	0.2139	0.1187	6
300516	0.0201	0.1358	0.2198	0.2055	0.1021	6
300517	0.0271	0.1339	0.2193	0.2042	0.0982	6
300518	0.0254	0.1149	0.2128	0.1921	0.0837	6

TABLE C.5.23 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
300519	0.0275	0.1225	0.2161	0.1967	0.0856	16
300520	0.0493	0.1525	0.2274	0.2157	0.1038	6
300521	0.0505	0.1702	0.2350	0.2279	0.1222	6
300522	0.0407	0.1687	0.2344	0.2270	0.1251	6
300523	0.0582	0.1986	0.2521	0.2494	0.1598	6
300524	0.0692	0.2136	0.2655	0.2625	0.1879	62
300525	0.0451	0.1939	0.2511	0.2463	0.1663	6
300526	0.0737	0.2286	0.2782	0.2760	0.2070	62
300527	0.0798	0.2190	0.2675	0.2667	0.1858	62
300528	0.0696	0.2131	0.2617	0.2612	0.1731	62
300529	0.0652	0.1930	0.2472	0.2444	0.1450	62
300530	0.0706	0.1820	0.2406	0.2359	0.1292	6
310501	0.1007	0.2451	0.2948	0.2931	0.2314	62
310502	0.1451	0.2914	0.3180	0.3162	0.2643	62
310503	0.1306	0.2698	0.3024	0.3040	0.2373	62
310504	0.0978	0.2279	0.2711	0.2742	0.1816	62
310505	0.1157	0.2216	0.2647	0.2680	0.1667	62
310506	0.1482	0.2376	0.2773	0.2834	0.1861	62
310507	0.1349	0.2259	0.2667	0.2717	0.1659	62
310508	0.1347	0.2423	0.2842	0.2888	0.2027	62
310509	0.1528	0.2865	0.3112	0.3130	0.2500	62

TABLE C.5.24 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
310510	0.1669	0.3117	0.3304	0.3268	0.2832	2
310511	0.1849	0.3536	0.3530	0.3479	0.3141	2
50601	0.0000	0.1107	0.2074	0.1916	0.1101	6
50602	0.0599	0.1533	0.2303	0.2191	0.1521	63
50603	0.0585	0.1263	0.2149	0.2011	0.1163	63
50604	0.0713	0.1537	0.2286	0.2186	0.1375	63
50605	0.0743	0.1681	0.2380	0.2287	0.1580	63
50606	0.0947	0.2277	0.2838	0.2765	0.2252	63
50607	0.1004	0.2165	0.2706	0.2657	0.2010	63
50608	0.0970	0.2302	0.2895	0.2793	0.2382	63
50609	0.1255	0.2641	0.3152	0.3031	0.2740	42
50610	0.1516	0.2837	0.3272	0.3138	0.2903	42
50611	0.1373	0.2453	0.2997	0.2942	0.2443	2
50612	0.1212	0.2399	0.2918	0.2880	0.2306	2
50613	0.1438	0.2679	0.3080	0.3040	0.2537	2
60601	0.1430	0.3396	0.3571	0.3423	0.3282	62
60602	0.1685	0.3666	0.3726	0.3560	0.3484	2
60603	0.1862	0.3833	0.3822	0.3644	0.3608	2
60604	0.1884	0.3919	0.3873	0.3689	0.3673	2
60605	0.1845	0.3527	0.3548	0.3480	0.3180	2

TABLE C.5.25 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
60606	0.1989	0.3659	0.3621	0.3547	0.3278	2
60607	0.2128	0.3836	0.3719	0.3636	0.3407	2
60608	0.2257	0.3997	0.3815	0.3720	0.3536	2
60609	0.2614	0.4150	0.3897	0.3799	0.3638	2
60610	0.2466	0.3539	0.3432	0.3473	0.2919	2
60611	0.2184	0.3186	0.3205	0.3290	0.2544	2
60612	0.1973	0.3045	0.3137	0.3218	0.2446	2
60613	0.2578	0.4636	0.4352	0.4077	0.4278	42
60614	0.2196	0.4483	0.4252	0.3991	0.4159	42
60615	0.1876	0.4178	0.4059	0.3826	0.3922	42
60616	0.1862	0.3734	0.3697	0.3587	0.3404	2
60617	0.2093	0.3939	0.3814	0.3692	0.3556	2
60618	0.2444	0.4299	0.4027	0.3881	0.3826	2
140801	0.3141	0.2349	0.3234	0.2868	0.3121	3
140802	0.3133	0.2693	0.3526	0.3090	0.3495	3
140803	0.3098	0.3164	0.3856	0.3341	0.3900	3
140804	0.3089	0.3487	0.4073	0.3506	0.4158	3
140805	0.3087	0.4121	0.4494	0.3833	0.4637	3
140806	0.3092	0.4518	0.4764	0.4048	0.4929	3
140807	0.3100	0.4878	0.5019	0.4258	0.5196	3
140808	0.3087	0.5229	0.5280	0.4479	0.5458	3

TABLE C.5.26 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
140809	0.3121	0.5470	0.5280	0.4645	0.5642	3
140810	0.3112	0.5876	0.5280	0.4818	0.5823	3
140811	0.3128	0.5996	0.5280	0.4966	0.5968	3
140812	0.3135	0.6171	0.5280	0.5188	0.6171	3
140813	0.3170	0.6262	0.5280	0.5301	0.6274	3
140814	0.3183	0.6413	0.5280	0.5477	0.6423	34
140815	0.3239	0.6499	0.5280	0.5573	0.6497	34
140816	0.2690	0.6277	0.6049	0.5305	0.6138	34
150801	0.2189	0.2242	0.3026	0.2754	0.2787	3
150802	0.2200	0.2917	0.3590	0.3201	0.3520	3
150803	0.2225	0.3707	0.4106	0.3606	0.4149	3
150804	0.2190	0.4257	0.4473	0.3893	0.4574	3
150805	0.2202	0.4634	0.4729	0.4101	0.4856	3
150806	0.2274	0.5020	0.5006	0.4332	0.5149	3
150807	0.2265	0.5247	0.5178	0.4478	0.5326	3
150808	0.2287	0.5476	0.5358	0.4635	0.5504	34
150809	0.2366	0.5887	0.5565	0.4818	0.5705	34
150810	0.2472	0.6055	0.5791	0.5027	0.5915	34
150811	0.2613	0.6121	0.5878	0.5110	0.5994	4
150812	0.1450	0.2096	0.2819	0.2616	0.2455	3

TABLE C.5.27 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
150813	0.2928	0.2984	0.3560	0.3228	0.3438	3
150814	0.6409	0.3027	0.3560	0.3287	0.4240	3
150815	0.7301	0.3914	0.3560	0.3744	0.4970	3
150816	0.7320	0.4561	0.3560	0.4094	0.5429	3
200801	0.3907	0.2690	0.3560	0.3094	0.3726	3
200802	0.3885	0.3386	0.3560	0.3460	0.4305	3
200803	0.3873	0.3808	0.3560	0.3676	0.4632	3
200804	0.3855	0.4050	0.3560	0.3801	0.4810	3
200805	0.3836	0.4455	0.3560	0.4020	0.5103	3
200806	0.3864	0.4929	0.3560	0.4295	0.5443	3
200807	0.3843	0.5201	0.3560	0.4468	0.5639	3
200808	0.3838	0.5807	0.3560	0.4748	0.5931	3
200809	0.3833	0.5966	0.3560	0.4935	0.6109	3
200810	0.3849	0.6110	0.3560	0.5119	0.6271	3
200811	0.3858	0.6248	0.3560	0.5290	0.6412	3
200812	0.3871	0.6447	0.3560	0.5520	0.6586	3
200813	0.3848	0.6552	0.3560	0.5636	0.6667	3
200814	0.3856	0.6643	0.3560	0.5733	0.6732	3
200815	0.3898	0.6796	0.3560	0.5891	0.6833	3
200816	0.3922	0.6940	0.3560	0.6036	0.6919	3
210801	0.4663	0.2887	0.3560	0.3208	0.4049	3

TABLE C.5.28 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
210802	0.4764	0.3471	0.3560	0.3510	0.4527	3
210803	0.4734	0.3990	0.3560	0.3776	0.4914	3
210804	0.4786	0.4557	0.3560	0.4085	0.5332	3
210805	0.4777	0.5062	0.3560	0.4386	0.5677	3
210806	0.4712	0.5456	0.3560	0.4649	0.5956	3
210807	0.4705	0.5959	0.3560	0.4934	0.6219	3
210808	0.4750	0.6145	0.3560	0.5170	0.6418	3
210809	0.4753	0.6269	0.3560	0.5323	0.6535	3
210810	0.4764	0.6411	0.3560	0.5488	0.6654	3
210811	0.4766	0.6609	0.3560	0.5704	0.6798	3
210812	0.4542	0.6763	0.3560	0.5864	0.6895	3
210813	0.4662	0.6911	0.3560	0.6014	0.6981	3
210814	0.4725	0.7042	0.3560	0.6145	0.7060	3
210815	0.4758	0.7156	0.3560	0.6258	0.7117	3
210816	0.4758	0.7268	0.3560	0.6367	0.7164	34
210817	0.4806	0.7358	0.3560	0.6456	0.7203	4
290801	0.5187	0.3408	0.3560	0.3485	0.4624	3
290802	0.5191	0.4095	0.3560	0.3839	0.5145	3
290803	0.5213	0.5218	0.3560	0.4494	0.5911	3
290804	0.5231	0.6000	0.3560	0.4994	0.6368	3

TABLE C.5.29 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
290805	0.5246	0.6268	0.3560	0.5330	0.6630	3
290806	0.5268	0.6455	0.3560	0.5545	0.6773	3
290807	0.5295	0.6597	0.3560	0.5702	0.6877	3
290808	0.5329	0.6914	0.3560	0.6028	0.7059	3
290809	0.5362	0.7009	0.3560	0.6118	0.7083	3
290810	0.5340	0.7146	0.3560	0.6254	0.7150	34
290811	0.4472	0.6661	0.3560	0.5755	0.6815	3
290812	0.4372	0.6046	0.3560	0.5038	0.6290	3
40901	0.5811	0.3203	0.3560	0.3377	0.4392	3
40902	0.5767	0.4533	0.3560	0.4076	0.5393	3
40903	0.5776	0.5274	0.3560	0.4531	0.5924	3
40904	0.5799	0.5994	0.3560	0.4988	0.6357	3
40905	0.5765	0.6279	0.3560	0.5344	0.6631	3
40906	0.5767	0.6474	0.3560	0.5567	0.6776	3
40907	0.5842	0.6797	0.3560	0.5912	0.7002	3
40908	0.5854	0.7026	0.3560	0.6142	0.7122	3
40909	0.5836	0.7187	0.3560	0.6300	0.7197	4
40910	0.4039	0.6794	0.3560	0.5886	0.6835	3
40911	0.3926	0.6679	0.3560	0.5767	0.6758	3
40912	0.3921	0.6545	0.3560	0.5625	0.6664	3
40913	0.3916	0.6285	0.3560	0.5331	0.6454	3

TABLE C.5.30 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
40914	0.3827	0.5329	0.3560	0.4550	0.5743	3
50901	0.3526	0.4314	0.3560	0.3935	0.4887	3
50902	0.3614	0.6202	0.3560	0.5224	0.6280	3
50903	0.5569	0.6647	0.3560	0.5756	0.6904	3
50904	0.5807	0.7137	0.3560	0.6251	0.7163	4
50905	0.3327	0.6512	0.3560	0.5576	0.6496	34
50906	0.3134	0.5967	0.3560	0.4920	0.5931	3
50907	0.3067	0.4773	0.4942	0.4186	0.5121	3
50908	0.2515	0.3534	0.4044	0.3517	0.4103	3
50909	0.2522	0.4623	0.4761	0.4092	0.4905	3
100901	0.4764	0.2766	0.4761	0.3144	0.3930	3
100902	0.4719	0.3097	0.4761	0.3320	0.4219	3
100903	0.4764	0.3986	0.4761	0.3776	0.4902	3
100904	0.4767	0.4951	0.4761	0.4318	0.5586	3
100905	0.4753	0.5801	0.4761	0.4751	0.6038	3
100906	0.4777	0.6159	0.4761	0.5190	0.6422	3
100907	0.4830	0.6453	0.4761	0.5538	0.6679	3
100908	0.4803	0.6561	0.4761	0.5656	0.6757	3
100909	0.4813	0.6853	0.4761	0.5960	0.6950	3
100910	0.4876	0.7005	0.4761	0.6111	0.7026	3

TABLE C.5.31 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
100911	0.4918	0.7121	0.4761	0.6226	0.7087	3
100912	0.4946	0.7230	0.4761	0.6334	0.7139	4
120901	0.6963	0.3695	0.4761	0.3656	0.5138	3
120902	0.7120	0.4348	0.4761	0.3992	0.5495	3
120903	0.7120	0.5452	0.4761	0.4678	0.6287	3
120904	0.7115	0.6326	0.4761	0.5425	0.6847	3
120905	0.6507	0.6189	0.4761	0.5250	0.6661	3
120906	0.6502	0.5958	0.4761	0.4956	0.6440	3
120907	0.6502	0.5412	0.4761	0.4640	0.6165	3
120908	0.6474	0.4977	0.4761	0.4353	0.5877	3
120909	0.6466	0.4180	0.4761	0.3896	0.5340	3
120910	0.6465	0.3364	0.4761	0.3473	0.4728	3
120911	0.6506	0.6398	0.4761	0.5500	0.6849	3
120912	0.6525	0.6635	0.4761	0.5759	0.7004	3
120913	0.5630	0.7345	0.4761	0.6457	0.7256	4
120914	0.5714	0.7225	0.4761	0.6338	0.7201	34
120915	0.5710	0.7112	0.4761	0.6226	0.7151	3
120916	0.5649	0.6990	0.4761	0.6104	0.7089	3
120917	0.5634	0.6763	0.4761	0.5874	0.6959	3
120918	0.5576	0.6522	0.4761	0.5620	0.6812	3
120919	0.5552	0.6084	0.4761	0.5100	0.6441	3

TABLE C.5.32 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
120920	0.5529	0.5839	0.4761	0.4797	0.6180	3
120921	0.5511	0.4945	0.4761	0.4317	0.5693	3
120922	0.5526	0.4091	0.4761	0.3834	0.5097	3
120923	0.5516	0.3340	0.4761	0.3447	0.4534	3
120924	0.5537	0.1923	0.4761	0.2504	0.2878	3
10401	0.6323	0.6458	0.5947	0.5502	0.5977	42
10402	0.5992	0.6245	0.5594	0.5246	0.5615	42
10403	0.5662	0.6053	0.5216	0.4995	0.5192	2
10404	0.6720	0.7018	0.6419	0.6078	0.6376	42
10405	0.6342	0.6724	0.6000	0.5768	0.5975	42
10406	0.6181	0.6507	0.5676	0.5530	0.5638	2
10407	0.6185	0.6424	0.5545	0.5435	0.5495	2
10408	0.6080	0.6297	0.5325	0.5283	0.5243	2
10409	0.6234	0.6656	0.5953	0.5700	0.5936	42
10410	0.5804	0.6328	0.5447	0.5326	0.5398	2
10411	0.7610	0.7937	0.7297	0.7014	0.7058	2
10412	0.7785	0.8013	0.7356	0.7094	0.7098	2
20401	0.5235	0.5883	0.4722	0.4760	0.4540	2
20402	0.5960	0.6305	0.5268	0.5283	0.5162	2
20403	0.5942	0.6275	0.5231	0.5247	0.5122	2

TABLE C.5.33 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
20404	0.7252	0.7912	0.5231	0.7004	0.7251	42
20405	0.8114	0.8247	0.5231	0.7373	0.7407	42
20406	0.7611	0.8651	0.8131	0.7861	0.7575	4
20407	0.7695	0.9184	0.8131	0.8629	0.7821	4
20408	0.6898	0.8737	0.8131	0.7978	0.7643	4
20409	0.7388	0.8896	0.8131	0.8194	0.7702	4
20410	0.7456	0.9042	0.8131	0.8406	0.7754	4
40401	0.5850	0.7205	0.6907	0.6289	0.6815	42
40402	0.7266	0.7650	0.7268	0.6733	0.7067	42
40403	0.8133	0.8092	0.7629	0.7202	0.7296	42
40404	0.8208	0.8177	0.7696	0.7296	0.7335	42
40405	0.8306	0.8446	0.7885	0.7601	0.7439	42
40406	0.8141	0.8363	0.7669	0.7487	0.7299	44
40407	0.8092	0.8408	0.7683	0.7537	0.7304	44
40408	0.8446	0.8714	0.8087	0.7933	0.7545	44
40409	0.8282	0.8941	0.8292	0.8246	0.7645	44
40410	0.6284	0.6667	0.5899	0.5695	0.5873	42
50401	0.6951	0.7073	0.6432	0.6125	0.6381	42
50402	0.7598	0.7645	0.6951	0.6698	0.6798	2
50403	0.8112	0.8071	0.7331	0.7150	0.7072	44
50404	0.5036	0.5930	0.4724	0.4816	0.4516	2

TABLE C.5.34 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
60401	0.6053	0.6580	0.5784	0.5605	0.5755	2
60402	0.7515	0.7358	0.6554	0.6395	0.6459	2
60403	0.7670	0.7576	0.6751	0.6615	0.6620	2
60404	0.7376	0.8945	0.8402	0.8264	0.7703	4
60405	0.6199	0.6604	0.5735	0.5620	0.5689	2
60406	0.6520	0.6764	0.5835	0.5783	0.5771	2
60407	0.6971	0.7088	0.6159	0.6111	0.6081	2
90401	0.8167	0.9293	0.8735	0.8804	0.7838	4
90402	0.7631	0.9113	0.8735	0.8521	0.7784	4
90403	0.7776	0.9161	0.8626	0.8595	0.7798	4
90404	0.0000	0.9013	0.8339	0.8347	0.7665	42
90405	0.7296	0.7435	0.6779	0.6481	0.6669	2
90406	0.7954	0.7903	0.7179	0.6964	0.6966	2
90407	0.7556	0.7556	0.6747	0.6592	0.6620	2
150401	0.4792	0.5340	0.4312	0.4491	0.3967	2
150402	0.5328	0.5956	0.4682	0.4851	0.4430	2
150403	0.5626	0.6022	0.4771	0.4936	0.4537	2
150404	0.5870	0.6239	0.5051	0.5210	0.4867	2
150405	0.5772	0.6176	0.4972	0.5133	0.4774	2
150406	0.6265	0.6283	0.5110	0.5266	0.4934	2

TABLE C.5.35 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
150407	0.6476	0.6575	0.5443	0.5597	0.5303	2
150408	0.6697	0.6740	0.5617	0.5771	0.5489	2
150409	0.8386	0.9223	0.8653	0.8696	0.7805	4
150410	0.7463	0.8974	0.8426	0.8321	0.7713	4
150411	0.7664	0.8956	0.8410	0.8295	0.7706	4
150412	0.5607	0.7289	0.8410	0.6397	0.6968	4
180401	0.8084	0.7501	0.6712	0.6553	0.6592	2
180402	0.7779	0.7165	0.6286	0.6211	0.6205	2
180403	0.7337	0.6963	0.6026	0.6006	0.5948	2
180404	0.7298	0.6839	0.5846	0.5879	0.5758	2
180405	0.7201	0.6810	0.5762	0.5848	0.5659	2
180406	0.7311	0.6817	0.5744	0.5851	0.5635	2
180407	0.6946	0.6641	0.5512	0.5667	0.5377	2
180408	0.7114	0.6770	0.5647	0.5803	0.5520	2
180409	0.7435	0.7035	0.5949	0.6069	0.5838	2
180410	0.7143	0.6766	0.5719	0.5801	0.5617	2
180411	0.7401	0.7058	0.6064	0.6099	0.5972	2
180412	0.7915	0.7412	0.6449	0.6453	0.6336	2
180413	0.8236	0.7669	0.6773	0.6718	0.6625	42
180414	0.8340	0.7871	0.7028	0.6935	0.6835	42
180415	0.8672	0.8276	0.7511	0.7390	0.7189	42

TABLE C.5.36   COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
180416	0.8719	0.8357	0.7575	0.7483	0.7229	42
190401	0.8615	0.8100	0.7262	0.7174	0.7011	42
190402	0.8488	0.7878	0.6954	0.6930	0.6767	42
190403	0.7924	0.7476	0.6494	0.6509	0.6374	42
190404	0.7785	0.7302	0.6272	0.6333	0.6163	2
190405	0.7398	0.7045	0.5903	0.6067	0.5781	42
190406	0.8325	0.7843	0.6900	0.6885	0.6722	42
190407	0.8826	0.8611	0.7863	0.7788	0.7410	44
190408	0.8922	0.8676	0.7913	0.7871	0.7437	44
210401	0.3954	0.6695	0.6410	0.5775	0.6423	34
210402	0.6966	0.7252	0.6906	0.6332	0.6809	42
210403	0.7857	0.7544	0.7146	0.6623	0.6979	42
210404	0.8620	0.7847	0.7394	0.6934	0.7145	42
210405	0.8786	0.8033	0.7546	0.7132	0.7241	42
210406	0.8644	0.8168	0.7659	0.7282	0.7310	42
210407	0.8738	0.8233	0.7712	0.7357	0.7341	42
210408	0.8685	0.8282	0.7679	0.7409	0.7313	2
210409	0.8855	0.8199	0.7613	0.7313	0.7274	2
210410	0.8725	0.8102	0.7534	0.7205	0.7225	42
210411	0.8339	0.7882	0.7359	0.6968	0.7114	42

TABLE C.5.37 COMPARISONS OF VOID FRACTION DATA

TEST NO	VEXP.	VEATON	VBEG&BR	VMUKJ&BR	VGOZHOV	FLOW PAT
210412	0.8475	0.7679	0.7199	0.6759	0.7007	42
210413	0.7003	0.6893	0.6491	0.5968	0.6470	42
210414	0.4725	0.6493	0.6090	0.5550	0.6129	42
10501	0.3832	0.7016	0.6090	0.6120	0.6838	4
10502	0.6915	0.7007	0.6616	0.6082	0.6575	42
10503	0.8112	0.7360	0.6925	0.6433	0.6811	42
10504	0.8303	0.7481	0.7025	0.6553	0.6884	42
10505	0.8588	0.7804	0.7281	0.6881	0.7061	42
10506	0.8318	0.8441	0.7281	0.7615	0.7520	4
10507	0.8442	0.7818	0.7210	0.6888	0.7001	2
10508	0.6601	0.6536	0.5954	0.5583	0.5965	42
10509	0.6283	0.6220	0.5412	0.5206	0.5389	2
10510	0.5967	0.6029	0.5047	0.4958	0.4960	2
10511	0.5506	0.5825	0.4674	0.4702	0.4488	2
10512	0.5541	0.5950	0.4773	0.4846	0.4582	2
10513	0.5218	0.5465	0.4396	0.4574	0.4075	2
10514	0.6051	0.6142	0.4921	0.5085	0.4715	2

TABLE C.5.38 COMPARISONS OF VOID FRACTION DATA

APPENDIX C

C.6 VOID FRACTION CORRELATIONS; SAMPLE OF CALCULATION.

