HEAT TRANSFER, PRESSURE DROP AND VOID FRACTION IN TWO-PHASE, TWO-COMPONENT FLOW IN A VERTICAL TUBE

By

Manit Sujumnong

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

Department of Mechanical and Industrial Engineering

The University of Manitoba

Winnipeg, Manitoba, Canada

1997

0-612-32023-5

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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Abstract

There are very few data existing in two-phase, two-component flow where heat transfer, pressure drop and void fraction have all been measured under the same conditions. Such data are very valuable for two-phase heat-transfer model development and for testing existing heat-transfer models or correlations requiring frictional pressure drop (or wall shear stress) and/or void fraction. An experiment was performed which adds markedly to the available data of the type described in terms of the range of gas and liquid flow rates and liquid Prandtl number. Heat transfer and pressure drop measurements were taken in a vertical 11.68-mm i.d. tube for two-phase (gas-liquid) flows covering a wide range of conditions. Mean void fraction measurements were taken, using quick-closing valves, in a 12.7-mm i.d. tube matching very closely pressures, temperatures, gas-phase superficial velocities and liquid-phase superficial velocities to those used in the heat-transfer and pressure-drop experiments. The gas phase was air while water and two aqueous solutions of glycerine (59 and 82% by mass) were used as the liquid phase. In the two-phase experiments the liquid Prandtl number varied from 6 to 766, the superficial liquid velocity from 0.05 to 8.5 m/s, and the superficial gas velocity from 0.02 to 119 m/s. The measured two-phase heat-transfer coefficients varied by a factor of approximately 1000, the two-phase frictional pressure drop ranged from small negative values (in slug flow) to 93 kPa and the void fraction ranged from 0.01 to 0.99; the flow patterns observed included bubble, slug, churn, annular, froth, the various transitions and annular-mist. Existing heat-transfer models or correlations requiring frictional pressure drop (or wall shear stress) and/or void fraction were tested against the present data for mean heat-transfer coefficients. It was found

that the methods with more restrictions (in terms of the applicable range of void fraction, liquid Prandtl number or liquid superficial Reynolds number) give better predictions. Among the most restrictive methods, the method of Drucker et al. is recommended. A method less restrictive, but still giving good predictions, is the Liquid Acceleration Model for superficial liquid Reynolds numbers greater than 2000. For local heat-transfer coefficients, a method proposed by Vijay, where Spalding's single-phase boundary-layer theory was adapted to the two-phase case, was tested considering the flow patterns individually and various methods of calculating two-phase properties. Good predictions were obtained for the case of bubble and froth flows when liquid properties were used as the two-phase mixture properties.

Acknowledgements

During the course of the study, Dr. G. E. Sims (the author's advisor) has provided the author the endlessly consistent indispensable academic guidance and caring. Without all of his support, it would be impossible to withstand all the past difficulties. The author would like to express his gratitude and appreciation to his advisor. Special thanks are due to Dr. H. M. Soliman and Dr. W. E Muir for their helpful suggestions during all the progress-report meetings. The author would like to thank Dr. V. S. Krishnan for taking his valuable time to be part of the examination.

Special thanks to Mr. John Finken for his tireless help on the technical works and his friendship. Thank to Mr. Kim Marjury for his help on electronic works. For Mr. Casey Van Gorp, the author would like to express his sincere appreciation on his help for all computer related problems. Thanks to Ms. R. Trestrail for her great help on typing this thesis. Good friends like; the Coyle family, the Piamsalee family, G. Tanner, I. Frigui, C. Van Gorp, G. Johnston, Z. Teclemariam, M. Sukkaboon and many more in Winnipeg who always make the author feel great when they are around; the author's warmest regards go to them.

Special thanks are expressed to the author's father, mother, sister and brother for their endless love and support. For Promsiri, the author's wife, who all this while provides very good care to their family. The author would like to thank her from his heart. For the two angels "Nong Ham and Nong Bambam" who may have thought their daddy lived in the telephone; they are the true driving force of his study.

The author appreciates the financial supports made by the Natural Science and Engineering Research Council of Canada (NSERC) and the government of Thailand.

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Nomenclature

		Units
A_c	Cross-sectional area of tube wall	(m^2)
A_T	Flow area of the tube	(m^2)
B_0, B_1		
B_2, B_3	Constants appearing in Equation D.8	
C	Discharge coefficient for flow through an orifice plate	(-)
C_p	Specific heat	(J/kg·K)
d	Diameter of orifice throat	(m)
D	Inside diameter of the tube	(m)
D_o	Outside diameter of the tube	(m)
D_p	Diameter of the pipe connected to the orifice plate	(m)
$\bar{e}$	Mean deviation defined in Equation 5.1	
$\bar{e}_{rms}$	Root-mean-square deviation, Equation 5.2	
E	Total voltage drop across the heated tube	(V)
f	Friction coefficient defined in Equations 5.3 to 5.5	(-)
g	Acceleration due to gravity	(m/s^2)
G	Mass velocity	$(kg/m^2 \cdot s)$
h	Enthalpy per unit mass of fluid	(J/kg)
h, h(z)	Local heat-transfer coefficient	$(W/m^2 \cdot K)$
$\bar{h}$	Length-mean heat-transfer coefficient	$(W/m^2 \cdot K)$
I	Current flowing through the tube	(A)
k	Thermal conductivity	(W/m.K)
k_t	Thermal conductivity of tube material	(W/m.K)
L	Length of the heated test section	(m)
ΔL	Length used to calculate the length-mean heat-transfer coefficient	(m)
$\dot{m}$	Mass flow rate	(kg/s)
N	Number of variables	(-)
Nu	Local Nusselt number = hD/k_L	(-)
$\overline{Nu}$	Mean Nusselt number = $\bar{h}D/k_L$	(-)

P	Pressure	(Pa)
P_a	Partial pressure of dry air	(Pa)
P_{FN}	P-function, Equation F.2	(-)
P_v	Partial pressure of vapor	(Pa)
Pr	Prandtl number	(-)
Pr_T	Turbulent Prandtl number	(-)
ΔP	Pressure drop (total without subscripts)	(Pa)
ΔP_{TPF}	Two-phase frictional pressure drop	(Pa)
$\Delta P/L$	Total pressure drop per unit length	(N/m^3)
q''	Heat flux	(W/m^2)
q_V'''	Heat generated per unit volume of the heated tube	(W/m^3)
q_W''	Heat flux at the wall	(W/m^2)
Q	Volumetric flow rate	(m^3/s)
r	Radial coordinate measured from the axis of the tube	(m)
R	Gas constant	(kJ/kg·K)
R_t	Total resistance of test tube	(ohm)
Re	Reynolds number	(-)
Re_d	Reynolds number based on orifice throat diameter	(-)
Re_{SG}	Superficial gas Reynolds number = $\rho_G \cdot V_{SG} \cdot D/\mu_G$	(-)
Re_{SL}	Superficial liquid Reynolds number = $\rho_L \cdot V_{SL} \cdot D/\mu_L$	(-)
S_q	Spalding function, Equation F.1	(-)
St	Stanton number = $Nu/Re \cdot Pr$	(-)
t	Wall thickness of the tube	(m)
T	Temperature	(°C)
T_{AVG}	Mean temperature of tube wall	(°C)
T_L	Temperature of the liquid at the inlet to the mixer	(°C)
T_o	Temperature as measured by the thermocouples on the heated tube	(°C)
ΔT_W	Temperature drop across the tube wall	(°C)

V	Velocity	(m/s)
V_{EXP}	Experimental value of a variable, Equation 5.1	
V_{PRED}	Predicted value of a variable, Equation 5.1	
V_{SG}	Superficial gas velocity	(m/s)
V_{SL}	Superficial liquid velocity	(m/s)
x	Flow quality = $\frac{\dot{m}_G}{\dot{m}_G + \dot{m}_L}$	(-)
X	Martinelli parameter	(-)
y	Coordinate measured from the tube wall	(m)
Y	Expansion factor, Equation D.38	
z	Axial coordinate measured from the commencement of heated section	(m)
Z^+	Variable defined in Equation F.3	(-)
Z^*	Variable defined in Equation 5.8	(-)

Greek Symbols

α	Void fraction	
α'	Temperature coefficient of thermal conductivity of tube material	$(°C)^{-1}$
β'	Temperature coefficient of electrical resistivity of tube material	$(°C)^{-1}$
ρ	Density	(kg/m^3)
ρ'_o	Resistivity defined in Appendix D	(ohm.m)
μ	Dynamic viscosity	(kg/m.s)
ν	Kinematic viscosity	(m^2/s)
τ	Shear stress	(Pa)
ω	Uncertainty interval in a variable, Appendix E	
Ψ^2	$\overline{h}_{TP} / \overline{h}_{SP}$	(-)

Subscripts

a	Dry air
abs	Absolute
ave	Average
B	Bulk, liquid or mixture
G	Gas
i	Location at which a thermocouple is attached to the wall
IN, OUT	At the inlet and outlet of heated tube
L	Liquid
MIX	Gas-liquid mixture
O	Outside
Pred	Predicted
SG	Superficial gas
SL	Superficial liquid
SP	Single-phase (generally, liquid)
T	Turbulent
TP	Two-phase
TPF	Two-phase frictional
v	Vapor
W	At the wall
z	Axial component (in the direction of flow)

Superscripts

GL	Glycerine
H_2O	Water
L	Liquid

Chapter 1

INTRODUCTION

1.1 BACKGROUND AND PURPOSE OF PRESENT STUDY

Two-phase gas-liquid flow has been studied extensively due to its occurrence and numerous applications in industry. These occurrences and applications range from straight-forward transfer systems such as in pumping processes to those involving heat transfer such as in power generation, refrigeration, distillation and chemical processes. The flow of a liquid and a permanent gas (usually referred to as two-phase, two-component flow) is also involved in several engineering processes. Examples are in oil and natural-gas pipe lines, oil wells, bubble columns, and petro-chemical processes. Knowledge of the heat-transfer characteristics in heat-exchange systems is necessary for design, operation and safety considerations; this heat-exchange process often involves two-phase gas-liquid flow. In recent years, then, much research effort has been expended in the area of two-phase gas-liquid flow and other related fields due to the demand for a better understanding of the nature of the flows.

Papers in the literature (e.g., 2, 6, 8, 16, 22, 40, 48, 51 to 54, 56, 63, 65, 66, 69, 76 to 80, 88, 91, 97) on two-phase, two-component flow in tubes show that the majority of the research has focused on hydrodynamic aspects of the flow, namely, pressure drop, void fraction, flow pattern, and phase distribution. There have also been a number of papers involving heat transfer in two-phase, two-component flow; some have dealt with heat transfer only (e.g., 10, 57, 81), some with heat transfer and pressure drop (e.g., 1, 71, 94) and a very few with heat transfer, pressure drop and void fraction (57, 79, 80, 88, 89).

The purpose of the present work is to perform experiments which add significantly to the data where all of heat-transfer coefficient (h_{TP}), pressure drop (ΔP_{TP}) and void fraction (α) are measured under the same conditions (the conditions of interest here are of a two-phase, gas-liquid, two-component, non-boiling, co-current vertically upward flow in a tube). Such data are very valuable for testing and developing predictive methods for heat transfer; a number of correlations are available, where, in order to test them requires all of the parameters mentioned. It is therefore a secondary purpose of the present work to test those correlations.

Since heat transfer and pressure drop depend upon liquid viscosity, three liquids were chosen for this study in order to cover a wide range of liquid viscosities. Prandtl numbers varied from approximately 6 to 766. The three liquids were distilled water, 59% glycerine and water, and 82% glycerine and water by weight solutions. For ease in reading this thesis, henceforth the two aqueous solutions of glycerine, namely 59% and 82% glycerine by weight, will be referred to as G1 and G2, respectively. The glycerine concentrations in G1 and G2 were chosen such that there was a factor of approximately 10 in the liquid-phase Prandtl number Pr_L from water to G1 and a further factor of approximately 10 in Pr_L from G1 to G2.

1.2 LAYOUT OF THE THESIS

The results of the literature survey done on the research area of forced-convective heat transfer in two-phase, two-component, gas-liquid flow in vertical tubes are reported in Chapter 2. Different works are described briefly and the conclusions drawn by the authors are summarized.

The experimental apparatus and systems used for measuring key variables are described in Chapter 3. Also, detailed information on various components of the experimental rig is given in Appendix A. Appendix B gives details on calibrations of the measuring devices used during the course of the investigation.

Chapter 4 describes the procedures which were used in conducting the experimental work. All calculation procedures involved in this thesis are given in Appendix D. Appendix C gives the fluid properties used in data reduction.

Heat-transfer and pressure-drop results of liquid single-phase tests which were conducted on the experimental rig are shown and discussed in Chapter 5. The results of two-phase pressure drop and two-phase flow-pattern observation are presented in Chapter.6. The two-phase pressure-drop data were compared with some of the existing correlations.

Chapter 7 shows the results of the two-phase heat-transfer tests. In this chapter, local and mean heat-transfer coefficients are presented. These results are later compared with existing correlations and shown in Chapter 8. An uncertainty analysis and repeatability tests were performed in order to check the accuracy and consistency of the collected data and experimental facility. The results are shown in Appendix E. Appendix G gives the complete set of tabulated data for all gas-liquid mixtures used in this investigation. Chapter 9 contains the conclusions that were drawn from the present study.

The number of each figure, equation and table in this thesis begins with the number of the chapter or the letter of the appendix in which it appears. The "Nomenclature" lists all the variables appearing in the body, and the most important of those in the appendices, of the thesis. The units of these variables are also given in this section.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTORY REMARKS

In the past few decades, the field of two-phase flow has received a great deal of attention from research scientists and engineers. A large number of publications, in both research and development are to be found in the open literature. Many studies have dealt with two-phase hydrodynamics (i.e., pressure drop, flow pattern, and void fraction) such as (5, 6, 9, 30, 41, 42, 58, 61, 67, 68, 86) and the results of some of those studies are used later in the present work. There are major reviews of works which were done on the subject of forced-convective boiling heat transfer in two-phase flows such as (59 and 60) including books (7, 18, 34). However, the situation of forced-convective heat transfer where no boiling occurs has received much less attention. In this chapter, the relevant literature as defined in Section 2.2 is reviewed.

2.2 CRITERIA FOR SELECTION OF THE REVIEWED MATERIALS

The studies reviewed here were selected based on the following criteria:

1) The flows must be in vertical tubes; this is because the flow patterns, to a greater or lesser degree, are dependent upon the orientation of the flow channel.

2) The flow must be forced-convective.

3) The flow must be co-current and vertically upward.

4) The flow must be non-boiling, the two phases being a liquid and non-condensable gas.

2.3 TWO-PHASE TWO-COMPONENT HEAT TRANSFER IN VERTICAL TUBES

Table 2.1 summarizes the details of the experimental investigations, in chronological order, of two-phase two-component heat transfer which were conducted in the past. Table 2.2 summarizes, and presents in chronological order, the heat-transfer predictive methods which have been proposed by different authors, with the definitions of terms and range of applicability as stated by the original authors. Because of the focus of this thesis, following is a review, in chronological order, of works where heat transfer, pressure drop and/or void fraction were studied under the same flow conditions.

Kudirka et al. (50) measured local heat-transfer coefficients at the distance z = 14.3 D of his test section. Air was introduced into the liquid stream through a porous tube located upstream of the heated section. Water and ethylene glycol were used for the liquid phase. Flow patterns were observed at a section following the test section.

Ueda and Nose (90) focused on two-phase air-water upflow in the annular and annular-mist flows. The local heat transfer was measured at $z/D = 32$. Also, data on pressure drop, mean liquid film thickness, state of the gas-liquid interface, and droplet entrainment were taken. On the heat-transfer aspect, the data were analysed theoretically on the assumption that the liquid film consisted of a laminar sublayer and a turbulent layer. Details are shown in Table 2.2.

Vijay et al. (94) conducted an investigation on heat transfer and pressure drop using three gas-liquid mixtures, i.e., air-water, air-75% glycerine by weight solution, and air-glycerine. The liquid Prandtl number covered the range from 5 to 7,125. In general, the authors observed an increase of mean heat-transfer coefficient $\overline{h}_{TP}$ with air flow rate. However, the $\overline{h}_{TP}$ decreased when the flow pattern changed from annular to annular-mist flow and kept on decreasing as the air flow rate increased. The authors proposed a correlation expressing the relationship between two-phase frictional pressure drop and mean heat-transfer coefficients, as shown in Table 2.2.

Aggour (1) studied the effect of gas-phase density on heat transfer, pressure drop and flow pattern. Three gases (air, helium, and Freon-12 vapour) were used allowing a change in gas-phase density by a factor of approximately 30. Water was the only liquid used. For heat transfer, the $\overline{h}_{TP}$ was enhanced by approximately 25 percent (when the gas density was increased by a factor of 7) in the region where $V_{SL} \leq 1.04$ m/s and $V_{SG} \geq 1.52$ m/s. Also in his study, generally, the two-phase frictional pressure drop ΔP_{TPF} is insensitve to gas density except in the range of $V_{SL} \leq 1.04$ m/s and $V_{SG} \geq 1.52$ m/s, where the frictional pressure drop increases approximately 60 % (when the gas density increases by the factor of 7) in the most extreme case.

Chu and Jones (14) conducted their experiment (with $0.1 \leq \alpha \leq 0.85$) on air-water in both upward and downward flows. They observed that heat transfer did not affect void fraction. However, the flow orientation did have some influence on void fraction; that is, at the same V_{SG}/V_{SL}, void fraction in downflow cases was greater than that in upward flow. Due to this orientation effect, the heat-transfer coefficient in downflow was higher than that in upward flow at the same V_{SG}/V_{SL}. Two independent techniques, namely a conducting probe and radiation beam attenuation, were employed for void fraction measurement during the investigation.

The Ueda and Hanaoka (89) investigation consisted of three parts. In the first part, void fraction and frictional pressure drop were measured in the slug and annular flow regimes. A mathematical expression was presented to predict interfacial shear stress, the flow state of the liquid film and the liquid film thickness. The velocity distribution in the liquid film was calculated in the second part, and an expression was derived to predict the frictional pressure drop. In the third part, a heat-transfer experiment for two-phase, two-component flow was conducted using air-water and air-(water-Salton). A correlation was presented, the details of which are shown in Table 2.2.

Domanskii et al. (20) conducted a heat-transfer investigation using air-water, air-alcohol and air-glycerine solutions. The experimental data were then used to test their correlation which is described in Table 2.2. Their theory assumed that the heat-transfer process in the bubble-flow regime is similar to isotropic turbulence. The authors correlated their data within ±12 percent.

Dobran (19) proposed an analytical model such that, in annular-dispersed two-phase flow, the liquid film consists of two liquid layers, namely a continuous liquid layer and a wavy layer. The theory showed a significant influence of entrained liquid droplets in the gas core on both hydrodynamics and heat transfer.

Rezkallah (71) studied the effect of surface tension on heat transfer, pressure drop and flow pattern. Void fraction, where needed, was calculated using Chrisholm's correlation (13). Air was used for the gas phase. Three liquids, namely, water, 58% by weight glycerine-water solution, and silicone (5cs viscosity grade), were used for the liquid phase. The authors drew conclusions as follows: The effect of lowering the surface tension on the flow pattern was most pronounced on the bubble-slug boundary, expanding the bubble-flow region in the air-silicone (lowest surface tension) system. The frictional pressure-drop data for the air-silicone were slightly lower than those for the air-glycerine and water solution. The behaviour and shape of the local heat-transfer coefficient along the test section length remained unchanged in most cases with trends that varied according to the combination of the gas-liquid flow rates. The author also proposed two heat-transfer correlations for mean heat-transfer coefficients, one for each of laminar and turbulent flows.

Drucker et al. (23) studied heat transfer of air-water mixtures flowing inside tubes and over rod bundles. For the case of a two-phase mixture flowing inside tubes, the authors proposed a correlation (based on existing heat-transfer data for air-water with liquid Reynolds numbers in the range of 2,000 to 150,000 and void fractions up to 0.4) for heat-transfer coefficients as a function of Gr / Re^2 where Gr is a Grashof number defined in Table 2.2 and Re is the Reynolds number of the continuous phase.

Marié (57) was one of the recent works that treated theoretically the effect of void fraction on heat transfer and pressure drop in the bubble-flow regime. The modelling was based on two main arguments. First, the persistence of the logarithmic velocity and temperature profiles near the wall for low values of void fraction; second, the similarity of the modification caused by the bubbles on the profiles and those created by a grid in a single-phase turbulent boundary layer. Two theoretical models for heat transfer and pressure drop were proposed and tested against the data of Souhar (85) and Bobkov (10). The author stated that the models worked well for void fractions up to 0.2-0.3.

Sekoguchi et al. (81) investigated the dependence of heat transfer on the cross-sectional distribution of void fraction which takes place in bubble flow. Two different types of gas injectors were employed to realize flows with different distributions of void fraction at the same gas-liquid flow rates. It was found that the two types of gas injection gave different void fraction distributions, resulting in different heat-transfer coefficients. The authors showed that increasing void fraction near the tube wall caused higher heat-transfer coefficients. The investigation was done using an air-water mixture.

Sato et al. (79, 80) presented a theoretical model to predict both pressure drop and heat-transfer coefficients in bubble flow. The model needs information on void-fraction distribution for the calculation procedures. Their theory was based on the idea that the eddy diffusivity to express the turbulent structure of the liquid phase was subdivided into two components, one from the inherent wall turbulence independent of bubble agitation, and the other from the additional turbulence caused by bubbles. The models were tested against the data of Hinata (38) and Sekoguchi (81). The results show good agreement between calculated values and those from experimental data.

Rite and Rezkallah (73) conducted an experiment on both normal (earth) and reduced gravity conditions. The values of mean void fraction and heat-transfer coefficients were collected for $0.04 < V_{SL} < 3.70$ m/s, $0.09 < V_{SG} < 26.00$ m/s, $466 < Re_{SL} < 61{,}333$ and $43 < Re_{SG} < 12{,}932$. A 9.53-mm i.d. circular tube was used. Air and water were used for gas and liquid phases, respectively. A heat-transfer correlation was proposed for the case of reduced gravity.

Wadekar et al. (95) conducted an experimental investigation using a 15.7 i.d.-mm. stainless steel tube. The authors used air and water as gas and liquid phases, respectively and worked in slug flow. The authors proposed a theoretical method to predict the mean heat-transfer coefficient based on the assumption that the two-phase heat transfer in slug flow consisted of two parts, namely one from falling liquid film (at the gas plug) and another one from liquid slug. The authors included the effect of sensible heating of the gas phase (gas plug) into the heat-transfer process over the falling liquid film. The equations describing their model are given in Table 2.2.

From the works reviewed in this section, it can be seen that some investigations focused on heat transfer and pressure drop (e.g., 1, 90 and 94) while some focused on heat transfer and void fraction (e.g., 14, 50, 73 and 95). For the investigations where the key variables of heat transfer, pressure drop and void fraction (including flow pattern) are studied under the same conditions, the work in the open literature is very limited (e.g., 81). These key variables (under the same flow conditions) are very useful for modelling. It is, therefore, the primary purpose of this investigation to study this group of key variables for a wide range of flow conditions and Prandtl number.

2.4 SUMMARY

The studies in which heat transfer was measured in two-phase two-component (gas-liquid) flow are described in Table 2.1 according to test section details, method of heating, flow pattern, etc. An examination of Table 2.1 would show that both local (1, 26, 50, 71, 87, 89, 90, 93, 100) and mean (1, 14, 20, 25, 33, 45, 47, 70, 71, 81, 92, 93, 95, 100) heat-transfer coefficients were measured. The size of the test-section tube varied from 10-mm to 70-mm i.d. and the heated length varied from 1.68 to 113.6 D. Heating was by steam condensing on the outside of the tube (70, 89, 92); electrical heating was either by heating tape (20, 45) or by the tube itself acting as a resistance heater (1, 14, 21, 25, 49, 50, 71, 81, 90, 93, 95, 100). The liquids used were water (1, 14, 20, 25, 33, 44, 45, 50, 70, 71, 81, 87, 89, 90, 92, 93, 95, 100), aqueous solutions of glycerine (20, 25, 71, 93), pure glycerine (93), ethylene glycol (50), petroleum oil (21, 47), toluene (70), and silicone (71). The flow patterns observed have included those from bubble to annular-mist. For heat-transfer prediction, Table 2.2 shows that some predictive methods require just independent variables, such as fluid properties, flow rates and tube size (e.g., 25, 33, 47, 50, 71). Some methods require the knowledge of pressure drop or wall shear stress (e.g., 20, 81, 90, 94). Other methods require void fraction explicitly (e.g., 20, 23, 45, 57, 89 and the Liquid Acceleration Model: L.A.M.). Even though it appears that a wide range of parameters (such as fluid properties, superficial velocity of both phases, and test-section diameter) were investigated, it is rare to find experimental investigations where the parameters of two-phase heat-transfer coefficient, pressure drop and void fraction are studied at the same time (57, 80). This group of key parameters is important for both practice and modelling in two-phase heat transfer. The present work markedly extends the range of results for which heat transfer, pressure drop and void fraction are reported for the same conditions.

Table 2.1 Details of Experimental Works

Reference	Test Section Details	Method of Heating	Method of Temp. Measurement	Liquid Phase	Gas Phase	Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)	Range of Re_{SL} Min. Max.	Range of V_{SL} (m/s) Min. Max.	Range of V_{SG}/V_{SL} Min. Max.	h_{TP} Basis	Flow Pattern Observed
Verschoor and Stemerding (92)	Ambraloy-927 D = 14 mm L = 40 cm L/D = 28.6	Steam at atmospheric pressure	Thermocouples soldered on the tube wall	Water	Air	0.02154 - 0.06867 Not given	2960 - 9460	0.140 - 0.448	0.02 - 225.0	Mean	Bubble Slug Annular
Ueda (87)	Steel D = 51 mm L = 10 cm L/D = 1.96	D.C. electrical heating by means of external resistance wire	Thermocouples inserted to the mid point of the tube wall thickness	Water	Air	0.0555 - 1.3981 0 - 0.0124	138 - 3460	0.02743 - 0.6797	0.17 - 1.29	Local	Bubble Slug Annular
Katsuhara and Kazama (45)	Copper D = 30 mm L = 27 cm L/D = 9	Electric (Nichrome wire wound around the tube)	4 thermocouples attached on the outer surface	Water	Air	0.11528 - 0.525 Not given	Not given	0.15849 - 0.762	0.04 - 3.43	Mean	Not reported
Groothuis and Hendal (33)	Copper D = 14 mm L = 20 cm L/D = 14.3	Steam	Constantan wires were buried inside the wall to form together with the tube material 8 cu-con thermocouples	1) Water 2) Gas-oil	Air Air	(1) 0.0307 - 0.1231 (2) 0.0339 - 0.0646 m_G not given	(1) 3182 - 16550 (2) 1853 - 3538	(1) 0.149 - 0.783 (2) 0.265 - 0.505	(1)1.0 - 210.0 (2) 0.7 - 70.0	Mean	Not observed

Reference	Test Section Details	Method of Heating	Method of Temp. Measurement	Liquid Phase	Gas Phase	Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)	Range of Re_{SL} Min. Max.	Range of V_{SL} (m/s) Min. Max.	Range of V_{SG}/V_{SL} Min. Max.	h_{TP} Basis	Flow Pattern Observed
Knott et al. *(47)*	Type 304 stainless steel D = 12.8 mm L = 1.524 m L/D = 113.6	A.C. electric heating, using the tube as a resistor	6 of no. 22 Cu-con. thermocouples soldered onto the tube wall	Paraffin-base petroleum oil	Nitrogen	0.0007307 - 0.01764 2.772×10^{-5} - 8.694×10^{-4}	6.7 - 162.0	0.03353 - 1.722	0.11 - 39.4	Mean	Bubble
Kudirka et al. *(50)*	Bronze D = 15.8 mm L = 27.9 cm L/D = 113.6	A.C. electric heating, using the tube as a resistor	8 Cu-con. thermocouples attached to the inner surface of the wall	1) Water 2) Ethylene glycol	Air Air	(1) 0.0604 - 0.544 0.0001 - 0.00863 (2) 0.068 - 0.3024 0.0001 - 0.00686	(1) 5440 - 44825 (2) 380 - 1700	(1) 0.3048 - 2.7432 (2) 0.3048 - 1.3716	(1) 0.16 - 71.0 (2) 0.25 - 65.0	Local at Z/D = 14.3	Bubble, Slug, Annular
Ueda and Hanaoka *(89)*	Brass D = 19.4 mm L = 1.3 m L/D = 66.8	Hot water circulated through a jacket around the tube	3 pairs of thermocouples soldered on the outer surface of the tube	1) Water 2) Mixture of water & Salton	Air Air	(1) 0.0288 - 0.19404 0.000138 - 0.001688 (2) 0.08756 - 0.1474 0.000138 - 0.001499	(1) 2800 - 16,000 (2) 680 - 5,000	(1) 0.09753 - 0.6583 (2) 0.30175 - 0.51512	(1) 0.58 - 50.3 (2) 0.72 - 12.9	Local and Mean	Bubble, Slug, Annular

Reference	Test Section Details	Method of Heating	Method of Temp. Measurement	Liquid Phase	Gas Phase	Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)	Range of Re_{SL} Min. Max.	Range of V_{SL} (m/s) Min. Max.	Range of V_{SG}/V_{SL} Min. Max.	h_{TP} Basis	Flow Pattern Observed
Domanskii et al. (20)	Copper D = 32 mm L = 1 m L/D = 31.25	Electrically by winding a Nichrome strip around the tube	6 Cu-con. thermocouples	1) Water 2) Alcohol 87% 3) Glycerol (54, 65, 71, 77, 85%)	Air Air Air	Not given	Not given	0.1 2.2 For all liquids used	Range of V_{SG} is 0.025 - 1.5 m/s	Mean	Bubble
Fedotkin and Zarudner (26)	D = 10 mm 21.5 mm 30.0 mm L = 1 m 2.5 m	Not given	Measured the wall temp. at 3 points in each chamber	Water and solutions of different $\mu_L \cdot 0.3 \times 10^{-3} < \mu_L < 28 \times 10^{-6}$ Pa · s	Air	Not given	700 - 11,400	1, 1.5, and 2 m/s	Not given	Local	Bubble, Slug, Annular
Dorresteijn (21)	D = 70 mm L = 1.1 m L/D = 15.7	A.C. electric heating, using the tube as a resistor	Cu-con. thermocouples	Gas-oil	Air	0.064 - 14.867 0.0000453 - 0.45733	300 - 66,000	0.02 - 4.633	0.004 - 4730	Not given	Bubble, Slug, Froth, Annular-Mist
Ueda and Nose (90)	D = 29.9 mm L = 1.3 m L/D = 43.5	A.C. electric heating of the tube, using the tube as a resistor	12 thermocouples attached on the outer surface at equal intervals	Water	Air	0.00448 - 0.3156 0.0103 - 0.01945	Re_{LF} = liquid film Reynolds number at 190 to 13,700	0.064 - 0.450	Range of V_{SG} is 10.0 - 50.0	Local at z/D = 32	Annular, Mist

Reference	Test Section Details	Method of Heating	Method of Temp. Measurement	Liquid Phase	Gas Phase	Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)	Range of Re_{SL} Min. Max.	Range of V_{SL} (m/s) Min. Max.	Range of V_{SG}/V_{SL} Min. Max.	h_{TP} Basis	Flow Pattern Observed
Kapinos et al. *(44)*	L/D = 1.68 to 59.1	Not given	Not given	Water	Air	Not given	3.7×10^4 23.8×10^4	not given	Range of V_{SG} is 40.0 to 150 m/s	Mean and Local	Annular, Mist (fog)
Ravipudi and Godbold *(70)*	Copper D = 19 mm L = 1.52 m L/D = 80	Steam	24 Cu-con. thermocouples 9 of which were placed inside the tube to measure the mixture temp. along the tube	1) Water 2) Toluene	Air Air	(1) 0.0869 - 0.698 0.00131 - 0.023 (2) 0.1323 0.001436 - 0.00756	(1) 10,100 - 52,540 (2) 2,022 -	(1) 0.3048 - 2.45367 (2) 0.5486 -	(1) 1.3 - 88.0 (2) 7.7 - 40.4	Mean	Bubble, Slug, Churn, Annular, Annular-Mist
Vijay *(93)*	Stainless Steel-304 D = 11.68 mm L = 0.6096 m L/D = 52.2	A.C. electric heating using the tube as a resistor	47 Cu-con. (D = 0.005") thermocouples were attached onto the outer surface of the tube	1) Water 2) Glycerol 75% by weight 3) Glycerine	Air Air Air	1)0.002104 - 1.1334 0.000094 - 0.02721 2) 0.001713 - 1.1491 0.0000405 - 0.0191 3) 0.0126 - 0.15623 0.0000239 - 0.01251	(1) 250 - 126,000 (2) 8.0 - 4,500 (3) 1.8 - 21.0	(1) 0.01981 - 10.6 (2) 0.0134 - 8.96 (3) 0.0945 - 1.1583	(1) 0.03 - 6,700 (2) 0.01 - 6,700 (3) 0.05 - 330	Local and Mean	Bubble, Slug, Froth, Annular, Annular-Mist

Reference	Test Section Details	Method of Heating	Method of Temp. Measurement	Liquid Phase	Gas Phase	Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)	Range of Re_{SL} Min. Max.	Range of V_{SL} (m/s) Min. Max.	Range of V_{SG}/V_{SL} Min. Max.	h_{TP} Basis	Flow Pattern Observed
Aggour (1)	Stainless Steel-304 D = 11.68 mm L = 0.6096 m L/D = 52.2	A.C. electric heating using the tube as a resistor	47 Cu-con. (D = 0.005") thermocouples were attached onto the outer surface of the tube	1) Water 2) Water 3) Water	Air Helium Freon-12 vapour	1) 0.03364 - 1.1334 0.0000945 - 0.0252 2) 0.03364 - 1.1334 0.00000252 - 0.004246 3) 0.03364 - 0.45359 0.000105 - 0.025956	(1) 4,150 - 128,000 (2) 3,995 - 126,000 (3) 4,230 - 55,200	(1) 0.3139 - 10.57 (2) 0.3139 - 10.57 (3) 0.3139 - 10.57	(1) 0.02 - 305.8 (2) 0.042 - 196.0 (3) 0.035 - 114.0	Local and Mean	Bubble, Slug, Froth, Annular, Annular-Mist
Chu and Jones (14)	Stainless Steel D = 26.67 mm L = 0.91 m L/D = 34.3	A.C. electric heating using 12 heating wires wound around the stainless steel tube	Three Chr-Alum TC were soldered in a recessed hole in a test section wall (at same axial location 120° apart azimuthally	Water	Air	0.2337 - 1.8036 0.0002645 - 0.001285	16,000 112,000	0.421 3.24	0.13 2.12	Mean	Bubble, Slug, Froth
Zaidi (100)	Stainless Steel-304 D = 11.68 mm L = 0.6096 m L/D = 52.2	A.C. electric heating using the tube as a resistor	47 Cu-con. (D = 0.005") thermocouples were attached onto the outer surface of the tube	1) Water 2) Surfactant water solution	Air Air	(1) 0.006048 - 1.1334 0.0000126 - 0.02495 (2) 0.006048 - 0.68 0.00001764 - 0.024696	(1) 710 - 153,000 (2) 818 - 81,500	(1) 0.0579 - 10.607 (2) 0.0579 - 6.34	(1) 0.02 - 2,033 (2) 0.05 - 1,682	Local and Mean	Bubble, Slug, Churn, Froth, Annular, Annular-Mist

Reference	Test Section Details	Method of Heating	Method of Temp. Measurement	Liquid Phase	Gas Phase	Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)	Range of Re_{SL} Min. Max.	Range of V_{SL} (m/s) Min. Max.	Range of V_{SG}/V_{SL} Min. Max.	h_{TP} Basis	Flow Pattern Observed
Elamvaluthi and Srinivas (25)	Brass D = 10 mm L = 86.1 cm L/D = 86	A.C. electric heating using a Nichrome wire wound around the test section	Four Cu-con. thermocouples were fixed to the wall at equidistance to measure wall temperature	1) Water 2) Aqueous glycerine	Air Air	(1) 0.02356 - 0.12562 m_G not given (2) 0.01575 - 0.1178 m_G not given	(1) 4.3 - 22.9 (2) 0.15 - 1.15	Not given	(1) 0.3 - 2.5 (2) 0.6 - 4.6	Mean	Bubble, Slug
Rezkallah (71)	Stainless Steel-304 D = 11.68 mm L = 0.6096 m L/D = 52.2	A.C. electric heating using the tube as a resistor	47 Cu-con. (D = 0.005") thermocouples were attached onto the outer surface of the tube	1) Water 2) 58% glycerol 3) Silicone 5CS Viscous grade	Air Air Air	(1) 0.00605 - 1.1335 0.00005292 - 0.019656 (2) 0.00265 - 0.90668 0.00000756 - 0.0209 (3) 0.002179 - 0.9067 0.00000882 - 0.01978	(1) 845 - 127,000 (2) 42 - 13,000 (3) 51 20,700	(1) 0.056 - 10.6 (2) 0.022 - 7.38 (3) 0.022 - 9.20	(1) 0.021 - 2,298 (2) 0.00784 - 9,716 (3) 0.00894 - 5,050	Local and Mean	Bubble, Slug, Churn, Froth, Annular, Annular-Mist
Sekoguchi et al. (81)	Stainless Steel -304 D = 16.9 mm L = 0.97 m L/D = 57.4	A.C. electric heating using the tube as a resistor	14 thermocouples were located every 50 mm along the tube axis to measure the outer wall temperature	Water	Air	Not given	Not given	0.3 2.0	Range of V_{SG} 0.08 to 8.0 m/s	Mean	Bubble

Reference	**Test Section Details**	**Method of Heating**	**Method of Temp. Measurement**	**Liquid Phase**	**Gas Phase**	**Range of $\dot{m}_L$ and $\dot{m}_G$ (kg/s)**	**Range of Re_{SL} Min. Max.**	**Range of V_{SL} (m/s) Min. Max.**	**Range of V_{SG}/V_{SL} Min. Max.**	**h_{TP} Basis**	**Flow Pattern Observed**
Wadekar et al. (95)	Stainless Steel D = 15.7 mm L = 1.3 m	A.C. electric heating using the tube as a resistor	13 thermocouples along the axial length	Water	Air	Total mass flux 45.51, 51.81, 85.73, 101.38 ($kg/m^2 \cdot s$)		Not given	Not given	Mean	Slug

Table 2.2 Summary of the Correlations for Predicting[1,2]

Author	Statement of Correlations and Definition of Terms	Range of Applicability and Comments
Katsuhara and Kazama (45)	$\overline{Nu}_{TP} = 8.7\,(1-\alpha)^{0.125}(Re_{MIX})^{0.25}(Pr_{MIX})^{0.4}$ where $\overline{Nu}_{TP} = \bar{h}_{TP}\,D/k_{MIX}$ $k_{MIX} = \alpha\,(\rho_G/\rho_{MIX})k_G + (1-\alpha)(\rho_L/\rho_{MIX})\,k_L$ $\rho_{MIX} = \alpha\,\rho_G + (1-\alpha)\,\rho_L$ $Pr_{MIX} = \alpha\,(\rho_G/\rho_{MIX})\,Pr_G + (1-\alpha)(\rho_L/\rho_{MIX})\,Pr_L$ $Re_{MIX} = V_{MIX}\,D/\nu_{MIX}$ $V_{MIX} = (\dot{m}_G + \dot{m}_L)/A_T\,\rho_{MIX}$ $\nu_{MIX} = \alpha\,(\rho_G/\rho_{MIX})\,\nu_G + (1-\alpha)(\rho_L/\rho_{MIX})\,\nu_L$	$0.08 < \alpha < 0.6$
Groothuis and Hendal (33)	(1) Air-Water $\overline{Nu}_{TP} = 0.029\,(Re_2)^{0.87}(Pr_L)^{1/3}(\mu_B/\mu_W)^{0.14}$ (2) Air-(Gas-oil) $\overline{Nu}_{TP} = 2.6\,(Re_2)^{0.39}(Pr_L)^{1/3}(\mu_B/\mu_W)^{0.14}$ where $Re_2 = Re_{SL} + Re_{SG}$	(1) $Re_{SL} > 5{,}000$ $Re_{SG} > 0,\ \frac{V_{SG}}{V_{SL}} \geq 1$ (2) $1{,}400 \leq Re_{SL} \leq 3{,}500$ $Re_{SG} > 0,\ V_{SG}/V_{SL} \geq 1$
Knott et al. (47)	$\frac{\bar{h}_{TP}}{\bar{h}_L} = \left[1 + \frac{V_{SG}}{V_{SL}}\right]^{1/3}$ where $\bar{h}_L$ was calculated from the Sieder-Tate correlation	$Re_{SL} \leq 1{,}500$, $0.1 \leq V_{SG}/V_{SL} \leq 40$
Kudirka et al. (50)	$Nu_{TP} = 125\left(\frac{V_{SG}}{V_{SL}}\right)^{1/8}(Re_{SL})^{1/4}(Pr_L)^{1/3}\left(\frac{\mu_G}{\mu_L}\right)^{0.6}\left(\frac{\mu_B}{\mu_W}\right)^{0.14}$	$2.5 \times 10^{-4} \leq x \leq 0.092$ where x = quality $\equiv \dot{m}_G/(\dot{m}_L + \dot{m}_G)$
Ueda and Hanaoka (89)	$Nu_{TP} = 0.075\,(Re_M)^{0.6}\,\frac{Pr_L}{1 + 0.035(Pr_L - 1)}$ where $Re_M = \rho_L U_M^{*} D/\mu_L$, $U_M^{*} = V_L + 1.2Re_S^{-0.25}V_S - 12Fr_{ED}V_{ED} + 16Fr_S^{1.25}V_S$, $V_L = V_{SL}/(1-\alpha)$, $V_G = V_{SG}\alpha$ $V_S = V_G - V_L$, $Re_S = V_S D(1-\sqrt{\alpha})/\nu_L$, $V_{ED} = V_{SL} + V_{SG}$ $Fr_{ED} = g\alpha D(1-\sqrt{\alpha})/V_{ED}^2$ $Fr_S = g\alpha D(1-\sqrt{\alpha})/V_S^2$	$1.5 \times 10^3 \leq Re_M \leq 6 \times 10^4$

[1]Fluid properties are evaluated at bulk temperature unless otherwise specified.

[2]The meaning of symbols appears in Nomenclature.

Author	Statement of Correlations and Definition of Terms	Range of Applicability and Comments
Domanskii et al. (20)	$\frac{\bar{h}_{TP} \nu_L}{k_L U^*} = \frac{Pr_L}{\bar{Y}}$ where $\bar{Y}$ = dimensionless temperature difference, U^* = friction velocity $= \left[\left(\frac{\tau_W}{\rho_L} \right)^2 + \xi^4 \nu_L g V_S \alpha (T - \alpha)^2 \right]^{0.25}$ τ_W = wall shear stress and ξ = a proportionality constant	
Fedotkin and Zarudner (26)	$Nu_{TP} = C_3 Re_2^n Pr_L^{0.43} \left(\frac{Pr_L}{Pr_W} \right)^{0.25}$ where C_3, n = constants Pr_W = Prandtl number of liquid at the tube wall $Re_2 = Re_{SL} + Re_{SG}$	$1 < Pr_L < 200$ $700 < Re_{SL} < 11{,}400$
Ueda and Nose (90)	(1) Laminar liquid film flow: $\frac{h_{TP}}{k_L} \left(\frac{\nu_L^2}{g} \right)^{1/3} = X^* = \frac{Re_L^*}{T^*}$ where $Re_L = -\frac{4}{3} (Y_i^*)^3 + 2\tau_i (Y_i^*)^2$ $T^* = \frac{4}{3} (\tau_i^* - Y_i^*)(Y_i^*)^3 + (Y_i^*)^4$, $Y_i^* = Y_i (g/\nu_L^2)^{1/3}$, $\tau_i^* = \frac{\tau_i}{\rho_L g} (g/\nu_L^2)^{1/3}$ $\tau_i = -\frac{r_i}{2} \left[\frac{\Delta P}{\Delta L} \right] - \frac{1}{2\pi r_i} \left[\frac{\Delta M_D}{\Delta L} \right]$ $r_i = R - Y_i$, $\frac{\Delta M_D}{\Delta L} = V_G (\Delta \dot{m}_{ED} / \Delta L) g$ $\dot{m}_{ED}$ = mass flow rate of the entrained droplets (2) Turbulent liquid film flow: $q = -\rho_L g C_{PL} \left[\frac{\nu_L}{Pr_L} + \varepsilon_h \right] \frac{dT}{dY}$ and $h_{TP} = q_W / (T_W - T_{BF})$ where T_{BF} = bulk mean temperature of the liquid film and ε_h = eddy diffusivity for heat transfer	

Author	Statement of Correlations and Definition of Terms	Range of Applicability and Comments
Kapinos et al. (44)	$Nu_{TP} = \frac{h_{TP} D}{k_G}$ $= 340 \; Re_{SG}^{0.8} G^{-0.15} k_{\ell}^{0.86} q^{-0.82}$ For L/D < 30, the above correlation should be multiplied by ξ_1 given by $\xi_1 = 1 + 10.2/(L/D)^{1.74}$	The terms appearing in the correlation were not defined in (44).
Liquid Acceleration Model (L.A.M.)	$\frac{\bar{h}_{TP}}{\bar{h}_L} = \left(\frac{1}{1-\alpha} \right)^n$	Collier (78) suggested that in the bubble flow regime, n = ⅓ and 0.8 for laminar and turbulent, respectively
Ravipudi and Godbold (70)	$\overline{Nu}_{TP} = 0.56 \left(\frac{V_{SG}}{V_{SL}} \right)^{0.3} \left(\frac{\mu_G}{\mu_L} \right)^{0.2} (Re_{SL})^{0.6} \; Pr_L^{1/3} \left(\frac{\mu_B}{\mu_W} \right)^{0.14}$	$8{,}554 < Re_{SL} < 89{,}626$ $1 < V_{SG}/V_{SL} < 90$
Sekoguchi et al. (81)	The author proposed the following method to calculate ε_H (the eddy diffusivity of heat) as: $\varepsilon_{H_{TP}} = \varepsilon'_H + \varepsilon''_H$ where $\varepsilon_{H_{TP}}$ = the eddy diffusivity of two-phase flow ε'_H = the eddy diffusivity for heat evaluated as single-phase turbulent flow. ε''_H = the additional eddy diffusivity for heat yielded by the existence of bubbles. (For laminar flow, $\varepsilon'_H = 0$ but $\varepsilon''_H \neq 0$) $\varepsilon'_H = 0.4 \left[1 - \exp\left(\frac{-Y^*}{16} \right) \right]^2 Y^* \left[1 - \frac{11}{6}\left(\frac{Y^*}{R^*} \right) + \frac{4}{3}\left(\frac{Y^*}{R^*} \right)^2 - \frac{1}{3}\left(\frac{Y^*}{R^*} \right)^3 \right] \nu_L$ where Y^* = dimensionless distance $= U_1^* Y/\nu_L$ U^* = the frictional velocity $= \sqrt{\tau_W/\rho_L}$ τ_W = the wall shear stress R^+ = the dimensionless radius $= U_1^* R/\nu_L$ d_B = the bubble diameter U_B = the terminal velocity of a bubble rising in still liquid	Only for bubble flow regime

Author	Statement of Correlations and Definition of Terms	Range of Applicability and Comments
Vijay et al. (94)	$\Psi^2 = (\phi^2)^n$ where $n = 0.427$ for bubble flow $n = 0.489$ for slug flow $n = 0.269$ for froth flow $n = 0.455$ for annular flow and $n = 0.451$ for all flow regimes including transitions The following equation was also recommended: $\Psi^2 = A(\phi^2)^P (Re_{SL})^q$ where A, P, q are constants depending on the flow regime. $\Psi^2 = \dfrac{\bar{h}_{TP}}{\bar{h}_L}$, $\phi^2 = \dfrac{\Delta P_{TPF}}{\Delta P_L}$	The correlation does not apply to annular-mist transition. In addition, it does not work well for slug flow and slug-annular transition with frictional pressure drops less than 1,000 Pa/m.
Elamvaluthi and Srinivas (25)	$\overline{Nu}_{TP} = 0.5\left(\dfrac{\mu_G}{\mu_L}\right)^{0.25}(Re_2)^{0.7}Pr_L^{1/6}\left(\dfrac{\mu_B}{\mu_W}\right)^{0.14}$ where $Re_2 = Re_{SL} + Re_{SG}$	$300 < Re_2 < 16{,}500$ $V_{SG}/V_{SL} = 0.3 - 4.6$
Marié (57)	$\dfrac{\bar{h}_{TP}}{\bar{h}_L} = 1 + \dfrac{10}{3(1-\alpha)}\left[\dfrac{1 + \dfrac{Pr'}{2}\sqrt{\dfrac{C_F}{2}}}{1 + Pr'\sqrt{\dfrac{C_F}{2}}}\right] \cdot \sqrt{1.1\alpha(1-\alpha)}\ \dfrac{U_\infty}{V_{SL}}$ where $\dfrac{C_F}{2} = 0.0395\left(\dfrac{V_{SL}D}{\nu_L}\right)^{-1/4}$, $Pr' = \dfrac{C_\theta K_\theta - CK + 2\Pi_\theta - 2\Pi}{K}$, $K = 0.41, \quad K_\theta = 0.47$ $\dfrac{2\Pi}{K} = \dfrac{2\Pi_\theta}{K_\theta} = 0.65$ $C = 4.9$ and $C_\theta = 12.5\ Pr_L^{2/3} + \ln Pr_L - 5.3$ where Pr_L = liquid Prandtl number	Only for bubble flow regime $0 < \alpha \leq 0.3$ U_∞ = bubble rise velocity.
Drucker et al. (23)	$\Psi^2 = 1 + 2.5(\alpha Gr/Re^2)^{0.50}$ where $\Psi^2 = \bar{h}_{TP}/\bar{h}_L$ Gr = Grashof number, $= [(\rho_L - \rho_G)gD^3]/\rho_L \nu_L^2$ D = Tube diameter	$2{,}000 \leq Re_{SL} \leq 150{,}000$ $\alpha \leq 0.4$ $1.77 < Pr < 130$

Author	Statement of Correlations and Definition of Terms	Range of Applicability and Comments
Rezkallah (71)	$\frac{\bar{h}_{TP}}{\bar{h}_L} = 1 + 4.0\left(\frac{V_{SG}}{V_{SL}}\right)^{0.25} Pr_L^{-0.23}$ where $Re_{SL} \leq 2{,}000$ $\frac{\bar{h}_{TP}}{\bar{h}_L} = \left(\frac{1}{1-\alpha}\right)^{0.9}$ where $Re_{SL} > 2{,}000$	
Dobran (19)	$Nu_\delta \equiv \frac{q_W \delta}{(T_W - T_\delta) k_L}$ $= \frac{Pr_L \delta^+}{T^+(\delta^+)}$ where Pr_L = liquid Prandtl number $T^+ = C_{PL}\,\rho_L U^* (T_W - T)/q_W$ $U^* = (\lvert\tau_W\rvert/\rho_L)^{1/2}$ δ^+ = dimension film thickness $= \rho_L \delta U^*/\mu_L$ δ ≡ film thickness	The theory only applies to annular-flow.
Wadekar et al. (95)	$h = \beta h_{f,c} + (1 - \beta) h_s$ where β = length fraction $= L_p/(L_p + L_s)$ L_p = length of the gas plug L_s = length of the liquid slug $h_{f,c}$ = heat transfer coefficient for falling film h_s = heat transfer coefficient for liquid slug h = mean two-phase heat-transfer coefficient	The theory applies to slug flow only.

Chapter 3

DESCRIPTION OF THE APPARATUS

3.1 INTRODUCTORY REMARKS

In this chapter, details of the experimental apparatus are described. This experimental facility was first built and used by Vijay (93). Subsequently, this experimental rig was modified to include some new instrumentation and control devices. In the present study, some modifications were done on the apparatus in order to achieve better stability of air flow. Further, a new test section was built for mean void-fraction measurement which then allowed the collection of data on heat transfer, pressure drop and mean void fraction at the same flow conditions. Other than the modifications mentioned above, the material presented in this chapter is essentially the same as that in (71) and is presented here for the sake of completeness. The circled numbers appearing in the figures correspond to components used in the systems which are described in more detail in Appendix A. It will be noticed that some figures have been taken from other sources, and where the dimensions or sizes were given in Imperial units, these have been retained here.

3.2 FLOW CIRCUITRY

Figure 3.1 shows a simplified flow diagram of the overall system. Starting from the liquid storage tank, the working liquids flow through a heat exchanger (in order to keep liquid temperatures at inlet to the gas-liquid mixing chamber at a desired value). After the heat exchanger, the liquids were pumped by a positive-displacement gear pump

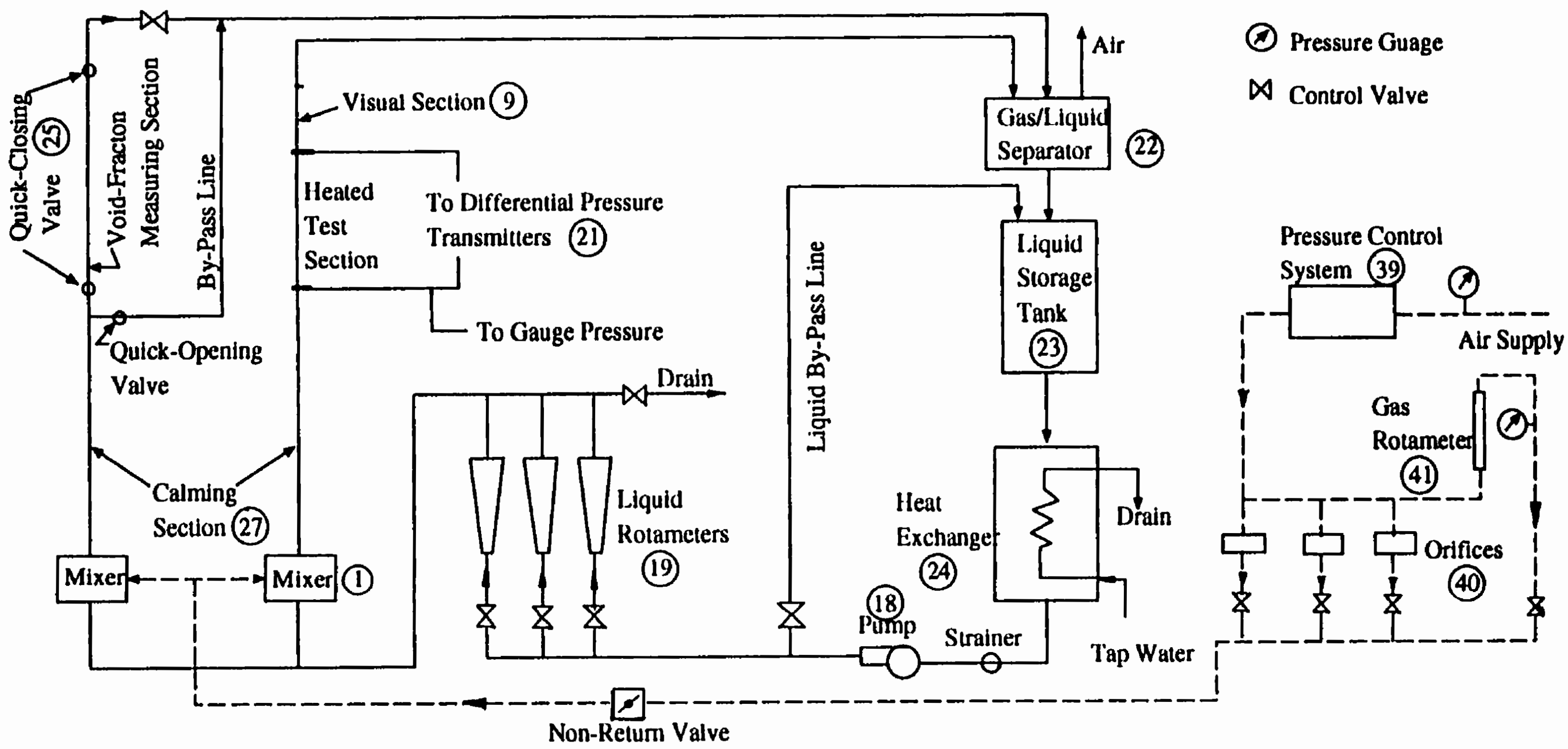

Figure 3.1 Schematic of Two-Phase Apparatus

to the gas-liquid mixing chamber through a selected flowmeter; for control some liquid flow was by-passed to the storage tank. The air flowed through an air filter and a feedback pressure controller unit to a set of orifice meters or a rotameter before entering the gas-liquid mixing chamber. To prevent the back-flow of liquid into the air supply line, a check-valve was installed on the air feed line prior to the mixing chamber. The gas-liquid mixture then flowed through the calming section, heated test section, and observation section in that order. The two-phase flow then exited to the separation tank where the air escaped to the atmosphere and liquid was returned to the storage tank. For the mean-void-fraction measurement, this flow circuitry remained the same except that the flow was routed through the void-fraction-measuring section instead of the heat-transfer test section (see Figure 3.1). The same mixer was used for the void-fraction measurement (but at a new location) as for the heat-transfer test section. Details of liquid flow and the air flow circuits are given in the following sections.

3.2.1 Liquid Flow Loop

Figure 3.1 also shows the details of the liquid flow loop which consisted of the following elements:

1) A 0.15-m^3 liquid storage tank made from stainless steel.
2) A liquid-to-liquid shell-and-tube heat exchanger.
3) A 5-hp Waukesha positive-displacement gear pump with a 24-USGPM maximum flow rate.

4) Three Fischer & Porter variable-area flowmeters of varying ranges with control valves, in parallel.

5a) Then either (for heat transfer and pressure-drop studies) the gas-liquid mixing chamber, followed by a 1.52-m calming section of 11.68-mm i.d., or

5b) For mean-void-fraction measurement, the gas-liquid mixing chamber (same as in 5a) followed by a 1.52-m calming section of 12.7-mm i.d.

6a) The heated test section of 11.68-mm i.d. and 61.0-cm long followed by a 30.5-cm observation section, or

6b) For mean-void-fraction measurement, a system of 12.7-mm i.d.quick-closing valves (5-ms closing time) pneumatically driven by actuators (QUADRA-POWR, series B605, Jamesbury Corp., Worcester,Mass., USA) located upstream and downstream of a clear polycarbonate tube of 12.7-mm i.d.

7) A stainless-steel gas-liquid separation tank.

8) The heat-exchanger cooling-water system consisted of two parallel flowmeters of different ranges and valves to control the cooling tap-water flow rates.

9) Three Rosemount differential pressure transmitters of different ranges in parallel to measure the total pressure drop across the heated test section. The high-pressure side was also connected to a Rosemount gauge-pressure transmitter.

10) Other elements such as pressure gauges, a pressure relief valve, a strainer, etc. are also shown in Figure 3.1.

3.2.2 Air Flow Circuit

As shown in Figure 3.2, this air flow circuit consisted of the following:

1) A main air supply line (campus supply) with a shut-off valve.

2) Two pressure regulators (ARO, 200 psi max) and a ball valve all connected in parallel to set air pressure at an appropriate value before flowing through an air filter and feedback pressure controller, (Fisher Control Inc., Canada, 3/8 inch type GS/513 actuator together with control panel type 4160K), respectively.

3) A set of three orifices of different sizes and a rotameter (Brooks), all connected in parallel through four needle valves to control air flow rates.

4) A 254-cm well-type water manometer to measure the pressure drop across the orifices.

5) A check-valve prior to the gas-liquid mixing chamber to prevent any back-flow of working liquid into the air supply system.

3.3 HEAT-TRANSFER AND PRESSURE-DROP TEST-SECTION DESIGN

This test section consisted of the gas-liquid mixing chamber, a 1.52 m long calming length, a 61.0-cm heated tube, and the 30.5-cm transparent flow-observation section. All

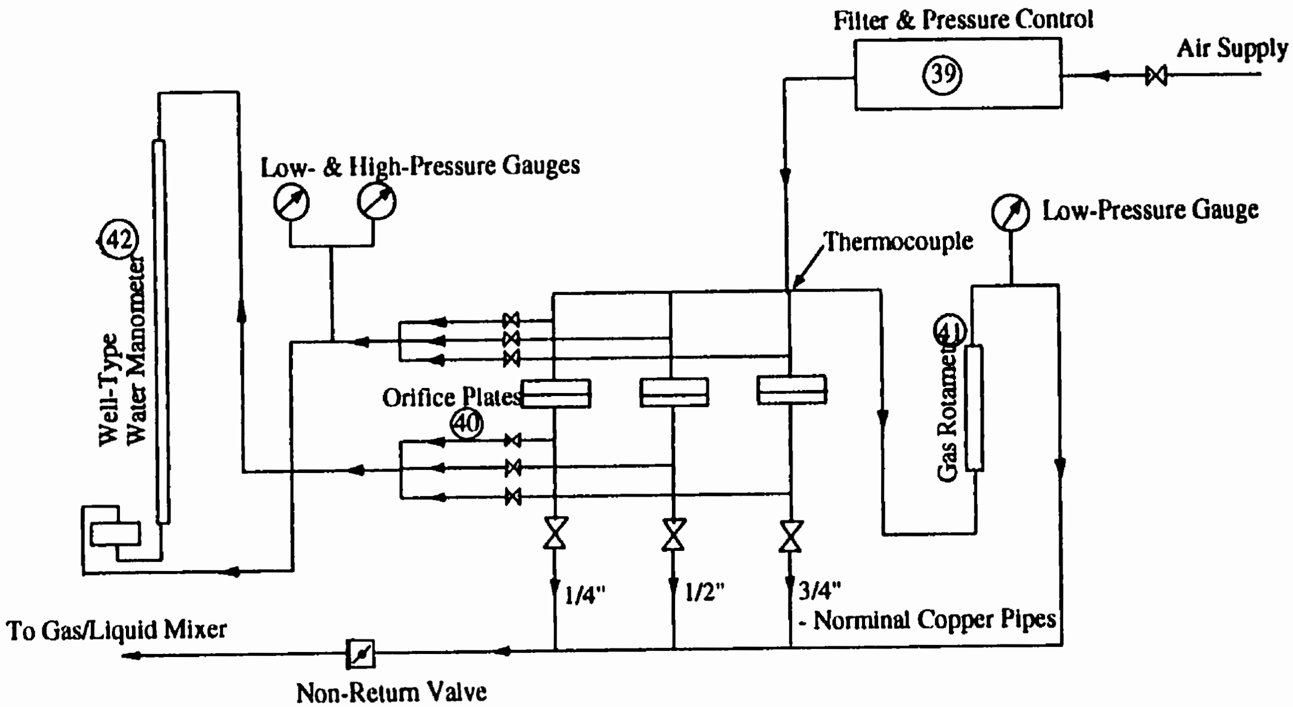

Figure 3.2 Detailed Schematic of Air Flow Circuit

of these sections had the same inside diameter of 11.68 mm. Details of the gas-liquid mixing chamber and heated section are given below.

3.3.1 Gas-Liquid Mixing Chamber

In the mixing chamber, the liquid stream flows upwards inside the porous tube (see Figure 3.3). This porous tube was a Grade E "Porosint" bronze tube (supplied by Sintered Products Limited, Sutton-in-Ashfield, Notts, England); the arrangement allowed air to flow through the porous tube, radially inwards. The two-phase mixture then was created inside the porous tube and proceeded upwards to the calming section.

3.3.2 Heat-Transfer Test Section

Figure 3.4 illustrates the details of the heated test section. The heated test section was made of type 304 stainless steel tubing, 11.68-mm i.d., 12.7-mm o.d., and 61.0 cm long. The tube-wall thickness and the average roughness were measured (93) to be 0.51 ± 0.025 mm (or 0.020 ± 0.001 in.) and $1.02 \times 10^{-3} \pm 1.2 \times 10^{-4}$ mm (or 40 ± 5 μ in.), respectively. The tube was used as an electrical resistor to generate A.C. Joulean heating. Electrical heating allows for ease of measuring and controlling the heat flux, and gives a constant-heat-flux boundary condition. Two bus bars for power supply were silver-soldered to the tube. A 2.54 × 2.54 × 61.0 cm Permali (a highly electrically insulating material, supplied by Permali Canada Ltd.) bar was firmly attached between the bus bars in order to avoid buckling of the heated tube due to the weight of the bus bars and power

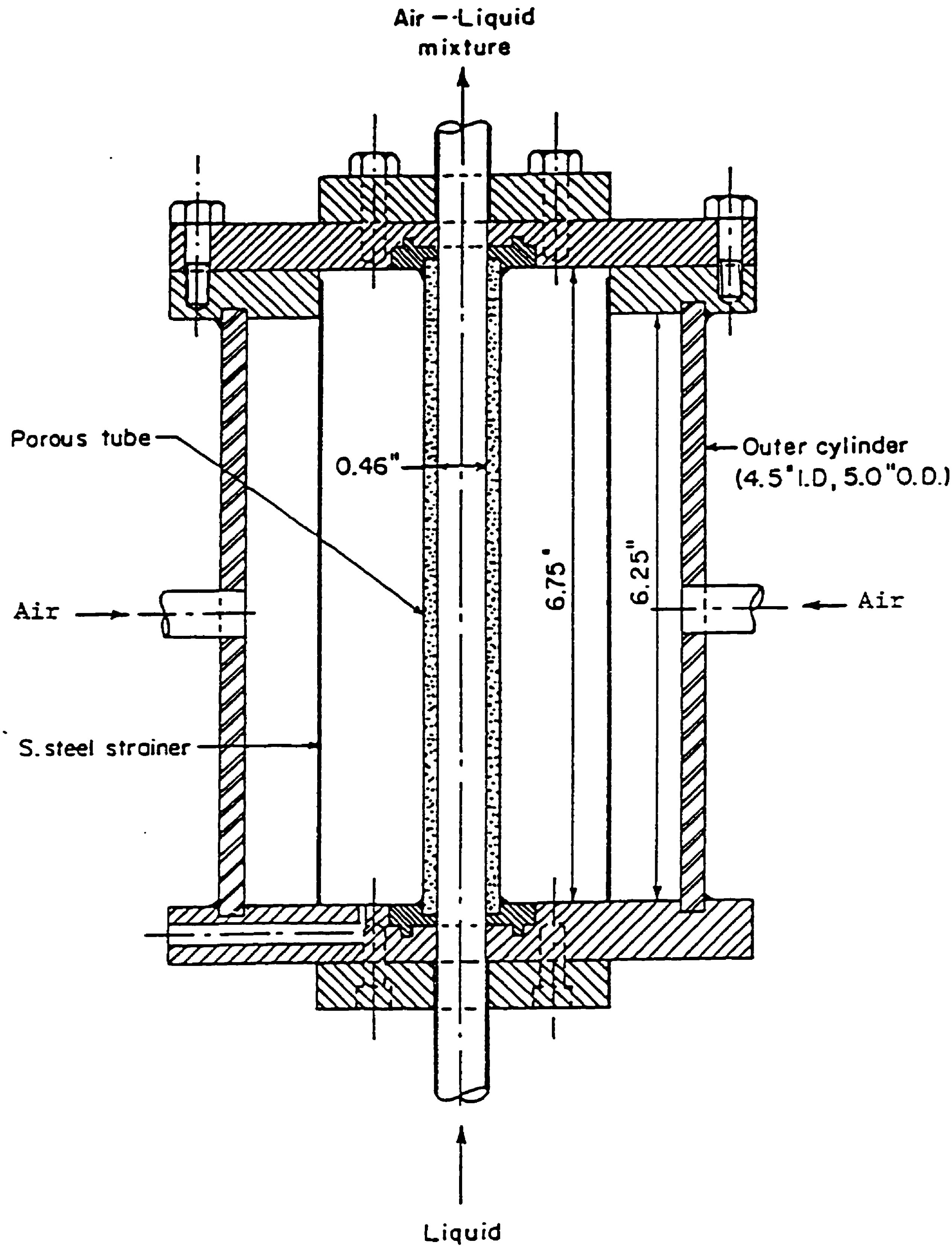

Figure 3.3 The Mixer, From (93)

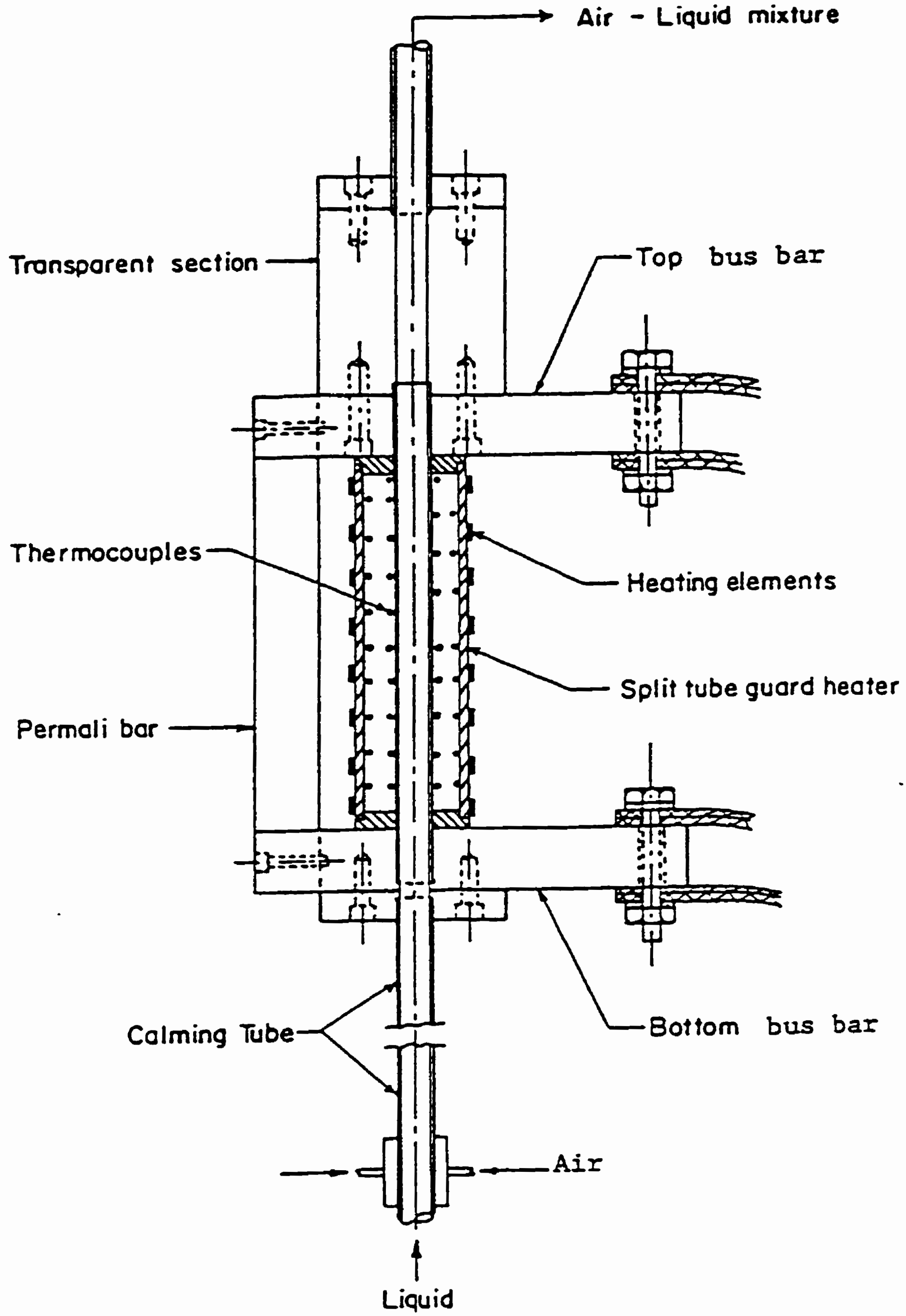

Figure 3.4 The Heated Test Section. From (93)

cables. For temperature measurement along the heated tube, thermocouples were mounted to the outside surface of the tube as detailed later.

To minimize heat losses from the heated tube to the surroundings, a split-tube guard heater, consisting of lower and upper guard heaters, was installed around the heated test tube. The annular space between the heated tube and the guard heaters was loosely filled with fibreglass insulating material. These two guard heaters were wrapped with Briskeat silicon-rubber-embedded heating tape 1.27 cm wide. The whole assembly was then wrapped around by the same insulating material and was secured by Scotch electrical tape (93). Each guard heater was heated independently by DC power-supply units. The guard heaters established a near-zero temperature-gradient condition at the outer surface of the heated-tube wall. This condition was achieved by adjusting the power supply of each guard heater until the temperature of the inner surface of each guard heater at mid-point position was very close (within 0.1 °C) to the temperatures of the outer surface of the heated tube at the corresponding position.

3.3.3 Observation Section

The observation section allowed for both visual observations and photography of the flow patterns. Since this section had the same internal diameter as, and was placed immediately downstream of, the heated test section, it was believed that the flow patterns observed were the same as those occurring in the heated test section. In order to minimize the distortion of the visualization, an externally rectangular prismatic body, 76.2 mm ×

76.2 mm × 30.5 cm, of which the hole-side surface was highly polished, made of transparent cast acrylic was used.

3.4 VOID-FRACTION MEASURING SECTION

This measuring section, shown in Figure 3.1, was built in order to measure actual mean void fraction, using the "holdup" technique, of any two-phase flow condition corresponding to those flowing in the heated test section. On constructing the void-fraction test section, it was not possible with commercially available materials to match precisely the internal diameter of the void-fraction test section with the heated test section (11.68-mm i.d.), although a reasonably close match was achieved. A polycarbonate tube of 12.7-mm i.d. was used for the calming length (1.52-m long) and the void-fraction measuring section itself (91.2-cm long); the internal diameter of the quick-closing valves was 12.7 mm. The procedure for matching flow conditions in the heated section and the void-fraction section is given in Section 4.4.

Since the bodies of the upstream and downstream quick-closing valves could block the view of the gas-liquid interface when the void-fraction values were very high or very low, a simple technique of adding (or withdrawing) liquid was used in order to be able to measure the void fraction.

3.5 TEMPERATURE MEASUREMENTS

This section describes the details of the following:

1) Fluid-temperature measurements,

2) Wall-temperature measurements, and

3) Temperature-measuring systems.

3.5.1 Fluid-Temperature Measurements

Five copper-constantan 0.457-mm (0.018-in.) diameter thermocouples (OMEGA PR-T-24) which were calibrated in the laboratory before installation were newly installed by the present author at the following locations: two for the liquid temperature at the inlet to the mixing chamber (one for the heat-transfer test section and one for the void-fraction test section), two at the outlet of the transparent observation section, and one for the air temperature at the inlet to the mixing chamber (for the void-measurement test section).

Also one copper-constantan 0.254-mm (0.010-in.) diameter size (T/G-30-DT thermocouple supplied by Thermoelectric Canada Ltd.) was previously installed by Vijay (93) to measure the air temperature at the inlet of the orifices.

3.5.2 Wall-Temperature Measurements

During the course of experiments, outer-wall temperatures of the heated test section were measured using thermocouples. Together with the information such as tube wall thickness, tube physical properties, the electrical current and the calculation method given by Kreith and Summerfield (49), the inner-wall temperatures were calculated. The details on this method are given in Appendix D. The inner-wall temperatures were then used in the calculation of the local heat-transfer coefficients.

On the outer surface of the heated test tube, copper-constantan 0.0127-mm (0.005-in.) diameter thermocouples were installed. Also, copper-constantan 0.254-mm (0.010-in.) diameter thermocouples were installed on the inner surface of the guard heaters. These thermocouple wires were calibrated in the laboratory at the time of installation, and over the temperature range involved in the present study (93). Figure 3.5 depicts the locations of thermocouples on the outer wall of the heated tube and the inner wall of the guard heaters. Forty-three thermocouples (nos. 5-47) measured the outer wall temperatures at 16 axial locations of the heated test tube, of which those at plane nos. 2, 4, 6, 8, 11, 14, and 15 were used (93) to calculate the local heat-transfer coefficients (see Appendix D). To install these thermocouples Scotch electrical tape no. 27 was used to electrically insulate the thermocouples from the tube and also to attach them to the tube wall. At the desired location, a layer of the tape was wrapped around the tube, the thermocouple bead was placed in position, 2-3 turns of the wire were wrapped around the tube to minimize the possible conduction error due to the temperature gradient along the wire. More details are given in Appendix D. Eighteen thermocouples (nos. 48-65) were located at nine elevations along the guard heaters (93). However, only thermocouples nos. 52, 53, 56, 57, 62, and 63 were chosen to represent three elevations along the guard heaters. Thermocouples nos. 1-4 read the temperatures of lower and upper bus bars.