C.6 Void Fraction Correlations Sample of Calculations

Consider Test No. 60401

Liquid flowrate	$Q_f = 0.033456\ m^3/s$
Air flowrate	$Q_g = 0.082084\ m^3/s$
Pressure	$P = 1310.00\ mm\ H_2O$
Air density	$\rho_g = 1.3886\ kg/m^3$
Water density	$\rho_f = 999.223\ kg/m^3$
Liquid specific volume	$V_f = 1.000777604 \times 10^{-3}\ m^3/kg$
Air specific volume	$V_g = 0.720149791\ m^3/kg$
Cross sectional area	$A = 0.032365472\ m^2$
Water Temperature	$t_f = 14.4°C$
Air temperature	$t_g = 16.9°C$
Experimental void fraction	$\alpha = 0.6053$
Flow pattern	2 = Slug

6.1 Chisholm Correlation

$$\alpha = \frac{xV_g}{xV_g + s(1-x)V_f}$$

Where

$$S = \left(\frac{x\rho_f}{\rho_g} + (1-x)\right)^{1/2}$$

The mass dryness fraction (x)

$$x = \frac{M_g}{M_g + M_f}$$

$$x = \frac{Q_g\rho_g}{(Q_g \, x \, \rho_g) + (Q_f \, x \, \rho_f)}$$

$$x = \frac{0.082084 \, x \, 1.3886}{(0.082084 \, x \, 1.3886) + (0.033456 \, x \, 999.223)}$$

$$x = \frac{0.113981842}{0.1139818 + 33.43000}$$

$$x = 3.39798139 \times 10^{-3}$$

$$S = \left(0.00339798139 \, x \, \frac{999.223}{1.3886} + (1 - 0.00339798139)\right)^{1/2}$$

$$\left[2.445154227 + 0.996602019\right]^{1/2}$$

$$S = 1.855197091$$

$$\alpha = \frac{2.44705588 \, x \, 10^{-3}}{2.44705588 \, x \, 10^{-3} + 1.850330873 \, x \, 10^{-3}}$$

$\alpha = 0.569428793$ By computer $\alpha = 0.5675$

C.6.2 Rouhani Correlation

$$\alpha = \frac{xV_g}{K[xV_g + (1-x)V_f] + (UR/G)}$$

$$K = 1.0 + 0.12\ (1\text{-}x)$$

$$UR = 1.18\left(\frac{g\sigma(\rho_f-\rho_g)}{\rho_f^2}\right)^{1/4}$$

$$K = 1 + 0.12\ (1 - 3.39798139 \times 10^{-3})$$
$$= 1.119592242$$

$$G = \frac{M}{A} = \frac{M_g + M_f}{A} = \frac{Q_g\rho_g + Q_f\rho_f}{A}$$

$$= \frac{0.082084 \times 1.3886 + 0.033456 \times 999.223}{0.032365472}$$

$$G = 1036.412538 \text{ Kg/m}^2 \text{ sec}$$

$$\sigma = 75.75 - \left(\frac{5.85}{38.5}\right)T$$

$$\sigma = 75.75 - 0.15195 \times 14.4$$
$$= 73.56192 \text{ dynes/cm}$$

$$UR = 1.18\left(\frac{9.81 \times 73.56192 \times 10^{-3}\ (999.223 - 1.3886)}{(999.223)^2}\right)^{1/4}$$

$$= 1.18 \times 0.163875459$$
$$= 0.193373042$$

$$\alpha = \frac{2.447055588 \times 10^{-3}}{3.856359981 \times 10^{-3} + 1.865792191 \times 10^{-4}}$$

$\alpha = 0.605266$ By computer $\alpha = 0.6053$

When UR = 0.0

$$\alpha = \frac{2.447055588 \ x \ 10^{3}}{3.856359981 \ x \ 10^{-3}}$$

$\alpha = 0.634550$ By computer $\alpha = 0.6346$

When

$$UR = 7.3 \left(\frac{g\sigma(\rho_f - \rho_g)}{\rho_f^2} \right)^{1/4}$$

$$UR = 7.3 \text{ x } 0.163875459$$
$$= 1.196290851$$

$$\alpha = \frac{2.447055588 x 10^{-3}}{3.856359981 \ x \ 10^{-3} + 1.154261268 \ x \ 10^{-3}}$$

$\alpha = 0.4883736$ By computer $\alpha = 0.4884$

When

$$UR = 8.0 \left(\frac{g\sigma(\rho_f - \rho_g)}{\rho_f^2} \right)^{1/4}$$

$$UR = 8.0 \text{ x } 0.163875459$$
$$= 1.311003672$$

$$\alpha = \frac{2.447055588 \ x \ 10^{-3}}{3.856359981 \ x \ 10^{-3} + 1.264943856 \ x \ 10^{-3}}$$

$\alpha = 0.4778188$ By computer $\alpha = 0.4788$

C.6.3 Smith Correlation

$$\alpha = \frac{xV_g}{xV_g + S(1-x)V_f}$$

$$S = 0.4 + 0.6\left(\frac{\frac{V_g}{V_f} + 0.4\ (\frac{1}{x}-1)}{1 + 0.4\ (\frac{1}{x}-1)}\right)^{0.5}$$

$$S = 0.4 + 0.6\left(\frac{\frac{0.720149791}{1.000777604\ x\ 10^{-3}} + 0.4\ (293.29237)}{1 + 0.4\ (293.29237)}\right)^{0.5}$$

$$S = 1.99575575$$

$$\alpha = \frac{2.447055588\ x\ 10^{-3}}{2.446055588\ x\ 10^{-3} + 1.9905209\ x\ 10^{-3}}$$

$\alpha \doteq 0.5514396$ By computer $\alpha = 0.5514$

C.6.4 Hughmark Correlation

$\alpha = C\beta$ where $C = f(Z)$

$Z = Re_h^{1/6} \text{ x } F_r^{1/8} \text{ x } (1-\beta)^{1/4}$

$$Re_h = \frac{G_{tot}\, d}{\mu_h}$$

$$\mu_h = \beta\mu_g + (1-\beta)\mu_f$$

$$F_r = \frac{(U_m)^2}{gd}$$

$$U_m = U_{sf} + U_{sg} = 1.0337 + 2.5362 = 3.5699$$

$\mu_g = (1.70744 + 0.00612487\ t_g - 0.00003139\ t_g^2) \text{ x } 10^{-5}$

$\mu_g = 1.801985005 \text{ x } 10^{-5}$

$\mu_f = (1.7726 - 0.0557784\ t_f + 0.001026\ t_f^2 - 0.0000083\ t_f^3)\ 10^{-3}$

$\mu_f\ =\ 0.781423347 \times 10^{-3}$

$$\beta = \frac{Q_g}{Q_g + Q_f} = \frac{0.082084}{0.082084 + 0.033456}$$

$\beta\ =\ 0.710437943$

$\mu_h = 0.710437943 \times 1.801985005 \times 10^{-5} + (1-0.716437943) \times 0.7814233 \times 10^{-3}$

$\mu_h = 2.390725369 \times 10^{-4}$

$$G_{tot} = \frac{M_{tot}}{A} = \frac{M_g + M_f}{A} = \frac{\rho_g\, Q_g + \rho_f Q_f}{A}$$

$$G_{tot} = \frac{1.3886 \times 0.082084 + 999.223 \times 0.033456}{0.032365472}$$

$G_{tot}\ =\ 1036.412538$

$$Re_h = \frac{1036.412538 \times 0.203}{2.390725369 \times 10^{-4}}$$

$$= 880033.0977$$

$$F_r = \frac{(3.5699)^2}{9.81 \times 0.203}$$

$$= 6.399514926$$

$Z = (880033.0977)^{1/6} \times (6.399514926)^{1/8} \times (1-0.710437943)^{-1/4}$

$= 16.82989369$

$\log_e C = -2.201825 + 2.073839(\log_e Z) - 0.788378(\log_e Z)^2 + 0.129714(\log_e Z)^3$
$- 0.00743(\log_e Z)^4$

$\log_e C = -2.201825 + 5.85477245 - 6.28354114 + 2.918715747 - 0.471985597$

$\log_e C = -0.18386354$

$C = 0.832049337$

$\alpha\ =\ 0.832049337 \times 0.710437943$

$\alpha\ =\ 0.591119491$ By Computer $\alpha\ =\ 0.5890$

C.6.5 Eaton Correlation

$$XE = \frac{N_{fv}^{0.575}}{N_{gv}} \times \frac{1}{N_d^{0.0277}} \left(\frac{p}{P_b}\right)^{0.05} \left(\frac{N_f}{N_f \text{ water at } 15°C}\right)^{0.1}$$

$$N_{fv} = U_{sf}\left(\frac{\rho_f}{g\sigma}\right)^{1/4} = 1.0337\left(\frac{999.223}{9.81 \times 73.566192 \times 10^{-3}}\right)^{1/4}$$

$$= 6.305646293$$

$$N_{g_v} = U_{sg}\left(\frac{\rho_f}{g\sigma}\right)^{1/4} = 2.5362\left(\frac{999.223}{9.81 \times 73.566192 \times 10^{-3}}\right)^{1/4}$$

$$= 15.47100719$$

$$N_d = d\left(\frac{\rho_f g}{\sigma}\right)^{1/2} = 0.203\left(\frac{999.223 \times 9.81}{73.56192 \times 10^{-3}}\right)^{1/2}$$

$$= 74.10290346$$

$$N_f = \mu_f\left(\frac{g}{\rho_f \sigma^3}\right)^{1/4}$$

$$= 0.781423347 \times 10^{-3}\left(\frac{9.81}{999.223\ (73.56192 \times 10^{-3})^3}\right)^{1/4}$$

$$= 1.741398785 \times 10^{-3}$$

From tables water at 15°C

$$N_{f_{water\ 15°C}} = \mu_f\left(\frac{g}{\rho_f \delta^3}\right)^{1/4} = 1136 x 10^{-6}\left(\frac{9.81}{999.223 \times (73.56 \times 10^{-3})^3}\right)^{1/4}$$

$$= 2.531762254 \times 10^{-3}$$

$$X_E = \frac{(6.305646293)^{0.575}}{15.47100719} x \frac{1}{(74.10290346)^{0.0277}} x \left(\frac{1310.0}{100}\right)^{0.05}$$

$$x \left(\frac{1.741398785 \ x \ 10^{-3}}{2.531762254 \ x \ 10^{-3}}\right)^{0.1}$$

$$= 0.186348514 \text{ x } 0.887576028 \text{ x } 1.137269952 \text{ x } 0.963268883$$

$$X_E = 0.181193491$$

Using Eaton graph X_E versus H_L

$$H_L = 0.355$$

$$\alpha = 1 - 0.355$$

$\alpha = 0.6450$ By computer $\alpha = 0.6580$

C.6.6 Beggs and Brill Correlation

$$N_{FR} = \frac{(U_m^2)}{gd}$$

$$U_m = U_{sf} + U_{sg} = 1.0337 + 2.5362 = 3.5699$$

$$N_{FR} = \frac{(3.5699)^2}{9.81\ x\ 0.203} = 6.399514926$$

x = ln(1-β)

x = ln(1 - 0.710437943)

x = -1.239385646

L_1 = exp [-4.62-3.3757(-1.239385646(-0.481(-1.239385646)^2-0.0207(-1.239385646)^3]

L_1 = exp (-4.62+4.656371872-0.73885293+0.039408484)

L_1 = 0.515265707

L_2 = exp [1.062-4.602(-1.239385646)-1.609(-1.239385646)^2

-0.179(-1.239385646)^3+0.0006355(-1.239385646)^5]

L_2 = exp (1.061+5.703652742-2.471547537+0.34077868-1.856974908x10^{-3}

L_2 = 102.7220616

Liquid hold-up for horizontal flow

$$H_L(\theta) = \frac{a(1-\beta)^b}{N_{FR})^c}$$

For $L_1 < N_{FR6,L}2$

And from Table 2.1.5 a = 0.845

b = 0.5351

c = 0.0173

$$H_L = \frac{0.845(1-0.710437943)^{0.5351}}{(6.399514926)^{0.0173}}$$

$$H_L = 0.42158808$$

$$\alpha = 1\text{-}0.42158808$$

$\alpha = 0.578411919$ By computer $\alpha = 0.5784$

Inclination of Flow	Flow Pattern	Values of Coefficients					
		C1	C2	C3	C4	C5	C6
Horizontal & Uphill Flow	All	-0.380113	0.129875	-0.119788	2.343227	0.475686	0.288657
Downhill Flow	Stratified	-1.330282	4.808139	4.171584	56.262268	0.079951	0.504887
	Other	-0.516644	0.789805	0.551627	15.519214	0.371771	0.393952

Table C.6.1 Values of Coefficients *(Mukherjee and Brill)* Hold-up Correlation

C.6.7 Mukherjee and Brill Correlation

For horizontal flow

$$H_L = \exp\left[(C_1 + C_4 N_f^2) \times \frac{N_{gv}^{C5}}{N_{fv}^{C6}}\right]$$

From Table C.6.1 for horizontal flow and for all flow patterns

$$C_1 = -0.380113$$

$$C_4 = 2.343227$$

$$C_5 = 0.475686$$

$$C_6 = 0.288657$$

From Eaton sample of calculation for the same test

$$N_f = 1.741398785 \times 10^{-3}$$

$$N_{gv} = 15.47100719$$

$$N_{fv} = 6.305646293$$

$$H_L = \exp\left[(-0.380113 + 7.105764944 \times 10^{-6}) \times 2.162667681\right]$$

$$H_L = 0.439532888$$

$$\alpha = 1 - 0.439532888$$

$\alpha = 0.560467111$ By computer $\alpha = 0.5605$

C.6.8 Guzhov Correlation

$$N_{FR} = \frac{U_m)^2}{gd}$$

$$N_{FR} = \frac{(3.5699)^2}{9.81 \ x \ 0.203}$$

$$N_{FR} = 6.399514926$$

For horizontal flow with no inclination

$$H_L = 1 - 0.81 \ x \ \beta(1 - \exp(-2.2\sqrt{N_{FR}}))$$

$$H_L = 1 - 0.81 \ x \ 0.710437943 \ (1-\exp(-2.2\sqrt{6.399514926}\ ))$$

H_L = 0.42674814

α = 1 - 0.42674814

α = 0.57325186 By computer α = 0.5755

APPENDIX D

D.1 TAITEL & DUKLER DIMENSIONLESS PROCEDURE.

D.2 PRESENT DIMENSIONLESS PROCEDURE.

D.3 THE MEASURED TOTAL AND INTEFACIAL (ILG) PRESSURE GRADIENTS DATA.

APPENDIX D

D.1 TAITEL & DUKLER DIMENSIONLESS PROCEDURE.

APPENDIX D

This appendix shows the procedures followed by Taitel & Dukler and in this study (Bishop also followed the same procedure) to transform the stratified energy equations to a dimensionless form

D.1 Taitel & Dukler Dimensionless Procedure

liquid phase,

$$-A_L\left(\frac{dp}{dx}\right)-\tau_{wL}S_L+\tau_i S_i+\rho_L A_L g\sin\beta \;=\; 0 \qquad (D.1.1)$$

gas phase,

$$-A_G\left(\frac{dp}{dx}\right)-\tau_{wG}S_G-\tau_i S_i+\rho_G A_G g\sin\beta \;=\; 0 \qquad (D.1.2)$$

From equations (D.1.1) and (D.1.2)

$$\left(\frac{dp}{dx}\right) \;=\; -\frac{\tau_{wL}S_L}{A_L}+\frac{\tau_i S_i}{A_L}+\rho_L g\sin\beta \;=\; 0$$

and

$$\left(\frac{dp}{dx}\right) \;=\; -\frac{\tau_{wG}S_G}{A_G}-\frac{\tau_i S_i}{A_G}+\rho_G g\sin\beta \;=\; 0$$

For equal pressure gradient in both phases;

$$-\frac{\tau_{wG}S_G}{A_G}-\frac{\tau_i S_i}{A_G}+\rho_G g\sin\beta=-\frac{\tau_{wL}S_L}{A_L}+\frac{\tau_i S_i}{A_L}+\rho_L g\sin\beta$$

$$\frac{\tau_{wG}S_G}{A_G}-\frac{\tau_{wL}S_L}{A_L}+\frac{\tau_i S_i}{A_L}+\frac{\tau_i S_i}{A_G}+(\rho_L-\rho_G)g\sin\beta \;=\; 0 \qquad (D.1.3)$$

The shear stresses are evaluated in a conventional manner

$$\tau_{wL}=f_L\frac{\rho_L U_L^2}{2};\quad \tau_{wG}=f_G\frac{\rho_G U_G^2}{2};\quad \tau_i=f_i\frac{\rho_g(U_G-U_i)^2}{2} \qquad (D.1.4)$$

with the friction factors evaluated from

$$f_L = C_L\left(\frac{D_L U_L}{\nu_L}\right)^{-n}; \quad f_G = C_G\left(\frac{D_G U_G}{\nu_G}\right)^{-m} \tag{D.1.5}$$

where

$$D_L = \frac{4A_L}{S_L}; \quad D_G = \frac{4A_G}{S_G + S_i} \qquad \text{and} \qquad f_i \sim f_G \quad \text{(Gazley, 1949)}$$

Therefore for $U_G >> U_i$

$$\tau_i = f_G \frac{\rho_G U_G^2}{2} = \tau_{wG}$$

Hence, from equation (D.1.3) substituting for τ

$$f_G \frac{\rho_G U_G^2}{2} \cdot \frac{S_G}{A_G} - f_L \frac{\rho_L U_L^2}{2} \cdot \frac{S_L}{A_L} + f_G \frac{\rho_G U_G^2}{2} \cdot \frac{S_i}{A_L} + f_G \frac{\rho_G U_G^2}{2} \cdot \frac{S_i}{A_G} + (\rho_L - \rho_G) g \sin\beta = 0$$

$$f_G \frac{\rho_G U_G^2}{2} \cdot \frac{S_G}{A_G} - f_L \frac{\rho_L U_L^2}{2} \cdot \frac{S_L}{A_L} + f_G \frac{\rho_G U_G^2}{2} \cdot S_i\left(\frac{1}{A_L} + \frac{1}{A_G}\right) + (\rho_L - \rho_G) g \sin\beta = 0$$

now substitute for f from equation (D.1.5)

$$C_G\left(\frac{D_G U_G}{\nu_G}\right)^{-m} \frac{\rho_G U_G^2}{2} \cdot \frac{S_G}{A_G} - C_L\left(\frac{D_L U_L}{\nu_L}\right)^{-n} \frac{\rho_L U_L^2}{2} \cdot \frac{S_L}{A_L} + C_G\left(\frac{D_G U_G}{\nu_G}\right)^{-m} \frac{\rho_G U_G^2}{2} \cdot S_i\left(\frac{1}{A_L} + \frac{1}{A_G}\right) + (\rho_L - \rho_G) g \sin\beta = 0 \tag{D.1.6}$$

Transforming equation (D.1.6) to dimensionless form. The reference variables are: D for length, D^2 for area, the superficial velocities, U_{sL} and U_{sG} for the liquid and gas velocities, respectively. By designating the dimensionless quantities by a tilde (~).

$$C_G\left(\frac{D_G}{D} \cdot D \cdot \frac{U_G}{U_{sG}} \cdot U_{sG} \cdot \frac{1}{\nu_G}\right)^{-m} \frac{\rho_G}{2} \frac{U_G^2}{U_{sG}^2} \cdot U_{sG}^2 \cdot \frac{S_G}{D} \cdot D \cdot \frac{D^2}{A_G} \cdot \frac{1}{D^2} +$$

$$C_G\left(\frac{D_G}{D} \cdot D \cdot \frac{U_G}{U_{sG}} \cdot U_{sG} \cdot \frac{1}{\nu_G}\right)^{-m} \frac{\rho_G}{2} \frac{U_G^2}{U_{sG}^2} \cdot U_{sG}^2 \cdot \frac{S_i}{D} \cdot D\left[\frac{D^2}{A_L} \cdot \frac{1}{D^2} + \frac{D^2}{A_G} \cdot \frac{1}{D^2}\right]$$

$$-C_L\left(\frac{D_L}{D} \cdot D \cdot \frac{U_L}{U_{sL}} \cdot U_{sL} \cdot \frac{1}{\nu_L}\right)^{-n} \frac{\rho_L}{2} \frac{U_L^2}{U_{sL}^2} \cdot U_{sL}^2 \cdot \frac{S_L}{D} \cdot D \cdot \frac{D^2}{A_L} \cdot \frac{1}{D^2} + (\rho_L - \rho_G) g \sin\beta \quad = \quad 0$$

therefore'

$$C_G(\tilde{D}_G\cdot\tilde{U}_G)^{-m}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\frac{\rho_G U_{sG}^2}{2D}\cdot\tilde{U}_G^2\cdot\frac{\tilde{S}_G}{\tilde{A}_G}+C_G(\tilde{D}_G\cdot\tilde{U}_G)^{-m}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\frac{\rho_G U_{sG}^2}{2D}\left[\frac{\tilde{S}_i}{\tilde{A}_L}+\frac{\tilde{S}_i}{\tilde{A}_G}\right]-$$

$$C_L(\tilde{D}_L\cdot\tilde{U}_L)^{-n}\left(\frac{DU_{sL}}{\nu_L}\right)^{-n}\frac{\rho_L U_{sL}^2}{2D}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}+(\rho_L-\rho_G)g\sin\beta=0$$

$$(\tilde{D}_G\cdot\tilde{U}_G)^{-m}\left[C_G\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot\left(\frac{\rho_G U_{sG}^2}{2D}\right)\cdot\tilde{U}_G^2\right]\cdot\left[\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{\tilde{S}_i}{\tilde{A}_L}+\frac{\tilde{S}_i}{\tilde{A}_G}\right]-$$

$$(\tilde{D}_L\cdot\tilde{U}_L)^{-n}\left[C_L\left(\frac{DU_{sL}}{\nu_L}\right)^{-n}\left(\frac{\rho_L U_{sL}^2}{2D}\right)\cdot\tilde{U}_L^2\left(\frac{\tilde{S}_L}{\tilde{A}_L}\right)\right]+(\rho_L-\rho_G)g\sin\beta=0$$

Hence,

$$(\tilde{D}_L\cdot\tilde{U}_L)^{-n}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}\left[C_L\left(\frac{DU_{sL}}{\nu_L}\right)^{-n}\cdot 1/2\frac{\rho_L U_{sL}^2}{D}\right]-(\tilde{D}_G\cdot\tilde{U}_G)^{-m}\cdot\tilde{U}_G^2[\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{\tilde{S}_i}{\tilde{A}_L}+$$

$$\frac{\tilde{S}_i}{\tilde{A}_G}][C_G(D\frac{U_{sG}}{\nu_G})^{-m}\cdot 1/2\frac{\rho_G U_{sG}^2}{D}]-(\rho_L-\rho_G)g\sin\beta=0 \qquad (D.1.7)$$

Multiplying equation (D.1.7) by

$$\frac{4}{4C_G\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\left(1/2\cdot\frac{\rho_G U_{sG}^2}{D}\right)}$$

equation (D.1.7) becomes,

$$\frac{\left[\frac{4C_L}{D}\left(\frac{DU_{sL}}{\nu_L}\right)^{-n}\cdot 1/2\rho_L U_{sL}^2\right]}{\left[\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2\right]}\cdot(\tilde{D}_L\cdot\tilde{U}_L)^{-n}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}-(\tilde{D}_G\cdot\tilde{U}_G)^{-m}\cdot\tilde{U}_G^2[\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{\tilde{S}_i}{\tilde{A}_L}+$$

$$\frac{\tilde{S}_i}{\tilde{A}_G}]-\frac{4(\rho_L-\rho_G)g\sin\beta}{\left[\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2\right]}=0 \qquad (D.1.8)$$

which it can be written as

$$\chi^2(\tilde{D}_L\cdot\tilde{U}_L)^{-n}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L} - (\tilde{D}_G\cdot\tilde{U}_G)^{-m}\cdot\tilde{U}_G^2\left(\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{\tilde{S}_i}{\tilde{A}_L}+\frac{\tilde{S}_i}{\tilde{A}_G}\right)-4Y=0 \qquad (D.1.9)$$

where,

$$\chi^2 = \frac{\frac{4C_L}{D}\left(\frac{DU_{sL}}{\nu_L}\right)^{-n} \cdot 1/2\rho_L U_{sL}^2}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m} \cdot 1/2\rho_G U_{sG}^2}$$

and

$$Y = \frac{(\rho_L - \rho_G) g \sin\beta}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m} \cdot 1/2\rho_G U_{sG}^2} = \frac{(\rho_L - \rho_G) g \sin\beta}{\left(\frac{dp}{dx}\right)_{sG}}$$

APPENDIX (D)

APPENDIX D

D.2 PRESENT DIMENSIONLESS PROCEDURE.

D.2 Present Dimensionless Procedure

$$-\left(\frac{dp}{dx}\right)_{TPL}-\rho_L g\left(\frac{dh}{dx}\right)-\frac{\alpha\rho_L}{2}\frac{dU_L^2}{dx}-\frac{\tau_{WL}S_L}{A_L}+\frac{\tau_{iL}S_i}{A_L}+\rho_L g\sin\beta = 0 \qquad (D.2.1)$$

$$-\left(\frac{dp}{dx}\right)_{TPG}-\frac{\alpha\rho_G}{2}\frac{dU_G^2}{dx}-\frac{\tau_{WG}S_G}{A_G}-\frac{\tau_{iG}S_i}{A_G}+\rho_G g\sin\beta = 0 \qquad (D.2.2)$$

From equations (D.2.1) and (D.2.2) we get;

$$-\left(\frac{dp}{dx}\right)_{TPL}-\rho_L g\left(\frac{dh}{dx}\right)-\frac{\alpha\rho_L}{2}\frac{dU_L^2}{dx}+\frac{\alpha\rho_G}{2}\frac{dU_G^2}{dx}+\left(\frac{dp}{dx}\right)_{TPG}+\frac{\tau_{WG}S_G}{A_G}-\frac{\tau_{WL}S_L}{A_L}$$
$$+\frac{\tau_{iG}S_i}{A_G}+\frac{\tau_{iL}S_i}{A_L}+(\rho_L-\rho_G)g\sin\beta = 0 \qquad (D.2.3)$$

Let

$$-\left(\frac{dp}{dx}\right)_{TPL}-\rho_L g\left(\frac{dh}{dx}\right)-\frac{\alpha\rho_L}{2}\frac{dU_L^2}{dx}+\frac{\alpha\rho_G}{2}\frac{dU_G^2}{dx}+\left(\frac{dp}{dx}\right)_{TPG} = I$$

Hence, equation (D.2.3) becomes,

$$\frac{\tau_{WL}S_L}{A_L}-\frac{\tau_{WG}S_G}{A_G}-\frac{\tau_{iG}S_i}{A_G}-\frac{\tau_{iL}S_i}{A_L}-I-(\rho_L-\rho_G)g\sin\beta = 0 \qquad (D.2.4)$$

The shear stresses are evaluated in a conventional manner;

$$\tau_{WL} = f_L\left(\frac{\rho_L U_L^2}{2}\right); \qquad \tau_{WG} = f_G\left(\frac{\rho_G U_G^2}{2}\right);$$
$$\tau_{iL} = f_{iL}\frac{\rho_L(U_G-U_i)^2}{2}; \quad \tau_{iG} = f_{iG}\frac{\rho_L(U_G-U_i)^2}{2} \qquad (D.2.5)$$

Substitute for τ from equation (D.2.5) into (D.2.4), assuming $U_G >> U_i$

$$f_L\left(\frac{\rho_L U_L^2}{2}\right)\cdot\frac{S_L}{A_L}-f_G\left(\frac{\rho_G U_G^2}{2}\right)\cdot\frac{S_G}{A_G}-f_{iG}\left(\frac{\rho_G U_G^2}{2}\right)\cdot\frac{S_i}{A_G}-f_{iL}\left(\frac{\rho_L U_L^2}{2}\right)\cdot\frac{S_i}{A_L}-I-(\rho_L-\rho_G)g\sin\beta = 0$$

$$f_L\left(\frac{\rho_L U_L^2}{2}\right)\cdot\frac{S_L}{A_L}-f_G\left(\frac{\rho_G U_G^2}{2}\right)\cdot\frac{S_G}{A_G}-\left(\frac{\rho_G U_G^2}{2}\right)\left[f_{iL}\frac{S_i}{A_G}+f_{iL}\frac{S_i}{A_L}\right]-I$$
$$-(\rho_L-\rho_G)g\sin\beta = 0 \qquad (D.2.6)$$

Equation (D.2.6) can be transformed to dimensionless form. The reference variables are: D for length, D^2 for area, the superficial velocities, U_{sL} and U_{sG} for liquid and gas velocities respectively. By designating the dimensionless quantities by tilde (~).

$$f_L\left(\frac{\rho_L}{2}\frac{U_L^2}{U_{sL}^2}\cdot U_{sL}^2\right)\frac{S_L}{D}\cdot D\cdot\frac{D^2}{A_L}\cdot\frac{1}{D^2}-f_G\left(\frac{\rho_G}{2}\frac{U_G^2}{U_{sG}^2}\cdot U_{sG}^2\right)\frac{S_G}{D}\cdot D\cdot\frac{D^2}{A_G}\cdot\frac{1}{D^2}-$$

$$\left(\frac{\rho_G}{2}\frac{U_G^2}{U_{sG}^2}\cdot U_{sG}^2\right)\left[f_{iG}\frac{S_i}{D}\cdot D\cdot\frac{D^2}{A_G}\cdot\frac{1}{D^2}+f_{iL}\frac{S_i}{D}\cdot D\cdot\frac{D^2}{A_L}\cdot\frac{1}{D^2}\right]-I-(\rho_L-\rho_G)g\sin\beta = 0$$

$$\frac{f_L}{D}\left(\frac{\rho_L U_{sL}^2}{2}\right)\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}-\frac{f_G}{D}\left(\frac{\rho_G U_{sG}^2}{2}\right)\tilde{U}_G^2\cdot\frac{\tilde{S}_G}{\tilde{A}_G}-\left(\frac{\rho_G U_{sG}^2}{2}\right)\cdot\tilde{U}_G^2\left[\frac{f_{iG}}{D}\frac{\tilde{S}_i}{\tilde{A}_G}+\frac{f_{iL}}{D}\frac{\tilde{S}_i}{\tilde{A}_L}\right]-I-(\rho_L-\rho_G)g\sin\beta = 0$$

$$\frac{f_L}{D}\left(\frac{\rho_L U_{sL}^2}{2}\right)\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}-\left(\frac{\rho_G U_{sG}^2}{2}\right)\cdot\tilde{U}_G^2\left[\frac{f_G}{D}\cdot\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{f_{iG}}{D}\frac{\tilde{S}_i}{\tilde{A}_G}+\frac{f_{iL}}{D}\frac{\tilde{S}_i}{\tilde{A}_L}\right]-I-$$

$$(\rho_L-\rho_G)g\sin\beta = 0 \qquad (D.2.7)$$

divide equation (D.2.7) by

$$\frac{f_G}{D}\left(\frac{\rho_G U_{sG}^2}{2}\right)$$

$$\frac{\frac{f_L}{D}\left(\frac{\rho_L U_{sL}^2}{2}\right)}{\frac{f_G}{D}\left(\frac{\rho_G U_{sG}^2}{2}\right)}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}-\tilde{U}_G^2\left[\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{f_{iG}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_G}+\frac{f_{iL}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_L}\right]-\frac{I}{\frac{f_G}{D}\left(\frac{\rho_G U_{sG}^2}{2}\right)}-\frac{(\rho_L-\rho_G)g\sin\beta}{\frac{f_G}{D}\left(\frac{\rho_G U_{sG}^2}{2}\right)} = 0$$

$$(D.2.8)$$

A widely used method for the correlation of the liquid and gas friction factors in the form of the Blasius equation:

$$f_L = C_L\left(\frac{D_L U_L}{\nu_L}\right)^{-n} = C_L\left(\frac{D U_{sL}}{\nu_L}\right)^{-n}\cdot(\tilde{D}_L\cdot\tilde{U}_L)^{-n};$$

$$f_G = C_G\left(\frac{D_G U_G}{\nu_G}\right)^{-m} = C_G\left(\frac{D U_{sG}}{\nu_G}\right)^{-m}\cdot(\tilde{D}_G\cdot\tilde{U}_G)^{-m} \qquad (D.2.9)$$

Substitute for f from eqn (D.2.9) into eqn (D.2.8) and multiply top and bottom by 4,

$$\frac{\frac{4C_L}{D}\left(\frac{DU_{sL}}{\nu_L}\right)^{-n}\cdot 1/2\rho_L U_{sL}^2}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2}\cdot\frac{(\tilde{D}_L\cdot\tilde{U}_L)^{-n}}{(\tilde{D}_G\cdot\tilde{U}_G)^{-m}}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}-\tilde{U}_G^2\left[\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{f_{iG}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_G}+\frac{f_{iL}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_L}\right]$$

$$-\frac{4I}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2(\tilde{D}_G\cdot\tilde{U}_G)^{-m}}-\frac{4(\rho_L-\rho_G)g\sin\beta}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2(\tilde{D}_G\cdot\tilde{U}_G)^{-m}}=0$$

$$\chi^2\cdot\frac{(\tilde{D}_L\cdot\tilde{U}_L)^{-n}}{(\tilde{D}_G\cdot\tilde{U}_G)^{-m}}\cdot\tilde{U}_L^2\cdot\frac{\tilde{S}_L}{\tilde{A}_L}\quad-\quad\tilde{U}_G^2\left[\frac{\tilde{S}_G}{\tilde{A}_G}+\frac{f_{iG}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_G}+\frac{f_{iL}}{f_G}\frac{\tilde{S}_i}{\tilde{A}_L}\right]-Z-4Y=0 \qquad (D.2.10)$$

where,

$$\chi^2 = \frac{\frac{4C_L}{D}\left(\frac{DU_{sL}}{\nu_L}\right)^{-n}\cdot 1/2\rho_L U_{sL}^2}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2} = \frac{\left(\frac{dp}{dx}\right)_{sL}}{\left(\frac{dp}{dx}\right)_{sG}} \qquad (L-M \quad Parameter)$$

$$Z = \frac{4I}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2(\tilde{D}_G\cdot\tilde{U}_G)^{-m}} = \frac{4I}{\left(\frac{dp}{dx}\right)_{sG}\cdot(\tilde{D}_G\cdot\tilde{U}_G)^{-m}}$$

and

$$Y = \frac{(\rho_L-\rho_G)g\sin\beta}{\frac{4C_G}{D}\left(\frac{DU_{sG}}{\nu_G}\right)^{-m}\cdot 1/2\rho_G U_{sG}^2(\tilde{D}_G\cdot\tilde{U}_G)^{-m}} = \frac{(\rho_L-\rho_G)g\sin\beta}{\left(\frac{dp}{dx}\right)_{sG}\cdot(\tilde{D}_G\cdot\tilde{U}_G)^{-m}}$$

APPENDIX D

D.3 THE MEASURED TOTAL AND INTEFACIAL (ILG) PRESSURE GRADIENTS DATA.

FROM **Table D.3.1** TO **Table D.3.8**

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
140801	0.009252	0.005808	152.0140	11.8422	0.985	0.80
140802	0.009191	0.006980	151.6068	11.670	0.971	0.71
140803	0.009170	0.008517	151.9630	12.1214	1.008	0.87
140804	0.009129	0.009633	152.309	12.0804	1.005	0.68
140805	0.009108	0.012196	151.9624	11.8010	0.982	0.65
140806	0.009108	0.014161	152.3876	12.3534	1.027	0.70
140807	0.009108	0.016296	151.5536	11.8642	0.987	0.88
140808	0.009108	0.018813	151.0306	11.5982	0.965	1.02
140809	0.009108	0.020908	150.1608	11.5160	0.958	0.87
140810	0.009108	0.023286	149.3019	10.8955	0.906	0.97
140811	0.009108	0.025491	148.0510	10.5195	0.875	0.84
140812	0.009108	0.029138	147.0830	9.6556	0.803	0.80
140813	0.009004	0.030947	146.6472	10.1773	0.846	0.68
140814	0.008899	0.034092	145.3052	10.0868	0.839	0.96
140815	0.008899	0.036057	143.6972	9.1393	0.760	0.92
140816	0.011505	0.036004	154.1613	7.9183	0.659	0.90

Table D.3.1 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
150801	0.011273	0.005917	171.8528	11.6424	0.968	0.86
150802	0.011206	0.008614	171.72558	11.2852	0.939	0.91
150803	0.011139	0.011700	171.0964	11.2092	0.932	0.71
150804	0.010985	0.014251	170.6584	10.5480	0.877	0.93
150805	0.010985	0.016445	169.2434	10.0779	0.838	0.89
150806	0.010985	0.019164	168.1878	9.3757	0.780	1.50
150807	0.010951	0.021022	167.7315	9.4358	0.785	1.03
150808	0.010951	0.023223	166.2264	8.6017	0.715	0.89
150809	0.010882	0.025924	163.9678	8.9453	0.744	0.83
150810	0.010882	0.029459	162.1748	9.7392	0.810	2.21
150811	0.010882	0.030966	159.1792	10.8561	0.903	0.83
150812	0.013156	0.005722	192.8686	12.9072	1.074	1.20
150813	0.013142	0.009692	188.9358	10.8127	0.899	0.94
150814	0.005211	0.005792	102.7146	5.8515	0.487	0.80
150815	0.004951	0.007910	92.9227	5.7005	0.474	0.67
150816	0.004951	0.010087	93.0080	5.9067	0.491	0.45
200801	0.006838	0.005851	134.8468	8.6194	0.717	0.67

Table D.3.2 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
200802	0.006920	0.007864	134.9684	8.9337	0.743	0.54
200803	0.006866	0.009183	134.8362	8.7245	0.726	0.63
200804	0.006866	0.010046	134.7514	8.6606	0.720	0.65
200805	0.006866	0.011697	135.1847	8.8793	0.739	0.52
200806	0.006866	0.014066	134.9928	8.8925	0.740	0.57
200807	0.006866	0.015731	134.3460	8.4873	0.706	0.42
200808	0.006866	0.018771	134.8242	8.9495	0.744	0.65
200809	0.006866	0.021071	134.2897	8.9175	0.742	0.54
200810	0.006866	0.023543	134.1010	8.6704	0.721	0.66
200811	0.006866	0.026073	133.5600	8.5646	0.712	0.50
200812	0.006866	0.029862	132.6838	8.1988	0.682	0.56
200813	0.006866	0.031943	132.6338	8.5928	0.715	0.64
200814	0.006866	0.033789	132.1866	8.2861	0.689	0.84
200815	0.006866	0.037016	131.3174	8.2035	0.682	0.66
200816	0.006866	0.040232	131.1738	8.3296	0.693	0.77
210801	0.005695	0.005742	122.8696	8.1687	0.679	0.42
210802	0.005695	0.007251	122.4022	8.4043	0.699	0.44

Table D.3.3 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
210803	0.005695	0.008809	122.4178	8.3474	0.694	0.62
210804	0.005595	0.010793	122.4520	8.3693	0.696	0.58
210805	0.005662	0.013269	122.3652	8.1793	0.680	0.53
210806	0.005628	0.015640	122.6348	8.2650	0.687	0.57
210807	0.005662	0.018722	122.7258	8.5215	0.709	0.49
210808	0.005662	0.021596	122.5288	8.4183	0.700	0.57
210809	0.005662	0.023645	122.1186	8.1338	0.677	0.47
210810	0.005662	0.026058	122.2410	8.4595	0.704	0.64
210811	0.005662	0.029561	121.4064	7.8516	0.635	0.57
210812	0.005662	0.032404	121.9408	9.6134	0.800	0.53
210813	0.005662	0.035323	121.3552	9.6100	0.799	0.49
210814	0.005527	0.037538	120.5482	8.9485	0.744	0.55
210815	0.005527	0.040037	120.7712	9.2986	0.773	0.69
210816	0.005627	0.043068	119.6948	8.8158	0.733	0.61
210817	0.005662	0.045476	118.1274	8.3712	0.694	0.59
290801	0.004706	0.006340	114.9012	7.9490	0.661	0.54
290802	0.004642	0.008136	114.8558	7.7704	0.646	0.45

Table D.3.4 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
290803	0.004706	0.012718	115.0694	7.9262	0.659	0.43
290804	0.004738	0.017427	115.0112	8.1005	0.674	0.46
290805	0.004706	0.021234	114.8014	7.8291	0.651	0.53
290806	0.004738	0.024188	114.8852	7.7652	0.646	0.55
290807	0.004674	0.026275	114.3760	7.3879	0.614	0.40
290808	0.004674	0.031697	114.6288	8.1180	0.675	0.48
290809	0.004984	0.034712	114.3664	8.0840	0.672	0.55
290810	0.004984	0.037519	113.7994	7.5500	0.628	0.59
290811	0.005867	0.031103	123.806	8.3795	0.697	0.29
290812	0.005867	0.020381	125.2364	8.6173	0.717	0.54
40901	0.005161	0.006176	110.301	7.5727	0.630	0.51
40902	0.005044	0.010073	110.641	7.6909	0.640	0.66
40903	0.004893	0.013331	110.9308	7.7118	0.641	0.47
40904	0.004801	0.017505	110.9508	7.837	0.652	0.55
40905	0.004801	0.021667	110.8966	7.7819	0.647	0.54
40906	0.004863	0.024892	110.6644	7.8633	0.654	0.52
40907	0.004610	0.029411	110.7096	7.936	0.660	0.55

Table D.3.5 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
40908	0.004610	0.033551	110.0692	7.6332	0.635	0.41
40909	0.004610	0.036738	109.7392	7.7480	0.644	0.47
40910	0.006767	0.036571	130.971	8.4382	0.702	0.49
40911	0.006811	0.034294	132.1884	8.7987	0.732	0.51
40912	0.006789	0.031511	133.3594	9.5785	0.797	0.56
40913	0.006723	0.026366	134.1446	9.6081	0.799	0.54
40914	0.006700	0.016328	135.0402	9.8248	0.817	0.49
50901	0.007888	0.011999	144.4747	10.8877	0.906	0.67
50902	0.007936	0.027383	142.5646	10.9136	0.908	0.66
50903	0.004738	0.027336	113.670	8.4641	0.704	0.46
50904	0.004769	0.036464	110.666	7.9255	0.659	0.48
50905	0.008941	0.036212	146.0686	8.4128	0.700	0.76
50906	0.008983	0.024563	152.0796	10.7012	0.890	0.60
50907	0.008920	0.015331	153.7218	11.410	0.949	0.80
50908	0.009978	0.010243	165.0268	12.7986	1.065	0.81
50909	0.010128	0.015552	164.5568	12.643	1.052	0.61
100901	0.005790	0.005509	123.3019	8.6390	0.719	0.56

Table D.3.6 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
100902	0.005790	0.006338	123.5738	8.8930	0.740	0.60
100903	0.005790	0.008895	123.7894	8.9993	0.749	0.76
100904	0.005790	0.012873	123.9388	8.7888	0.731	0.59
100905	0.005790	0.016958	123.827	8.6492	0.719	0.72
100906	0.005790	0.022158	123.3106	8.4934	0.706	0.56
100907	0.005790	0.027206	123.5185	8.7202	0.725	0.64
100908	0.005790	0.029139	122.7287	8.2928	0.690	0.39
100909	0.005685	0.034344	122.376	8.2934	0.690	0.49
100910	0.005790	0.037867	121.8823	7.9362	0.660	0.51
100911	0.005764	0.040334	120.6832	7.3375	0.610	0.51
100912	0.005790	0.043020	120.1148	7.6563	0.637	0.39
120901	0.002996	0.005473	97.0779	6.9300	0.576	0.50
120902	0.003670	0.007845	95.8804	6.2282	0.518	0.37
120903	0.003328	0.011583	96.3668	7.1093	0.591	0.45
120904	0.003328	0.018193	96.3337	6.7897	0.565	0.51
120905	0.003907	0.018084	103.4318	7.2939	0.607	0.39
120906	0.003907	0.015160	103.5207	7.1164	0.592	0.39

Table D.3.7 Total Pressure Drop and ILG Derived from Experimental Readings

Test No.	Water Flow Rate m^3/s	Air Flow Rate m^3/s	Water Height mm	Level Change mm	Level Gradient mmH_2O/m	Total Pressure mmH_2O/m
120907	0.003907	0.012468	103.7016	7.1945	0.598	0.54
120908	0.003907	0.010374	103.8699	7.1332	0.593	0.40
120909	0.003868	0.007582	103.800	6.9645	0.579	0.46
120910	0.003868	0.005579	103.9686	7.0950	0.590	0.66
120911	0.003710	0.020308	103.8037	7.2128	0.600	0.37
120912	0.003670	0.023462	103.8928	7.4219	0.617	0.50
120913	0.004769	0.041016	110.2069	7.7527	0.645	0.38
120914	0.004801	0.038475	111.1721	8.0151	0.667	0.58
120915	0.004769	0.035954	111.7123	8.3507	0.695	0.63
120916	0.004801	0.033664	111.8310	7.9979	0.665	0.51
120917	0.004893	0.029842	112.3134	8.2848	0.689	0.54
120918	0.004832	0.025560	113.0316	8.3656	0.696	0.55
120919	0.004863	0.018883	112.9867	8.3086	0.691	0.50
120920	0.004893	0.015755	113.1422	8.3753	0.697	0.53
120921	0.004924	0.011659	113.4293	8.3618	0.695	0.58
120922	0.004924	0.008399	113.2567	8.2623	0.687	0.61
120923	0.004924	0.006330	113.4835	8.5358	0.710	0.57
120924	0.004954	0.002842	113.4611	8.3740	0.696	0.59

Table D.3.8 Total Pressure Drop and ILG Derived from Experimental Readings

APPENDIX (E)

APPENDIX E

E.1 THE MAIN COMPUTER PROGRAM USED FOR PROCESSING THE EXPERIMENTAL READINGS FOR BOTH SINGLE AND TWO-PHASE FLOW.

E.2 COMPUTER PROGRAM USED FOR PLOTTING THE EXPERIMENTAL FLOW PATTERN MAP.

E.3 COMPUTER PROGRAM USED FOR PLOTTING THE EXPERIMENTAL TWO-PHASE FRICTION MULTIPLIERS VERSUS OTHER MODELS USED IN THE COMPARISONS.

E.4.1 COMPUTER PROGRAM USED TO CALCULATE THE MEAN VOID FRACTION FROM THE GAMMA-RAY READINGS (FOR 5 STEPS).

E.4.2 COMPUTER PROGRAM USED TO CALCULATE THE MEAN VOID FRACTION FROM THE GAMMA-RAY READINGS (FOR 13 STEPS).

E.4.3 COMPUTER PROGRAM USED FOR PLOTTING THE EXPERIMENTAL TWO-PHASE VOID FRACTION VERSUS OTHER MODELS USED IN THE COMPARISONS.

E.5.1 COMPUTER PROGRAM USED FOR THE CALIBRATION OF THE DEPTH GAUGES (WHERE THE LIQUID HEIGHT IS GIVEN IN TERMS OF VOLTS).

E.5.2 COMPUTER PROGRAM USED IN THE TESTING OF SMOOTH STRATIFIED FLOW CONDITIONS TO DETERMINE THE LIQUID HEIGHT IN THE TEST SECTION USING THE TWO DEPTH GAUGES (THE HEIGHT IS GIVEN IN mm).