3.5.3 Temperature-Measuring Systems

Figure 3.6 shows the system used for measuring the emf output of the thermocouples. The emf of thermocouples mentioned in the previous sections was read or recorded by any one or a combination of the following devices:

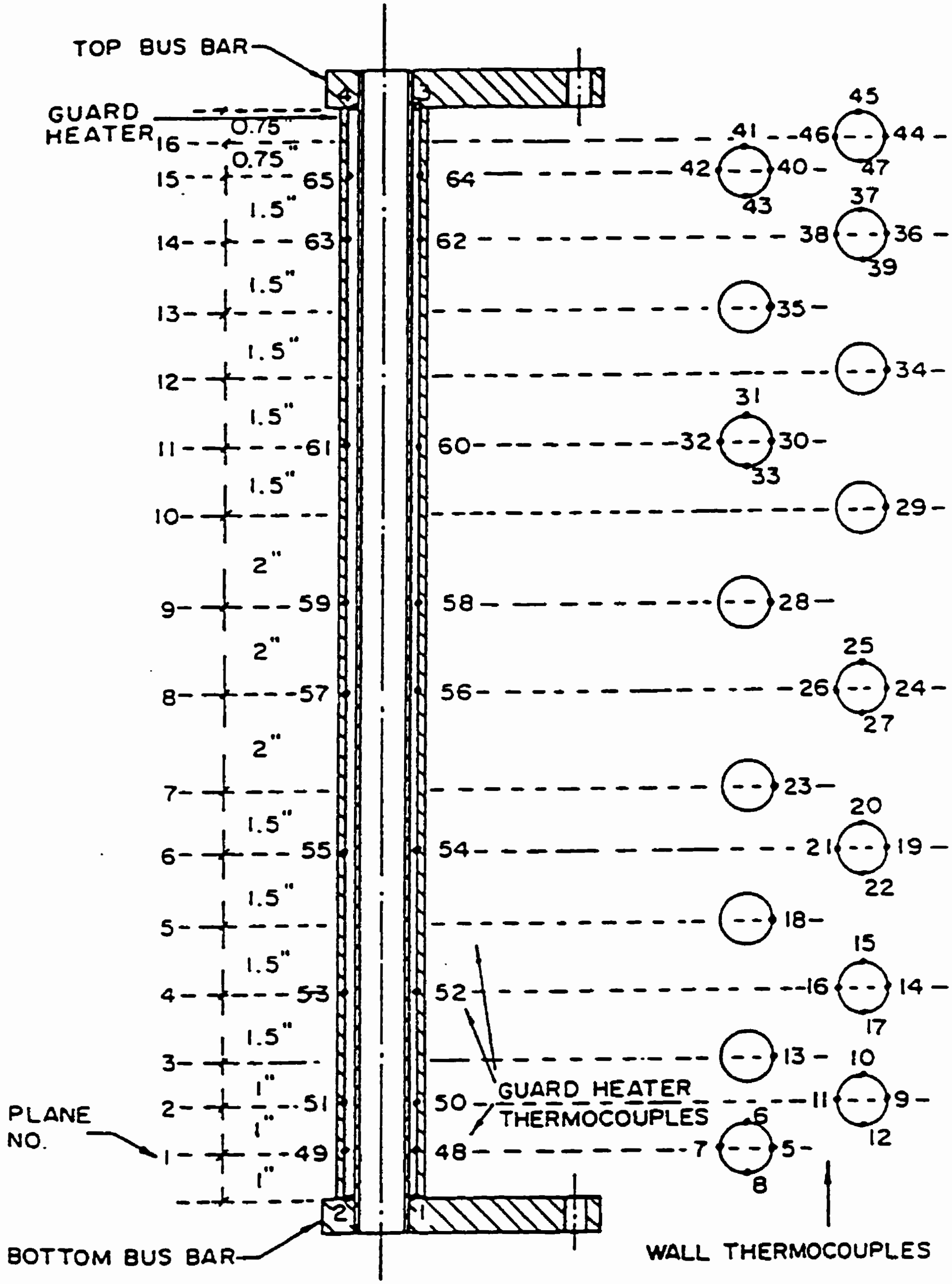

Figure 3.5 Location of Wall Thermocouples. From (93)

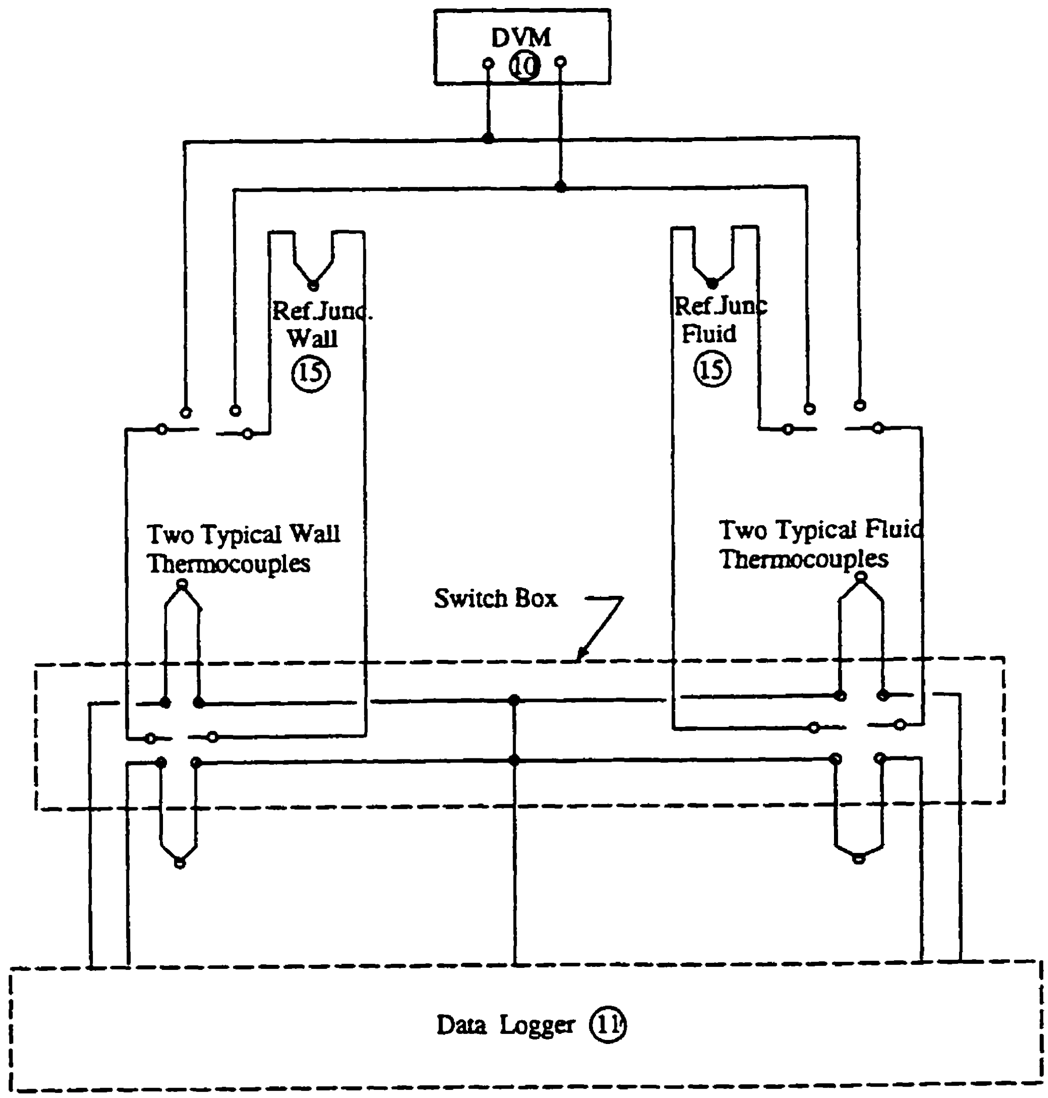

Figure 3.6 Thermocouple emf Measuring Circuit

1) A Fluke 2240A data logger, and

2) A Keithley 181 multimeter capable of measuring potentials.

The Fluke data logger, with a scanning speed up to 15 channels per second, had 50 analog inputs. The first channel (no. 0) was connected to a 1-mV standard potential source. The remaining 49 channels recorded the emf of all the wall thermocouples and those of the bus bars. The Keithley 181 multimeter was used to indicate the emf of fluid thermocouples and guard-heater thermocouples, and could be used to indicate the emf of wall and bus bar thermocouples.

The correspondence between the data-logger inputs and inputs of the multiple-point selector switch is given in Table 3.1.

3.6 POWER SUPPLY CIRCUIT

Figure 3.7 shows the power-supply system. This system was used to supply, control and measure the electric power to the heated test section. The components of this system consisted of the following:

1) A 240 V, 100 A, AC main power source.

2) A variac to control electrical power to the heated test section.

3) A power-measuring circuit consisting of a calibrated current transformer, ammeter and voltmeter. The ammeter readings were used to calculate the local heat flux (details in Appendix D). The combination of voltmeter and ammeter readings gave a check.

4) The type 304 stainless-steel test tube acting as an electrical resistor.

Table 3.1

Correspondence Between the Data Logger Inputs and the Multi-Point Selector Switch

TC No.	To Measure the Temperature of	Fluke Data Logger Channel No.	DVM Selector Switch No.
1-4	lower & upper bus bars*	1-4	1-4
5-47	the outer wall of the heated test tube*	5-47	5-47
52	the inner wall of the guard heater*	-	52
53	the inner wall of the guard heater*	-	53
56	the inner wall of the guard heater*	-	56
57	the inner wall of the guard heater*	-	57
62	the inner wall of the guard heater*	-	62
63	the inner wall of the guard heater*	-	63

* Location of the thermocouples given in Figure 3.5.

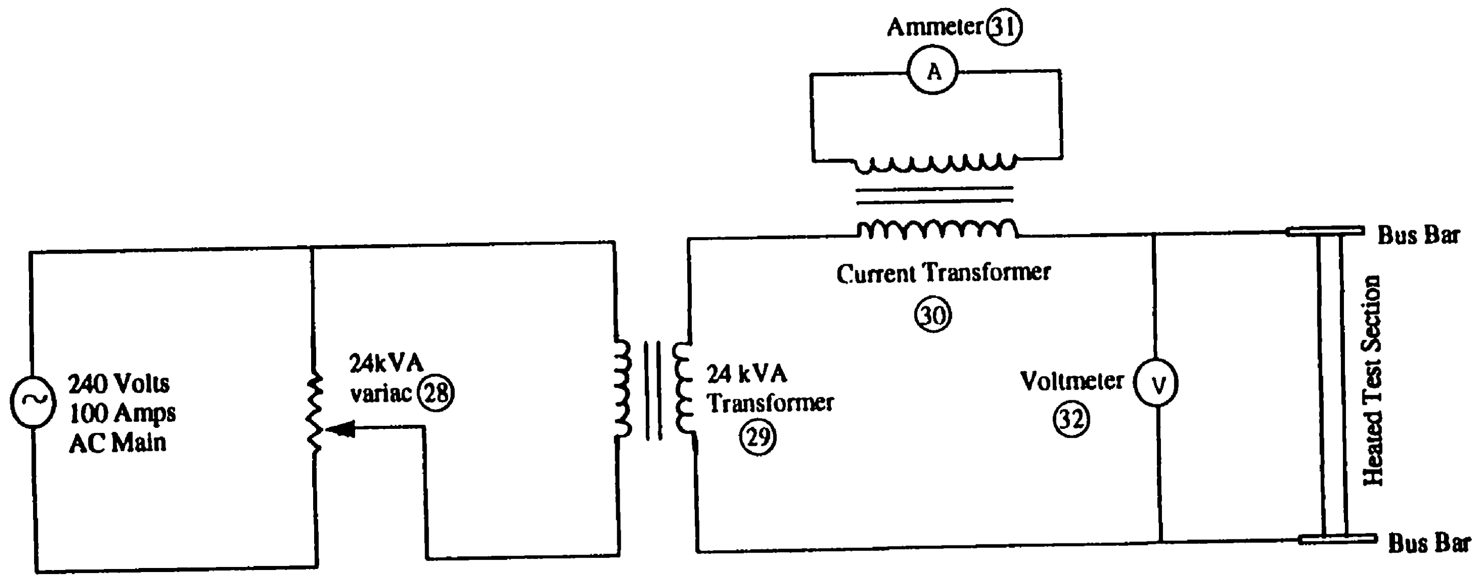

Figure 3.7 Power Supply Circuit

5) A 24 kVA transformer.

3.7 EQUIPMENT FOR PHOTOGRAPHY

Figure 3.8 shows the arrangement for photography; this was used earlier by Zaidi (100). The equipment consisted of the following:

1) A Pentax Spotmatic camera with Super Takumar 50 mm *f*/4.0 close-up lens.

2) A light tunnel made of cardboard. A glass diffuser screen was placed inside the tunnel to obtain uniform illumination of the visual section.

3) An EG&G Microflash electronic flash unit (flash duration of 0.5 μs) with the driver unit producing a 2-kV pulse to trigger the flash. The front panel of this flash unit was covered with a mylar diffuser.

4) The observation section as described in Section 3.3.3.

5) A parabolic reflector to focus light on the flow channel.

6) A General Radio type 1538-A Strobotac electronic stroboscope.

The lamp light shown in Figure 3.8 and the Strobotac were used to observe and help to identify (together with the high-speed photographs) the flow patterns. The film used was Kodak Plus-X Pan (ISO 125).

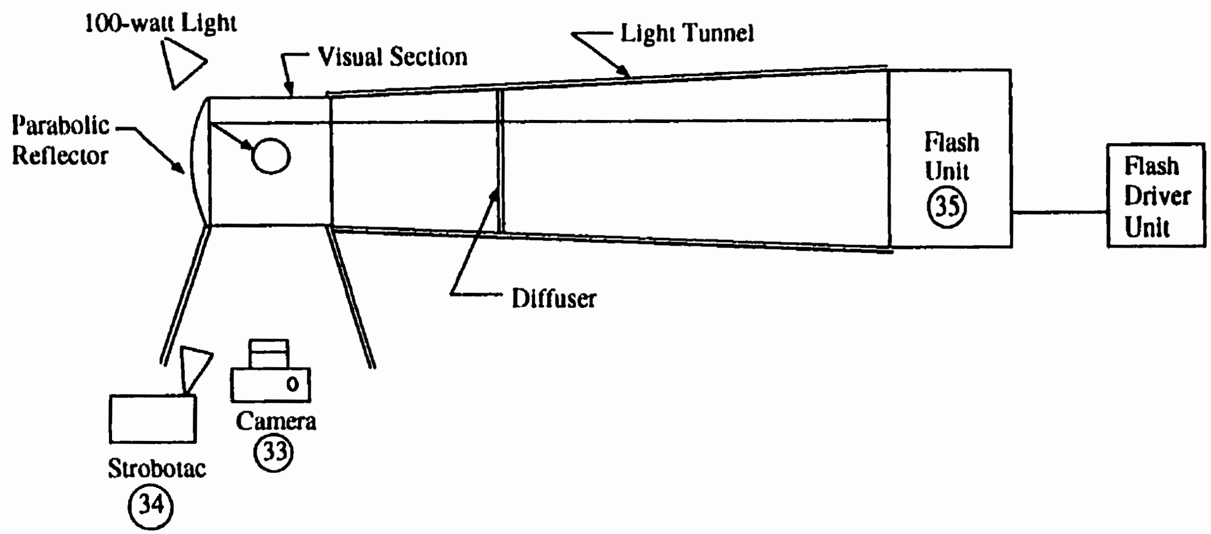

Figure 3.8 Set-Up of the Photographic Section

Chapter 4

EXPERIMENTAL PROCEDURE

4.1 GENERAL REMARKS

The details of the procedures performed for data collection are described in this chapter. Figures 4.1 and 4.2 show the measurements taken in connection with the experiments conducted in the heat-transfer and pressure-drop section, and void-fraction test section, respectively; Table 4.1 lists these measurements. The range of variables obtained during the course of experiments are presented in Table 4.2. It can be seen in Table 4.2 that, during the course of the experiment, the system pressure was not kept constant. This was done because (i) as demonstrated by Aggour (1) that heat-transfer coefficient and pressure drop are, for the most part, insensitive to the system pressure (details discussed later) and (ii) it was desirable to obtain a wide range of air flow rates, and hence, a wide range of flow patterns.

The experiments were conducted in such a way that, at a fixed liquid flow rate, the air flow rate was started from the minimum and gradually increased to the maximum, which throughout this thesis is referred to as a "run".

For each air-liquid system, the experiments on (i) heat transfer and pressure drop and (ii) void-fraction measurement were conducted separately. Therefore, the following procedures were employed for the data collection:

1) For Heat-Transfer and Pressure-Drop Tests.

   (i) Start-up and shut-down procedures (Sections 4.2.1 and 4.2.3).

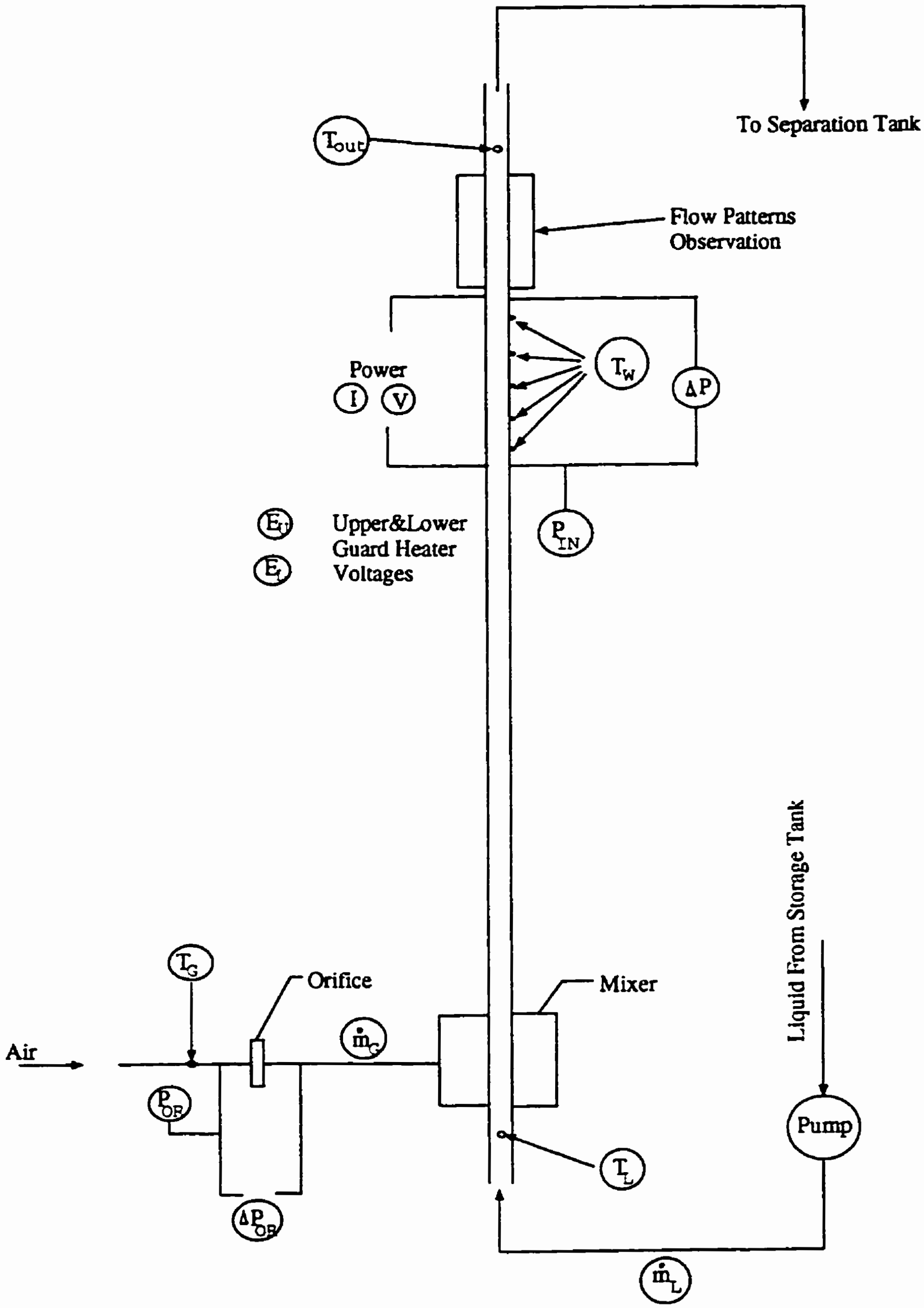

Figure 4.1 Measured Variables

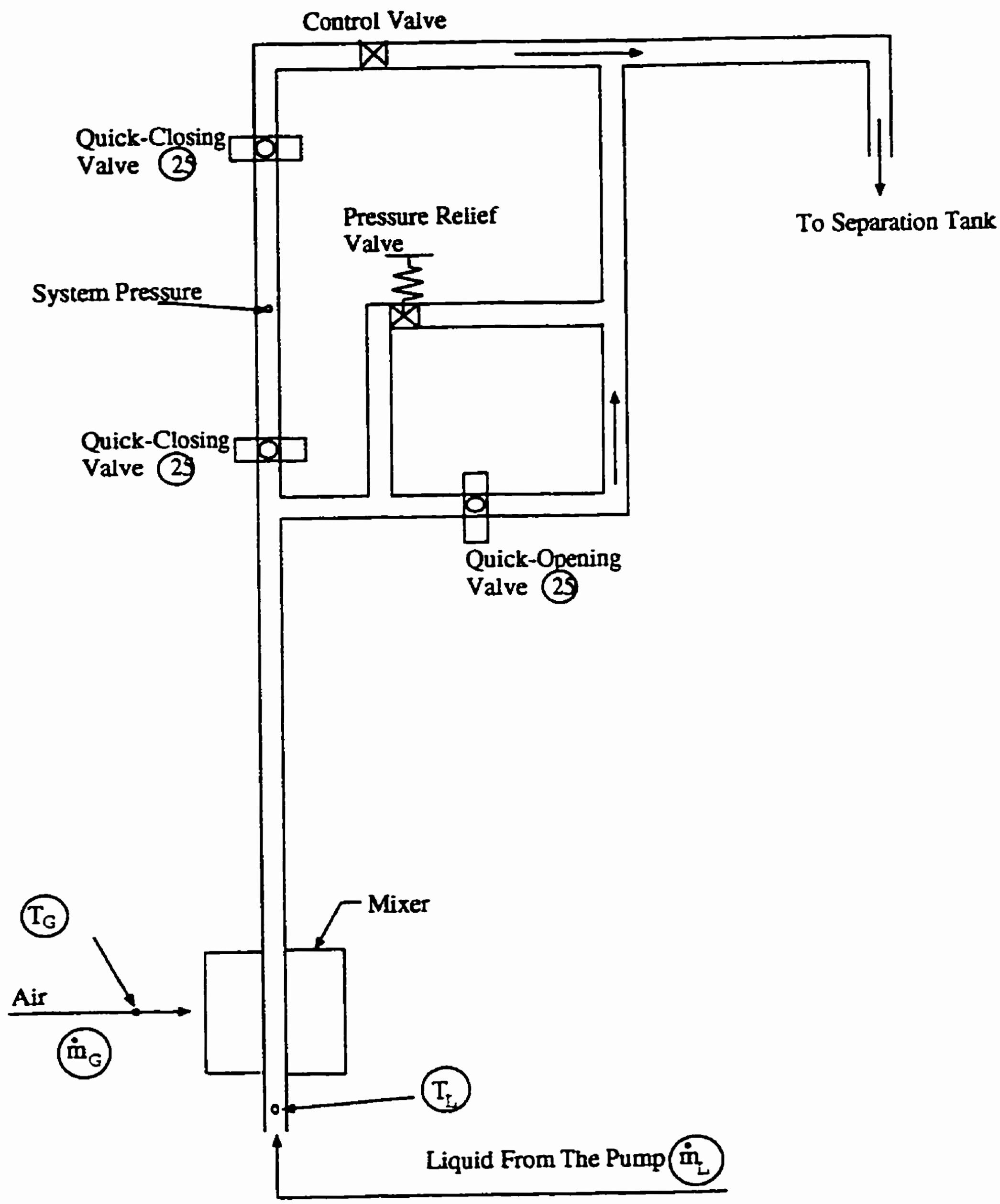

Figure 4.2 Measured Variables For Void Fraction

Table 4.1 List of Variables Measured in the Present Experiments

Power to Test Section		Guard Heater		Liquid Flow Rate		Test Section Pressure	
(I) Ammeter Reading	**(V) Voltmeter Reading**	**TC No.54 & No. 55**	**TC No.60 & No. 61**	**Meter No.**	**Reading (%)**	P_{IN}	ΔP_{TOTAL}
Used to calculate the local heat flux	VI was used to check the power input to the test section	Were adjusted to control the temperature of the guard heater		Used with the calibration curves to calculate $\dot{m}_L$		Pressure at inlet to the test section	Total pressure drop across the test section

Gas Line Data			
O.P.N.	P_G	ΔP_{OR}	P_{GL}
Orifice plate or rotameter no.	Press. at inlet to the orifice or rotameter	Press. drop across the orifice plate or rotameter reading	Gas pressure in the supply line
used, together with the gas temperature at the inlet to the orifice plate assembly (T_{G}), to calculate the gas flow rate ($\dot{m}_G$)			
Barometric pressure	Measured at beginning and the end of each run		
Flow pattern	Observed visually and photographed for each test		
Void Fraction (α)			
Identifying the location of gas-liquid interface in order to obtain the volume occupied by the air			

Thermocouple Readings	
TC No.	To measure the temperature of
1-4	Top and bottom bus bars
5-47	The outer wall of the heated test tube (T_o)
52-63	The inner wall of the guard heater
	The mixture at the outlet of the test section (T_{out})
	The water at the inlet to the mixer (T_L)
	The gas at the inlet to the orifice plate assembly (T_{GI})

Table 4.2 Range of Variables in the Present Two-Phase Study

Variable	Air - Water min.	Air - Water max.	Air - G1 min.	Air - G1 max.	Air - G2 min.	Air - G2 max.
$\dot{m}_L$ (kg/hr)	21.54	3,297.71	21.08	2,718.83	22.92	2,043.71
$\dot{m}_G$ (kg/hr)	0.00916	88.88	0.02292	60.92	0.02292	47.89
V_{SL} (m/s)	0.055	8.462	0.0458	6.091	0.0488	4.328
V_{SG} (m/s)	0.0214	118.879	0.0458	62.3628	0.0336	72.23
$\bar{q}''$ (kW/m^2)	14.578	258.18	2.694	46.988	2.426	8.588
T_{MIX} (°C)	17.81	31.77	18.67	32.94	16.05	23.97
Re_{SL} (-)	621	1.068×10^5	69.3	9,406	10.4	672
Re_{SG} (-)	16.5	1.484×10^5	36.4	9.94×10^4	39.2	7.935×10^4
Pr_L (-)	5.5	7.2	49.3	79.5	499	766
Pr_G (-)	0.801	0.812	0.802	0.814	0.793	0.813
α (-)	0.05845	0.9858	0.0107	0.9845	0.0066	0.9040
$\bar{h}_{TP}$ (W/m^2· K)	2,080	38,196	433	5,794	177	1,970
P_{mean} (abs) kPa	101.35	342.66	106.18	306.81	110.31	281.99
flow pattern	Bubble to Annular-Mist		Bubble to Annular-Mist		Bubble to Annular	

(ii) Acquisition of Data (Section 4.3.1 and 4.3.2).

(iii) Flow-Pattern Observation (Section 4.5).

2) For Void-Fraction Measurement.

(i) Start-up and shut-down procedures (Section 4.2.2 and 4.2.3).

(ii) Acquisition of Data (Section 4.4.1 and 4.4.2).

(iii) Flow-Pattern Observation (Section 4.5).

For each particular air-liquid system, step 1 was used to conduct the experiment on heat transfer and pressure drop until the air-liquid system was completed. After that, the same air-liquid system was used for void-fraction measurements where step 2 procedures were used.

4.2 START-UP AND SHUT-DOWN PROCEDURES

In order to obtain proper experimental data and to avoid any damage to the equipment, the following steps of preparation were taken:

(i) Cooling water was fed to the heat exchanger.

(ii) The temperature-measuring instruments (i.e., data logger, DVM, ice-point reference unit) were switched on approximately one hour prior to the tests to obtain an adequate warm-up time.

(iii) A check was made that the air lines from orifice plates to the well-type manometer were clear by bleeding air through them.

(iv) The water level in the well-type manometer was checked and, if necessary, adjusted.

After the above preparation procedures, air was supplied to the mixing chamber before any liquid in order that the mixer always started with a dry condition for the two-phase tests; this also ensured that no liquid could leak into the air line.

4.2.1 Start-Up Procedure for Heat-Transfer and Pressure-Drop Tests

The following procedures were taken to start-up the heat-transfer and pressure-drop tests:

1) The air flow rate through an orifice plate (or rotameter) was adjusted using the pressure controller and needle valve downstream of the orifices (or rotameter).

2) The pump was turned on with the by-pass valve to the liquid storage tank fully open.

3) All pressure transmitter leads containing liquid were checked for the presence of air and purged if necessary. This step was repeated as often as required during the course of the experiments.

4) The liquid flow rate was set to the desired value by a combination of closing the by-pass valve at the liquid pump discharge and adjusting the control valve on the appropriate liquid flowmeter. To obtain stable liquid flow rates, a large pressure difference across the control valve upstream of the liquid flowmeter was maintained. The liquid flowmeter was monitored regularly during the experiment and adjusted if necessary.

5) Simultaneously with step 4, the air flow rate was monitored closely and readjusted to the desired value.

6) The power supply to the heated test section was turned on with the power-control variac setting at zero. Then, the power supply was slowly increased to the desired value (criterion discussed later).

7) The power supplies to the upper and lower guard heaters were turned on with their setting at zero input value.

In single-phase flow tests, the same steps described above were taken, excluding steps 1 and 5.

4.2.2 Start-Up Procedure for Void-Fraction Measurement

For void-fraction measurement, the start-up procedures in Section 4.2.1 were used excluding steps 3, 6, and 7. As mentioned in Section 3.4, the inner diameter of the tube used as the void-fraction measuring section and its calming section were 12.7-mm (0.5 in.), while the heated test section diameter was 11.68-mm (0.46 in.). However, it has been demonstrated by Chrisholm (13) that the controlling parameter of void fraction, for fixed fluid properties, is the two-phase quality, x. Therefore, the superficial velocities of both phases, temperature and pressure, at the mid-way point of the void-fraction measuring section were kept as close as possible to those of the corresponding datum point of heat-transfer and pressure-drop tests. More details are given in Section 4.4.1.

4.2.3 Shut-Down Procedures

After each run was completed, the rig was shut down in the following steps:

1) The power sources to the heated test section and guard heaters were switched off. This step was only for the heat-transfer and pressure-drop runs.

2) After some time (when the wall temperature had closely approached the liquid temperature), the by-pass valve on the liquid pump discharge was opened fully.

3) The control valve on the liquid flowmeter was closed.

4) The liquid pump was shut off.

5) The cooling water to the heat exchanger was shut off.

6) The liquid in the test section and calming section was drained out.

7) The air flow rate was adjusted to a high value and left running through the mixing chamber for some time to dry the mixing chamber and test section. Then, the air supply was shut off.

4.3 ACQUISITION OF DATA ON HEAT TRANSFER AND PRESSURE DROP

4.3.1 Establishing Steady-State Conditions

During the course of experiments, it was of course important to establish steady-state conditions before taking data. The following variables were continuously monitored and adjusted until desired steady conditions were reached before taking any data.

1) The liquid inlet temperature to the mixing chamber.

2) The wall temperature at seven elevations along the heated test section tube.

3) The guard-heater temperature at two elevations.

4) The power supply to the test section.

The liquid inlet temperature (T_L) was maintained at approximately 21 °C. This was done by controlling the cooling water rate to the heat exchanger. This was then monitored and the fluctuations kept in the range of ± 0.05 °C (0.1 °F).

The electrical power to the heated test section was supplied based on the following considerations: (T_W - T_B) should be small enough so as to keep radial variations in fluid properties small, but large enough so as to obtain accurate values of the heat-transfer coefficient (here T_W is inner wall temperature and T_B is fluid bulk temperature). A temperature difference (T_W - T_B) of about 7.5 °C was considered to be suitable for these requirements.

In order to obtain steady-state conditions, temperatures and flow rates were monitored and adjustments were made until they were steady for ten minutes. The steady-state conditions were deemed to prevail when the difference between the readings (for both wall temperatures and the liquid temperature at the inlet (to the mixer, T_L)) of two successive recorded emf's (the time interval was 5 to 7 minutes) was within ± 0.05 °C (± 0.1 °F).

During the course of all the experiments, it was attempted to keep approximately the same temperature difference (T_W - T_B) at mid-point of the test section. The spread in (T_W - T_B) for the entire series of the tests was as follows:

Air-Water	8.1 ±2.5 °C
Air-G1	7.9 ± 2.5 °C
Air-G2	7.2 ± 2.0 °C

The guard-heater temperatures at two elevations (no. 54-55 and no. 60-61) at approximately 0.3 and 0.7 of the heated length were checked regularly and, if necessary, the power supply level, for each guard heater, was independently adjusted to bring the guard heater temperatures as close as possible to the wall temperatures at corresponding elevations. An attempt was made in such a way that the temperature difference, between guard heaters and outer surface of the heated tube, did not differ by more than approximately ± 0.15 °C (± 0.3 °F).

For conditions where slug flow prevailed, the wall temperatures fluctuated considerably. Only T_L was used to check whether otherwise steady-state conditions prevailed.

4.3.2 Taking of Data

After steady-state conditions were established, all variables listed in Table 4.1 (except the part for void-fraction measurement) were read and recorded to determine heat-transfer and pressure-drop results. Among these variables, the thermocouple readings were collected last. Normally, six samples of thermocouple readings were taken; however, 10 samples of such reading were taken in the case of slug flow. Table 4.2 gives the range of variable obtained in the present study. Table 4.3 shows the matrix of the whole experiment in terms of superficial velocities.

Table 4.3 The Matrix of the Experiment

Gas-Liquid	V_{SL} m/s	Range of V_{SG} m/s (Min.-Max.)
Air - Water	0.055	0.540 - 113.048
	0.116	0.987 - 118.264
	0.311	0.591 - 107.406
	1.042	0.021 - 68.958
	3.170	0.043 - 31.699
	6.346	0.277 - 18.288
	8.464	0.463 - 9.339
Air - G1	0.046	0.079 - 81.574
	0.418	0.046 - 76.322
	1.033	0.046 - 62.225
	2.682	0.040 - 31.200
	6.081	0.034 - 9.147
Air - G2	0.049	0.052 - 81.879
	0.366	0.046 - 57.693
	2.877	0.034 - 10.763
	4.319	0.027 - 0.923

4.4 ACQUISITION OF DATA ON VOID FRACTION

4.4.1 Establishing Steady-State Conditions

As mentioned earlier, the void-fraction measurements were conducted after the heat-transfer and pressure-drop tests for each liquid. The following steps were taken to establish steady-state conditions:

1) The superficial velocities of both air and liquid were adjusted until they approached (within ± 3 %) those of the corresponding datum point in the heat-transfer and pressure-drop tests.

2) The temperature of the two-phase mixture at the mid-way point of the measuring section was determined and, if necessary, adjusted to be as close as possible (within ± 0.1 °C) to the mean bulk temperature of the corresponding datum point in the heat-transfer tests.

3) The system pressure at mid-way point of the measuring section was kept as close as possible (within 0.7kPa or 0.1 psi) to the system pressure of the corresponding heat-transfer datum point.

Steady-state conditions were deemed to prevail when the pressure and temperature of the mid-way point between the two quick-closing valves had been steady for approximately 7 minutes.

4.4.2 Taking of Data

After steady-state conditions were established, the two-phase mixture was flowing through the measuring section, and the following steps were taken:

1) The two quick-closing valves were snapped to the closed position while the quick-opening by-pass valve opened to let the mixture flow through the by-pass section to the separation tank.

2) The gas-liquid interface was located and air-volume fraction (void fraction) was then calculated. This step was taken several minutes after step 1 to ensure that the liquid had drained off the wall above the gas-liquid interface line. At the upper and lower ends of this measuring section, the gas-liquid interface could not be seen due to part of the body of the quick-closing valves. If this happened, liquid of a measured amount was either withdrawn from, or fed into, the section until the gas-liquid interface was seen.

3) In preparation for the next test, the quick-closing valves were switched to the open position and at the same time the quick-opening by-pass valve was switched to the closed position.

For each datum point, several samples of void fraction were collected by repeating steps 1 to 3. The arithmetic mean of samples was then obtained to represent the value of mean void fraction of each datum point. Due to the high viscosity of G2, which required a long time to have a dry-wall condition above the gas-liquid interface, the number of samples taken was reduced. However, in the case of slug flow, the number of samples was increased in order to obtain an adequate representation of the mean value. Table 4.4

shows the numbers of samples taken for each setting of the gas and liquid flow rate for the three air-liquid systems.

4.5 FLOW PATTERN OBSERVATION

For the heat-transfer and pressure-drop tests, after the air and liquid flow rates were set and the flow reached steady-state conditions, the flow patterns were first observed by naked eye with a 100-watt incandescent light providing back lighting. A stroboscope was also used to identify the flow pattern. The flow pattern observations were then recorded on the data sheet. A photograph was taken for each test using the photographic set-up shown in Figure 3.8. The photograph was later used together with the corresponding record on the data sheet for final flow-pattern identification.

At each datum point of void-fraction measurement, after the flow reached steady-state conditions, the flow was observed by naked eye using the 100-watt incandescent lamp light and stroboscope. It was found that each observed flow pattern was the same as the one observed in the corresponding heat-transfer and pressure-drop test.

Table 4.4 Number of Samples Taken in Void-Fraction Measurement for Each Setting of Gas and Liquid Flow Rates

Mixture	Flow Pattern	No. of Samples
Air-Water	Slug	12
	Others	7
Air-G1	Slug	6
	Others	5
Air-G2	Slug	4
	Others	3

Chapter 5

RESULTS AND DISCUSSION OF SINGLE-PHASE LIQUID FLOW

5.1 INTRODUCTORY REMARKS

This chapter presents the results and a discussion of single-phase liquid tests using the three liquids of the two-phase experiments. The purpose of conducting single-phase tests was to check the performance and reliability of the experimental facility; as well, the single-phase data appear in a number of two-phase correlations. If the single-phase results for pressure drop and heat transfer agree with well-established theories or empirical results, then it is fair to assume that the facility is suitable for two-phase study. The single-phase experimental results are discussed according to:

1) Frictional pressure drop, and

2) Local and mean heat-transfer coefficients.

Two parameters, as defined by Equations 5.1 and 5.2, are employed to indicate the deviations between the experimental results and the predictions using correlations or theoretical expressions. These same parameters are used throughout the thesis wherever needed.

$\bar{e}$ = the mean algebraic deviation

$$\bar{e} = \left\{ \frac{1}{N} \sum \frac{V_{exp} - V_{pred}}{V_{pred}} \right\} \times 100 \quad (\%) \tag{5.1}$$

$\bar{e}_{rms}$ = the r.m.s. deviation

$$\bar{e}_{rms} = \left\{ \frac{1}{N} \sum \left[\frac{V_{exp} - V_{pred}}{V_{pred}} \right]^2 \right\}^{1/2} \times 100 \quad (\%) \tag{5.2}$$

where

N = the number of experimental data points used in the comparison,

V_{exp} = the experimental value of the variable, and

V_{pred} = the predicted value of the same variable.

5.2 SINGLE-PHASE PRESSURE DROP

The experimental frictional pressure drop was calculated using measured total pressure drop (taken simultaneously with heat-transfer results) and the method described in Appendix D. This frictional pressure drop was then converted to a single-phase friction coefficient, f_{sp}, a dimensionless variable, and compared with the corresponding predicted value from the equations given below:

$$f_{sp} = 16\ Re_{SL}^{-1} \quad ; \quad Re_{SL} \leq 2000 \tag{5.3}$$

$$f_{sp} = 0.079\ Re_{SL}^{-0.25} \quad ; \quad 2000 < Re_{SL} < 30{,}000 \tag{5.4}$$

$$f_{sp} = 0.046\ Re_{SL}^{-0.2} \quad ; \quad Re_{SL} \geq 30{,}000 \tag{5.5}$$

Figure 5.1 shows the comparison between the experimental and predicted values of the friction coefficient, f_{sp}, for all liquids used in the experiments. The experimental friction coefficients were corrected to constant-property values as recommended in Kays

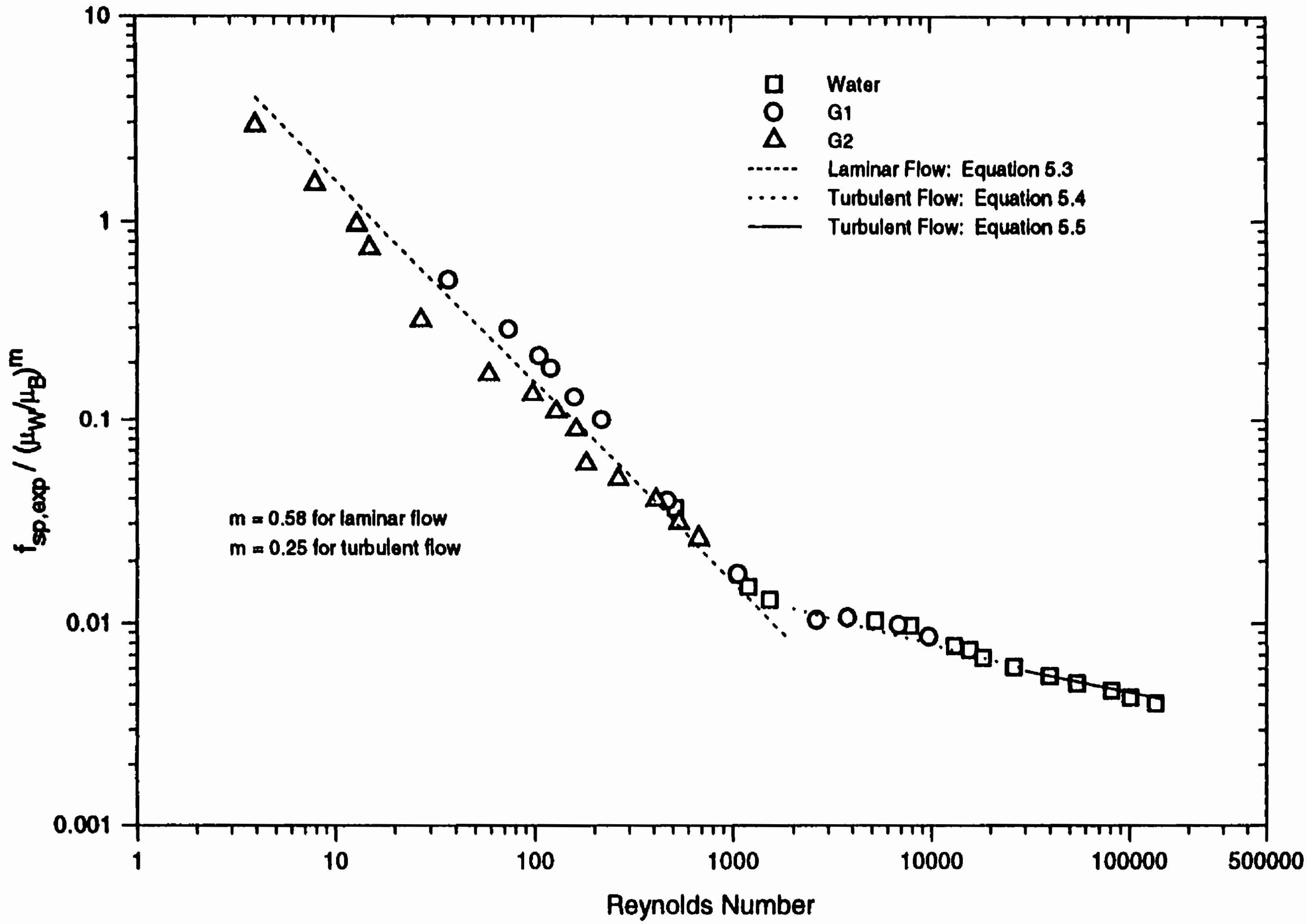

Figure 5.1 Comparison of the Single-Phase Friction Coefficient with Correlations

and Crawford (46). Table 5.1 shows the deviations between the predictions and the corrected values in both laminar and turbulent flows.

Table 5.1 Summary of Comparison of the Single-Phase Pressure-Drop Tests

Liquid	Laminar Flow			Turbulent Flow		
	N	$\bar{e}$ (%)	e_{rms} (%)	N	$\bar{e}$ (%)	e_{rms} (%)
Water	3	17.7	18.3	11	1.8	6.3
G1	8	30.5	32.2	4	4.4	7.9
G2	14	-18.6	23.6	-	-	-

In the turbulent region, the experimental results for water and G1 (no G2 results) show excellent agreement with the predictions. In the laminar region, the results in Table 5.1 indicate reasonable agreement between the experimental data and the predictions. The deviations in this region are greater than those in the turbulent region which may be caused by some combination of the following: (i) for water and some of the G1 data, the frictional pressure drops are very small (less than 2.5 cm of water) where the measurement errors are larger than for the higher pressure drops, (ii) some vibration may be introduced into the system by the pump, and (iii) the correction for fluid properties (wall to bulk) may not be entirely correct.

5.3 SINGLE-PHASE HEAT TRANSFER

This section presents the experimental results of both local and mean heat transfer. The experimental local heat-transfer coefficients were calculated from:

$$h_{sp} = q''_W/(T_W - T_B) \qquad (5.6)$$

where

h_{sp} = the local single-phase heat-transfer coefficient,

q''_W = the wall heat flux,

T_W = the wall temperature, and

T_B = the bulk temperature of the liquid.

Then, the mean heat-transfer coefficient was obtained through:

$$\bar{h}_{sp} = \frac{1}{\Delta z}\int_{z_1}^{z_2} h_{sp}\,dz \qquad (5.7)$$

where

$\bar{h}_{SP}$ = the mean single-phase heat-transfer coefficient,

z = the axial distance,

z_1, z_2 = the axial distances the first and the last temperature-measuring locations used,

Δz = $z_2 - z_1$.

The results for both local and mean heat transfer are presented and discussed below.

5.3.1 Local Heat-Transfer Results

Figures 5.2 to 5.4 show plots of local heat-transfer coefficients, for the three liquids, as a function of axial distance z along the heated tube. These experimental data were compared quantitatively with predictive methods in laminar flow. Although not

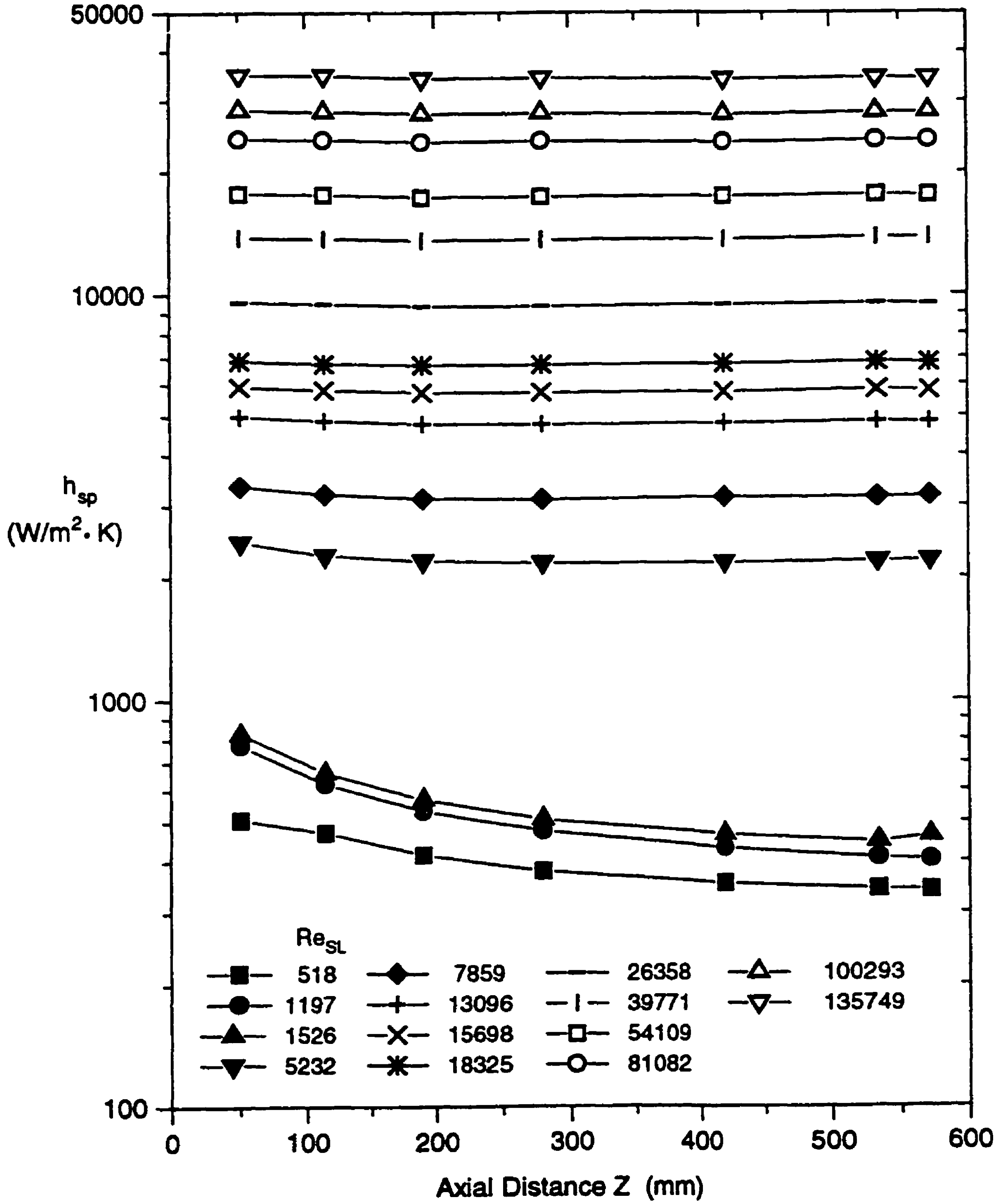

Figure 5.2 Single-Phase Water Local Heat-Transfer Results

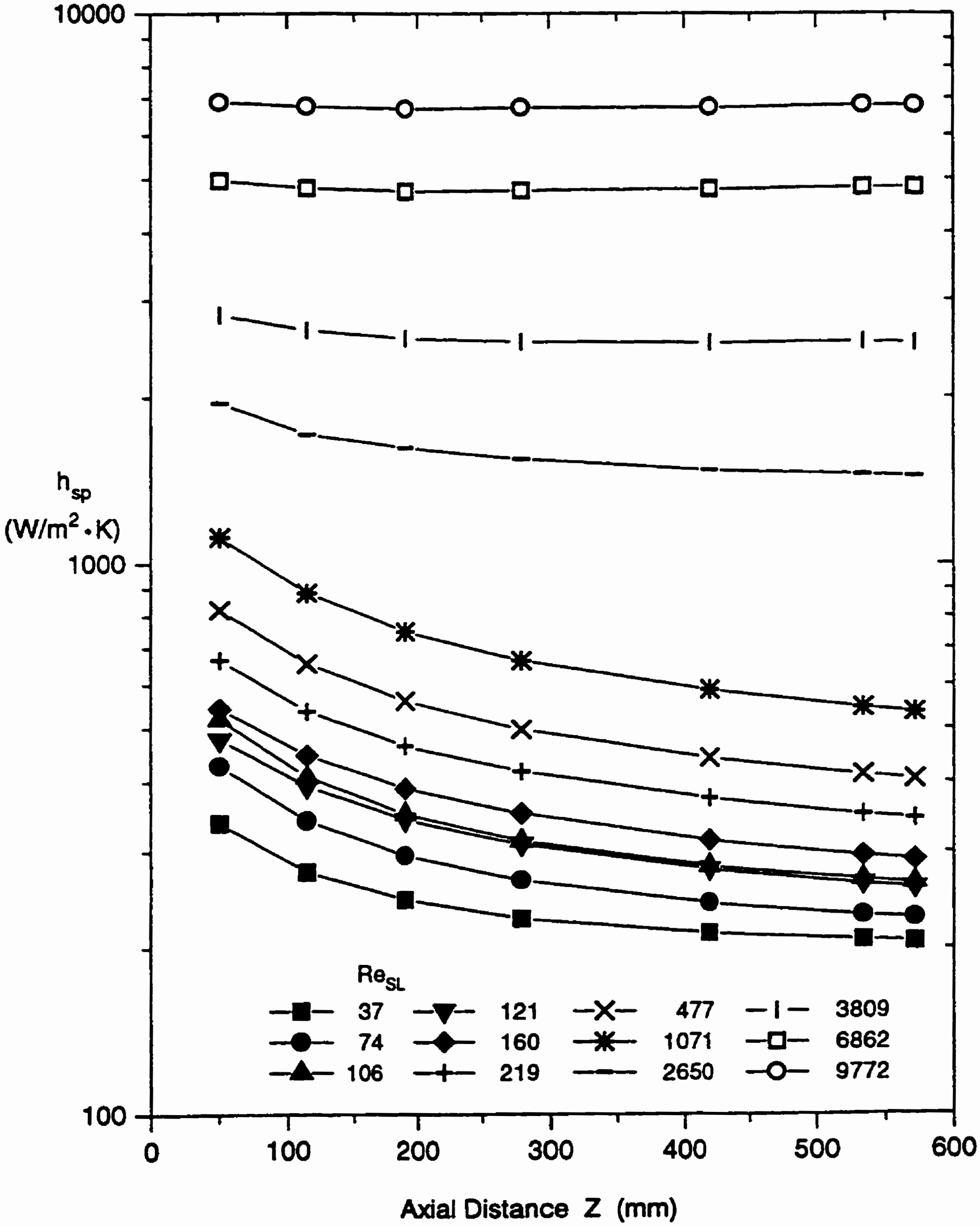

Figure 5.3 Single-Phase G1 Local Heat-Transfer Results

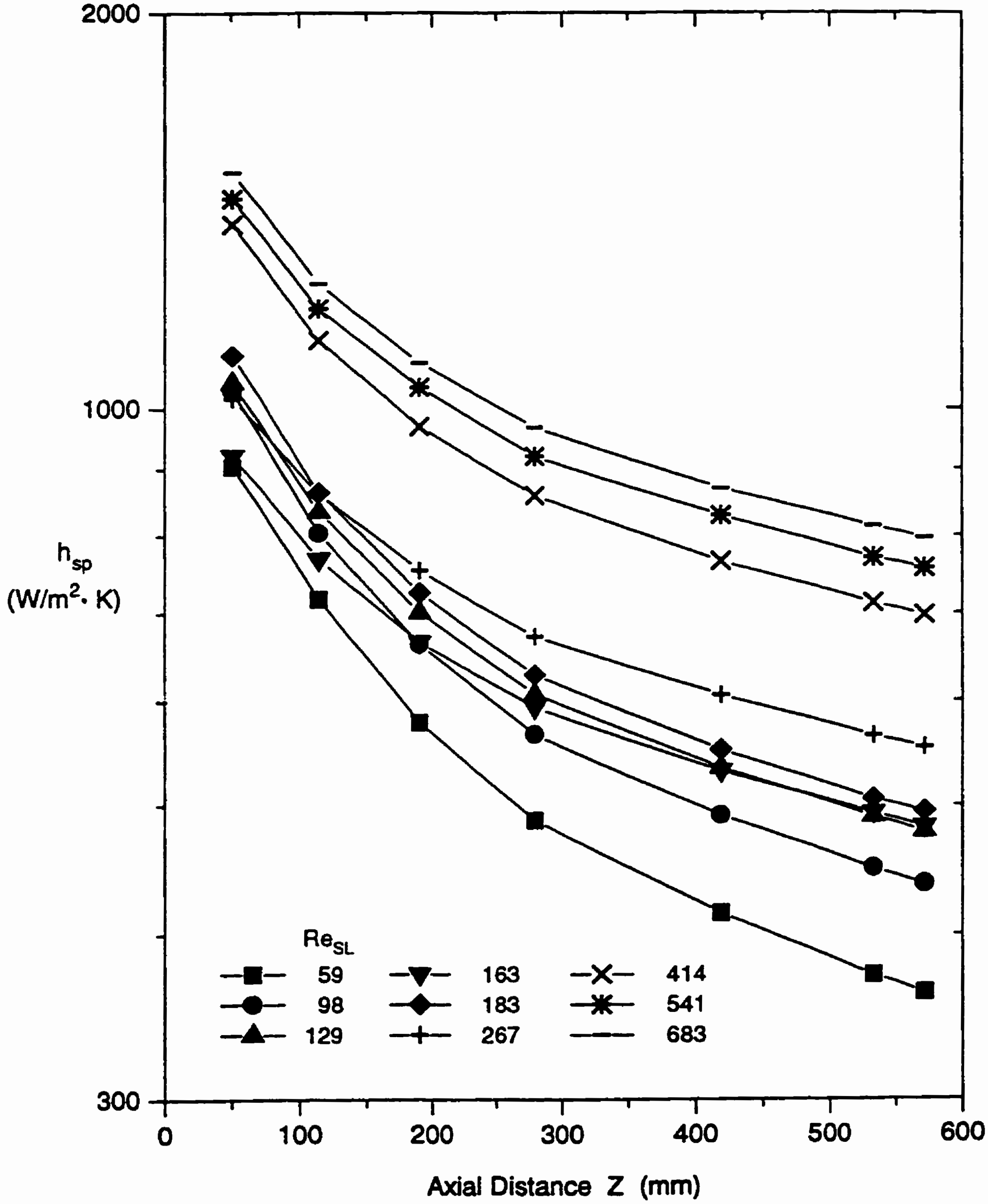

Figure 5.4 Single-Phase G2 Local Heat-Transfer Results

meant to be a test of the single-phase data, some material dealing with local heat-transfer coefficientsin turbulent flow appears in Appendix F.

The experimental heat-transfer data for laminar flow ($Re_{SL} \leq 2000$) were compared with the predictions of the following expression as recommended by Kakac et al. (43).

$$Nu_{\varphi} = \begin{cases} 1.302\,(Z^{*\,-1/3}) - 1 & \text{for } Z^{*} \leq 0.00005 \\ 1.302\,(Z^{*\,-1/3}) - 0.5 & \text{for } 0.00005 \leq Z^{*} \leq 0.0015 \\ 4.364 + 8.68\,(10^{3} Z^{*})^{-0.506}\, e^{-41 Z^{*}} & \text{for } Z^{*} \geq 0.0015 \end{cases} \qquad (5.8)$$

where

Z^*	=	$(z/D)/(Re_{SL} \cdot Pr_L)$,
z	=	the axial distance,
D	=	the tube diameter,
Re_{SL}	=	the liquid Reynolds number, and
Pr_L	=	the liquid Prandtl number

Figure 5.5 shows the comparison of experimental data (after corrections for variations in fluid properties, as recommended by Kays and Crawford (46)), against the predictions using Equation 5.8. Table 5.2 summarizes the deviation of the experimental data from the predictions. In general, the results show excellent agreement between experiments and predictions in laminar flow for all three liquids.

An examination of Figures 5.2 to 5.4 would show that, for turbulent flow (Re_{SL} > 2000), the fully developed conditions cover practically the whole length of the tube.

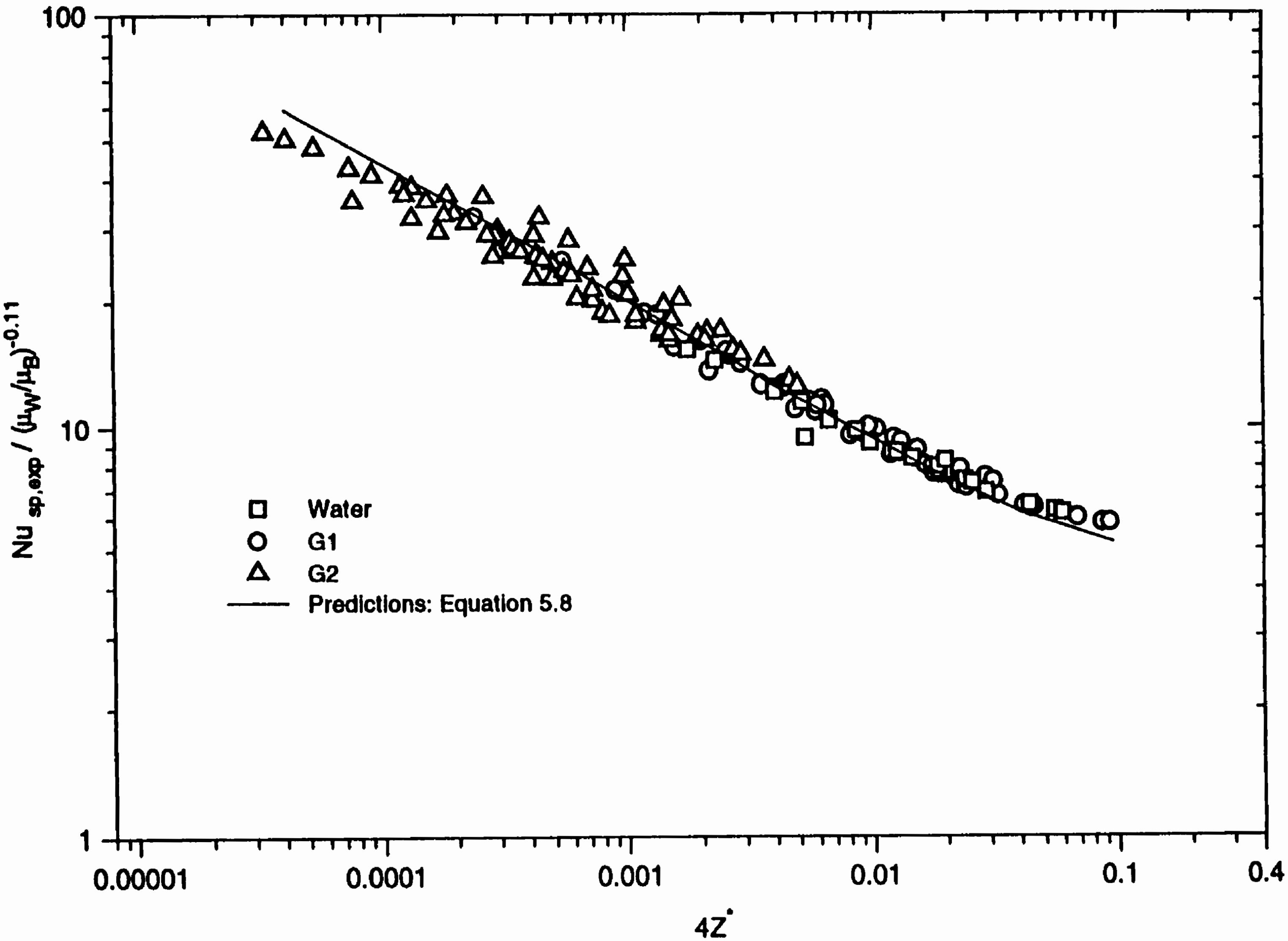

Figure 5.5 Comparison of Experimental Data for Laminar Flow

Therefore, it would appear that an adequate test for turbulent flow would be comparison against a well-accepted correlation for mean heat-transfer coefficients which is done below.

Table 5.2 Summary of Comparison of Single-Phase Local Heat-Transfer in Laminar Flow

Liquid	No. of points	$\bar{e}$ (%)	$\bar{e}_{rms}$ (%)
Water	21	0.85	6.37
G1	56	2.41	5.81
G2	63	-2.92	11.04

5.3.2 Mean Heat-Transfer Results

The experimental mean heat-transfer coefficients were obtained using Equation (5.7). These experimental data were compared with the well-known correlations recommended by Sieder and Tate (82) for laminar and turbulent flows. The details are as follows:

1. Laminar Flow ($Re_{SL} \leq 2000$)

The following expression was used to predict mean heat-transfer coefficients in the laminar region:

$$\overline{Nu}_{sp} = 1.86\,(Re_{SL}\,Pr_L\,D/L)^{1/3}(\mu_B/\mu_W)^{0.14} \tag{5.9}$$

Figure 5.6 shows the plot of experimental data compared with the predictions. As shown in Table 5.3, there is generally excellent agreement between the experimental data and the predictions ($\bar{e}_{rms}$ of 3.7, 6.4 and 14.1% for water, G1 and G2, respectively).

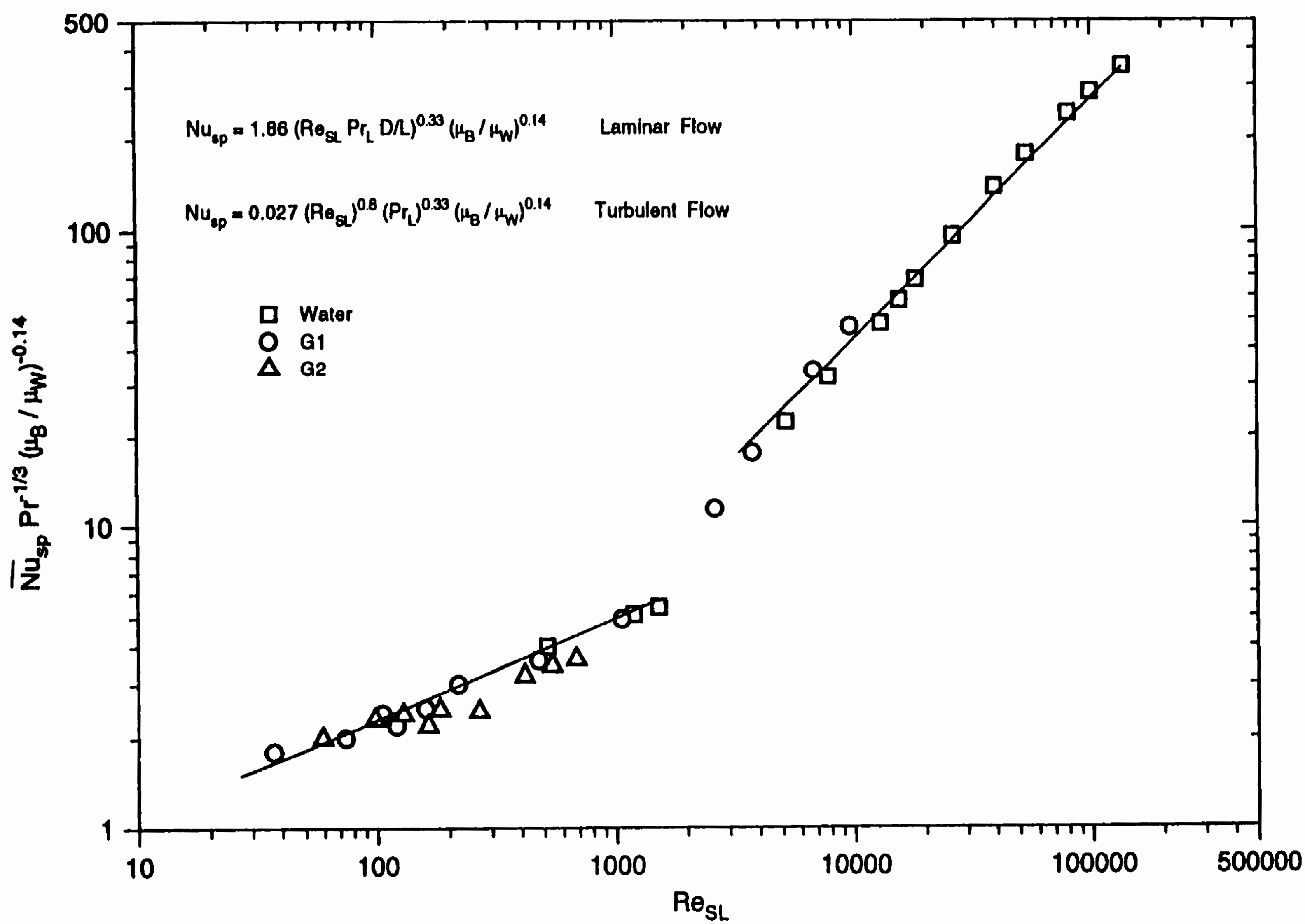

Figure5.6 Comparison of Single-Phase Mean Heat-Transfer Data with the Correlations of Sieder and Tate

2. Turbulent Flow ($Re_{SL} > 2000$)

The Sieder-Tate correlation, as recommended by Incropera and DeWitt (39), for turbulent flow is given by

$$\overline{Nu}_{sp} = 0.027\,(Re_{SL})^{0.8}\,(Pr_L)^{1/3}\,(\mu_B/\mu_W)^{0.14} \tag{5.10}$$

This correlation is applicable over a wide range of Pr, i.e., $0.7 < Pr_L < 16{,}700$. Figure 5.6 indicates very good agreement between the experimental data and the predictions for $Re_{SL} > 3800$ (the authors recommended the correlation for $Re_{SL} \geq 10{,}000$).

Table 5.3 Summary of the Mean Heat-Transfer Data

Liquid	Laminar			Turbulent*		
	N	$\bar{e}$ (%)	$\bar{e}_{rms}$ (%)	N*	$\bar{e}$ (%)	$\bar{e}_{rms}$ (%)
Water	3	-3.0	3.7	11	-0.6	6.9
G1	8	-3.7	6.4	3	2.1	10.0
G2	9	-10.8	14.1	-	-	-

* $Re_{SL} \geq 3800$

5.4 SUMMARY

According to the material presented in this chapter, the results for both pressure drop and heat transfer lead to the following conclusions:

1) The experimental results for local and mean heat-transfer coefficients agree well with those predicted by well-established single-phase predictions.

2) The experimental results for friction coefficients show good agreement when compared with predictions, especially in the turbulent flow region.

3) In general, the experimental facility continues to perform satisfactorily. Therefore, the two-phase-flow data, presented in the next chapter, should be reliable.

Chapter 6

FLOW PATTERN, VOID FRACTION AND PRESSURE DROP IN TWO-PHASE FLOW

6.1 INTRODUCTORY REMARKS

This chapter presents the hydrodynamic results of the two-phase flow investigated in the present study. The two-phase hydrodynamics includes flow pattern, void fraction and pressure drop. The two-phase flow pattern is an important feature in any two-phase gas-liquid flow study. In different flow patterns, the gas and liquid phases interact with each other in a unique manner leading to unique two-phase pressure-drop and heat-transfer behaviour. The purpose of the flow-pattern observations here is to provide information so that pressure drop, heat-transfer and void-fraction data can be discussed in terms of flow pattern when needed. The descriptions of the two-phase gas-liquid flow patterns in a vertical tube are given together with example photographs, Figure 6.1, of the basic flow patterns. Table 6.1 gives information on the number of tests where the various flow patterns were observed in this study. The same flow pattern codes in Table 6.1 are also used throughout the thesis. Flow-pattern maps for each gas-liquid system are presented. The flow-pattern data are then compared with some existing flow maps from the literature. The actual mean void-fraction data measured during the course of experiment are then given and compared with some predictive methods. The final section presents the total and frictional pressure-drop data of all three air-liquid systems. The present frictional pressure drop data are compared with some existing correlations.

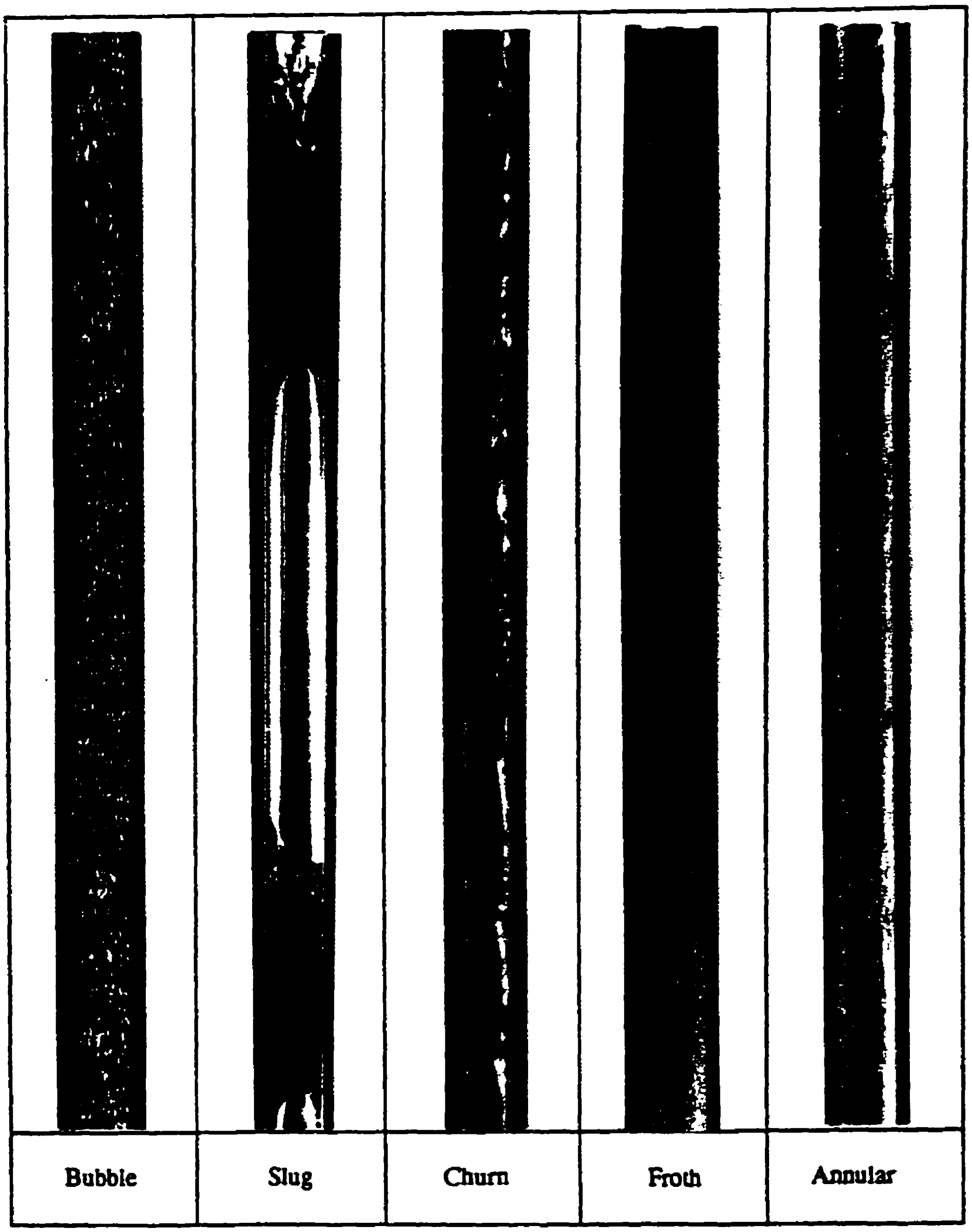

Figure 6.1 Flow Patterns in Co-Current Vertical Flow

Table 6.1 Summary of the Flow Pattern Observations in the Present Study

Flow Pattern	Flow-Pattern Code	Number of Tests (where the indicated flow pattern was observed)			Total
		Air-Water	Air-G1	Air-G2	
Bubble	B ○	13	15	2	30
Slug	S △	16	9	15	40
Churn	C ▽	7	6	5	18
Annular	A □	12	20	18	50
Froth	F ◇	11	8	-	19
Bubble-Slug	B - S ⊖	4	1	4	9
Bubble-Froth	B - F ⊙	7	3	-	10
Slug-Churn	S - C △	5	5	3	13
Slug-Annular	S - A △	-	-	3	3
Slug-Froth	S - F △	3	4	1	8
Churn-Annular	C - A ▽	4	2	-	6
Froth-Annular	A - F ◇	7	2	-	9
Annular-Mist	A - M □	15	2	-	17

6.2 DESCRIPTION OF FLOW PATTERNS

In vertical two-phase gas-liquid flow in a channel, the gas and liquid phases distribute themselves in a variety of flow patterns depending upon the flow rates of both phases, tube size, and fluid properties. These two-phase flow patterns have been studied by a number of investigators such as (9, 32, 35, 58, 61, 86, 96, 99). There is a large volume of literature in which the terminology and description of the flow patterns often varies from one study to another. Among these, the characterization and description proposed by Hewitt and Hall-Taylor (35), Taitel et al. (86) and Wallis (96) appear to be the best. Their descriptions were used to classify the flow patterns involved in the present study. To classify the two-phase gas-liquid flow patterns, the following definitions were used:

Bubble Flow: The liquid phase is the continuous phase. Typically, two types of bubble flow can be found in this flow regime. They are termed as "independent bubble" in which discrete bubbles are spaced one from the other and "packed bubbles" where bubbles touch each other. These two types of bubble flow were observed by Roumy (74).

Slug Flow: As the gas flow rate increases, bubble coalescence takes place and eventually the bubble diameter approaches the diameter of the tube. These large bubbles are typically "bullet-shaped" and are often termed "Taylor bubbles". These Taylor bubbles are separated by liquid slugs which may contain a dispersion of small bubbles. In slug flow, while the Taylor bubbles move up, the liquid phase flows down outside the Taylor bubbles in the form of a falling liquid film on the tube wall, even though the net flow of both gas and liquid phases is upward. Some investigators (e.g., 58 and 99) refer to the slug flow as "plug flow".

Churn Flow: With higher gas velocity, a breakdown of the Taylor bubbles leads to an unstable flow regime in which there is an oscillatory motion of liquid upwards and downwards in the tube. This oscillatory motion is found in wide-bore tubes, but may not take place in narrow-bore tubes in which case a smoother transition between slug and annular flows may be observed (36). During the course of the present experiment, churn flow was observed.

Annular Flow: With the increase of gas flow rate, the liquid phase flows along the wall as a wavy film and the gas phase flows in the centre of the tube. The liquid may contain fine gas bubbles and the gas core may contain entrained liquid droplets.

Mist Flow: When the gas velocity becomes greater, the liquid film along the tube wall becomes thinner and thinner and eventually the liquid film is swept away by the gas phase. The liquid phase is then entrained as very fine droplets in a continuous gas phase. In this present investigation, genuine mist flow did not occur. However, the transition pattern, annular-mist flow, was observed.