APPENDIX E

E.1 THE MAIN COMPUTER PROGRAM USED FOR PROCESSING THE EXPERIMENTAL READINGS FOR BOTH SINGLE AND TWO-PHASE FLOW.

```
C     THIS PROGRAM COMPUTES THE EXP. TWO PHASE MULTIPLIERS
C     FOR BOTH GAS AND LIQUID.ALSO IT DETERMINES THE
C     MULTIPLIERS USING THE HOMOGENEOUS MODEL,DUKLER,CHISHOLM,
C     CHENOWETH-MARTIN,BAROCZY,AND LOCKHART-MARTINELLI CORRELATIONS.
C     THE DATA PRESENTED HERE ARE FOR 8.5 INCH BORE PERSPEX
C     PIPE WITH AIR AND WATER AS THE TWO COMPONENTS BEING   MIXED
C     AT THE BEGINING OF TEST SECTION.PRESSURE READINGS WERE TAKEN
C     AT A METRE INTERVAL ALONG THE TEST SECTION.
C
      COMMON DG1,DG2,DG3,N(500),T(500),P(500),VDF(500),DF(500),
     1DG(500),PE(500),QF(500),QG(500),WG(500),K(500),D,PI,AP,
     2M,STN(500),R,RR,VGG(500),VFF(500),XOR,HOR(500),NOR,
     1        ELL(500),PTT(500)
      INTEGER CRF,CRG,CRH,CRD,CRLMF,CRLMG
      DIMENSION TME(500),TMH(500),TMD(500),TMCH(500),TMCM(500),
     1TMLMF(500),TMLMG(500),TMEG(500),TMHG(500),TMDG(500),
     2TMB(500),TERM(500),CRF(500),CRG(500),CRH(500),CRD(500),
     3CRLMF(500),CRLMG(500),USF(500),USG(500),
     4TG(500),BETA(500),GTOTL(500),QALTY(500),PINDX(500)
C     K=1     BUBBLE
C     K=2     SLUG
C     K=3     STRATIFIED
C     K=4     WAVY
C     K=5     ANNULAR
C     K=6     PLUG
C     K=44    UNSETTLED WAVY FLOW.LIQUID LEVEL BUILDS UP
C             DOWN STREAM
C     CR=-1    RE LT 2000
C     CR=0     RE GT 2000 AND RE LT 20000
C     CR=1     RE LT 100000 AND RE GT 20000
C     CR=2     RE GT 100000
      CALL CONVERSION
      GASCT=.000287
      GRVTY=9.807
      R1=(2-R)/2
      R2=2*R1
      DO 20001 I=1,M
      VG=VGG(I)
      VF=VFF(I)
      USF(I)=QF(I)/AP
      USG(I)=QG(I)/AP
```

```
C      START OF P/Z CALCULATION
       GTOT=(QF(I)*DF(I)+QG(I)*DG(I))/AP
       GTOTL(I)=GTOT
       RFT=GTOT*D/VF
       CALL RETEST(RFT,FFT,CRF(I))
3      PFT=FFT*GTOT**2/(2*D*DF(I))
       TME(I)=PE(I)/PFT
       RGT=GTOT*D/VG
       CALL RETEST(RGT,FGT,CRG(I))
9      PGT=FGT*GTOT**2/(2*D*DG(I))
       TMEG(I)=PE(I)/PGT
       IF(RFT.LT.25000..AND.RFT.GT.2000.)TME(I)=0.0
       IF(RGT.LT.25000..AND.RGT.GT.2000.)TMEG(I)=0.0
C      HOMOGENEOUS MODEL
       X=QG(I)*DG(I)/(GTOT*AP)
       QALTY(I)=X
       B=QG(I)/(QF(I)+QG(I))
       BETA(I)=B
       G=1-B
       A=ALOG(G)
       VH=B*VG+G*VF
       RH=GTOT*D/VH
       CALL RETEST(RH,FH,CRH(I))
5      PH=FH*GTOT**2*(X/DG(I)+(1-X)/DF(I))/(2*D)
       TMH(I)=PH/PFT
       TMHG(I)=PH/PGT
       IF(RH.LT.25000..AND.RH.GT.2000.)TMH(I)=0.0
       IF(RH.LT.25000..AND.RH.GT.2000.)TMHG(I)=0.0
       IF(RFT.LT.25000..AND.RFT.GT.2000.)TMH(I)=0.0
       IF(RGT.LT.25000..AND.RGT.GT.2000.)TMHG(I)=0.0
C      DUKLER CORRELATION
       IF(VDF(I).EQ.0.0)GO TO 6
       DD=B*DG(I)+G*DF(I)
       F=-ALOG(G)
       E=1.281-.478*F+.444*F**2-.094*F**3+.00843*F**4
       PSY=DF(I)*G**2/(DD*(1-VDF(I)))+DG(I)*B**2/(DD*VDF(I))
       VD=B*VG+G*VF
       RD=GTOT*D*PSY/VD
       CALL RETEST(RD,FD,CRD(I))
7      FFD=FD*(1+F/E)
       PD=FFD*GTOT**2*PSY/(2*D*DD)
```

```
      TMD(I)=PD/PFT
      TMDG(I)=PD/PGT
      IF(RD.LT.25000..AND.RD.GT.2000.)GO TO 6
      GO TO 10
6     TMD(I)=0.0
      TMDG(I)=0.0
C     CHISHOLM CORRELATION
10    Z=FGT*DF(I)/(FFT*DG(I))
      ZI=Z**.5
      IF(RFT.LT.25000..AND.RFT.GT.2000.)GO TO 35
      IF(RGT.LT.25000..AND.RGT.GT.2000.)GO TO 35
      IF(ZI.LE.9.5)GO TO 25
      IF(ZI.GT.9.5.AND.ZI.LT.28)GO TO 26
      BCH=15000/(Z*GTOT**.5)
      GO TO 27
25    IF(GTOT.LE.500)GO TO 28
      IF(GTOT.GT.500.AND.GTOT.LT.1900)GO TO 29
      BCH=55/GTOT**.5
      GO TO 27
28    BCH=4.8
      GO TO 27
29    BCH=2400/GTOT
      GO TO 27
26    IF(GTOT.LE.600)GO TO 30
      BCH=21/Z**.5
      GO TO 27
30    BCH=520/(ZI*GTOT**.5)
27    TMCH(I)=1+(Z-1)*(BCH*X**(R1)*(1-X)**(R1)+X**(R2))
      IF(VDF(I).EQ.0.0)GO TO 33
      TK=T(I)+273
      TERM(I)=1-GTOT**2*(X**2*TK*GASCT/(VDF(I)*P(I)**2))
C     CHENOWETH MARTIN CORRELATION
C     FOR LIQUID VOLUME FRACTION LESS THAN .007,ERROR MESSAGE
C     IS PRODUCED SETTING THE TWO PHASE MULTIPLIER TO ZERO.
C     EXTENSION OF THE RANGE OF THE POLYNOMIAL FIT IS REQUIRED
C     FOR SMALLER VALUES OF "B".
33    IF(G.GE..07)GO TO 11
      IF(Z.LE.50)GO TO 12
      IF(Z.LE.100)GO TO 13
      IF(Z.LE.200)GO TO 14
      IF(Z.GT.200.AND.Z.LE.500) GO TO 15
```

```
      B500=65.31393539+82.59327014*A+41.00736661*A**2+8.812604934*
     1A**3+.7983872946*A**4
      TMCM(I)=B500
      GO TO 40
11    B0=.9984778757-1.031743707*A+.03145126553*A**2-.3157101727*
     1A**3
      TMCM(I)=B0
      GO TO 40
12    B50=4.870768633+4.314395825*A+2.337328508*A**2
      TMCM(I)=B50-(1-Z/50)*B50
      GO TO 40
13    B100=23.1320003+17.34038494*A+4.212264895*A**2-.157322532*
     1A**3
      B50=4.870768633+4.314395825*A+2.337328508*A**2
      TMCM(I)=B50+(Z/50-1)*(B100-B50)
      GO TO 40
14    B200=-.4002432041-.2335712751*A+2.696966803*A**2+1.105942557*
     1A**3+.2292410911*A**4
      B100=23.1320003+17.34038494*A+4.212264895*A**2-.157322532*A**3
      TMCM(I)=B100+(Z/100-1)*(B200-B100)
      GO TO 40
15    B500=65.31393539+82.59327014*A+41.00736661*A**2+8.812604934*
     1A**3+.7983872946*A**4
      B200=-.4002432041-.2335712751*A+2.696966803*A**2+1.105942557*
     1A**3+.2292410911*A**4
      TMCM(I)=B200+(B500-B200)*(Z-200)/300
40    IF(G.LT..007)TMCM(I)=0.0
C     LOCKHART MARTINELLI CORRELATION
C     LOCK-MART CORRELATION IS EXTENDED FOR XLM > 100
C     AND LESS OR EQUAL TO 1000
      GO TO 31
35    TMCH(I)=0.0
      TMCM(I)=0.0
31    RFLM=(1-X)*GTOT*D/VF
      IF(RFLM.EQ.0.0)GO TO 66
      CALL RETEST(RFLM,FFLM,CRLMF(I))
      IF(RFLM.LT.25000..AND.RFLM.GT.2000.)GO TO 66
32    RGLM=X*GTOT*D/VG
      IF(RGLM.EQ.0.0)GO TO 66
      CALL RETEST(RGLM,FGLM,CRLMG(I))
      IF(RGLM.LT.25000..AND.RGLM.GT.2000.)GO TO 66
34    XLM=((1-X)/X)*(FFLM*DG(I)/(FGLM*DF(I)))**.5
      A=ALOG(XLM)
```

```
      IF(XLM.GT.100)GO TO 57
      IF(RFLM.GT.2000.AND.RGLM.GT.2000) GO TO 50
      IF(RFLM.LE.2000.AND.RGLM.GT.2000) GO TO 52
      IF(RFLM.GT.2000.AND.RGLM.LE.2000) GO TO 54
      IF(XLM.LT.1) GO TO 56
      VVG2=2.610404687+.101283467*A+5.726725265*A**2-6.310718705*A**3
     1+4.280192873*A**4-1.427159734*A**5+.2442578117*A**6
     2-.01584725635*A**7
      VVF2=2.609930397-1.097911043*A+.5583817165*A**2-.1951651221*A**3
     1+.03620386668*A**4-.002659685406*A**5
      TMLMF(I)=VVF2**2
      TMLMG(I)=VVG2**2
      GO TO 60
56    VVF1=2.60997411-1.025208328*A+.9193521817*A**2+.4503779331*A**3
     1+.5050558188*A**4+.1382119158*A**5+.01900414834*A**6
      VVG1=2.61007206+1.475223603*A+.6420600964*A**2+.1302008707*A**3+
     1.002216135198*A**4-.003097175991*A**5-.0003227634316*A**6
      TMLMF(I)=VVF1**2
      TMLMG(I)=VVG1**2
      GO TO 60
50    IF(XLM.LT.1) GO TO 51
      TTF2=4.199938412-2.051851893*A+.9008215725*A**2-.4161997166*A**3
     1+.1394900102*A**4-.02451068379*A**5+.001670453502*A**6
      TTG2=4.200117503+2.287848357*A+.3043882286*A**2+1.2277525144*
     1A**3-.9313047181*A**4+.3976301436*A**5-.07085705889*A**6+.0053
     276857115*A**7
      TMLMF(I)=TTF2**2
      TMLMG(I)=TTG2**2
      GO TO 60
51    TTF1=4.199281747-2.477469389*A-1.684998137*A**2-5.040648902*A**3
     1-3.897981432*A**4-1.588436339*A**5-.3029787767*A**6
     2-.02296824998*A**7
      TTG1=4.199943529+2.312901027*A+1.551428201*A**2+1.102259514*A**3
     1+.5371038997*A**4+.1490180927*A**5+.02124923531*A**6
     2+.00120931503*A**7
      TMLMF(I)=TTF1**2
      TMLMG(I)=TTG1**2
      GO TO 60
52    IF(XLM.LT.1) GO TO 53
      VTF2=3.48000021-1.764228833*A+1.290241065*A**2-1.122938442*A**3
     1+.6231952608*A**4-.1870006156*A**5+.02820821765*A**6
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     2-.001683874959*A**7
      VTG2=3.480333245-4.201908418*A+21.54483951*A**2-25.80776402*A**3
     1+15.69941316*A**4-4.897974195*A**5+.7715782588*A**6
     2-.04747326846*A**7
       TMLMF(I)=VTF2**2
      TMLMG(I)=VTG2**2
      GO TO 60
53    VTF1=3.479441823-1.111333064*A+1.810215402*A**2+.9576921726*A**3
     1+.5605476801*A**4+.09663830564*A**5+.01201352676*A**6
      VTG1=3.480064648+2.280113539*A+1.863252128*A**2+1.42330111*A**3
     1+.7175259202*A**4+.2048822674*A**5+.03013049794*A**6
     2+.001776677817*A**7
      TMLMF(I)=VTF1**2
       TMLMG(I)=VTG1**2
      GO TO 60
54    IF(XLM.LT.1) GO TO 55
      TVF2=3.480032223-2.396720733*A+3.041953583*A**2-2.799168943*A**3
     1+1.424601836*A**4-.3952810053*A**5+.05633372155*A**6
     2-.003228419148*A**7
      TVG2=3.480856386-8.945210048*A+36.3454554*A**2-42.89041856*A**3
     1+25.60232101*A**4-7.932419743*A**5+1.238134934*A**6
     2-.07576584718*A**7
      TMLMF(I)=TVF2**2
      TMLMG(I)=TVG2**2
      GO TO 60
55    TVF1=3.48029967-1.534967516*A-.11094655*A**2-1.489976001*A**3
     1-.8786798354*A**4-.3288376218*A**5-.05543108066*A**6
     2-.004578245644*A**7
      TVG1=3.480049097+2.047775767*A+.8109023841*A**2+.02182375062*
     1A**3-.1469529208*A**4-.0665664344*A**5-.01208375752*A**6
     2-.0008077979251*A**7
      TMLMF(I)=TVF1**2
      TMLMG(I)=TVG1**2
      GO TO 60
C     EXTENSION OF THE CORRELATION
57    TMLMG(I)=ALOG(111.)+.8489831*ALOG(XLM/100.)
      TMLMF(I)=ALOG(1.11)-.04532298*ALOG(XLM/100.)
      TMLMG(I)=(EXP(TMLMG(I)))**2
      TMLMF(I)=(EXP(TMLMF(I)))**2
      GO TO 60
66    TMLMF(I)=0.0
```

```
      TMLMG(I)=0.0
   60 TMLMF(I)=TMLMF(I)*((1-X)**2)*(FFLM/FFT)
      TMLMG(I)=TMLMG(I)*(X**2)*(FGLM/FGT)
      IF(RFT.LT.25000..AND.RFT.GT.2000.)GO TO 42
      GO TO 44
42    TME(I)=0.0
      TMH(I)=0.0
      TMD(I)=0.0
44    IF(RGT.LT.25000..AND.RGT.GT.2000.)GO TO 43
      GO TO 45
43    TMEG(I)=0.0
      TMHG(I)=0.0
      TMDG(I)=0.0
C     BAROCZY CORRELATION
C     FOR QUALITIES LESS THAN .000001 ,THE BAROCZY MULT. IS SET TO 1.0

C     THE PROGRAM IS VALID FOR X LESS OR EQUAL TO 0.4. FOR 89GHN9
C      VALUES,ERROR MESSAGE IS PRODUSED SETTING "TMB" TO ZERO.
C     THE SAME MESSAGE APPEARS WHEN C EXCEEDS .005.
45    IF(X.EQ.0.0)GO TO 23
      A=ALOG(X)
      C=(DG(I)/DF(I))*(VF/VG)**.2
      PINDX(I)=C
      IF(X.LT..001.AND.X.GE..000001)GO TO 64
      IF(X.LT..000001)GO TO 65
      IF(C.GE..001.AND.C.LE..002)GO TO 61
      IF(C.GT..002.AND.C.LE..003)GO TO 62
      IF(C.GT..003.AND.C.LE..004)GO TO 63
      C5=5.242938204+.836212894*A+.02568660441*A**2
      C4=5.474991751+.8798436666*A+.0280732611*A**2
      C4=EXP(C4)
      C5=EXP(C5)
      TMB(I)=C4+(C5-C4)*(C-.004)/.001
      GO TO 70
61    C1=6.761433864+.9264567065*A-.1743093806*A**2-.05057031267*A**3
     1-.003490810436*A**4
      C2=6.172327345+1.067502975*A+.04101449738*A**2
      C1=EXP(C1)
      C2=EXP(C2)
      TMB(I)=C1+(C2-C1)*(C-.001)/.001
      GO TO 70
```

```
62      C2=6.172327345+1.067502975*A+.04101449738*A**2
        C3=5.755718441+.9450772699*A+.03166408673*A**2
        C2=EXP(C2)
        C3=EXP(C3)
        TMB(I)=C2+(C3-C2)*(C-.002)/.001
        GO TO 70
63      C4=5.474991751+.8798436666*A+.0280732611*A**2
        C3=5.755718441+.9450772699*A+.03166408673*A**2
        C3=EXP(C3)
        C4=EXP(C4)
        TMB(I)=C3+(C4-C3)*(C-.003)/.001
70      IF(X.GT..4.OR.C.GT..005)TMB(I)=0.0
        GO TO 21
64      C6=13.96575981+3.183123805*A+.2619656081*A**2+
       1.007202603753*A**3
        TMB(I)=C6
        GO TO 21
65      TMB(I)=1.0
21      PE(I)=PE(I)/1000
        IGTOT=IFIX(GTOT)
        IF(X.LT.0.001)GO TO 22
        IF(IGTOT.EQ.1356)TMB(I)=1.0
        IF(IGTOT.EQ.1356)GO TO 22
        IF(IGTOT.LE.339)GO TO 95
        IF(IGTOT.GT.339.AND.IGTOT.LT.678)GO TO 100
        IF(IGTOT.GE.678.AND.IGTOT.LT.1356)GO TO 105
        IF(IGTOT.GT.1356.AND.IGTOT.LT.2712)GO TO 110
        IF(IGTOT.GE.2712.AND.IGTOT.LT.4068)GO TO 115
        IF(IGTOT.GE.4068)GO TO 120
95      CALL CORRECTION(X,C,339,RTMB)
        TMB(I)=RTMB*TMB(I)
        GO TO 22
100     CALL CORRECTION(X,C,339,RTMB0)
        CALL CORRECTION(X,C,678,RTMB1)
        A=(RTMB0-RTMB1)/(678-339)
        RTMB=RTMB0-A*(GTOT-339.0)
        TMB(I)=RTMB*TMB(I)
        GO TO 22
105     CALL CORRECTION(X,C,678,RTMB1)
        CALL CORRECTION(X,C,1356,RTMB2)
        A=(RTMB1-RTMB2)/(1356-678)
        RTMB=RTMB1-A*(GTOT-678.0)
```

```
      TMB(I)=RTMB*TMB(I)
      GO TO 22
110   CALL CORRECTION(X,C,1356,RTMB2)
      CALL CORRECTION(X,C,2712,RTMB3)
      A=(RTMB2-RTMB3)/(2712-1356)
      RTMB=RTMB2-A*(GTOT-1356.0)
      TMB(I)=RTMB*TMB(I)
      GO TO 22
115   CALL CORRECTION(X,C,2712,RTMB3)
      CALL CORRECTION(X,C,4068,RTMB4)
      A=(RTMB3-RTMB4)/(4068-2712)
      RTMB=RTMB3-A*(GTOT-2712)
      TMB(I)=RTMB*TMB(I)
      GO TO 22
120   CALL CORRECTION(X,C,4068,RTMB4)
      TMB(I)=RTMB4*TMB(I)
22    CONTINUE
      GO TO 20
23    TMB(I)=0.0
      PE(I)=PE(I)/1000.
20    CONTINUE
C     ALL THESE PDS ADDED FOR BRITOIL WORK
      PFT=PFT
      PH=PH
      PD=PD
      PDCH=TMCH(I)*PFT
      PDCM=TMCM(I)*PFT
      PDLM=TMLMF(I)*PFT
      PDB=TMB(I)*PFT
      PEE=PE(I)*1000.0
      EXPHL=1-VDF(I)
      IF(EXPHL.GT.1.0)GO TO 20001
C      WRITE(6,90001)N(I),EXPHL,PEE,PFT,PH,PD,PDCH,PDCM,
C     1PDLM,PDB,K(I)
C90001 FORMAT(I7,9F11.3,I6)

      WRITE(6,*)N(I),FFT

20001 CONTINUE
      DO 900 I1=1,M,13
      WRITE(6,906)
```

```
906    FORMAT(1H1,//////////)
       WRITE(6,901)
901    FORMAT(3X,4HTEST,3X,4HTEMP,2X,6HP MEAN,2X,4HVOID,2X,
      110HWATER FLOW,9H AIR FLOW,8H DENSITY,2X,7HDENSITY,
      13X,7HPR-GRAD,3X,4HFLOW)
       WRITE(6,907)
907    FORMAT(3X,3HRUN,18X,5HFRCTN,4X,4HRATE,6X,4HRATE,4X,5HWATER,5X,
      13HAIR)
       WRITE(6,902)
902    FORMAT(4X,2HNO,5X,1HC,4X,5HKN/M2,11X,6HM3/SEC,4X,6HM3/SEC,
      13X,5HKG/M3,4X,5HKG/M3,3X,5HKN/M3,3X,7HPATTERN)
       I2=I1+12
       DO 1000 I=I1,I2
       IF(I.EQ.M+1)GO TO 705
       IF(PE(I).EQ.0.0.AND.VDF(I).EQ.0.0)GO TO 840
       IF(PE(I).EQ.0.0)GO TO 850
       IF(VDF(I).EQ.0.0)GO TO 860
       WRITE(6,904)N(I),T(I),P(I),VDF(I),QF(I),QG(I),DF(I),DG(I),
      1PE(I),K(I)
904    FORMAT(/I8,F6.1,F8.2,F7.4,2F10.6,F8.2,F8.4,3X,F7.5,I6)
       GO TO 1000
840    WRITE(6,845)N(I),T(I),P(I),VDF(I),QF(I),QG(I),DF(I),DG(I),K(I)
845    FORMAT(/I8,F6.1,F8.2,3X,F7.4,2X,2F10.6,F8.2,F8.4,39X,2H--,2X,I6)
       GO TO 1000
850    WRITE(6,855)N(I),T(I),P(I),VDF(I),QF(I),QG(I),DF(I),DG(I),K(I)
855    FORMAT(/I8,F6.1,F8.2,F7.4,2F10.6,F8.2,F8.4,39X,2H--,2X,I6)
       GO TO 1000
860    WRITE(6,865)N(I),T(I),P(I),VDF(I),QF(I),QG(I),DF(I),
      1DG(I),PE(I),K(I)
865    FORMAT(/I8,F6.1,F8.2,3X,F7.4,2X,2F10.6,F8.2,F8.4,3X,F7.5,I6)
1000    CONTINUE
        GO TO 707
705    WRITE(6,711)
707    WRITE(6,905)
905    FORMAT(//,5X,5HTABLE,10X,79HPRESSURE DROP,SETTLING LENGTH AND
      1OTHER DATA DERIVED FROM EXPERIMENTAL READINGS)
900    CONTINUE
       DO 2000 I1=1,M,13
       WRITE(6,807)
807    FORMAT(1H1,//////////)
       WRITE(6,802)
```

```
802    FORMAT(2X,4HTEST,3X,4HVOID,3X,9HTWO-PHASE,28X,
      139HVALUES OF TWO-PHASE FRICTION MULTIPLIER)
       WRITE(6,803)
803    FORMAT(2X,3HRUN,11X,8HFRICTION)
       WRITE(6,804)
804    FORMAT(9X,5HFRCTN,2X,9HPRES-GRAD,5X,12HEXPERIMENTAL,6X,
      111HHOMOG MODEL,7X,9HLOCK-MART,8X,6HCH-MRT,2X,
      27HBAROCZY,2X,5HCHLSM,3X,6HDUCKLR)
       WRITE(6,805)
805    FORMAT(3X,2HNO,12X,5HKN/M3)
       I2=I1+12
       DO 3000 I=I1,I2
       IF(I.EQ.M+1)GO TO 709
       IF(TME(I).EQ.0.0.AND.TMLMF(I).EQ.0.0)GO TO 1300
       IF(TME(I).EQ.0.0)GO TO 1400
       IF(TMLMF(I).EQ.0.0)GO TO 1100
       WRITE(6,1001)N(I),VDF(I),PE(I),TME(I),TMEG(I),TMH(I),TMHG(I),
      1TMLMF(I),TMLMG(I),TMCM(I),TMB(I),TMCH(I),TMD(I)
1001   FORMAT(/I7,F8.4,F9.5,F10.3,F11.6,F7.3,F9.6,2F10.4,F8.3,
      13F8.3)
       GO TO 3000
1300   IF(VDF(I).EQ.0.0)GO TO 1700
       WRITE(6,1500)N(I),VDF(I),TMH(I),TMHG(I),TMCM(I),
      1TMB(I),TMCH(I),TMD(I)
1500   FORMAT(/I7,F8.4,5X,2H--,8X,2H--,8X,2H--,3X,
      1F7.3,F9.6,2(5X,2H--,3X),F8.3,3F8.3)
       GO TO 3000
1400   IF(VDF(I).EQ.0.0)GO TO 1800
       WRITE(6,1600)N(I),VDF(I),TMH(I),TMHG(I),TMLMF(I),TMLMG(I),
      1TMCM(I),TMB(I),TMCH(I),TMD(I)
1600   FORMAT(/I7,F8.4,5X,2H--,2X,6X,2H--,2X,6X,2H--,3X,F7.3,F9.6,
      12F10.6,F8.3,3F8.3)
       GO TO 3000
1100   WRITE(6,1200)N(I),VDF(I),PE(I),TME(I),TMEG(I),TMH(I),TMHG(I),
      1TMCM(I),TMB(I),TMCH(I),TMD(I)
1200   FORMAT(/I7,F8.4,F9.5,F10.3,F11.6,F7.3,F9.6,5X,2H--,8X,2H--,3X,
      1F8.3,3F8.3)
       GO TO 3000
1700   WRITE(6,1900)N(I),TMH(I),TMHG(I),TMCM(I),TMB(I),TMCH(I)
1900   FORMAT(/I7,4X,2H--,7X,2H--,8X,2H--,8X,2H--,3X,
      1F7.3,F9.6,2(5X,2H--,3X),F8.3,2F8.3,5X,2H--)
```

```
      GO TO 3000
1800  WRITE(6,1910)N(I),TMH(I),TMHG(I),TMLMF(I),TMLMG(I),TMCM(I),
     1TMB(I),TMCH(I)
1910  FORMAT(/I7,4X,2H--,7X,2H--,8X,2H--,8X,2H--,3X,F7.3,
     1F9.6,2F10.6,F8.3,2F8.3,5X,2H--)
3000  CONTINUE
      GO TO 708
 709   WRITE(6,711)
711   FORMAT(//////)
708   WRITE(6,808)
808   FORMAT(//,10X,5HTABLE,30X,32HCOMPARISON OF FRICTION PRESSURE ,
     19HDROP DATA)
2000  CONTINUE


      WRITE(6,2100)
2100  FORMAT(1H1,//,3X,'NO',6X,'GTOTL',4X,'QALTY',
     15X,'PINDX',6X,'TMBE',6X,'TME',5X,'USF',6X,
     2'USG',5X,'VDF',4X,'BETA',4X,'PATERN',4X,'FFSP',6X,'RE',//)
      DO 5000 I=1,M
      STN(I)=STN(I)/1000.0
      IF(K(I).EQ.3)GO TO 4050
      REF=(DF(I)*USF(I)*D)/VFF(I)
      FFC=(PI**2)*(D**5)*1000.0/8.0
      FFSP=FFC*PE(I)/((QF(I)**2)*DF(I))
      IF(K(I).EQ.9)GO TO 4100
      WRITE(6,4000)N(I),GTOTL(I),QALTY(I),PINDX(I),TMB(I),TME(I),
     1USF(I),USG(I),VDF(I),BETA(I),K(I)
4000  FORMAT(/I8,F8.2,2F10.6,2X,F7.4,2X,4F8.4,F9.6,I6)
      GO TO 5000


4050  HLL=ELL(I)/1000.
      PE(I)=(PE(I)*249.09*100.)/(2.54*10.)
      PEF=PTT(I)*9.807
      IF(HLL.EQ.0.0) GOTO 4052
      BST1=D/2.-HLL
      BST2=BST1/(D/2.)
      SL=D*ACOS(BST2)
      AL=(D/2.)**2*ACOS(BST2)-BST1*((D/2.)**2-BST1**2)**0.5
      DL=(4.*AL)/SL
```

```
      REF=(4.*DF(I)*QF(I))/(VFF(I)*SL)
C      IF(PEF.LE.0.0) GOTO 4055

C      FFSP=((SL)**2*(DL)**3*PEF)/(8.*DF(I)*QF(I)**2)


CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C    THIS SECTION FOR STRTIFIED FLOW USING BISHOP et. al. MODULE   C
C                                                                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC


C     THIS SECTION ADDED FOR MR. E.M.ALI
C     FOR TILDE TERM WE WILL USE T,FOLLOWED BY VARIABLE,FOLLOWED BY X
C     FOR EXAMPLE TALX
C     HOPEFULLY WE WILL AVOID USING TERMS USED ELSEWHERE,UNLESS
C     COMMON TERMS
      CGTX=0.046
      CLTX=0.046
      XTN=0.20
      XTM=0.20
      CGLX=16.0
      CLLX=16.0
      XLN=1.0
      XLM=1.0
C     ALMOST CERTAINLY ALL TURBULENT FLOWS
C     VALUES OF SL,DL AND ALREADY CALCULATED
      ULX=QF(I)/AL
      FLTX=CLTX *(DF(I)*DL*ULX/VFF(I))**(-XTN)
      FLTX=4.0*FLTX
      FLSX=CLTX*(D*USF(I)*DF(I)/VFF(I))**(-XTN)
      AG=AP-AL
      SG=(PI*D)-SL
      SI=2*((D/2)**2-BST1**2)**0.5
      DGX=4*AG/(SG+SI)
      UGX=QG(I)/AG
      FGSX=CGTX*(D*USG(I)*DG(I)/VGG(I))**(-XTM)
      FGTX=CGTX*((DG(I)*DGX*UGX/VGG(I))**(-XTM))
      FGTX=FGTX
C     TAKE FI=FIL=FIG
C     TAKE FI=FG  WE CAN MAKE THIS ANY RATIO eg. FI/FG=ANY VALUE
```

```
C     THIS IS WHERE WE MAKE CHANGES FOR FI
      FILX=FGTX
      FIGX=FGTX
C     MAKE LOCK-MART X SQUARED=XSGX
      XSGX=(FLSX*(0.5*DF(I)*(USF(I)**2)))/
     1(FGSX*(0.5*DG(I)*(USG(I)**2)))
      TDLX=DL/D
      TDGX=DGX/D
      TULX=ULX/USF(I)
      TUGX=UGX/USG(I)
      TSI=SI/D
      TSL=SL/D
      TSG=SG/D
      TAL=AL/(D**2)
      TAG=AG/(D**2)
      TERM1=XSGX*((TDLX*TULX)**(-XTN))*((TULX**2)*TSL)
     1/(TAL*((TDGX*TUGX)**(-XTM)))
      TERM2=(TUGX**2)*((TSG/TAG)+((TSI/TAL)*(FILX/FGTX))
     1+((TSI/TAG)*(FIGX/FGTX)))

C     TERM Z  (THETA=ANGLE OF INCLINATION)

      ANGLE=0.0
      TAWWL=(FLTX*DF(I)/2)*(ULX**2)
      TAWWG=(FGTX*DG(I)/2)*(UGX**2)
      TAWWIL=(FILX*DG(I)/2)*(UGX-ULX)**2
      TAWWIG=(FIGX*DG(I)/2)*(UGX-ULX)**2
      TERMI=(TAWWL*SL/AL)-(TAWWG*SG/AG)-(TAWIL*SI/AL)-(TAWIG*SI/AG)
     1-(DF(I)-DG(I))*GRVTY*SIN(ANGLE)
      TERM3=4.0*(4*CGTX/D)*((DG(I)*D*USG(I)/VGG(I))**(-XTM))*
     1(0.5*DG(I)*(USG(I)**2))
      TERM5=((TDGX*TUGX)**(-XTM))
      TERMZ=4*TERMI/(TERM3*TERM5)
      TERMY=((DF(I)-DG(I))*GRVTY*SIN(ANGLE))/TERM3
      TERM4=4*TERMY/TERM5
      ANSWER=TERM1-TERM2-TERMZ-TERM4
C     ANSWER SHOULD EQUAL ZERO PRINT OUT TERM1,TERM2,TERMZ AND TERM4
C     AND ANSWER SO WE CAN SEE RELATIVE MAGNITUDES
C     TERM2 AND TERMZ CAN BE ADJUSTED BY CHOOSING DIFFERENT VALUES
C     FOR FILX,FIGX COMPARED TO FGTX
C      WRITE(6,*)N(I),ELL(I),TERM1,TERM2,TERMZ,TERM4,ANSWER
```

```
C4444  FORMAT(/I8,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.5,1X,F10.5)
C       WRITE(6,*)N(I),AL,AG,SL,SG,DL,DGX,TERMI,SI,DF(I),VFF(I),
C      1DG(I),VGG(I),TULX,TUGX,TAL,TAG,USF(I),USG(I),ULX,UGX,
C      1TSL,TSG,TSI,TDGX,TDLX,QF(I),QG(I),TERM3,TERM5,TAWWL,
C      1TAWWG,TAWWIL,TAWWIG,FLTX,FGTX,FILX,FIGX,FLSX,FGSX,XSGX

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      NIKOLAOS ANDRITSOS  AND T. J. HANRATTY METHOD TO CALCULATE C
C      STRESS AT THE WALL FOR THE LIQUID PHASE                    C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

C      FI=FG  BECAUSE USG<= ((DGO/DG(I))**0.5)*(5.0)

       TAWWILX=TAWWIL*(UGX**2)/(UGX-ULX)**2
C       HPLUS1=(0.098*(REF**0.85)/(1-(HLL/D))**0.5)**5.0
C       HPLUS=((1.082*(REF**0.5))**5.0+HPLUS1)**0.2
        HPLUS=(0.098*(REF**0.85))/((1-(HLL/D))**0.5)
       TAWC=(DF(I)*(HPLUS*VFF(I)/(D*DF(I)))**2.3516)*
      1((HLL/D)**(-3.4206))
       TAWWLX=TAWC-(TAWWILX/3.0)
       TAWWLX=1.5*TAWWLX/(1-(HLL/D))
C      FROM EQUATION (2)
       DPDXHL=((TAWWILX*SI)-(TAWWLX*SL))/AL
       DPDXHG=(-(TAWWILX*SI)-(TAWWILX*SG))/AG
C       IF(HLL.LT.0.100) GOTO 5000
       IF(HLL.GT.0.175) GOTO 5000
       RATIO=HLL/D
       TAWWLEX=(TAWWILX*SI)/SL+(PE(I)*AL)/SL
       TAWCEX=((2.*TAWWLEX)/3.)*(1-RATIO)+(TAWWILX/3.)
       HNUD=(HPLUS*VFF(I))/(DF(I)*D)
       DEFF=(TAWCEX-TAWC)*100/TAWC
       WRITE(6,*)N(I),TAWCEX,DF(I),HNUD,RATIO,DEFF

       IF(PEF.LE.0.0) GOTO 4055
       FFSP=((SL)**2*(DL)**3*PEF)/(8.*DF(I)*QF(I)**2)
       GOTO 4100
4052   REF=0.0
4055   FFSP=0.0

C4100   WRITE(6,4200)N(I),GTOTL(I),QALTY(I),PINDX(I),TMB(I),
C      1TME(I),USF(I),USG(I),VDF(I),BETA(I),K(I),FLTX,REF
```

```
C4200  FORMAT(/I8,F8.2,2F10.6,2X,F7.4,2X,4F8.4,F9.6,I6,1X,F10.8,F10.0)
4100   CONTINUE
5000    CONTINUE
       WRITE(6,2600)
2600   FORMAT(1H1,//,5X,'NO',8X,'UG/UF',6X,'UG-UF',6X,'GTOTL',
      18X,'VDF',10X,'BETA',6X,'FRDM',6X,'WEBM',8X,'PATERN',//)
       DO 2500 I=1,M
       FRDM=((USF(I)+USG(I))**2)/(D*GRVTY)
       FRDM=ALOG(FRDM)
       IF(VDF(I).EQ.0.0)GO TO 2800
       UG=USG(I)/VDF(I)
       UF=USF(I)/(1.0-VDF(I))
       SLIPR=UG/UF
       SLIP=UG-UF
       DNSTYM=DG(I)*VDF(I)+DF(I)*(1.0-VDF(I))
       WEBM=((USG(I)+USF(I))**2)*D*DNSTYM/STN(I)
       GO TO 2900
2800   SLIPR=0.0
       SLIP=0.0
       WEBM=0.0
2900   WRITE(6,2700)N(I),SLIPR,SLIP,GTOTL(I),VDF(I),
      1BETA(I),FRDM,WEBM,K(I)
2500   CONTINUE
2700   FORMAT(/I8,6F12.4,F12.3,I10)
C       WRITE(6,3050)
C3050   FORMAT(1H1,//,5X,'NO',8X,'RUS',8X,'RVD',7X,'LN(FRG)',
C      18X,'VDF',6X,'BETA',8X,'LN(FRF)',5X,'LN(REG)',5X,
C      2'LN(REF)',4X,'PATERN',//)
       DO 3100 I=1,M
       RUS=USG(I)/USF(I)
       IF(BETA(I).EQ.0.0)GO TO 3200
       RVD=VDF(I)/BETA(I)
       FRG=ALOG((USG(I)**2)/(D*GRVTY))
       REG=D*DG(I)*USG(I)/VGG(I)
       REG=ALOG(REG)
       GO TO 3250
3200   RVD=0.0
       FRG=0.0
       REG=0.0
3250   FRF=ALOG((USF(I)**2)/(D*GRVTY))
       REF=D*DF(I)*USF(I)/VFF(I)
```

```
      REF=ALOG(REF)
C      WRITE(6,3150)N(I),RUS,RVD,FRG,VDF(I),BETA(I),
C     1FRF,REG,REF,K(I)
3100  CONTINUE
C3150  FORMAT(/,I8,8F12.5,I10)
C      WRITE(6,6400)
C6400  FORMAT(1H1,//,5X,'NO',8X,'RH',6X,'XFRDM',3X,
C     1'XWEBM',6X,'XNAR',7X,'XNKU',5X,'REFR/WE',6X,'FFSKH',8X,
C     2'XFFD',8X,'XFFH',9X,'RFT',//)
      DO  6500 I=1,M
      B=BETA(I)
      G=1-B
      VG=VGG(I)
      VF=VFF(I)
      VH=B*VG+G*VF
      DD=B*DG(I)+G*DF(I)
      RFT=GTOTL(I)*D/VF
      RH=GTOTL(I)*D/VH
      XFRDM=((USF(I)+USG(I))**2)/(D*GRVTY)
      XWEBM=((USG(I)+USF(I))**2)*D*DD/STN(I)
      XNAR=(STN(I)**1.5)*DF(I)/((GRVTY**0.5)
     1*(VF**2)*((DF(I)-DG(I))**0.5))
      RRR=RH*XFRDM/XWEBM
      XFFH=PE(I)*2*D*DD/(GTOTL(I)**2)
      IF(VDF(I).EQ.0.0) GO TO 6450
      UG=USG(I)/VDF(I)
      UF=USF(I)/(1-VDF(I))
      PSY=DF(I)*G**2/(DD*(1-VDF(I)))+DG(I)*B**2/
     1(DD*VDF(I))
      SKH=DF(I)*(UF**2)*(1+(1-(DG(I)/DF(I)))*
     1(UG/UF))/2*D
      FFSKH=PE(I)/SKH
      XFFD=(PE(I)*2*D*DD)/((GTOTL(I)**2)*PSY)
      XNKU=(DG(I)**0.5)*(UG)*(GRVTY*STN(I)*(DF(I)-
     1DG(I)))**(-0.25)
C      GO TO 6455
6450  FFSKH=0.0
      XFFD=0.0
      XNKU=0.0
C6455  WRITE(6,6600)N(I),RH,XFRDM,XWEBM,XNAR,XNKU,RRR,
C     1FFSKH,XFFD,XFFH,RFT
```

```
C6600  FORMAT(/,I8,F12.1,1F8.2,1F10.2,E12.4,F10.4,4E12.4,F12.1)
6500  CONTINUE


      IF(NOR.EQ.888)GO TO 2099
C      WRITE(6,6700)
C6700  FORMAT(1H1,//,5X,'NO',5X,'VDF',8X,'BETAR',6X,
C     1'QALR',4X,'TPMFOV',5X,'DP',6X,'PATRN',5X,'XTTE',7X,'XPHI',
C     26X,'HOR',6X,'VELHFO',4X,'VELHF',//)
      DO 6800 I=1,M


      IF(QALTY(I).EQ.0.0)GO TO 6758
      XTTE=(PINDX(I)**0.5)*(1-QALTY(I))**0.9
     1/QALTY(I)**0.9
      GO TO 6759
 6758 XTTE=1.0
 6759 WF=QF(I)*DF(I)
      VELHF=1000.0*(USF(I)**2)/(2*GRVTY)
      DELPTP=HOR(I)*DF(I)*GRVTY/1000.0
      VELHFO=1000.0*(GTOTL(I)**2)/(2*GRVTY*(DF(I)**2))
      DELPFO=XOR*(GTOTL(I)**2)/(2*DF(I))
      IF(DELPFO.EQ.0.0)GO TO 6751
      TPMFOV=DELPTP/DELPFO
      GO TO 6752
 6751 DELPFO=1.0
 6752 SPECVH=((1-QALTY(I))/DF(I))+(QALTY(I)/DG(I))
      AAAA=(GTOTL(I)**2)*SPECVH/2
      IF(XOR.EQ.0.0)GO TO 6753
      BBBB=(HOR(I)/(VELHF*XOR))**0.5
      GO TO 6754
 6753 BBBB=1.0
 6754 QALR=QALTY(I)/(1-QALTY(I))
      BETAR=BETA(I)/(1-BETA(I))
C      WRITE(6,6750)N(I),AAAA,BETAR,QALR,
C     1TPMFOV,DELPTP,K(I),XTTE,BBBB,HOR(I),VELHFO,VELHF
C6750  FORMAT(/,I8,1E12.4,2E10.3,F10.3,E10.3,I3,2F12.6,3F10.3)
6800  CONTINUE
C      DO 1189 I=1,M
C     BRITOIL CONTRACT
C
```

```
C       PEE=PE(I)*1000.0
C
C       VG=VGG(I)
C       VF=VFF(I)
C       USM=USF(I)+USG(I)
C       X=QALTY(I)
C       B=BETA(I)
C       G=1-B
C       A=ALOG(G)
C       F=-ALOG(G)
C       EXPHL=1-VDF(I)
C      EATON HOLDUP
C      USED IN DUKLER PRESSURE-DROP
C      HOLDUP IS FUNCTION OF XE
C       IF(K(I).EQ.9)GO TO 1189
C       ZNGV=USG(I)*(DF(I)/(GRVTY*STN(I)))**0.25
C       ZNLV=USF(I)*(DF(I)/(GRVTY*STN(I)))**0.25
C       ZNLE=VF*(GRVTY/(DF(I)*STN(I)**3))**0.25
C       ZNDE=D*(DF(I)*GRVTY/STN(I))**0.5
C       EAXE=1.82*(ZNLV**0.575)*((P(I)/100.0)**0.05)*(ZNLE**0.1)/
C      1(ZNGV*ZNDE**0.0277)
C       HLEA1=0.0133
C       HLEA2=14.182*EAXE**3-11.554*EAXE**2+3.636*EAXE-
C      10.00901
C       HLEA3=0.168*EAXE**3-0.710*EAXE**2+1.117*EAXE+0.172
C       HLEA4=0.0012*EAXE**3-0.02299*EAXE**2+0.14725*EAXE+
C      10.62775
C       HLEA5=0.9656
C       IF(EAXE.LE.0.006)HLEA=HLEA1
C       IF(EAXE.GT.0.006.AND.EAXE.LE.0.30)HLEA=HLEA2
C       IF(EAXE.GT.0.30.AND.EAXE.LE.1.0)HLEA=HLEA3
C       IF(EAXE.GT.1.0.AND.EAXE.LE.9.0)HLEA=HLEA4
C       IF(EAXE.GT.9.0)HLEA=HLEA5
C      BEGGS AND BRILL HOLDUP
C       BBL1=EXP(-4.62-3.757*A-0.481*A**2-0.0207*A**3)
C       BBL2=EXP(1.061-4.602*A-1.609*A**2-0.179*A**3+0.000635*A**5)
C       BBNFR=(USM**2)/(D*GRVTY)
C       IF(BBNFR.LT.BBL1)GO TO 1222
C       IF(BBNFR.GT.BBL1.AND.BBNFR.GT.BBL2)GO TO 1223
C       IF(BBNFR.GE.BBL1.AND.BBNFR.LE.BBL2)GO TO 1224
C 1222  BBHL=0.98*G**0.4846/BBNFR**0.0868
```

```
C       GO TO 1225
C 1223 BBHL=1.065*G**0.5824/BBNFR**0.0609
C       GO TO 1225
C 1224 BBHL=0.845*G**0.5351/BBNFR**0.0173
C 1225 CONTINUE
C      MUKHERJEE AND BRILL HOLDUP HORIZ. FLOW
C       HLZMB=EXP((-0.380113+2.343227*ZNLE**2)*(ZNGV**0.475686/
C      1ZNLV**0.288657))
C      GUZHOV HOLDUP
C       GRHON=(DF(I)*G)+(DG(I)*B)
C       GVN=(VF*G)+(VG*B)
C       GREN=GRHON*USM*D/GVN
C       GFSP1=0.0056+0.5*GREN**(-0.32)
C       GNFR=USM**2/D*GRVTY
C       GLP=(0.2/GFSP1)*(EXP(-2.5*B))/(G)
C       GHL=1-0.81*B*(1-EXP(-2.2*GNFR**0.5))
C       IF(EXPHL.GT.1.0)GO TO 1189
C       WRITE(6,1188)N(I),EXPHL,HLEA,BBHL,HLZMB,GHL,PE(I),K(I)
C 1188 FORMAT(I7,5F10.5,F11.5,I10)
C 1189 CONTINUE
      DO 1199 I=1,M
      PEE=PE(I)*1000.0
      VG=VGG(I)
      VF=VFF(I)
      USM=USF(I)+USG(I)
      X=QALTY(I)
      B=BETA(I)
      G=1-B
      A=ALOG(G)
      F=-ALOG(G)
      EXPHL=1-VDF(I)
      IF(K(I).EQ.9)GO TO 1199
      ZNGV=USG(I)*(DF(I)/(GRVTY*STN(I)))**0.25
      ZNLV=USF(I)*(DF(I)/(GRVTY*STN(I)))**0.25
      ZNLE=VF*(GRVTY/(DF(I)*STN(I)**3))**0.25
      ZNDE=D*(DF(I)*GRVTY/STN(I))**0.5
      HLZMB=EXP((-0.380113+2.343227*ZNLE**2)*(ZNGV**0.475686/
     1ZNLV**0.288657))
      EAXE=1.82*(ZNLV**0.575)*((P(I)/100.0)**0.05)*
     1(ZNLE**0.1)/(ZNGV*ZNDE**0.0277)
      HLEA1=0.0133
```

```
      HLEA2=14.182*EAXE**3-11.554*EAXE**2+3.636*EAXE-
     10.00901
      HLEA3=0.168*EAXE**3-0.710*EAXE**2+1.117*EAXE+0.172
      HLEA4=0.0012*EAXE**3-0.02299*EAXE**2+0.14725*EAXE+
     10.62775
      HLEA5=0.9656
      IF(EAXE.LE.0.006)HLEA=HLEA1
      IF(EAXE.GT.0.006.AND.EAXE.LE.0.30)HLEA=HLEA2
      IF(EAXE.GT.0.30.AND.EAXE.LE.1.00)HLEA=HLEA3
      IF(EAXE.GT.1.0.AND.EAXE.LE.9.0)HLEA=HLEA4
      IF(EAXE.GT.9.0)HLEA=HLEA5
C     BEGGS AND BRILL HOLDUP
      BBL1=EXP(-4.62-3.757*A-0.481*A**2-0.0207*A**3)
      BBL2=EXP(1.061-4.602*A-1.609*A**2-0.179*A**3+0.000635*A**5)
      BBNFR=(USM**2)/(D*GRVTY)
      IF(BBNFR.LT.BBL1)GO TO 1322
      IF(BBNFR.GT.BBL1.AND.BBNFR.GT.BBL2)GO TO 1323
      IF(BBNFR.GE.BBL1.AND.BBNFR.LE.BBL2)GO TO 1324
 1322 BBHL=0.98*G**0.4846/BBNFR**0.0868
      GO TO 1325
 1323 BBHL=1.065*G**0.5824/BBNFR**0.0609
      GO TO 1325
 1324 BBHL=0.845*G**0.5351/BBNFR**0.0173
 1325 CONTINUE
C     DUKLER PRESSURE-DROP
C     CALC. FOR SMOOTH TUBE AND AS PER 5 INCH TUBE
C     HLSUB USED IN GENERAL
      HLSUB=BBHL
      IF(HLSUB.GE.1.0)GO TO 1199
      ALF=1-HLSUB
      DVVN=(G*VF)+(B*VG)
      DRHOM=(DF(I)*(G**2)/HLSUB)+(DG(I)*(B**2)/ALF)
      DRE=DRHOM*USM*D/DVVN
      FN=0.0056+0.5*(DRE**(-0.32))
      FFF1=1.281-0.478*F+0.444*(F**2)-0.094*(F**3)+0.00843*(F**4)
      FFF2=F/FFF1
      FDUK1=FN*(1+FFF2)
      DUDPF1=FDUK1*DRHOM*(USM**2)/(2*D)
      DPEXP=PE(I)
      DUF2=0.212*(DRE**(-0.222))
      DUAR=ALOG(DRE)
```

```
      DUF3=1084.06-381.55*DUAR+50.261*DUAR**2-2.946*DUAR**3+
     10.0648*DUAR**4
      DUF3=EXP(DUF3)
      IF(DRE.LE.100000.0)DUF=DUF3
      IF(DRE.GT.100000.0)DUF=DUF2
      FDUK2=DUF*(1+FFF2)
      DUDPF2=FDUK2*DRHOM*(USM**2)/(2*D)
C     BEGGS AND BRILL PRESSURE-DROP
C     CALC. AS PER SMOOTH TUBE AND AS PER 5 INCH TUBE
      BBY=G/(HLSUB**2)
      BBY1=ALOG(BBY)
      BBY2=-0.0523+3.182*BBY1-0.8725*(BBY1**2)+0.01853*(BBY1**4)
      IF(BBY.GT.1.0.AND.BBY.LT.1.2)GO TO 11121
      GO TO 11122
11121 BBS=ALOG(2.2*BBY-1.2)
      GO TO 11123
11122 BBS=BBY1/BBY2
11123 BBRHO=G*DF(I)+B*DG(I)
      BBV=G*VF+B*VG
      BBRE=(BBRHO*USM*D)/BBV
      BBFN1=(2*ALOG10(BBRE/((4.5223*ALOG10(BBRE))-3.8215)))**-2
      BBFN2=0.0056+0.5*(BBRE**(-0.32))
      BBFN3=0.212*(BBRE**(-0.222))
      AR=ALOG(BBRE)
      BBFN4=1084.06-381.55*AR+50.261*AR**2-2.946*AR**3+0.0648*AR**4
      BBFN4=EXP(BBFN4)
      IF(BBRE.LE.100000.0)BBFN=BBFN4
      IF(BBRE.GT.100000.0)BBFN=BBFN3
      FNSP1=BBFN1*EXP(BBS)
      FNSP2=BBFN2*EXP(BBS)
      FNTP=BBFN*EXP(BBS)
      BBDPF1=FNSP1*BBRHO*USM**2/(2*D)
      BBDPF2=FNSP2*BBRHO*USM**2/(2*D)
      BBDPF3=FNTP*BBRHO*USM**2/(2*D)
C     MUKHERJEE AND BRILL PRESSURE-DROP USING BEGGS AND BRILL
C     VISCOSITY
C     FLOW PATTERN PREDICTION
      ZNGVL=ALOG10(ZNGV)
      ZMBN2=10.0**(1.401-2.694*ZNLE+0.521*ZNLV**0.329)
      ZMBN3=10.0**(0.431-3.003*ZNLE)
      ZMBN4=10.0**(0.321-0.017*ZNGV-2.972*ZNLE-0.033*ZNGVL**2)
      ZMBRHO=(DF(I)*HLSUB)+(DG(I)*(1-HLSUB))
```

```
      ZMBRE=ZMBRHO*USM*D/BBV
      ZMBFN1=0.0056+0.5*(ZMBRE**(-0.32))
      ZMBFN2=0.212*(ZMBRE**(-0.2220))
      ZMBAR=ALOG(ZMBRE)
      ZMBFN3=1084.06-381.55*ZMBAR+50.261*ZMBAR**2-2.946*ZMBAR**3+
     10.0648*ZMBAR**4
      ZMBFN3=EXP(ZMBFN3)
      IF(ZMBRE.LE.100000.0)ZMBFN=ZMBFN3
      IF(ZMBRE.GT.100000.0)ZMBFN=ZMBFN2
C     BUBBLE AND SLUG
      DPBS1F=ZMBFN1*(USM**2)*ZMBRHO/(2*D)
      DPBS2F=ZMBFN*(USM**2)*ZMBRHO/(2*D)
C     STRATIFIED CASE A NOT CALC.BUT DEL NEEDED
C     NEWTON RALPHSON METHOD A.GILCHRIST
      KRALPH=0
      DEL1=PI
 1111 DEL2=DEL1-(DEL1-SIN(DEL1)-2*PI*HLSUB)/(1-COS(DEL1))
      DEL3=(((DEL2-DEL1)**2)**0.5)/DEL1
      IF(DEL3.GT.0.005)GO TO 1112
      GO TO 1113
 1112 DEL1=DEL2
      KRALPH=KRALPH+1
      IF(KRALPH.GT.100)GO TO 11125
      GO TO 1111
11125 WRITE(6,*)'N-RALPHSON FAILED'
      GO TO 2099
 1113 DEL=DEL2
C     STRATIFIED CASE B
      ZMBDL=D*(DEL-SIN(DEL))/(DEL+2*SIN(DEL/2))
      ZMBDG=D*(2*PI-(DEL-SIN(DEL)))/(2*PI-DEL+2*SIN(DEL/2))
      ZMBUL=USF(I)/HLSUB
      ZMBUG=USG(I)/(1-HLSUB)
      ZMBREL=ZMBDL*ZMBUL*DF(I)/VFF(I)
      ZMBFL=0.0056+0.5*(ZMBREL**(-0.32))
      ZMBREG=ZMBDG*ZMBUG*DG(I)/VGG(I)
      ZMBFG=0.0056+0.5*(ZMBREG**(-0.32))
      ZMBTWL=ZMBFL*DF(I)*(ZMBUL**2)/2.0
      ZMBTWG=ZMBFG*DG(I)*(ZMBUG**2)/2.0
      ZMBPG=(1-(DEL/(2*PI)))*PI*D
      DPST1F=-(ZMBTWL*(PI*D-ZMBPG)+(ZMBTWG*ZMBPG))/AP
      ZMBFL2=0.212*(ZMBREL**(0.222))
```

```
      ARRL=ALOG(ZMBREL)
      ZMBFL3=1084.06-381.55*ARRL+50.261*ARRL**2-
     12.946*ARRL**3+0.0648*ARRL**4
      ZMBFL3=EXP(ZMBFL3)
      ARRG=ALOG(ZMBREG)
      ZMBFG3=1084.06-381.55*ARRG+50.261*ARRG**2-
     12.946*ARRG**3+0.0648*ARRG**4
      ZMBFG3=EXP(ZMBFG3)
      ZMBFG2=0.212*(ZMBREG**(0.222))
      IF(ZMBREL.LE.100000.0)ZMBFLF=ZMBFL3
      IF(ZMBREL.GT.100000.0)ZMBFLF=ZMBFL2
      IF(ZMBREG.LE.100000.0)ZMBFGG=ZMBFG3
      IF(ZMBREG.GT.100000.0)ZMBFGG=ZMBFG2
      ZMBTWL2=ZMBFLF*DF(I)*(ZMBUL**2)/2.0
      ZMBTWG2=ZMBFGG*DG(I)*(ZMBUG**2)/2.0
      DPST2F=-(ZMBTWL2*(PI*D-ZMBPG)+(ZMBTWG2*ZMBPG))/AP
C     MUK AND BRILL ANNULAR  FLOW
      ZMBFAC=G/HLSUB
      IF(ZMBFAC.LT.0.01)ZMBFR=1.0
      IF(ZMBFAC.GE.0.01.AND.ZMBFAC.LT.0.2)ZMBFR=1.0
      IF(ZMBFAC.GE.0.2.AND.ZMBFAC.LT.0.3)ZMBFR=1.1
      IF(ZMBFAC.GE.0.3.AND.ZMBFAC.LT.0.4)ZMBFR=1.225
      IF(ZMBFAC.GE.0.4.AND.ZMBFAC.LT.0.5)ZMBFR=1.275
      IF(ZMBFAC.GE.0.5.AND.ZMBFAC.LT.0.7)ZMBFR=1.275
      IF(ZMBFAC.GE.0.7.AND.ZMBFAC.LT.1.0)ZMBFR=1.125
      IF(ZMBFAC.GE.1.0.AND.ZMBFAC.LT.10.0)ZMBFR=1.0
      IF(ZMBFAC.GT.10.0)ZMBFR=1.0
      ZMBAF1=ZMBFR*ZMBFN1
      ZMBAF2=ZMBFN
      ZMBRHON=DF(I)*(G)+DG(I)*B
      DPA1F=ZMBAF1*ZMBRHON*(USM**2)/(2*D)
      DPA2F=ZMBFN*ZMBRHON*(USM**2)/(2*D)
      IF(ZNGV.GE.ZMBN2)DPDZ1F=DPA1F
      IF(ZNGV.GE.ZMBN2)DPDZ2F=DPA2F
      IF(ZNGV.GT.ZMBN3)DPDZ1F=DPBS1F
      IF(ZNGV.GT.ZMBN3)DPDZ2F=DPBS2F
      IF(ZNGV.LE.ZMBN3)DPDZ1F=DPBS1F
      IF(ZNGV.LE.ZMBN3)DPDZ2F=DPBS2F
      IF(ZNLV.GT.ZMBN4)DPDZ1F=DPBS1F
      IF(ZNLV.GT.ZMBN4)DPDZ2F=DPBS2F
      IF(ZNLV.LE.ZMBN4)DPDZ1F=DPST1F
```

```
      IF(ZNLV.LE.ZMBN4)DPDZ2F=DPST2F
C     OLIEMANS
C     OLIEMANS PRESSURE DROP
      GOL=HLSUB-G
      VTPO=((VF*G)+(VG*(1-HLSUB)))/(1-GOL)
      GTPO=GTOTL(I)/(1-GOL)
      DEFFO=D*(1-GOL)**0.5
      RHOOL=((DF(I)*(G))+(DG(I)*(1-HLSUB)))/(1-GOL)
      REOL=D*GTOTL(I)/(VTPO*((1-GOL)**0.5))
      OLFTP1=0.0056+0.5*(REOL**(-0.32))
      OLFTP2=BBFN
      DPOL1F=OLFTP1*(GTPO**2)/(2*DEFFO*RHOOL)
      DPOL2F=BBFN*(GTPO**2)/(2*DEFFO*RHOOL)
      IF(EXPHL.GT.1.0)GO TO 1199
C     WRITE(6,1198)N(I),PEE,DUDPF1,DUDPF2,BBDPF1,BBDPF2,BBDPF3,DPDZ1F,
C     1DPDZ2F,DPOL1F,DPOL2F,K(I)
C 1198 FORMAT(I7,10F10.3,I10)
 1199 CONTINUE
C      DO 3333 I=1,M
C      WRITE(6,3334)N(I),T(I),VDF(I),QF(I),QG(I),DF(I),DG(I),
C     1PE(I),K(I)
C 3334 FORMAT(I8,F6.1,F7.3,2F10.6,F8.2,F8.4,F9.5,I5)
C 3333 CONTINUE

C     VOID FRACTION CORRELATIONS
      WRITE(6,5555)
5555  FORMAT(//////)
      WRITE(6,6666)
6666  FORMAT(1X,7HTEST NO,1X,5HVEXP.,1X,6HVCHISH,1X,6HVROHN1,1X,
     16HVROHN2,1X,6HVROHN3,1X,6HVROHN4,1X,6HVSMITH,1X,5HVHUMA)
      DO 50001 I=1,M
      X=QALTY(I)
      SLIP=((X*DF(I)/DG(I))+(1+X))**0.5
C     CHISHOLM VOID FRACTION
      VCHS=X*DF(I)/(X*DF(I)+SLIP*(1+X)*DG(I))
C     ROUHANI VOID FRACTION
      ROHK1=1+0.12*(1-X)
      ROHK2=((X/DG(I))+(1-X)/DF(I))
      ROHK3=(GRVTY*STN(I)*(DF(I)-DG(I))/DF(I)
     1**2)**0.25
```

```
      UROH1=1.18*ROHK3
      UROH2=7.3*ROHK3
      UROH3=8.0*ROHK3

      VROHN1=(X/DG(I))/(ROHK1*ROHK2)
      GTOT=GTOTL(I)
      VROHN2=(X/DG(I))/((ROHK1*ROHK2)+(UROH1/GTOT))
      VROHN3=(X/DG(I))/((ROHK1*ROHK2)+(UROH2/GTOT))
      VROHN4=(X/DG(I))/((ROHK1*ROHK2)+(UROH3/GTOT))

C     SMITH VOID FRACTION

      SMITHS=0.4+0.6*((DF(I)/DG(I)+0.4*(1/X-1))/(1.0+0.4*(1/X-1)))
     1**0.5
      VSMITH=X*DF(I)/(X*DF(I)+SMITHS*(1-X)*DG(I))

C     HUGHMARK VOID FRACTION

      B=BETA(I)
      G=1-B
      VG=VGG(I)
      VF=VFF(I)
      VH=B*VG+G*VF
      RH=GTOT*D/VH
      REH1=RH
      DH=DG(I)*DF(I)/(X*DF(I)+(1-X)*DG(I))
      DH1=B*DG(I)+(1-B)*DF(I)
      FRDM=GTOT**2/(GRVTY*D*DH**2)
      ZHUMA=REH1**(0.16667)*FRDM**0.125*G**-0.25
      ZHUMA=ALOG(ZHUMA)
      CHUMA=-2.201825+2.073839*ZHUMA-0.788378*ZHUMA**2
     1+0.129714*ZHUMA**3-0.00743*ZHUMA**4
      CHUMA=EXP(CHUMA)
      VHUMA=CHUMA*B

      WRITE(6,50000)N(I),VDF(I),VCHS,VROHN1,VROHN2,VROHN3,
     1VROHN4,VSMITH,VHUMA
50000 FORMAT(I7,8F7.4)
50001 CONTINUE
      WRITE(6,777)
 777  FORMAT(//////)