Froth Flow: Zaidi (100) gives a good description of this flow regime as "This flow pattern is mainly characterized by the existence of tiny bubbles in a packed form; these bubbles are practically indistinguishable individually. One gets the impression of a homogeneous flow and the mixture has a milky appearance". Froth flow occurs at high liquid and gas flow rates.

The preceding flow patterns are the basic flow patterns observed in the present study. In practice, often a two-phase flow does not clearly fall into one of these basic flow patterns. Instead, the two-phase flow contains elements of two basic flow patterns. Such a flow is classified as a "transition flow pattern". An example of a transition flow pattern is bubble-slug where one can observe big bubbles but not enough to be classified as Taylor bubbles. Other examples of transition flow patterns would be bubble-froth, slug-churn, churn-annular, annular-mist and annular-froth. For annular-mist, when one observes the flow by unaided eye the flow is somewhat transparent and gives the impression of mist flow. However, when a stroboscope is used to illuminate the flow, a thin film of liquid is observed along the tube wall. For the case of annular-froth, without the help of the stroboscope one has the impression of froth flow; however, a thin liquid film can be seen along the tube wall when the stroboscope is used. This liquid film can be observed in the annular-mist and froth-annular transitions from the photographs as well.

6.3 PRESENTATION OF DATA ON FLOW PATTERN MAPS

A two-phase gas-liquid flow pattern map is a plot of flow patterns together with transition boundaries using a co-ordinate system. In the literature there are mainly two basic types of co-ordinates which appear in the literature. With the first type, some investigators (9, 58, 61, 86, 99) used dimensional co-ordinates such as superficial velocities or mass flow rates of both phases. In the second type, investigators such as Griffith and Wallis (32) used dimensionless co-ordinates for the flow pattern map. Some authors such as Taitel et al. (86), McQuillan and Whalley (58) and Mishima and Ishii (61) attempted to generalize the presentation of the map using analytical expressions that determine the conditions necessary for the existence of each of the flow patterns.

In the present study, superficial velocities of both gas and liquid phases were used as co-ordinates for the flow-pattern maps to present the data. Figure 6.2 gives the present air-water data compared with transition boundaries constructed by Rezkallah (71), who used all previous air-water data taken independently from the same experimental rig to establish the boundaries. The present air-water data show good agreement with the transition boundaries of Rezkallah's map. Figure 6.3 shows the present air-G1 data when plotted on Rezkallah's map based on his air-58% glycerine data. In general, the present data agree reasonably well with Rezkallah's map. The present data suggest that the bubble-slug transition boundary should occur at higher superficial gas velocities (see the dashed line in Figure 6.3). In the region of the discrepancy between Rezkallah's boundary and the present dashed line, Rezkallah has only one datum point, this being bubble-slug and lying to the left of the present line suggesting bubble-slug transition. Figure 6.4 presents the flow regimes of the present air-G2 experiment.

All boundaries appear to be insensitive to liquid viscosity. For the bubble-slug boundary, it appears to move slightly to the right for air-G1, where for air-G2 it is roughly the same as for air-water; in total, though, considering the amount of data on which this observation is made and the difficulty of flow-regime determination, this boundary is reasonably insensitive to viscosity; this would be consistent with others' observations.

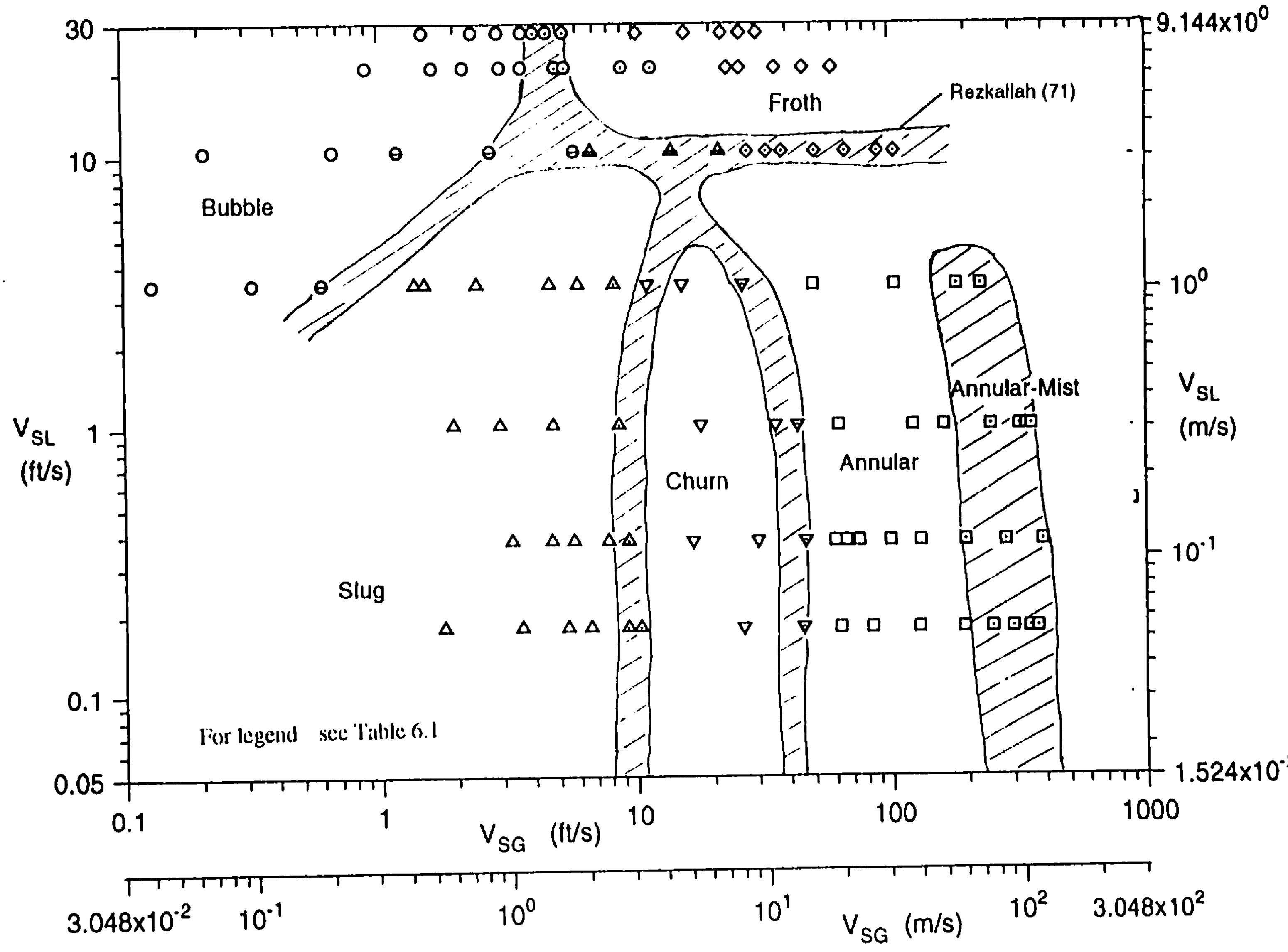

Figure 6.2 Present Air-Water Flow-Pattern Data

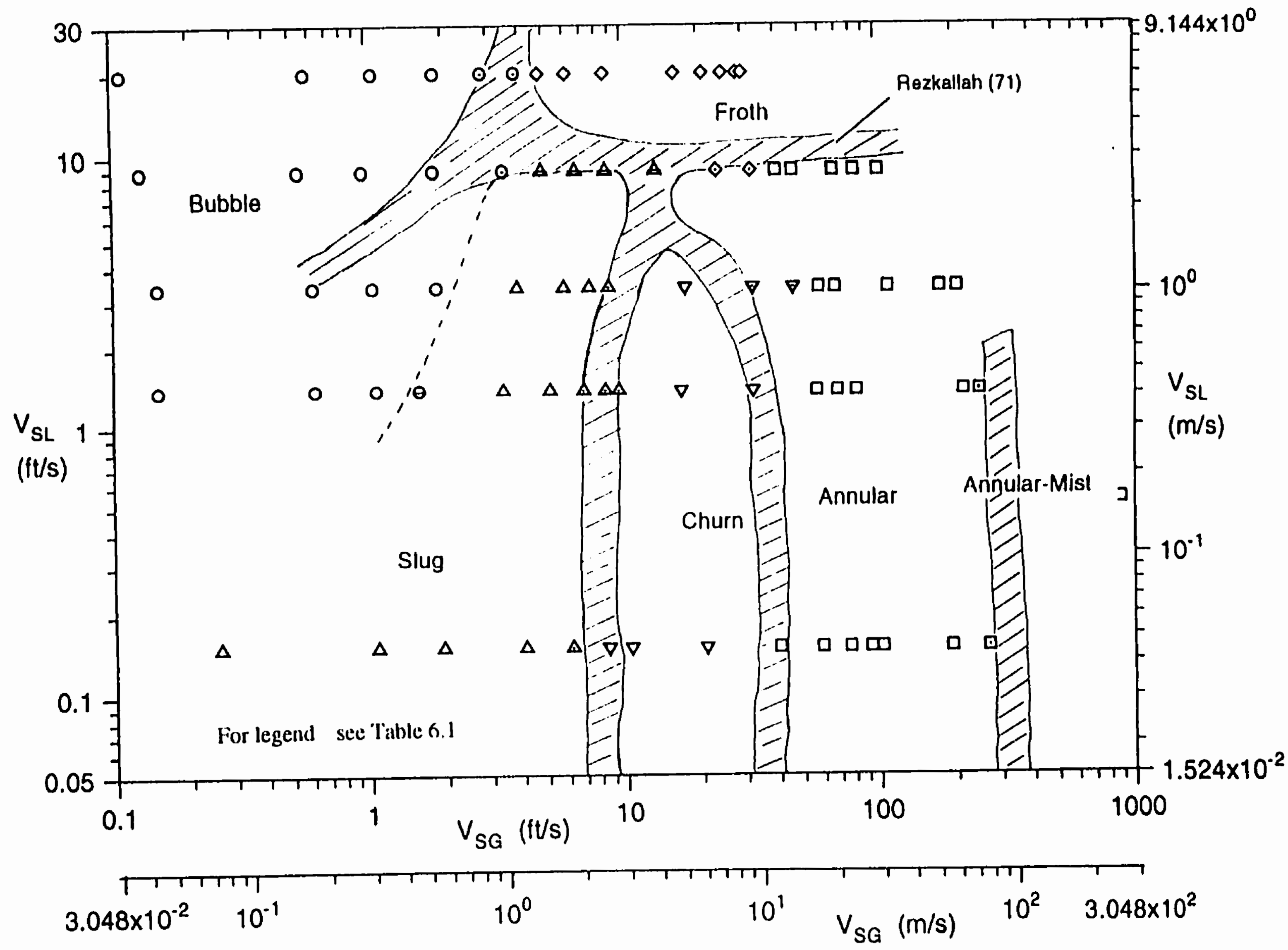

Figure 6.3 Present Air-G1 Flow-Pattern Data

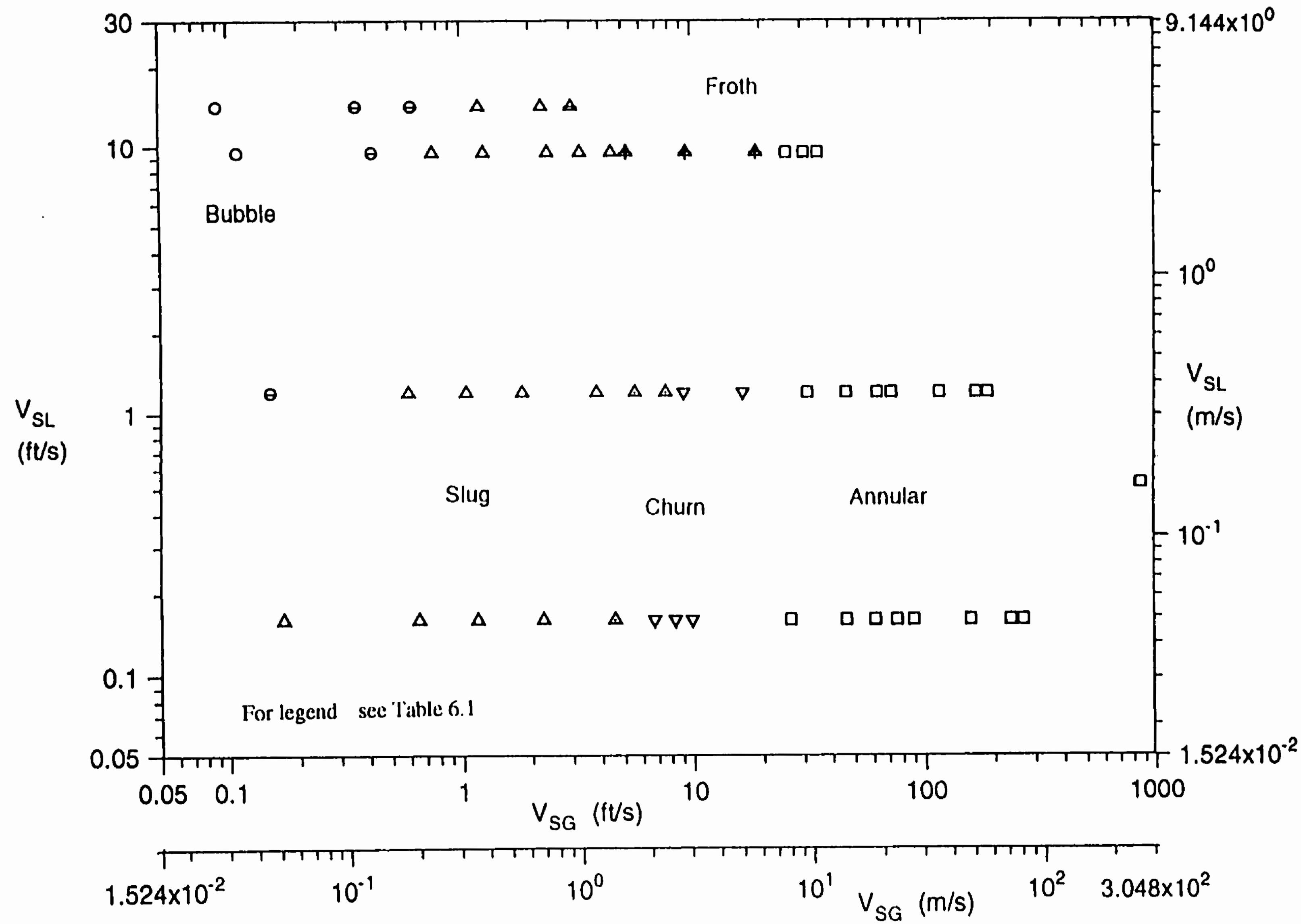

Figure 6.4 Present Air-G2 Flow-Pattern Data

To examine how closely the present data agree with some other studies in the literature, the present flow-pattern data were plotted on the maps of Govier and Aziz (29) and Taitel et al. (86). The Govier and Aziz map is based on data of Govier et al. (30), and correlations of Brown et al. (11) and Duns and Ross (24). The co-ordinate system of the maps includes the effect of velocities, densities and surface tension. The comparison of the present air-water data with the Govier and Aziz map is shown in Figure 6.5. The parameters Y^* and X^* are defined as

$$Y^* = \left[\frac{\rho_L \sigma_{WA}}{\rho_W \sigma_{LG}}\right]^{1/4} \qquad \text{and} \qquad X^* = Y^* \left[\frac{\rho_G}{\rho_A}\right]^{1/3}$$

where,

σ_{WA} = the surface tension of the air-water system at standard atmospheric conditions (taken as 15.5 °C and 101.3 kPa),

σ_{LG} = the surface tension of a given gas-liquid system under flow conditions,

ρ_L = the density of the liquid under flow conditions,

ρ_W = the density of water at standard atmospheric conditions,

ρ_G = the density of the gas under the flow conditions, and

ρ_A = the density of air at standard atmospheric conditions.

The original map of Govier and Aziz delineated four basic regions, namely, bubble, slug, churn (the original authors used the term "froth" for the present "churn") and the region that covers both annular and annular-mist in the present investigation, which the original authors termed as "annular mist". The map was restricted to a modified liquid velocity of $Y^* V_{SL} = 3.05$ m/s (10 ft/s). Figure 6.5 shows good agreement between the present air-water data and the Govier and Aziz map. Since the parameters $X^{*}V_{SG}$ and $Y^{*}V_{SL}$ are meant to be universal parameters, it is then interesting to examine the other gas-liquid flow-pattern data from the present investigation on Govier and Aziz's map. Figure 6.6 and 6.7 are the plots of the air-G1 and air-G2 systems on the map of Govier and Aziz, respectively. The results show that the transitions are essentially insensitive to liquid viscosity.

Another comparison was made between the present data and the analytical transition boundaries proposed by Taitel et al. (86). The superficial velocities of both phases were used as co-ordinates in the comparison here. The analytical transition boundaries are functions of gas and liquid densities, superficial velocities, surface tension, tube diameter and hydrodynamic entry length (not all boundaries depend on each of the foregoing). The following analytical expressions were proposed by the authors (86) and the transition boundaries were plotted in Figure 6.8 to 6.10 for air-water, air-G1 and air-G2, respectively:

Bubble-Slug Transition (Curve A)

$$V_{SL} + V_{SG} = 4.0 \left\{ \left[\frac{D^{0.429} \dfrac{\sigma^{0.089}}{\rho_L}}{\nu_L^{0.072}} \right] \left[\frac{g(\rho_L - \rho_G)}{\rho_L} \right]^{0.446} \right\}$$

Dispersed[1] Bubble - Bubble Transition (Curve B)

[1] "Dispersed bubble" was defined in (86) as fine and independent bubble flow.

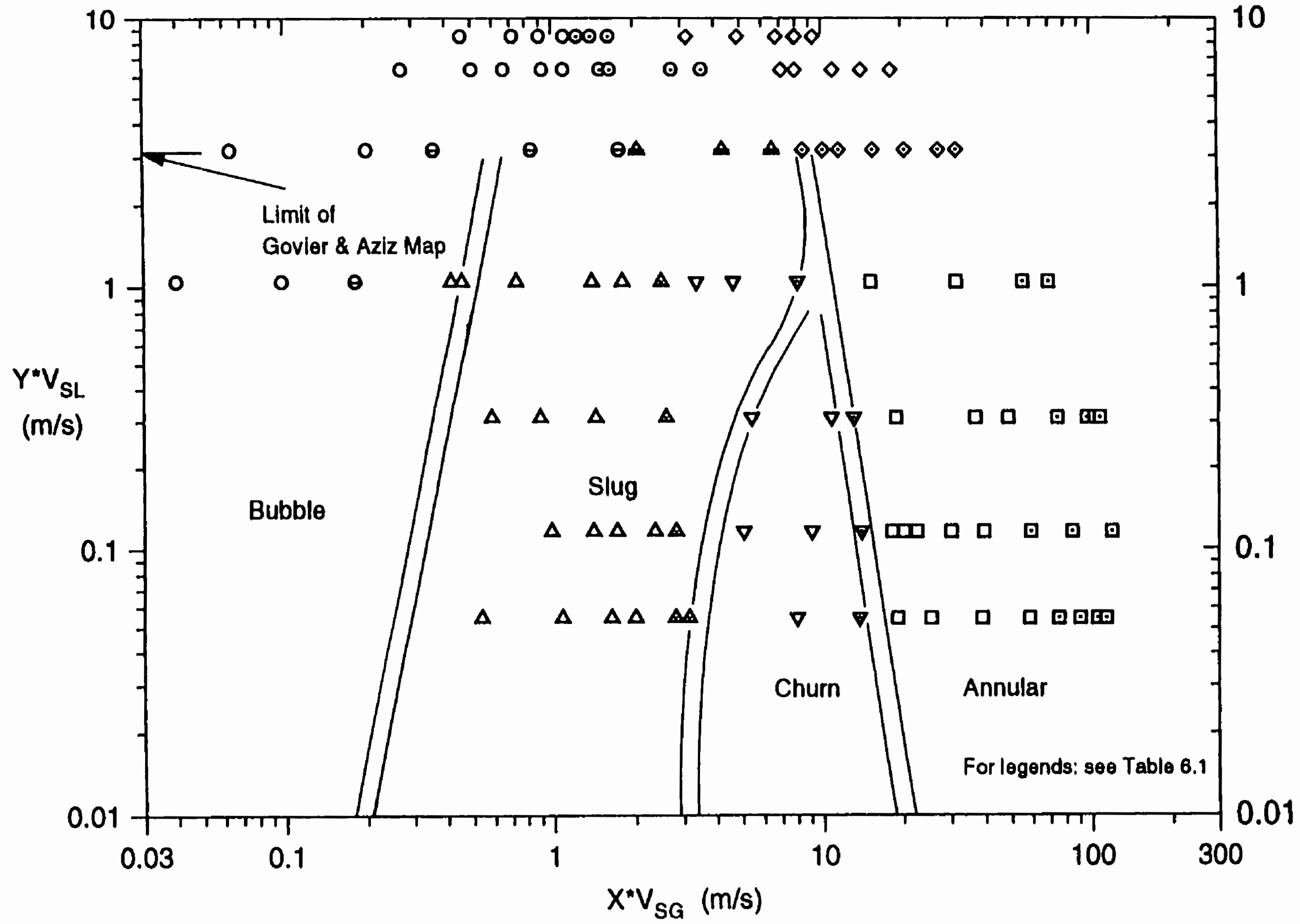

Figure 6.5 Present Air-Water Data on a Govier & Aziz Map (29)

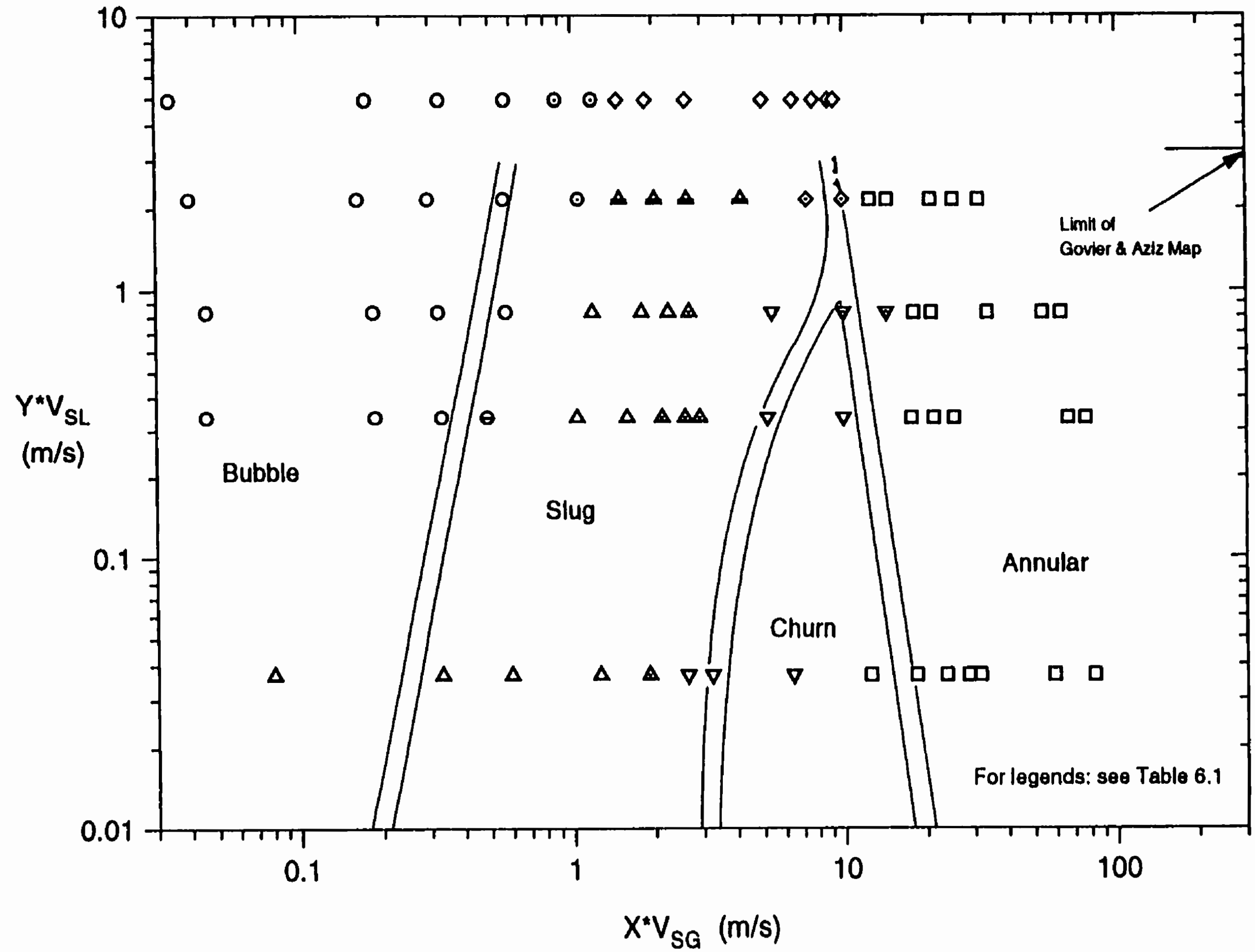

Figure 6.6 Present Air-G1 Data on a Govier & Aziz Map (29)

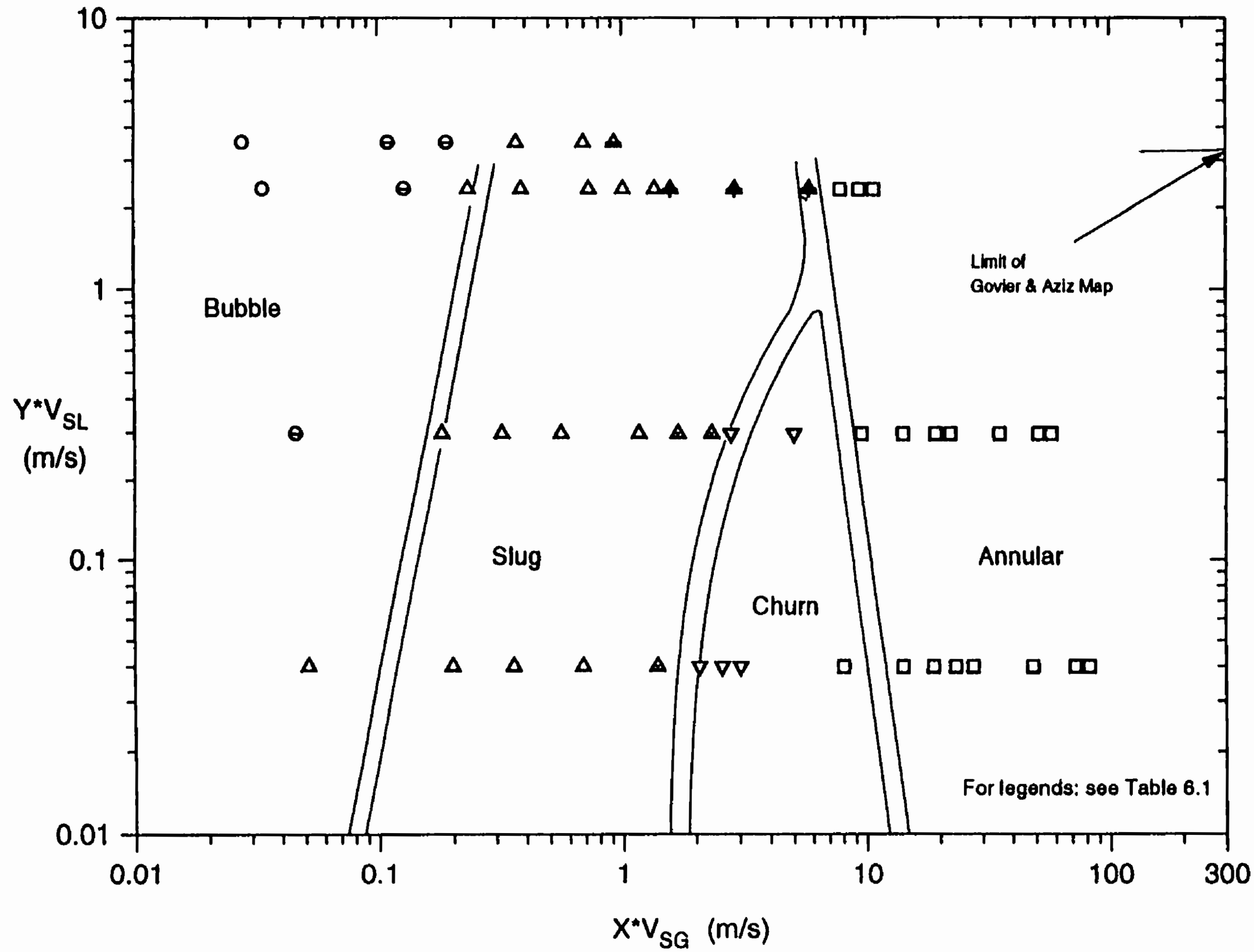

Figure 6.7 Present Air-G2 Data on a Govier & Aziz Map (29)

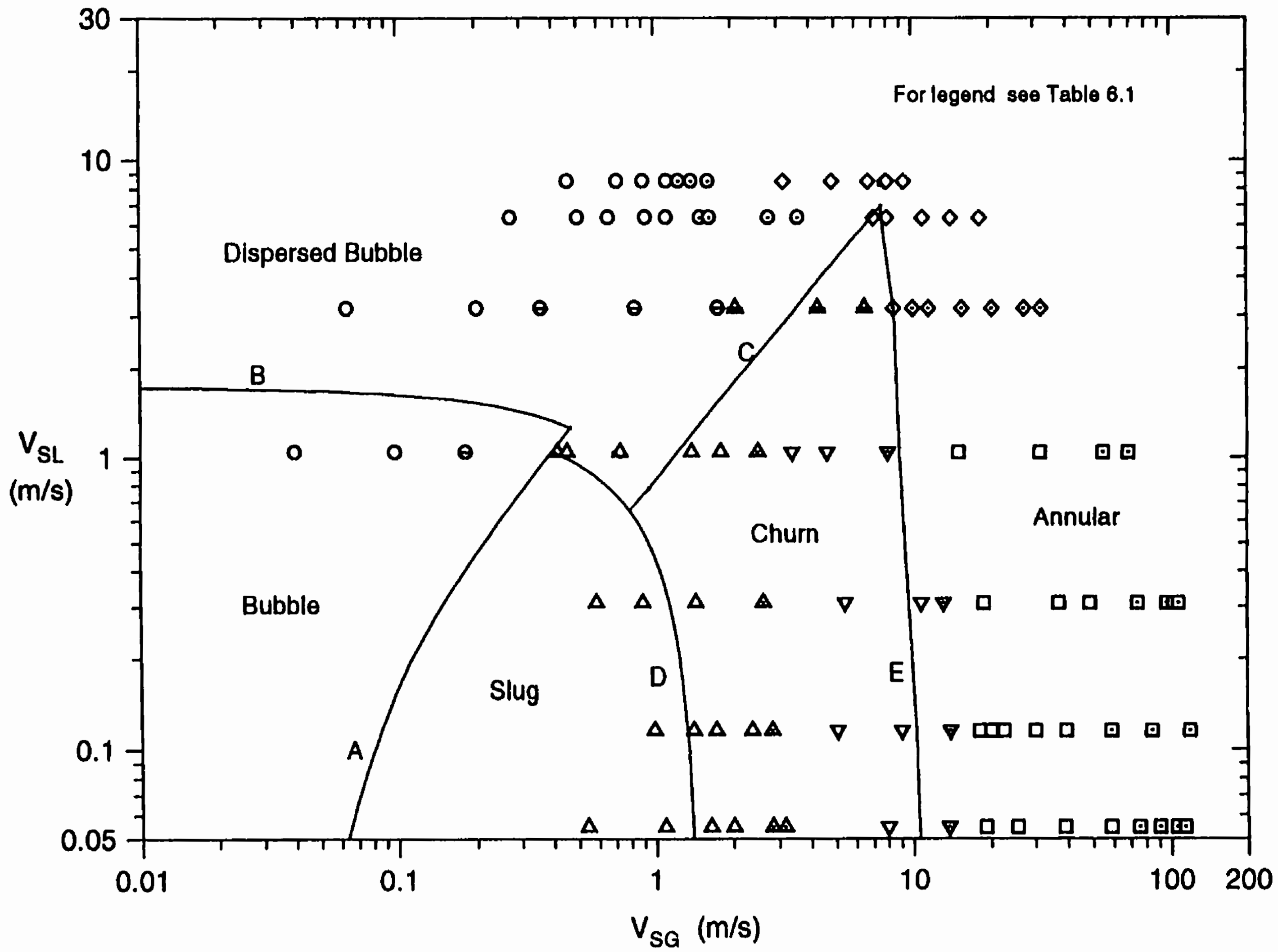

Figure 6.8 Present Air-Water Data with Taitel et al. (86) Boundaries

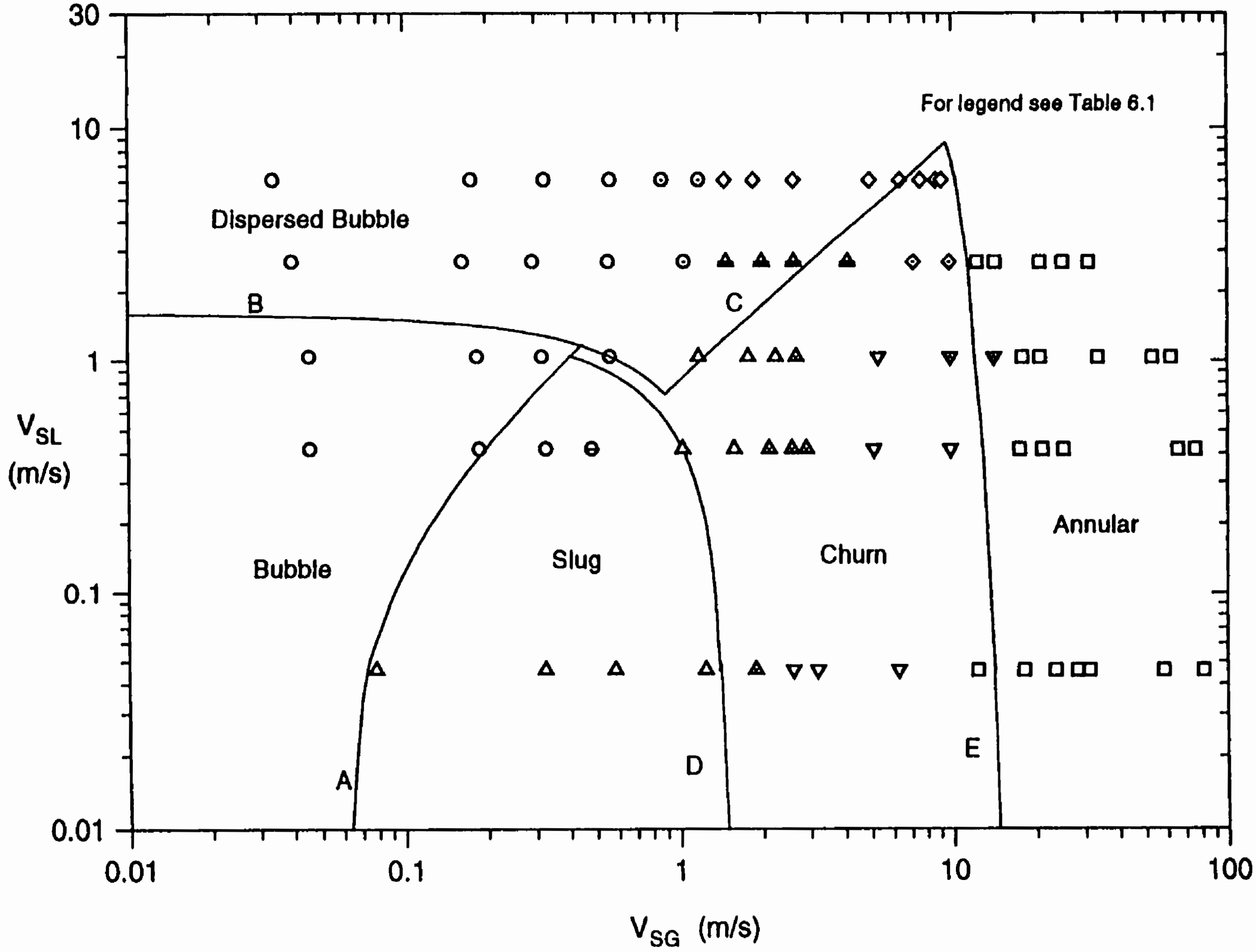

Figure 6.9 Present Air-G1 Data with Taitel et al. (86) Boundaries

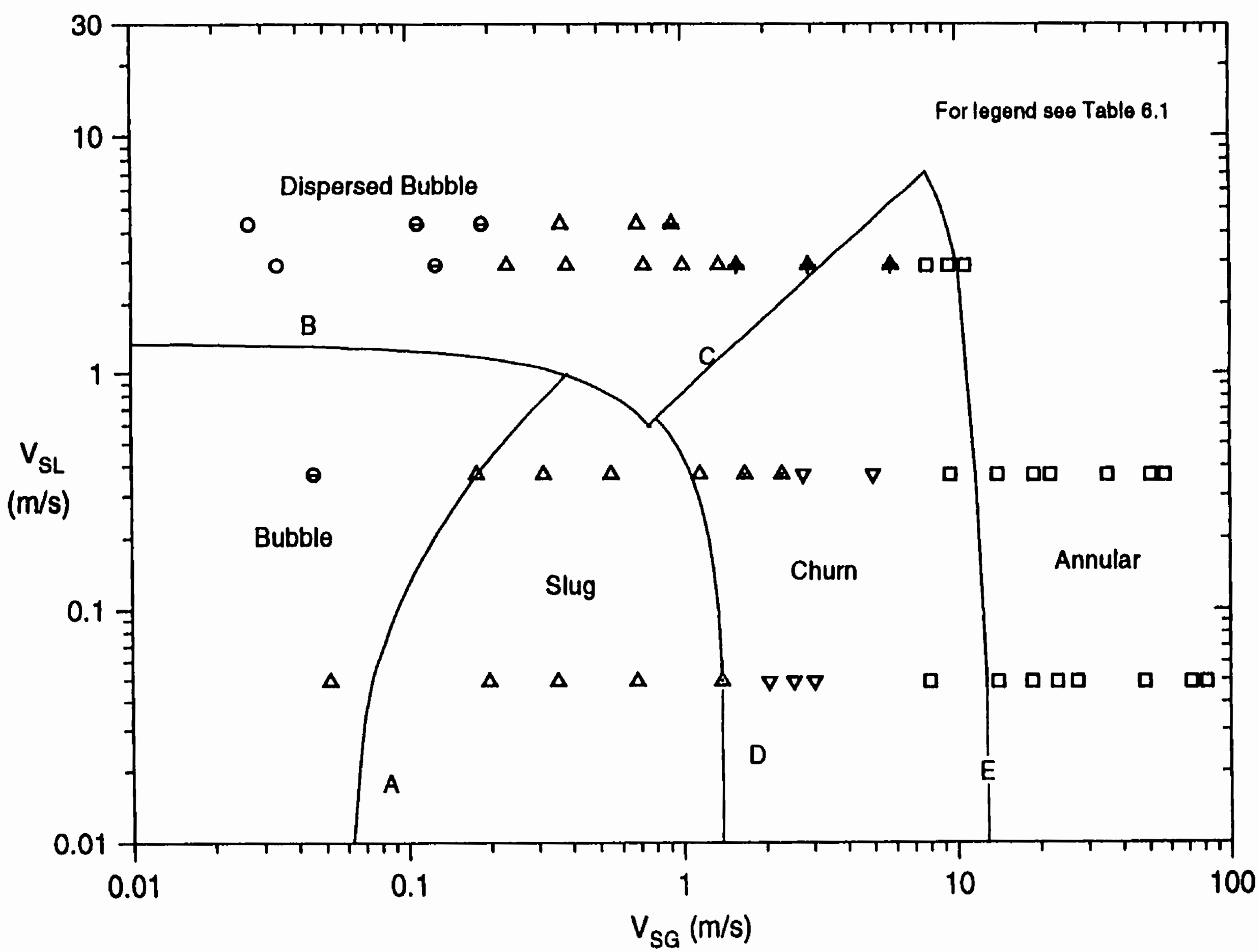

Figure 6.10 Present Air-G2 Data with Taitel et al. (86) Boundaries

$$V_{SL} = 3.0V_{SG} - 1.15\left\{\frac{g(\rho_L - \rho_G)\sigma}{\rho_L^2}\right\}^{1/4}$$

Bubble-Churn Transition (Curve C)

$$V_{SL} = 0.923\,V_{SG} - 0.734\left\{\frac{g(\rho_L - \rho_G)\sigma}{\rho_L^2}\right\}^{1/4}$$

Slug-Churn Transition (Curve D)

$$\ell_E/D = 40.6\left\{\frac{(V_{SG} + V_{SL})}{\sqrt{gD}} + 0.22\right\}$$

where ℓ_E is the hydrodynamic entry length. In this present study, ℓ_E/D = 182.6 at the beginning of the visualization section.

Churn-Annular Transition (Curve E)

$$\frac{V_{SG}\,\rho_G^{0.5}}{[\sigma g\,(\rho_L - \rho_G)]^{0.25}} = 3.1$$

The results in Figures 6.8 to 6.10 indicate that the theory of Taitel et al. agrees fairly well with the present data. It should be noted that "froth flow" was not mentioned in the Taitel et al. work (86). The analytical slug-churn transition of Taitel et al. generally predicts transition to churn flow at lower V_{SG} than observed with the present data. According to Taitel et al., bubble flow cannot exist under Curve B in systems having small-diameter tubes, the criterion for a "small-diameter tube" being that

$$\left[\frac{\rho_L^2 g D^2}{(\rho_L - \rho_G)\,\sigma}\right]^{0.25} \leq 4.36$$

According to this criterion, the tube used in the present investigation is considered to be a "small-diameter tube". However, bubble flow did exist under the "Curve B" during the course of experiments as seen in Figure 6.8 and 6.9 and for this reason, Curve A (bubble-slug boundary) has been drawn in the figures.

6.4 MEAN VOID FRACTION

The void fraction is defined as "the fraction of channel volume that is occupied by the gas phase". There are a number of works on mean-void-fraction prediction in the literature such as Chisholm (13), CISE (15) and the ones (correlations of Zivi, Thom, Turner and Wallis, Lockhart and Martinelli, Baroczy, and the Homogeneous Model) summarized in Butterworth (12). In this section, the measured void fraction data of the present investigation are presented. In addition, comparisons between the present data and some predictions are made in order to examine how closely the methods predict the data.

Figures 6.11 to 6.13 show the present data for air-water, air-G1 and air-G2 systems, respectively. As expected, at a fixed liquid superficial velocity, the void fraction increases with gas superficial velocity. The measured void fraction approaches the value of unity when the ratio of V_{SG}/V_{SL} is sufficiently high.

Figures 6.14 to 6.16 show typical results when the present data are compared with some predictive methods in the literature. It can be seen that the present data fall in the

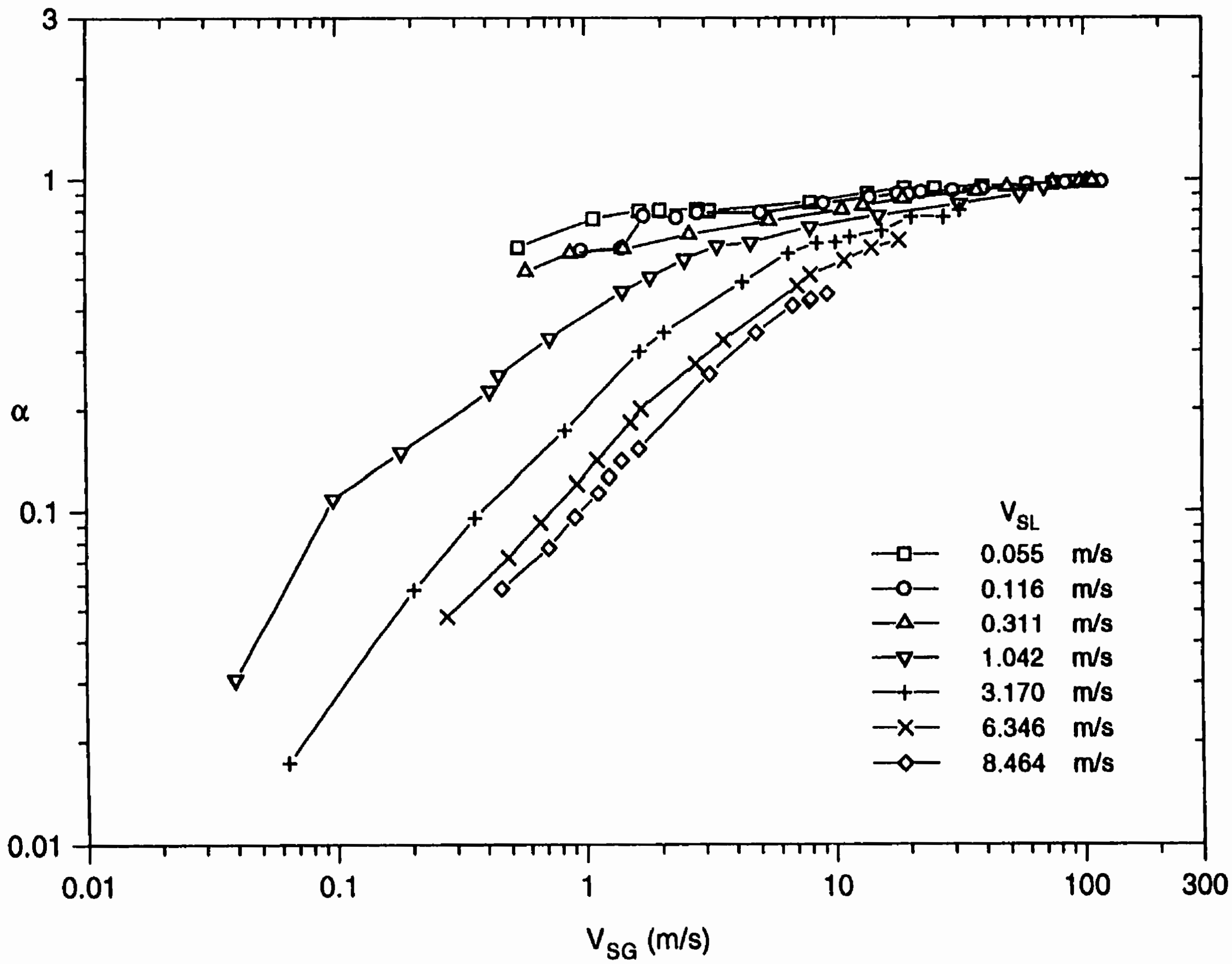

Figure 6.11 Measured Mean Void Fraction for Air-Water

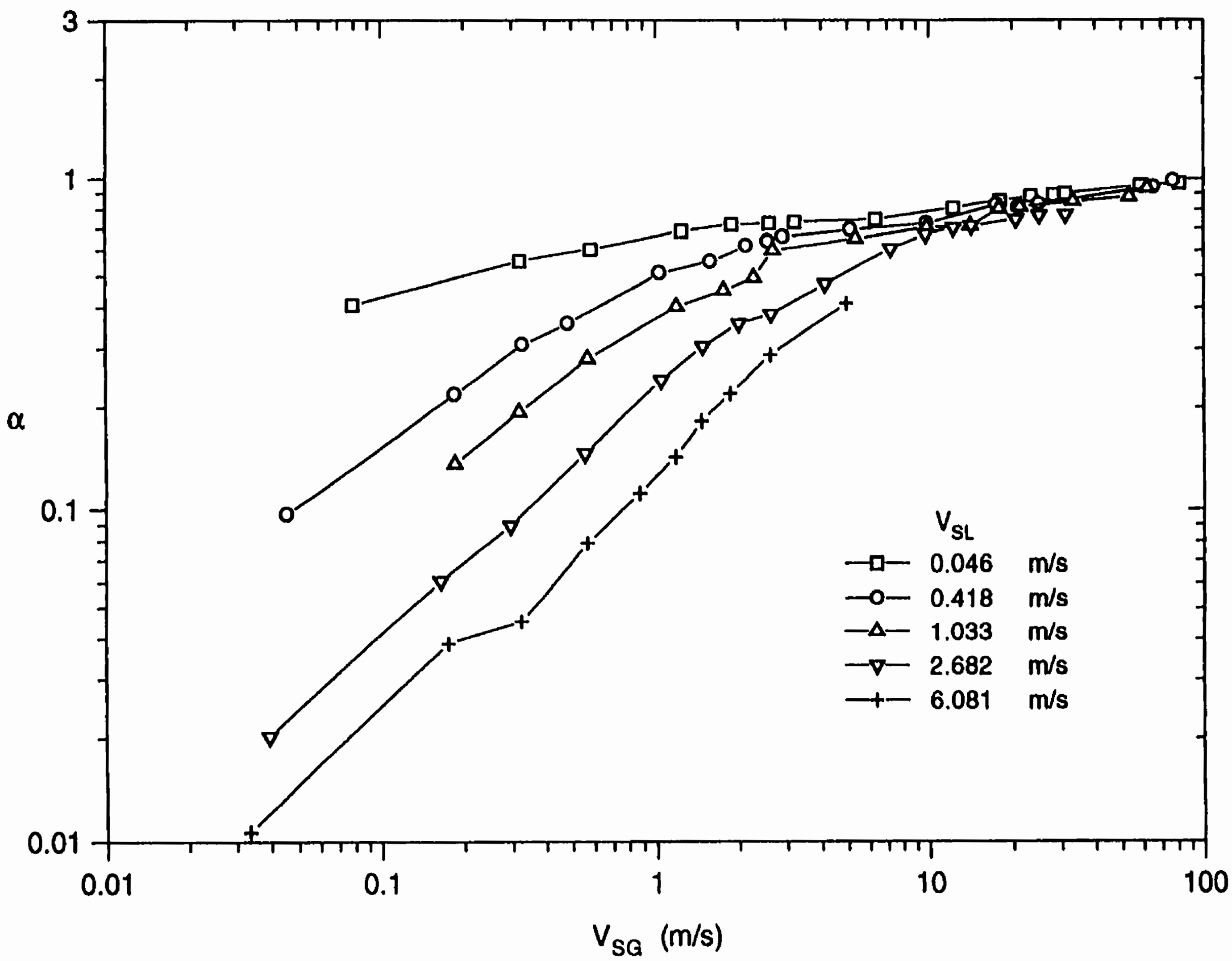

Figure 6.12 Measured Mean Void Fraction for Air - G1

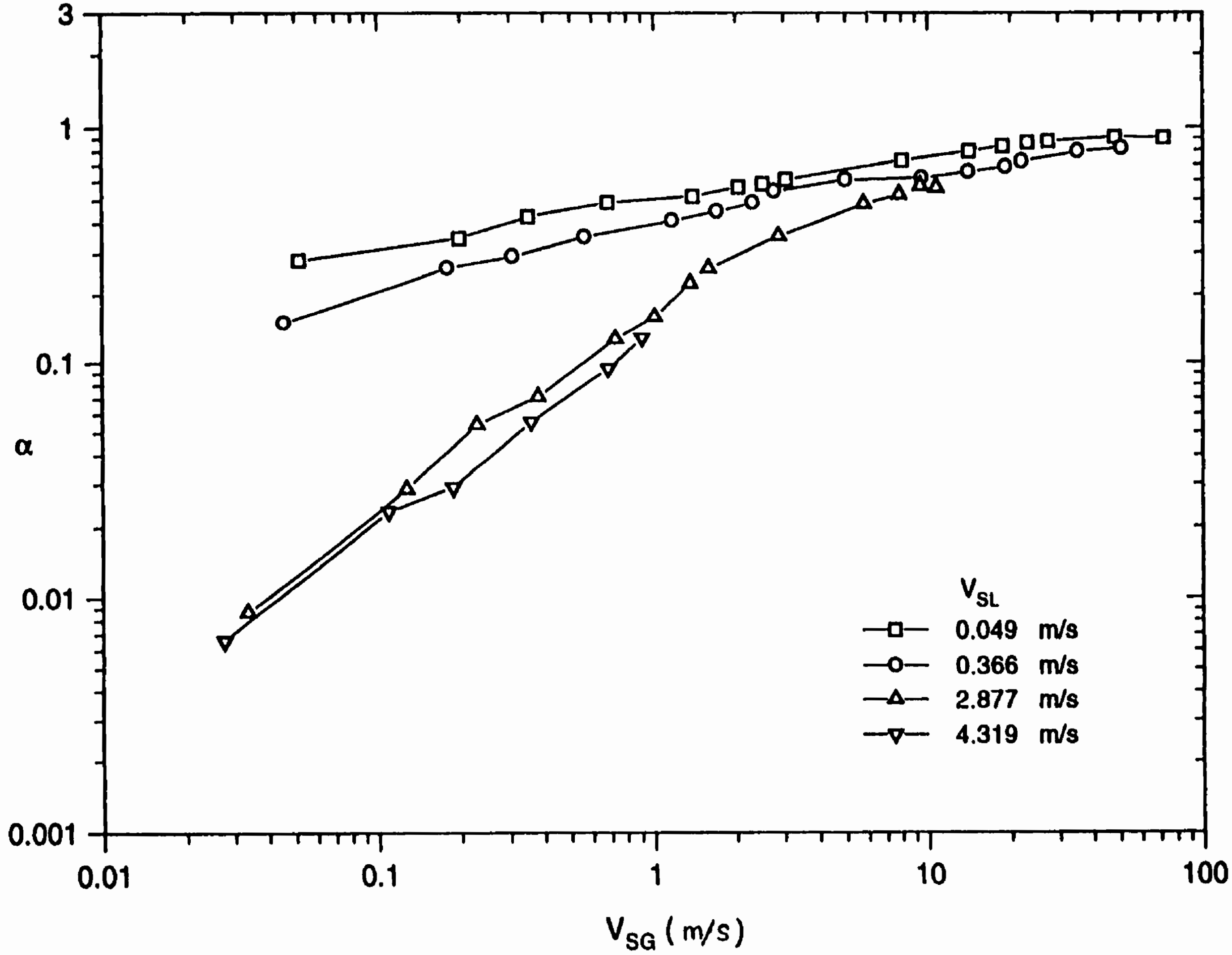

Figure 6.13 Measured Mean Void Fraction for Air-G2

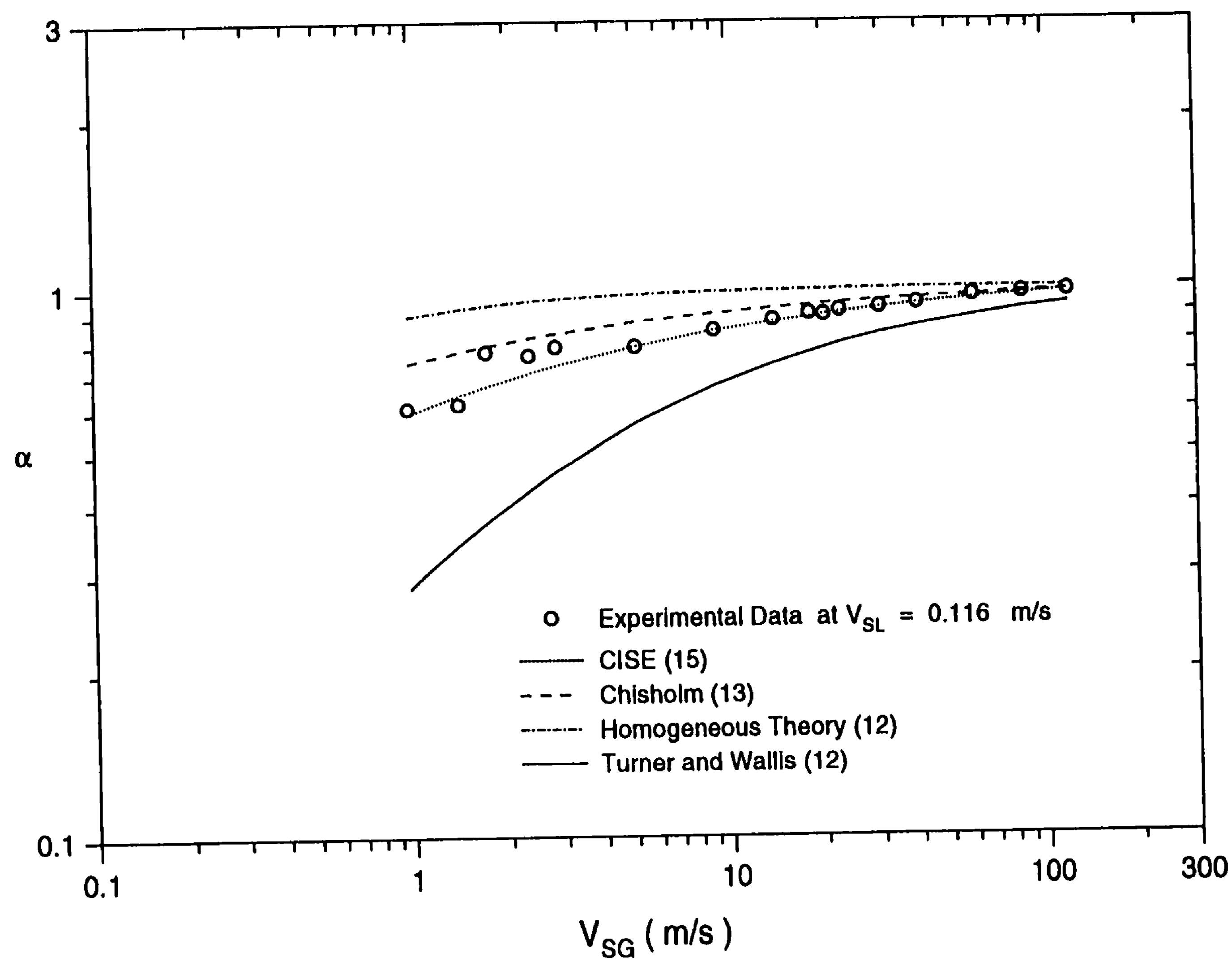

Figure 6.14 Comparison of Mean Void Fraction for Air-Water

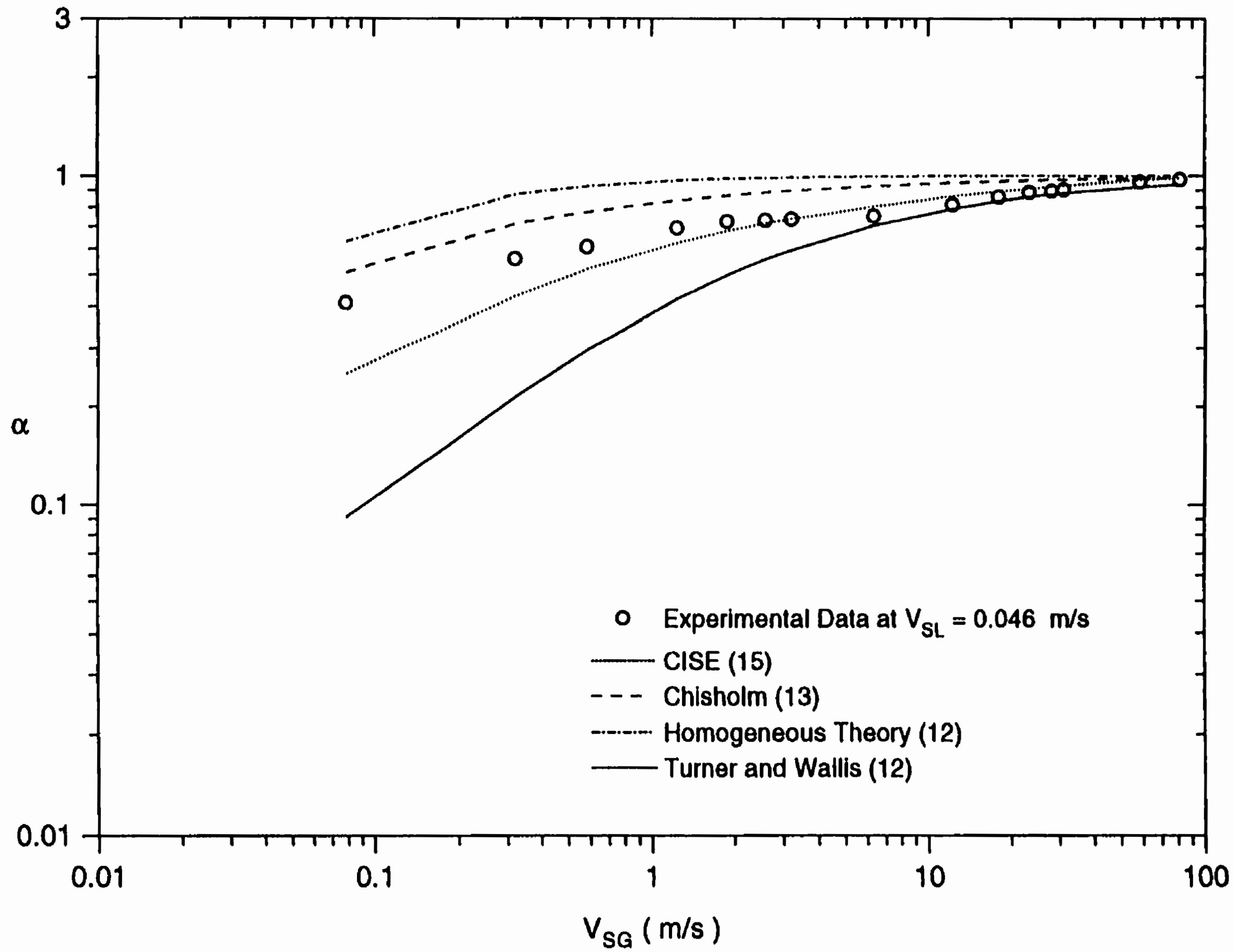

Figure 6.15 Comparison of Mean Void Fraction for Air-G1

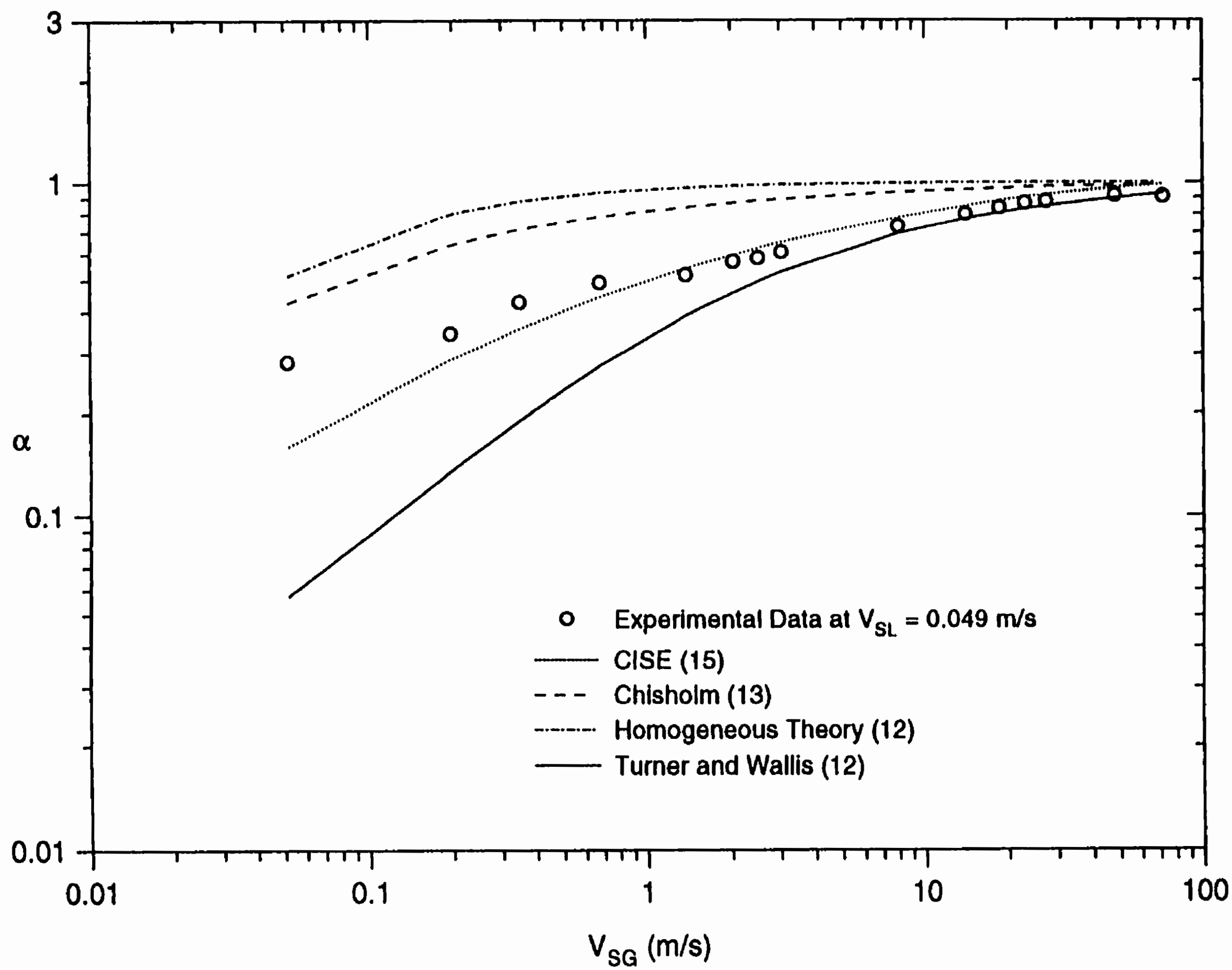

Figure 6.16 Comparison of Mean Void Fraction for Air-G2

middle of predictions. The present data of all air-liquid systems show good agreement with two well-known correlations, namely, CISE (15) and Chisholm (13). The majority of present data for air-water agree with Chisholm's correlation within 15% as shown in Figure 6.17a. For the more viscous liquids, the majority of the data agree with Chisholm's prediction within 25 and 50 percents for air-G1 and air-G2, respectively, as the results are shown in Figures 6.17b and c.

For the CISE correlation, since this method is for steam-water systems, it is reasonable to compare this method with the present air-water data only. Figure 6.18 shows that the method generally gives good prediction for the present data. Table G.1 gives details of the void fraction measured in the present investigation.

6.5 PRESSURE-DROP RESULTS AND DISCUSSION

This section presents both the two-phase total and frictional pressure-drop data[2] of the present investigation. The method of calculating the two-phase frictional pressure drop from the measured total pressure drop is given in Appendix D.

Figures 6.19 to 6.21 show the two-phase total pressure gradient data for air-water, air-G1 and air-G2 systems, respectively. It is useful to have a letter (indicating the flow pattern) beside each datum point, as then, one can use this flow pattern information as needed in the pressure-gradient analysis. In general, at any fixed V_{SL}, the two-phase total pressure drop increases with V_{SG}. However, the experimental data consistently show that the total pressure drop decreases when the flow is in the form of slug flow and at low V_{SL}

[2] Pressure drop was defined as $\Delta P = (P_{IN} - P_{OUT})$.