      WRITE(6,888)
```

```
 888  FORMAT(1X,7HTEST NO,4X,5HVEXP.,4X,6HVEATON,4X,
     17HVBEG&BR,3X,8HVMUKJ&BR,2X,6HGOZHOV,
     15X,8HFLOW PAT)

      DO 1189 I=1,M

C     BRITOIL CONTRACT

      PEE=PE(I)*1000.0

      VG=VGG(I)
      VF=VFF(I)
      USM=USF(I)+USG(I)
      X=QALTY(I)
      B=BETA(I)
      G=1-B
      A=ALOG(G)
      F=-ALOG(G)
      EXPHL=1-VDF(I)

C     EATON HOLDUP
C     USED IN DUKLER PRESSURE-DROP
C     HOLDUP IS FUNCTION OF XE

      IF(K(I).EQ.9)GO TO 1189
      ZNGV=USG(I)*(DF(I)/(GRVTY*STN(I)))**0.25
      ZNLV=USF(I)*(DF(I)/(GRVTY*STN(I)))**0.25
      ZNLE=VF*(GRVTY/(DF(I)*STN(I)**3))**0.25
      ZNDE=D*(DF(I)*GRVTY/STN(I))**0.5
      EAXE=1.82*(ZNLV**0.575)*((P(I)/100.0)**0.05)*(ZNLE**0.1)/
     1(ZNGV*ZNDE**0.0277)
      HLEA1=0.0133
      HLEA2=14.182*EAXE**3-11.554*EAXE**2+3.636*EAXE-
     10.00901
      HLEA3=0.168*EAXE**3-0.710*EAXE**2+1.117*EAXE+0.172
      HLEA4=0.0012*EAXE**3-0.02299*EAXE**2+0.14725*EAXE+
     10.62775
      HLEA5=0.9656
      IF(EAXE.LE.0.006)HLEA=HLEA1
      IF(EAXE.GT.0.006.AND.EAXE.LE.0.30)HLEA=HLEA2
      IF(EAXE.GT.0.30.AND.EAXE.LE.1.0)HLEA=HLEA3
```

```
      IF(EAXE.GT.1.0.AND.EAXE.LE.9.0)HLEA=HLEA4
      IF(EAXE.GT.9.0)HLEA=HLEA5
      VDFEA=1-HLEA

C     BEGGS AND BRILL HOLDUP

      BBL1=EXP(-4.62-3.757*A-0.481*A**2-0.0207*A**3)
      BBL2=EXP(1.061-4.602*A-1.609*A**2-0.179*A**3+0.000635*A**5)
      BBNFR=(USM**2)/(D*GRVTY)
      IF(BBNFR.LT.BBL1)GO TO 1222
      IF(BBNFR.GT.BBL1.AND.BBNFR.GT.BBL2)GO TO 1223
      IF(BBNFR.GE.BBL1.AND.BBNFR.LE.BBL2)GO TO 1224
 1222 BBHL=0.98*G**0.4846/BBNFR**0.0868
      GO TO 1225
 1223 BBHL=1.065*G**0.5824/BBNFR**0.0609
      GO TO 1225
 1224 BBHL=0.845*G**0.5351/BBNFR**0.0173
      VDFBB=1-BBHL

 1225 CONTINUE

C     MUKHERJEE AND BRILL HOLDUP HORIZ. FLOW

      HLZMB=EXP((-0.380113+2.343227*ZNLE**2)*(ZNGV**0.475686/
     1ZNLV**0.288657))
      VDFMB=1-HLZMB

C     GUZHOV HOLDUP

      GRHON=(DF(I)*G)+(DG(I)*B)
      GVN=(VF*G)+(VG*B)
      GREN=GRHON*USM*D/GVN
      GFSP1=0.0056+0.5*GREN**(-0.32)
      GNFR=USM**2/D*GRVTY
      GLP=(0.2/GFSP1)*(EXP(-2.5*B))/(G)
      GHL=1-0.81*B*(1-EXP(-2.2*GNFR**0.5))
      VDFG=1-GHL
      IF(EXPHL.GT.1.0)GO TO 1189

C      WRITE(6,777)
C 777  FORMAT(//////)
```

```
C       WRITE(6,888)
C 888   FORMAT(1X,7HTEST NO,4X,5HVEXP.,4X,6HVEATON,4X,
C      17HVBEG&BR,3X,8HVMUKJ&BR,5X,6HGOZHOV,
C      12X,8HFLOW PAT)
        WRITE(6,1188)N(I),VDF(I),VDFEA,VDFBB,VDFMB,VDFG,K(I)
 1188   FORMAT(I7,5F10.4,I10)
 1189   CONTINUE

        IF(NOR.LT.1)GO TO 2099
        CALL ORIFICE
 2099   STOP
        END


        SUBROUTINE CONVERSION
        DIMENSION TG(500)
        COMMON DG1,DG2,DG3,N(500),T(500),P(500),VDF(500),DF(500),
       1DG(500),PE(500),QF(500),QG(500),WG(500),K(500),D,PI,AP,
       2M,STN(500),R,RR,VGG(500),VFF(500),XOR,HOR(500),NOR,ELL(500)
       1,PTT(500)
        READ(5,*)M,NR,D,VD3,FACTR,R,RR,NOR
        WRITE(6,318)M,NR,D,VD3,FACTR,R,RR,NOR
 318    FORMAT(1H1,////,4X,2I10,5F10.6,I10,////)
        IF(NOR.EQ.8)GO TO 100
        IF(NOR.LT.1)GO TO 100
        READ(5,*)XOR
        WRITE(6,120)XOR
 120    FORMAT(////,F12.8)
 100    PI=3.14159265
        AP=(PI/4)*D**2
        H1=((101325.+100000.)/(13550.*9.807))*100.
        H0=(101325./(13550.*9.807))*100.
        DG1=1.293*(H1/76.)/(1.+.00367*19.)
        NF=M-NR
        WRITE(6,410)
        WRITE(6,413)
 413    FORMAT(4X,2HNO,4X,3HEMF,3X,4HTEMP,4X,2HHL,5X,2HPG,4X,
       12HS1,4X,2HS2,4X,2HS3,4X,2HS4,4X,3HVDF,4X,3HPOT,5X,2HPE,
       26X,4HPRES,4X,3HELL,4X,3HPTT,3X,5HPATRN)
        WRITE(6,414)
```

```
414   FORMAT(10X,2HMV,6X,1HC,4X,5HCMH2O,3X,3HBAR,3X,2HCM,4X,2HCM,
     14X,2HCM,4X,2HCM,18X,7HMMH2O/M,3X,5HMMH2O)
      DO 801 I=1,M
      IF(I.GT.NR)GO TO 302
      IF(NOR.EQ.8)GO TO 130
      IF(NOR.LT.1)GO TO 130
      READ(5,*)N(I),EMF,T(I),HL,PG,S1,S2,S3,S4,VDF(I),POT,PE(I),
     1P(I),ELL(I),PTT(I),K(I),HOR(I)



      GO TO 150
130   READ(5,*)N(I),EMF,T(I),HL,PG,S1,S2,S3,S4,VDF(I),POT,
     1PE(I),P(I),ELL(I),PTT(I),K(I)

      PRINT*,N(I),EMF,T(I),HL,PG,S1,S2,S3,S4,VDF(I),POT,PE(I),
     1P(I),ELL(I),PTT(I),K(I),HOR(I)


150   WRITE(6,3088)N(I),EMF,T(I),HL,PG,S1,S2,S3,S4,VDF(I),POT,
     1PE(I),P(I),ELL(I),PTT(I),K(I)
3088   FORMAT(I8,F7.3,F6.1,F8.1,F6.2,4F6.1,F7.4,F7.2,F9.2,
     1F8.2,1X,F7.3,F7.4,I6)
      GO TO 307
302   IF(NOR.LT.1)GO TO 304
      IF(NOR.EQ.8)GO TO 304
      READ(5,*)N(I),EMF,T(I),HL,PG,S,VDF(I),POT,PE(I),
     1P(I),ELL(I),PTT(I),K(I),HOR(I)
      GO TO 316
304   READ(5,*)N(I),EMF,T(I),HL,PG,S,VDF(I),POT,
     1PE(I),P(I),ELL(I),PTT(I),K(I)
      ELE=VDF(I)
316   WRITE(6,306)N(I),EMF,T(I),HL,PG,S,VDF(I),POT,PE(I),P(I)
     1          ,ELL(I),PTT(I),K(I)
306   FORMAT(I8,F7.3,F6.1,F8.1,F6.2,F24.1,F7.4,F7.2,F9.2,F8.2,
     1F7.3,F8.4,I6)
307   VD1=ELE+FACTR*POT
C      IF(VD1.EQ.0.0)GO TO 313
      VDL=EL+FACTR*PT
      VD=ALOG(VD1/VDL)
C      VDF(I)=VD/VD3
```

```
C       IF(D.GT.0.130)GO TO 317
C       IF(K(I).EQ.3.OR.K(I).EQ.4)GO TO 315
C       IF(K(I).EQ.34.OR.K(I).EQ.43)GO TO 315
C       GO TO 314
C315    VDF(I)=-0.007968920837+0.6902376155*VDF(I)+0.3472509355
C      1*VDF(I)**2-0.03755343158*VDF(I)**3
C       GO TO 314
C313    VDF(I)=0.0
C       GO TO 314
C317    VDF(I)=0.0004023068891+1.360189569*VDF(I)
C      1-0.7472010053*VDF(I)**2+0.6114242107*VDF(I)**3-
C      20.2270207231*VDF(I)**4
314     H=P(I)/135.5+H0
        P(I)=H*13.55*1000.*9.807/100000.0
        DF(I)=999.903+.055173*T(I)-.00770233*T(I)**2+.0000386*T(I)**3
        DG(I)=1.293*(H/76.)/(1.+.00367*T(I))
        VF=1.77226-.0557784*T(I)+.001026*T(I)**2
       1-.0000083*T(I)**3
        VG=1.70744+.00612487*T(I)-.000031396*T(I)**2
        STN(I)=75.75-(5.85/38.5)*T(I)
        VF=VF/1000.
        VG=VG/100000.
        VGG(I)=VG
        VFF(I)=VF
        PE(I)=PE(I)*249.09/(2.54*10.)
C       TG(I)=(24./.95)*EMF
        IF(NOR.LT.1)GO TO 701
        TG(I)=EMF
        DG0=1.293*(H0/76.)/(1.+.00367*TG(I))
        IF(HOR(I).EQ.21) GO TO 510
        IF(HOR(I).EQ.22) GO TO 520
        IF(HOR(I).EQ.31) GO TO 610
        IF(HOR(I).EQ.351) GO TO 710
        IF(HOR(I).EQ.352) GO TO 720
        QF(I)=4.7472*(HL**0.5)
        QF(I)=QF(I)/3600.0
        IF(I.LE.NR)GO TO 308
C       DG2=1.293*(H1/76.)/(1.+.00367*TG(I))
C       H3=((101325.+PG*100000.)/(13550.*9.807))*100.
C       DG3=1.293*(H3/76.)/(1.+.00367*TG(I))
C       QGC=QGR(S1)+QGR(S2)+QGR(S3)+QGR(S4)
```

```
C     WG(I)=QGC*DG0
C     QG(I)=WG(I)/DG(I)
C     GO TO 301
C308  PGAB=PG*100.+101.325
      PGAB=PG*100.+101.325
      WG(I)=1292.233*(((PGAB/6.8948)/(TG(I)*1.8+492.))**.5)*
     1((S/2.54)**.5)*.45359
      REG=WG(I)/(.00469*.45359)
      IF(S.EQ.0.0) GO TO 1301
      IF(REG.EQ.0.0) GO TO 1301
      IF(REG.LT.0.0) GO TO 1301
      RX=ALOG(REG)
      ZR=1.243406-0.027838*RX+0.000739*RX**2
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.014363585*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
  710 QF(I)=7.12157*(HL**0.5)
      QF(I)=QF(I)/3600.0
      IF(I.LE.NR)GO TO 308
      PGAB=(PG*100.0)+101.325
      WG(I)=196.52096*(((PGAB/6.8948)/(TG(I)*1.8+492.0))**0.5)*
     1((S/2.54)**0.5)*0.45359
      REG=WG(I)/(0.00469*0.45359)
      IF(S.EQ.0.0) GO TO 1301
      IF(REG.LT.0.0) GO TO 1301
      IF(REG.EQ.0.0) GO TO 1301
      RX=ALOG(REG)
      ZR=2.024362-0.24141*RX+0.019685*RX**2
     1-0.000551*RX**3
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.012766842*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
  720 QF(I)=7.12157*(HL**0.5)
      QF(I)=QF(I)/3600.0
      IF(I.LE.NR)GO TO 308
      PGAB=(PG*100.0)+101.325
      WG(I)=1292.233*(((PGAB/6.8948)/(TG(I)*1.8+492.0))**0.5)*
```

```
     1((S/2.54)**0.5)*0.45359
      REG=WG(I)/(0.00469*0.45359)
      IF(S.EQ.0.0) GO TO 1301
      IF(REG.EQ.0.0) GO TO 1301
      IF(REG.LT.0.0) GO TO 1301
      RX=ALOG(REG)
      ZR=1.243406-0.027838*RX+0.000739*RX**2
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.014363585*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
  610 QF(I)=4.7472*(HL**0.5)
      QF(I)=QF(I)/3600.0
      IF(I.LE.NR)GO TO 308
      PGAB=(PG*100.0)+101.325
      WG(I)=196.52096*(((PGAB/6.8948)/(TG(I)*1.8+492.0))**0.5)*
     1((S/2.54)**0.5)*0.45359
      REG=WG(I)/(0.00469*0.45359)
      IF(S.EQ.0.0) GO TO 1301
      IF(REG.LT.0.0) GO TO 1301
      IF(REG.EQ.0.0) GO TO 1301
      RX=ALOG(REG)
      ZR=2.024362-0.24141*RX+0.019685*RX**2
     1-0.000551*RX**3
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.012766842*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
  520 QF(I)=1.96947*(HL**0.5)
      QF(I)=QF(I)/3600.0
      IF(I.LE.NR)GO TO 308
      PGAB=(PG*100.0)+101.325
      WG(I)=1292.233*(((PGAB/6.8948)/(TG(I)*1.8+492.0))**0.5)*
     1((S/2.54)**0.5)*0.45359
      REG=WG(I)/(0.00469*0.45359)
      IF(S.EQ.0.0) GO TO 1301
      IF(REG.EQ.0.0) GO TO 1301
      IF(REG.LT.0.0) GO TO 1301
      RX=ALOG(REG)
```

```
      ZR=1.243406-0.027838*RX+0.000739*RX**2
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.014363585*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
 510  QF(I)=1.96947*(HL**0.5)
      QF(I)=QF(I)/3600.0
      IF(I.LE.NR)GO TO 308
      PGAB=(PG*100.0)+101.325
      WG(I)=196.52096*(((PGAB/6.8948)/(TG(I)*1.8+492.0))**0.5)*
     1((S/2.54)**0.5)*0.45359
      REG=WG(I)/(0.00469*0.45359)
      IF(S.EQ.0.0) GO TO 1301
      IF(REG.EQ.0.0) GO TO 1301
      IF(REG.LT.0.0) GO TO 1301
      RX=ALOG(REG)
      ZR=2.024362-0.24141*RX+0.019685*RX**2
     1-0.000551*RX**3
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.012766842*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
1301  WG(I)=0.0
      QG(I)=0.0
      GO TO 801
308   DG2=1.293*(H1/76.)/(1.+.00367*TG(I))
      H3=((101325.+PG*100000.)/(13550.*9.807))*100.
      DG3=1.293*(H3/76.)/(1.+.00367*TG(I))
      QGC=QGR(S1)+QGR(S2)+QGR(S3)+QGR(S4)
      WG(I)=QGC*DG0
      QG(I)=WG(I)/DG(I)
      GO TO 801
 701  TG(I)=(24.0/0.95)*EMF
      DG0=1.293*(H0/76.0)/(1.0+0.00367*TG(I))
      QF(I)=(1.45/30.)*HL**.5*101.94
C     QF(I)=1.96947*(HL**0.5)
      QF(I)=QF(I)/3600.0
      IF(I.GT.NR)GO TO 708
      DG2=1.293*(H1/76.)/(1.+.00367*TG(I))
```

```
      H3=((101325.+PG*100000.)/(13550.*9.807))*100.
      DG3=1.293*(H3/76.)/(1.+.00367*TG(I))
      QGC=QGR(S1)+QGR(S2)+QGR(S3)+QGR(S4)
      WG(I)=QGC*DG0
      QG(I)=WG(I)/DG(I)
      GO TO 801
708    PGAB=PG*100.+101.325
      IF(S.EQ.0.0)GO TO 709
      WG(I)=1278.98*((PGAB/6.8948)/(TG(I)*1.8+492.))**.5*
     1(S/2.54)**.5*.45359
      REG=WG(I)/(.00469*.45359)
      RX=ALOG(REG)
      ZR=.9948152513+.03265792929*RX-.004168990102*RX**2
     1+.0001330225936*RX**3
      EPY=S/(2.54*PGAB/6.8948)
      EXPC=1.0-0.01458333*EPY
      WG(I)=WG(I)*ZR*EXPC/3600.0
      QG(I)=WG(I)/DG(I)
      GO TO 801
709   WG(I)=0.0
801    CONTINUE
      WRITE(6,410)
410   FORMAT(//////////)
      WRITE(6,411)
411   FORMAT(3X,2HNO,4X,4HTEMP,3X,5HPRESS,5X,2HQF,8X,2HQG,7X,2HDG,
     16X,2HDF,7X,2HWG,5X,3HVDF,9X,2HPE,4X,6HPATERN)
      WRITE(6,412)
412   FORMAT(11X,1HC,4X,5HKN/M2,5X,6HM3/SEC,3X,6HM3/SEC,3X,5HKG/M3,
     13X,5HKG/M3,4X,6HKG/SEC,14X,4HN/M3)
      DO 310 I=1,M
      WRITE(6,311)N(I),T(I),P(I),QF(I),QG(I),DG(I),DF(I),
     1WG(I),VDF(I),PE(I),K(I)
311   FORMAT(I8,F6.1,F8.2,2F10.6,F8.4,F8.3,F9.5,1X,F6.4,F13.4,I8)
310   CONTINUE
      WRITE(6,410)
      RETURN
      END
      FUNCTION QGR(S)
      COMMON DG1,DG2,DG3,N(500),T(500),P(500),VDF(500),
     1DF(500),DG(500),PE(500),QF(500),QG(500),WG(500),K(500),
     2D,PI,AP,M,STN(500),R,RR,VGG(500),VFF(500),XOR,HOR(500),NOR,
```

```
     1         ELL(500),PTT(500)
      Q=69.79848882+20.23981018*S+0.0253036929*S**2
     1+0.01238440072*S**3-0.0002735459412*S**4
      CT=((DG3*DG1)**.5)/DG2
      QGR=Q*CT/60000.0
      QGR=QGR*(3.4/3.75)+.0007013
      IF(S.EQ.0.0)QGR=0.0
      RETURN
      END
      SUBROUTINE RETEST(RE,FT,JJ)
      COMMON DG1,DG2,DG3,N(500),T(500),P(500),VDF(500),DF(500),
     1DG(500),PE(500),QF(500),QG(500),WG(500),K(500),D,PI,AP,
     2M,STN(500),R,RR,VGG(500),VFF(500),XOR,HOR(500),NOR,ELL(500)
     1,PTT(500)
      AR=ALOG(RE)
      IF(RE.LT.2000)GO TO 2
      IF(NOR.EQ.8)GO TO 11
      IF(D.GT.0.130)GO TO 4
      IF(NOR.LT.1)GO TO 5
      IF(NOR.EQ.2)GO TO 1
      IF(NOR.EQ.3)GO TO 3
      IF(NOR.EQ.51)GO TO  5
      IF(NOR.EQ.53)GO TO  5
      IF(RE.GE.133000)GO TO 4
      FT=-583.9995691+239.5386454*AR-35.63242117*AR**2
     1+2.299863293*AR**3-0.054941099*AR**4
      GO TO 6
1     IF(RE.GE.133000)GO TO 4
      FT=294.9725433-91.54157127*AR+10.60102906*AR**2
     1-0.54788079*AR**3+0.010607516*AR**4
      GO TO 6
3     IF(RE.GE.600000)GO TO 4
      FT=0.6204371712+0.1466993127*AR -0.0544531814*AR**2
     1+0.004665130554*AR**3-0.000124778211*AR**4
      IF(RE.LT.100000.0.AND.RE.GT.15000.0)JJ=1
      IF(RE.GE.100000.0)JJ=2
      GO TO 8
  11  IF(RE.GE.150000)GO TO 4

      FT=5799.802-2072.084*AR+277.672*AR**2
     1-16.546*AR**3+0.3698*AR**4
```

```
      GO TO 6
5     IF(RE.GE.100000)GO TO 4
      FT=1084.055501-381.5544769*AR+50.26051543*AR**2
     1-2.94562527*AR**3+0.06476364087*AR**4
6     FT=EXP(FT)
      JJ=1
      GO TO 8
4     IF(RE.LT.209000.)GO TO 9
      FT=RR*RE**(-R)
      JJ=2
      GO TO 8
2     FT=64/RE
      JJ=-1
C     IF(RE.LT.209000.)GO TO 9
C     AR=ALOG(RE)
C     FT=0.05529519-(AR*0.003038014)
      GO TO 8
9     AR=ALOG(RE)
      FT=0.4416447-(AR*0.03715733)-(0.002393404*AR**2)
     1+(0.0002128791*AR**3)
      GO TO 8
8     IF(RE.LT.15000..AND.RE.GT.2000.)JJ=0
      RETURN
      END
      SUBROUTINE CORRECTION(X,C,IGTOT,RTMB)
      IF(IGTOT.EQ.339)GO TO 5
      IF(IGTOT.EQ.678)GO TO 10
      IF(IGTOT.EQ.1356)GO TO 15
      IF(IGTOT.EQ.2712)GO TO 20
      IF(IGTOT.EQ.4068)GO TO 25
5     RT1=1.581866908-225.6780954*C+38327.37361*C**2
     1-2025021.215*C**3
      RT2=RT1
      RT3=1.523982116-271.3031864*C+46610.53568*C**2
     1-2387801.69*C**3
      RT4=1.537467874-54.22916382*C+7339.63855*C**2
     1-354930.1629*C**3
      RT5=RT4
35    IF(X.LE.0.01)GO TO 40
      IF(X.LE.0.05)GO TO 41
      IF(X.LE.0.10)GO TO 42
```

```
      IF(X.LE.0.20)GO TO 43
40    AA=(RT1-RT2)/(0.01-0.001)
      RTMB=RT1-AA*(X-0.001)
      GO TO 30
41    AA=(RT2-RT3)/(0.05-0.01)
      RTMB=RT2-AA*(X-0.01)
      GO TO 30
42    AA=(RT3-RT4)/(0.10-0.05)
      RTMB=RT3-AA*(X-0.05)
      GO TO 30
43    AA=(RT4-RT5)/(0.20-0.10)
      RTMB=RT4-AA*(X-0.10)
      GO TO 30
10    RT1=1.252488916-49.33253751*C+4462.000387*C**2
      RT2=1.304708284-17.137396*C+882.4607369*C**2
      RT3=1.279406888-79.94199075*C+13298.72526*C**2
     1-663906.1468*C**3
      RT4=1.295867563-8.334689436*C+388.0756072*C**2
      RT5=1.300994696-35.63547499*C+5915.885313*C**2
     1-308163.9222*C**3
      GO TO 35
15    RTMB=1.0
      GO TO 30
20    RT1=0.7639026905+51.08937985*C-7920.581378*C**2
     1+407496.8278*C**3
      RT2=0.7449498217-55.91887372*C+11590.43566*C**2
     1-619289.3859*C**3
      RT3=0.7478987996-36.11489217*C+6590.878348*C**2
     1-323348.1681*C**3
      RT4=0.7540579051-22.48224933*C+4397.834059*C**2
     1-213836*C**3
      RT5=0.7351567674+4.047577695*C-232.2425808*C**2
      GO TO 35
25    RT1=0.6536586924+63.54014267*C-9351.163969*C**2
     1+471203.0296*C**3
      RT2=0.6128202321-76.66470325*C+15137.91641*C**2
     1-771889.1592*C**3
      RT3=0.6284534151-68.49645331*C+12799.12036*C**2
     1-656891.3365*C**3
      RT4=0.6259496202-22.52213653*C+4546.007189*C**2
     1-231288.7587*C**3
```

```
      RT5=0.6003899964+8.569140736*C-949.977975*C**2
     1+36220.92632*C**3
      GO TO 35
30    CONTINUE
      RETURN
      END
      SUBROUTINE ORIFICE
      COMMON DG1,DG2,DG3,N(500),T(500),P(500),VDF(500),DF(500),
     1DG(500),PE(500),QF(500),QG(500),WG(500),K(500),D,PI,AP,
     2M,STN(500),R,RR,VGG(500),VFF(500),XOR,HOR(500),NOR,ELL(500)
     1,PTT(500)
      DIMENSION XCOL(150),XPSI(150),XBR(150),XCR(150),XKR(150),
     1XKCH(150),XCCH(150),XBCH(150),TPFOCH(150),RMFSCH(150),QLTY(150)
      DO 50 I1=1,M,13
C      WRITE(6,30)
C30    FORMAT(1H1,///////////)
C      WRITE(6,40)
C40    FORMAT(5X,'NO',7X,'HOR',7X,'QLTY',6X,'GTOTL',7X,'XMF',
C    17X,'XMFS',6X,'RMFS',6X,'YOR',7X,'TRM',6X,'XTRM',6X,'XRMFS',
C    23X,'PATTERN',/)
      I2=I1+12
      DO 10 I=I1,I2
C      IF(I.EQ.M+1)GO TO 70
      XMF=QF(I)*DF(I)
      WTOT=QG(I)*DG(I)+QF(I)*DF(I)
      GTOTL=WTOT/AP
      QLTY(I)=(QG(I)*DG(I))/WTOT
      YOR=(QLTY(I)/(1.0-QLTY(I)))*((DF(I)/DG(I))**0.5)
      TRM=(1.0+4.25*YOR+YOR**2)**0.5
      XXX=(1-QLTY(I))**2
      XTRM=(XXX)*((TRM)**2)
      COL=(0.928+0.375*((YOR)**0.5)+(0.913*YOR))**2
      XCOL(I)=XXX*COL
      DENR=DF(I)/DG(I)
      IF(NOR.EQ.51)GO TO  200
      IF(NOR.EQ.53)GO TO 200
      XMFS=XOR*(HOR(I)**0.5)*((DF(I)/999.903)**0.5)
      GO  TO  201
 200  XMFS=AP*DF(I)*((2.0*9.807*HOR(I)/(1000.0*XOR))**0.5)
 201  RMFS=(XMFS/XMF)-1.0
      XRMFS=(XXX)*((RMFS+1)**2)
```

```
      XPSI(I)=((XRMFS)-1)/(DENR-1)
      IF(QLTY(I).EQ.0.0)GO TO 5
      XBR(I)=(XPSI(I)- QLTY(I)**2) /(QLTY(I)*(1-QLTY(I)))
      XCR(I)=(XBR(I)*(DENR-1)+2)/(DENR**0.5)
      IF(XCR(I).LT.2)GO TO 7
      XKR(I)=((XCR(I)*DENR**0.5)-(DENR*(XCR(I)**2-4))**0.5)/2
      GO TO 6
5     XBR(I)=0.0
      XCR(I)=0.0
7     XKR(I)=0.0
6     IF(YOR.GE.1.)GO TO 11
      XKCH(I)=(1+QLTY(I)*(DENR-1))**0.5
      XCCH(I)=(DF(I)/(DG(I)+QLTY(I)*(DF(I)-DG(I))))**0.5+
     1((DG(I)+QLTY(I)*(DF(I)-DG(I)))/DF(I))**0.5
      GO TO 12
11    XKCH(I)=DENR**0.25
      XCCH(I)=((DENR)**0.25)+((DENR)**(-0.25))
12    XBCH(I)=((DENR/XKCH(I))+XKCH(I)-2)/(DENR-1)
      TPFOCH(I)=1+(DENR-1)*((XBCH(I)*QLTY(I)*(1-QLTY(I)))
     1+(QLTY(I)**2))
      RMFSCH(I)=(TPFOCH(I)**0.5)/(1-QLTY(I))
C      WRITE(6,20)N(I),HOR(I),QLTY(I),GTOTL,XMF,XMFS,RMFS,
C     1YOR,TRM,XTRM,XRMFS,K(I)
C20    FORMAT(/,I8,F12.2,9F10.4,I6)
10    CONTINUE
C      GO TO 80
C70    WRITE(6,30)
C80    WRITE(6,60)
C60    FORMAT(//,5X,'TABLE',10X,'CHISHOLM CORRELATION PARAMETERS',
C     1' AND OTHER DATA DERIVED FROM EXPERIMENTAL READINGS')
50    CONTINUE
      DO 170 I1=1,M,13
C      WRITE(6,100)
C100    FORMAT(1H1,//////////)
C      WRITE(6,120)
C120   FORMAT(5X,'NO',9X,'HOR',5X,'QLTY',5X,'XCOL',4X,'XPSI',
C     15X,'XBR',5X,'XCR',5X,'XKR',4X,'XKCH',4X,'XBCH',4X,'XCCH',
C     22X,'TPFOCH',2X,'RMFSCH',2X,'PATTERN',/)
      I2=I1+12
C      DO 140 I=I1,I2
C      WRITE(6,160)N(I),HOR(I),QLTY(I),XCOL(I),XPSI(I),XBR(I),
```

```
C      1XCR(I),XKR(I),XKCH(I),XBCH(I),XCCH(I),TPFOCH(I),RMFSCH(I),K(I)
C140    CONTINUE
C160    FORMAT(/I10,F12.2,11F8.4,I6)
C       WRITE(6,60)
170    CONTINUE
       RETURN
       END
```