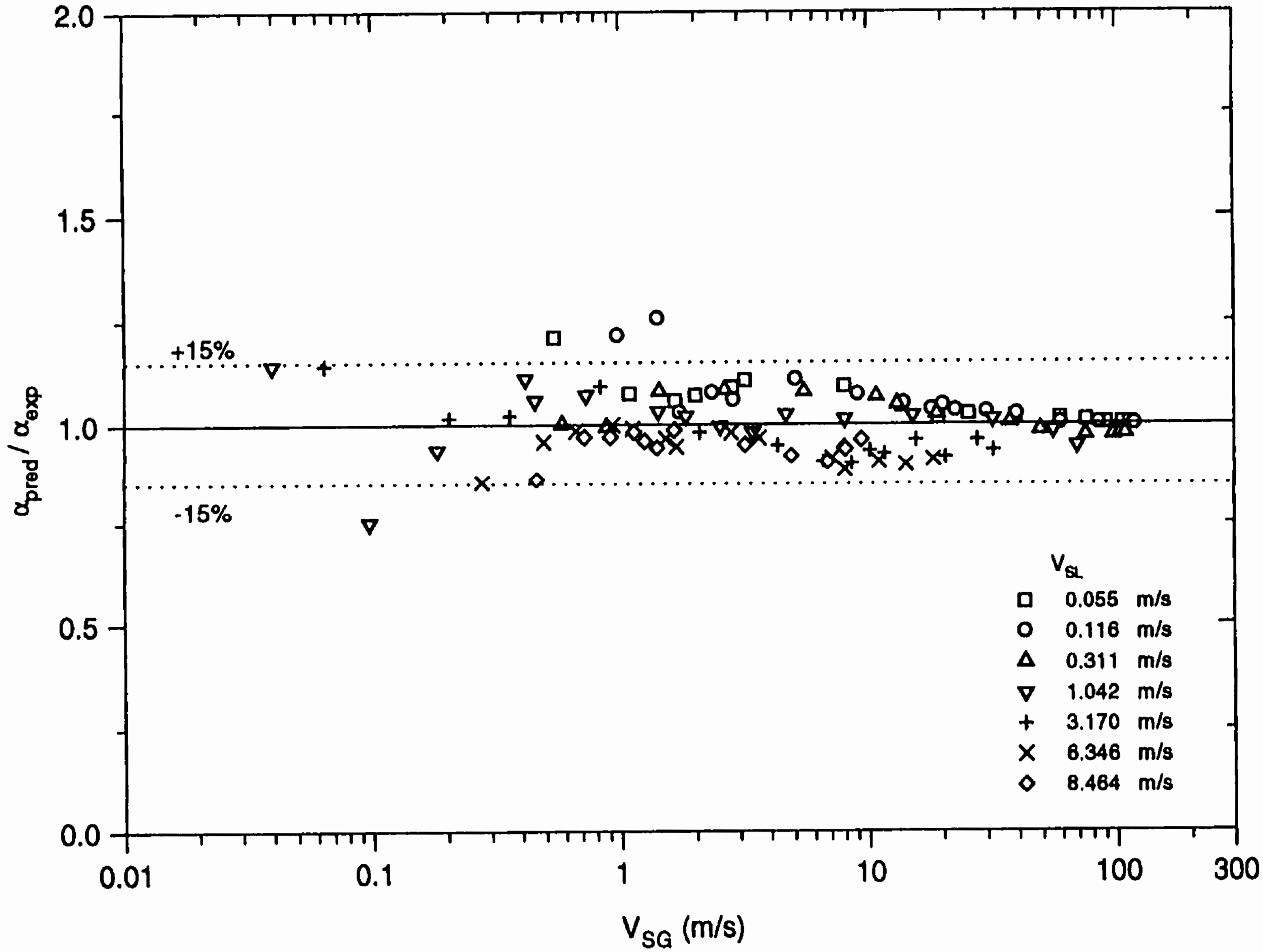

Figure 6.17a Comparison of Measured Void Fraction with Chisholm's Correlation (13) for Air-Water

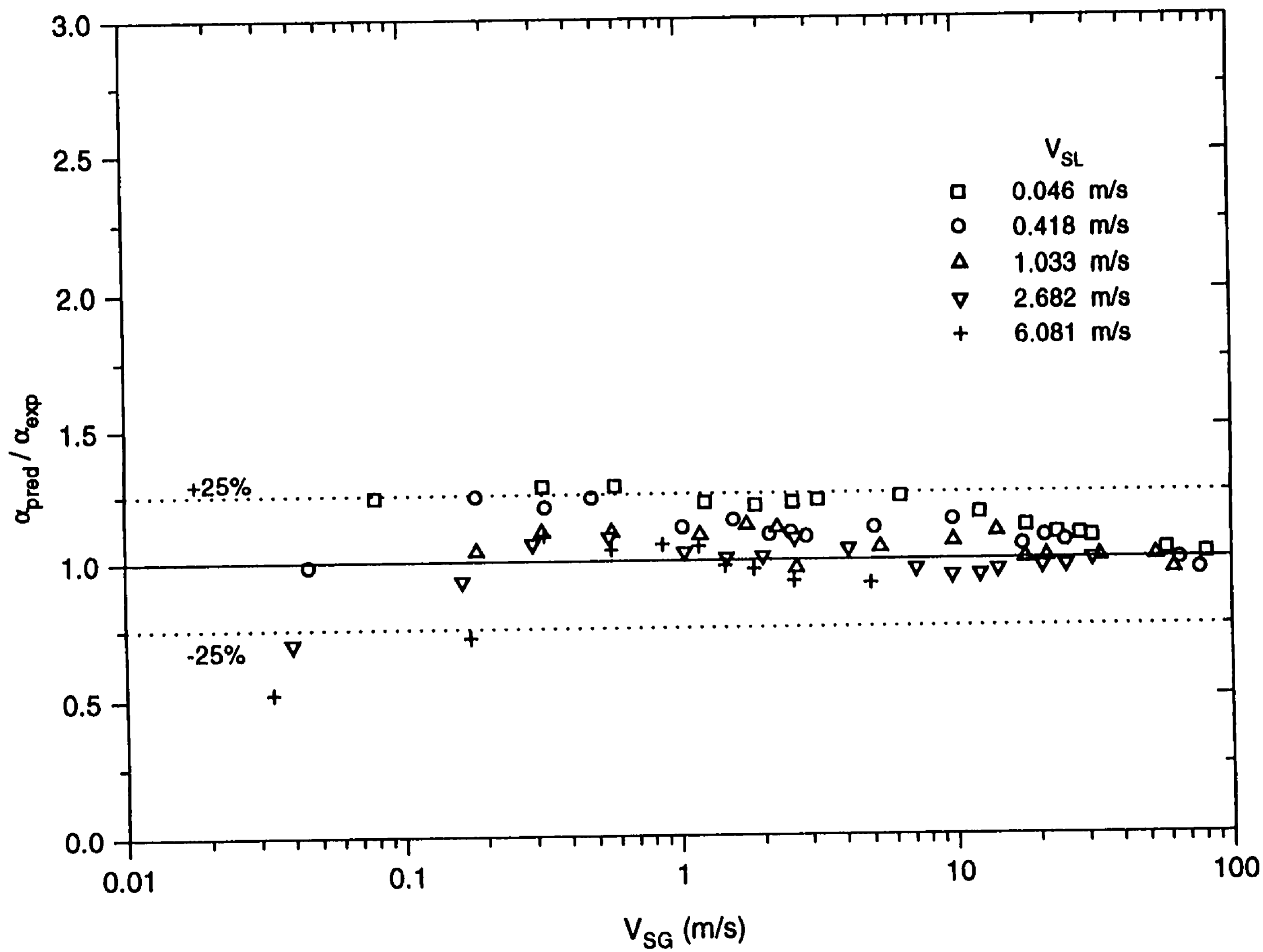

Figure 6.17b Comparison of Measured Void Fraction with Chisholm's Correlation (13) for Air-G1

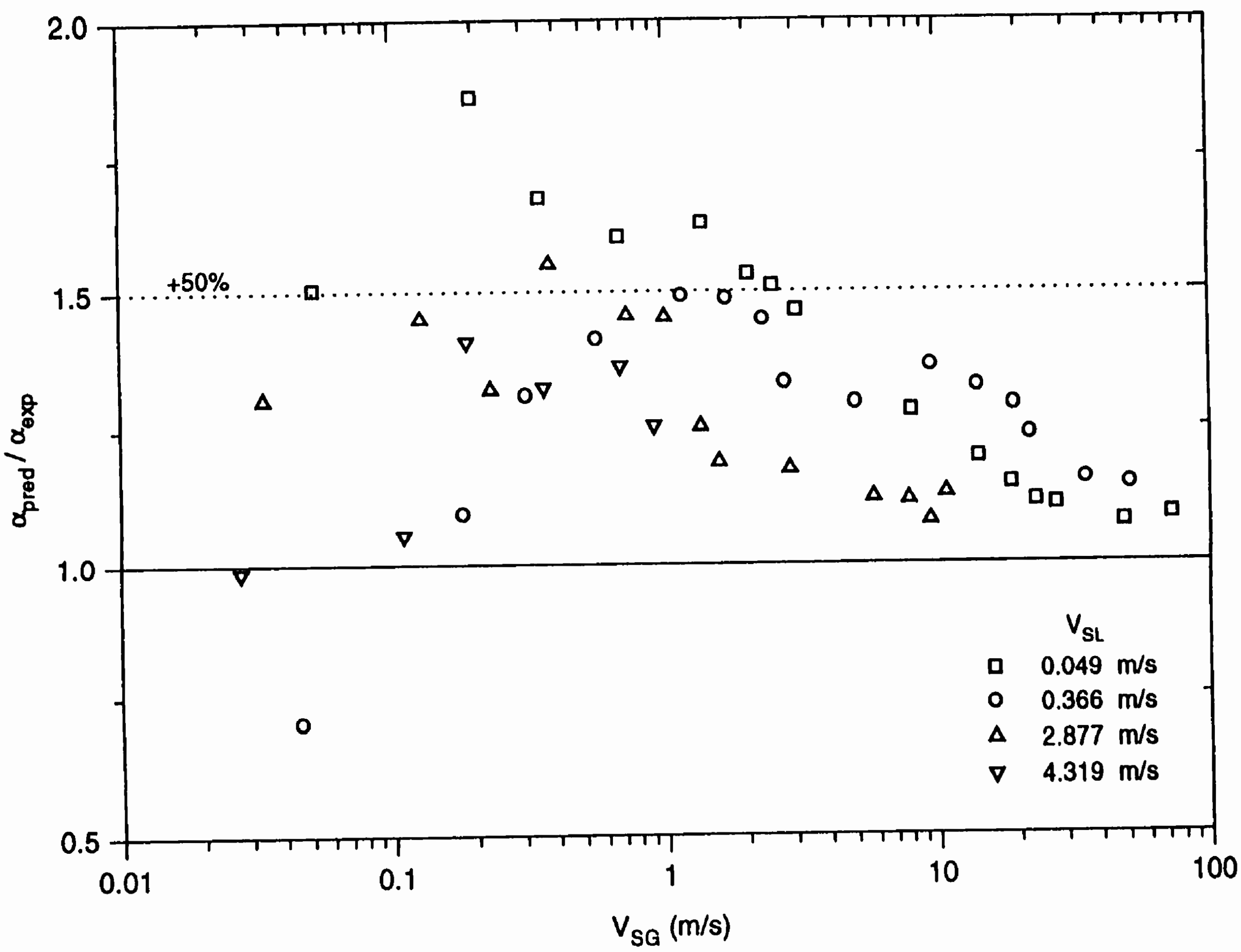

Figure 6.17c Comparison of Measured Void Fraction with Chisholm's Correlation (13) for Air-G2

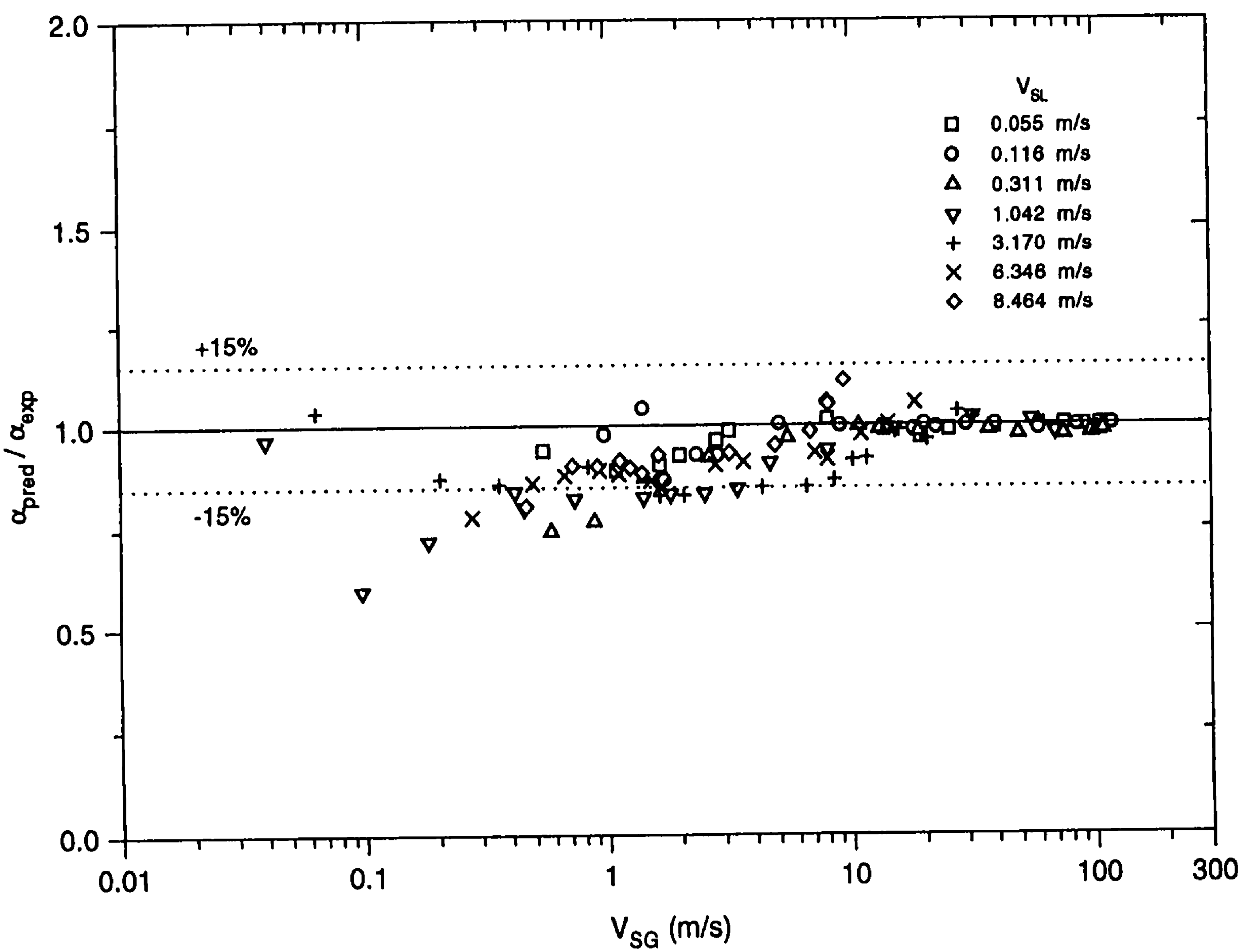

Figure 6.18 Comparison of Measured Void Fraction with CISE (15) for Air-Water

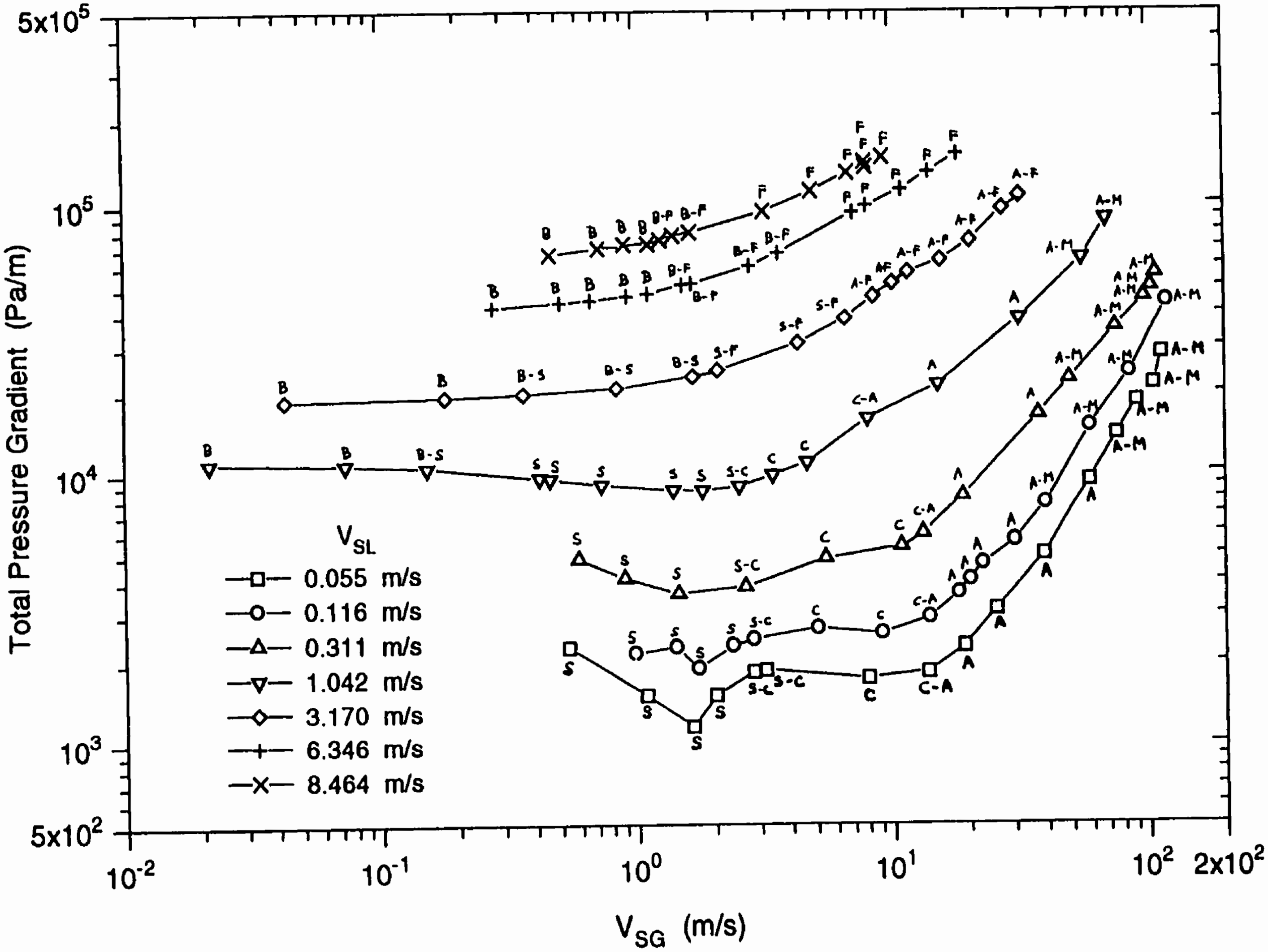

Figure6.19 Two-Phase Total Pressure Gradient for Air-Water

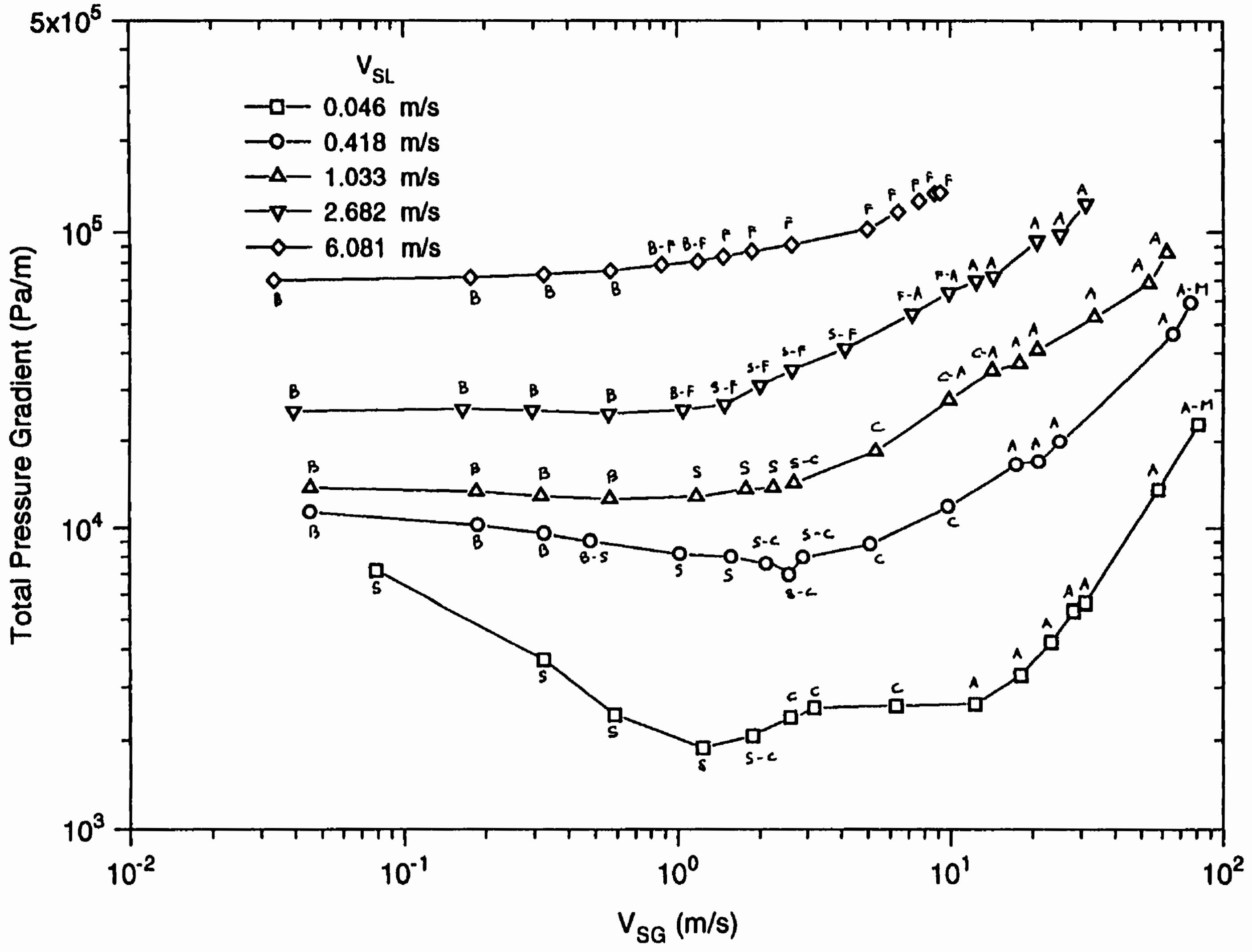

Figure 6.20 Two-Phase Total Pressure Gradient for Air-G1

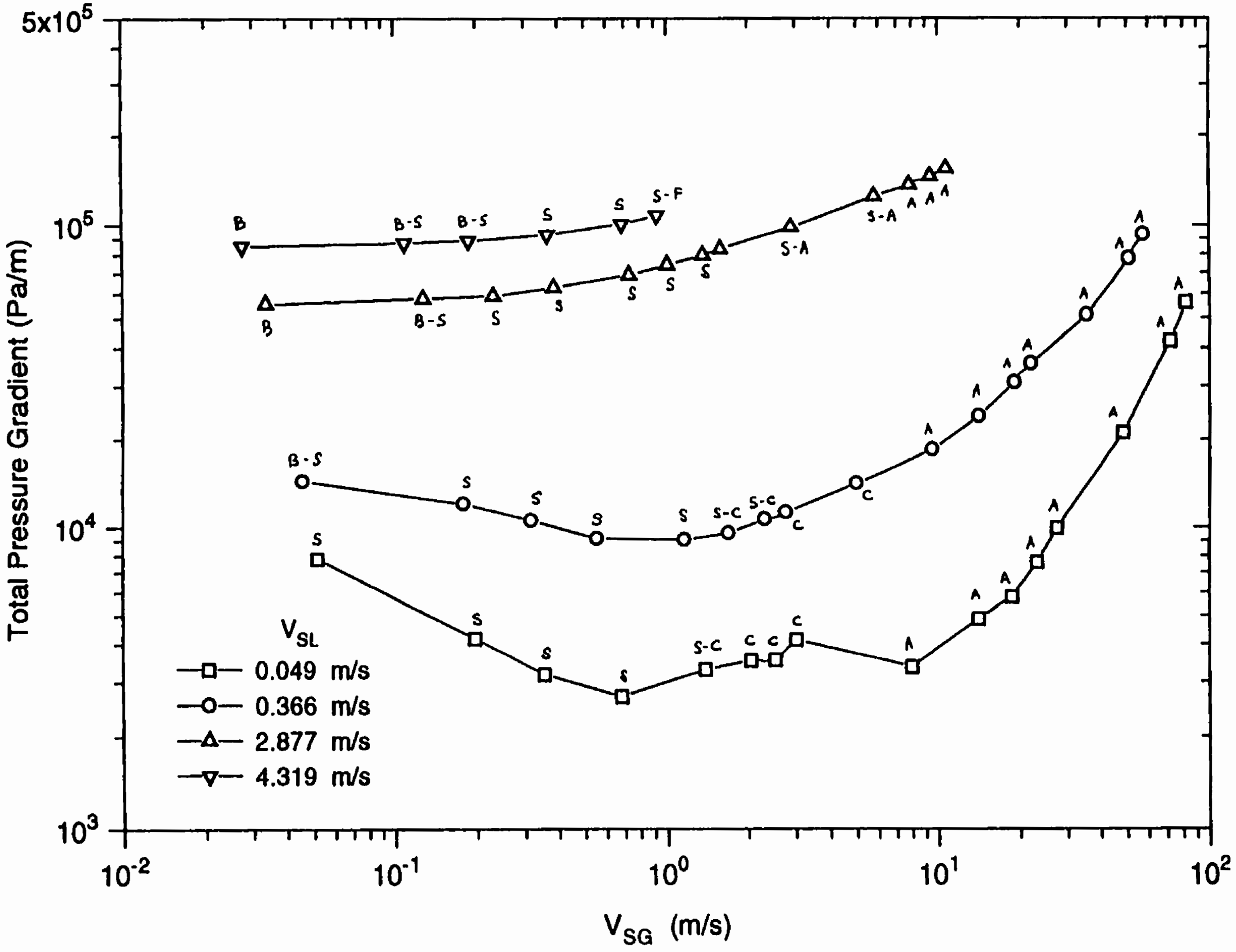

Figure 6.21 Two-Phase Total Pressure Gradient for Air-G2

as seen in Figures 6.19 to 6.21. The decreasing trend stops when the flow pattern changes to churn flow (including slug-churn). This decrease of the total pressure drop in slug flow may be caused by the liquid flowing down the tube wall.

Figures 6.22 to 6.25 show the present total-pressure-gradient data of the air-water and air-G1 systems compared with the previous data from independent works using the same experimental facility. The results show excellent agreement among these data.

Figures 6.26 to 6.28 show the results of two-phase frictional pressure drop for air-water, air-G1 and air-G2, respectively, in the present investigation. The relevant equations for obtaining the frictional pressure drop from the total pressure drop are Equations D.26 to D.29 in Appendix D, where the measured void fraction had been used in the determination of the head term. At low V_{SL}, when the flow is associated with the bubble-slug transition and slug flow regimes, the two-phase frictional pressure drop had negative values. The negative-value data cannot be plotted on a logarithmic scale and, therefore, are excluded from the graphs. These data points which have been excluded from Figures 6.26 to 6.28 are as follows:

For air-water:	6 points at	V_{SL}	=	0.055	m/s
		V_{SG}	≤	3.17	m/s
	4 points at	V_{SL}	=	0.116	m/s
		V_{SG}	≤	2.35	m/s
	1 point at	V_{SL}	=	0.311	m/s
		V_{SG}	≤	1.44	m/s
For air-G1:	7 points at	V_{SL}	=	0.0457	m/s

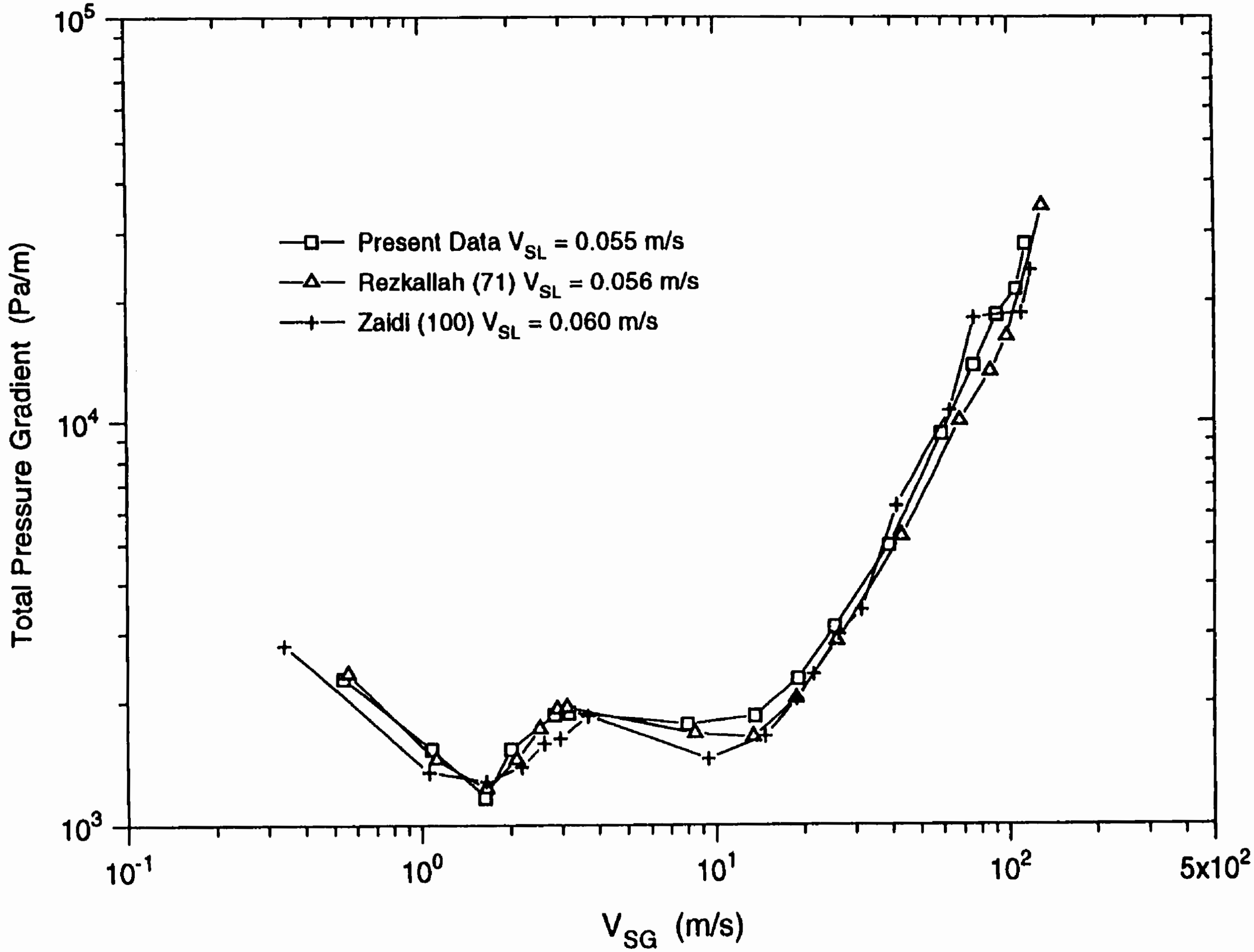

Figure 6.22 Comparison of Total-Pressure-Gradient Data for Air-Water at V_{SL} = 0.055 m/s (approx.)

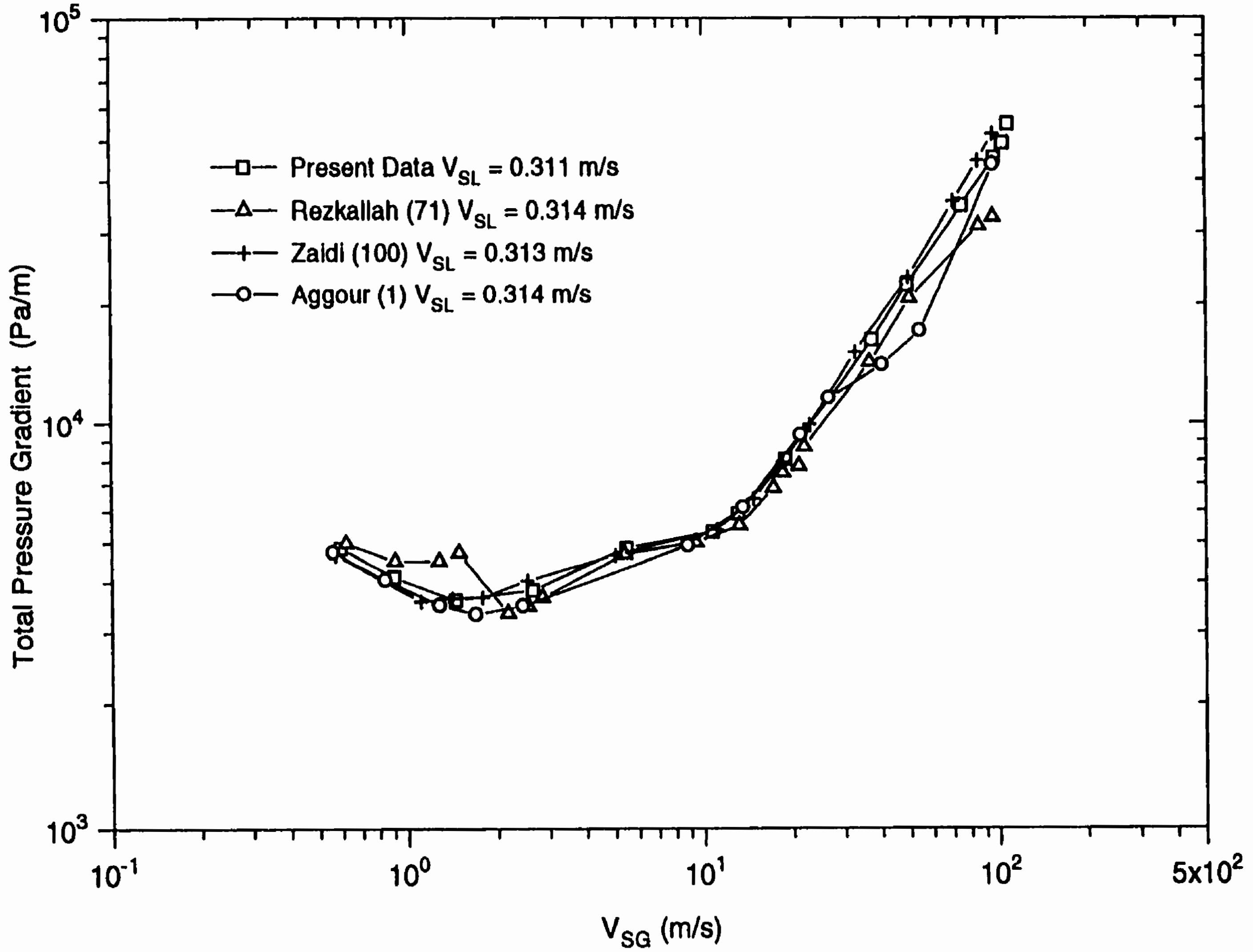

Figure 6.23 Comparison of Total-Pressure-Gradient Data for Air-Water at V_{SL} = 0.311 m/s (approx.)

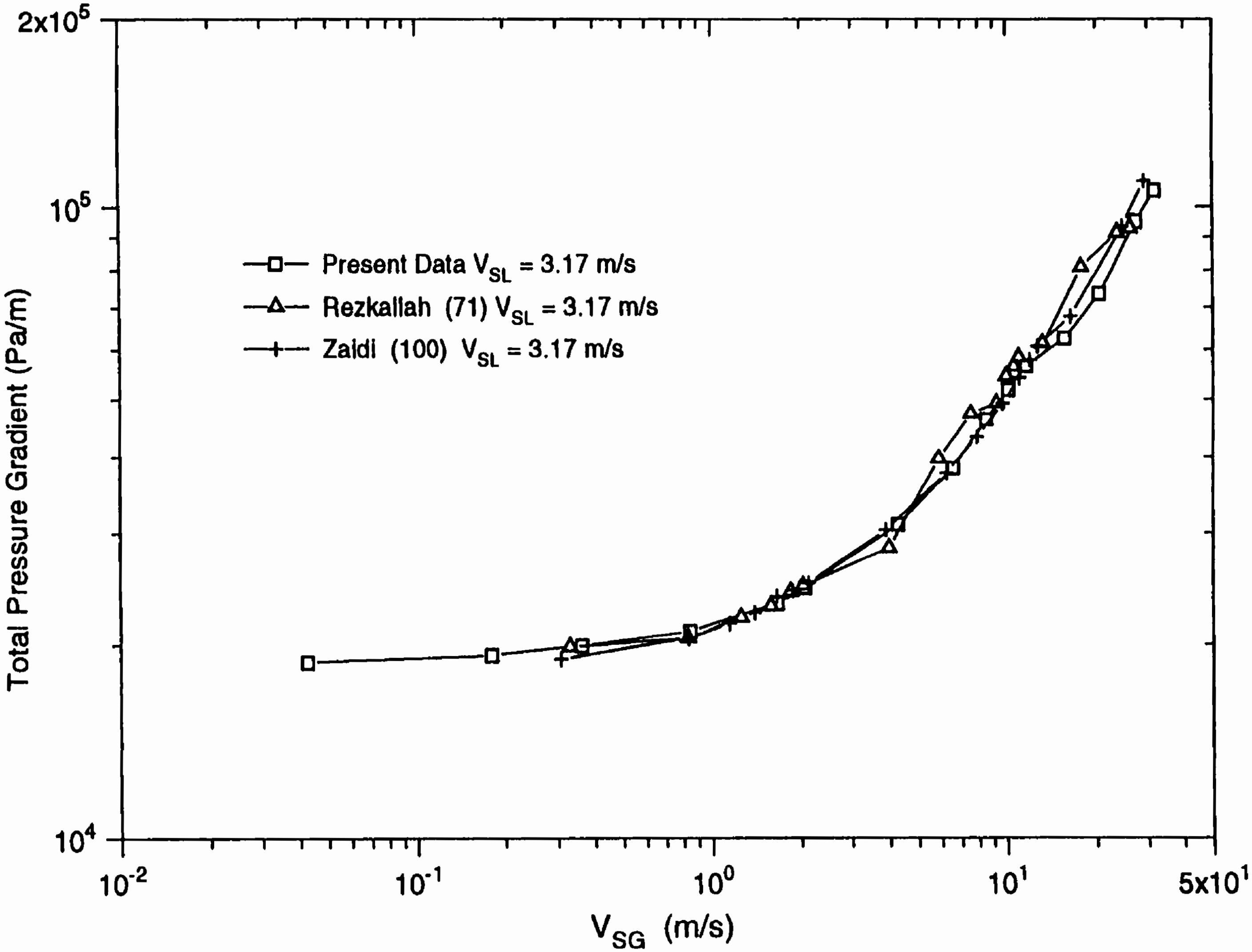

Figure 6.24 Comparison of Total-Pressure-Gradient Data for Air-Water at V_{SL} = 3.17 m/s (approx.)

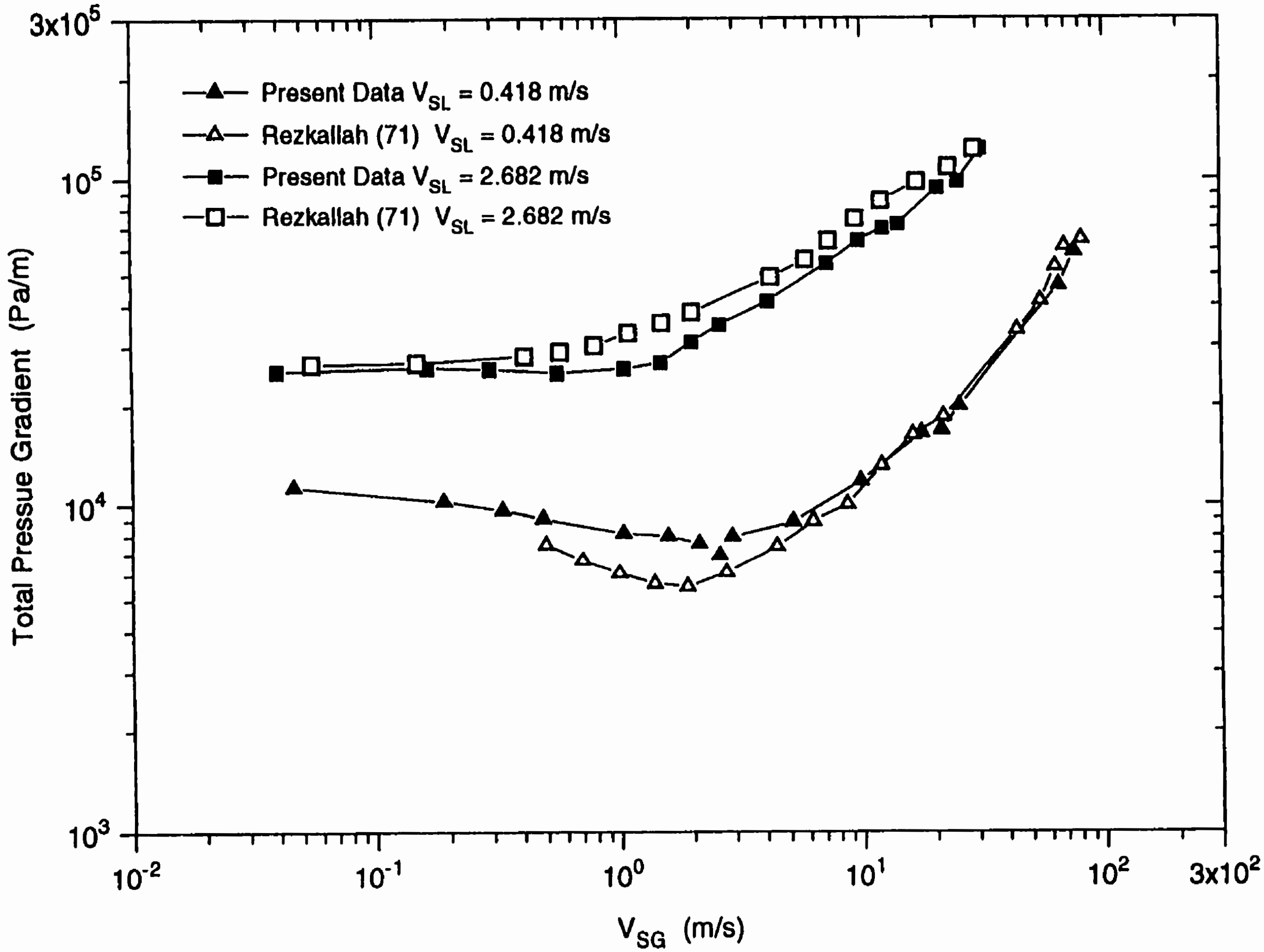

Figure 6.25 Comparison of Total-Pressure-Gradient Data for Air-G1

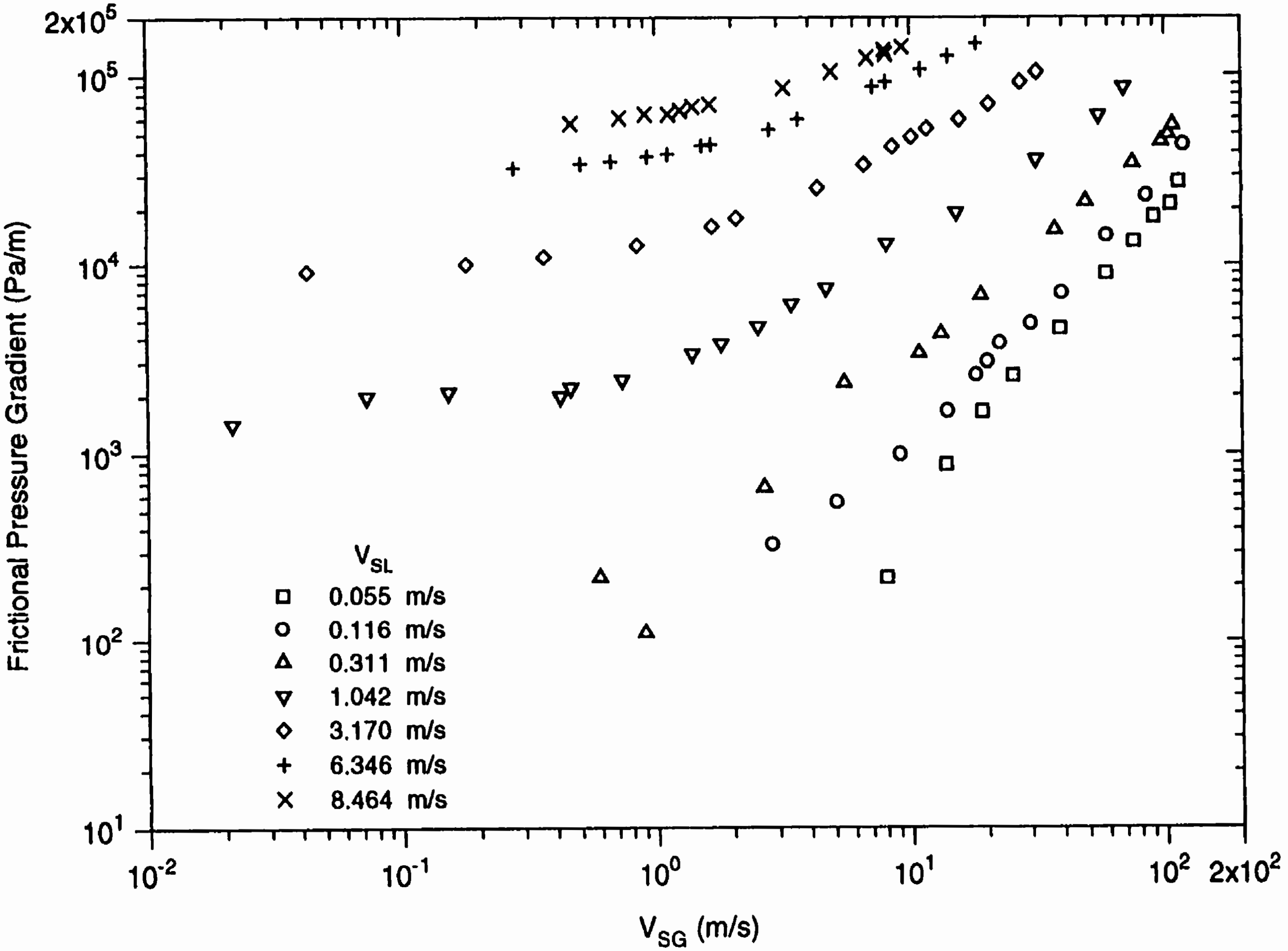

Figure 6.26 Two-Phase Frictional-Pressure-Gradient Data for Air-Water

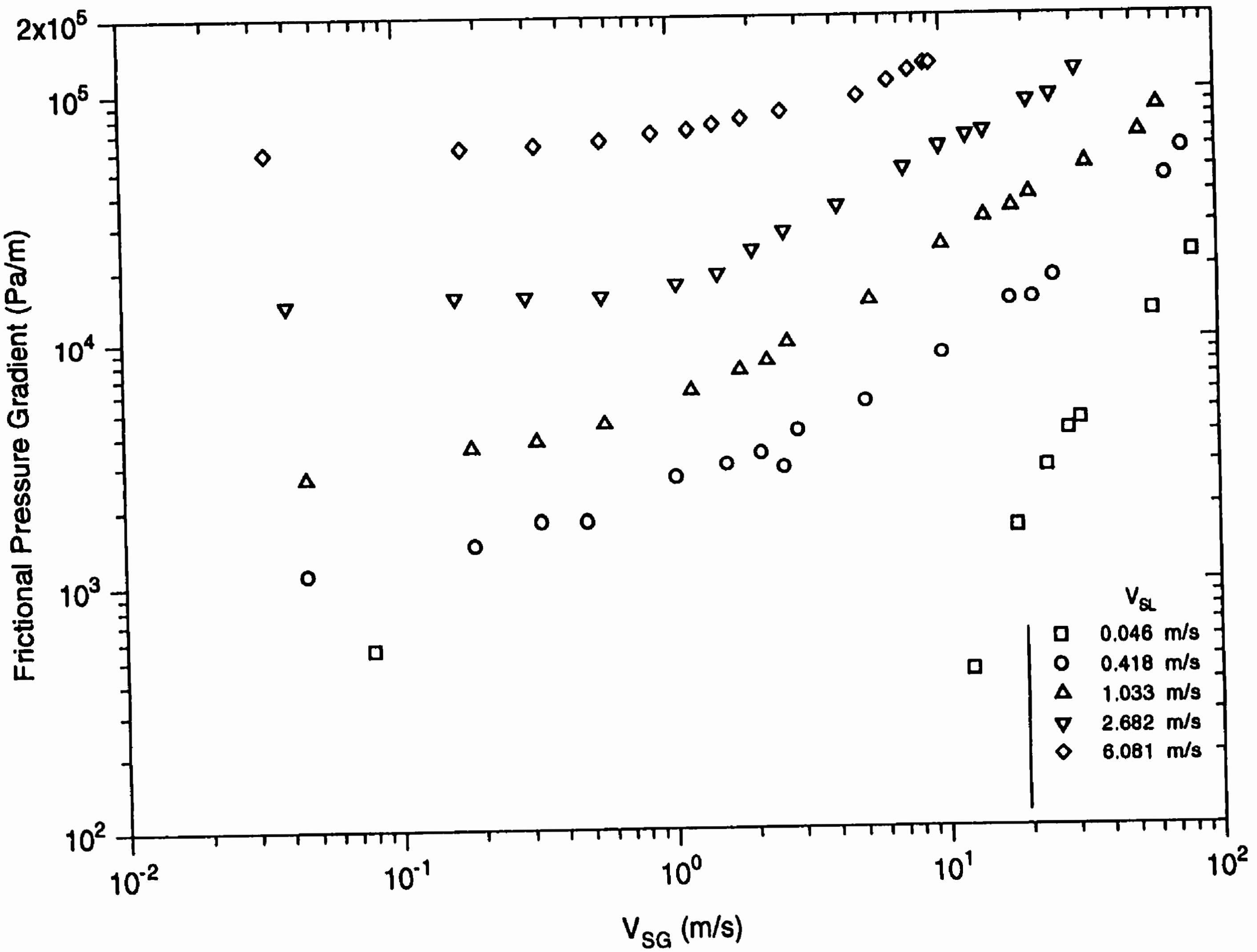

Figure 6.27 Two-Phase Frictional-Pressure-Gradient Data for Air-G1

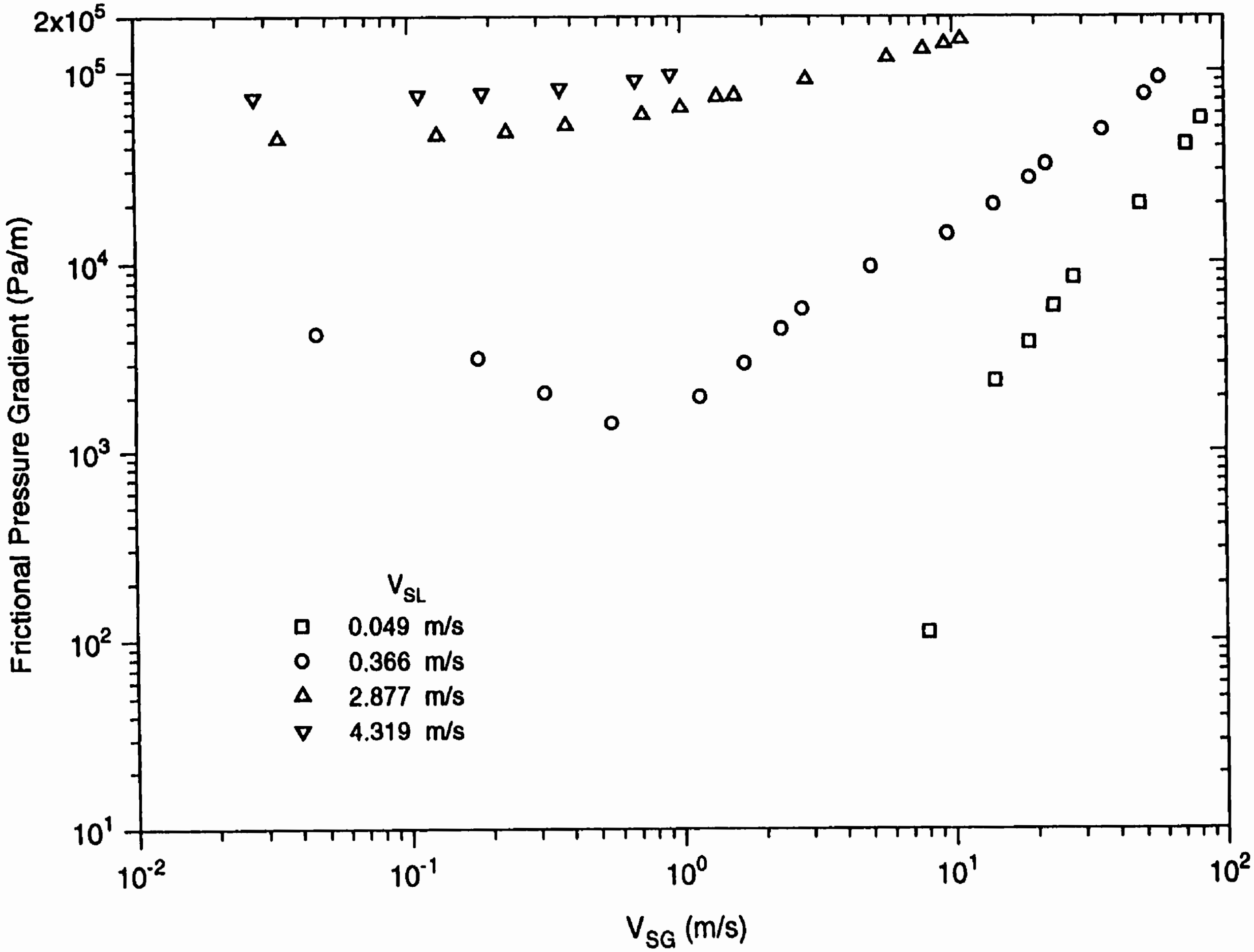

Figure 6.28 Two-Phase Frictional-Pressure-Gradient Data for Air-G2

$0.33 \leq V_{SG} \leq 6.33$ m/s

For air-G2: 8 points at $V_{SL} = 0.0487$ m/s

$V_{SG} \leq 3.02$ m/s

Without the negative data, the results from Figure 6.26 to 6.28 indicate that, in general, the frictional pressure drop increases with V_{SG}. For the cases of decreasing and the case of negative frictional pressure gradient, these two behaviours were also found in the experimental investigation of Cognet et al. (17). The authors observed these behaviours in the bubble-slug transition and slug flow.

The two-phase frictional pressure drop data for all three air-liquid systems were compared with two well-known correlations, namely, Lockhart and Martinelli (55) and Friedel (28). These two predictive methods (28 and 55) were chosen because the Lockhart-Martinelli correlation (55) is classic while the correlation of Friedel (28) was recommended by Whalley (98). It should be noted that all the data where the negative values of frictional pressure drop occurred were excluded from this comparison. This is because the correlations never give negative values of ΔP_{TPF}.

Figure 6.29 to 6.31 show the results when the present data are compared with Lockhart and Martinelli's correlation. The results are plotted on graphs using the Lockhart-Martinelli parameter, X^2, which is a non-dimensional parameter proposed by the authors (55). The appropriate regimes in terms of turbulent-turbulent, turbulent-viscous, etc. were used in the prediction. The data for the air-water system show fair agreement with the correlation. At high liquid velocities, the correlation of Lockhart and Martinelli gives excellent agreement with the present data. However, at low V_{SL} the correlation gives poor agreement, but the prediction was relatively improved when V_{SG} is increased

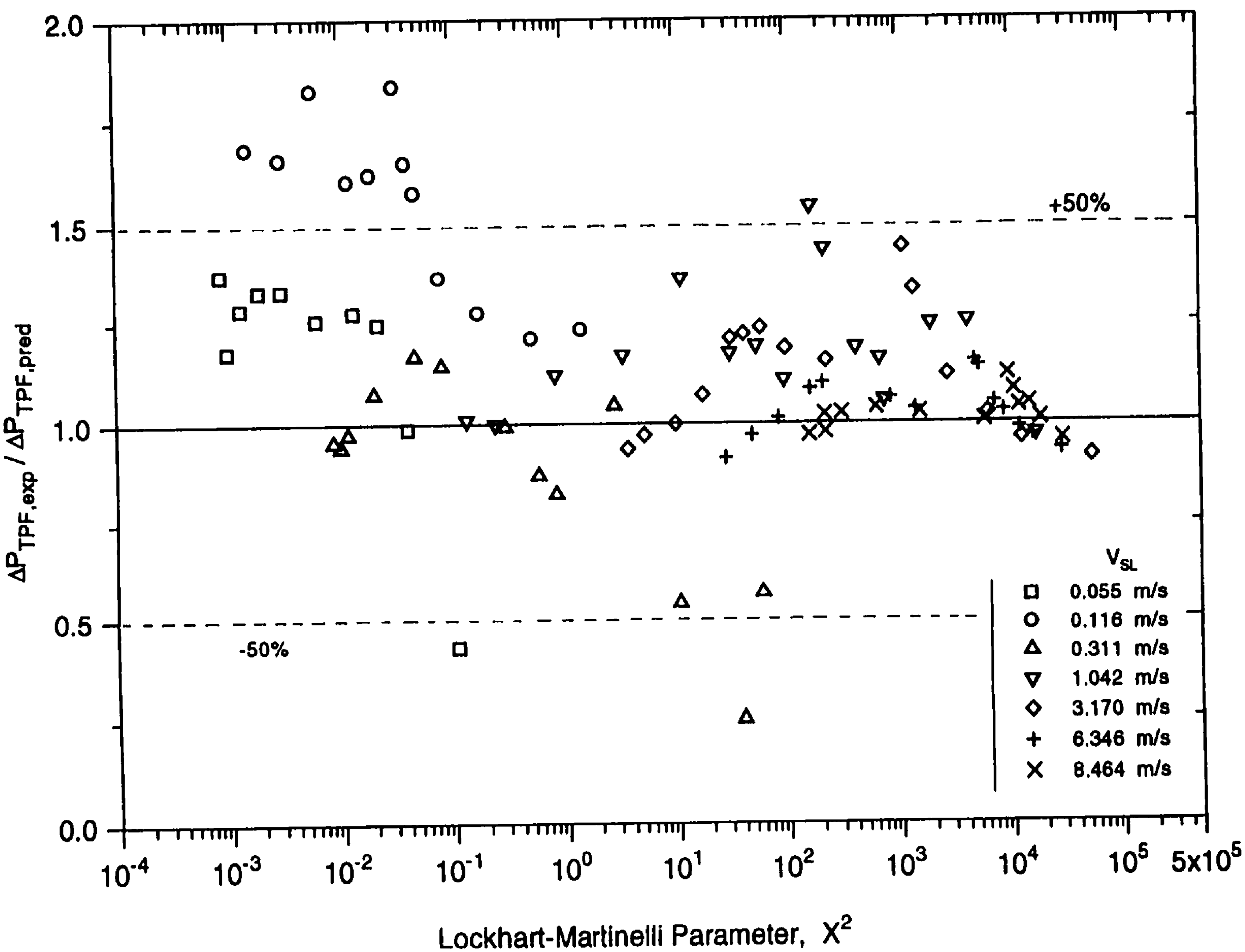

Figure 6.29 Comparison of Two-Phase Frictional Pressure Drop for Air-Water Data with the Lockhart-Martinelli Correlation (55)

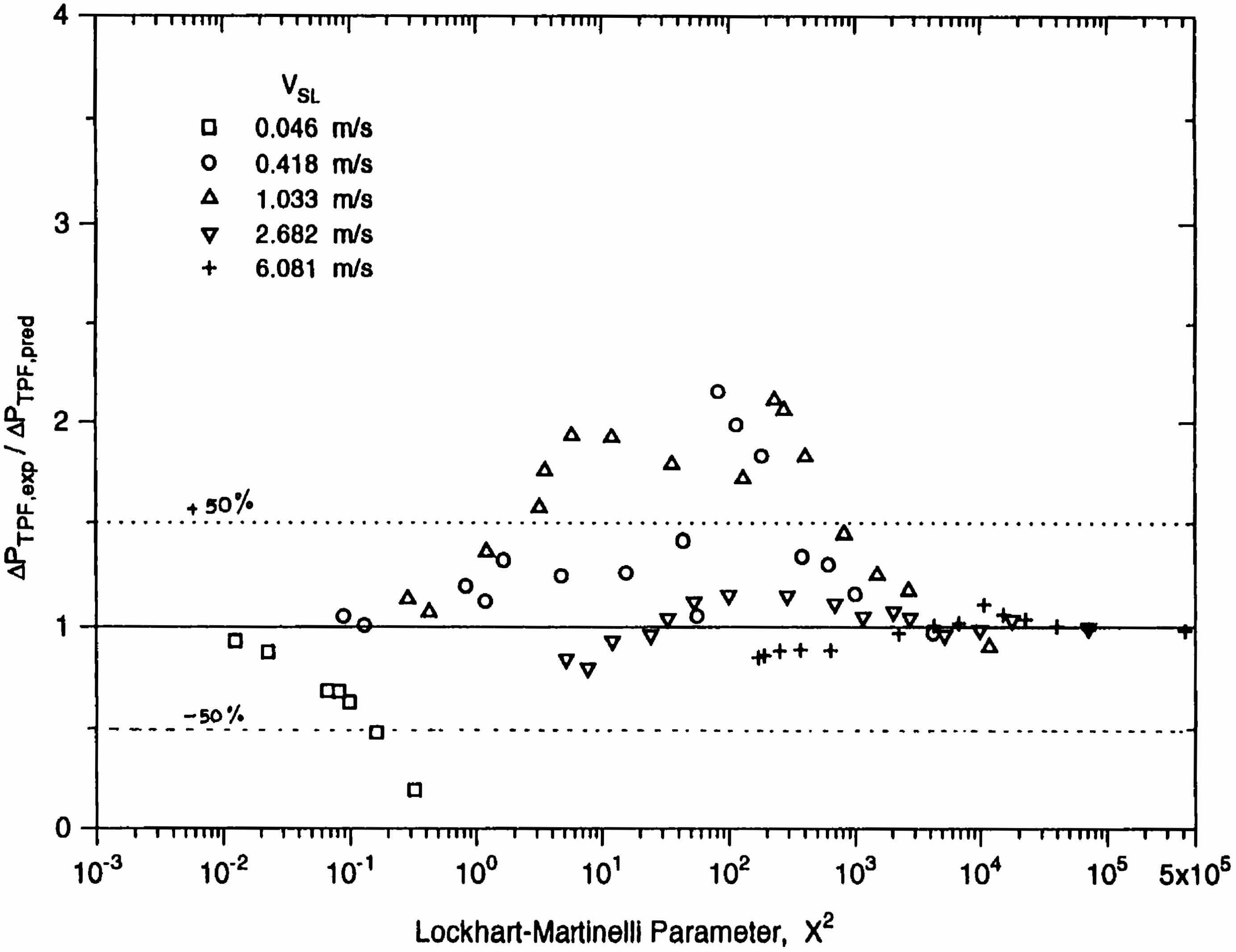

Figure 6.30 Comparison of Two-Phase Frictional-Pressure-Drop Data for Air-G1 with the Lockhart-Martinelli Correlation (55)

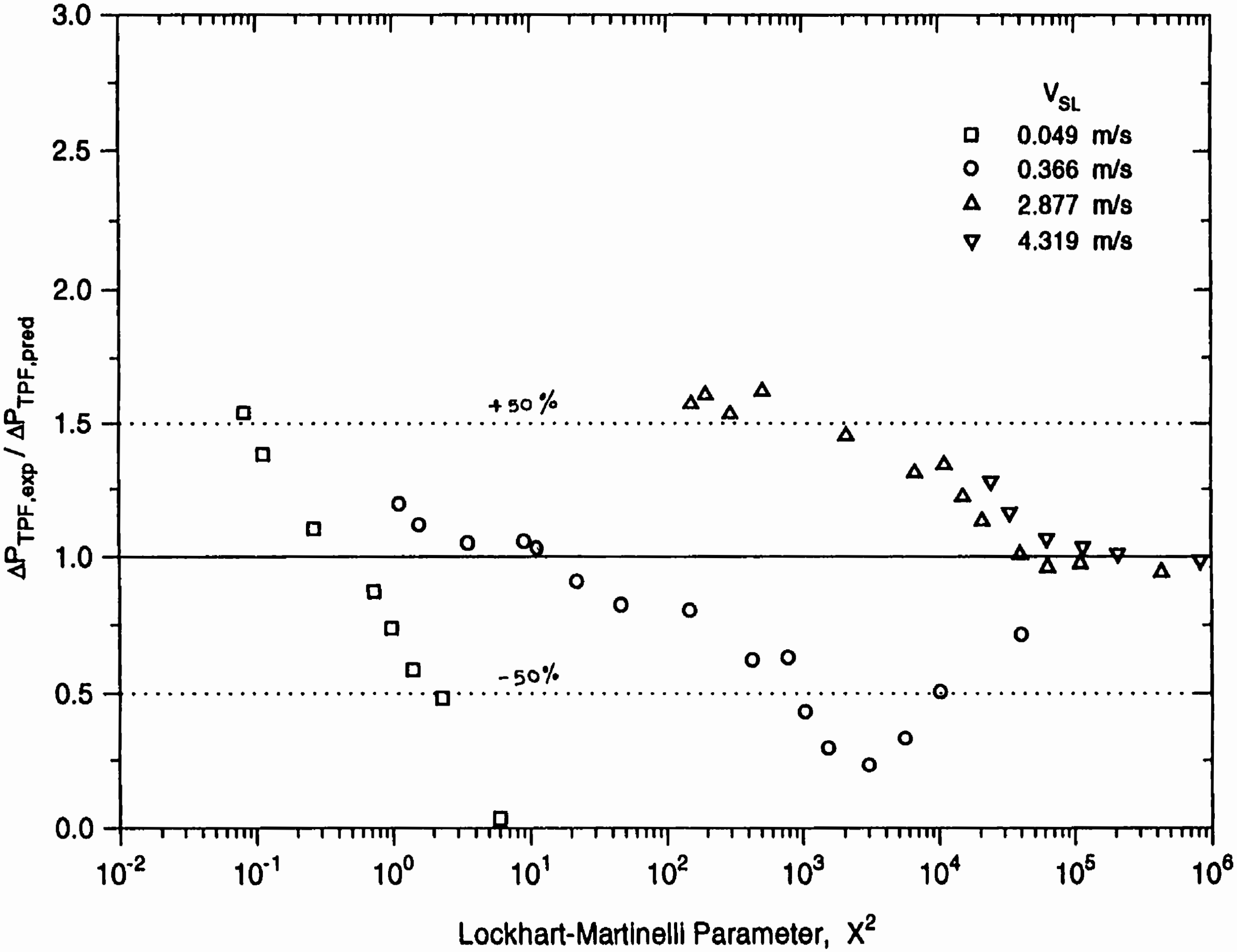

Figure 6.31 Comparison Two-Phase Frictional-Pressure-Drop Data for Air-G2 with the Lockhart-Martinelli Correlation (55)

(at fixed V_{SL}). The poor predictions are normally associated with unsteady flow conditions such as bubble-slug, slug, slug-churn and churn flows. The same is for the case of air-G1 and air-G2, where the method generally gives good agreement at high V_{SL} (i.e., $V_{SL} \geq 2.682$ and $V_{SL} = 4.319$ m/s for air-G1 and air-G2, respectively).

Friedel (28) gave an empirical expression for a two-phase multiplier, Φ^2_{LO}, which is applicable to any gas-liquid system, except when $(\mu_L/\mu_G) > 1000$. The two-phase multiplier was defined as

$$\Phi^2_{LO} = \frac{(-dp/dz)_{TPF}}{(-dp/dz)_{LO}}$$

where $(-dp/dz)_{LO}$ is the frictional pressure gradient in single-phase liquid flow with the same mass flow rate as the total two-phase flow rate. Figures 6.32 to 6.34 show a comparison of the present data with the prediction of Friedel. Good agreement can be seen for all liquids at $V_{SL} \geq 2.682$ m/s. At the lowest values of V_{SL}, the correlation markedly overpredicts the values of frictional pressure drop.

6.6 SUMMARY

It has been demonstrated in this chapter that flow pattern in two-phase gas-liquid flow is an important factor in frictional pressure drop. As shown in Appendix D, in order to determine an accurate value of two-phase frictional pressure drop, the value of mean void fraction is needed. Repeatability tests for two-phase pressure drop for all air-liquid systems in the present study were performed. The results show excellent repeatability and are presented in Appendix E. For predictions, Whalley (98) commented that "Substantial

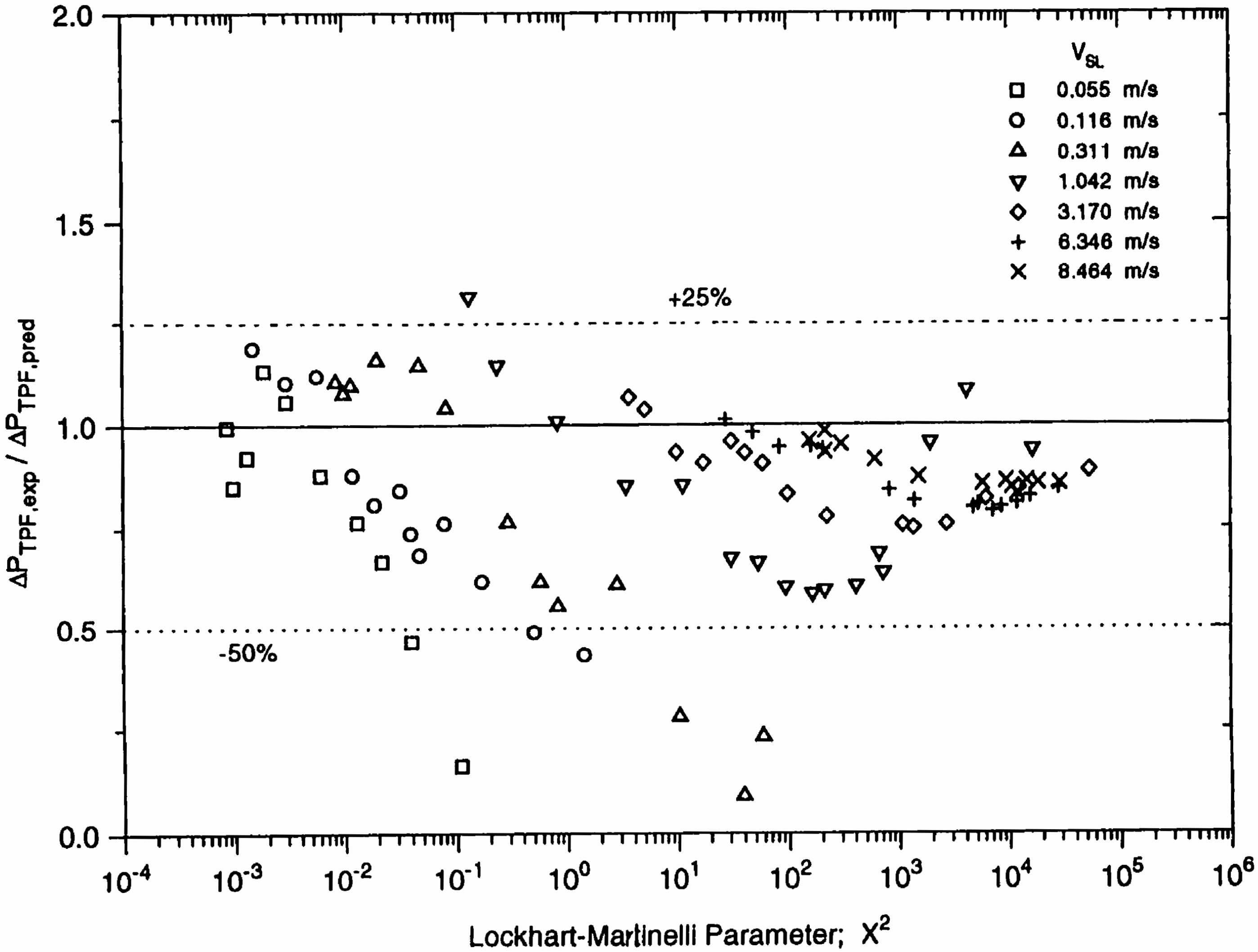

Figure 6.32 Comparison of Two-Phase Frictional-Pressure-Drop Data for Air-Water with Friedel's Correlation (28)

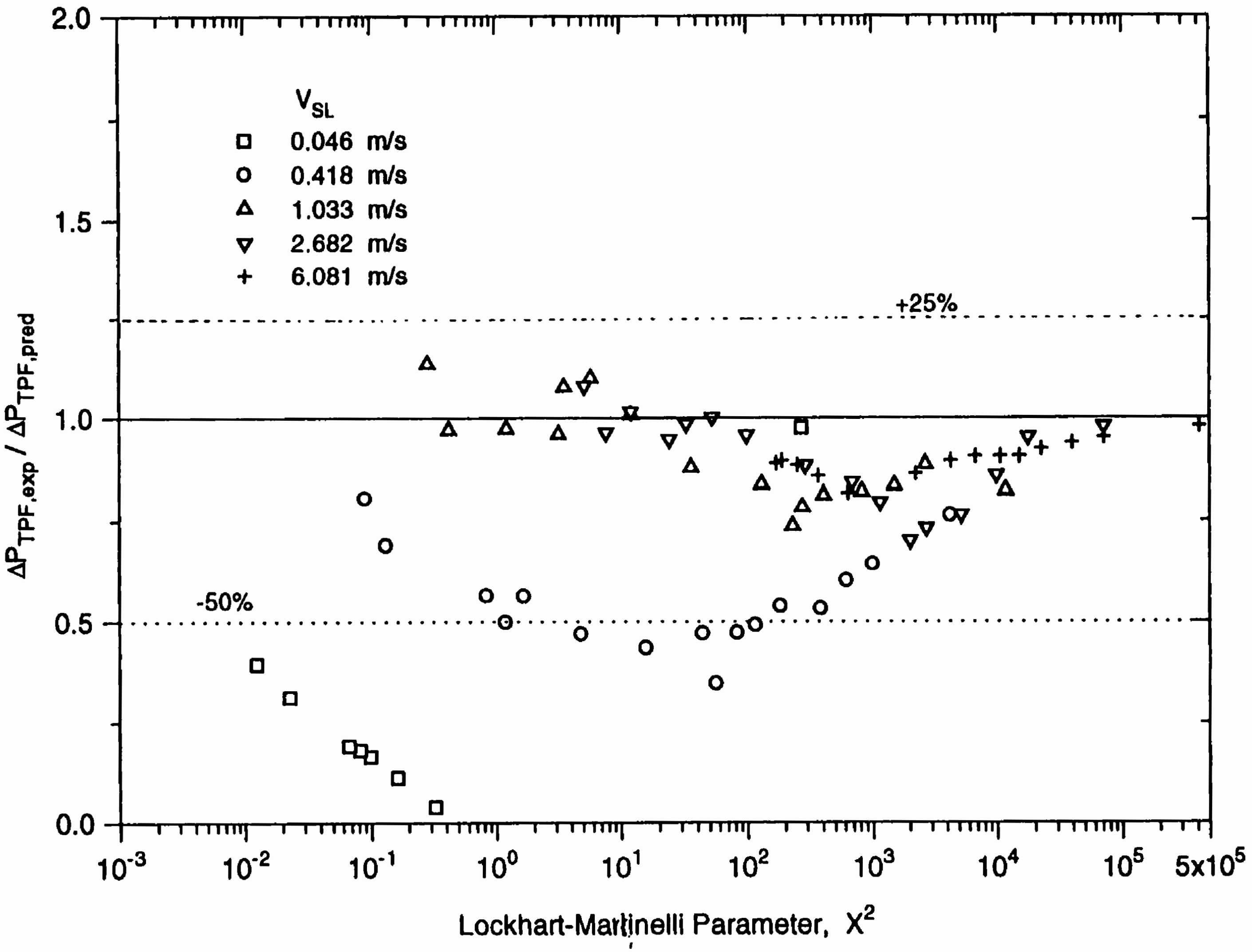

Figure 6.33 Comparison of Two-Phase Frictional-Pressure-Drop Data for Air-G1 with Friedel's Correlation (28)

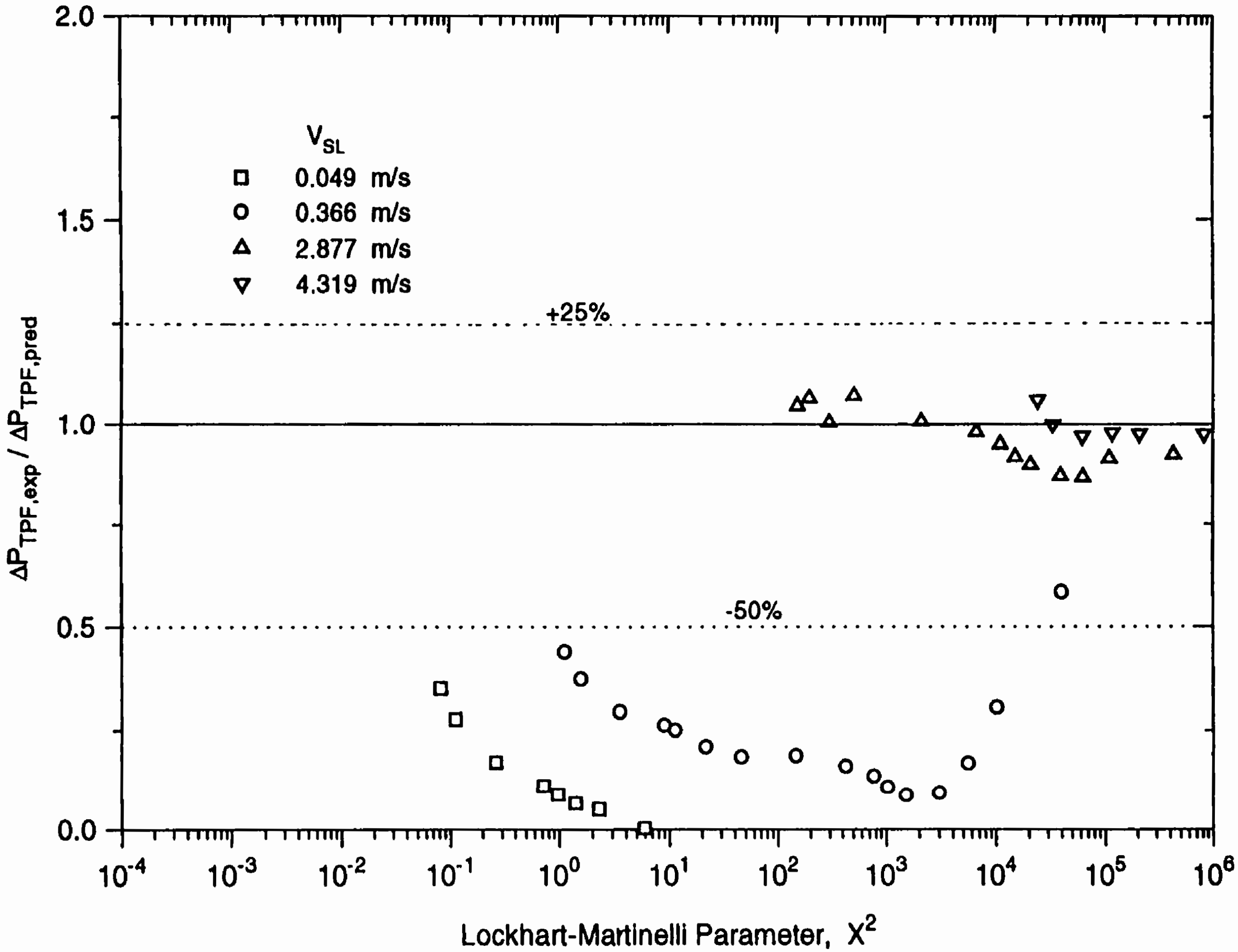

Figure 6.34 Comparison of Two-Phase Frictional-Pressure-Drop Data for Air-G2 with Friedel's Correlation (28)

improvement in the accuracy will not be made until modelling methods based on individual flow patterns and their characteristics are used".

Chapter 7

PRESENTATION AND DISCUSSION OF HEAT-TRANSFER DATA

7.1 INTRODUCTORY REMARKS

This chapter presents and discusses the results of the two-phase heat-transfer tests conducted in the present investigation. During the course of experiments, both local and mean heat-transfer coefficients of all three air-liquid systems were obtained. The results of these local heat-transfer coefficients are shown in the next section. This is followed by the presentation and discussion of mean heat-transfer coefficients. Repeatability tests for heat transfer were done for all three air-liquid systems during the experiment of which the results are presented in Appendix E.

As pointed out in Chapter 4, during the course of the experiment, the system pressure varied from datum point to datum point at each run. These system pressures varied from 110.3 to 227.5 kPa for the case of $V_{SL} < 4.23$ m/s and 158.6 to 344.7 kPa for the case of $V_{SL} > 4.23$ m/s. However, the effect of gas density on heat transfer was investigated by Aggour (1) who found that for the flow where $V_{SL} > 4.23$ m/s the effect of gas density on heat transfer is negligible. For the case of lower V_{SL} (i.e., $V_{SL} < 4.23$ m/s), the heat-transfer coefficient increases by approximately 20 percent when gas-phase density increases by a factor of 7. The results of Aggour (1) indicate that, for the range of variation of the system pressure change involved in the present investigation, the heat-transfer coefficient was affected approximately by 5 percent in the case of $V_{SL} < 4.23$ m/s and the variation of system pressure has almost no effect on h_{TP} for the case of $V_{SL} > 4.23$ m/s.

The argument was made earlier that because of the good agreement between the present single-phase data and well-accepted correlations, one would expect the two-phase data to be reliable. Still, where comparisons can be made with other studies for reasonably similar conditions, and the agreement between the present and other data is good, then confidence should be further enhanced. Therefore, some of the present air-water and air-G1 data were compared with data (at very similar flow conditions) of independent previous studies (1, 71, 100) using the same experimental facility and with more recent data (where a different experimental facility, of 9.53-mm i.d., was used) of Rite and Rezkallah (73) and Rite (72). The results in Figures 7.1a to c indicate good agreement between the present data of air-water systems and others which were independently taken. Figures 7.2a and 7.2b also indicate good agreement, for the air-G1 system, between the present data and those of Rezkallah (71) and Rite (72).

7.2 LOCAL HEAT-TRANSFER COEFFICIENTS

The procedure for calculating the two-phase local heat-transfer coefficient is similar to that of liquid single-phase flow, and is given in detail in Appendix D. Figures 7.3 (a to g), 7.4 (a to e) and 7.5 (a to d) show local heat-transfer coefficients for air-water, air-G1 and air-G2 systems, respectively. To avoid too much data on individual figures, thereby showing more clearly the effect of the addition of gas phase on h_{TP}, only selected data (approximately 80% of all the data, including the extreme cases) of the tests are

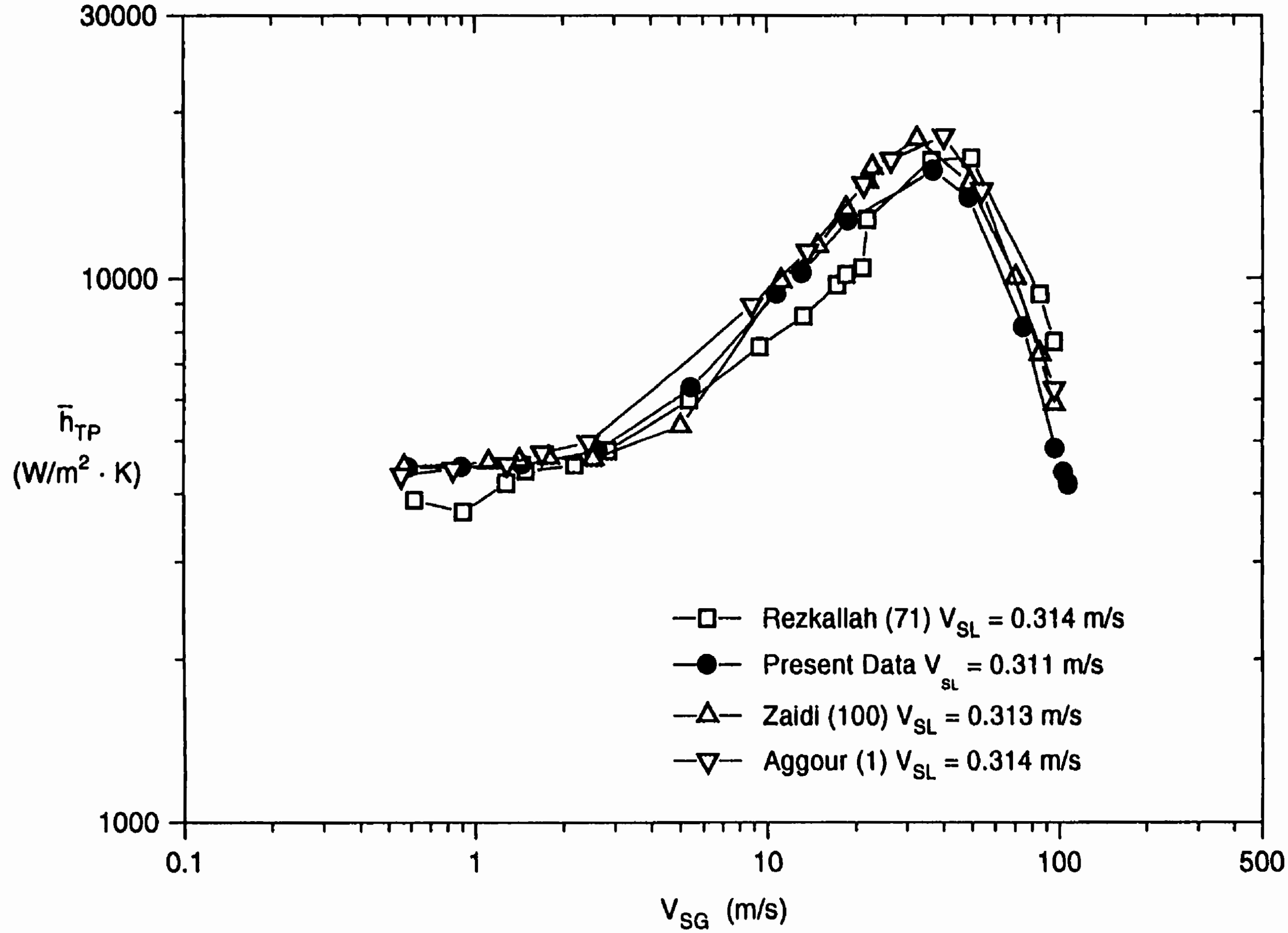

Figure 7.1a Comparison of Experimental Data for Air-Water with Others at V_{SL} = 0.311 m/s (approx.)

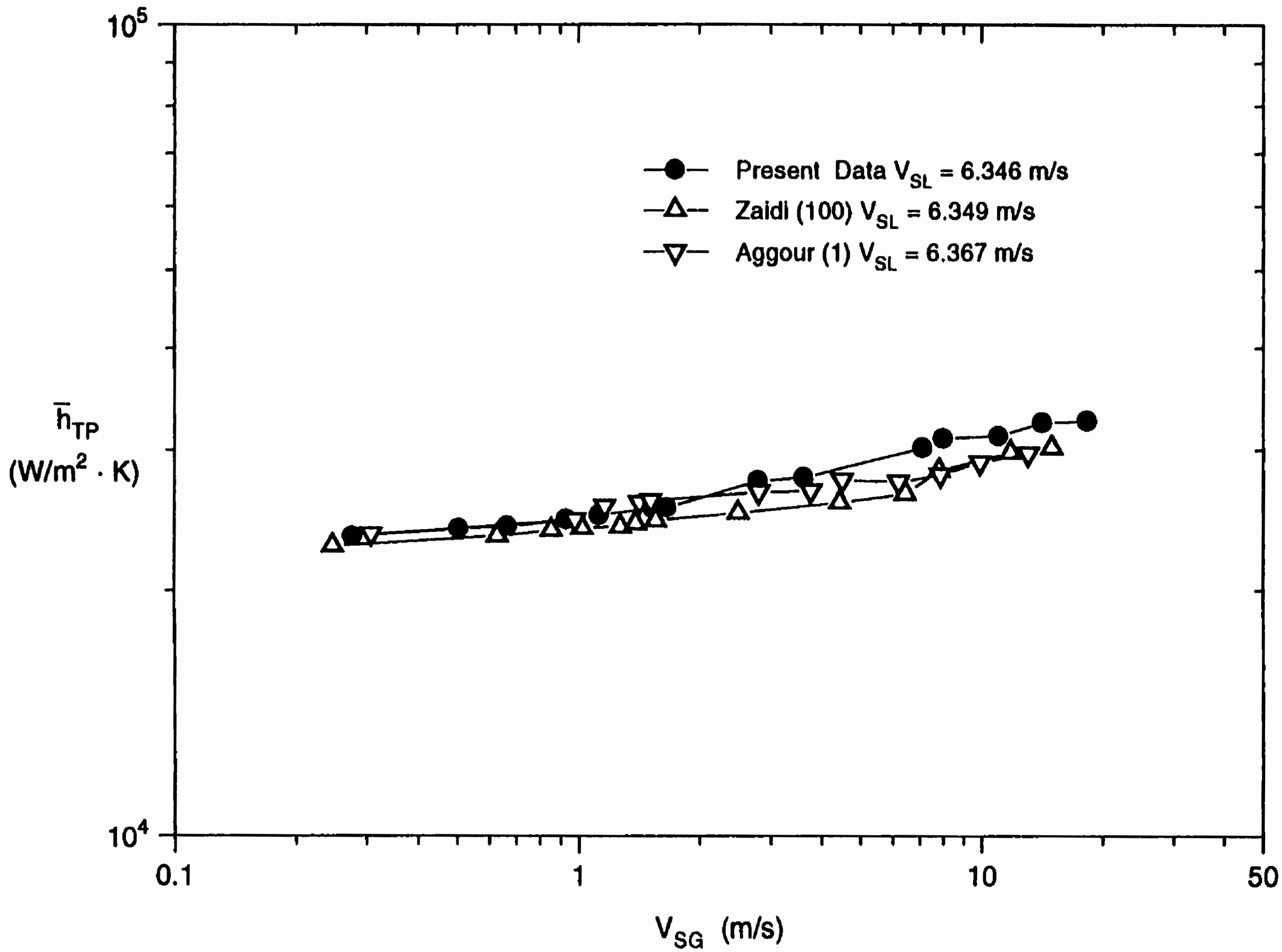

Figure 7.1b Comparison of Experimental Data for Air-Water with Others at V_{SL} = 6.346 m/s (approx.)

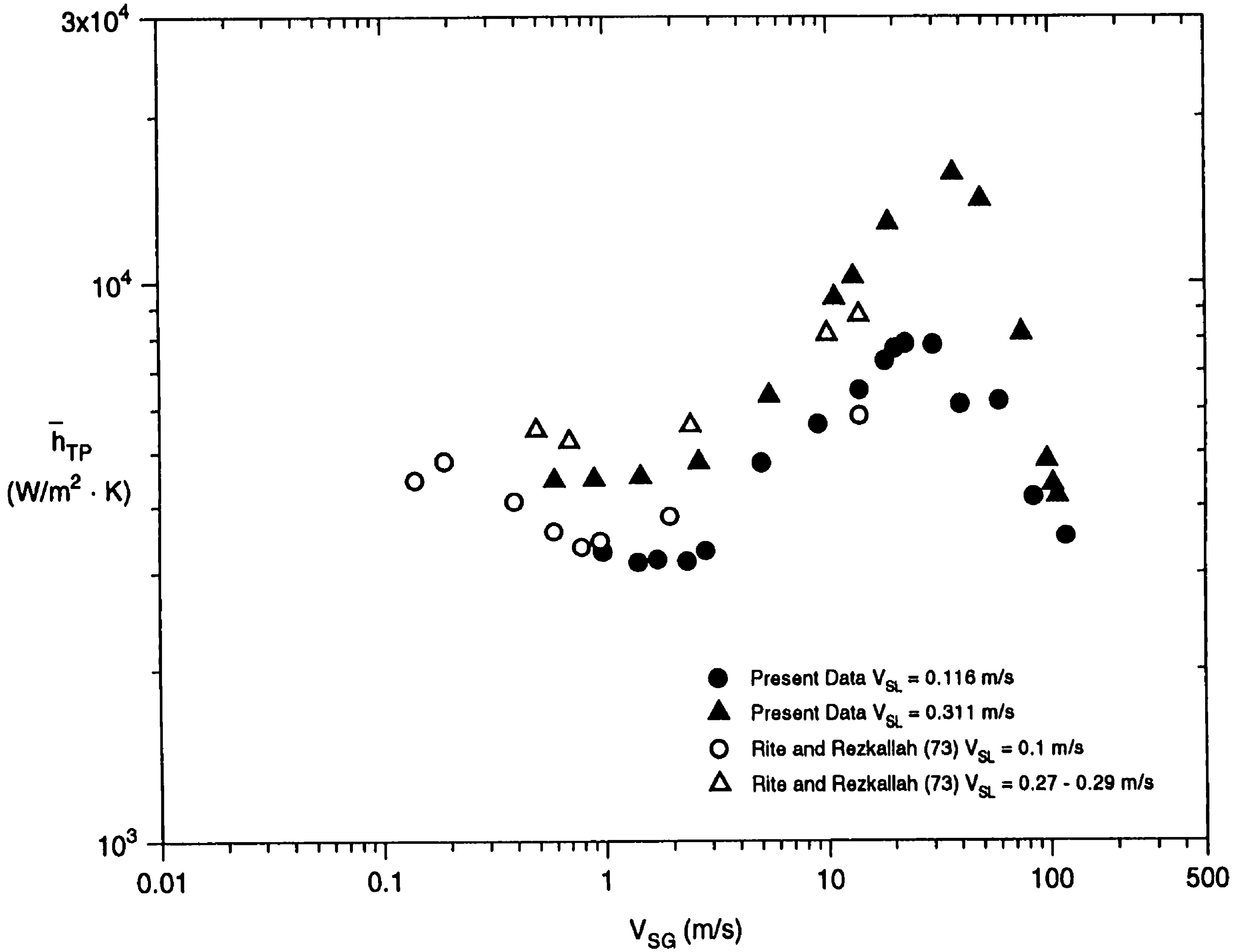

Figure 7.1c Comparison of Experimental Data for Air-Water with Rite and Rezkallah (73)

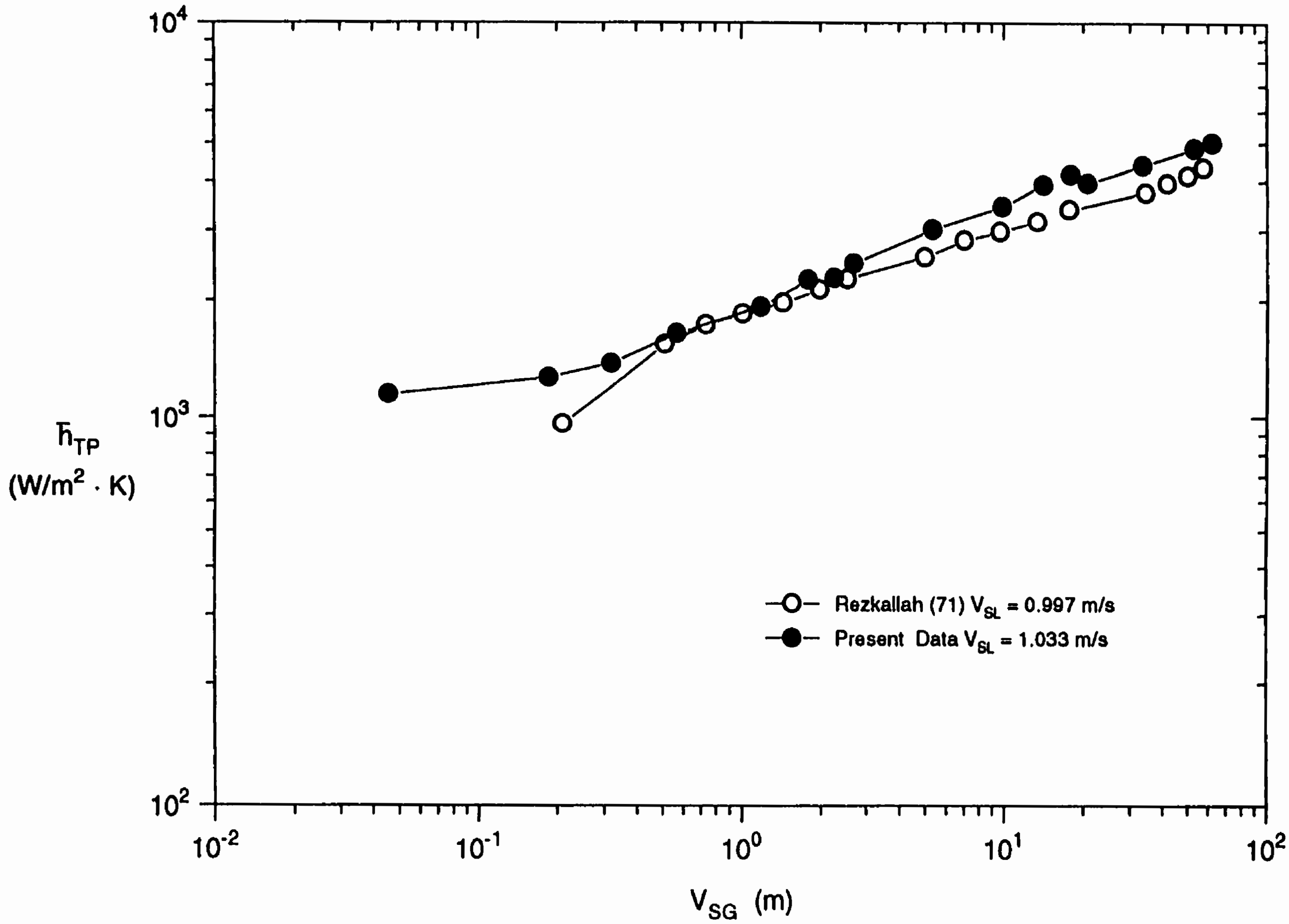

Figure 7.2a Comparison of Experimental Data for Air-G1 with Rezkallah (71) at V_{SL} = 1.033 m/s (approx.)

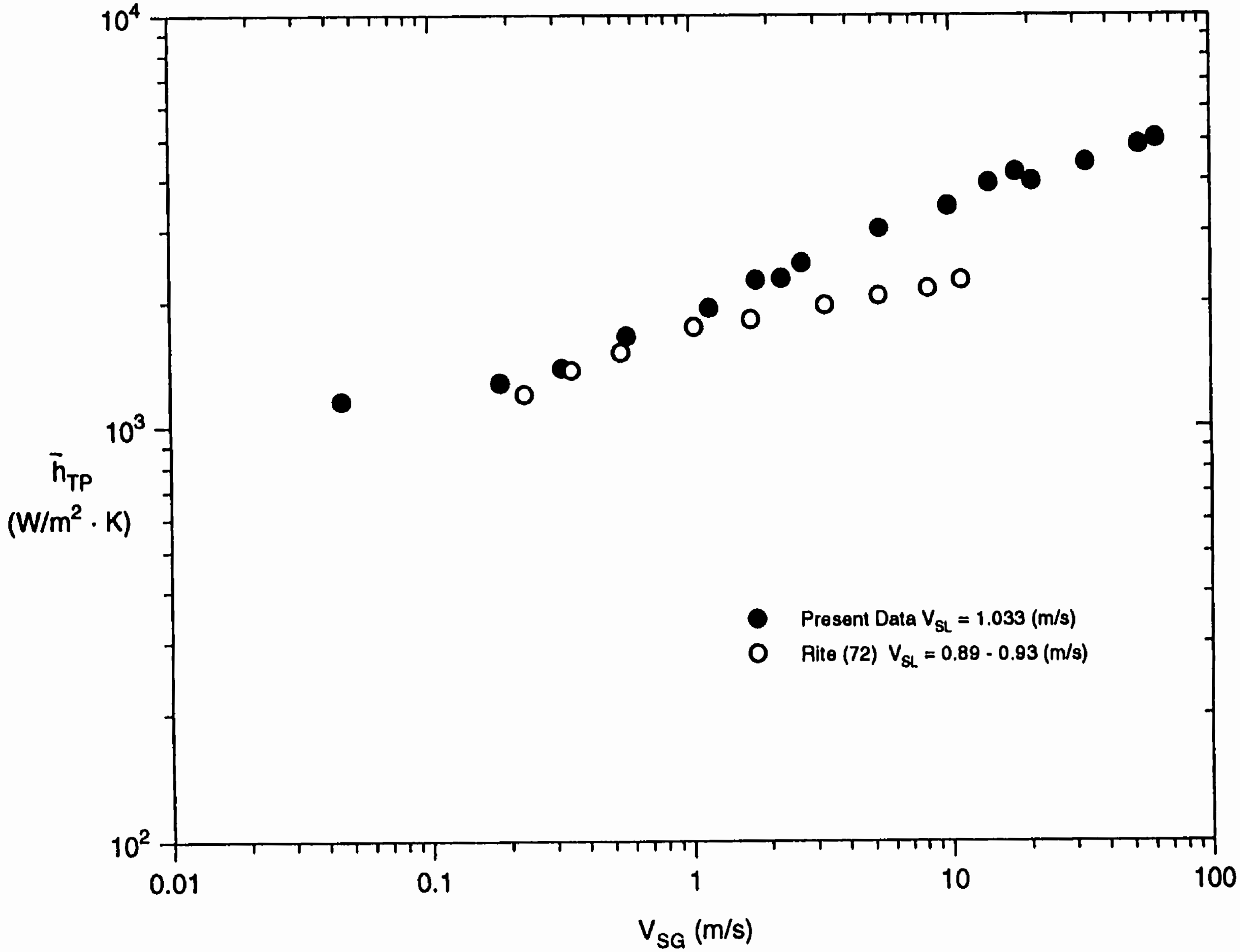

Figure 7.2b Comparison of Experimental Data for Air-G1 with Rite (72)

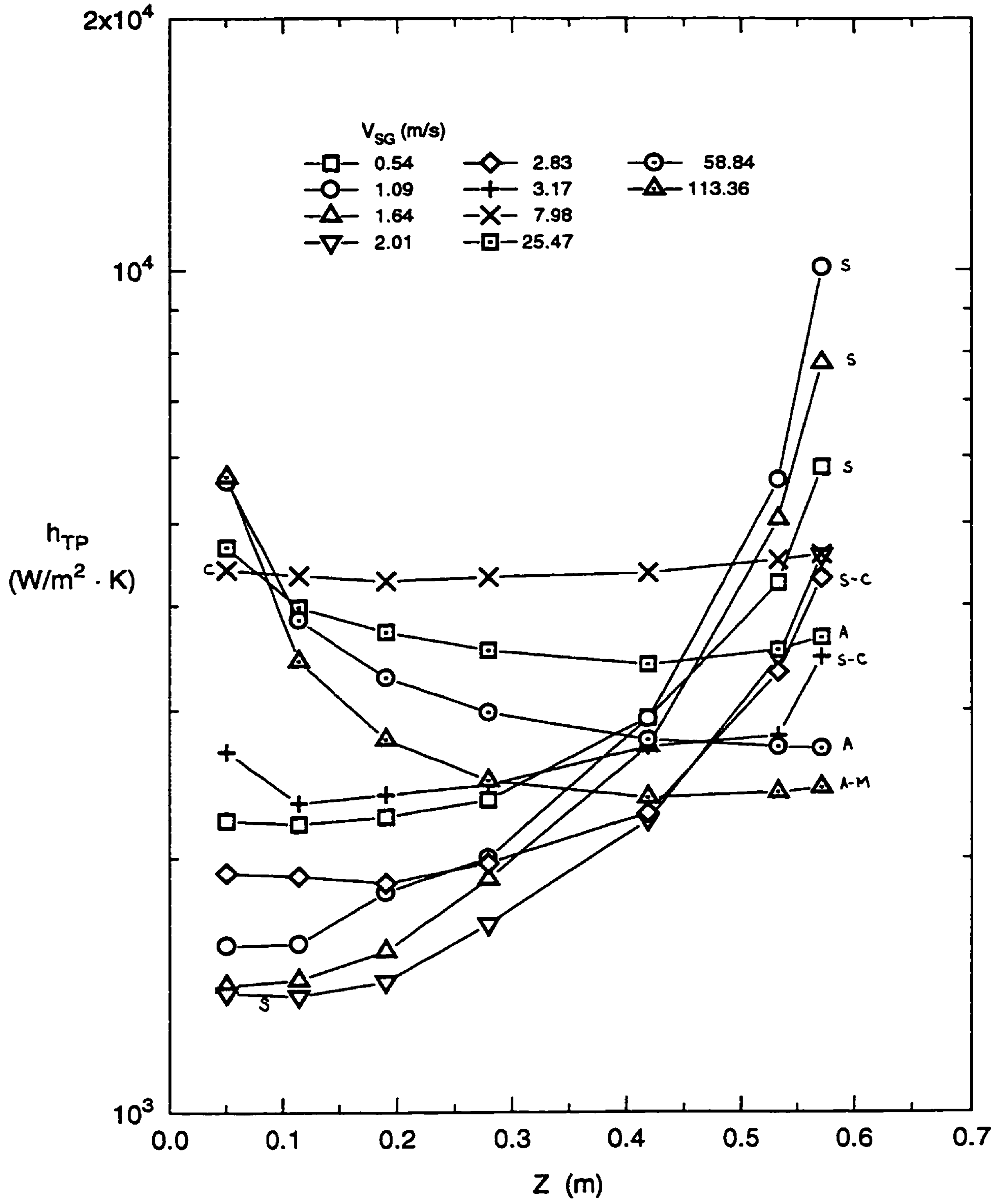

Figure 7.3a Two-Phase Air-Water Local Heat-Transfer Results at V_{SL} = 0.055 m/s

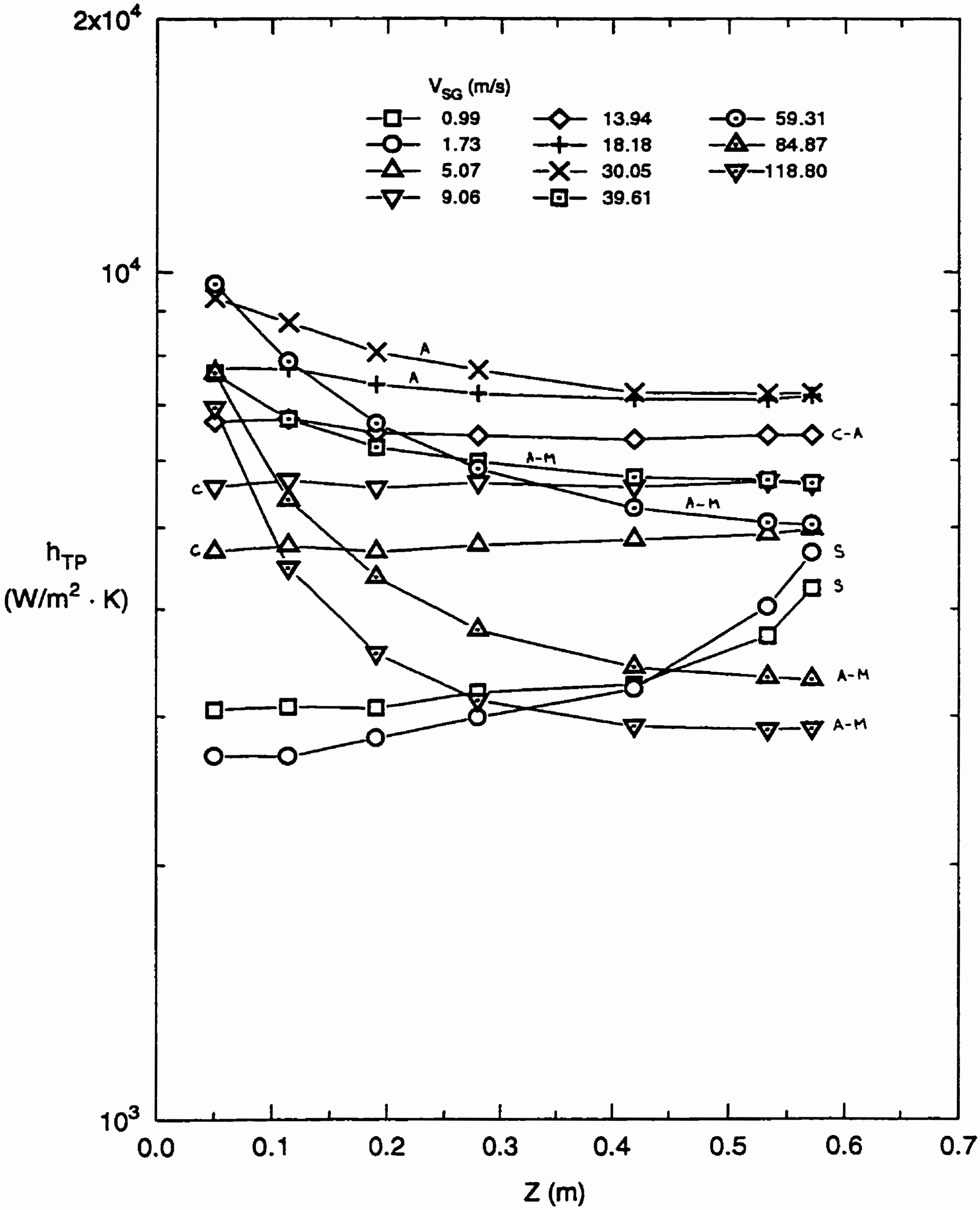

Figure 7.3b Two-Phase Air-Water Local Heat-Transfer Results at V_{SL} = 0.116 m/s

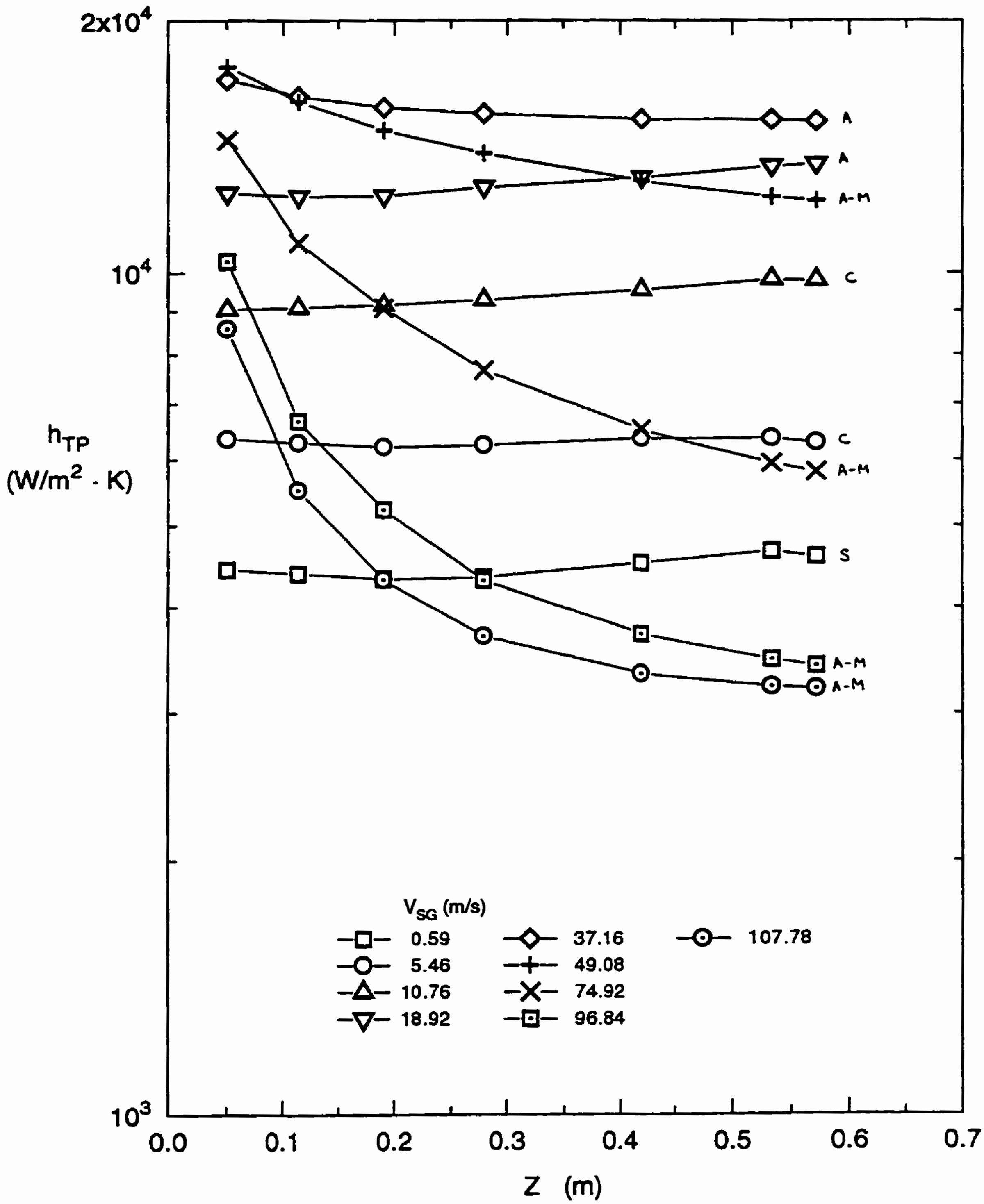

Figure 7.3c Two-Phase Air-Water Local Heat-Transfer Results at $V_{SL} = 0.311$ m/s

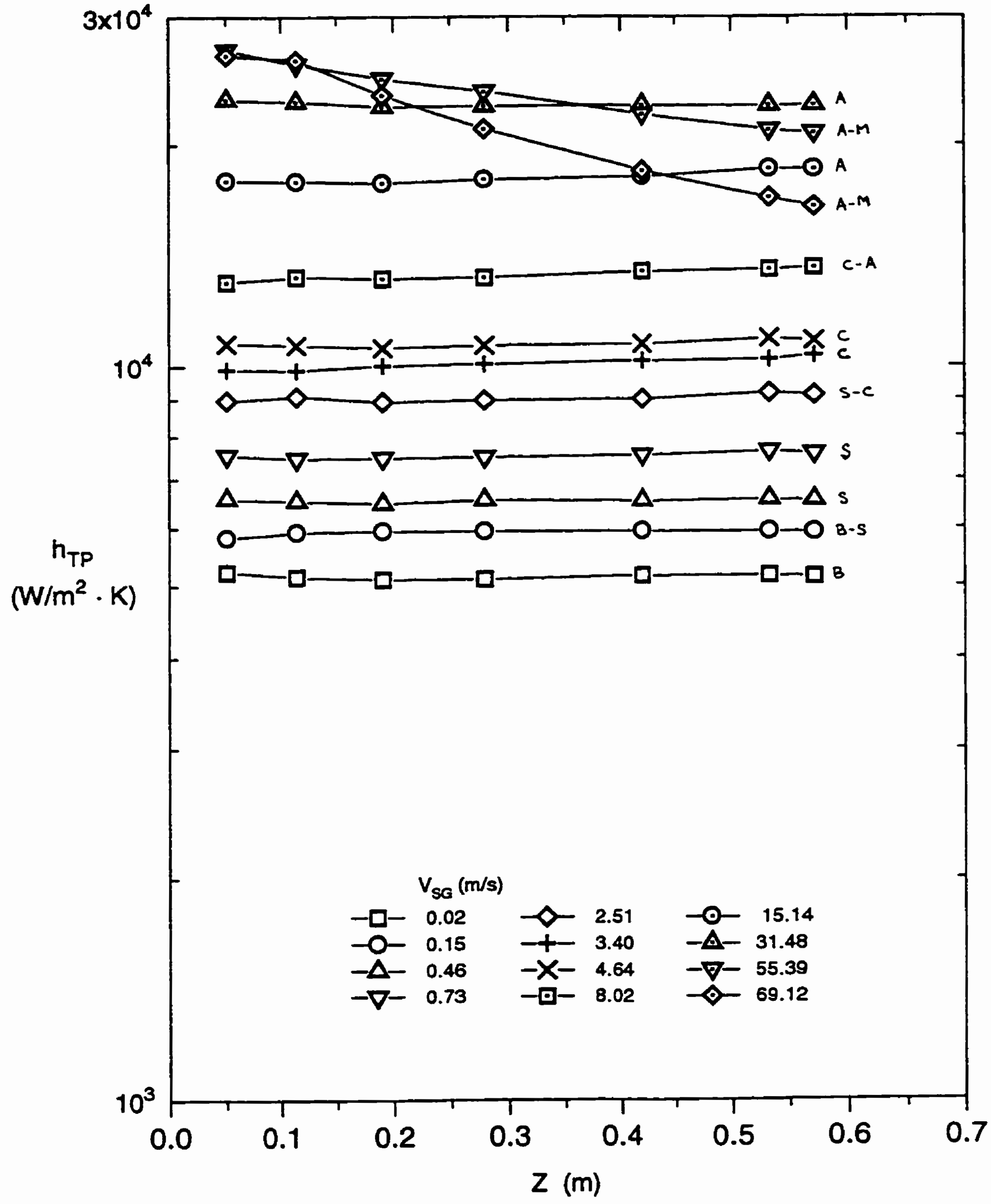

Figure 7.3d Two-Phase Air-Water Local Heat-transfer Results at $V_{SL} = 1.042$ m/s

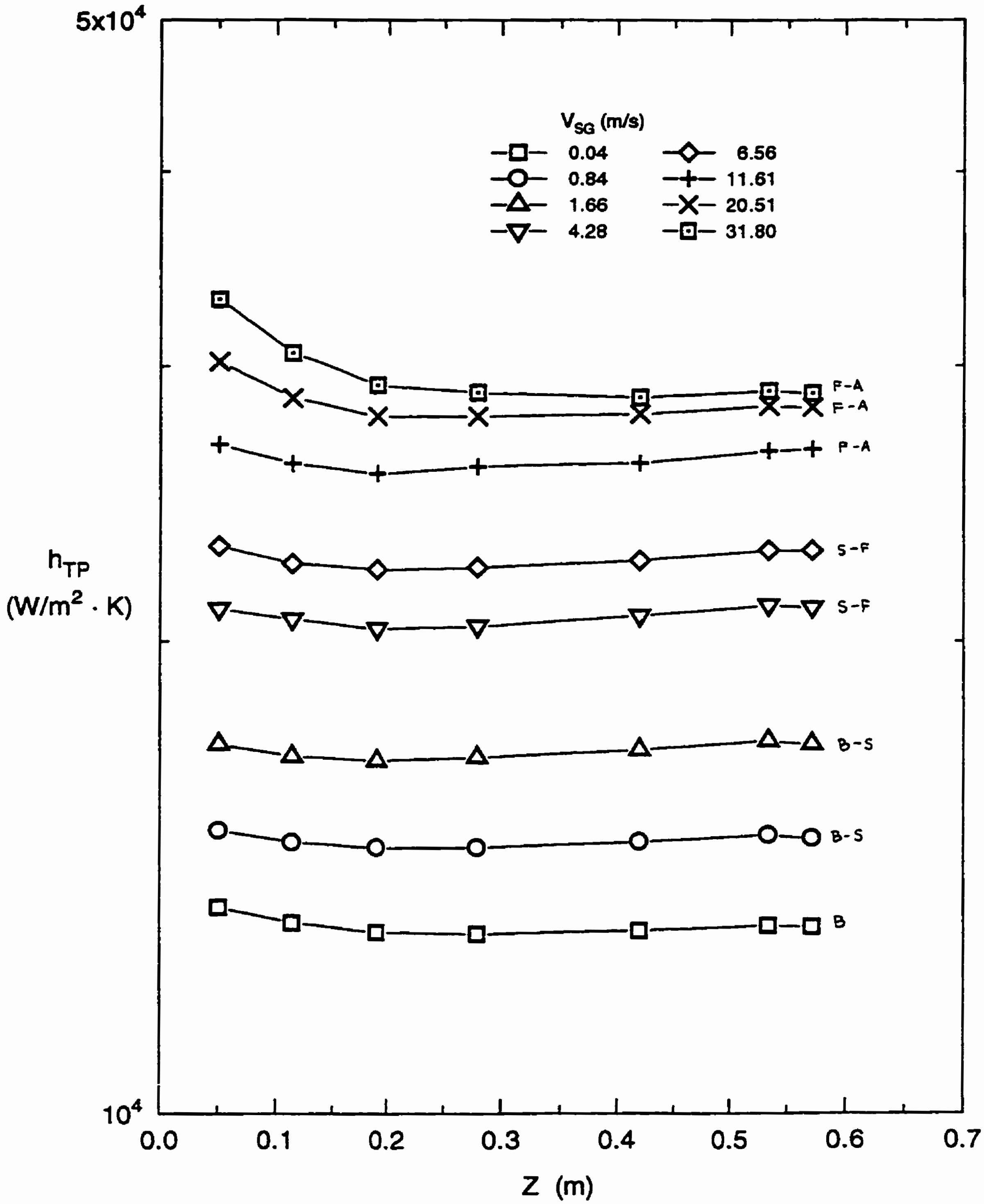

Figure 7.3e Two-Phase Air-Water Local Heat-Transfer Results at V_{SL} = 3.17 m/s

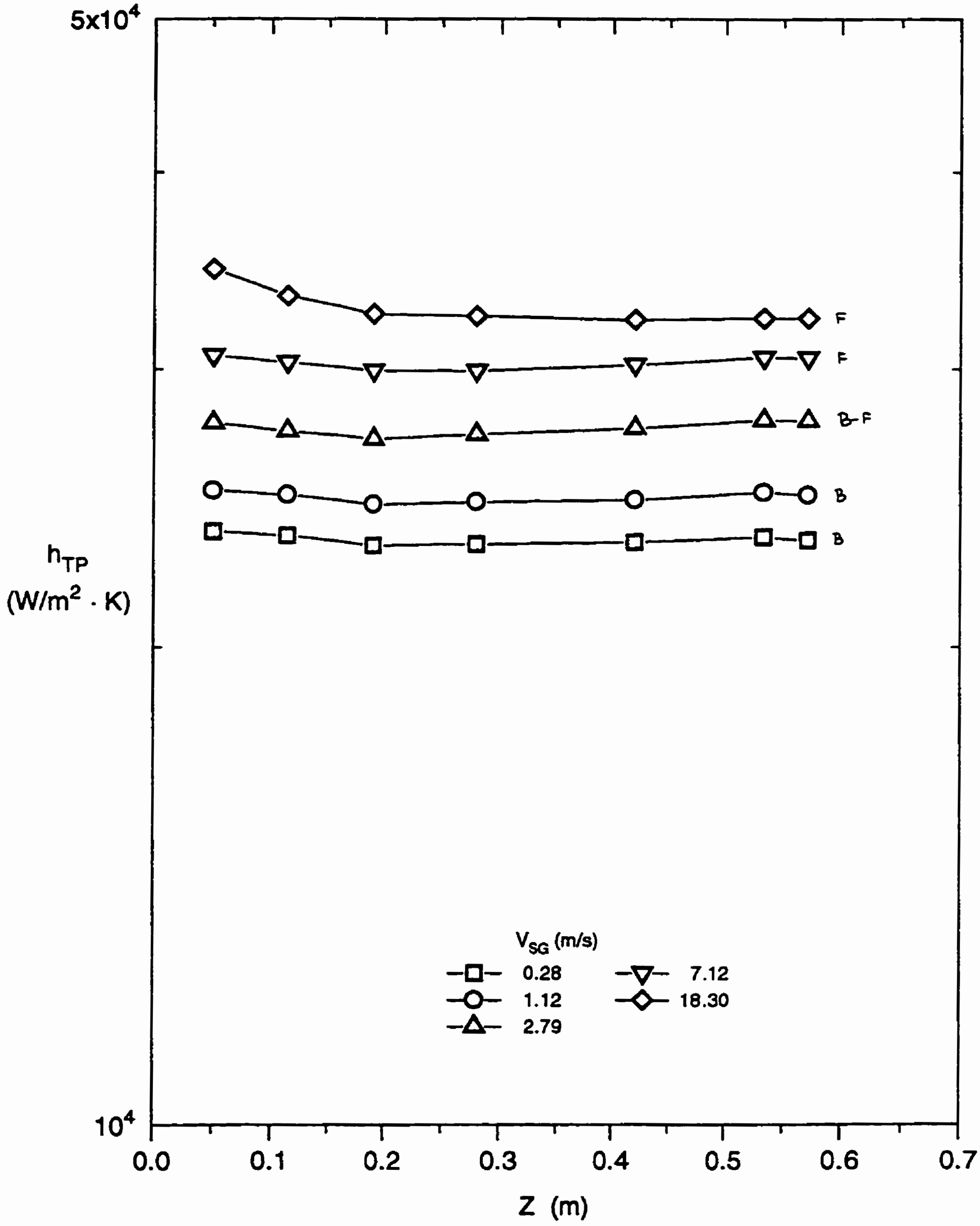

Figure 7.3f Two-Phase Air-Water Local Heat-Transfer Results at V_{SL} = 6.346 m/s

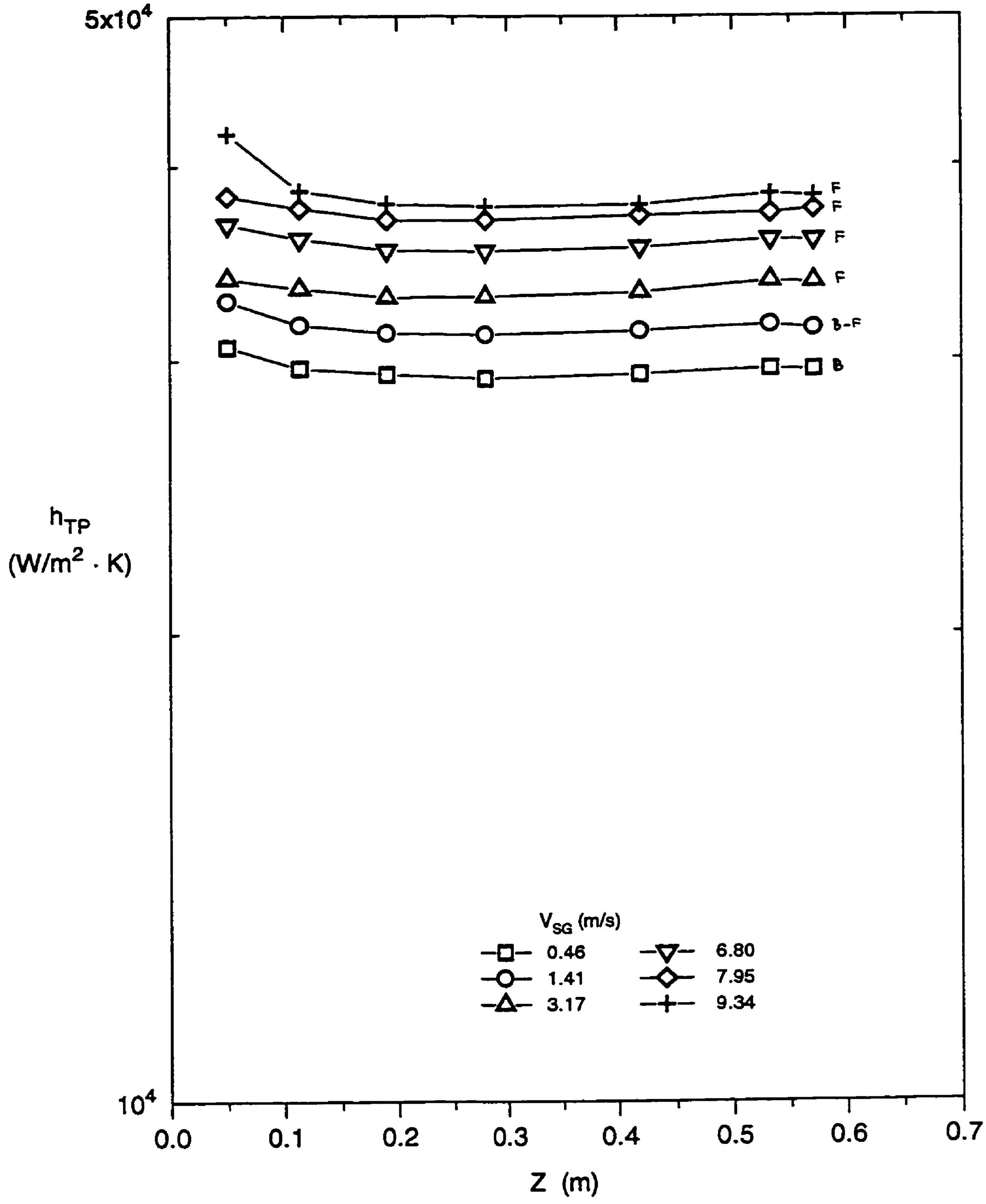

Figure 7.3g Two-Phase Air-Water Local Heat-Transfer Results at $V_{SL} = 8.464$ m/s

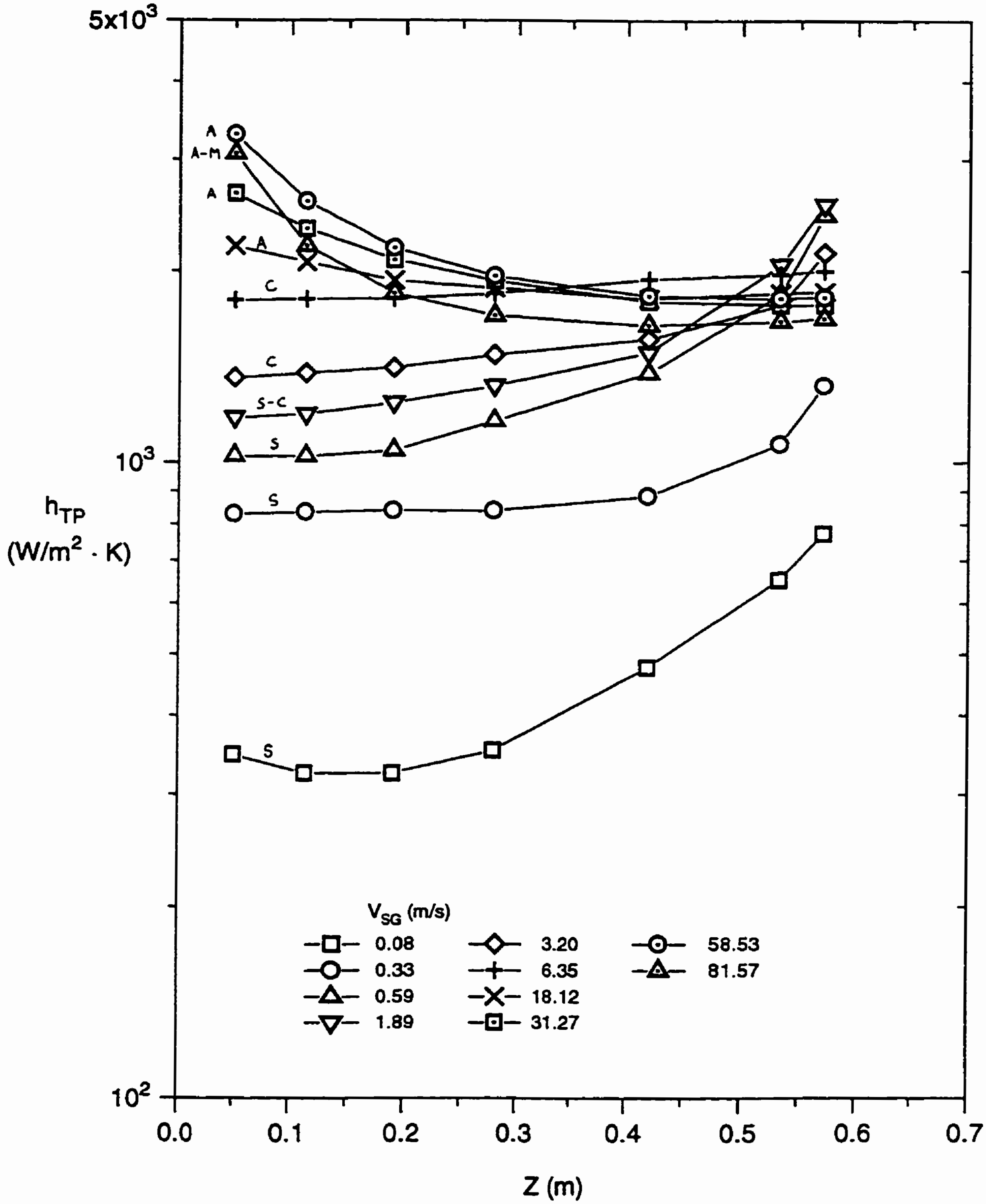

Figure 7.4a Two-Phase Air-G1 Local Heat-Transfer Results at $V_{SL} = 0.046$ m/s

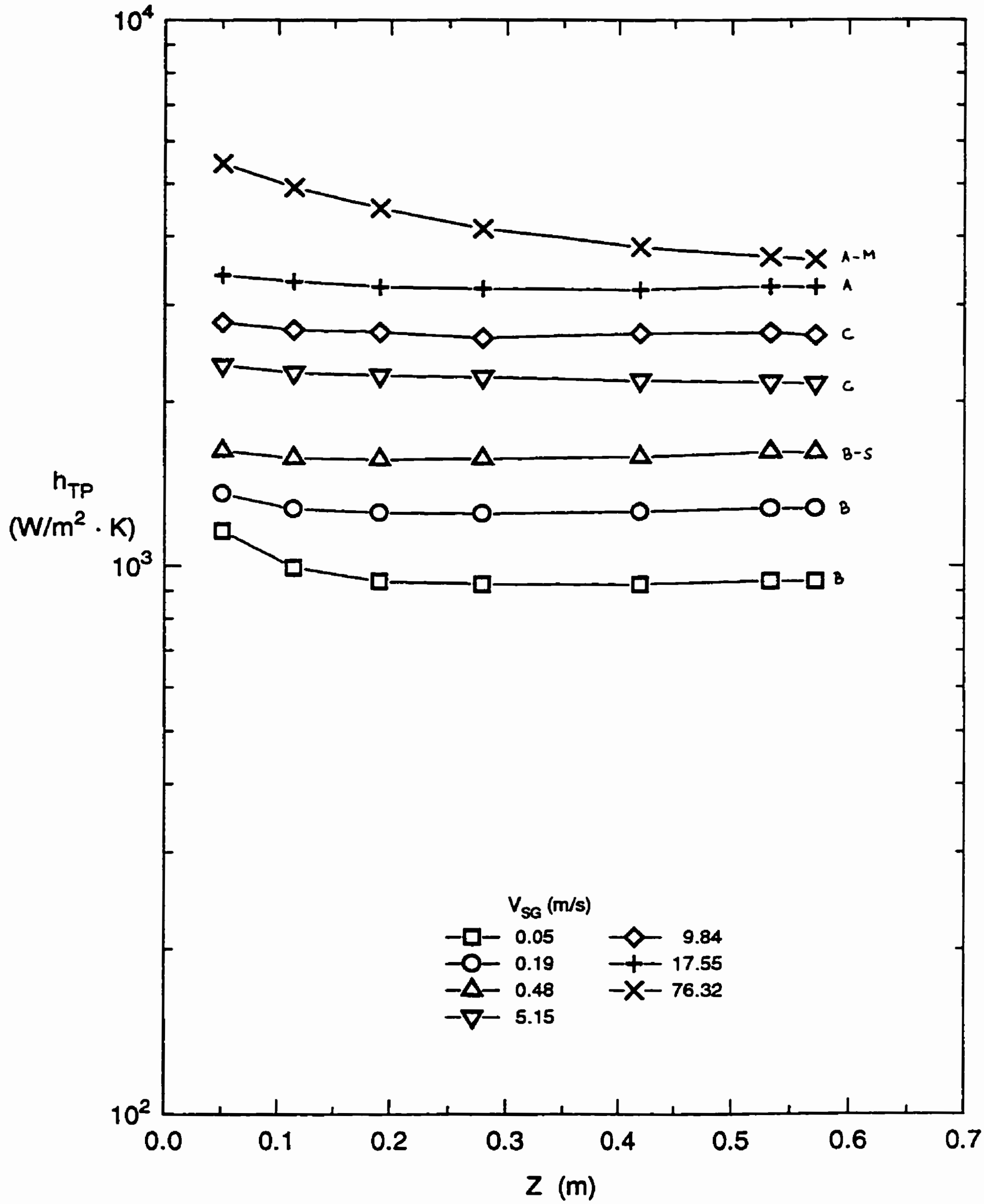

Figure 7.4b Two-Phase Air-G1 Local Heat-Transfer Results at V_{SL} = 0.418 m/s

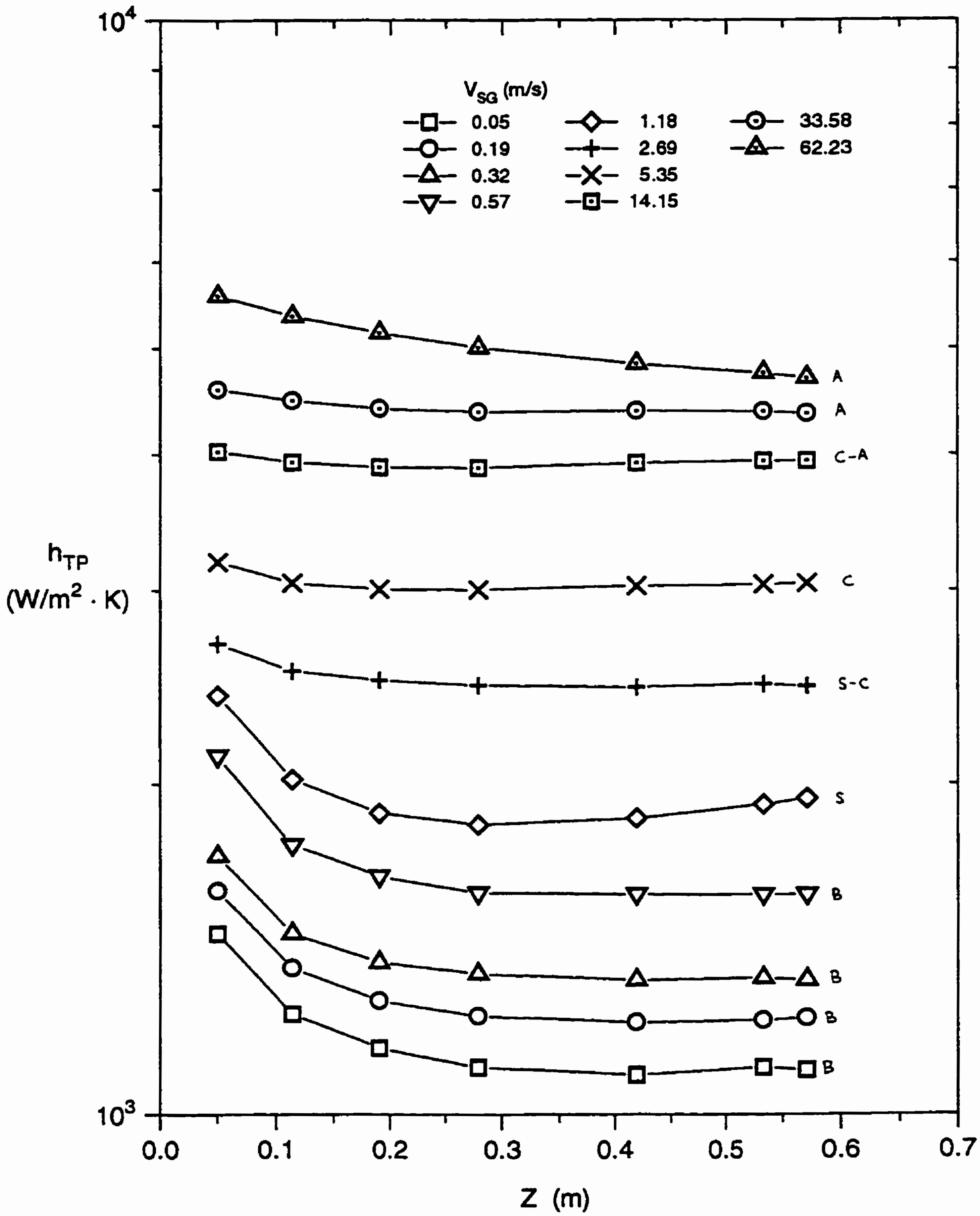

Figure 7.4c Two-Phase Air-G1 Local Heat-Transfer Results at V_{SL} = 1.033 m/s

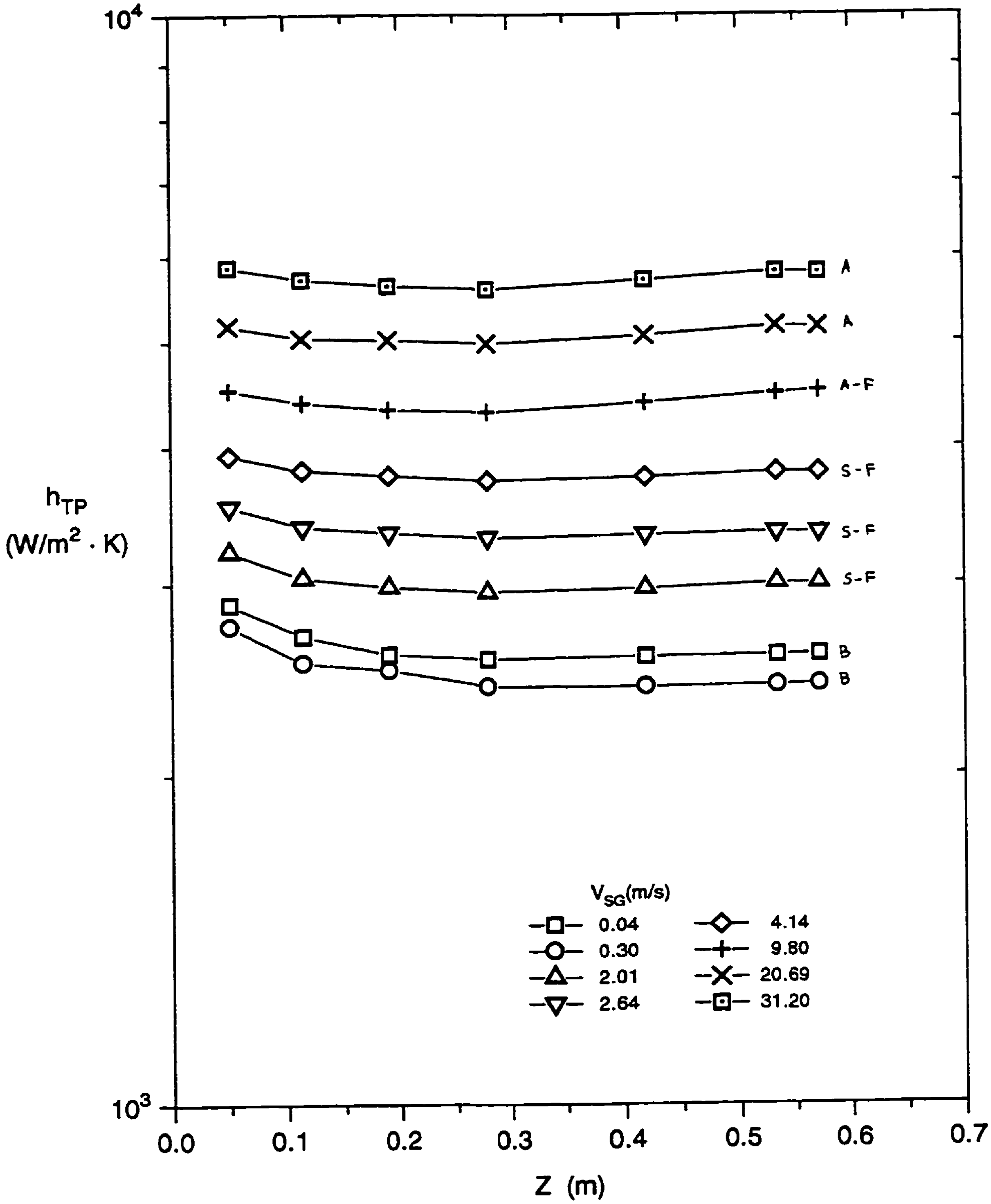

Figure 7.4d Two-Phase Air-G1 Local Heat Transfer Results at $V_{SL} = 2.682$ m/s

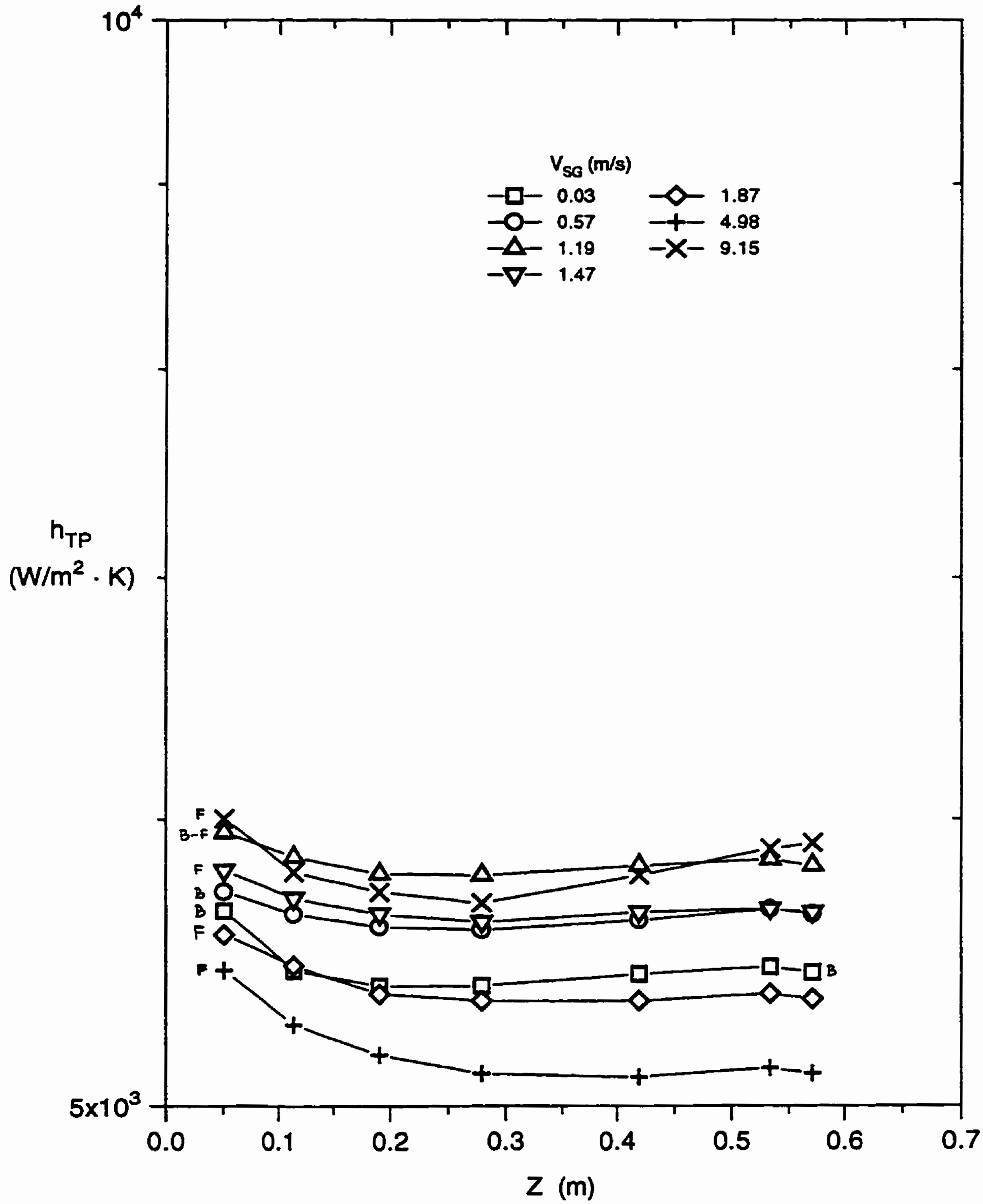

Figure 7.4e Two-Phase Air-G1 Local Heat-Transfer Results at V_{SL} = 6.081 m/s

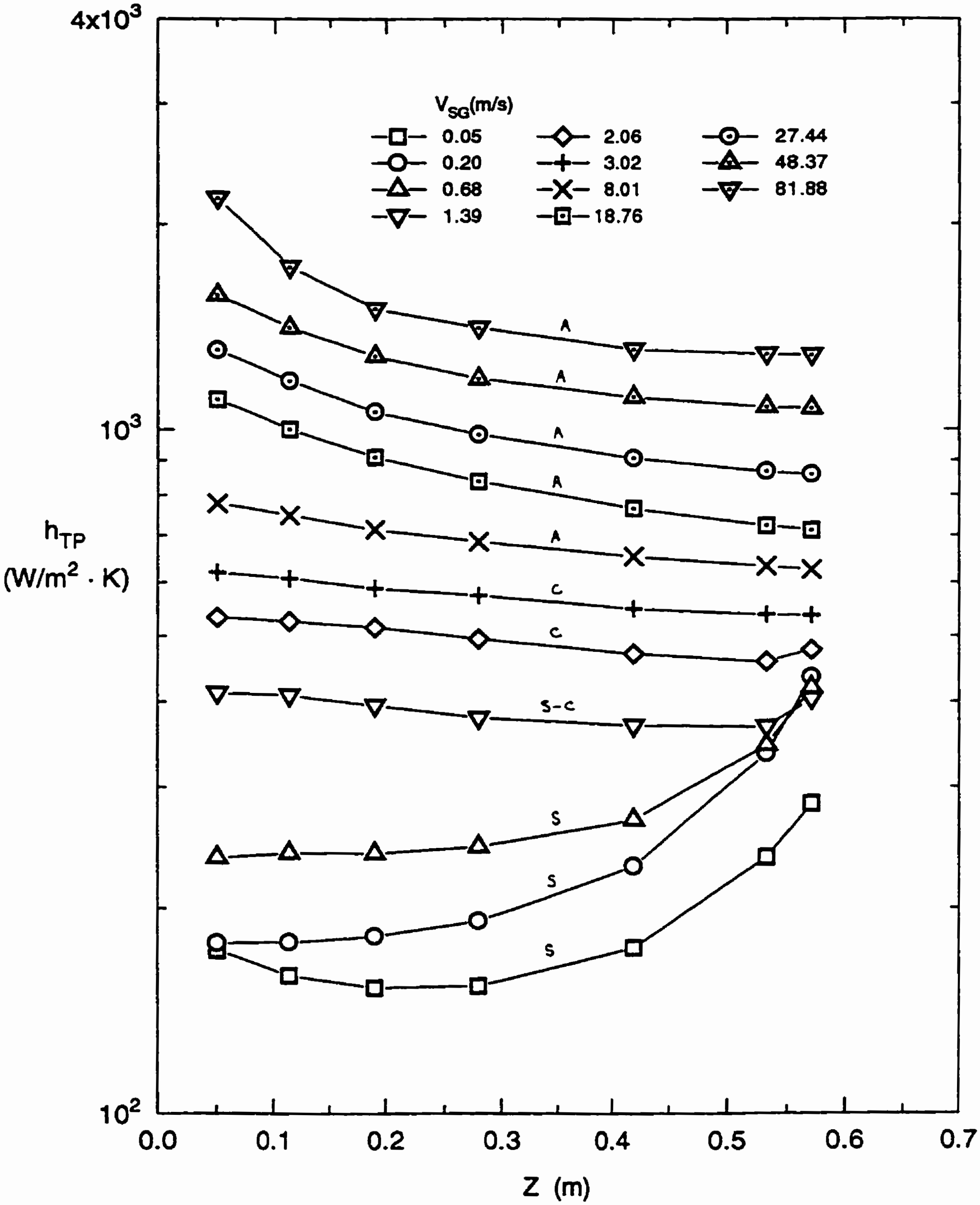

Figure 7.5a Two-Phase Air-G2 Local Heat-Transfer Results at V_{SL} = 0.049 m/s

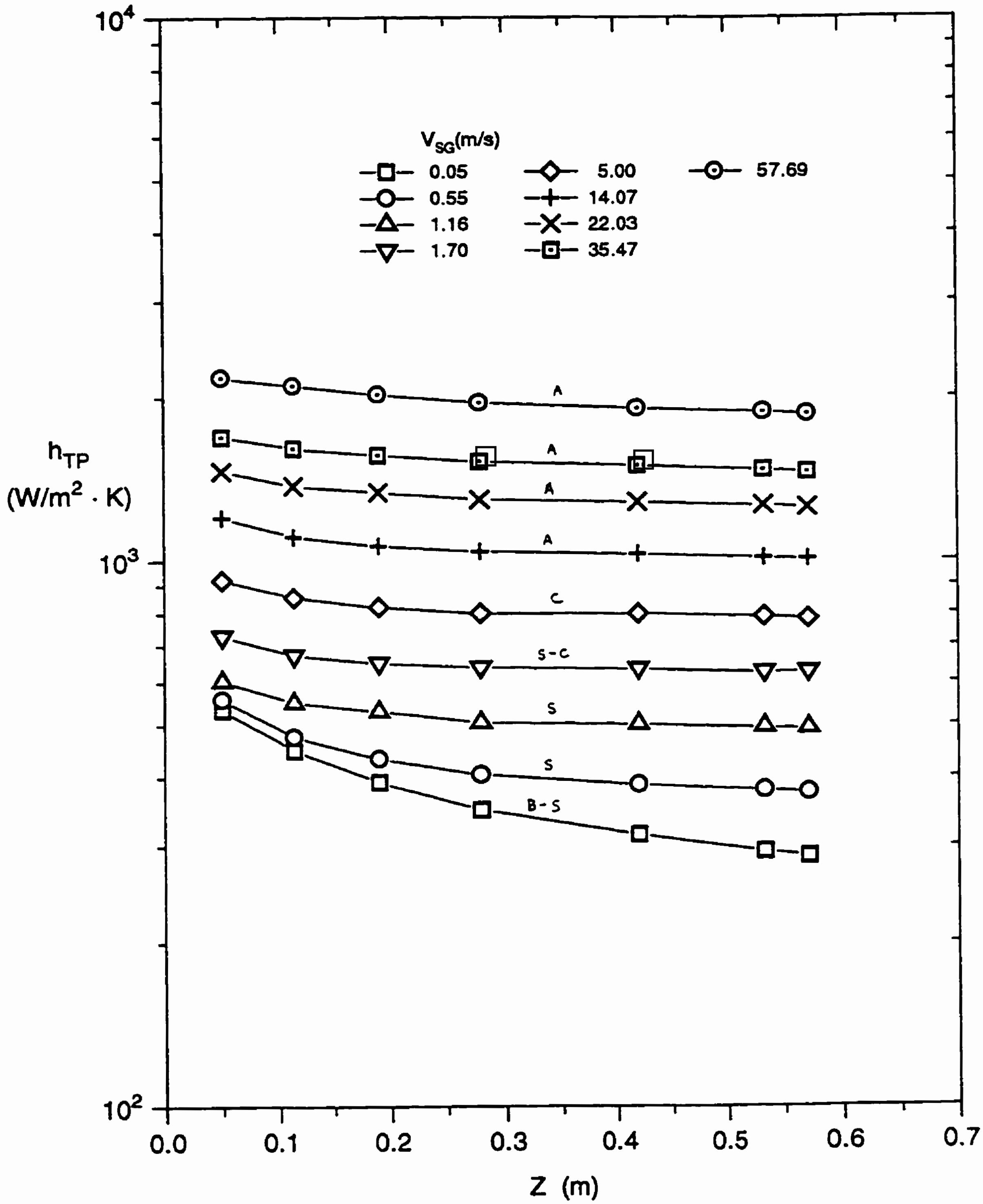

Figure7.5b Two-Phase Air-G2 Local Heat-Transfer Results at V_{SL} = 0.366 m/s

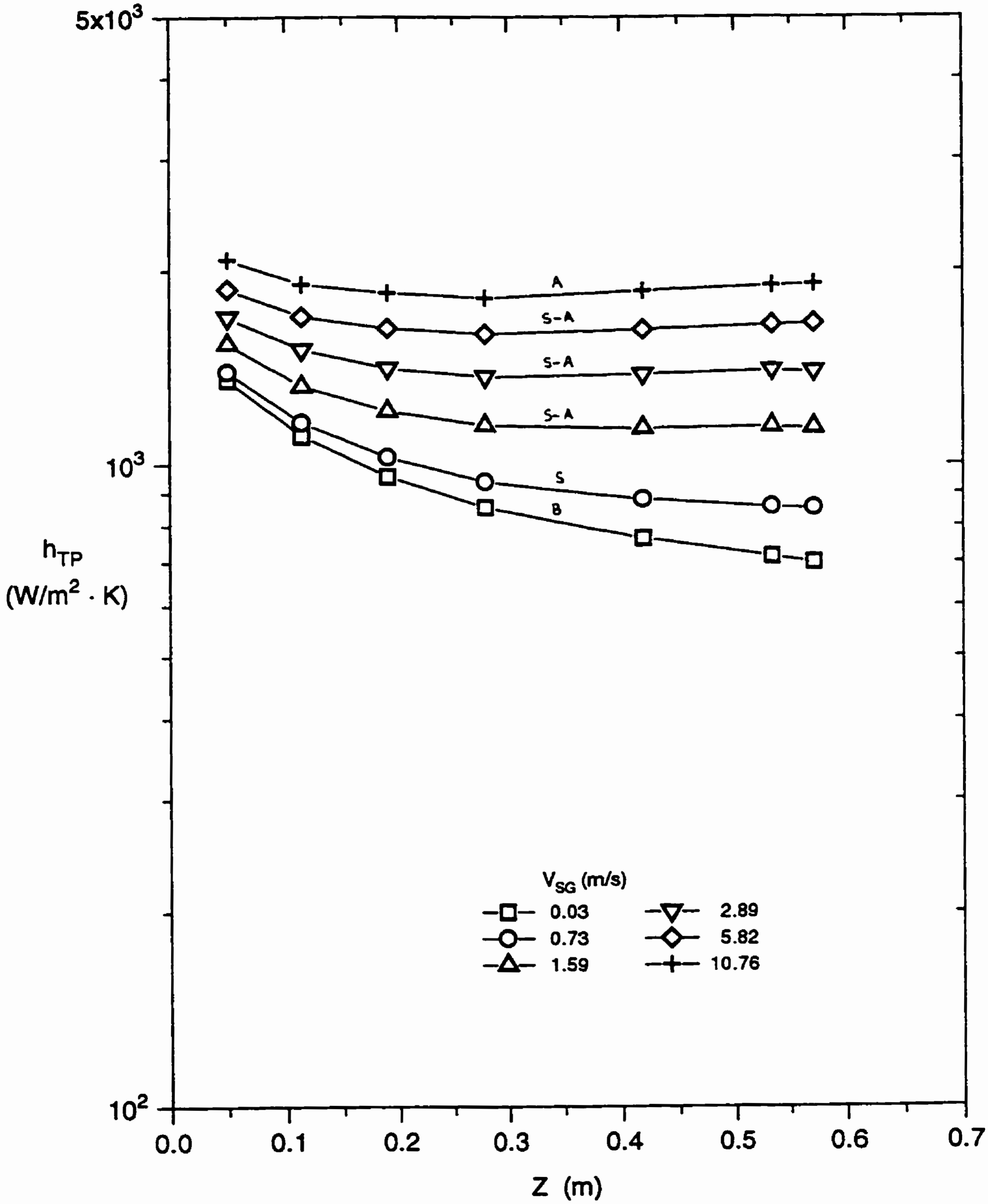

Figure 7.5c Two-Phase Air-G2 Local Heat-Transfer Results at V_{SL} = 2.877 m/s

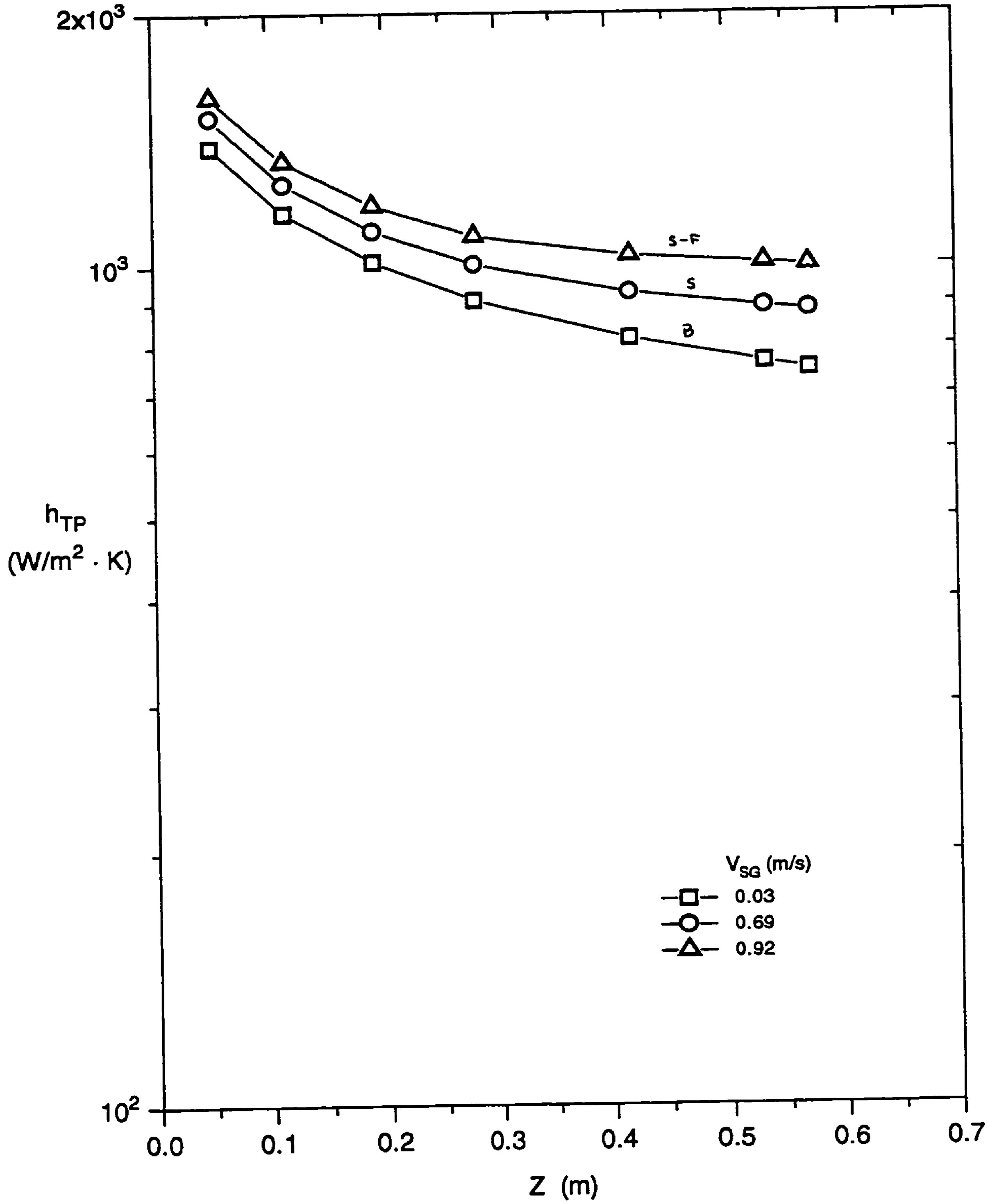

Figure 7.5d Two-Phase Air-G2 Local Heat-Transfer Results at $V_{SL} = 4.32$ m/s

shown. However, the complete set of data of all tests can be found in tabulated form in Appendix G.

In each individual figure, h_{TP} was plotted against the axial distance (z) along the heated test section for a given liquid superficial velocity, with the gas superficial velocity as a parameter. It is quite useful to have the letter code for the observed flow pattern appearing beside the data points. Hence, the results can be discussed in terms of flow pattern when needed. The letter code is the same as that appearing in Table 6.1. After analysis of the results, the following remarks can be made.