APPENDIX E

E.2 COMPUTER PROGRAM USED FOR PLOTTING THE EXPERIMENTAL FLOW PATTERN MAP.

```
C*******************************************
C       PROGRAM TO PLOT FLOW PATTERN MAPS
C             THE INPUT DATA ARE: USF,USG,CODE
C      ***********************************
      INTEGER P(500),N(500)
      REAL*8 X(500),Y(500)
      character*4 label(3)
      data label/' 0.1',' 1.0','10.0'/
      CALL RCO(10,'FLOWMAP;')
C       X,Y,AXIS
      CALL DEVPAP(500.0,500.0,0)
      CALL PICCLE
      CALL AXIPOS(1,35.0,40.0,170.0,1)
      CALL AXIPOS(1,35.0,40.0,130.0,2)
      CALL AXISCA(4,0,0.1,1.2,1)
      CALL AXISCA(4,0,0.1,1.2,2)
      CALL GRID(-3,0,0)
      call axlstr(label,3,36.0,-1)
      call axlstr(label,3,25.0,2)
      CALL MOVTO2(75.0,29.0)
      CALL CHAHOL('SUPERFICIAL GAS VELOCITY Usg (m/s)*.')
C********************************************
      CALL MOVTO2(26.0,56.0)
      CALL CHAANG(90.0)
      CALL CHAHOL('SUPERFICIAL LIQUID VELOCITY Usg (m/s)*.')
      CALL CHAANG(0.0)
C*******************************
      CALL MOVTO2(20.0,15.0)
      CALL LINBY2(245.0,0.0)
      CALL LINBY2(0.0,165.0)
      CALL LINBY2(-245.0,0.0)
      CALL LINBY2(0.0,-165.0)
C*************************
      CALL MOVTO2(20.0,25.0)
      CALL LINBY2(245.0,0.0)
      CALL MOVTO2(35.0,18.5)
      CALL CHAHOL('FIG      EXPERIMENTAL FLOW PATTERN MAP*.')
C*******************
C       KEY
C      *****************
      CALL MOVTO2(230.0,160.0)
```

```
      CALL CHAHOL('KEY*.')
      CALL MOVTO2(212.0,155.0)
      CALL SYMBOL(5)
      CALL MOVTO2(220.0,154.0)
      CALL CHAHOL('PLUG*.')
      CALL MOVTO2(212.0,145.0)
      CALL SYMBOL(3)
      CALL MOVTO2(220.0,144.0)
      CALL CHAHOL('SLUG*.')
      CALL MOVTO2(212.0,135.0)
      CALL SYMBOL(4)
      CALL MOVTO2(220.0,134.0)
      CALL CHAHOL('STRATIFIED*.')
      CALL MOVTO2(212.0,125.0)
      CALL SYMBOL(6)
      CALL MOVTO2(220.0,124.0)
      CALL CHAHOL('WAVY*.')
      CALL MOVTO2(212.0,115.0)
      CALL SYMBOL(7)
      CALL MOVTO2(220.0,114.0)
      CALL CHAHOL('TRANSITIONS*.')
C     CALL MOVTO2(212.0,105.0)
C     CALL SYMBOL(2)
C     CALL MOVTO2(220.0,104.0)
C     CALL CHAHOL('UNSETTLED WAVY*.')
C     CALL MOVTO2(212.0,95.0)
C     CALL SYMBOL(7)
C     CALL MOVTO2(220.0,94.0)
C     CALL CHAHOL('TRANSITION*.')
C     CALL MOVTO2(212.0,85.0)
C     CALL SYMBOL(8)
C     CALL MOVTO2(220.0,84.0)
C     CALL CHAHOL('STRA WAVY TRANS*.')
C     CALL MOVTO2(212.0,75.0)
C     CALL SYMBOL(5)
C     CALL SYMBOL(3)
C     CALL MOVTO2(220.0,74.0)
C     CALL CHAHOL('BUBL PLUG TRANS*.')
C****************************
C      PLOTING THE POINTS
C     ********************
```

```
      DO 10 I=1,500
      READ(8,*,ERR=999) N(I),X(I),Y(I),P(I)
      XVAL=X(I)
      YVAL=Y(I)
      IF(P(I).EQ.2)GO TO 100
      IF(P(I).EQ.3)GO TO 200
      IF(P(I).EQ.4)GO TO 300
      IF(P(I).EQ.6)GO TO 400
      IF(P(I).EQ.62)GO TO 600
      IF(P(I).EQ.42)GO TO 600
      IF(P(I).EQ.44)GO TO 600
      IF(P(I).EQ.34)GO TO 600
      IF(P(I).EQ.16)GO TO 600
      IF(P(I).EQ.63)GO TO 600
      IF(P(I).EQ.32)GO TO 600
  100 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(3)
      GO TO 10
  200 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(4)
      GO TO 10
  300 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(6)
      GO TO 10
  400 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(5)
      GO TO 10
  500 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(1)
      GO TO 10
  600 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(7)
      GO TO 10
  700 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(2)
      GO TO 10
  800 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(8)
      GO TO 10
  900 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(5)
```

```
      CALL SYMBOL(3)
      GO TO 10
   10 CONTINUE
  999 Ntests=I-1
      PRINT*,'NO OF TESTS RECORDED=',Ntests
      CALL DEVEND
      STOP
      END
```