1) At very low V_{SL} ($V_{SL} \leq 0.311$ m/s) and low gas flow rates, h_{TP} increases along the heated test section. This heat-transfer trend is contradictory to that of single-phase flow. However, this peculiar trend is always associated with slug flow. This increasing trend was also observed in the previous studies of Vijay (93), Aggour (1), Zaidi (100), and Rezkallah (71). This h_{TP}-profile is likely caused by the influence of the liquid falling film on the tube wall. In this range of V_{SL}, as gas flow rate increases, the h_{TP}-profile becomes flatter and then tips downwards along the test section; these profiles are observed when the two-phase flow is churn or annular flow. When V_{SG} is higher yet, the flow becomes annular-mist flow, and the h_{TP}-profile decreases more steeply with z. One explanation might be that in annular mist flow, as V_{SG} increases, more and more gas occupies the flow channel space (higher and higher values of void fraction) giving lower and lower effective Prandtl numbers of the two-phase mixture. In other words, the gas-liquid mixture was moving toward single-phase gas flow resulting in steeper and steeper h_{TP}-profiles, where an analogy to that of single-phase flow can be made. Figure 7.6, taken

from Kays and Crawford (46), shows the effect of Prandtl number on local Nusselt numbers in the thermal entry region of a circular tube in single-phase flow.

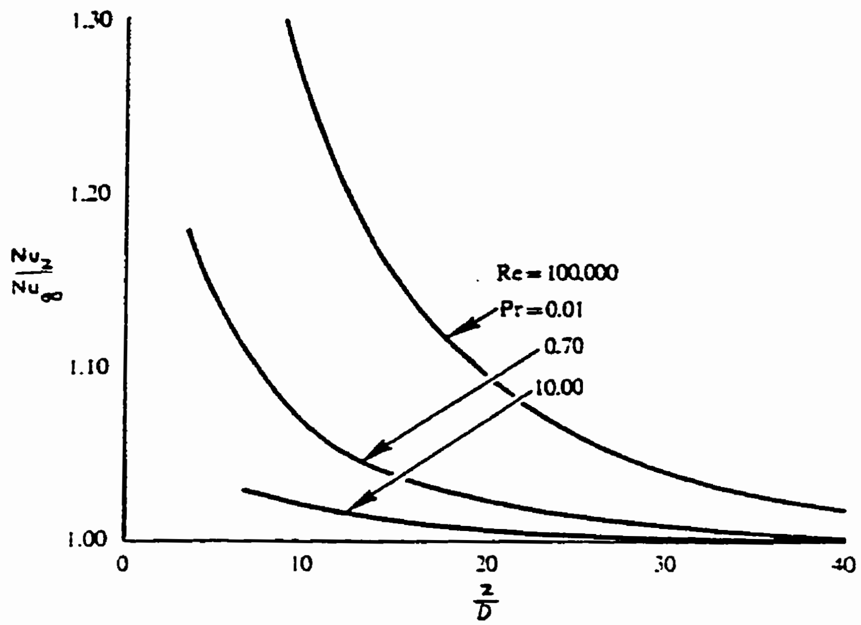

Figure 7.6 Influence of Pr on Nu in Thermal Entry Length, taken from (46)

2) At medium liquid velocity ($0.311 < V_{SL} \leq 3.170$ m/s), starting with low V_{SG}, the h_{TP}-profile decreases with z, slightly for air-water (or not at all for V_{SL} = 1.042m/s), but in a more pronounced fashion for the more viscous liquids. Further, some data in this range of V_{SL} and V_{SG} are associated with slug flow; however, the peculiar increasing trend of h_{TP} with respect to z observed in 1) was not observed here. Possibly the upward liquid flow rate is great enough so that the downflow of the falling liquid film does not dominate the flow any longer. When the gas flow rate is increased, the h_{TP}-profiles become almost flat. When V_{SG} was further increased, the h_{TP}-profile decreases

with z, this being associated with annular-mist (this occurred in air-water and air-G1 systems only), some annular and annular-froth conditions.

3) At high V_{SL} ($V_{SL} > 3.170$ m/s), the h_{TP}-profiles essentially all decrease with z, the associated flow patterns being bubble and froth except for two profiles shown for slug and slug-froth in air-G2.

7.3 MEAN HEAT-TRANSFER COEFFICIENTS

The mean heat-transfer coefficients, $\bar{h}_{TP}$, in this section were calculated using the method described in Chapter 5 (length integration of local h_{TP}). Figures 7.7 to 7.9 show the results for two-phase mean heat-transfer coefficients of air-water, air-G1 and air-G2 obtained in this investigation, respectively. In general, for fixed V_{SG}, the h_{TP} increases with V_{SL} for all air-liquid systems. The letter code given beside each datum point is to identify the flow regime. This is useful since one can analyze the mean heat-transfer coefficients in terms of flow pattern if needed. After analysis of the data, the following remarks can be made:

For the Air-Water System (Figure 7.7):

At low V_{SL} ($V_{SL} \leq 0.311$ m/s), with low V_{SG}, the mean heat-transfer coefficient drops at first. This dropping trend was associated with slug flow. It is interesting that this dropping trend not only occurs in $\bar{h}_{TP}$ but also occurs in the case of pressure drop (see Figure 6.20). Likely the drop in both mean heat-transfer coefficient and pressure drop is caused by the liquid falling film on the tube wall. When V_{SG} increases further, the $\bar{h}_{TP}$ increases continuously through annular flow to an unmistakable maximum (for each V_{SL})

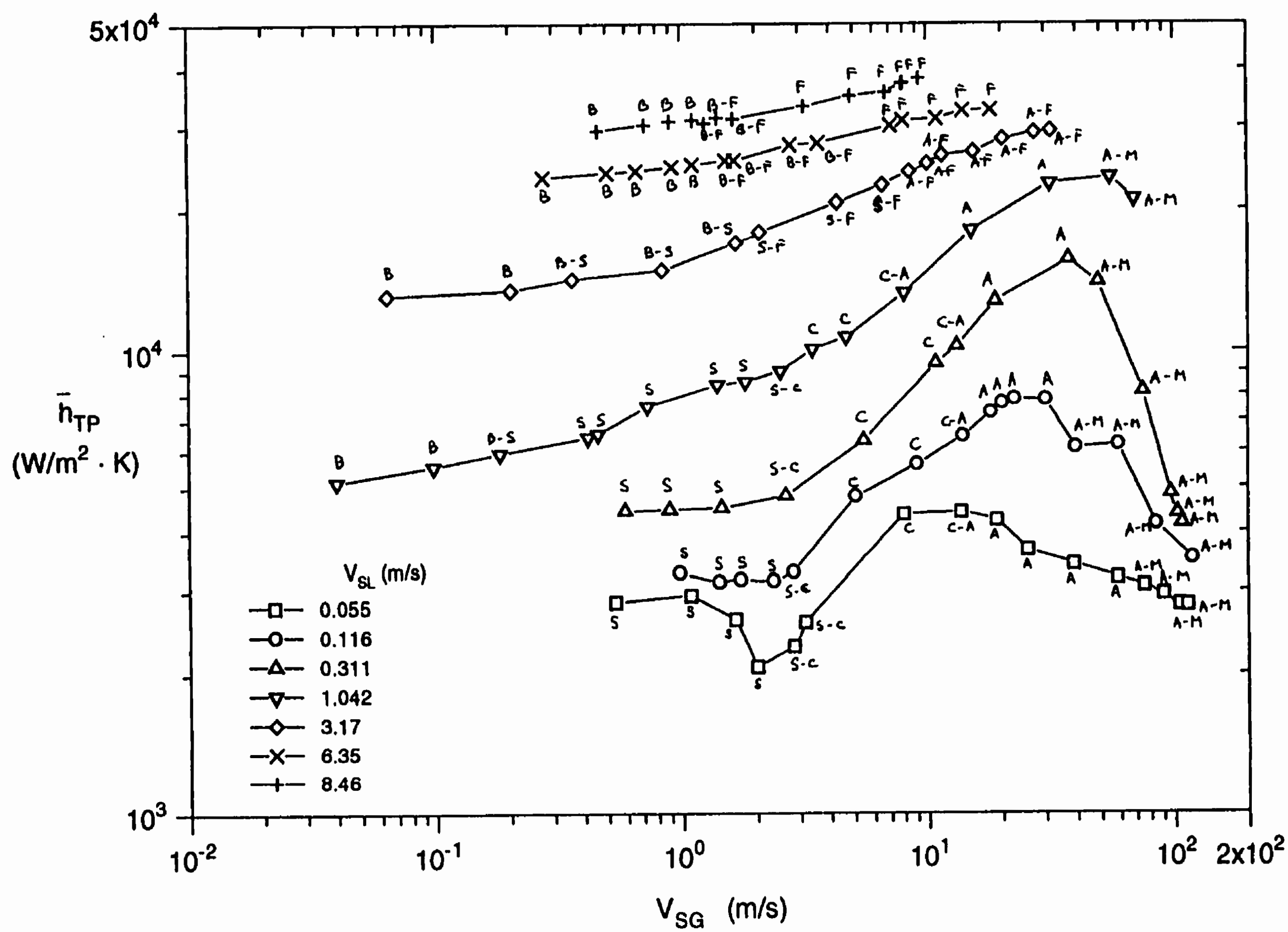

Figure 7.7 Mean Heat-Transfer Coefficients for Air-Water

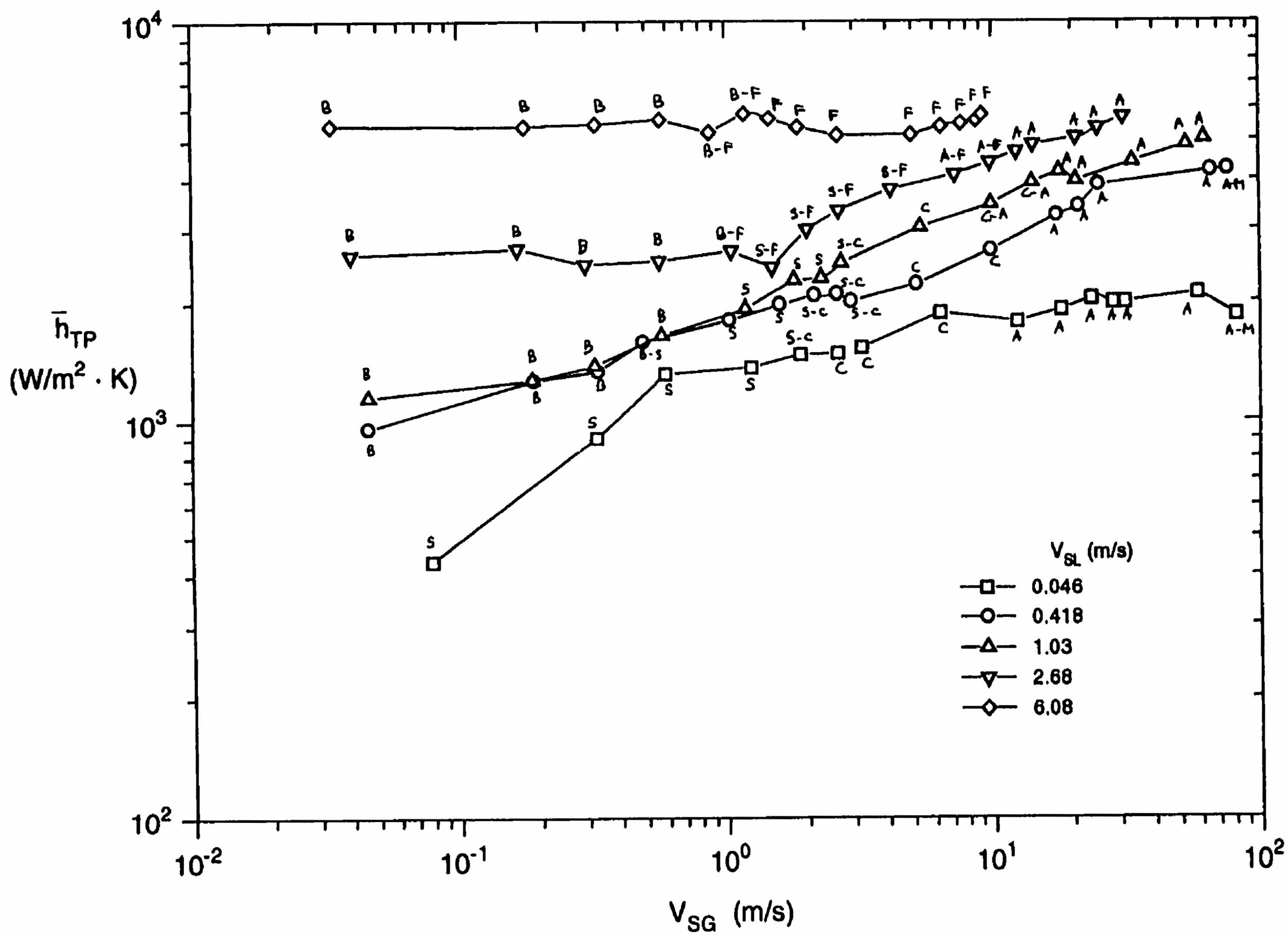

Figure 7.8 Mean Heat-Transfer Coefficients for Air-G1

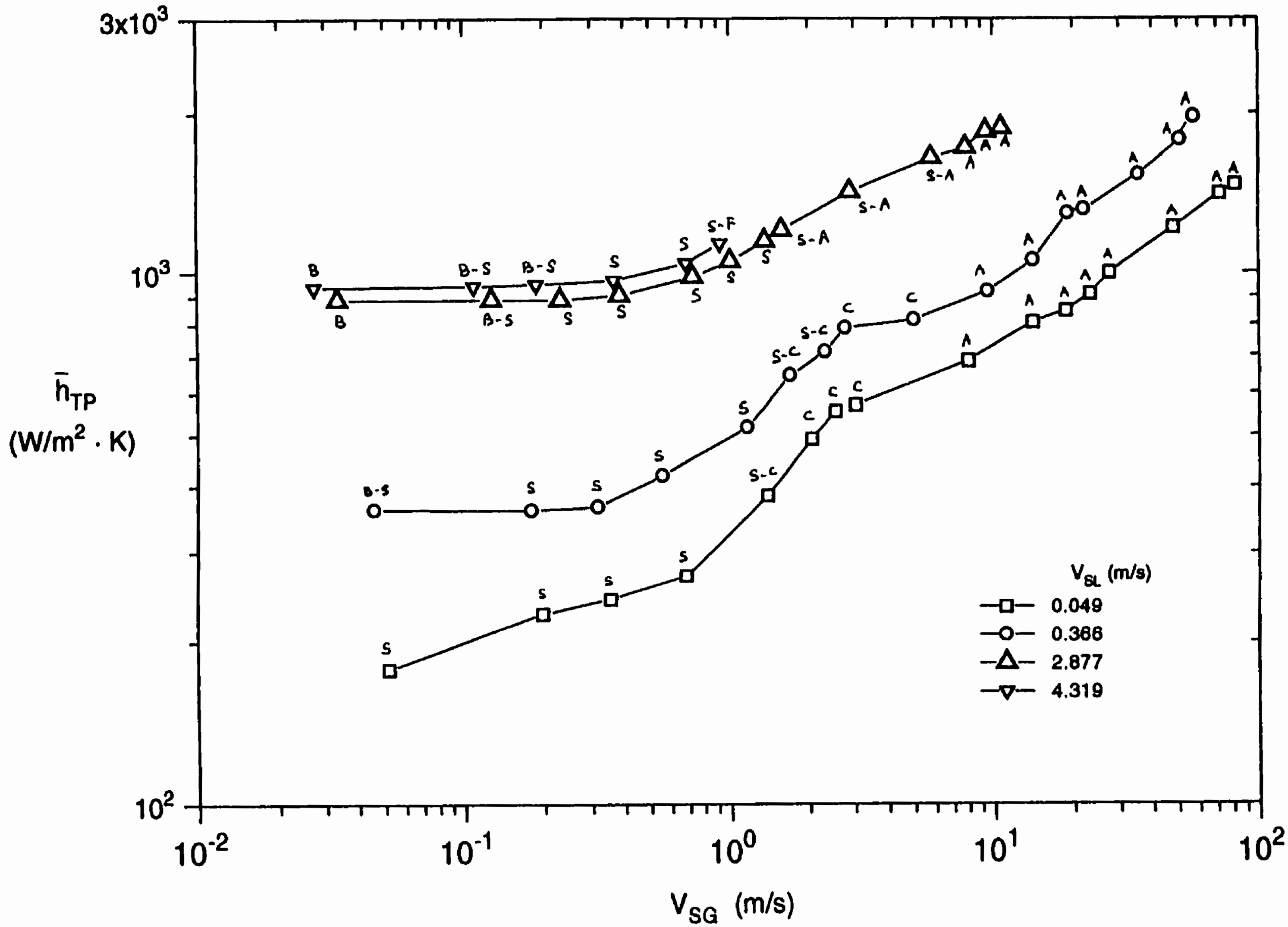

Figure 7.9 Mean Heat-Transfer Coefficients for Air-G2

and begins to drop when the flow becomes annular-mist. The h_{TP} keeps on dropping with increasing V_{SG}, which behavior might be explained by considering that in annular-mist flow the liquid film must be very thin (indeed, by naked eye one has the impression that there is no liquid film at all on the wall). The heat-transfer process associated with conditions near the wall (where the major resistance to heat transfer occurs) becomes more and more gas-like, with an associated reduction in the heat-transfer coefficient. At medium-to-high V_{SL} ($V_{SL} > 0.311$ m/s), the $\bar{h}_{TP}$ increases with V_{SG}, in general. However, when the flow becomes annular-mist, the $\bar{h}_{TP}$ starts to drop (as with lower V_{SL}). This can be seen for $V_{SL} = 1.04$ m/s. For the case of $V_{SL} \geq 3.17$ m/s where annular-mist flow was not observed, $\bar{h}_{TP}$ increased monotonically with V_{SG}, for fixed V_{SL}. The enhancement of $\bar{h}_{TP}$ with V_{SG} (at fixed V_{SL}) became less pronounced as the V_{SL} increased.

For the Air-G1 and Air-G2 Systems (Figures 7.8 and 7.9):

In general, $\bar{h}_{TP}$ increases as V_{SG} increases. This increase of $\bar{h}_{TP}$ with V_{SG} is more pronounced at lower liquid superficial velocities. The effect of gas on $\bar{h}_{TP}$ enhancement is almost not noticeable when V_{SL} is very high, such as in the case of air-G1 at $V_{SL} = 6.081$ m/s. Considering air-G1 and air-G2, the annular-mist flow pattern was observed only in the air-G1 system, and then only for two data points in Figure 7.8. One does not therefore see the dramatic decrease of $\bar{h}_{TP}$ with V_{SG} in annular-mist flow, which was seen with the air-water system at low V_{SL}. So far as the author is aware, the air-G2 heat-transfer data are new.

7.4 SUMMARY

The combination of the single-phase results (Chapter 5) and the material presented in this chapter (comparison with other studies on this apparatus and another) indicate that the results are reliable. Further, the air-G2 data have not appeared before in the literature. The advantage of having this combination of measured quantities (h_{TP}, α, and ΔP) will be demonstrated in the next chapter where heat-transfer correlations with pressure drop (or wall shear stress) and/or mean void fraction are assessed. The existence of these data should prove valuable for future modelling or correlation development.

Chapter 8

PREDICTIVE METHODS FOR TWO-PHASE TWO-COMPONENT HEAT TRANSFER

8.1 INTRODUCTORY REMARKS

A number of predictive methods for mean heat-transfer coefficients $\bar{h}_{TP}$ in two-phase flow in vertical tubes appear in the literature. While some of these methods are purely empirical, others are based on theoretical or semi-theoretical models. Rezkallah (71) made a thorough assessment of the methods for mean heat-transfer coefficients covering a very wide range of conditions. In his work, for the predictive methods which required void fraction α, predicted values of α using the Chisholm (13) correlation were used. In the present study α was measured, as was ΔP_{TOT} and heat-transfer coefficients. Having accurate values of α allowed for accurate values of ΔP_{TPF} to be determined, and in turn accurate values of wall shear stress, τ_W. The focus in this chapter is the assessment of heat-transfer predictive methods which require ΔP_{TPF}, or τ_W and/or α. The assessed methods (their restrictions can be found in Table 2.2) are as follows:

Katsuhara and Kazama (45),

Ueda and Hanaoka (89),

Liquid Acceleration Model (L.A.M.)

Vijay et al. (94),

Drucker et al. (23),

Marié (57).

In addition to the methods tested here, there are others which appear in the literature, for example, Ueda and Nose (90), in which the interfacial shear stress is required. Others like Dobran (19) proposed a theoretical model to predict $\bar{h}_{TP}$ in annular flow; however, the value of the temperature at the gas-liquid interface is needed.

For the prediction of local heat-transfer coefficients, Vijay (93) proposed a predictive method based on an analytical single-phase boundary-layer solution by Spalding (83),but adapted to the tube case. The method requires knowledge of the ΔP_{TPF}, and therefore the present results are very useful in assessing the method. Further, a number of new aspects, such as new mixture properties and flow patterns are explored and compared with Vijay's original method. The method is discussed in Section 8.3.

8.2 ASSESSMENT OF MEAN HEAT-TRANSFER CORRELATIONS USING THE PRESENT DATA

In this section, the results of the comparison between the predictive methods listed in Section 8.1 and the present heat-transfer data are presented. The data used for each method were strictly within the applicability range as stated by the original authors. The results of comparisons between the experimental data and the predictions are shown in Figures 8.1 to 8.6. Also, percentage deviations are shown in Table 8.1. Details and discussion for each comparison are given below.

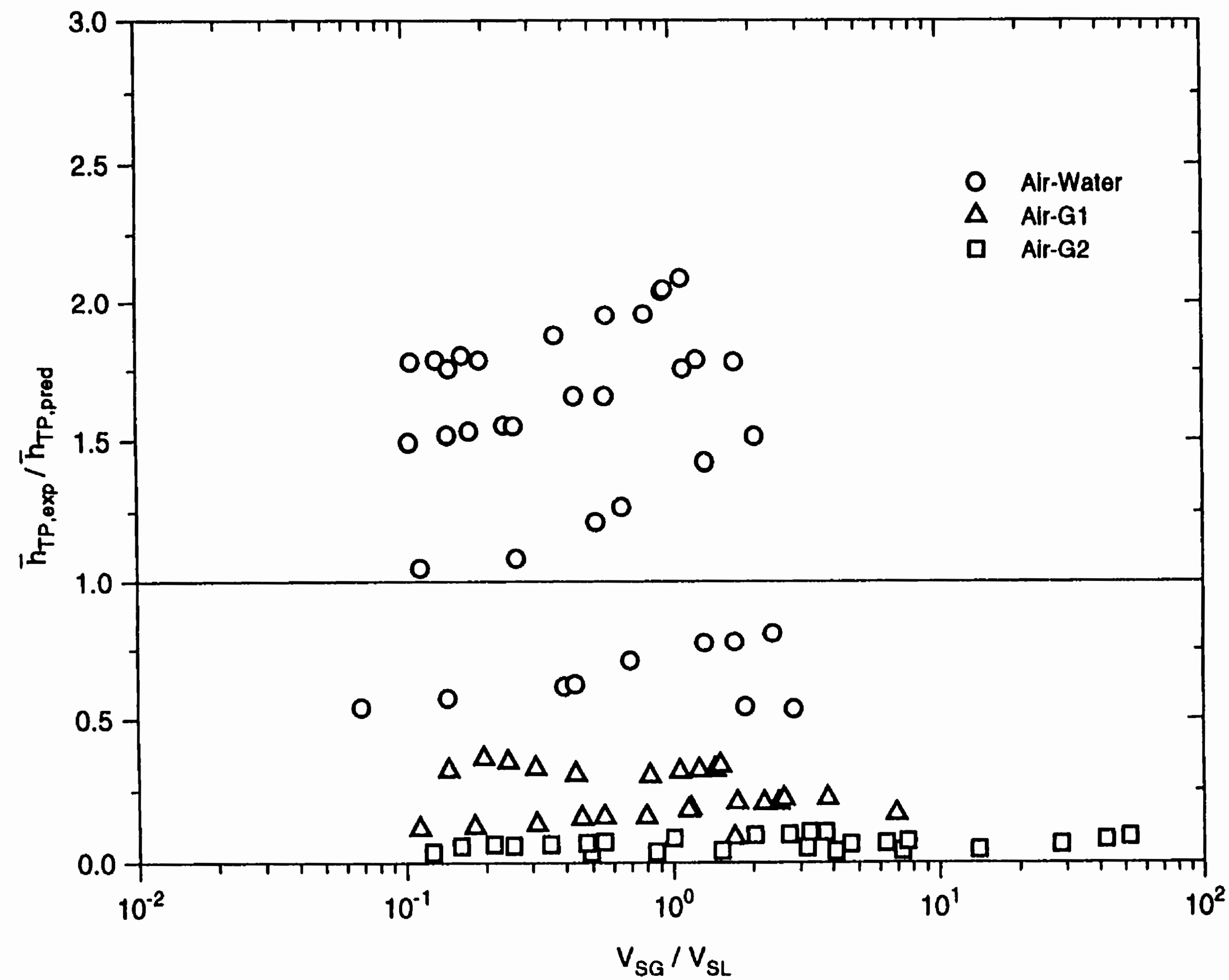

Figure 8.1 Comparison of Present Heat-Transfer Data with Katsuhara & Kazama Predictions (45)

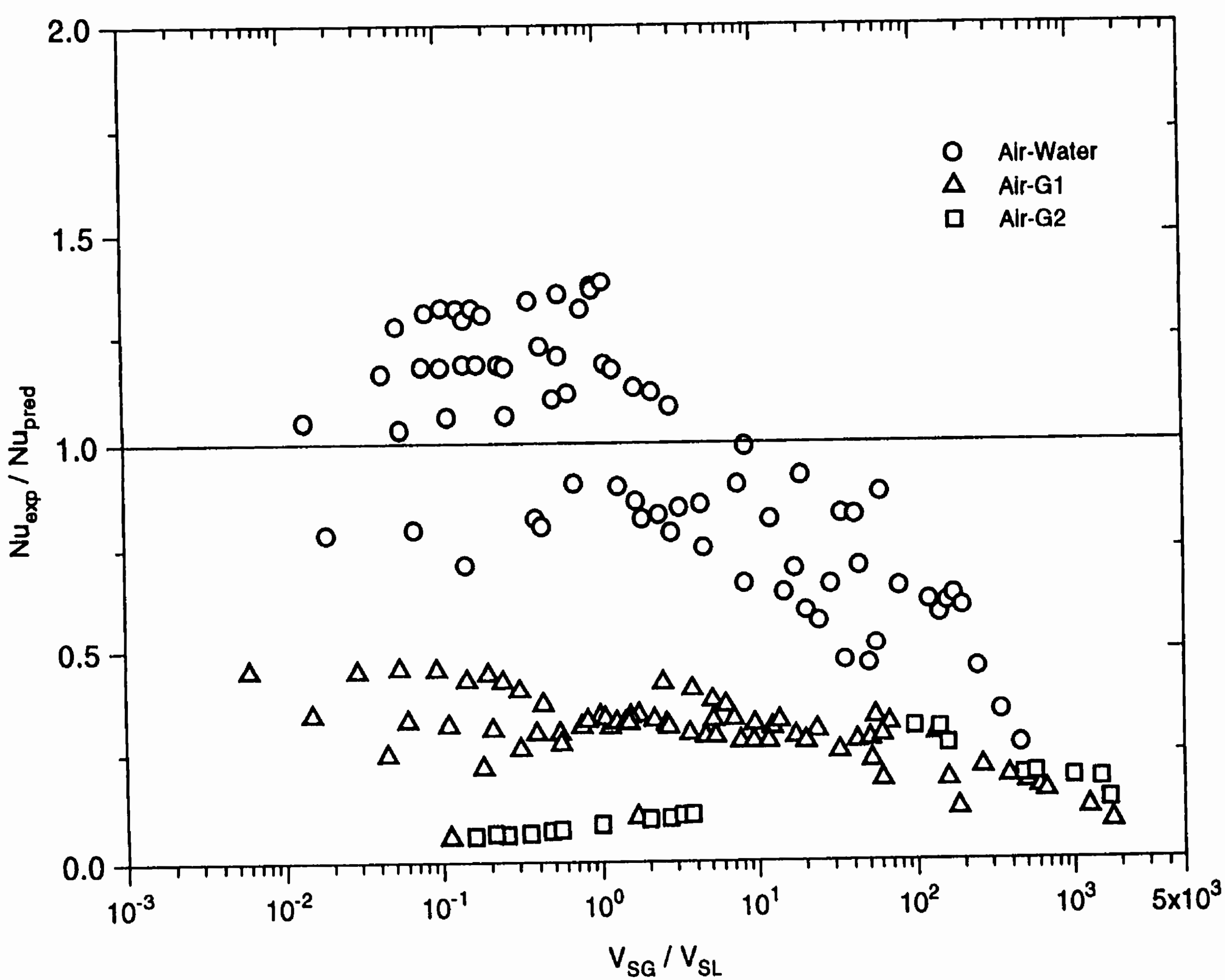

Figure 8.2 Comparison of Present Heat-Transfer Data with Ueda & Hanaoka Predictions (89)

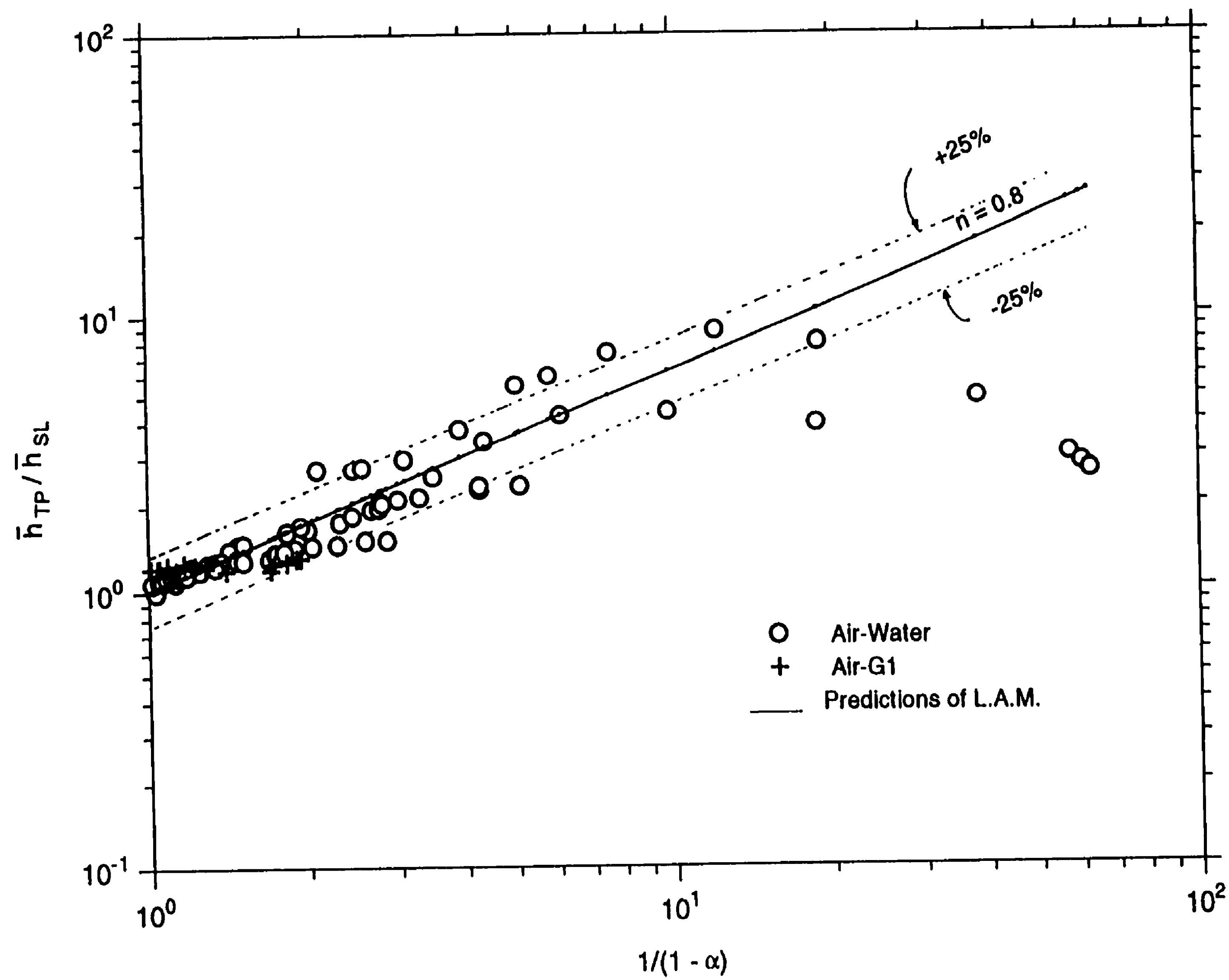

Figure 8.3a Comparison of Present Heat-Transfer Data with the Liquid Acceleration Model

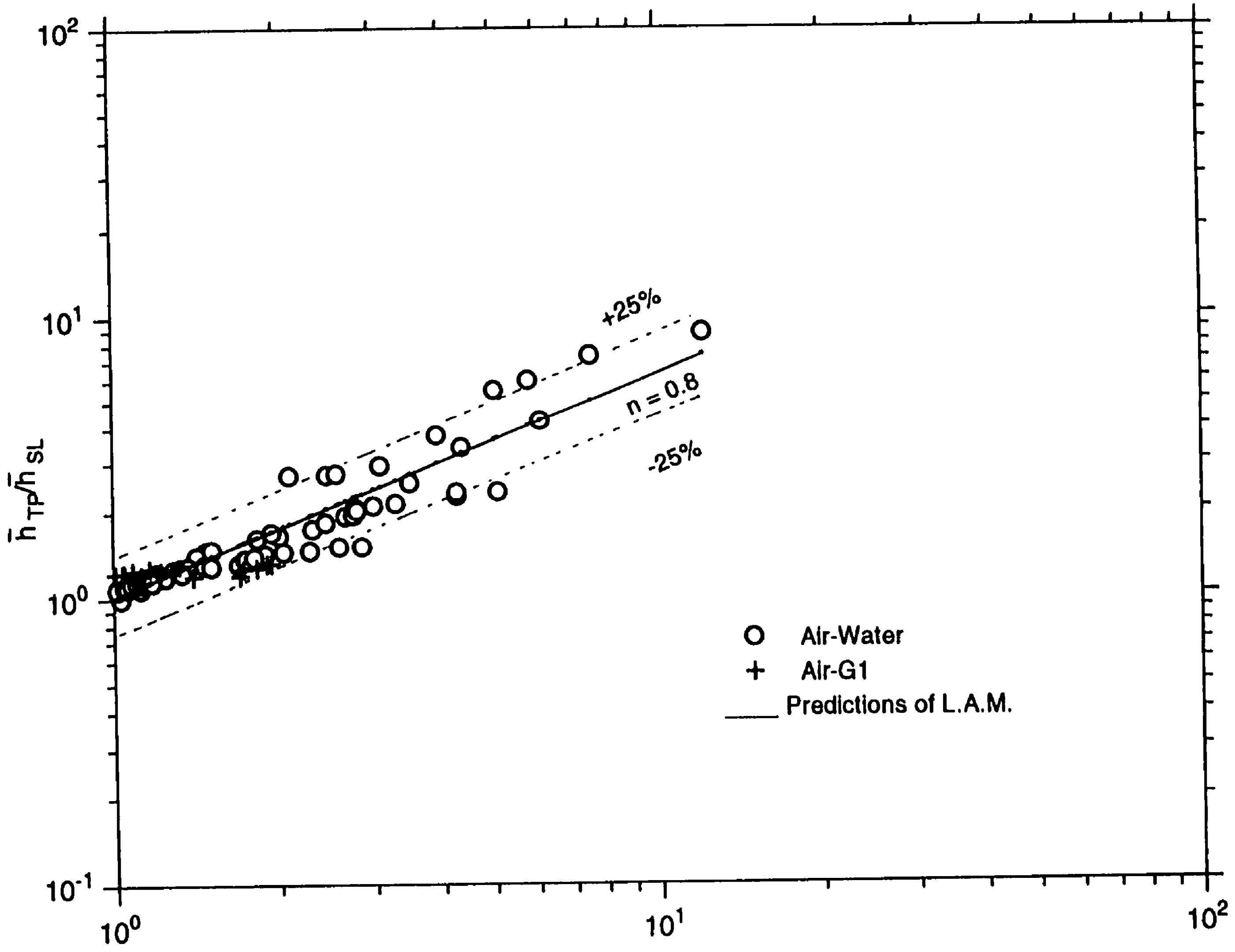

Figure 8.3b Comparison of Present Heat-Transfer Data (without Annular-Mist Data) with the Liquid-Acceleration Model

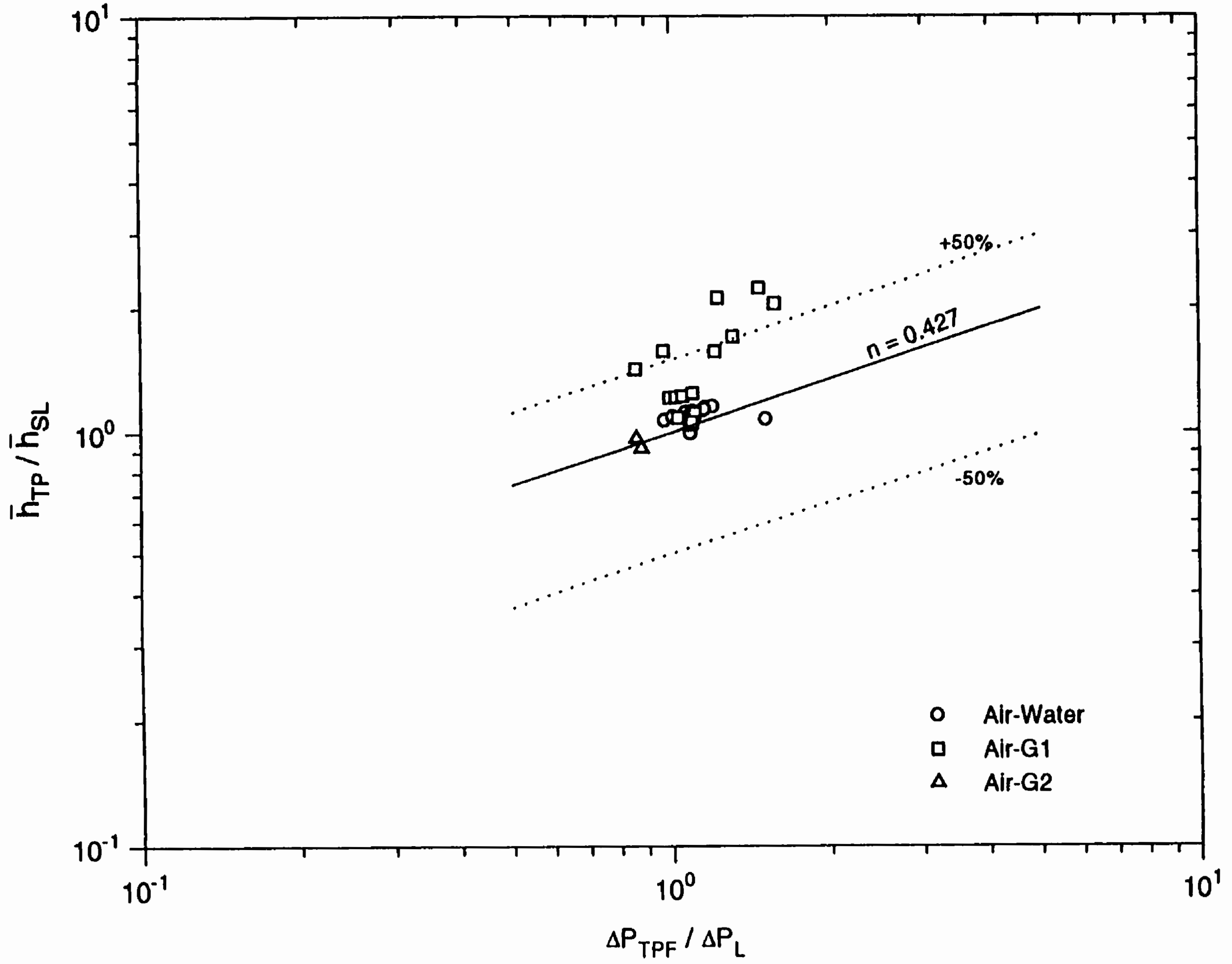

Figure 8.4a Comparison of Present Heat-Transfer Data with Vijay et al. (94) for Bubble Flow

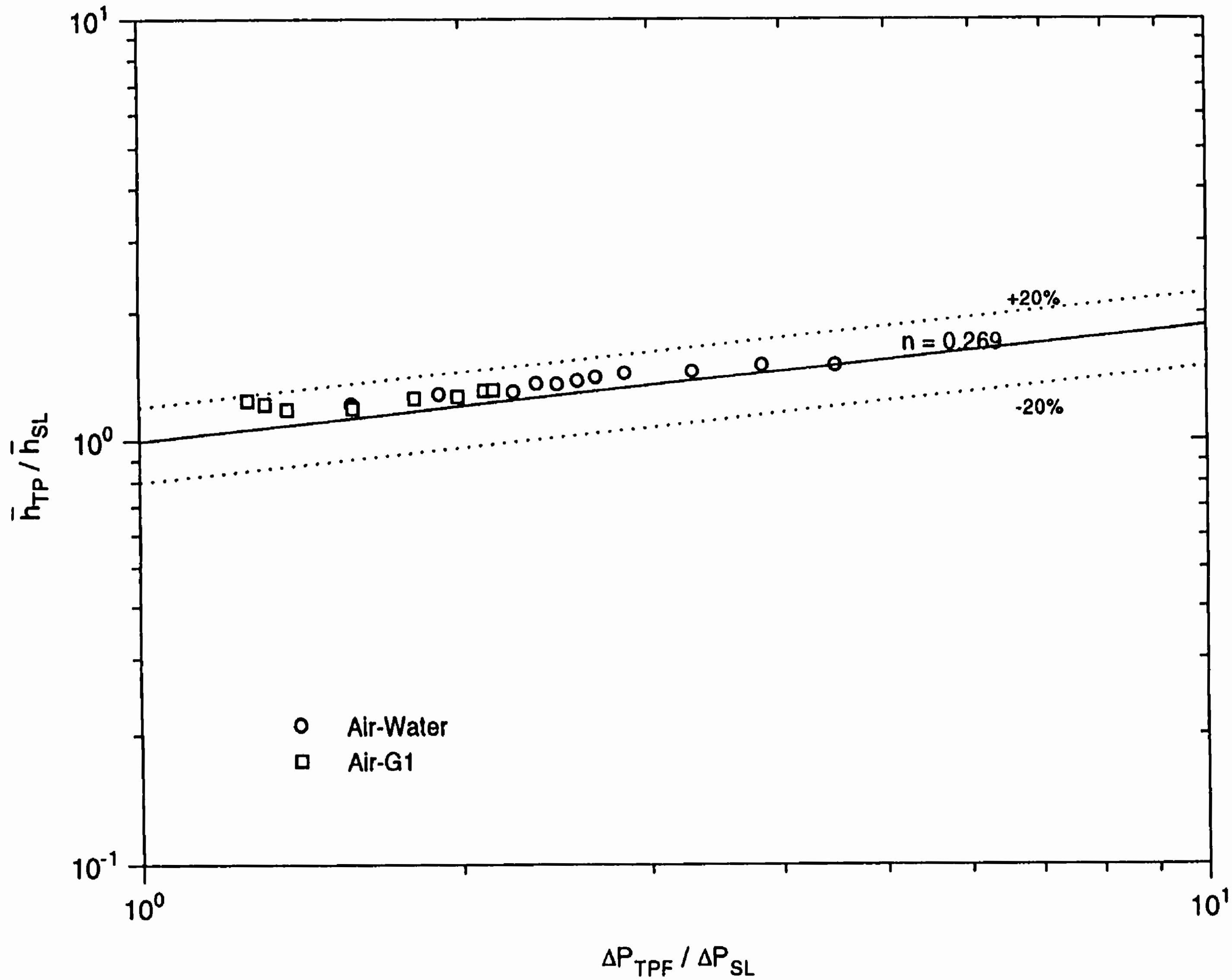

Figure 8.4b Comparison of Present Heat-Transfer Data with Vijay et al. (94) for Froth Flow

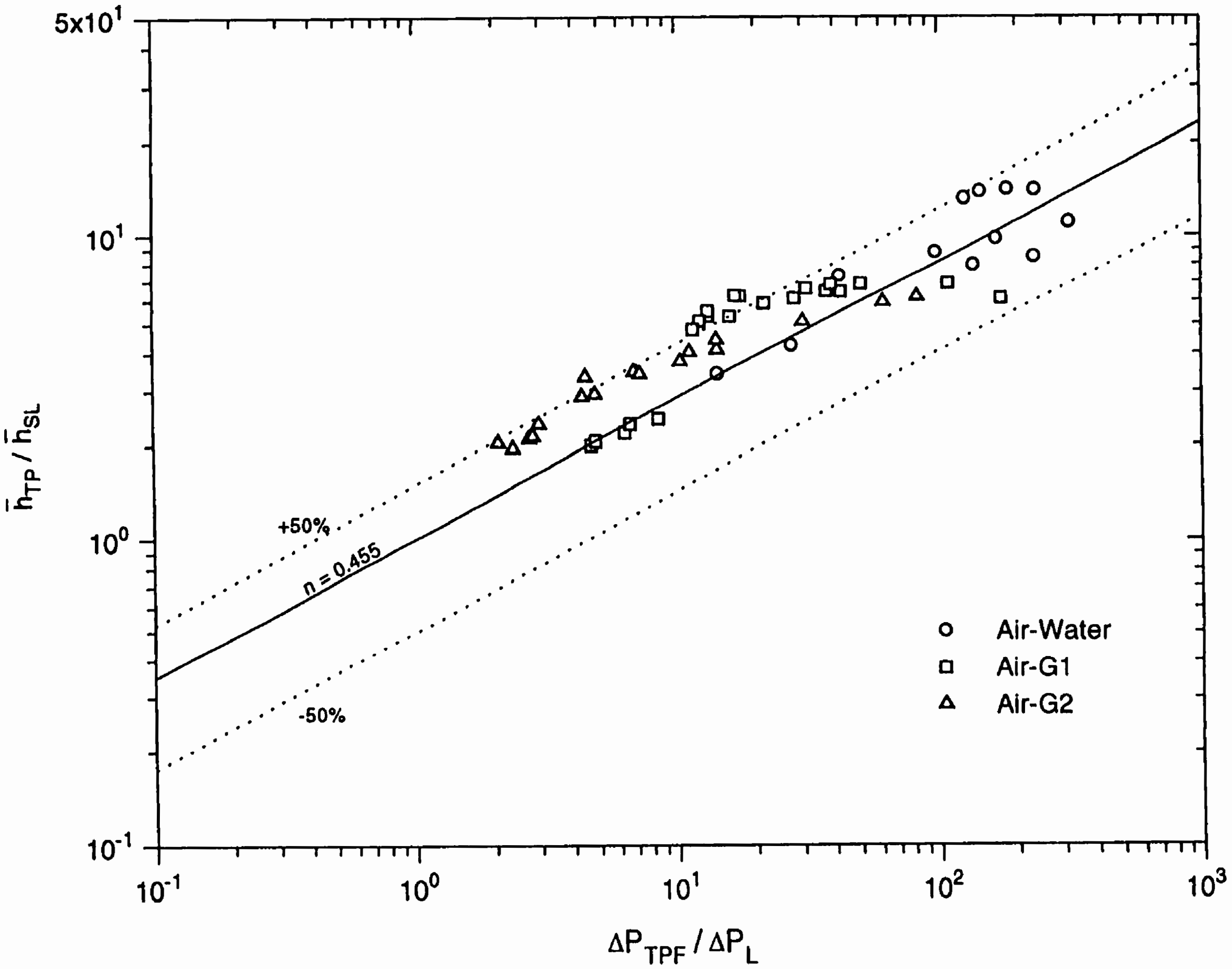

Figure 8.4c Comparison of Present Heat-Transfer Data with Vijay et al. (94) for Annular Flow

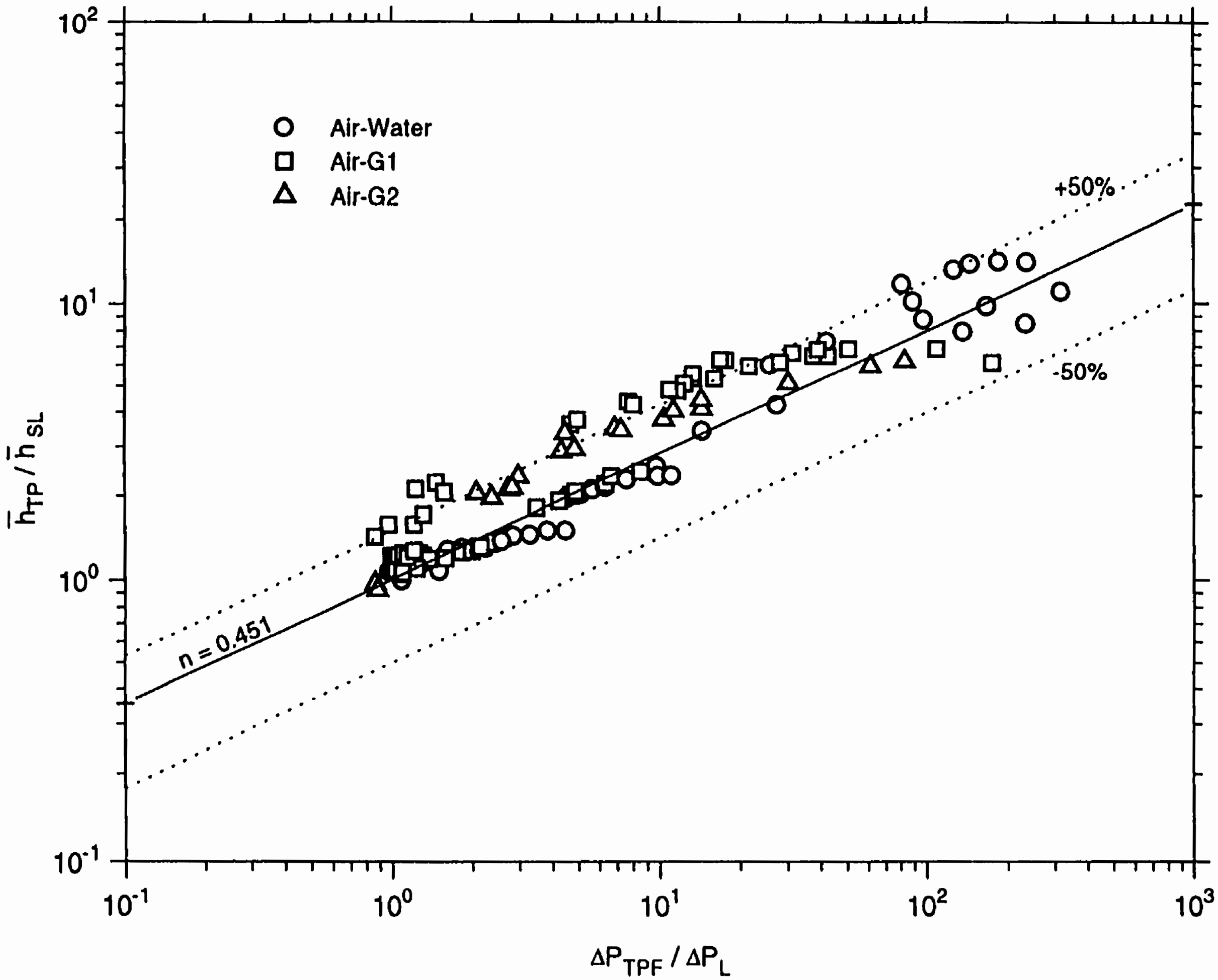

Figure 8.4d Comparison of Present Heat-Transfer Data with Vijay et al. (94) for All Flow Patterns (excluding Slug, Churn, their Transitions and Annular-Mist)

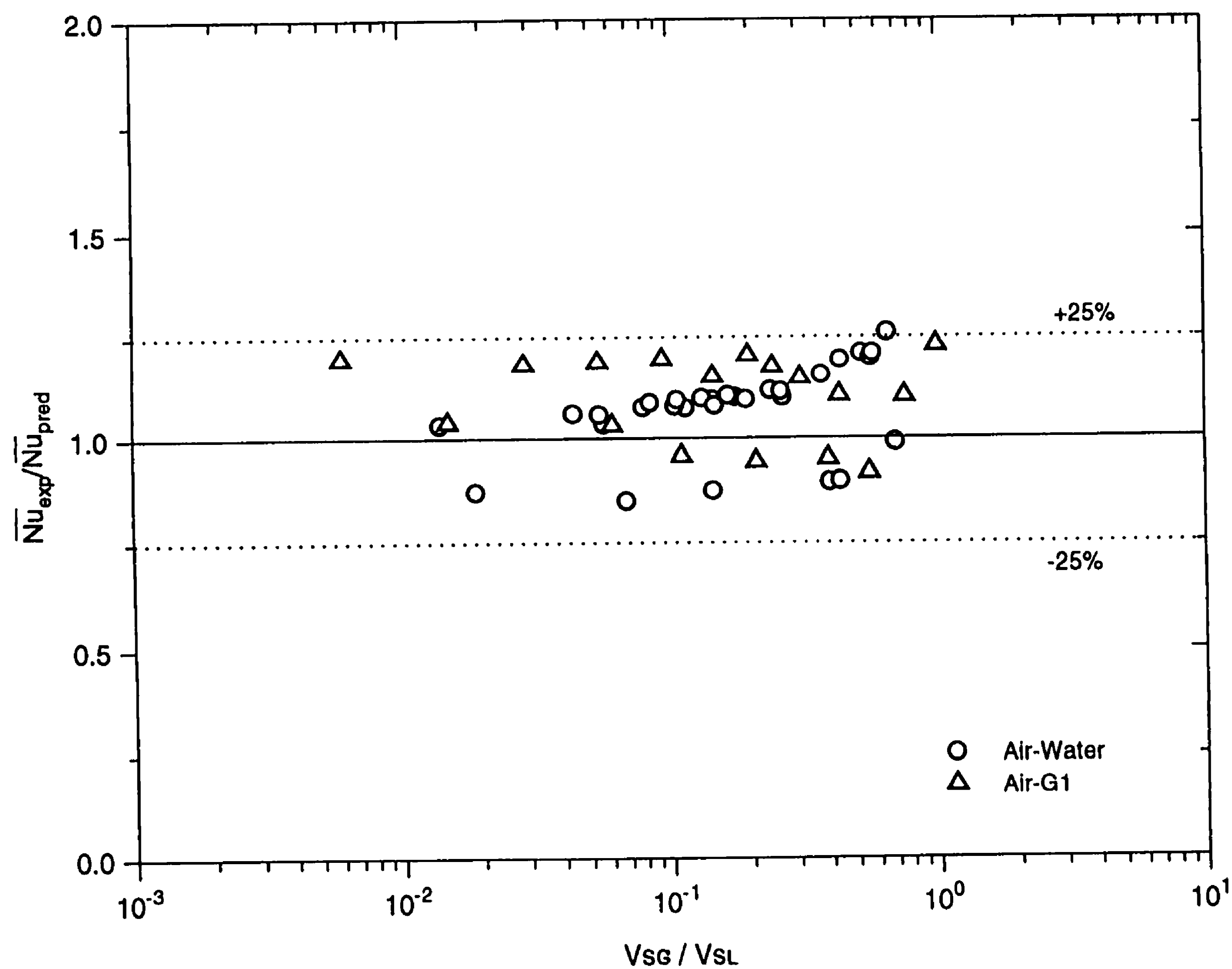

Figure8.5 Comparison of Present Heat-Transfer Data with Drucker et al. (23) Predictions

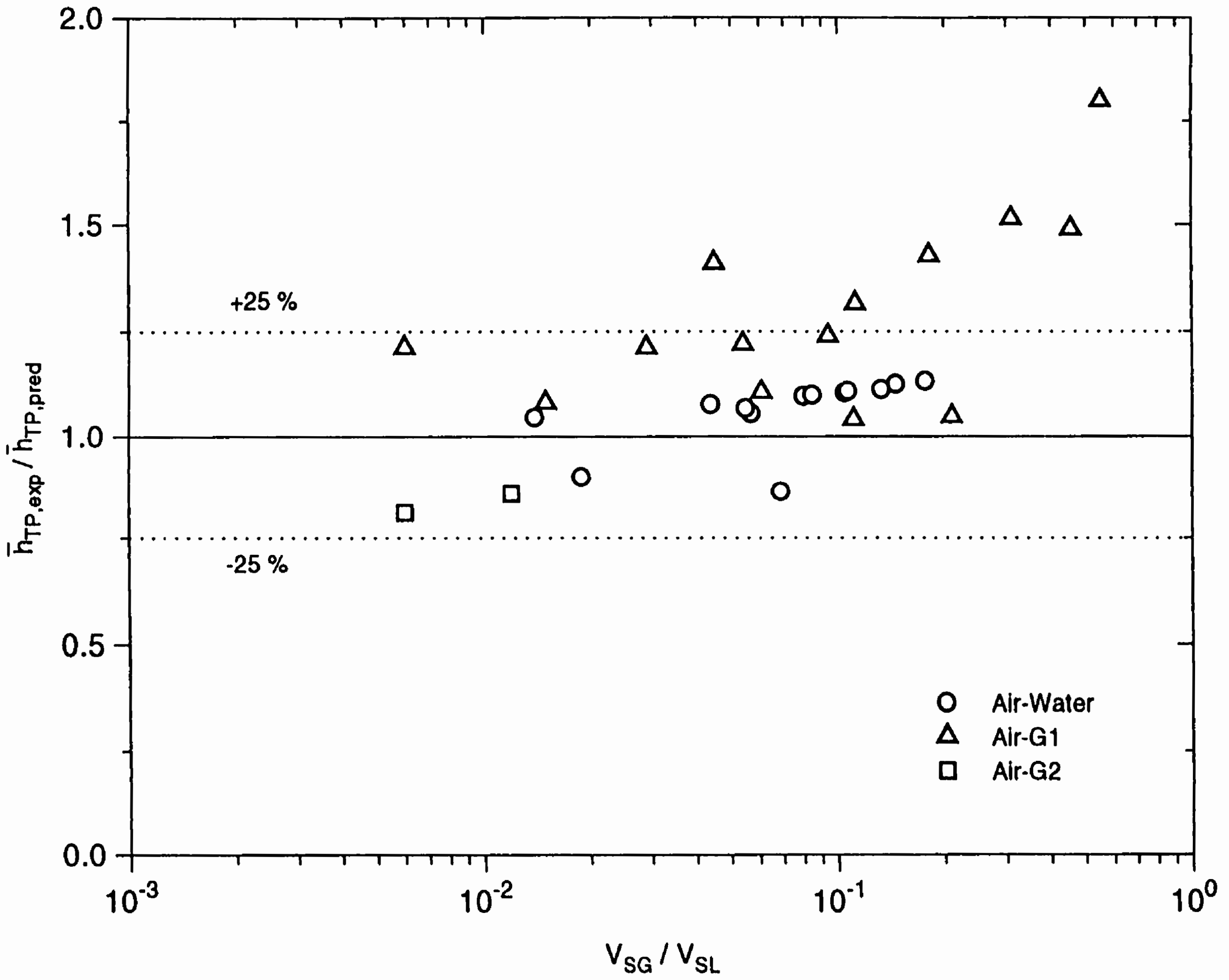

Figure 8.6 Comparison of Present Heat-Transfer Data for Bubble Flow with Marié (57) Predictions

Table 8.1 Assessment of Mean Heat-Transfer Correlations Using the Present Experimental Data

Works	Air-Water			Air-G1			Air-G2		
	N	$\bar{e}$	$\bar{e}_{rms}$	N	$\bar{e}$	$\bar{e}_{rms}$	N	$\bar{e}$	$\bar{e}_{rms}$
Katsuhara & Kazama (45)	38	38.28	63.56	25	-76.99	77.44	25	-93.42	93.44
Ueda & Hanaoka (89)	73	-6.24	29.23	70	-70.38	70.93	19	-85.99	86.30
L.A.M. ($Re_{SL} \geq 2000$)	72	-6.8	27.92	30	-7.37	16.90	-	-	-
L.A.M.+ ($Re_{SL} \geq 2000$)	65	-0.48	18.13	25	-3.81	14.68	-	-	-
Drucker et al. (23)	30	6.83	12.39	17	9.92	14.30	-	-	-
Vijay (94)									
Bubble n = 0.429	13	4.94	7.22	15	36.95	47.52	2	-0.25	3.19
Froth n = 0.269	11	5.83	6.26	8	8.74	9.58	-	-	-
Annular n = 0.455	12	8.70	25.66	21	27.25	41.28	17	30.67	36.71
*Overall n = 0.451	54	2.61	18.59	54	28.56	43.13	19	28.36	35.45
Marié (57)	13	5.96	10.08	15	29.32	35.89	2	-16.85	16.70

* All data excluding slug, slug and churn (and transitions) and annular-mist flows.
\+ Excluding annular-mist data.

The Katsuhara and Kazama correlation (45) was one of the earliest works to predict mean heat-transfer coefficients. The method requires the knowledge of α in order to obtain mixture properties. The results in Figure 8.1 show that a wide range of deviations between the present data and the predictions occurred in general. The correlation highly overpredicts for the more viscous liquids.

The Ueda and Hanaoka correlation (89) needs α to calculate the actual velocities. The method gives predictions similar to those of Katsuhara and Kazama (45), namely the method predicts much higher heat-transfer coefficients for the more viscous liquids. The results are shown in Figure 8.2.

The Liquid-Acceleration Model (L.A.M.) with the constant n = 0.8 as recommended by Collier (18) was tested against the present data where $Re_{SL} \geq 2000$. The model is based on the idea that the liquid phase in the two-phase mixture is accelerated because of the reduction of its own cross-sectional flow area. Dorresteijn (21), Aggour (1), and Rezkallah (71) used the constant n as 0.9, 0.83, and 0.9 respectively. Figure 8.3(a) shows a plot of the quantity $\bar{h}_{TP}/\bar{h}_{SP}$ against $1/(1 - \alpha)$. Some data points in annular-mist flow had large deviations from the predictions. This can be explained because, as shown in Chapter 7, the two-phase heat-transfer coefficient in the annular-mist regime decreases as the void fraction increases while the liquid-acceleration model mechanically gives values of higher $\bar{h}_{TP}$ as α increases. Figure 8.3(b) shows the plot of experimental data (excluding the annular-mist data) against predictions of the Liquid-Acceleration Model.

Vijay et al. (94) proposed a prediction method for bubble, slug, froth, and annular flows. However, due to the fact that many data points of slug flow had negative values of ΔP_{TPF}, the data in slug-flow regime were not used for this correlation. The results of comparison are shown in Figure 8.4(a to c). Also, Figure 8.4(d) shows the overall comparison of experimental data in bubble, froth and annular flow with the correlation where n = 0.451 was used. The proposed method of Vijay et al. works very well in froth flow and fairly well in annular flow (see Table 8.1). In bubble flow, the correlation works well with the present air-water and air-G2 ($\bar{e}_{rms}$ of 7.22 and 3.19%, respectively) data but not so well for the air-G1 data ($\bar{e}_{rms}$ of 47.5%).

Drucker et al. (23) included the effect of the buoyancy force in the form of a Grashof number in their correlation. The method is recommended for the flow when $\alpha \leq 0.4$ and $1.77 < Pr_L < 130$. This method gives good agreement between the present data and predictions ($\bar{e}_{rms}$ = 12.4 and 14.3 for air-water and air-G1, respectively) as shown in Figure 8.5.

Marié's method (57) is for bubble flow. In the derivation, a bubble diameter appears. For the comparison, as a rough measure of the present bubble diameters, a mean horizontal diameter was obtained from measurement using the photograph for each datum point in bubble flow (see Table G.1). The comparison of predictions against data is shown in Figure 8.6. The model works well for air-water ($\bar{e}_{rms}$ 10.1%), not so well for air-G1 ($\bar{e}_{rms}$ 35.9%) where it generally underpredicts, and well for the two air-G2 points ($\bar{e}_{rms}$ 16.7%).

From the material presented in this section, Table 8.1 shows that progress in the field of prediction modelling has been made over a period of years. More recent methods such as Drucker et al. (23) and Marié (57) give good predictions, in general. However, for these methods, many restrictions apply (e.g., Marié (57) is strictly used for bubble flow and Drucker et al. (23) is recommended for $\alpha \leq 0.4$ and $1.77 < Pr_L < 130$). The method proposed by Vijay et al. (94) gives reasonable agreement to the present data for bubble and froth flows. The Liquid-Acceleration Model is one of the methods that has few restrictions (compared to those assessed here) and still gives good prediction with $\bar{e}_{rms}$ = 18.5% when the method is tested without annular-mist data.

8.3 TESTING A PROPOSED METHOD TO PREDICT TWO-PHASE LOCAL HEAT-TRANSFER COEFFICIENTS

Vijay (93) examined the possibility of applying Spalding's (83) single-phase turbulent boundary-layer solution to the prediction of two-phase local heat-transfer coefficients. As demonstrated in Appendix F, the method (93) gives excellent agreement when it was used for liquid single-phase flow in a tube. An implication was that the two-phase flow would have certain mixture properties and the question then became one of determining whether one could find appropriate properties which would allow for good prediction. The method requires a knowledge of the two-phase wall shear stress; since the present experiment gives measured values of this quantity, the present data allow for a good testing of the idea.

In single-phase terms, the solution takes the form of

$$S_q = S_q(Pr, Z^+, Pr_T) \tag{8.1}$$

and

$$S_q = \frac{PrSt}{(f/2)^{1/2}} \tag{8.2}$$

The quantity St is the Stanton number. With f defined as

$$f = \frac{\tau_w}{(\rho V^2)/2}$$

and the usual definitions of St and Pr, the S_q becomes

$$S_q = \frac{h\,\mu}{k(\tau_w \rho)^{1/2}} \tag{8.3}$$

The quantity Z^+ in Equation 8.1 is defined as

$$Z^+ = \int_0^z \frac{(\tau_w \cdot \rho)^{1/2}}{\mu}\, dz \tag{8.4}$$

If the variations of τ_w, ρ and μ along z are considered to be small, then

$$Z^+ = \frac{(\tau_w \cdot \rho)^{1/2}}{\mu} \cdot z \tag{8.5}$$

To predict the quantity S_q, the following expression by Spalding (83) is valid for the entire range of Z^+ :

$$S_q = \left\{ \left[\frac{Pr_L / Pr_T}{6.64\,(Z^+/Pr_T)^{1/9} + P_{FN}} \right]^4 + [0.651\,(Z^+/Pr_L)^{-1/3}]^4 \right\}^{1/4} \tag{8.6}$$

where P_{FN} is called the P-function and given by

$$P_{FN} = 11.570\ [\,(Pr_L/Pr_T)^{3/4} - 1] \tag{8.7}$$

For the two-phase situation, S_q and Z^+ become, in parallel with Equation 8.3 and 8.5, respectively

$$S_{q,TP} = \frac{h_{TP}\,\mu_{MIX}}{k_{MIX}\,(\tau_W\,\rho_{MIX})^{1/2}} \tag{8.8}$$

$$Z^{+}_{TP} = \frac{(\tau_W\,\rho_{MIX})^{1/2}\, z}{\mu_{MIX}} \tag{8.9}$$

The predicted value of two-phase S_q can be calculated from the following expression:

$$S_{q,TP} = \left\{ \left[\frac{Pr_{MIX}/Pr_T}{6.64\ (Z^{+}_{TP}/Pr_T)^{1/4} + P_{FN}}\right]^4 + \left[0.651\ (Z^{+}_{TP}/Pr_{MIX})^{-1/3}\right]^4 \right\}^{1/4} \tag{8.10}$$

where

$$P_{FN} = 11.570\ [(Pr_{MIX}/Pr_T)^{3/4} - 1] \tag{8.11}$$

The subscript "MIX" refers to the properties of the two-phase mixture. Vijay (93) used a value of 0.887 for Pr_T as recommended by Spalding for the single-phase case. However, for the present assessment, since we are dealing with the two-phase case, and the proposal is still tentative, a value of $Pr_T = 1$ was used (in any case, predictions are not very sensitive to Pr_T).

Vijay (93) pointed out that the evaluation of the mixture properties had to be resolved. Vijay (93) examined some possible groups of mixture properties. In his investigation (93), the results showed that when the liquid properties were used as the mixture properties, the best agreement between the experimental data and the predictions were obtained. In the present investigation, the author attempted to examine five groups of mixture properties, namely:

Group 1: $\zeta_{MIX} = x\,\zeta_G + (1 - x)\,\zeta_L$ (8.12a)

Group 2: $\zeta_{MIX} = \alpha\zeta_G + (1 - \alpha)\,\zeta_L$ (8.12b)

Group 3: $1/\zeta_{MIX} = x/\zeta_G + (1 - x)/\zeta_L$ (8.12c)

Group 4: $1/\zeta_{MIX} = \alpha/\zeta_G + (1 - \alpha)/\zeta_L$ (8.12d)

Group 5: $\zeta_{MIX} = \zeta_L$ (8.12e)

The quantity ζ refers to fluid properties (i.e., density, viscosity, thermal conductivity, specific heat). The subscripts G and L refer to the gas and liquid-phase, respectively. For the mixture Prandtl number appearing in Equations (8.10) and (8.11), the following expression was used:

$$Pr_{MIX} = \frac{\mu_{MIX}\,C_{P,MIX}}{k_{MIX}} \tag{8.13}$$

Due to the fact that two-phase slug and churn flows are highly unsteady, the experimental data of slug, churn and their transitions were not used to test this method. The data analysis for annular-mist flow shows that the deviation between the data and the prediction varied from $\bar{e}_{rms}$ = 47 to 98% for the best mixture property group. Therefore, annular-mist flow is not of further interest here. Thus, only the data belonging to bubble, bubble-froth, froth, froth-annular, and annular flows were used to test this method. The test of Vijay's proposed method (i.e., Equation 8.10) was done for each gas-liquid system and for the individual flow regimes of bubble, froth (including bubble-froth and froth-annular), and annular.

After an examination of the mixture properties groups 1 to 5, the results showed that the best agreement between the data and the predictions was obtained when the properties of group 1 and group 5 were used (for all considered flow patterns). Therefore, the results of mixture properties group 5 are chosen to show the results of comparison between the present data and the predictions. Figures 8.7(a to c) show typical values of experimental $S_{q,TP}$ and the predictions when plotted against Z^+_{TP} for air-water, air-G1 and air-G2 systems, respectively. The values of experimental $S_{q,TP}$ were obtained by Equation 8.8 (with the measured value of τ_W). The value of Z^+_{TP} was obtained by Equation 8.9 with the measured value of the two-phase wall shear stress. The value of predicted $S_{q,TP}$ was calculated by Equation 8.10.

Figures 8.7a to c, show that the present data cover a wide range of Z^+_{TP} from approximately 100 to 500,000. It should be noted that, for froth and annular flows, the fully developed condition takes place over almost the whole length of the test section

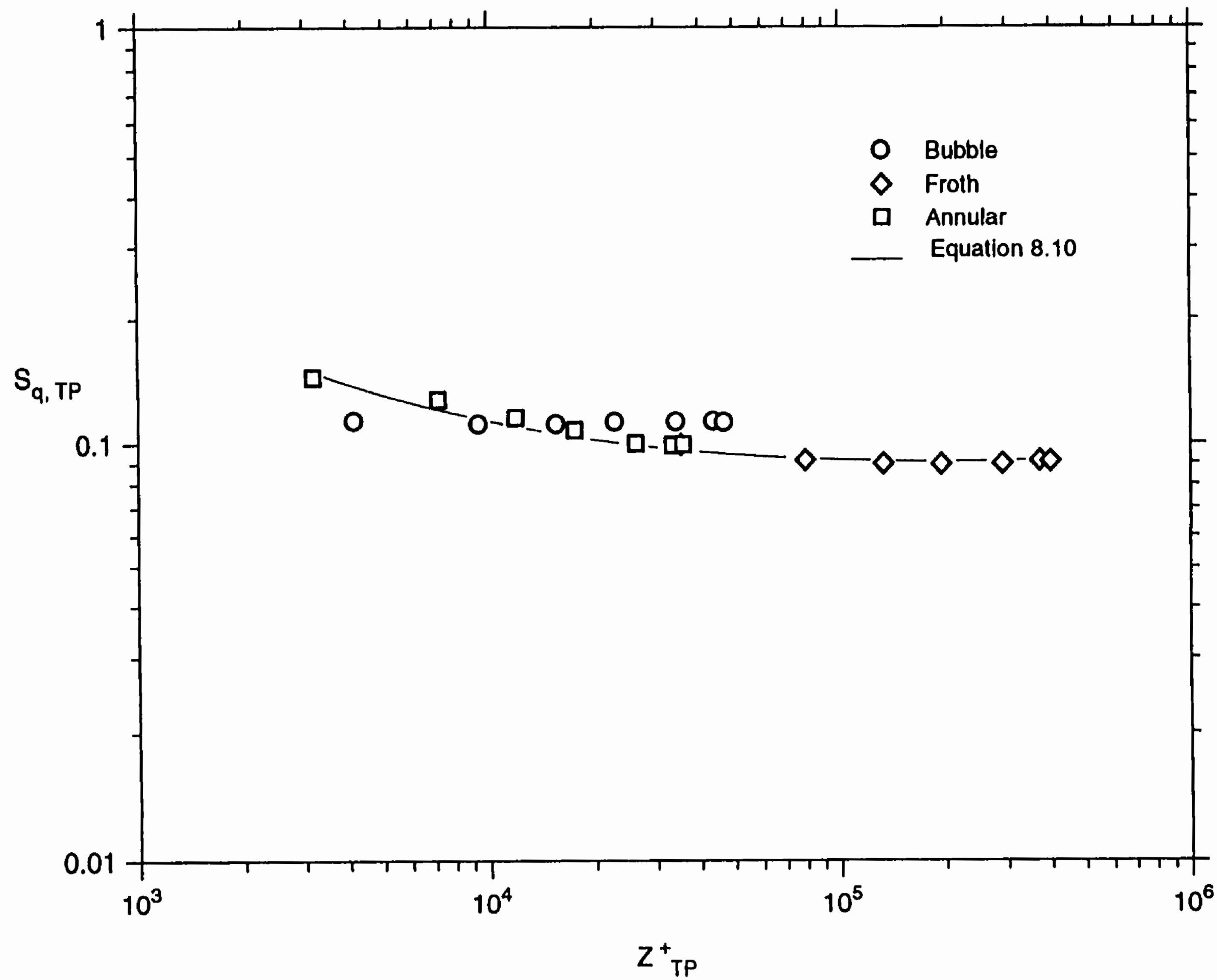

Figure 8.7a Typical Profile of $S_{q,TP}$ for Air-Water

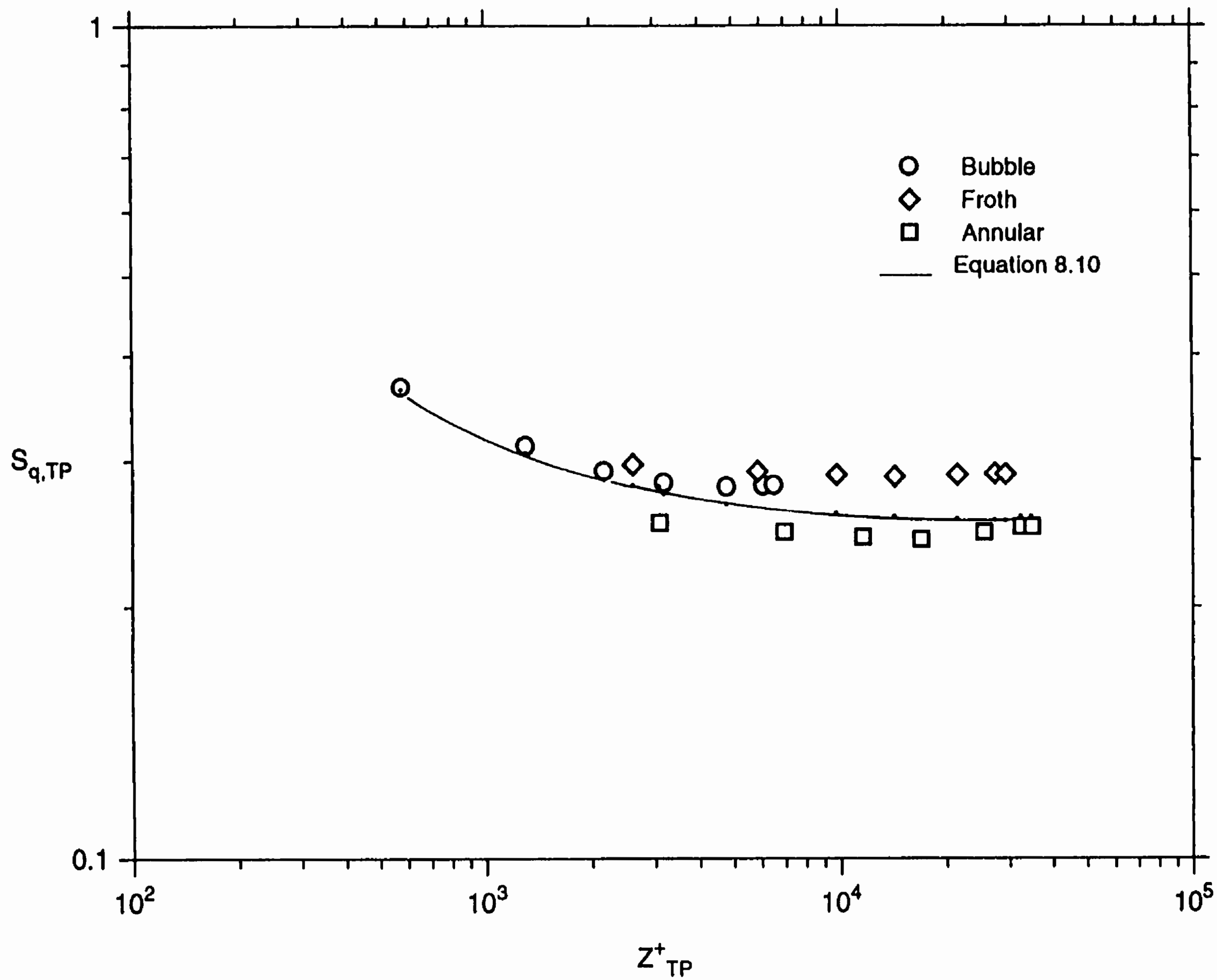

Figure 8.7b Typical Profile of $S_{q,TP}$ for Air-G1

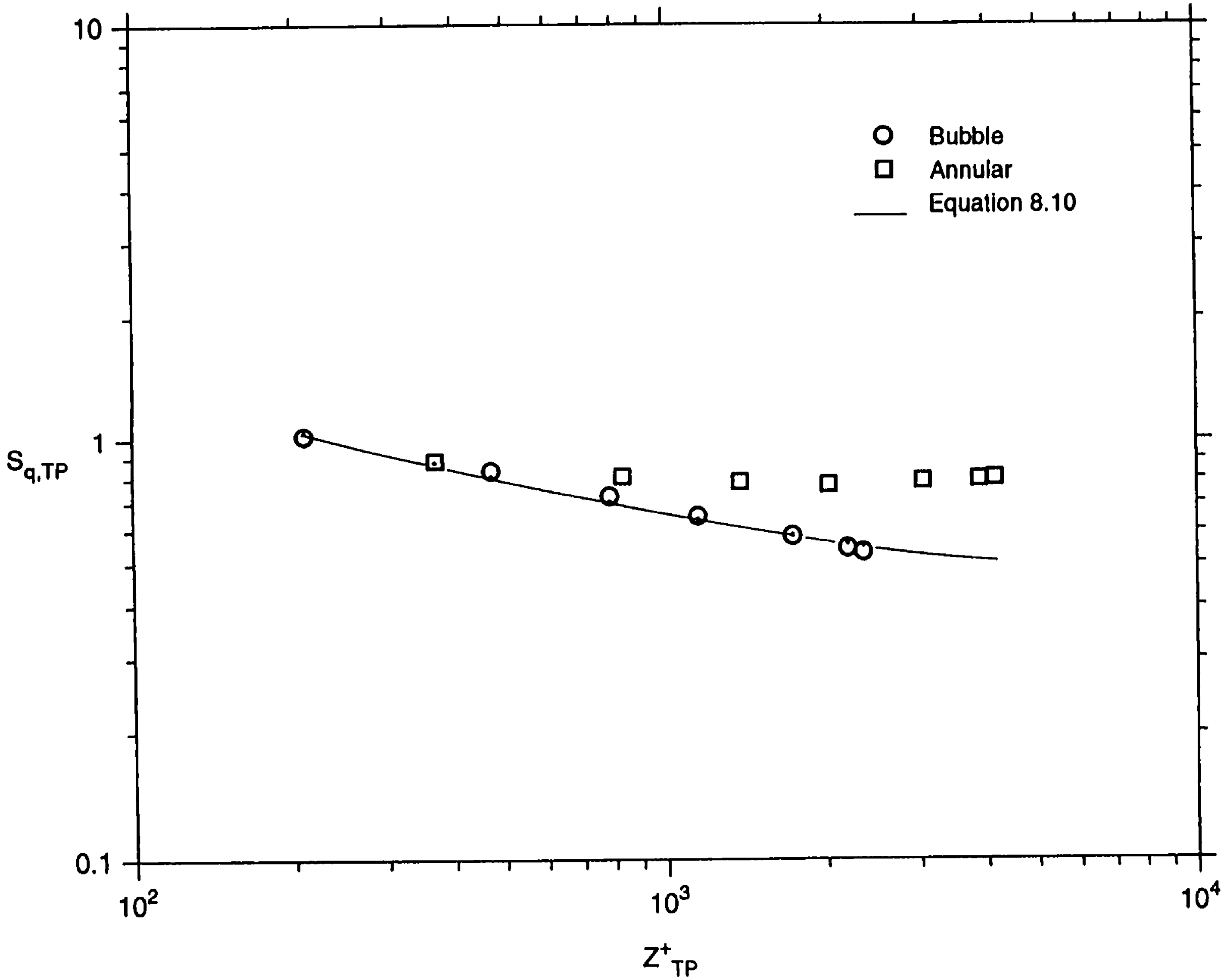

Figure 8.7c Typical Profile of $S_{q,TP}$ for Air-G2

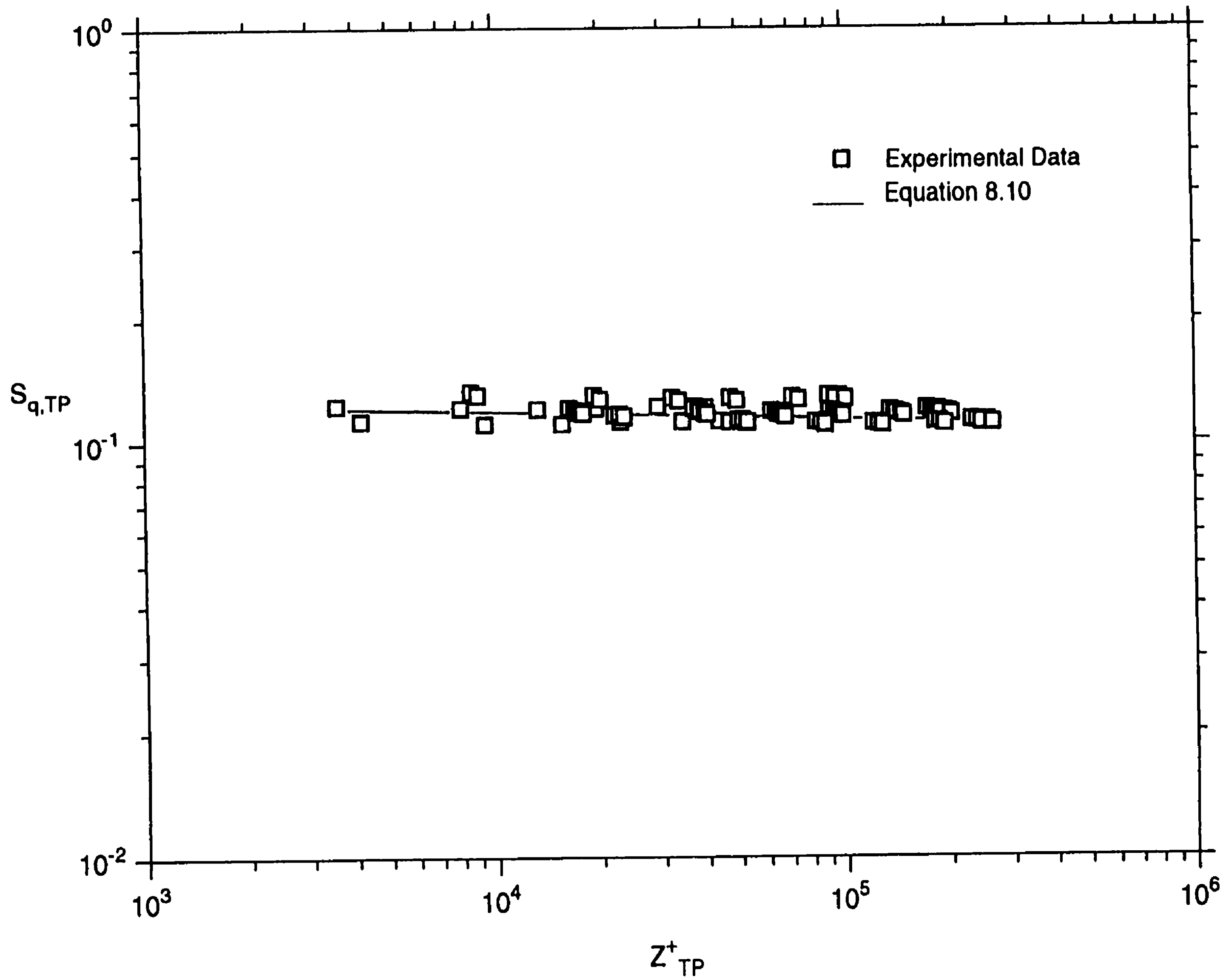

Figure 8.8a Comparison of Present Heat-Transfer Data with Equation 8.10 for Air-Water Bubble Flow

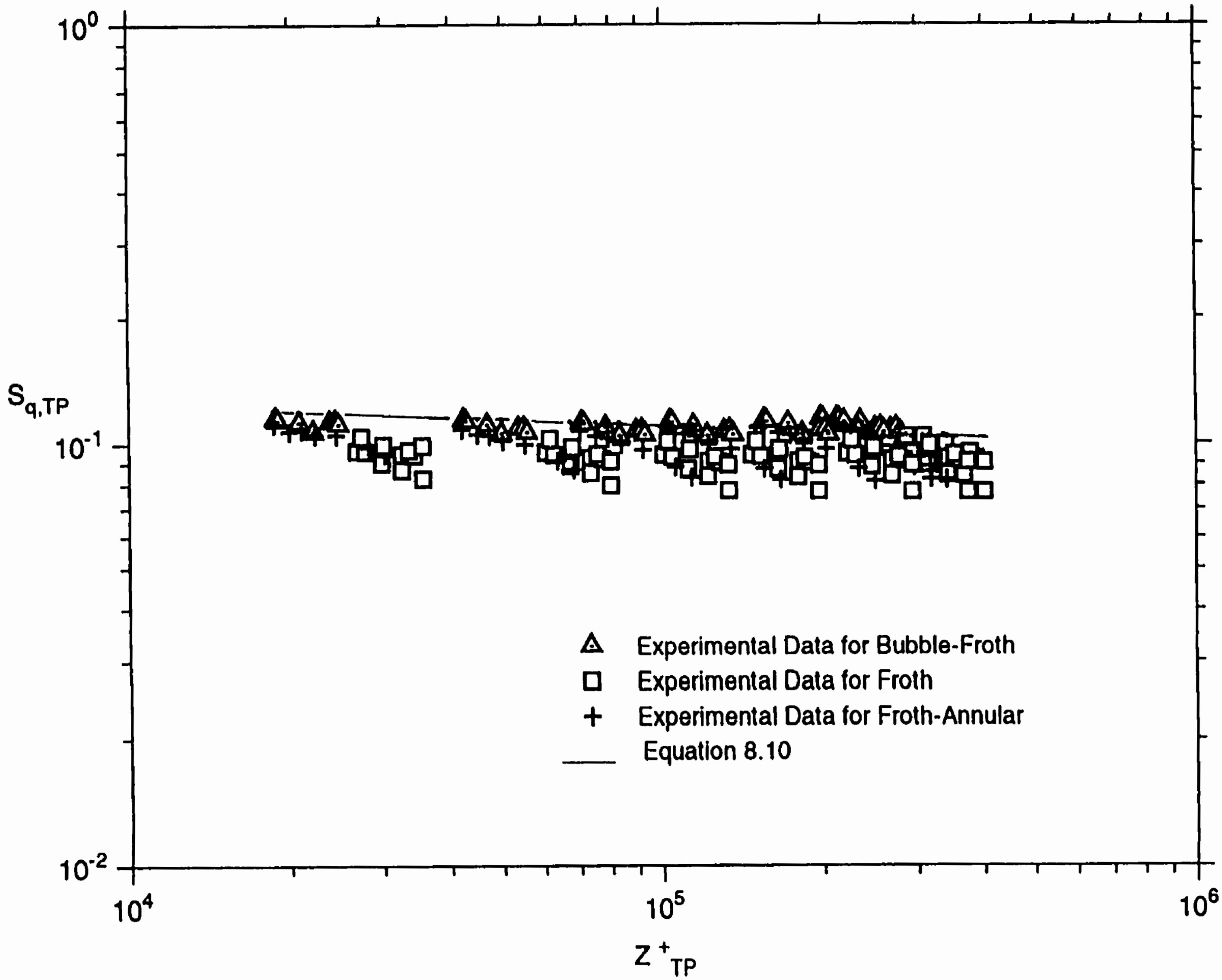

Figure 8.8b Comparison of Present Heat-Transfer Data with Equation 8.10 for Air-Water Froth Flow and Transitions

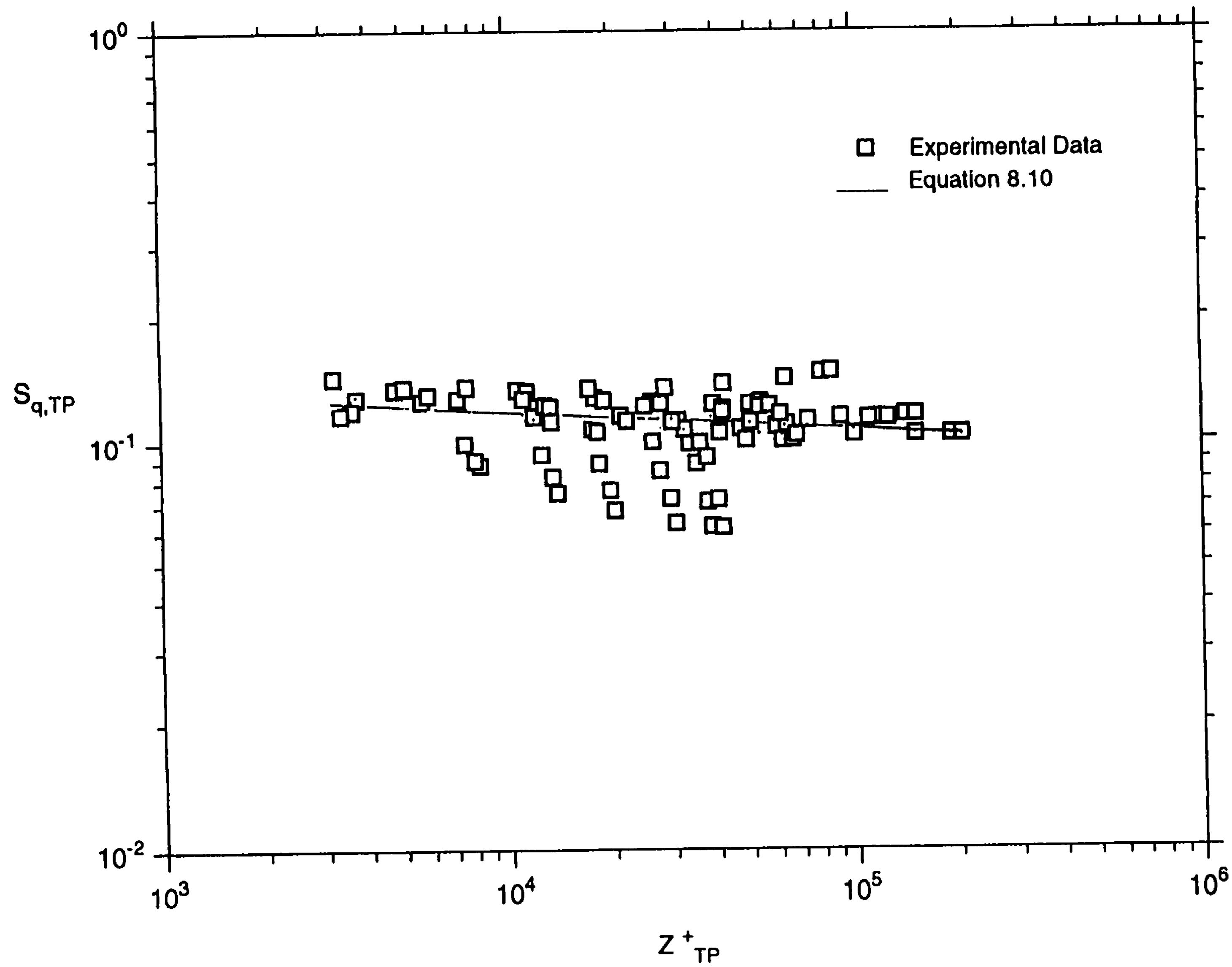

Figure 8.8c Comparison of Present Heat-Transfer Data with Equation 8.10 for Air-Water Annular Flow

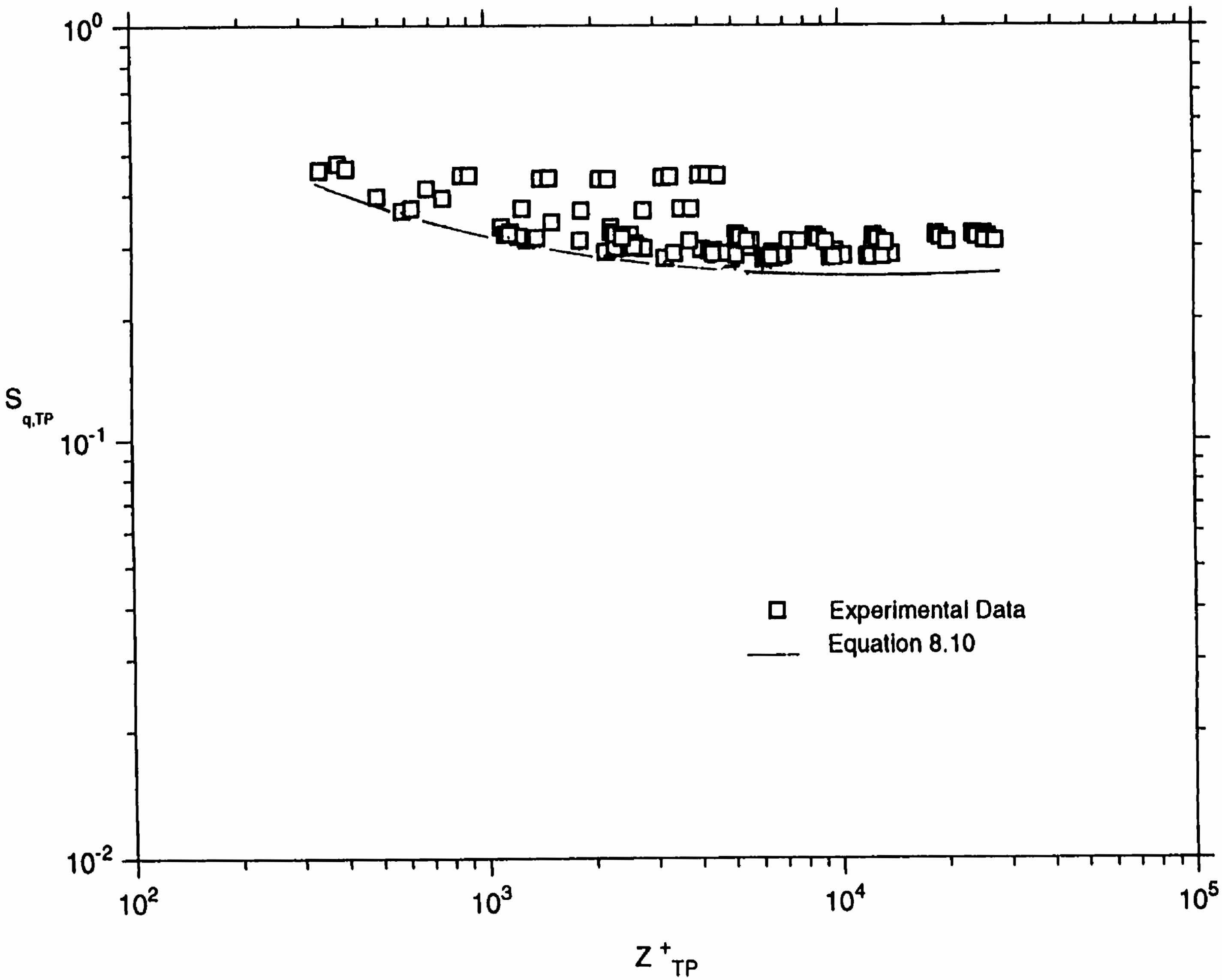

Figure 8.9a Comparison of Present Heat-Transfer Data with Equation 8.10 for Air-G1 Bubble Flow

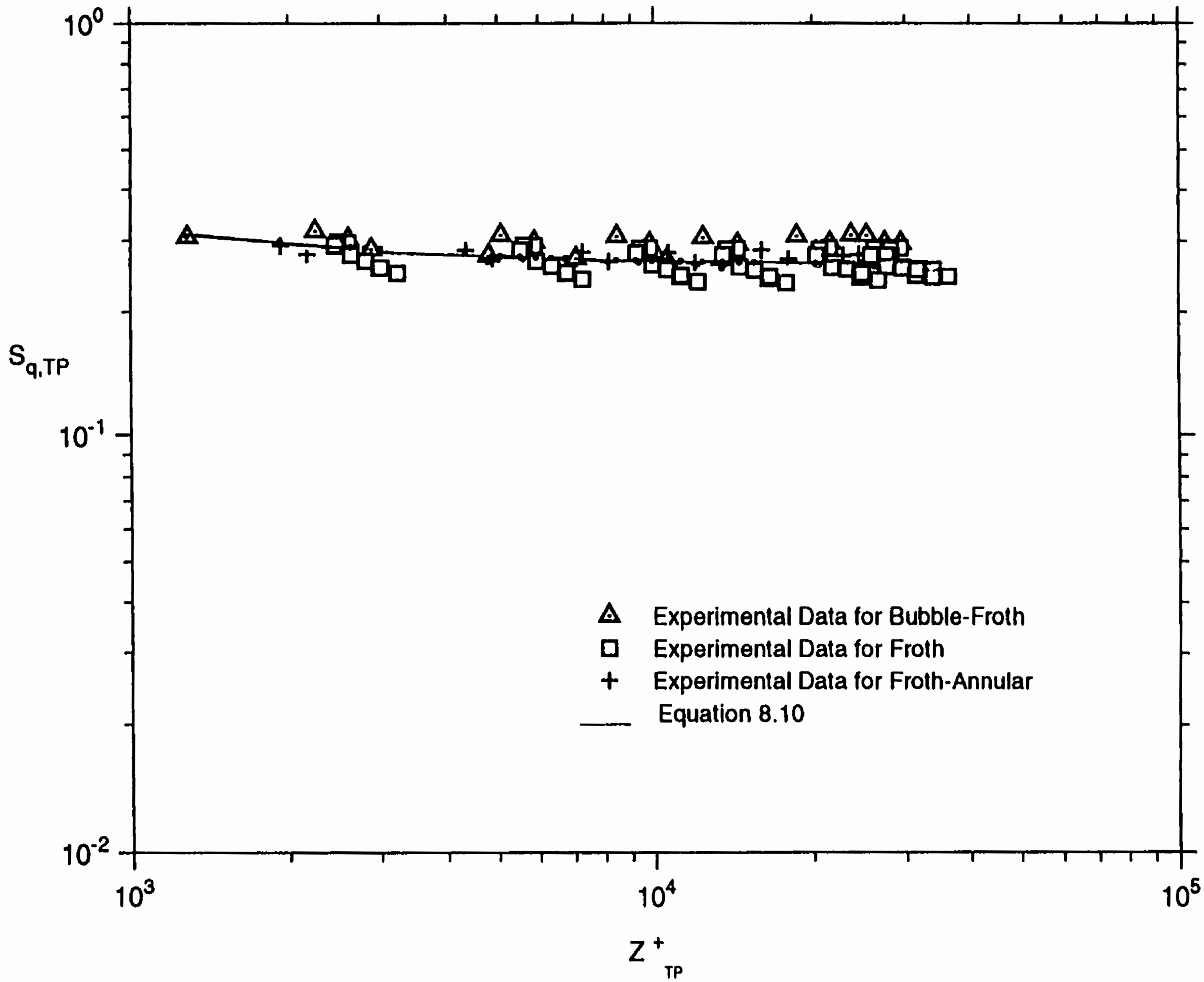

Figure 8.9b Comparison of Present Heat-Transfer Data with Equation 8.10
for Air-G1 Froth Flow and Transitions

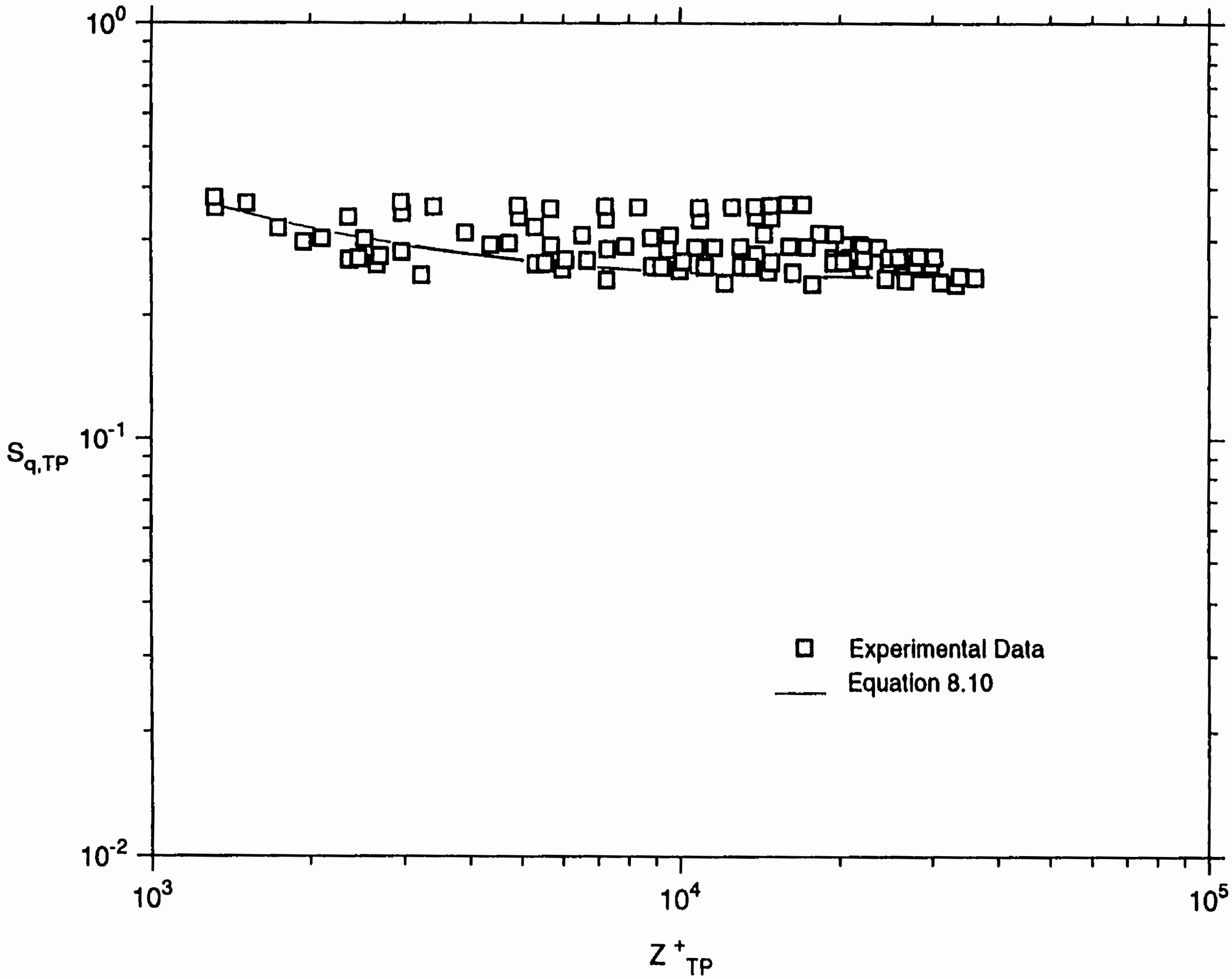

Figure 8.9c Comparison of Present Heat-Transfer Data with Equation 8.10
for Air-G1 Annular Flow

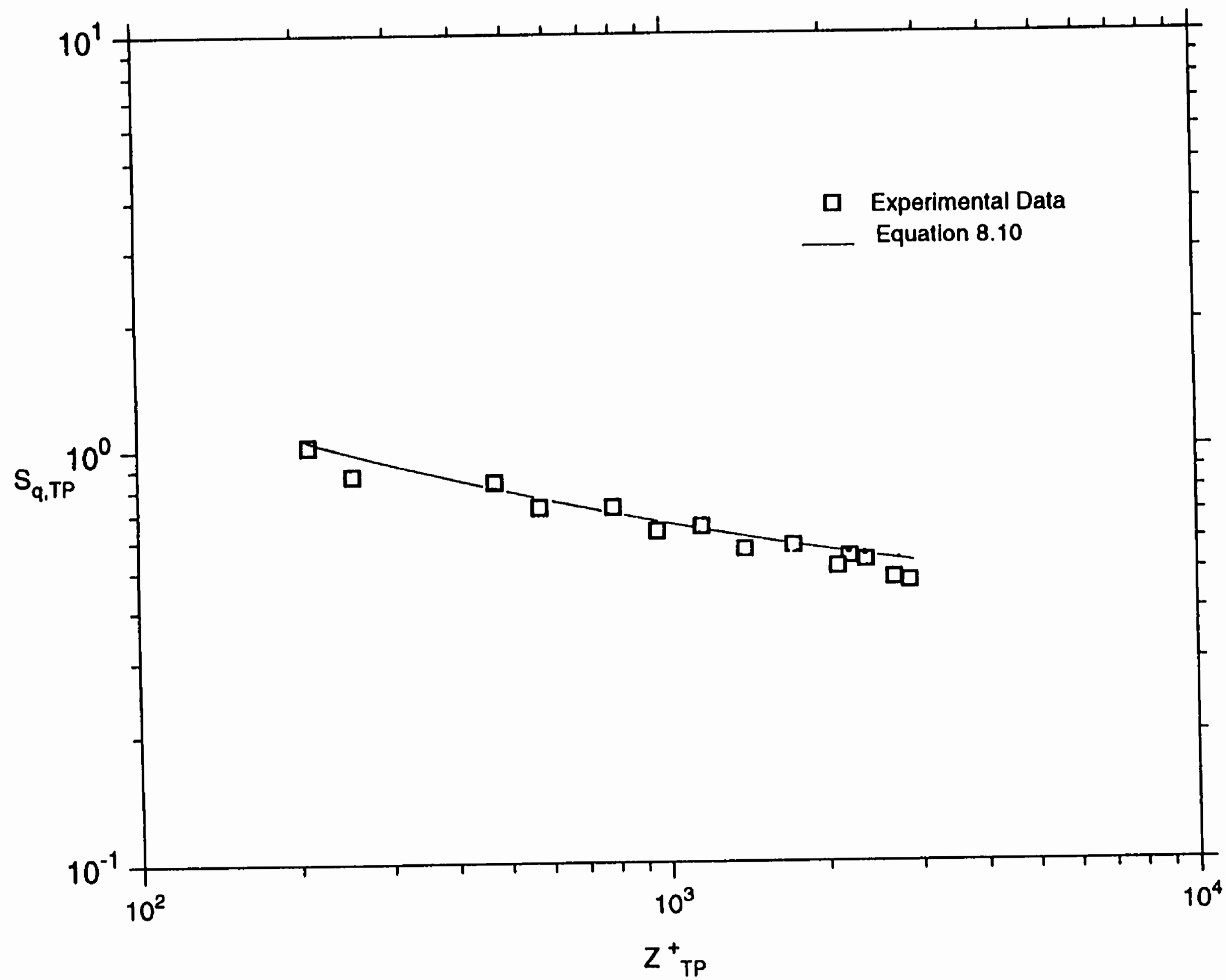

Figure 8.10a Comparison of Present Heat-Transfer Data with Equation 8.10 for Air-G2 Bubble Flow

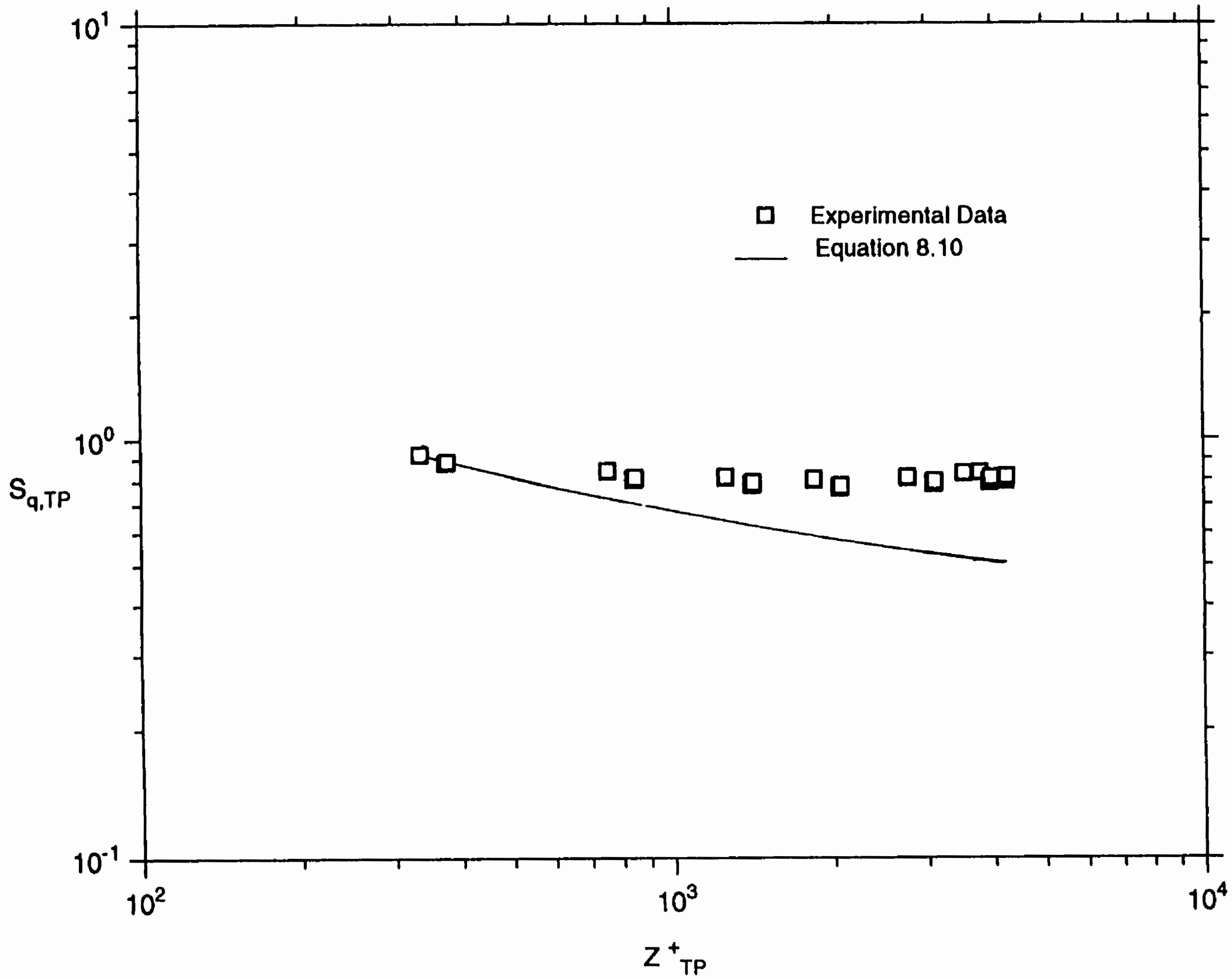

Figure 8.10b Comparison of Pesent Heat-Transfer Data with Equation 8.10 for Air-G2 Annular Flow

regardless of the liquid viscosity. For bubble flow, the fully developed condition establishes earlier with the lighter liquid. During data analysis, it was found that the deviations between the present data and the predictions were large for liquid superficial Reynolds number $Re_{SL} < 400$. This included six data points in annular flow of the air-G1 system ($Re_{SL} = 70$) and 15 data points in annular flow for the air-G2 system ($Re_{SL} = 10$ and 53). Since the original theory of Spalding (83) was meant for a turbulent boundary layer, a lower limit on Re_{SL} would not be surprising. Here, any datum point with $Re_{SL} <$ 400 was excluded from this testing method, which, of course, amounts to a restriction on the method.

Figures 8.8(a to c) to 8.10(a to b) show the results when all the data (of each gas-liquid system and particular flow regime) are plotted against predictions using group 5 properties. Table 8.2 shows the deviations between the experimental data and the predictions. For this table, it appears that the deviations for groups 1 and 5 are very close. This may be explained by the fact that the value of the quality, x, involved in the tested data, is generally small (see Equations 8.12a and 8.12e).

For air-water, Figures 8.8(a to c) show that the model gives excellent prediction for bubble flow, overprediction but fair for froth (including bubble-froth and froth-annular), and fair prediction for annular flow, respectively.

For air-G1, Figures 8.9(a to c) show that the prediction gives lower values of $S_{q,TP}$ than the data for bubble flow, good agreement with experimental data for froth (including bubble-froth and froth-annular), and fair agreement for annular flow. However, in general, the majority of the experimental data agree well with the prediction.

Table 8.2 Deviations Between the Present Data and the Predictions of Vijay's Proposed Method (Equation 8.10)

		Flow Regimes								
		Bubble			Froth*			Annular		
Gas-Liquid	Mixture Properties	N	$\bar{e}$	$\bar{e}_{rms}$	N	$\bar{e}$	$\bar{e}_{rms}$	N	$\bar{e}$	$\bar{e}_{rms}$
Air-Water	Group 1	91	4.5	6.9	175	-9.3	12.5	84	-2.9	20.3
	Group 5	91	4.5	6.9	175	-9.3	12.5	84	-0.4	19.0
Air-G1	Group 1	105	18.6	24.3	91	2.8	8.7	98	13.4	21.1
	Group 5	105	18.6	24.3	91	2.8	8.7	98	14.9	22.5
Air-G2	Group 1	14	-5.3	7.9	-	-	-	21	35.2	40.3
	Group 5	14	-5.3	7.9	-	-	-	21	35.2	40.3

* Froth and Transitions (Bubble–Froth and Froth-Annular).

For air-G2, Figure 8.10(a and b) show excellent agreement between predictions and experimental data of bubble flow. However, for annular flow, the experimental values of $S_{p,TP}$ are somewhat greater than the predictions at the end of the heated test section. These greater values of experimental $S_{q,TP}$ may be explained qualitatively as follows. In annular flow, usually the heat supply to the test section was high (compared with bubble flow) causing a larger bulk temperature rise along the Z^{+}_{TP}; for a high-viscosity liquid like G2, the viscosity is quite sensitive to the temperature. This may cause the liquid viscosity near the downstream end of the test section to become lower, leading to higher values of $S_{q,TP}$.

In general, the proposed method (Equation 8.10) gives good prediction of the tested data with groups 1 and 5 (where $Re_{SL} > 400$) as can be seen in Table 8.2. The method works well for two-phase froth flow where the $\bar{e}_{rms}$ is within 12.5 %, and for bubble flow the maximum $\bar{e}_{rms}$ is within 24.5 % for all air-liquid mixtures. The method also gives reasonable agreement with the tested data in annular flow. The great advantage of this method is that the model is convenient to use and still gives good predictions for bubble, froth (including bubble-froth and froth-annular) and annular flows. The fluid properties obtained by groups 1 and 5 give the best prediction (among five groups used in the present study).

Chapter 9

SUMMARY AND CONCLUSION

In the present investigation, a group of key variables, namely local and mean heat-transfer coefficients, pressure drop and mean void fraction have been measured over a wide range of Re_{SL}, Re_{SG}, and Pr_L; flow patterns were observed as well. The two-phase flow patterns encountered during the investigation ranged from bubble to annular-mist. Air was used as the gas phase. Three liquids, namely distilled water and two solutions of glycerine and water (59% and 82% by weight) were used for the liquid phase. The range of two-phase heat-transfer coefficients varied by a factor of approximately 1,000. The two-phase frictional pressure drop over the heated test section ranged from -1.03 Pa (in slug flow) to 92.5 kPa. The present investigation added markedly to the available data where heat-transfer coefficients, pressure drop and void fraction were measured under the same conditions.

The present experimental facility was used to perform liquid single-phase flow tests where the results on heat transfer and pressure drop were checked against well-accepted correlations and found to have excellent agreement with these. In addition, during the two-phase experiment some of the two-phase heat-transfer and pressure-drop data were checked against independent works using the same facility and another facility; good agreement was found. This suggests a good measure of confidence in the data. The hold-up method, using quick-closing valves, was employed for the mean void-fraction measurement. This method is classic and accurate. Having measured void fractions made for an accurate determination of two-phase frictional pressure drop, especially for conditions where the head term is comparable to the frictional term. The results showed that negative frictional pressure drops can be experienced in slug flow. This confirms the findings of Cognet et al. (17). The results of pressure drop were tested against Lockhart and Martinelli (55) and Friedel (28) where fairly good agreement was observed.

The flow patterns observed during the course of the experiment were compared with Govier and Aziz's map (29) and the method of Taitel et al. (86). The present observed flow patterns agreed well with Govier and Aziz over the range of the map. In general, the results show that the flow pattern is insensitive to the liquid viscosity, which agrees with the results from other works.

The results of measured void fraction were compared with predictive methods and it was found that the Chrisholm (13) and CISE (15) correlations give the best predictions among the tested correlations. As mentioned above, the combination of measured pressure drop and void fraction allows accurate determination of the frictional pressure drop and wall shear stress. This allows a good assessment of the heat-transfer predictive methods which require these variables.

For the testing of the correlations for mean heat-transfer coefficients, which require void fraction or wall shear stress, it was found that the methods with more restrictions give better prediction. Among the most restrictive methods, that of Drucker et al. ($2000 < Re_{SL} \leq 150000$, $\alpha \leq 0.4$ and $1.77 \leq Pr_L \leq 130$) is recommended; for the relevant data this method gives $\bar{e}_{rms} \leq 14.5\%$. A method less restrictive but still giving good prediction is the L.A.M. for $Re_{SL} > 2000$ and without annular-mist data; this method gives $\bar{e}_{rms} \leq 18$ %.

A predictive method,proposed by Vijay (93) which adapted Spalding's single-phase turbulent boundary-layer solution to the prediction of two-phase local heat-transfer coefficients, was tested against the present data according to flow patterns (considering bubble, froth and annular) and different groups of fluid properties. It was found that among the tested groups of fluid properties, using the liquid-phase properties (group 5) or group 1 (see Equation 8.12a) for the two-phase mixture, gives the best prediction over the range of the present data. The method works well for froth flow.

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Appendix A

DETAILED INFORMATION ON THE COMPONENTS USED IN THE EXPERIMENTAL FACILITY

In this appendix, detailed information on the measuring devices and other equipment is listed. Even though the void-fraction measuring facility and other equipment (such as the air pressure control system) were added to the experimental rig, the main facility was essentially the same as that built by Vijay (93) and used most recently by Rezkallah (71). Therefore, some of the material presented in this appendix was taken from these references and is given here for the sake of completeness.

Table A.1 lists all the important details such as the manufacturers, model number, etc., of the equipment used. The numbers appearing under the category of "Part Number" correspond with those circled numbers in Figures 3.2 to 3.9. Where the original specifications, etc. were given in Imperial units, these units have been retained here.

Table A.1

Information on the Components of the Experimental Facility

Part No. in Figs. 3.2 to 3.9	Name of the Component	Description
<u>MIXING CHAMBER</u>		
1	Stainless steel strainer	3.0-in. dia., 1/32 in. perforated stainless steel type 304 Sarco Strainer; Sarco Canada Limited, Agincourt, Ontario, Canada.

Part No. in Figs. 3.2 to 3.9	Name of the Component	Description
2	Porosint bronze tube	0.460-in. i.d. × 0.740-in. o.d. × 8.0 in. grade E; Sintered Products Limited, Sutton-in-Ashfield, Notts, England, U.K.
HEATED TEST SECTION		
3	Heated test tube	Stainless steel type 304; 0.460-in. i.d. × 0.020 in. thick; Atlas Alloys, L = 2 ft.; Atlas Steels Limited, Welland, Ontario, Canada.
4	Bus bars	Brass, 6.75 × 3.0 × 0.94 in.
5	Supporting bar	1.0 × 1.0 in. Permali insulating material; Permali (Canada) Limited, Toronto, Ontario, Canada.
6	Guard heater tube	1.5-in. i.d.. × 0.0625 in. thick split copper tube retained by Permali rings.
7	Heating elements	Two Briskeat silicone rubber-embedded heating tapes (0.3 in. wide × 8 ft. & 0.5 in. × 10 ft.); Briscoe Manufacturing Co., Columbus, Ohio, U.S.A.
8	Calming section	Stainless steel type 304; 0.406-in. i.d. with 0.020 in. thickness, Atlas Alloys, 5 ft. in length; Atlas Steel Limited, Welland, Ontario, Canada.
OBSERVATION SECTION		
9	Visual section	3.0 × 3.0 in. × 1 ft. cast acrylic rectangular prism with 0.460 in. precision-bored hole.
TEMPERATURE MEASURING INSTRUMENTS		
10	Digital voltmeter	Keithley 191 digital multimeter, model 191, 5-½ digit, 0.0005% resolution, accuracy 0.007% + 3 digits; Keithley Instruments, Inc., Cleveland, Ohio, U.S.A.
11	Data logger	Fluke data logger model 2240A, 60 channel capacity, scanning speed up to 15 channel/sec., accuracy ± 2 μV programmable, equipped with a digital display and printer, displays and prints date, time (hour, min., sec.), channel no., reading (mV or °C) and units; John Fluke Mfg. Co., Inc., Mountlake Terrace, Washington, U.S.A.

Part No. in Figs. 3.2 to 3.9	Name of the Component	Description
12	Thermocouples on heated test section	Copper-constantan thermocouples AWG no. 36 0.005- in. (0.012- mm) diameter T/G-36-DT, Thermoelectric (Canada) Ltd.
13	Thermocouples on guard heater	Copper-constantan thermocouples AWG no. 30 0.0-in. (0.0254-mm) diameter T/G-30-DT, Thermoelectric (Canada) Ltd.
14	Thermocouples for fluid temperatures	Copper-constantan thermocouples no. PR-T-24, Omega Engineering Inc., Stanford, Connecticut, U.S.A.
15	Ice bath	Omega ice point cell (model TRC III); OMEGA Engineering Inc., Stanford, Conn., U.S.A. Accuracy: 0 to 0.1°C. Stability ± 0.04°C for any constant ambient.
16	Selector switch	Thermo-Electric selector switch; 96 points, 48 switches, custom key palladium contact switches, model no. 33212. Double pole, double throw, centre OFF type.
17	Constant-temperature bath	Gebruder Haake model FS/FT constant temperature bath; specified accuracy: ± 0.02 °C; Gebruder Haake, Karlsruhe, W. Germany.
LIQUID FLOW LOOP		
18	Pump	Waukesha positive displacementpPump, model no. 25 1½ in.-o.d. All nickel-bronze construction (Waukesha Metal). Complete assembly supplied with a 5 hp (220 volt, DP) motor and a V-belt drive. max. flow = 24 USGPM (water); max. pressure = 150 psi and max. temp. = 225°F. Buna-N seals; Waukesha Foundry Company, Waukesha, Wisconsin, U.S.A.
19	Flowmeters	Fischer & Porter indicating type flowmetors (variable area flowmeters "rotameters").
	A	Model no. 10A3537A, 316 stainless steel float (½ -GUSVT-40), tube: FP = ½-21-G-10/83, percent scale. flowrate: max. = 0.328 USGPM liquid sp. gr. = 1.0

Part No. in Figs. 3.2 to 3.9	Name of the Component	Description
	B	Model no. 10A3537A, 316 stainless steel float (3/4 27-G-10/83), percent scale, flowrate: max. = 3.55 USGPM liquid sp. gr. = 1.0.
	C	Model no. 10A3537A, 316 stainless steel float (2-GSVGT-98). Tube: FP-2-27-G-10/83, percent scale, flowrate: max. = 30 USGPM liquid sp. gr. = 1.0.
	D	Model no. 10A3537P, 316 stainless steel float (NSVT-622). Tube: PP-1-60-P 8/83, percent scale, flowrate: max. = 20 USGPM liquid sp. gr. = 1.0. (Used for controlling the cooling water rate in the heat exchanger.) All flow rates were calibrated in laboratory for water for the present investigation. Fischer and Porter (Canada) Ltd., Downsview, Ontario.
20	Differential pressure transmitters	Three Rosemount differential pressure transmitters with ranges 0.0 - 30.0, 0.0 - 100.0 and 0.0 - 750.0 in. of water. Output: 4-20 mA DC; stability: ± 0.2% of upper range limit; linearity: ± 0.1% of calibrated range; accuracy: ± 0.2% of calibrated span; Rosemount Inc., Minneapolis, Minn., U.S.A.
21	Gauge pressure transmitter	One Rosemount gauge pressure transmitter. Range 0.0 - 100.0 psig. Accuracy: ± 0.25% of calibrated span; includes combined effects of linearity, hysteresis and repeatability. Other features are the same as in 20.
22	Gas-liquid separator tank	1½ × 1.0 ft. stainless steel tank with 3 in. outlet in the cover plate and 1½ in. drain; Greensteel Industries Ltd., Winnipeg, Manitoba, Canada.
23	Liquid storage tank	1½ × 3 ft. stainless steel tank with 3 holes in the cover plate (3 in. diameter). 1 ½ in. drain and a side mounted ½-in. i.d.. glass level indicator; Greensteel Industries Ltd.
24	Heat exchanger	Liquid-to-liquid shell-and-tube type exchanger. All copper 0.625-in. i.d. tubes by 4 ft. long, shell diameter 2 ft.; Automedic Instruments Ltd., Winnipeg, Manitoba, Canada.

Part No. in Figs. 3.2 to 3.9	Name of the Component	Description
VOID-FRACTION MEASURING SECTION		
25	Quick-closing or opening valves	0.5 in. 316 stainless steel ball valve; Jamesbury Corp., Worcester, Mass., U.S.A. Driven by QUADRA-POWR Actuator series B605, Jamesbury Corp., Worcester, Mass., U.S.A. Operating time 0.005 second (measured).
26	Void-fraction measuring tube	0.5 in. i.d., 0.75 in. o.d., L = 1.06 m; extruded polycarbonate tube catalog no. 1130-048-08 Johnston Plastics, Winnipeg, Manitoba, Canada.
27	Calming section	0.5-in. i.d., 0.75-in. o.d., L = 5 ft.; extruded acrylic tube catalog no. 1130-048-08 Johnston Plastics, Winnipeg, Manitoba, Canada.
POWER SUPPLY CIRCUIT		
28	Variac	Powerstat variable auto-transformer, model no. P1156-4PS. Single-phase, 240 volt-100 amps-24 kVA; American Superior Electric Company, U.S.A.
29	Transformer	Single-Phase Dry Type Distribution Transformer. Open-ventilated, class-F. Primary: 240 volt-100 amps, secondary: 1,200 amps. Pioneer Electric Manitoba Ltd., Winnipeg, Manitoba, Canada.
30	Current transformer	Weston model 327, type 2. Primary: 100 amps, secondary: 5 amps, Weston Electrical Instrument Corp., Newark, N.J., U.S.A.
31	Ammeter	Weston A.C. Ammeter, model 433 (25-500 cycles). Range: 5/2.5/1 amp.
32	Voltmeter	Keithley 179A true rms Digital Voltmeter.
PHOTOGRAPHIC SECTION		
33	Camera	Pentax Spotmatic Single-Lens Reflex Camera equipped with Super-Takumar 50 mm f/4 Macro (close up) lens.
34	Strobotac	General Radio type 1538-A Strobotac Electronic Stroboscope. Flashing-rate range: 110 to 150,000 flashes per minute, flash duration: 0.5 to 3 μs; General Radio Company, West Concord, Mass., U.S.A.

Part No. in Figs. 3.2 to 3.9	Name of the Component	Description
35	Flash unit	EG&G 549 Microflash system consisting of the model 549-11 Flash Unit and the model 549-21 Driver Unit. Flash duration 0.5 s; peak light: 50×10^{6} beam candle power, Edgerton, Germeshausen & Grier, Inc., Boston, Mass., U.S.A.
AIR FLOW LOOP		
36	Pressure regulator	Watts 0.25 in., 0 - 100 psi pressure regulator.
37	Pressure regulator	0.5 in., 200 psi max., ARO-pressure regulator.
38	Air filter	Watts Fluidair Inc., Series 03904, 250 psi (max).
39	Pressure control unit	3/8 in. port size feedback pressure controller; Type 4160 K controller 0-100 psig., Fisher Controls Inc., Canada.
40	Orifice plates	Three sharp-edged plates of 0.418, 0.141, and 0.046 in. diameter, designed and manufactured in the laboratory generally according to ASME Power Test Code. All orifice plates were calibrated in the laboratory.
41	Gas rotameter	Tube no. 3-15-4; Glass Float; Brooks Instrument Co. Inc., Hatfield, Penn., U.S.A.
42	Manometer	Meriam model 30EB25TM, Range 100", well-type manometer. Equipped with standard scale and stainless steel wetted parts.
FLUID-PROPERTY MEASURING EQUIPMENT		
43	Hydrometers	Certified hydrometers (calibrated to meet or exceed the tolerances of accuracy and physical specifications by NIST Circular 555) to measure the density of glycerine & water solution, range of specific gravity from 1.000 to 1.300, ERTCO PRECISION, Ever Ready Thermometer Co., West Preston, N.J., U.S.A.

Appendix B

CALIBRATION OF INSTRUMENTS

B.1 GENERAL REMARKS

This appendix shows the results of the calibrations of the measuring devices used in the present experiment. As mentioned in Appendix A, some devices such as thermocouples in heated the tube, the resistivity of the heated tube, the current and potential transformers were calibrated only once by Vijay (93) before installation into the facility. Other measuring devices such as liquid flowmeter, orifice plates, gas flowmeter, pressure transducers, etc. were calibrated by the present author. The results of the calibrations were used in the data reduction procedure. The following sections show the results of the calibrations.

B.2 CALIBRATION OF POWER-MEASURING DEVICES

B.2.1 Ammeter

The ammeter was calibrated against a high-precision reference meter (Electrodynamic; A.C. test set). The results are shown in the table below and Figure B.1.

Range (amps)	Max. Deviation Between Reference and Lab Readings (%)
1.0-5.0	1.47
0.5 - 2.5	0.77
0.2 - 1.0	2.2

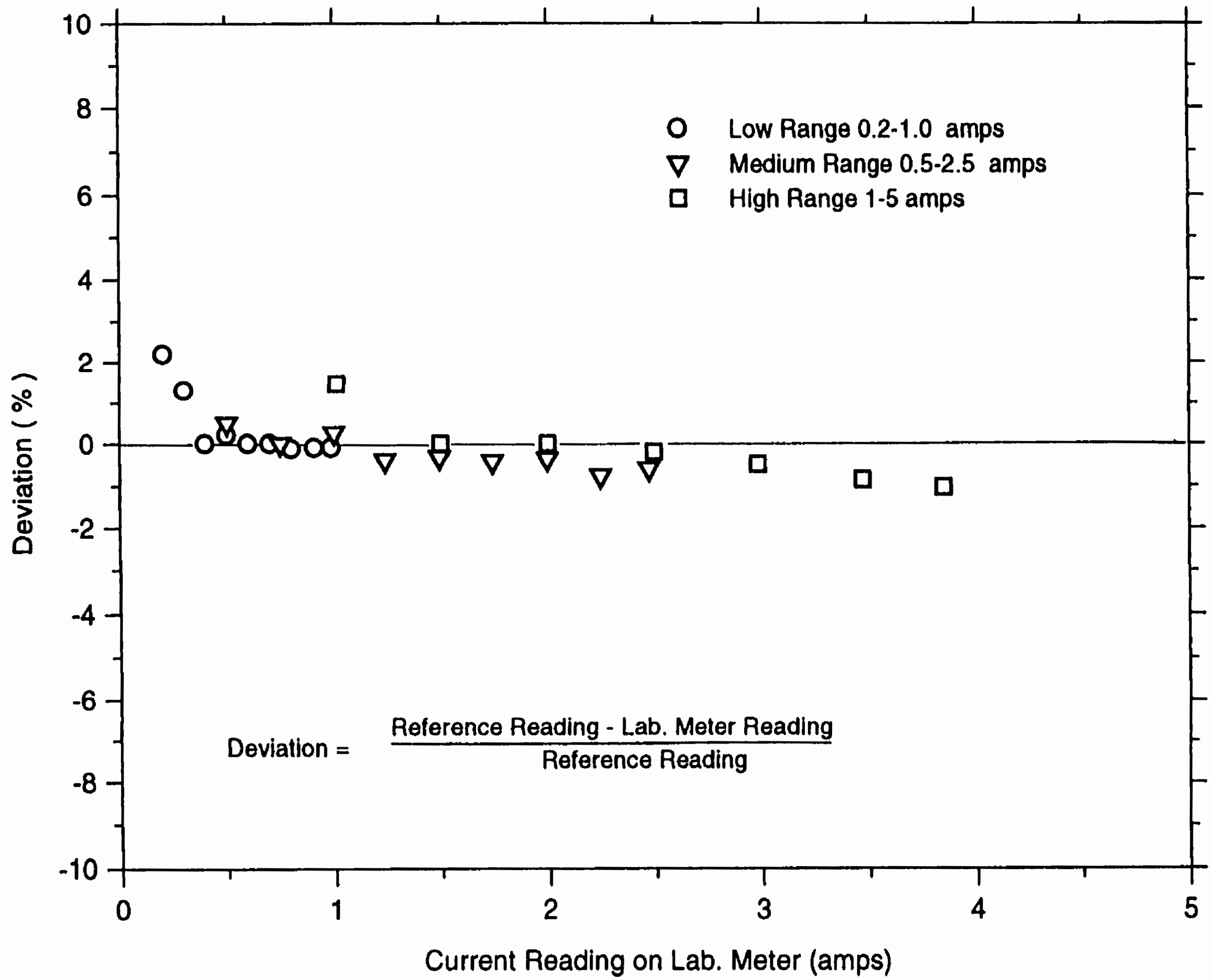

Figure B.1 Results of the Ammeter Calibration

B.2.2 Digital Voltmeter

The voltmeter readings were not used for heat-transfer data reduction. However, this reading together with the reading of the ammeter was used as a check on power input to the heated test section. The maximum deviation obtained between the voltmeter and a standard was less than 1.0%.

B.3 CALIBRATION OF TEMPERATURE-MEASURING DEVICES

There were some newly installed thermocouples in the facility other than those on the heated test section. These new thermocouples were calibrated against high-accuracy certified thermometers (Brooklyn Thermometer Co. Inc.). The deviation between the thermocouples and the standard thermometers was excellent with the maximum deviation being less than 0.05 °C.

B.4 CALIBRATION OF LIQUID ROTAMETERS

Three Fischer & Porter liquid rotameters were used in the experiment and were calibrated in situ in the laboratory. The calibration was done by collecting and weighing a certain amount of the liquid over a period of time. The results of the calibrations are shown in Figure B.2 for all the liquid used. The solid lines in Figure B.2 are the calibration curves for water provided by the manufacturer. The agreement between the manufacturer's curve and the present calibration is excellent for the case of water.

B.5 CALIBRATION OF THE PRESSURE TRANSMITTERS

Three differential and one gauge pressure transmitters were used in the present

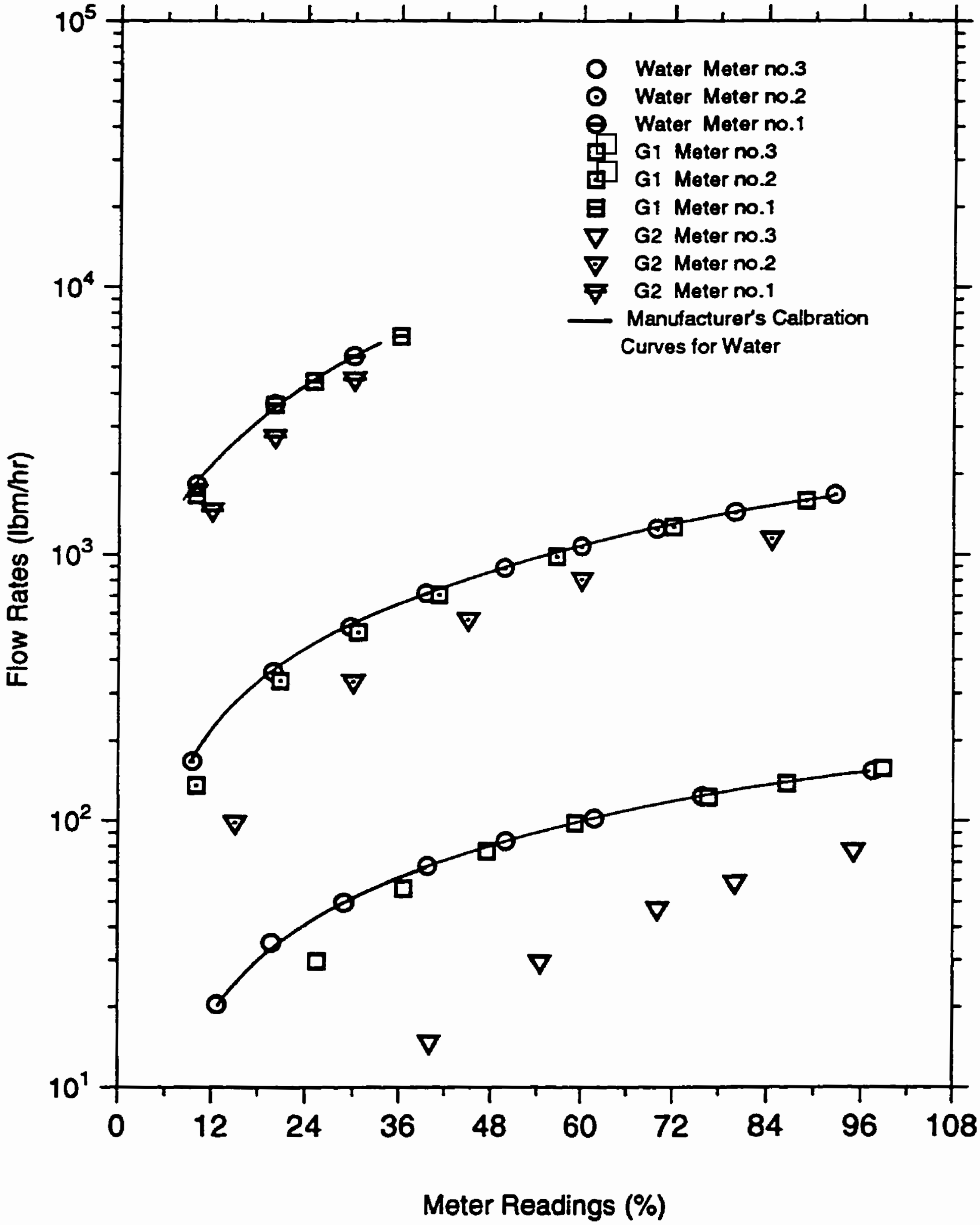

Figure B.2 Calibration of Liquid Flow Meters investigation. They were calibrated over their ranges in the laboratory and compared against the manufacturer's curves. Two differential pressure transmitters ranges, -25 to 5 and 0.0 to 100 in. of water, were calibrated using a water manometer, while another differential pressure transmitter range, 0.0 to 750 in. of water, was calibrated using a mercury manometer. The gauge pressure transmitter, range 0.0 to 100 psig,was calibrated against a calibrated pressure gauge. Figure B.3 to B.6 show excellent agreements between the present and manufacturer's calibrations. Table B.1 gives the equations for obtaining ΔP as funtion of voltage (V) measured across a 500 Ω resistor.

Table B.1 The Equations of the Pressure Transmitters

Transmitter No.	Range of Applicability	ΔP
1	-25 to +5 in H_2O	7.392V - 32.285
2	0 to 100 in H_2O	25.279V - 25.153
3	0 to 750 in H_2O	185.43V - 183.62
4	0 to 100 psig	25.358V - 25.358

B.6 CALIBRATION OF ORIFICE PLATES AND GAS ROTAMETER

Three orifice plates constructed by Vijay (93) essentiallyaccording to ASME Power Test Codes (Ref. B.1) were calibrated in situ in the laboratory using (i) a certified venturi (accuracy ± 0.5%) and (ii) a certified wet-test meter (accuracy ± 0.25%). The results of calibration for the three orifice plates are shown in Table B.2. The method of using these orifice plates and the gas rotameter to calculate the air flow rates is shown in Appendix C. The quantity C is the coefficient of the discharge of orifices. The quantity Re_d represents the

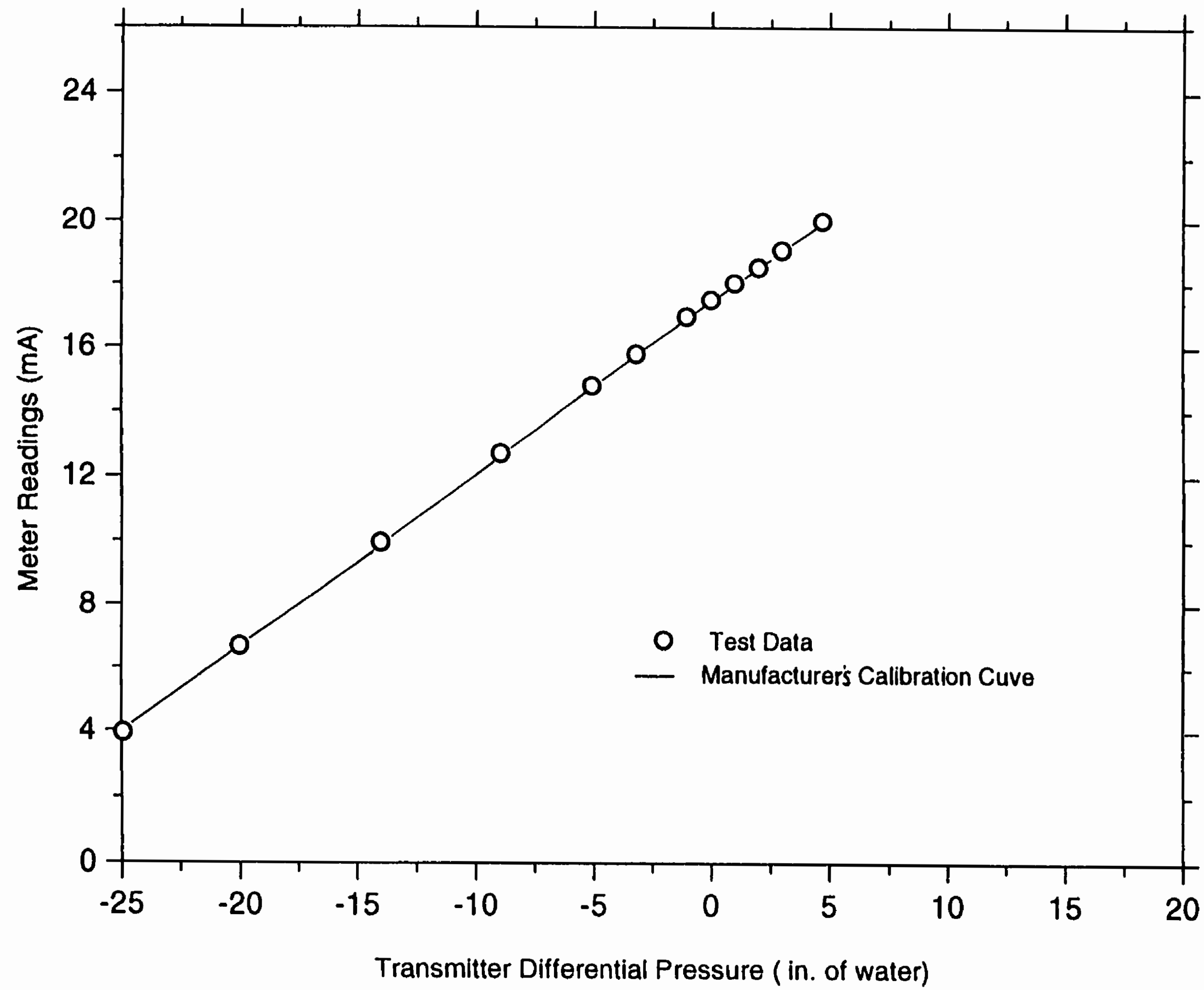

Figure B.3 Calibration of Differential Pressure Transmitter No.1 (-25 to +5 in. of water)

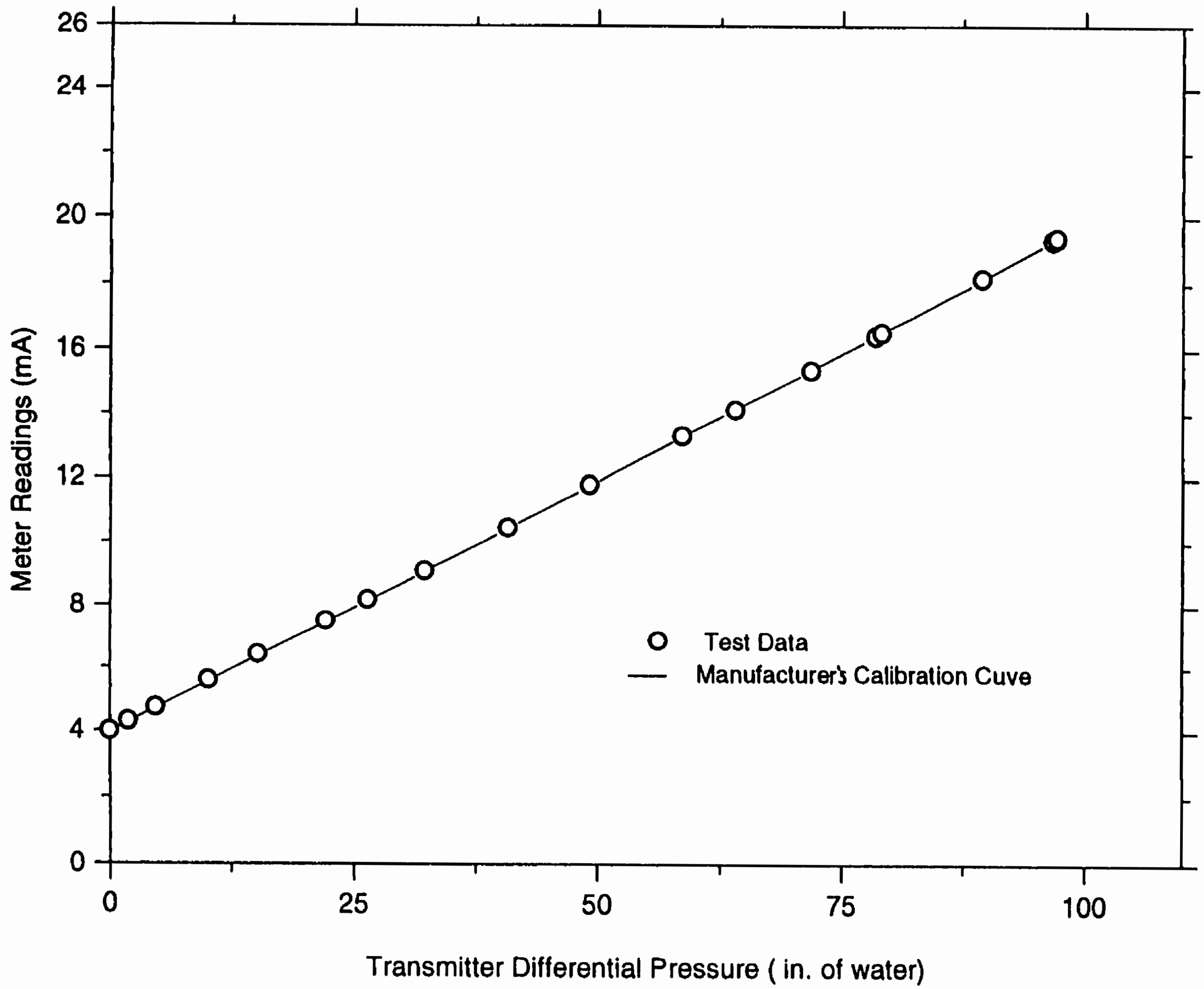

Figure B.4 Calibration of Differential Pressure Transmitter No.2 (0 to 100 in. of water)

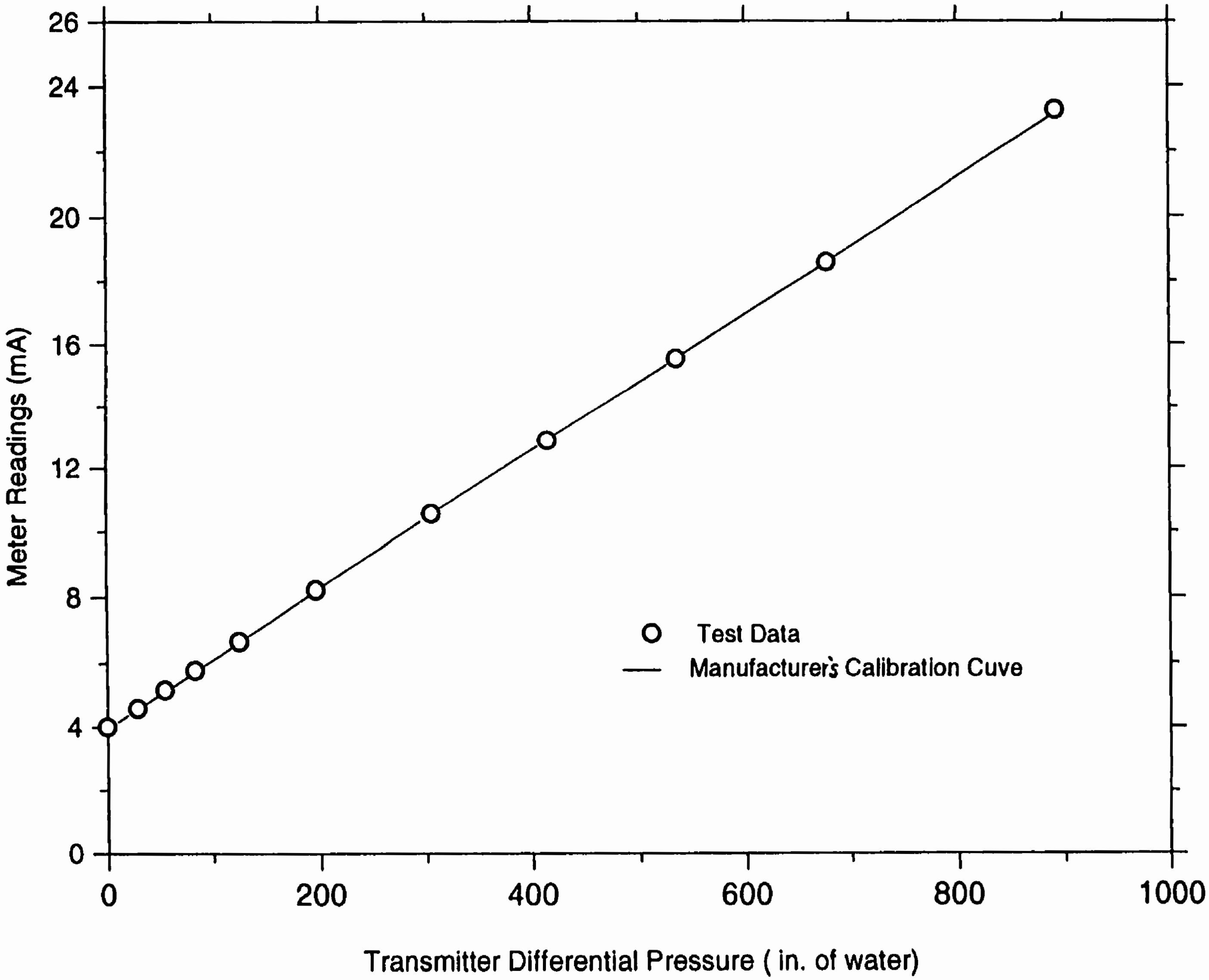

Figure B.5 Calibration of Differential Pressure Transmitter No.3 (0 to 750 in. of water)

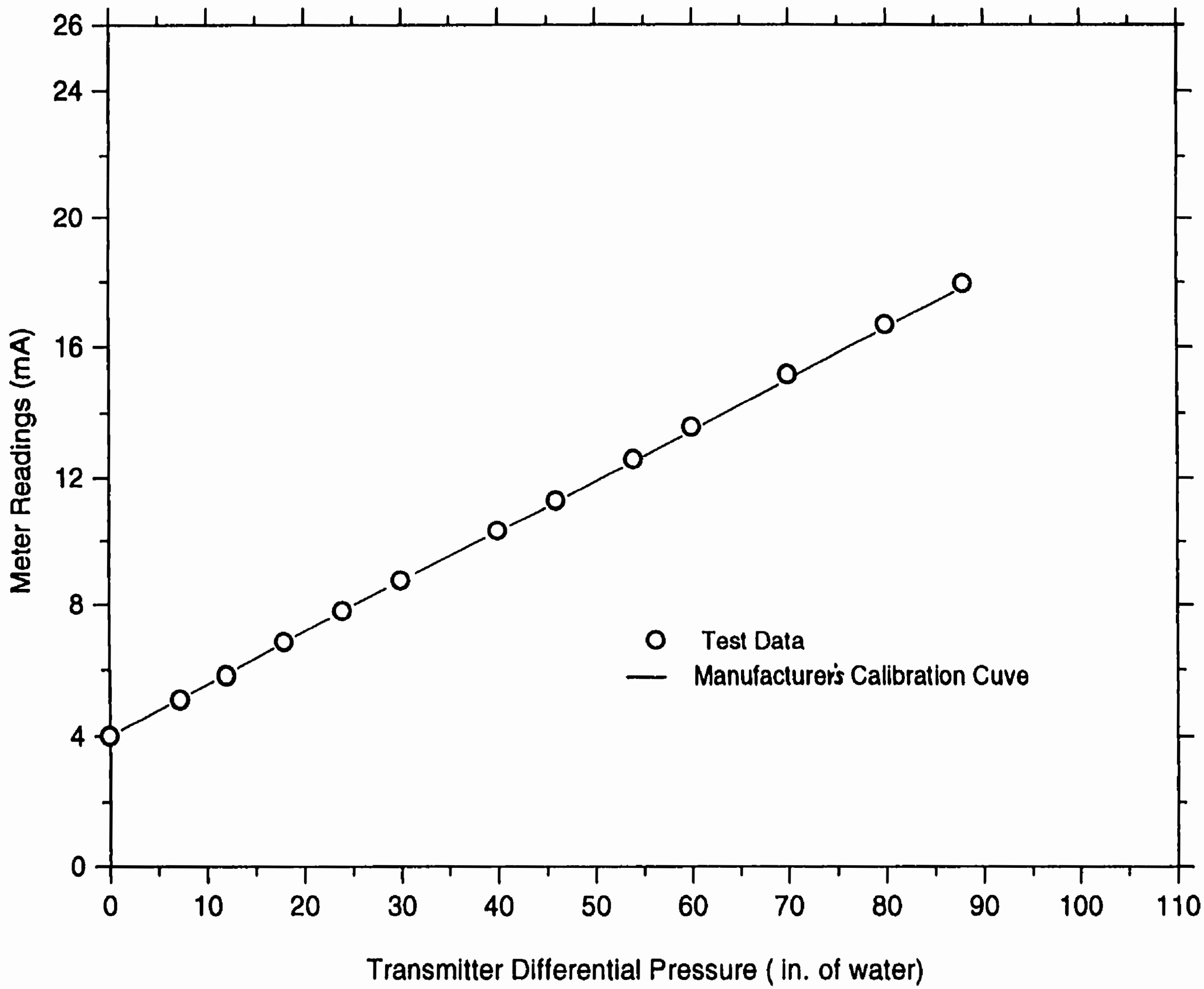

Figure B.6 Calibration of Gauge Pressure Transmitter (0 to 100 psig)

Reynolds number of the air based on the diameter of the orifices.