APPENDIX E

E.3 COMPUTER PROGRAM USED FOR PLOTTING THE EXPERIMENTAL TWO-PHASE FRICTION MULTIPLIERS VERSUS OTHER MODELS USED IN THE COMPARISONS.

```
C****************************************
C       PROGRAM TO PLOT EXPERIMENTAL VERSUS PREDICTED
C             VALUES OF TWO-PHASE FRICTION MULTIPLIERS,
C      **********************************
      CHARACTER*8 LABEL(4)
      INTEGER P(500)
      REAL*8 TEST(500),X(500),A(500),B(500),C(500),D(500),E(500),F(500

      SUM=0.0
      SUM1=0.0
      N=0.0
      DO 20 I=1,500
      READ(8,*,ERR=20) TEST(I),X(I),E(I),P(I)
      SUM=SUM+(((E(I)-X(I))/X(I)))**2
      SUM1=SUM1+(((E(I)-X(I))/X(I))*100)
      N=N+1
   20 CONTINUE
      CLOSE(8)
      DF=SQRT(SUM/N)*100
      DFAV=SUM1/N
      DATA LABEL /' 0.1',' 1.0','10.0',' 100'/
      CALL RCO(10,'BAROCZY;')
C      X,Y,AXIS
      CALL DEVPAP(500.0,500.0,0)
      CALL PICCLE
      CALL AXIPOS(1,42.0,40.0,130.0,1)
      CALL AXIPOS(1,42.0,40.0,130.0,2)
      XMIN=0.1
      XMAX=100.0
      YMIN=0.1
      YMAX=100.0
      CALL AXISCA(4,4,XMIN,XMAX,1)
      CALL AXISCA(4,4,YMIN,YMAX,2)
c      CALL AXIDRA(2,1,1)
c      CALL AXIDRA(-2,-1,2)
      call grid(-3,0,0)
      CALL GRAMOV(XMAX,YMIN)
      CALL GRALIN(XMAX,YMAX)
      CALL GRALIN(XMIN,YMAX)
      CALL MOVTO2(42.0,40.0)
      CALL GRALIN(XMAX,YMAX)
      CALL AXLSTR(LABEL,4,36.0,-1)
```

```
      CALL AXLSTR(LABEL,4,30.0,2)
      CALL MOVTO2(50.0,29.0)
      CALL CHAHOL('EXPERIMENTAL TWO-PHASE FRICTION MULTIPLIERS*.')
C*******************************************
      CALL MOVTO2(28.0,45.0)
      CALL CHAANG(90.0)
      CALL CHAHOL('BAROCZY TWO-PHASE FRICTION MULTIPLIERS*.')
      CALL CHAANG(0.0)
C******************************
      CALL MOVTO2(20.0,15.0)
      CALL LINBY2(245.0,0.0)
      CALL LINBY2(0.0,165.0)
      CALL LINBY2(-245.0,0.0)
      CALL LINBY2(0.0,-165.0)
C*************************
      CALL MOVTO2(20.0,15.0)
      CALL MOVTO2(190.0,65.0)
      CALL LINBY2(60.0,0.0)
      CALL LINBY2(0.0,-20.0)
      CALL LINBY2(-60.0,0.0)
      CALL LINBY2(0.0,20.0)
C********************
      CALL MOVTO2(195.0,60.0)
      CALL CHAHOL('RMS ERROR =*.')
      CALL CHAFIX(DF,8,3)
      CALL MOVTO2(195.0,55.0)
      CALL CHAHOL('AVER ERROR =*.')
      CALL CHAFIX(DFAV,8,3)
C***********************
      CALL MOVTO2(20.0,25.0)
      CALL LINBY2(245.0,0.0)
      CALL MOVTO2(35.0,18.5)
      CALL CHAHOL('FIG      COMPARISON BETWEEN EXPERIMENTAL AND
     - BAROCZY PREDICTIONS *.')
C******************
C      KEY
C      ****************
      CALL MOVTO2(230.0,160.0)
      CALL CHAHOL('KEY*.')
      CALL MOVTO2(215.0,155.0)
      CALL SYMBOL(5)
```

```
      CALL MOVTO2(220.0,154.0)
      CALL CHAHOL('PLUG*.')
      CALL MOVTO2(215.0,145.0)
      CALL SYMBOL(3)
      CALL MOVTO2(220.0,144.0)
      CALL CHAHOL('SLUG*.')
      CALL MOVTO2(215.0,135.0)
      CALL SYMBOL(4)
      CALL MOVTO2(220.0,134.0)
      CALL CHAHOL('STRATIFIED*.')
      CALL MOVTO2(215.0,125.0)
      CALL SYMBOL(6)
      CALL MOVTO2(220.0,124.0)
      CALL CHAHOL('WAVY*.')
      CALL MOVTO2(215.0,115.0)
      CALL SYMBOL(7)
      CALL MOVTO2(220.0,114.0)
      CALL CHAHOL('TRANSITIONS*.')
C     CALL MOVTO2(215.0,105.0)
C     CALL SYMBOL(2)
C     CALL MOVTO2(220.0,104.0)
C     CALL CHAHOL('SLUG ANN TRANS*.')
C     CALL MOVTO2(215.0,95.0)
C     CALL SYMBOL(7)
C     CALL MOVTO2(220.0,94.0)
C     CALL CHAHOL('SLUG WAVY TRANS*.')
C     CALL MOVTO2(215.0,85.0)
C     CALL SYMBOL(8)
C     CALL MOVTO2(220.0,84.0)
C     CALL CHAHOL('STRA WAVY TRANS*.')
C     CALL MOVTO2(215.0,75.0)
C     CALL SYMBOL(5)
C     CALL SYMBOL(3)
C     CALL MOVTO2(220.0,74.0)
C     CALL CHAHOL('BUBL PLUG TRANS*.')
C***************************
C      PLOTING THE POINTS
C     ********************
      DO 10 I=1,500
      READ(8,*,ERR=999)TEST(I),X(I),E(I),P(I)
      XVAL=X(I)
```

```
      YVAL=E(I)
      IF(P(I).EQ.2)GO TO 100
      IF(P(I).EQ.3)GO TO 200
      IF(P(I).EQ.4)GO TO 300
      IF(P(I).EQ.6)GO TO 400
      IF(P(I).EQ.62)GO TO 600
      IF(P(I).EQ.42)GO TO 600
      IF(P(I).EQ.44)GO TO 600
      IF(P(I).EQ.34)GO TO 600
      IF(P(I).EQ.16)GO TO 600
      IF(P(I).EQ.32)GO TO 600
      IF(P(I).EQ.63)GO TO 600
  100 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(3)
      GO TO 10
  200 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(4)
      GO TO 10
  300 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(6)
      GO TO 10
  400 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(5)
      GO TO 10
  500 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(1)
      GO TO 10
  600 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(7)
      GO TO 10
  700 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(2)
      GO TO 10
  800 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(8)
      GO TO 10
  900 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(5)
      CALL SYMBOL(3)
      GO TO 10
   10 CONTINUE
```

```
999  Ntests=I-1
     PRINT*,'NO OF TESTS RECORDED=',Ntests
     CALL DEVEND
     STOP
     END
```

APPENDIX E

E.4.1 COMPUTER PROGRAM USED TO CALCULATE THE MEAN VOID FRACTION FROM THE GAMMA-RAY READINGS (FOR 5 STEPS).

```
C   *************************************************************
C   * THIS PROGRAM WAS USED TO CALCULATE THE MEAN VOID FRACTION *
C   * USING 5 CHORDAL POSITIONS (STEPS) OF THE GAMMA-RAYS BEAM  *
C   * ACROSS THE TEST TUBE                                      *
C   *************************************************************
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION B1(13),C1(13),TF(13),TE(13),Y(500,13),N(500)

      OPEN(1,FILE='VOIDNEW1.DAT',STATUS='UNKNOWN')
      OPEN(2,FILE='VOIDNEW1.RES',STATUS='UNKNOWN')
      READ(1,*) (B1(I),I=1,5)
      READ(1,*) (C1(I),I=1,5)
      READ(1,*) (TE(I),I=1,5)
      READ(1,*) (TF(I),I=1,5)
      DO 20 I=1,500
      READ(1,*,ERR=30) (N(I),(Y(I,J),J=1,5))
 20   CONTINUE
 30   Ntest=I-1
      PRINT*,'NO OF TESTS RECORDS READ=',Ntest

      CON=0.45/(3.0*3.141592654)
      WRITE(2,1000)
 1000 FORMAT(10X,'TEST NO',10X,'EXP. VOID FRACTION')
      DO 300 I=1,Ntest
      SUM=0.0
      DO 200 J=1,5
      VF=(DLOG(Y(I,J))-DLOG(TF(J)))/(DLOG(TE(J))-DLOG(TF(J)))
      V=VF*B1(J)*C1(J)
      SUM=SUM+V
 200  CONTINUE
      VFR=SUM*CON

      WRITE(2,2000) N(I),VFR
 2000 FORMAT(10X,I7,15X,F10.4)
 300  CONTINUE
      STOP
      END
```

APPENDIX E

E.4.2 COMPUTER PROGRAM USED TO CALCULATE THE MEAN VOID FRACTION FROM THE GAMMA-RAY READINGS (FOR 13 STEPS).

```
C    ***************************************************************
C    *  THIS PROGRAM WAS USED TO CALCULATE THE MEAN VOID FRACTION *
C    *  USING 13 CHORDAL POSITIONS (STEPS) OF THE GAMMA-RAYS BEAM *
C    *  ACROSS THE TEST TUBE                                       *
C    ***************************************************************
C
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION B1(13),C1(13),TF(13),TE(13),Y(500,13),N(500)

      OPEN(1,FILE='VOIDNEWER.DAT',STATUS='UNKNOWN')
      OPEN(2,FILE='VOIDNEWER.RES',STATUS='UNKNOWN')
      READ(1,*) (B1(I),I=1,13)
      READ(1,*) (C1(I),I=1,13)
      READ(1,*) (TE(I),I=1,13)
      READ(1,*) (TF(I),I=1,13)
      DO 20 I=1,500
      READ(1,*,ERR=30) (N(I),(Y(I,J),J=1,13))
 20   CONTINUE
 30   Ntest=I-1
      PRINT*,'NO OF TESTS RECORDS READ=',Ntest

      CON=0.15/(3.0*3.141592654)
      WRITE(2,1000)
 1000 FORMAT(10X,'TEST NO',10X,'EXP. VOID FRACTION')
      DO 300 I=1,Ntest
      SUM=0.0
      DO 200 J=1,13
      VF=(DLOG(Y(I,J))-DLOG(TF(J)))/(DLOG(TE(J))-DLOG(TF(J)))
      V=VF*B1(J)*C1(J)
      SUM=SUM+V
 200  CONTINUE
      VFR=SUM*CON

      WRITE(2,2000) N(I),VFR
 2000 FORMAT(10X,I7,15X,F10.4)
 300  CONTINUE
      STOP
      END
```

APPENDIX E

E.4.3 COMPUTER PROGRAM USED FOR PLOTTING THE EXPERIMENTAL TWO-PHASE VOID FRACTION VERSUS OTHER MODELS USED IN THE COMPARISONS.

```
C*****************************************
C      PROGRAM TO PLOT EXPERIMENTAL VERSUS PREDICTED
C            VALUES OF TWO-PHASE VOID FRACTION,
C     **********************************
      INTEGER P(500)
      REAL*8 TEST(500),X(500),A(500),B(500),C(500),D(500),E(500),F(500

      SUM=0.0
      SUM1=0.0
      N=0.0
      DO 20 I=1,500
      READ(8,*,ERR=20) TEST(I),X(I),D(I),P(I)
      SUM=SUM+(((D(I)-X(I))/X(I)))**2
      SUM1=SUM1+(((D(I)-X(I))/X(I))*100)
      N=N+1
   20 CONTINUE
      CLOSE(8)
      DF=SQRT(SUM/N)*100
      DFAV=SUM1/N
C     CHARACTER*8 LABEL(7)
C     DATA LABEL /' 0.1',' 1.0','10.0'/
      CALL RCO(10,'CHISHOLM;')
C      X,Y,AXIS
      CALL DEVPAP(500.0,500.0,0)
      CALL PICCLE
      CALL AXIPOS(1,42.0,40.0,130.0,1)
      CALL AXIPOS(1,42.0,40.0,130.0,2)
      XMIN=0.0
      XMAX=1.0
      YMIN=0.0
      YMAX=1.0
      CALL AXISCA(3,4,XMIN,XMAX,1)
      CALL AXISCA(3,4,YMIN,YMAX,2)
      CALL AXIDRA(2,1,1)
      CALL AXIDRA(-2,-1,2)
      CALL GRAMOV(XMAX,YMIN)
      CALL GRALIN(XMAX,YMAX)
      CALL GRALIN(XMIN,YMAX)
      CALL MOVTO2(42.0,40.0)
      CALL GRALIN(XMAX,YMAX)
C     CALL AXLSTR(LABEL,3,36.0,-1)
C     CALL AXLSTR(LABEL,3,25.0,2)
```

```
      CALL MOVTO2(85.0,29.0)
      CALL CHAHOL('EXPERIMENTAL VOID FRACTION *.')
C*******************************************
      CALL MOVTO2(26.0,90.0)
      CALL CHAANG(90.0)
      CALL CHAHOL('CHISHOLM VOID FRACTION *.')
      CALL CHAANG(0.0)
C******************************
      CALL MOVTO2(20.0,15.0)
      CALL LINBY2(245.0,0.0)
      CALL LINBY2(0.0,165.0)
      CALL LINBY2(-245.0,0.0)
      CALL LINBY2(0.0,-165.0)
C**************************
      CALL MOVTO2(20.0,15.0)
      CALL MOVTO2(190.0,65.0)
      CALL LINBY2(60.0,0.0)
      CALL LINBY2(0.0,-20.0)
      CALL LINBY2(-60.0,0.0)
      CALL LINBY2(0.0,20.0)
C*********************
      CALL MOVTO2(195.0,60.0)
      CALL CHAHOL('RMS ERROR =*.')
      CALL CHAFIX(DF,8,3)
      CALL MOVTO2(195.0,55.0)
      CALL CHAHOL('AVER ERROR =*.')
      CALL CHAFIX(DFAV,8,3)
C************************
      CALL MOVTO2(20.0,25.0)
      CALL LINBY2(245.0,0.0)
      CALL MOVTO2(35.0,18.5)
      CALL CHAHOL('FIG       COMPARISON BETWEEN EXPERIMENTAL
     -VOID FRACTION AND CHISHOLM PREDICTIONS *.')
C*****************
C      KEY
C     *****************
      CALL MOVTO2(230.0,160.0)
      CALL CHAHOL('KEY*.')
      CALL MOVTO2(215.0,155.0)
      CALL SYMBOL(5)
      CALL MOVTO2(220.0,154.0)
```

```
      CALL CHAHOL('PLUG*.')
      CALL MOVTO2(215.0,145.0)
      CALL SYMBOL(3)
      CALL MOVTO2(220.0,144.0)
      CALL CHAHOL('SLUG*.')
      CALL MOVTO2(215.0,135.0)
      CALL SYMBOL(4)
      CALL MOVTO2(220.0,134.0)
      CALL CHAHOL('STRATIFIED*.')
      CALL MOVTO2(215.0,125.0)
      CALL SYMBOL(6)
      CALL MOVTO2(220.0,124.0)
      CALL CHAHOL('WAVY*.')
      CALL MOVTO2(215.0,115.0)
      CALL SYMBOL(7)
      CALL MOVTO2(220.0,114.0)
      CALL CHAHOL('TRANSITIONS*.')
C     CALL MOVTO2(215.0,105.0)
C     CALL SYMBOL(2)
C     CALL MOVTO2(220.0,104.0)
C     CALL CHAHOL('SLUG ANN TRANS*.')
C     CALL MOVTO2(215.0,95.0)
C     CALL SYMBOL(7)
C     CALL MOVTO2(220.0,94.0)
C     CALL CHAHOL('SLUG WAVY TRANS*.')
C     CALL MOVTO2(215.0,85.0)
C     CALL SYMBOL(8)
C     CALL MOVTO2(220.0,84.0)
C     CALL CHAHOL('STRA WAVY TRANS*.')
C     CALL MOVTO2(215.0,75.0)
C     CALL SYMBOL(5)
C     CALL SYMBOL(3)
C     CALL MOVTO2(220.0,74.0)
C     CALL CHAHOL('BUBL PLUG TRANS*.')
C***************************
C      PLOTING THE POINTS
C     ********************
      DO 10 I=1,500
      READ(8,*,ERR=999)TEST(I),X(I),D(I),P(I)
      XVAL=X(I)
      YVAL=D(I)
```

```
      IF(P(I).EQ.2)GO TO 100
      IF(P(I).EQ.3)GO TO 200
      IF(P(I).EQ.4)GO TO 300
      IF(P(I).EQ.6)GO TO 400
      IF(P(I).EQ.62)GO TO 600
      IF(P(I).EQ.42)GO TO 600
      IF(P(I).EQ.44)GO TO 600
      IF(P(I).EQ.34)GO TO 600
      IF(P(I).EQ.16)GO TO 600
      IF(P(I).EQ.32)GO TO 600
      IF(P(I).EQ.63)GO TO 600
  100 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(3)
      GO TO 10
  200 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(4)
      GO TO 10
  300 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(6)
      GO TO 10
  400 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(5)
      GO TO 10
  500 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(1)
      GO TO 10
  600 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(7)
      GO TO 10
  700 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(2)
      GO TO 10
  800 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(8)
      GO TO 10
  900 CALL GRAMOV(XVAL,YVAL)
      CALL SYMBOL(5)
      CALL SYMBOL(3)
      GO TO 10
   10 CONTINUE
999   Ntests=I-1
```

```
PRINT*,'NO OF TESTS RECORDED=',Ntests
CALL DEVEND
STOP
END
```

APPENDIX E

E.5.1 COMPUTER PROGRAM USED FOR THE CALIBRATION OF THE DEPTH GAUGES (WHERE THE LIQUID HEIGHT IS GIVEN IN TERMS OF VOLTS).

```
10 SLOT = 5: DIM R(2,1000)
15  INPUT " M NO. OF SAMPLING ===
     > :";M
20 AI13 =  - 16256 + SLOT * 16
25 A = 768: POKE A,169: POKE A +
     2,141: POKE A + 3,128 + 16 *
     SLOT: POKE A + 4,192: POKE A
      + 5,96
28  FOR K = 1 TO 10
30  FOR J = 1 TO M
40  FOR I = 0 TO 1
50  POKE A + 1,I: CALL A
60 R(I,J) =  PEEK (AI13 + 1) * 25
     6 +  PEEK (AI13)
70  NEXT : NEXT
80  FOR I = 0 TO 1
90 RSUM(I) = 0
100  FOR J = 1 TO M
110 RSUM(I) = RSUM(I) + R(I,J)
120  NEXT
130 RAVG(I,K) = RSUM(I) / M
160 V(I,K) = (RAVG(I,K)) * 4.9988
      / 4095
170  NEXT
180  NEXT
185  FOR I = 0 TO 1
190 Z = 0
200  FOR K = 1 TO 9
210  IF V(I,K) <  = V(I,K + 1) THEN
      GOTO 240
220 V = V(I,K):V(I,K) = V(I,K + 1
     ):V(I,K + 1) = V
230 Z = 1
240  NEXT
250  IF Z = 1 THEN  GOTO 190
255  NEXT
260  FOR K = 1 TO 10
270  PRINT V(0,K),V(1,K)
280  NEXT
285  FOR I = 0 TO 1
290 SV(I) = 0
300  FOR K = 2 TO 9
310 SV(I) = SV(I) + V(I,K): NEXT
     :SV(I) = SV(I) / 8
320  PRINT : PRINT : PRINT "MEAN
     VALUE OF 8 READINGS = "SV(I)

325  NEXT
330  PRINT : PRINT : PRINT "IF YO
     U ARE READY FOR NEXT SAMPLIN
     G PRESS SPACE BAR"
340  GET G$: IF G$ = "" THEN 340
350  IF G$ = " " THEN  HOME : GOTO
     28
```

APPENDIX E

E.5.2 COMPUTER PROGRAM USED IN THE TESTING OF SMOOTH STRATIFIED FLOW CONDITIONS TO DETERMINE THE LIQUID HEIGHT IN THE TEST SECTION USING THE TWO DEPTH GAUGES (THE HEIGHT IS GIVEN IN mm).

```
10 SLOT = 5:K(0) = 19.62:K(1) = 1
     9.61
20  DIM R(2,1000),H(500,2),D(500)
     ,N(300)
30  INPUT "NUMBER OF SAMPLING===>
     ?";M
40 AI13 =  - 16256 + SLOT * 16
50 A = 768: POKE A,169: POKE A +
     2,141: POKE A + 3,128 + 16 *
     SLOT: POKE A + 4,192: POKE A
      + 5,96
60 K = K + 1
70  INPUT "TEST NUMBER(IF IT IS T
     HE SAME TEST PRESS ZERO KEY=
     ==>? ";X
80 N(K) = N(K - 1)
90  IF X > 0 THEN N(K) = X
100  FOR J = 1 TO M
110  FOR I = 0 TO 1
120  POKE A + 1,I: CALL A
130 R(I,J) =  PEEK (AI13) + 256 *
      PEEK (AI13 + 1)
140  NEXT : NEXT
150  FOR I = 0 TO 1
160 RSUM(I) = 0
170  FOR J = 1 TO M
180 RSUM(I) = RSUM(I) + R(I,J)
190  NEXT
200 RAVG(I) = RSUM(I) / M
210 V(I) = RAVG(I) * 4.9988 / 409
     5
220  NEXT
230 H(K,0) = K(0) + 182.0910 - 35
     .8538 * V(0)
240 H(K,1) = K(1) + 181.371 - 35.
     8622 * V(1)
250 D(K) = H(K,0) - H(K,1)
260  PRINT N(K),,: PRINT : PRINT
     H(K,0),: PRINT : PRINT H(K,1
     ),: PRINT : PRINT D(K)
300  PRINT : PRINT " PRESS SPACE
     BAR FOR NEXT TEST OR PRINT E
     ND IF YOU FINISHED"
310  GET G$
320  IF G$ = " " THEN  GOTO 60
330  IF G$ = "END" THEN  GOTO 310

340  FOR I = 1 TO K
350 B$ =  STR$ (H(I,0)):H(I,0) =
      VAL ( LEFT$ (B$,7))
360 C$ =  STR$ (H(I,1)):H(I,1) =
      VAL ( LEFT$ (C$,7))
370 E$ =  STR$ (D(I)):D(I) =  VAL
     ( LEFT$ (E$,6))
380  NEXT
```

```
500  HOME : VTAB 6: HTAB 6: PRINT
     "(1) PRINT RESULTS ON THE PR
     INTER": PRINT
510  HTAB 6: PRINT "(2) SAVE RESU
     LTS ON DISK": PRINT
520  HTAB 6: PRINT "(3) END OF RU
     N"
530  VTAB 24: HTAB 6: INPUT "PLEA
     SE SELECT (1 TO 3)?;===>";AN
     $
540 AN =  VAL (AN$): IF AN < 1 OR
     AN > 3 THEN  PRINT  CHR$ (7)
     : GOTO 530
550  ON AN GOTO 600,750,1000
600 D$ =  CHR$ (4): PRINT D$"PR£3

640 NT = 0:S1 = 0:S2 = 0
650  FOR I = 1 TO K
660 B$ =  STR$ (H(1,0)):P1 = 10 -
      LEN (B$)
670 C$ =  STR$ (H(I,1)):P2 = 10 -
      LEN (C$)
680  PRINT N(I); SPC( 4);H(I,0); SPC(
     P1);H(1,1); SPC( P2);D(I)
681 NT = NT + 1
682 S1 = S1 + H(1,0):S2 = S2 + H(
     1,1)
686  IF N(I) <  > N(I + 1) THEN  PRINT
     S1 / NT; SPC( 4);S2 / NT; SPC(
     4);(S1 - S2) / NT:NT = 0:S1 =
     0:S2 = 0
690  NEXT
700 D$ =  CHR$ (4): PRINT D$"PR£0

710  GOTO 500
750  PRINT D$"MON C,I,O"
760  INPUT "FILE NAME ?===>";F$
770  PRINT D$"PR£3": PRINT "FILE
                  NAME IS: "F$: PRINT
     D$"PR£0"
780  HOME : PRINT "FILE NAME IS:"
     F$
790  PRINT D$"OPEN"F$: PRINT D$"D
     ELETE"F$: PRINT D$"OPEN"F$
800  PRINT D$"WRITE"F$
820  PRINT K
850  FOR I = 1 TO K
860  PRINT N(I): PRINT H(I,0): PRINT
     H(I,1): PRINT D(I)
880  NEXT
900  PRINT D$"CLOSE"F$
910  PRINT D$"NOMON C,I,O"
950  GOTO 500
1000  END
```