Table B.2 Coefficient of Discharge (C) of the Orifice Plates

Orifice No.	Diameter (in.)	C
1	0.418	$0.7357 \exp(-2.195 \times 10^{-6} Re_d)$
2	0.141	$0.7036 \exp(-1.941 \times 10^{-6} Re_d)$
3	0.046	$0.6811 \exp(-3.2507 \times 10^{-6} Re_d)$

Also, a gas rotameter (Brooks) for the very low air flow rate was calibrated in situ in the laboratory (at 14.84, 69.9 and 75.4 psia) using a low flow rate wet test meter Elsteo-Handel (accuracy ± 0.25%). The comparison between present calibrations at 14.84 psia and the calibration curve supplied by the Brook's manufacturer (see Figure B.7) shows good agreement.

B.7 THE QUICK-CLOSING AND QUICK-OPENING VALVES

Two quick-closing valves and one quick-opening valve (which were used used for void measurement) were tested for the operating time. It was found that their operating time was approximately 0.005 seconds.

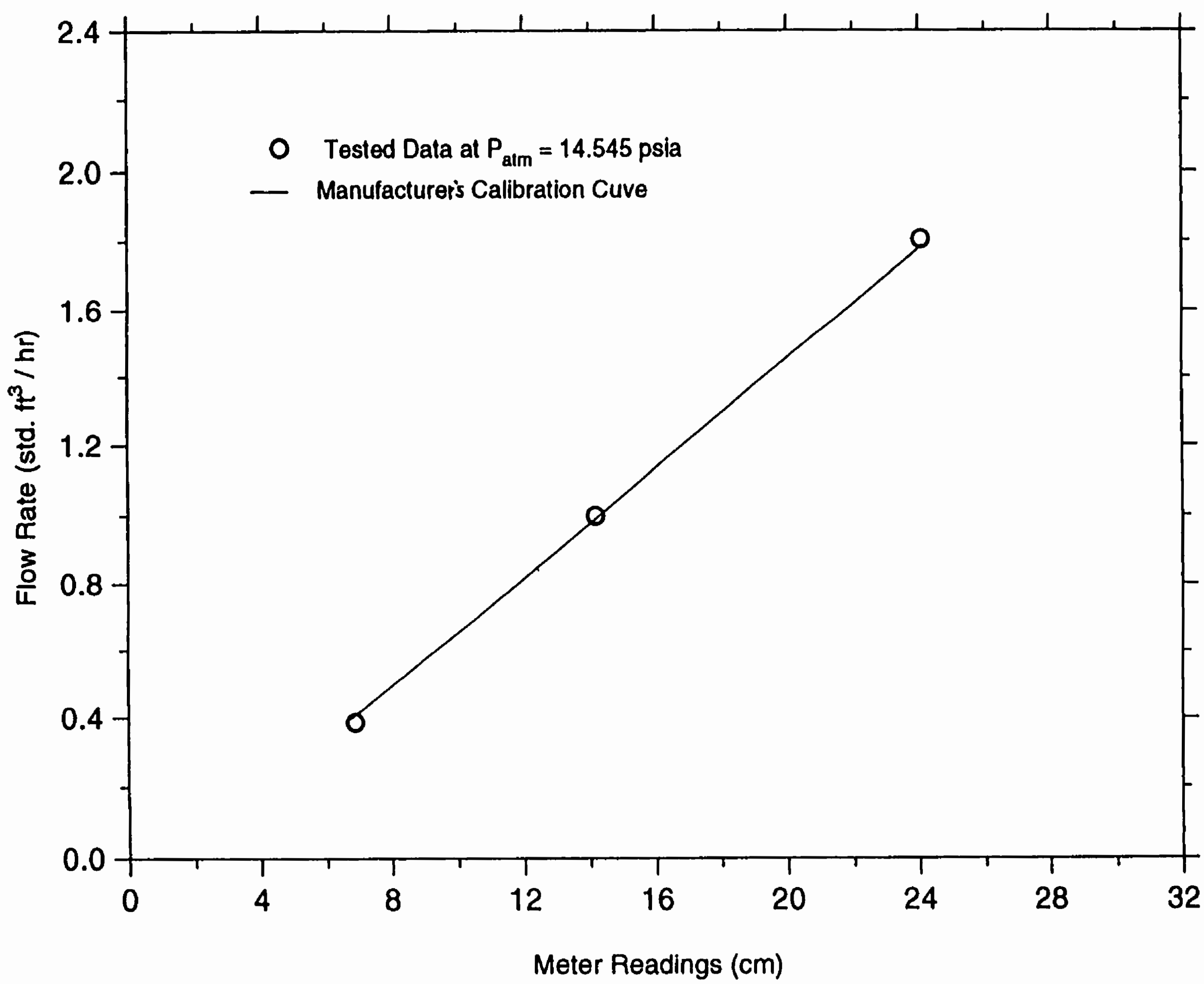

Figure B.7 Calibration of Brooks Rotameter for Gas Flow

Appendix C

PHYSICAL PROPERTIES OF FLUIDS USED IN THE PRESENT INVESTIGATION

The gas and liquid physical properties are necessary for the reduction of heat-transfer and pressure-drop data presented in this thesis. This appendix gives the physical properties of both gas and liquid phases used during the course of the experiments. While using air-G1 and air-G2, there was some preferential evaporation of the water into the air, so changing the concentration of the solution slightly. During the experiments, over all the runs and from the beginning of the first run to the end of the last run with air-G1, the range of the concentration was 58 to 60%. The coresponding range for air-G2 was 81.25 to 82.25%. The range for each run for both air-G1 and air-G2 is given in Table C.1. Nominal values of glycerine concentration for G1 and G2 were 59% and 82%, respectively.

Air was assumed to be an ideal gas with properties taken from (C.1). The properties of water were taken from (C.2). The physical properties of G1 and G2 were obtained directly from (C.3, C.4). Since the reduction of data was performed by computer, the physical properties were obtained from the equations describing them; these equations were obtained by curve-fitting techniques from the tabulated values.

Table C.2 shows the equations for gas and liquid physical properties (although the units appearing in the table are Imperial units, anywhere in the body of the thesis units are either SI or SI and Imperial appearing together, and in the tabulated data, SI units are used).

Table C.1 Liquids Used in the Present Investigation

Liquid	Run No.	% of glycerine/water by weight
G1	R1	58.5 ± 0.5
	R2	59.25 ± 0.5
	R3	59.5 ± 0.5
	R4	59.5 ± 0.5
	R5	59.5 ± 0.5
G2	R1	81.50 ± 0.25
	R2	81.85 ± 0.25
	R3	81.85 ± 0.25
	R4	82.00 ± 0.25
Water	R1-R7	100 % distilled water

Table C.2 Physical Properties of Fluids Used in the Present Investigation

<u>Definitions and Units</u>

R =	Gas constant = 53.34 ($ft \cdot lb_f/lb_m R$)	σ =	Surface tension (lb_f/ft)
C_P =	Specific heat at constant pressure ($Btu/lb_m \cdot °F$)	ρ =	Density (lb_m/ft^3)
k =	Thermal conductivity ($Btu/hr \cdot ft \cdot °F$)	P =	Pressure (lb_f/ft^2)
T =	Temperature (°F)	μ =	Viscosity ($lb_m/ft \cdot hr$)

Substance	Equation for Physical Properties*	Range of Validity*
Air	$\rho = P/RT$, T = absolute temperature (R)	Accurate in the range of pressures investigated
	$C_P = 7.54 \times 10^{-6} + 0.2401T$	$-10 \leq T \leq 242$
	$k = -6.154 \times 10^{-9}T^2 + 2.591 \times 10^{-5} + 0.01313$	$-10 \leq T \leq 242$
	$\mu = -2.673 \times 10^{-8}T^2 + 6.819 \times 10^{-5}T + 0.03936$	$-10 \leq T \leq 242$
Water	$\rho = (2.101 \times 10^{-8}T^2 - 1.303 \times 10^{-6}T + 0.01602)^{-1}$	$32 \leq T \leq 212$
	$C_P = 1.337 \times 10^{-6}T^2 - 3.374 \times 10^{-4}T + 1.018$	$32 \leq T \leq 212$
	$k = 4.722 \times 10^{-4}T + 0.3149$	$32 \leq T \leq 176$
	$\mu = (1.207 \times 10^{-5}T^2 + 3.863 \times 10^{-3}T + 0.09461)^{-1}$	$32 \leq T \leq 212$
	$\sigma = 5.52288 \times 10^{-12}T^3 - 8.05936 \times 10^{-9}T^2 - 4.75886 \times 10^{-6}T + 5.346 \times 10^{-3}$ against air	$68 \leq T \leq 150$
58.5% Glycerine and 41.5% water by weight	$\rho = 73.04095 - 0.0187T$	$59 \leq T \leq 86$
	$C_P = 0.78503 - 0.00024T$	$59 \leq T \leq 89.6$
	$k = 0.21396 + 0.00012T$	$50 \leq T \leq 140$
	$\mu = 124.086 - 2.549T + 0.01955T^2 - 5.2466 \times 10^{-5}T^3$	$50 \leq T \leq 140$
	$\sigma = 0.00492 - 3.9556 \times 10^{-6}T$	$68 \leq T \leq 140$

59.0% Glycerine and 41.0% water by weight	$\rho = 73.1303 - 0.0188T$	$59 \leq T \leq 86$
	$C_P = 0.78274 - 0.00024T$	$59 \leq T \leq 89.6$
	$k = 0.16787 + 0.002394T - 4.0015 \times 10^{-5}T^2 + 2.9415 \times 10^{-3}T^3 - 7.7 \times 10^{-10}T^4$	$50 \leq T \leq 140$
	$\mu = 127.734 - 2.6292T + 0.0202T^2 - 5.422 \times 10^{-5}T^3$	$50 \leq T \leq 140$
	$\sigma = 0.00492 - 3.939 \times 10^{-6}T$	$68 \leq T \leq 140$
59.25% Glycerine and 40.75% water by weight	$\rho = 73.226 - 0.01886T$	$59 \leq T \leq 86$
	$C_P = 0.7805 - 0.00024T$	$59 \leq T \leq 89.6$
	$k = 0.21272 + 0.00011T$	$50 \leq T \leq 140$
	$\mu = 131.383 - 2.7095T + 0.0208T^2 - 5.5974 \times 10^{-5}T^3$	$50 \leq T \leq 140$
	$\sigma = 0.00491 - 3.9156 \times 10^{-6}T$	$68 \leq T \leq 140$
81.5% Glycerine and 18.5% water by weight	$\rho = 77.1320 - 0.02117T$	$59 \leq T \leq 86$
	$C_P = 0.65283 - 0.00012T$	$59 \leq T \leq 89.6$
	$k = 0.1856$	$68 \leq T \leq 104$
	$\mu = 1{,}483.74 - 34.8668T + 0.2864T^2 - 7.9856 \times 10^{-4}T^3$	$50 \leq T \leq 140$
	$\sigma = 0.00462 - 3.0339 \times 10^{-6}T$	$68 \leq T \leq 140$
81.85% Glycerine and 18.15% water by weight	$\rho = 77.189 - 0.02117T$	$59 \leq T \leq 86$
	$C_P = 0.65018 - 0.00014T$	$59 \leq T \leq 89.6$
	$k = 0.18487$	$68 \leq T \leq 104$
	$\mu = 1{,}566.105 - 36.876T + 0.3032T^2 - 8.4598 \times 10^{-4}T^3$	$50 \leq T \leq 140$
	$\sigma = 0.004556 - 3.4496 \times 10^{-7}T - 1.2852 \times 10^{-8}T^2$	$68 \leq T \leq 140$

82.0% Glycerine and 18.0% water by weight	$\rho = 77.2144 - 0.02117T$ $C_P = 0.6491 - 0.00014T$ $k = 0.1846$ $\mu = 1{,}601.4 - 37.738T + 0.31045T^2 - 8.6631 \times 10^{-4}T^3$ $\sigma = 0.004554 - 3.304 \times 10^{-7}T - 1.2859 \times 10^{-8}T^2$	$59 \le T \le 86$ $59 \le T \le 89.6$ $68 \le T \le 104$ $50 \le T \le 140$ $62.6 \le T \le 140$

*T = temperature, (°F)

REFERENCES FOR APPENDIX C

C.1 Gambill, W.R., "Estimating Engineering Properties, Parts I to VI," Chemical Engineering 1957, 1958, 1959, 1960.

C.2 Greenland, R., Ph.D. Thesis, Mechanical Engineering Department, Imperial College of Science & Technology, University of London, London, England, U.K., 1963. As reported by Vijay (93).

C.3 Anon, "Physical Properties of Glycerine and its Solutions," Glycerine Producers' Association, 295 Madison Avenue, New York, N.Y., U.S.A.

C.4 "International Critical Tables of Numerical Data, Physics, Chemistry and Technology," Volume V, p. 116, McGraw-Hill Company Inc., 1924.

Appendix D

CALCULATION PROCEDURE

This appendix gives the definitions and calculation procedures for obtaining the heat-transfer coefficients and hydrodynamic quantities used in this investigation. Most of the calculation procedures given in this appendix are presented in Imperial units. This was done as it was desired to check the present results, where possible, against earlier results from the same experimental facility, which results were reported in Imperial units. The results were finally converted into SI units and presented in Appendix G. Much of the presentation that appears in this appendix follows closely that of Rezkallah (71).

D.1 DEFINITIONS OF THE HEAT-TRANSFER COEFFICIENTS

The local heat-transfer coefficients were calculated by the following equation:

$$h(z) = \dot{q}_W / (T_W - T_B) \qquad \text{(D.1)}$$

where h, $\dot{q}_W$, T_W and T_B are heat-transfer coefficient, heat flux, wall temperature and bulk fluid temperature at the location z, from the start of the heated section. The mean heat-transfer coefficients were then calculated from the local values by applying a length-mean integration, as follows:

$$\bar{h} = \frac{1}{\Delta L} \int_{L1}^{L2} h(z)dz \qquad \text{(D.2)}$$

where h(z)'s were obtained from Equation D.1 at 16 horizontal planes along the heated test section, as shown in Figure D.1. However, only the values at seven planes (denoted by circles) were used to calculate the $\bar{h}$; this was done for the following reasons:

1) Planes 1 and 16 were close to the bus bars (which act as heat sinks or sources) which were silver soldered to the heated test section.

2) There were planes such as 3, 5, 7, 9, 10, 12, and 13 where there was just one thermocouple representing each of them, this in contrast to the points denoted by circles, where there were four thermocouples placed around the circumference on the same plane. Vijay (93) reported that the values of the h around the heated tube at a certain plane varied by as much as 10%, which was attributed to the nonuniformity of the tube thickness (the maximum deviation measured by Vijay (93) was approximately 5.0%). In order to be well represented, therefore, only the values at points denoted by circles were used to calculate the overall mean values. The value of the mean heat-transfer coefficient was then calculated using Equation D.2 and the trapezoidal rule of integration.

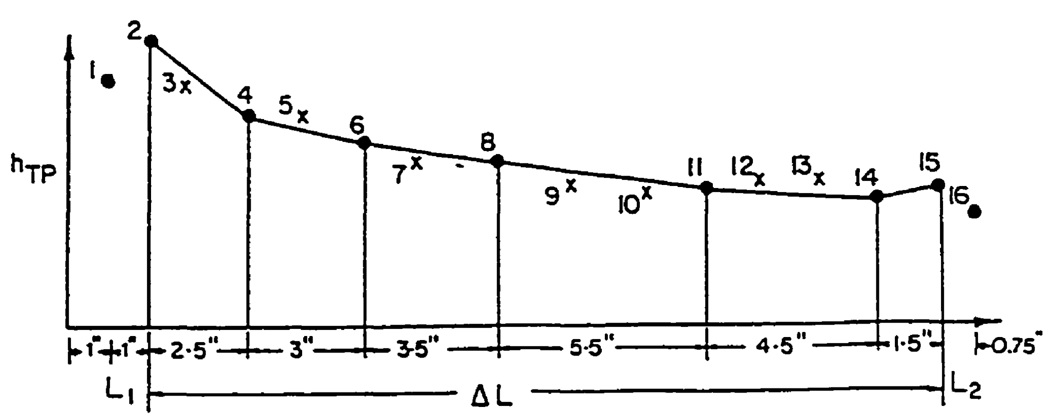

Figure D.1 Local Heat-Transfer Planes

D.2 CALCULATION OF THE LOCAL HEAT FLUX $(q_w^{\cdot})$

The heated tube acted as the heat source for the heat-transfer experiment. The local heat flux at the tube wall at location z along the test section was calculated from the knowledge of the local electrical resistivity and the electrical current flowing through the tube in the following manner.

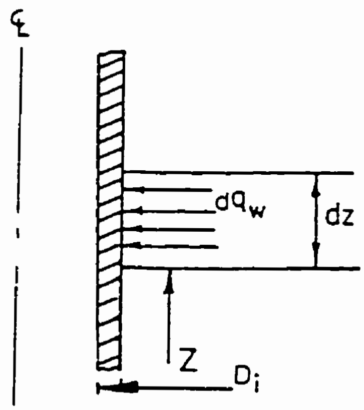

Figure D.2 Heat Flux on the Tube

Consider the elemental length dz of the heated tube at location z (see Figure D.2). Due to the fact that the heated tube was wrapped in insulation outside of which was a guard heater, it is assumed that all the heat generated was transferred to the flowing fluid inside the tube. The heat generated in this element is given by

$$dq_W = GI^2 dR_t \tag{D.3}$$

where dR_t is the resistance of elemental length dz of the tube and is given by

$$dR_t = \bar{\rho}' \frac{dz}{A_c} \quad \text{(D.4)}$$

and $\bar{\rho}'$ = the average resistivity of the tube at location z,

A_c = the cross-sectional area of the tube wall,

I = the electrical current flowing through the tube,

G = the conversion factor = 3.413 Btu/Watt.hr.

Therefore,

$$\dot{q}_W = \frac{dq_W}{dA_S} = \frac{GI^2 \bar{\rho}' \, dz}{A_c(\pi D_i)dz} \quad \text{(D.5)}$$

where $dA_S = \pi D_i \, dz$, is the elemental inside surface area of the tube. Hence,

$$\dot{q}_W = \frac{GI^2 \bar{\rho}'}{A_c(\pi D_i)} \quad \text{(D.6)}$$

Equation D.6 represents the net heat flux transferred to the fluid.

D.3 CALCULATION OF THE INNER WALL TEMPERATURE FROM THE MEASURED OUTER WALL TEMPERATURE

In order to obtain the local heat-transfer coefficient, the temperature at the fluid-wall interface (inner wall temperature) T_W (see Figure D.3) is required for use in Equation D.1. During the course of the experiment, the outer wall temperature T_O was measured, then the inner wall temperature was calculated from the following relation:

$$T_W = T_O - \Delta T_W \quad \text{(D.7)}$$

where ΔT_W = the temperature drop across the tube wall.

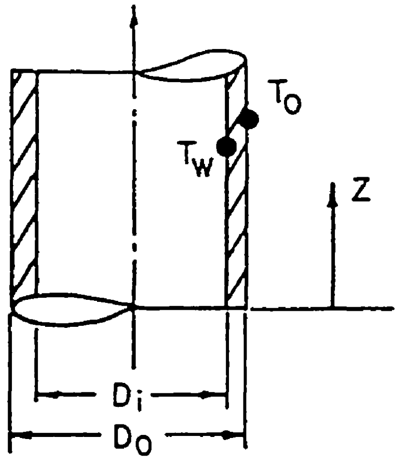

Figure D.3 The Temperature Drop Across the Tube

To obtain this temperature drop ΔT_W, the method developed by Kreith and Summerfield (D.1) was used. The expression for ΔT_W as given by the authors (D.1) is as follows:

$$\Delta T_W = B_o t^2 + B_1 t^3 + (B_2 + B_3) t^4 \quad (D.8)$$

where

t = the wall thickness,

$B_o = m / [(1+\beta' T_o)(1+\alpha' T_o)]$,
$B_1 = 2m / [3D_o(1+\beta' T_o)(1+\alpha' T_o)]$,
$B_2 = m^2(3\alpha' + 4\alpha' \beta' T_o + \beta') / [6(1+\beta' T_o)^3 (1+\alpha' T_o)^3]$,
$B_3 = m / [D_o^2(1+\beta' T_o)(1+\alpha' T_o)]$,

D_o = the outer diameter of the tube,

D_i = the inner diameter of the tube,

β' = the temperature coefficient of resistivity of the tube material, defined through,

$$\rho' = \rho_o'(1+\beta' T) \quad (D.9)$$

ρ' = the electrical resistivity of the tube material,

ρ_o' = the electrical resistivity of the tube material at 0°F.

$\alpha' =$ the temperature coefficient of thermal conductivity of the tube material defined through,

$$k' = k_o'(1+\alpha' T) \tag{D.10}$$

$k' =$ the thermal conductivity of the tube material,

$k_o' =$ the thermal conductivity of the tube material at 0 °F,

de/dz = the voltage gradient in the tube, and

$$m = G(de/dz)^2 / 2\rho_o' k_o' \tag{D.11}$$

For the elemental length dz, the voltage gradient can be expressed by

$$\frac{de}{dz} = -\rho' i = -\rho' \frac{I}{A_c}, \tag{D.12}$$

where i = the electrical current flux. Hence,

$$m = \frac{G}{2\rho_o' k_o'} \rho'^2 \left(\frac{I}{A_c}\right)^2 \tag{D.13}$$

where,

$$A_c = \frac{\pi}{4}(D_o^2 - D_i^2)$$

In order to obtain m, it was assumed that ρ' could be replaced by $\overline{\rho'}$ evaluated at T_{AVG} for the location of interest, i.e.,

$$\rho' = \overline{\rho'} = \rho_o'(1+\beta' T_{AVG}) \tag{D.14}$$

$$T_{AVG} = (T_O + T_W)/2 \tag{D.15}$$

Therefore,

$$m = \frac{G\overline{\rho'}^2}{2\rho_o^{'}k_o^{'}}\left(\frac{I}{A_c}\right)^2 \tag{D.16}$$

The electrical resistivity of the tube was measured by Vijay (93) in the laboratory and the following equation was used to calculate ρ' (where T is in °F):

$$\rho' = 0.21658\text{x}10^{-5}(1+0.6504\text{x}10^{-3}T) \quad \text{ohm·ft } 65<T<220 \text{ °F} \tag{D.17}$$

It is seen, then, that $\rho_o^{'} = 0.216581 \times 10^{-5}$ ohm·ft/°F.

The thermal conductivity of the heated tube material (type-304 stainless steel) was calculated from the equation reported by Bergles and Rohsenow (D.2) which agreed within ± 2% with the manufacturer's data [Vijay (93)]. The expression for k' is given by,

$$k' = 8.46(1+5.26\text{x}10^{-4}T) \quad \text{Btu/hr·ft·°F} \qquad 75<T<150 \text{ °F} \tag{D.18}$$

where T is in °F, i.e., $k_o^{'} = 8.46$ Btu/hr·ft·°F.

Up to this point, Equation D.8 now contains two unknowns, ΔT_W and implicitly T_W. In order to obtain ΔT_W, the following iteration method was applied.

1) At the beginning, T_W was assumed to be equal to T_O.
2) $\overline{\rho'}$ and m were calculated from Equations D.14 and D.16, respectively.
3) ΔT_W was calculated from Equation D.8 and T_W from Equation D.7.
4) This new value of T_W was then used to obtain the new value of T_{AVG}, and then steps 2 and 3 were repeated until two successive values of ΔT_W agreed within ± 0.0005 °F.

D.4 CALCULATION OF THE MIXTURE INLET TEMPERATURE (T_{IN})

As reported and used in Rezkallah (71), a general equation for the inlet temperature T_{IN} of gas-liquid mixture was derived by Vijay (93) for air-glycerine and water solution systems by performing a conservation of mass and energy on the control volume indicated by the dashed lines in Figure D.4. The general equation is

$$T_{IN} = \frac{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} T_{L1} + C_{Pa} T_{G2} + (\omega_3^{H_2O} - \omega_2^{H_2O}) h_{L3}^{L} + \omega_2^{H_2O} h_{v2}^{H_2O}}{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} + C_{PG}} \qquad \text{(D.19)}$$

$$\frac{-\omega_3^{H_2O} h_{v3}^{H_2O} - \omega_3^{GL} (h_{v3}^{GL} - h_{L3}^{L})}{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} + C_{Pa}}$$

where

$\dot{m}_{L1}$ = the liquid flow rate at the inlet to the mixer,

$\dot{m}_{a2}$ = the flow rate of dry air = $\dot{m}_{a3}$ = $\dot{m}_G$ (appears in Figure D.4),

T_{L1} = the liquid-phase temperature at the inlet to the mixer,

T_{G2} = the gas-phase temperature at the inlet to the mixer,

C_{PL}, C_{Pa} are the specific heats at constant pressure for the liquid and dry air, respectively,

h = the enthalpy per unit mass of fluid,

ω = the mass of liquid vapour per unit mass of dry air.

The superscripts H_2O, L and GL refer to water, water/glycerine solution and pure glycerine, respectively. The subscript v refers to the vapour of the fluid indicated by the superscript.

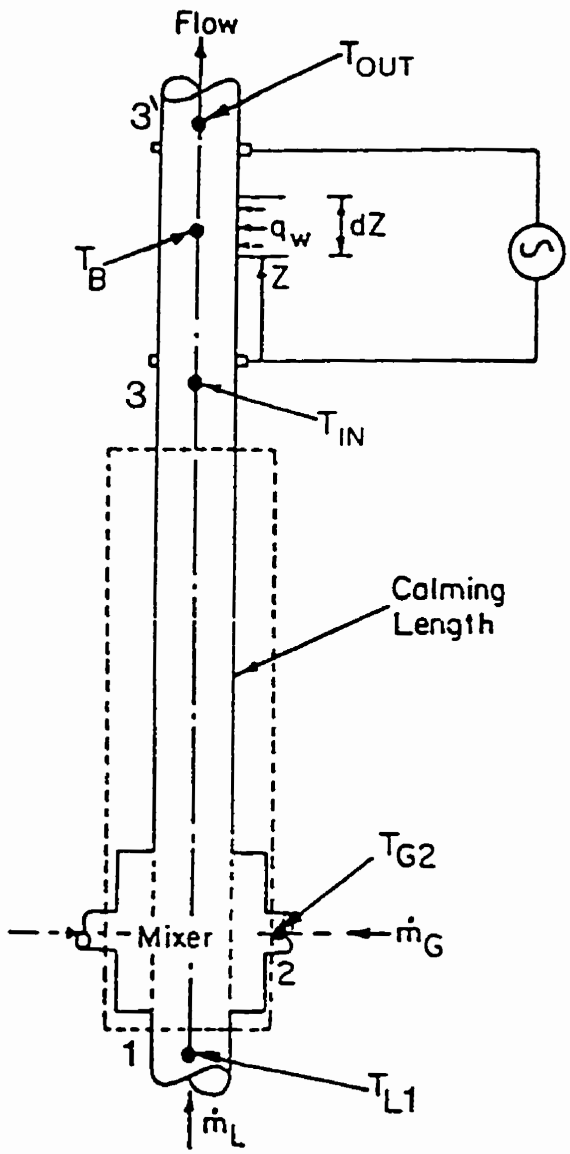

Figure D.4 Heat Balance Control Volume, From Ref.(100)

The quantities T_{L1}, T_{G2}, $\dot{m}_{L1}$ and $\dot{m}_{a2}$ in Equation D.19 are known from measurements while C_{PL} and C_{Pa} can be obtained from properfy tables. The terms in the numerator of Equation D.19 beginning with $(\omega_3^{H_2O} - \omega_2^{H_2O})\, h_{L3}$ may be manipulated into

$$(\omega_3^{H_2O} - \omega_2^{H_2O})[-h_{fg,3}^{H_2O} + (h_{L3}^{L} - h_{L3}^{H_2O})] - \omega_2^{H_2O}(h_{V3}^{H_2O} - h_{V2}^{H_2O}) - \omega_3^{GL}(h_{V3}^{GL} - h_{L3}^{L})$$

The only significant term here is

$$(\omega_3^{H_2O} - \omega_2^{H_2O})\, h_{fg,3}^{H_2O}$$

where $h_{fg,3}^{H_2O}$ is the latent heat of vaporization for water at T_3. Equation D.19 therefore becomes

$$T_{IN} = \frac{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} T_{L1} + C_{Pa} T_{G2} - (\omega_3^{H_2O} - \omega_2^{H_2O}) h_{fg,3}^{H_2O}}{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} + C_{Pa}} \qquad \text{(D.19a)}$$

The campus air supply system, which was used here, has air driers after the compressors. In this case $\omega_2 \cong 0$ and the above equation becomes

$$T_{IN} = \frac{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} T_{L1} + C_{Pa} T_{G2} - \omega_3^{H_2O} h_{fg,3}^{H_2O}}{\frac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} + C_{Pa}} \qquad \text{(D.20)}$$

In the gas phase at location 3, for ony dry air and water vapor present (even with a glycerine and water liquid phase solution, there would be essentially no glycerine vapor in the gas phase), ω_3^{H2O} would be given by

$$\omega_3^{H_2O} = 0.622 \frac{P_{V3}^{H_2O}}{P_{a3}}$$

where

$P_{V3}^{H_2O}$ = the partial pressure of water vapor at location 3,

P_{a3} = the partial pressure of air at location 3, and

= (actual static pressure at 3) - $P_{V3}^{H_2O}$.

The constant 0.622 is the ratio of molecular weights of water and air. When the liquid phase is pure water and the gas phase is saturated with water vapor

$$P_{V3}^{H_2O} = P_{sat,T_3}^{H_2O}$$

where $P_{sat,T_3}^{H_2O}$ is the saturation pressure for water at T_3. When the liquid phase is a solution of glycerine and water

$$P_{V3}^{H_2O} = K\,P_{sat,T_3}^{H_2O}$$

where K depends on the concentration and is essentially independent of temperature in the temperature range of interest. From information in Reference D.4,

$K \cong 0.77$ for air-G1, and

$K \cong 0.45$ for air-G2.

D.5 CALCULATION OF THE LOCAL BULK TEMPERATURE (T_B)

During the course of the heat-transfer experiment, it is assumed that the gas-liquid mixture enters the heat-transfer test section fully saturated. This means that the saturation process is completed in the calming section. Calculations and experiments were done by Sims (D.5) showing that this assumption is valid.

When a gas-liquid mixture flows in the heated tube section, with the temperature rise and the pressure drop along the test section, the saturation vapour content of the gas phase changes along the test section. Therefore, part of the liquid phase evaporates keeping the gas-liquid mixture saturated (the implied assumption here is that the gas phase remains saturated with vapor). The effect on T_B is significant only for the combination of high gas flow rates and low liquid flow rates. However, the effect of evaporation was taken into account in the calculation procedure for T_B for all conditions.

D.5.1 Calculation of T_B for Two-Phase Tests

In order to obtain the values of T_B along the heated test section, the mixture temperature at the outlet of the heated test section T_{OUT} was first calculated from the procedure given below. Then, after knowing the values of T_{IN} and T_{OUT}, the values of T_B were obtained by assuming that a linear temperature rise along the heated test section (any deviations from linearity would be extremely small).

The expression for T_{OUT} of the air-liquid systems used in the present investigation can be obtained in a similar manner to that for T_{IN} (given in the previous section). In this case, the term which describes the heat supply at the wall will appear in the expression for T_{OUT} (where $\dot{q}_w$ is the average of local value of heat flux). The control volume, for this case, surrounds the system from the point the liquid and gas enter the mixer [points 1 and 2 in Figure D.4] to the point where the gas-liquid mixture leaves the heated test section (point $3'$). Equation D.20, modified to accommodate a heat-flux term, would be

$$T_{OUT} = \frac{\dfrac{\dot{q}_W A_S}{\dot{m}_{a2}} + \dfrac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} T_{L1} + C_{Pa} T_{G2} - \omega_{3'}^{H_2O} h_{fg,3'}^{H_2O}}{\dfrac{\dot{m}_{L1}}{\dot{m}_{a2}} C_{PL} + C_{Pa}} \quad \text{(D.21)}$$

where A_S = inner surface area of the heated test section.

D.5.2 Calculation of T_B for Single-Phase Tests

This method is to obtain the values of T_B along the heated test section for liquid single-phase experiments. Consider a elemental volume of the heated test section, having an internal surface area dA_s (Figure D.2). The amount of heat transferred to the flowing fluid in the section is given by,

$$dq_W = \dot{q}_W dA_S \quad \text{(D.22)}$$

where

$$dA_S = pdz = \pi D_i dz$$

The quantities D_i and p are the inside diameter and perimeter of the tube, respectively. Let dT be the temperature rise of the liquid in this length dz. Applying the principal of energy conservation on this elemental volume, with the assumption of the steady state conditions, the following expression is obtained:

$$\dot{q}_W (pdz) = \dot{m}_L C_{PL} dT_B \quad \text{(D.23)}$$

Hence,

$$dT_B = \frac{\dot{q}_W (pdz)}{\dot{m}_L C_{PL}} \quad \text{(D.24)}$$

Integrating Equation (D.24) between Z_i and Z_{i+1} with the assumption that $\dot{q}_w$ and C_{PL} are constant throughout the interval dz gives:

$$\int_{(T_B)_i}^{(T_B)_{i+1}} dT_B = \frac{\dot{q}_w p}{\dot{m}_L C_{PL}} \int_{z_i}^{z_{i+1}} dz$$

Therefore,

$$(T_B)_{i+1} = (T_B)_i + \frac{\dot{q}_w p}{\dot{m}_L C_{PL}}(z_{i+1} - z_i) \qquad \text{(D.25)}$$

To calculate values of T_B along the heated section, the initial value of T_B is required. The value of T_{IN} (obtained from the previous section) is used for this initial value of T_B.

D.6 SUMMARY OF THE CALCULATION PROCEDURE FOR THE HEAT-TRANSFER COEFFICIENTS

For the calculation of the heat-transfer coefficients in the two-phase experiment, the following quantities were measured:

- I — the electrical current flowing through the tube,
- T_O — the temperatures at the outer wall surface at various locations along the tube,
- T_{L1} — liquid temperature at the inlet to the mixing chamber,
- T_{G2} — gas temperature at the inlet to the mixing chamber,
- $\dot{m}_{L1}$ — liquid flow rate at the inlet to the mixing chamber,
- $\dot{m}_{G2}$ — gas flow rate at the inlet to the mixing chamber (in the present case

$\dot{m}_{62} = \dot{m}_{a2}$, and

P_{IN} pressure at the inlet to the test section.

The calculation procedure for the heat-transfer coefficients was as follows:

1) The local values of inner wall temperature T_W were calculated from Equation D.8, using the iteration procedure described in Section D.3.

2) The local values of the heat flux $\dot{q}_W$ were calculated from equation D.6,

3) The mixture inlet temperature T_{IN} was calculated from the procedure in Section D.5,

4) The mixture outlet temperature T_{OUT} was calculated from the procedure in Section D.5. Then the values of T_B were calculated from the knowledge of T_{IN} and T_{OUT}, with the assumption that the bulk temperature rise was linear in the heated test section, and

5) Finally, the local and mean heat-transfer coefficient were calculated using Equations D.1 and D.2.

D.7 CALCULATION OF THE FRICTIONAL PRESSURE DROP

The two-phase frictional pressure drop was calculated from the measured void fraction and total pressure drop across the test section. The following method was used to calculate the frictional pressure drop.

The total pressure drop includes three terms, as seen in

$$\Delta P_{TOTAL} = P_{IN} - P_{OUT} = \Delta P_H + \Delta P_A + \Delta P_F \qquad (D.26)$$

where

P_{IN} is the pressure at the inlet of the test section,

P_{OUT} is the pressure at the outlet of the test section,

ΔP_H is the hydraulic pressure drop,

ΔP_A is the accelerational pressure drop, and

ΔP_F is the frictional pressure drop.

The hydraulic pressure drop or " head term" is given by

$$\Delta P_H = \rho L g \tag{D.27}$$

where $\rho = \rho_L$ and ρ_{MIX} for liquid single-phase and two-phase flow, respectively. The mixture density ρ_{MIX} is obtained from

$$\rho_{MIX} = (1-\alpha)\rho_L + \alpha\rho_G \tag{D.28}$$

where α is the measured void fraction.

Vijay (93) has demonstrated that the accelerational pressure drop is negligible in cases similar to the present situation. Therefore, Equation D.26 becomes

$$\Delta P_{TOTAL} = \Delta P_H + \Delta P_F$$

or

$$\Delta P_F = \Delta P_{TOTAL} - \Delta P_H \tag{D.29}$$

D.8 CALCULATION OF THE MEAN PRESSURE AND TEMPERATURE IN THE TEST SECTION

The average or system temperature was obtained from the following expression:

$$T_{MEAN} = (T_{IN} + T_{OUT}) / 2 \qquad (D.30)$$

where the calculated value of T_{OUT} was used.

In a similar manner, for mean or system pressure, the following equation was used:

$$P_{MEAN} = (P_{IN} + P_{OUT}) / 2$$

or

$$P_{MEAN} = P_{IN} - (\Delta P_{TOTAL}) / 2 \qquad (D.31)$$

D.9 CALCULATION OF VOID FRACTION (α)

The knowledge of void fraction was needed in order to calculate the two-phase frictional pressure drop (ΔP_{TPF}) appearing in Section D.7 as well as in the comparisons with the correlations that appear in this thesis. The experimental facility was arranged in such a way that both gas and liquid fractions of the two-phase mixture could be measured with the use of two quick-closing and one quick-opening valves with an operating time (measured) of approximately within five milliseconds. The value of the void fraction was calculated from

$$\alpha = \frac{V_G}{V_T} \qquad (D.32)$$

where, V_T = total volume = $V_G + V_L$,

V_G = the volume of the section occupied by gas phase,

V_L = the volume of the section occupied by liquid phase.

D.10 CALCULATION OF THE LIQUID AND GAS FLOW RATES AND SUPERFICIAL VELOCITIES

D.10.1 <u>Liquid Flow Rate and Superficial Velocity</u>

(i) *FLOW RATE* $\dot{m}_L$

The three flowmeters were calibrated "in situ" in the laboratory for each liquid used in this investigation. The equation for the liquid flow rate is in the form of,

$$\dot{m}_L = A_0 + A_1 R \quad \text{(D.33)}$$

where,

$\dot{m}_L$ = mass flow rate (lbm/hr),

A_0, A_1 = are constants for each rotameter and each liquid,

and

R = the percentage of the meter reading.

(ii) *SUPERFICIAL VELOCITY,* V_{SL}

By definition, including the effect of evaporation in the test section, the liquid superficial velocity was calculated from the following equation,

$$V_{SL} = \dot{m}_L / \rho_L A_T \quad \text{(D.34)}$$

where the tube cross-sectional area, $A_T = (\pi/4)D_i^2$.

D.10.2 <u>Gas Flow Rates and Superficial Velocity</u>

(i) *FLOW RATE,* $\dot{m}_G$

For very low flow rates, the air flow was measured by means of a gas rotameter. The following equations were used to obtain the air flow rate.

$$\dot{m}_G = 0.27364(\rho_{G1})^{0.5} Q_o \tag{D.35}$$

where,

$\dot{m}_G$ = the actual mass flow rate (lbm/hr)

ρ_{G1} = the air density at the rotameter (lbm/ft^3)

Q_o = the volume flow rate (ft^3/hr) obtained by Equation D.36 (at 69.9 psia and 70 F),

R is the gas-rotameter reading (cm).

$$Q_o = 0.0943R - 0.0627 \tag{D.36}$$

For higher air mass flow rates, air was supplied through one of three orifice plates. The orifice calculations were performed according to the ASME Power Test Code (D.6). The value of the discharge coefficient, C, in Equation D.37 was determined by calibration. Equation D.37 was used to determine the air flow rates passing through the orifices.

$$\dot{m}_G = YCMA_2[2g_o\rho_1(P_1 - P_2)]^{0.5} \tag{D.37}$$

where,

A_2 is throat area $= \frac{\pi}{4} d_i^2$ (ft^2),

C is the discharge coefficient,

$M = \left[1 - \left(\frac{A_2}{A_1}\right)^2\right]^{-0.5}$,

A_1 is the tube cross-sectional area $= \frac{\pi}{4} d_o^2$ (ft^2),

ρ_1 gas density at position 1 (see Figure D.5), lbm/ft^3,

g_o is the conversion factor (32.2 lbm·ft/lbf·s^2)

P_1, P_2 are pressure at position 1 and 2 respectively,

Y is the adiabatic expansion factor, or

$$Y = \left[\gamma^{2/k} \left(\frac{k}{k-1} \right) \left(\frac{1-\gamma^{\frac{k-1}{k}}}{1-\gamma} \right) \left(\frac{1-\beta^4}{1-\beta^4 \gamma^{2/k}} \right) \right]^{0.5} \tag{D.38}$$

where,

k = 1. 4 for air,

γ = P_2/P_1

β = the diameter ratio = d_i/D_o

d_i = orifice diameter

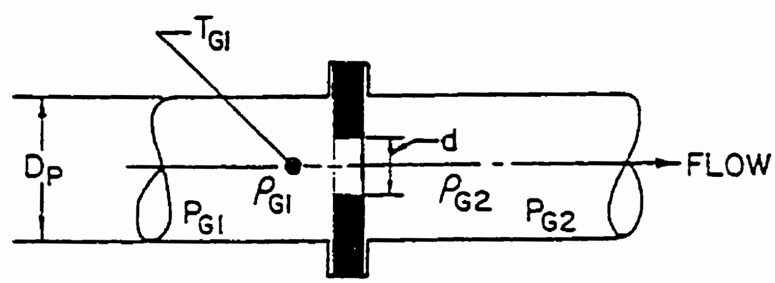

Figure D.5 Diagram of a Typical Orifice

The discharge coefficient C of the three orifices were obtained from Table B.1 in Appendix B. There are two unknown variables in the Equation D.37, namely $\dot{m}_G$ and C. Therefore, the value of the quantity $\dot{m}_G$ was solved by an iteration method.

(ii) *SUPERFICIAL VELOCITY (V_{SG})*

The gas superficial velocity was calculated by the following relation:

$$V_{SG} = \dot{m}_G / (\rho_G A_T) \quad \text{(D.39)}$$

The value of $\dot{m}_G$ was corrected due to the effect of evaporation taking place in the mixer and along the heated test section. The gas-phase density also changed along the heated test section due to the change in temperature and pressure of the two-phase mixture. For these reasons, the mean gas superficial velocity was determined by,

$$V_{SG,MEAN} = (V_{SG,INLET} + V_{SG,OUTLET}) / 2 \quad \text{(D.40)}$$

REFERENCES FOR APPENDIX D

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D.6 ASME Power Test Codes, Instruments and Apparatus, Chater 4, Flow Measurement, Part 5, Measurement of Quantity of Materials, February, 1959.

Appendix E

UNCERTAINTY ANALYSIS AND REPEATABILITY

E.1 GENERAL REMARKS

It is important in any experimental investigation to estimate the degree of uncertainty in the collected data and the experimental results. This appendix presents the uncertainty analysis of the independent and dependent variables involved in the present investigation. Also, repeatability tests on the main investigated variables, namely heat-transfer coefficients, pressure drop and void fraction, were performed in order to show the consistency of the experimental data.

E.2 UNCERTAINTY ANALYSIS

The accuracy of the measured quantities and of the calculated dependent (in the mathematical sense) variables was estimated by using the method of Kline and McClintock (E.1) and Moffat (E.2). The accuracy is represented by the value or "uncertainty" of each variable. It should be noted that the "error" in a measuement is usually defined as the difference between its true value and the measured value. The term "Uncertainty" is used to refer to "a possible value that an error may have." According to their method, if R (a dependent variable) is a function of independent variables, V_1, V_2, ..., V_n where each of these independent variables is normally distributed, then the relation between the uncertainty interval of the independent variable ω_i and the uncertainty interval of the dependent variable ω_R is expressed as:

$$\omega_R = \left[\left(\omega_1 \frac{\partial R}{\partial V_1}\right)^2 + \left(\omega_2 \frac{\partial R}{\partial V_2}\right)^2 + \ldots\ldots + \left(\omega_n \frac{\partial R}{\partial V_n}\right)^2\right]^{0.5} \qquad \text{(E.1)}$$

If the function is in the form of $R = V_1^a V_2^b V_3^c .....$ The fraction uncertainty of R is denoted as $\frac{\omega_R}{R}$ and the value can be calculated as follows:

$$\frac{\omega_R}{R} = \left[\left(\omega_1 \frac{\partial(\ln R)}{\partial V_1} \right)^2 + \left(\omega_2 \frac{\partial(\ln R)}{\partial V_2} \right)^2 + ...+ \left(\omega_n \frac{\partial(\ln R)}{\partial V_n} \right)^2 \right]^{0.5} \qquad \text{(E.2)}$$

The uncertainty interval of ω_i is normally known from measurement or estimation based on certain "odds" or "confidence" that the experimenter is willing to wager that any given reading lies within $\pm\omega_i$ of the true value. In the present work, the odds 20-to-1 were used. The estimated uncertainty in the main measured variables are summarized in Table E.1. Table E.2 gives the uncertainties in the variables, which affect the heat-transfer coefficient, void fraction and pressure drop.

Table E.1 Summary of Estimated Uncertainties in the Main Measured Variables

Variables	Fractional Uncertainties, ± %	
Local Heat-Transfer Coefficient (h)	5.5 - 11.0 5.1 - 12.5 5.2 - 13.3	Air-Water Air-G1 Air-G2
Mean Heat-Transfer Coefficient ($\bar{h}$)	5.8 - 10.6 5.5 - 10.7 5.4 - 11.5	Air-Water Air-G1 Air-G2
Liquid Superficial Velocity (V_{SL})	3.6 - 6.1	
Gas Superficial Velocity (V_{SG})	3.2 - 7.7	
Mean Void Fraction (α)	0.2 - 8.0	($\cong$20% for slug flow)
Total Pressure Drop across the heated test section	0.53 - 5.4	

Table E.2 Uncertainties in the Variables Affecting the Heat-Transfer Coefficients and Frictional Pressure Drop

Variables	Uncertainty Interval Based on Approximately 20 to 1 odds.	Comments
Do	0.2%	Measured by Vijay (93)
t	5.0%	Measured by Vijay (93)
L	0.1%	Measured by Vijay (93)
Z	0.2 - 1.0%	Measured by Vijay (93)
D	0.5%	Equation E.1 applied to $D = D_o - 2t$
Ac	5.5%	Equation E.1 applied to: $A_c = \frac{\pi}{4}(D_o^2 - D^2)$
A	0.8%	Equation E.1 applied to $A = \frac{\pi}{4}D^2$
I	0.6 - 5.0%	The largest error associated with the low value of reading namely at about 0.2 amps. The majority of data was taken where the error averaged ± 1.5%
T_o	0.2 °F	Calibrated by Vijay (93)
ΔT_W	0.002 °F	Since Equation D.7 is complicated, Equation E.1 applied to the following, used by Heineman (E.3) $\Delta T_W = \frac{\dot{q}_W}{2k_t}\left[\frac{D_o^2}{4}\ln\frac{D_o}{D} - \frac{D_o^2 - D^2}{8}\right]$
T_W	0.2 °F	Equation E.1 applied to: $T_W = T_o - T_W$
$\dot{q}_W$	5.5 - 10.2%	Equation E.2 applied to Equation D.5. The high error associated with low liquid flow rate. For the majority of data, the error in $\dot{q}_W$ averaged ± 6.8%
T_{in}	0.2 - 0.88 °F	Equation E.1 applied to Equation D.15
T_B	0.2 - 1.3 °F	Equation E.1 applied to Equation D.25

α	0.2 - 8.0%	For non-slug flow. The error in measured void fraction associated with slug flow was approximately 20%
ΔP_{TOT}	0.5 - 5.0%	Pressure transducers were calibrated in the lab.

E.3 REPEATABILITY

Air-water, air-G1 and air-G2 repeatability tests were performed at the end of each air-liquid investigation to check the consistency of the experimental facility on three main variables, namely, mean heat-transfer coefficient, total pressure drop and measured void fraction. Figures E.1 to E.9 show the results of the repeatability tests which indicate the excellent consistency between the original data and the repeated data.

In general, the deviations between the base data and the repeated data were less than 5 percent except when slug flow took place. In this case, slug flow, the deviation was about 8 percent, as can be seen (Figure E.1) from air-water system (V_{SL} = 0.116 m/s and V_{SG} = 3.00 m/s).

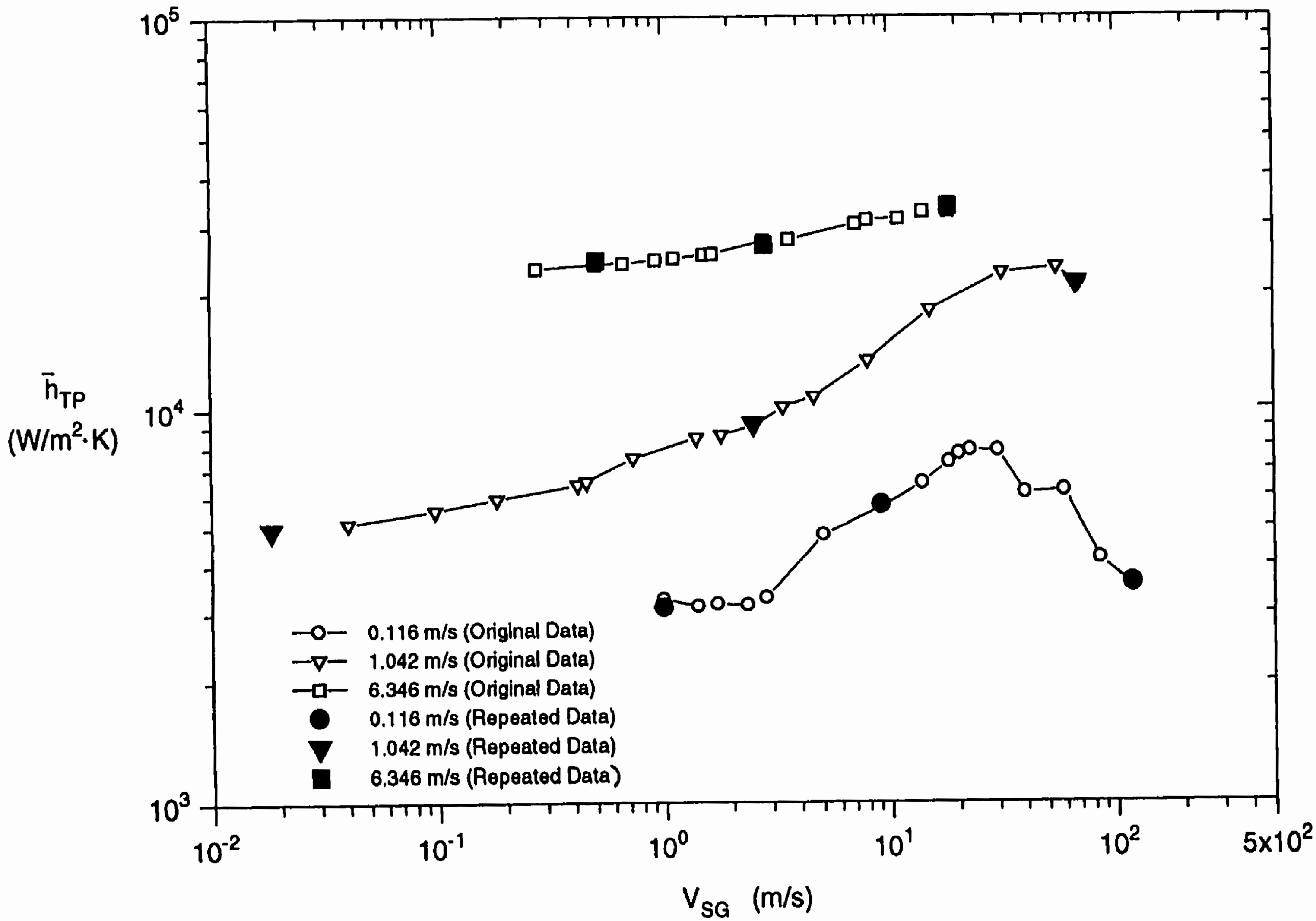


Figure E.1 Heat-Transfer Repeatability Results for Air-Water

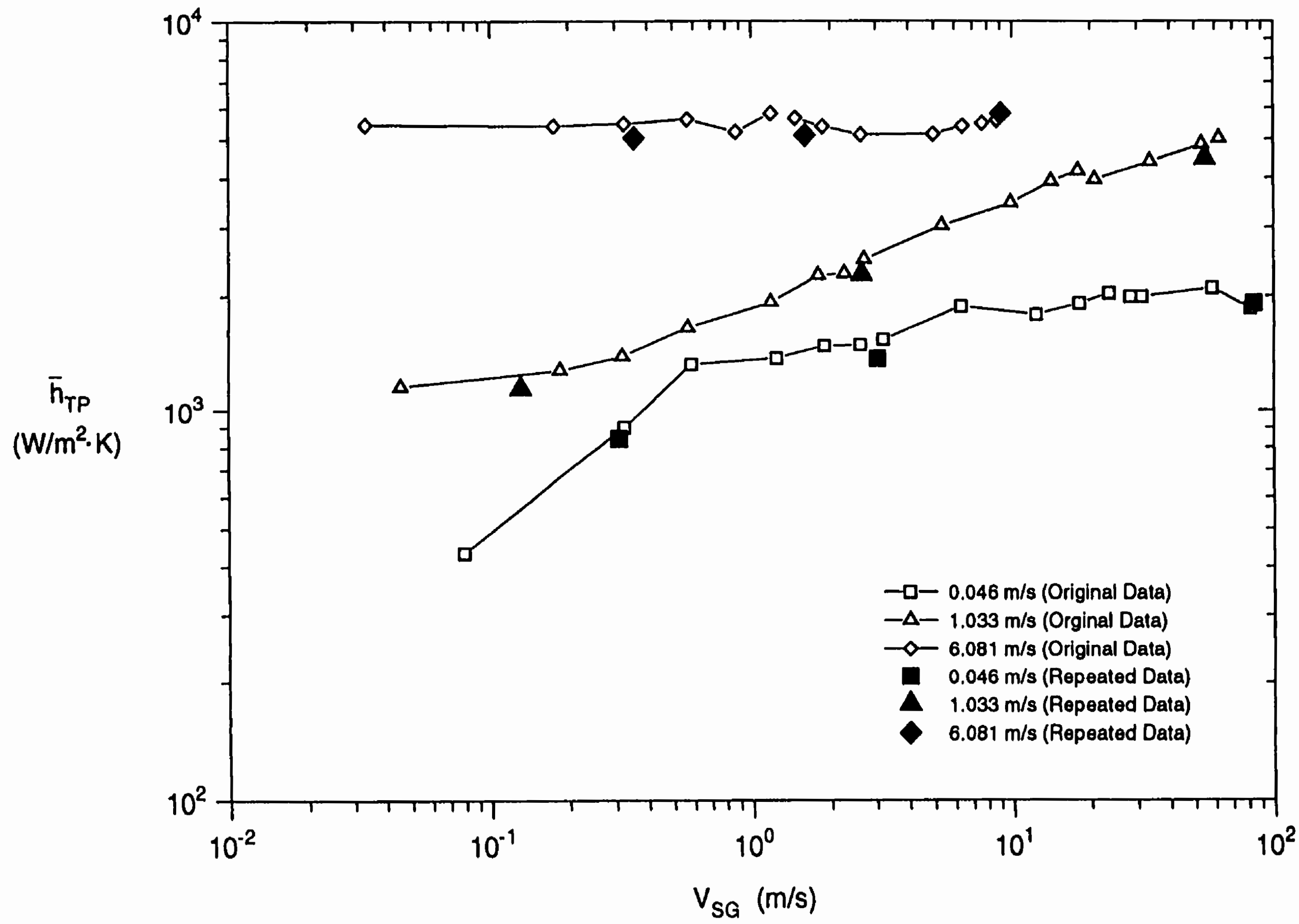


Figure E.2 Heat-Transfer Repeatability Results for Air-G1

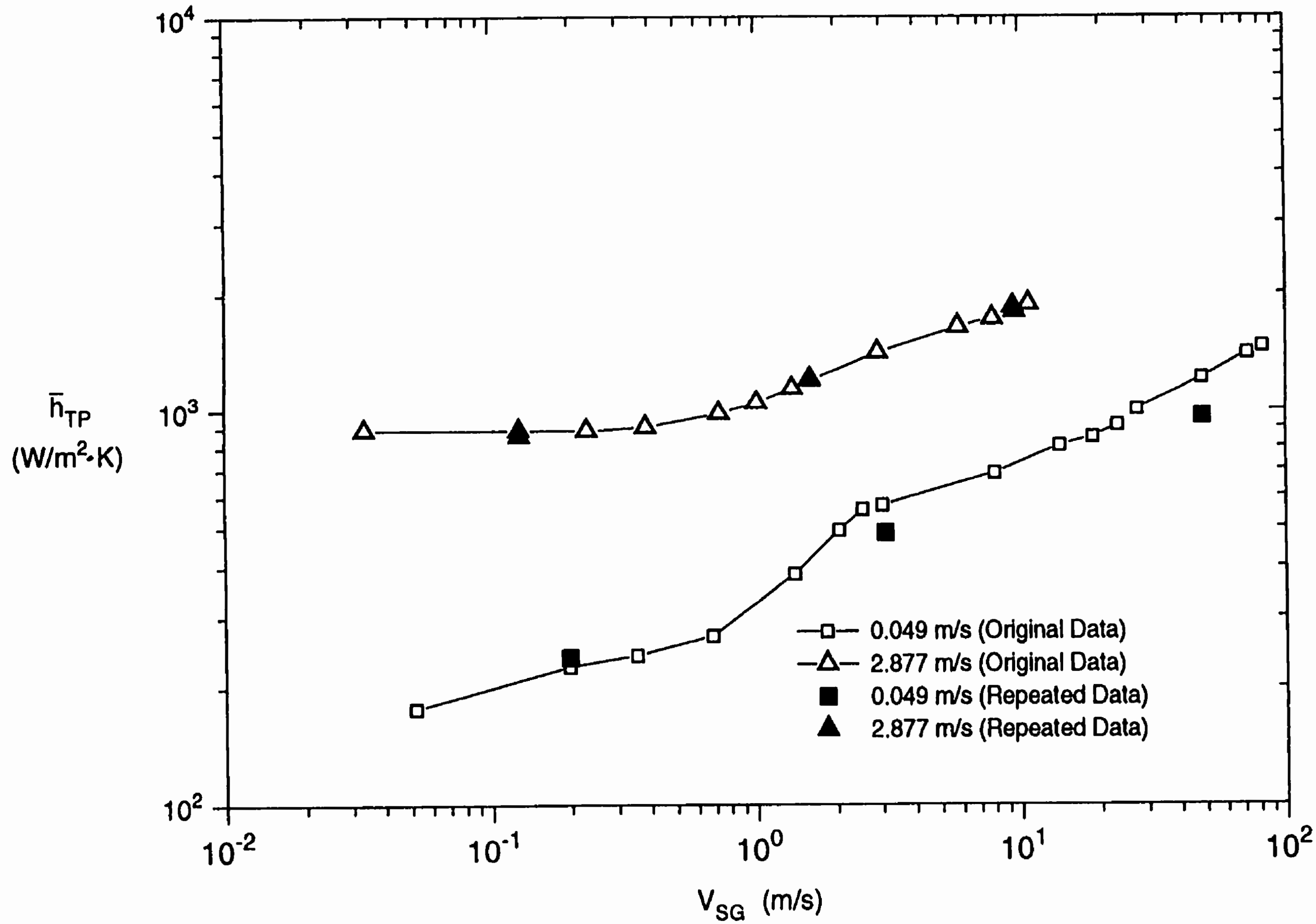


Figure E.3 Heat-Transfer Repeatability Results for Air-G2

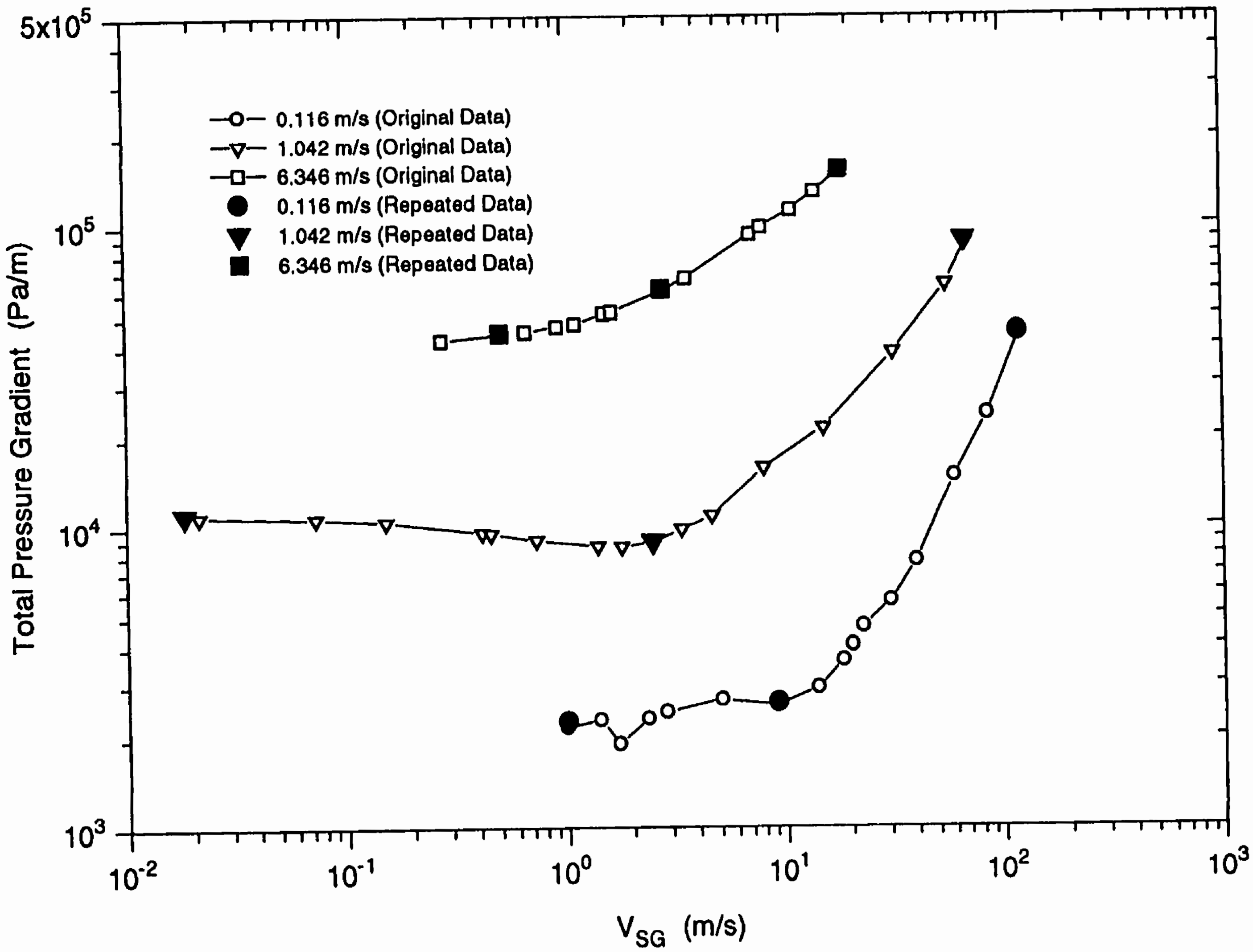


Figure E.4 Pressure-Drop Repeatability Results for Air-Water

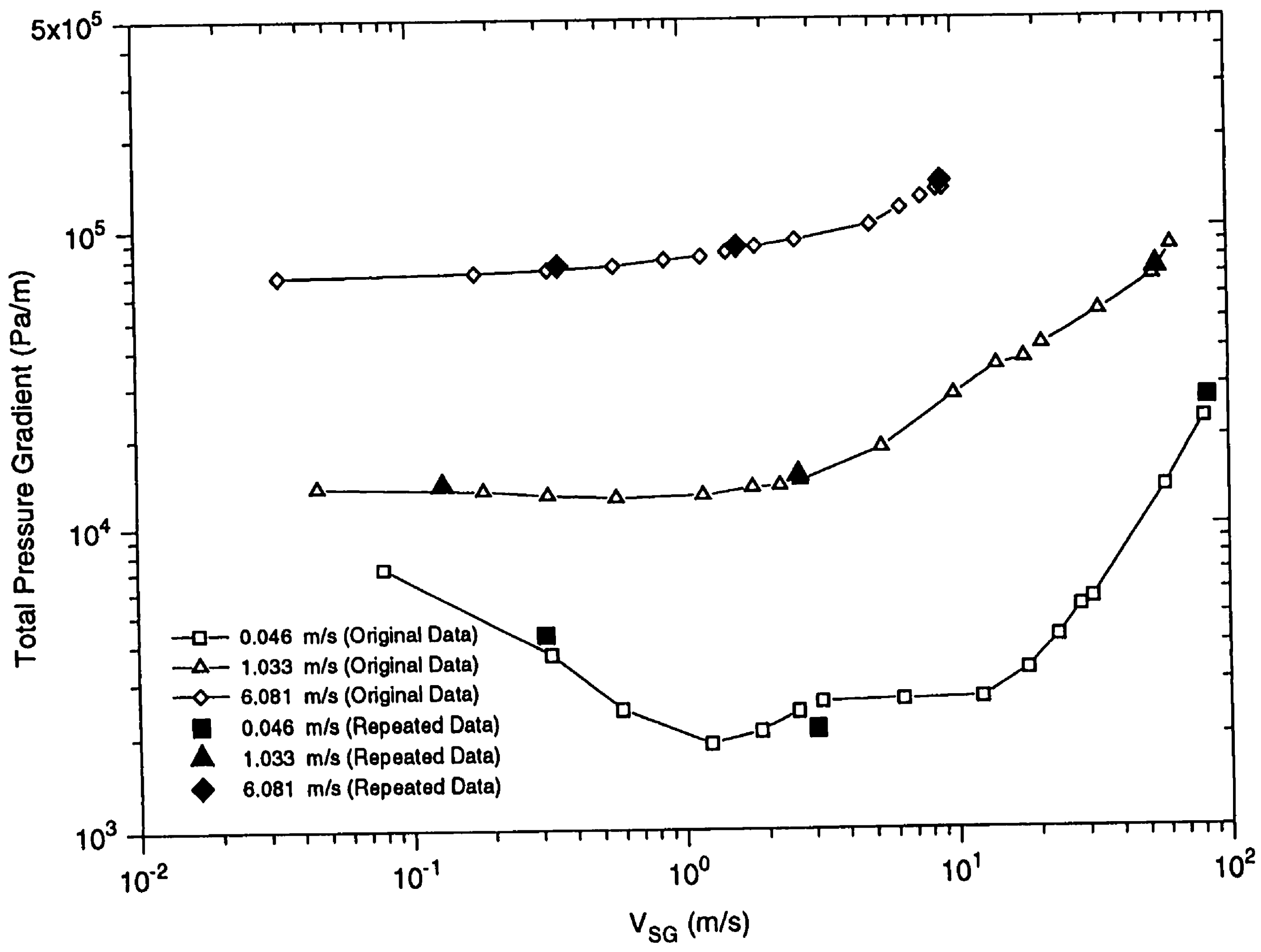


Figure E.5 Pressure-Drop Repeatability Results for Air-G1

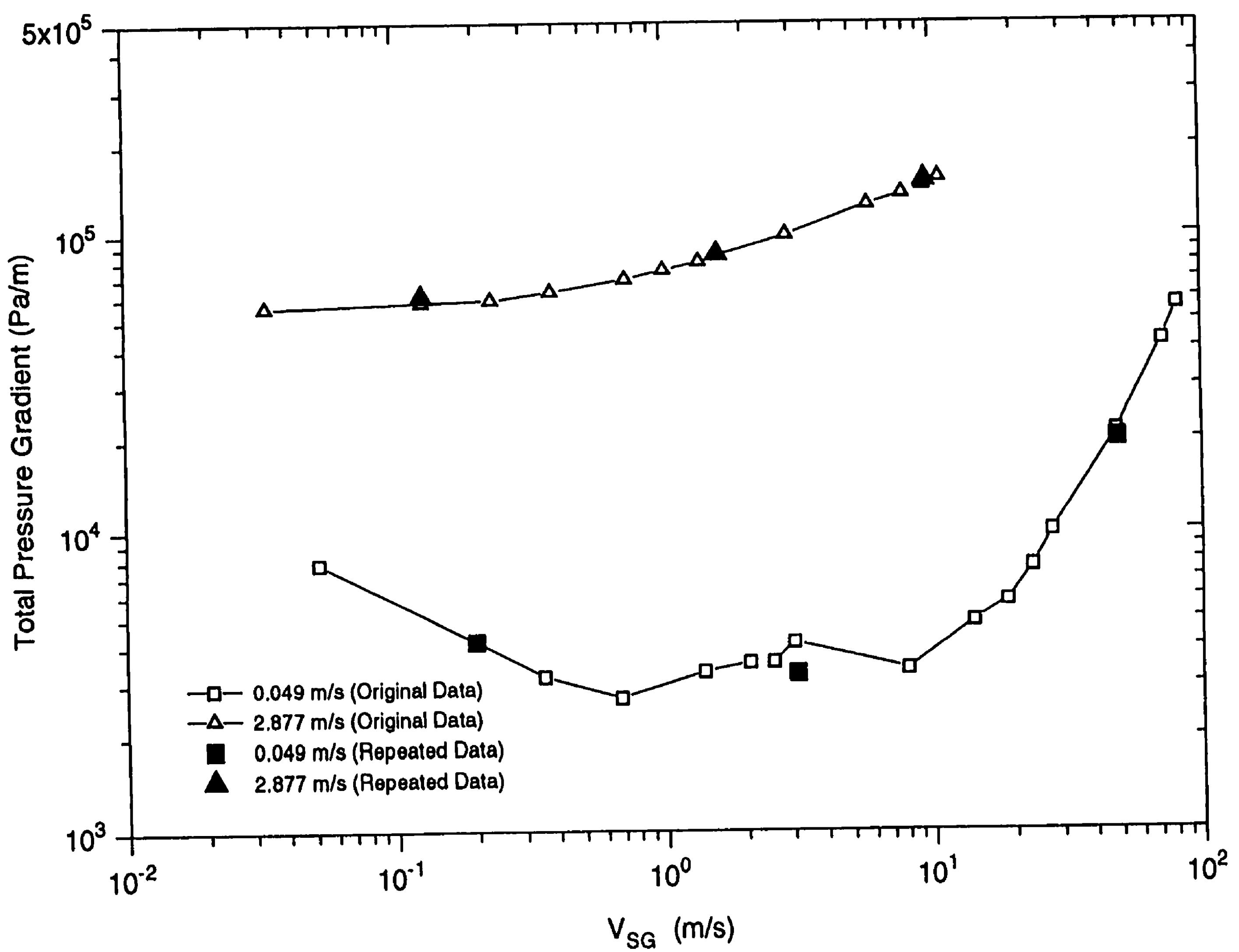


Figure E.6 Pressure-Drop Repeatability Results for Air-G2

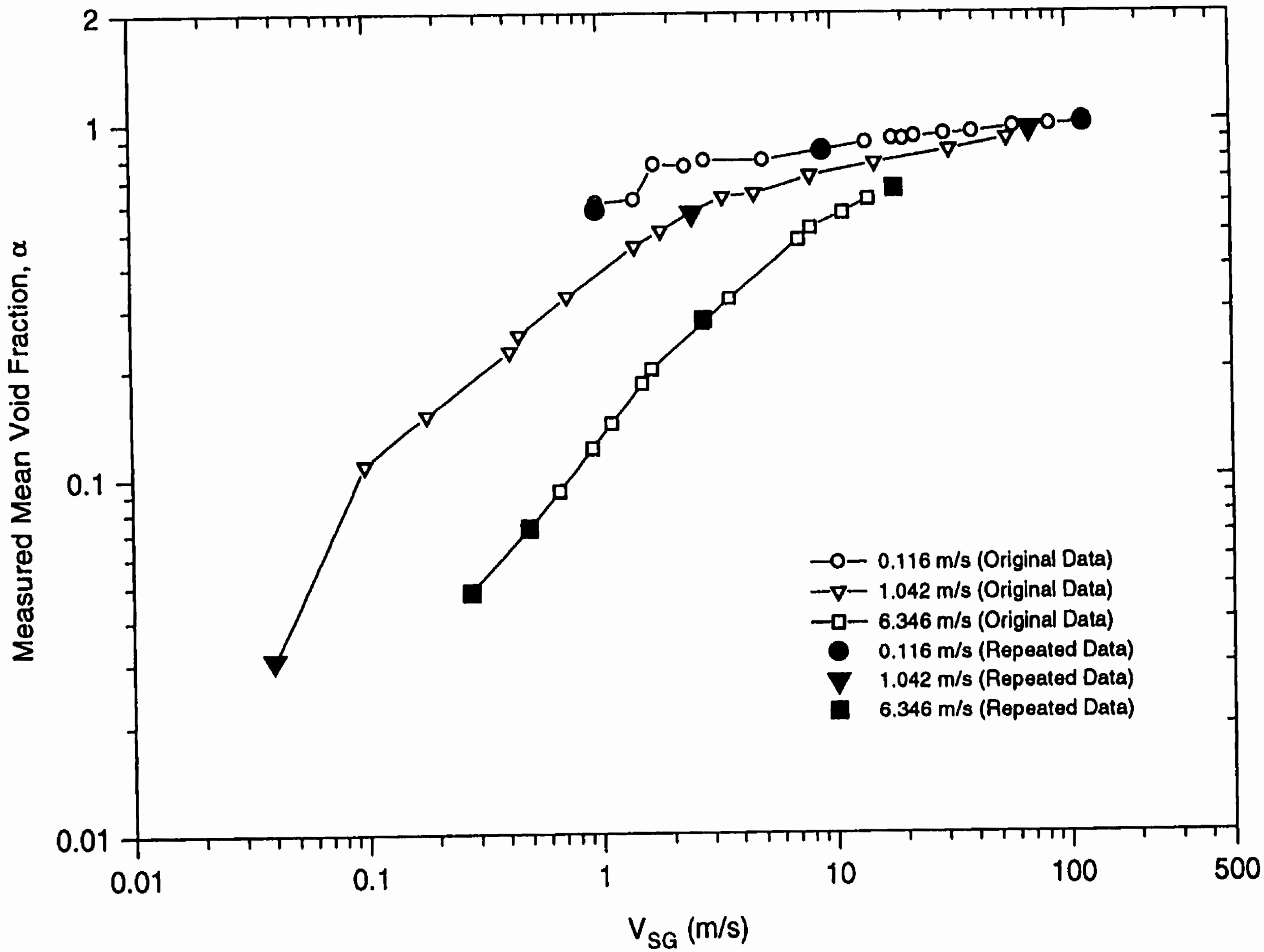


Figure E.7 Repeatability of Void Fraction Measurement for Air-Water

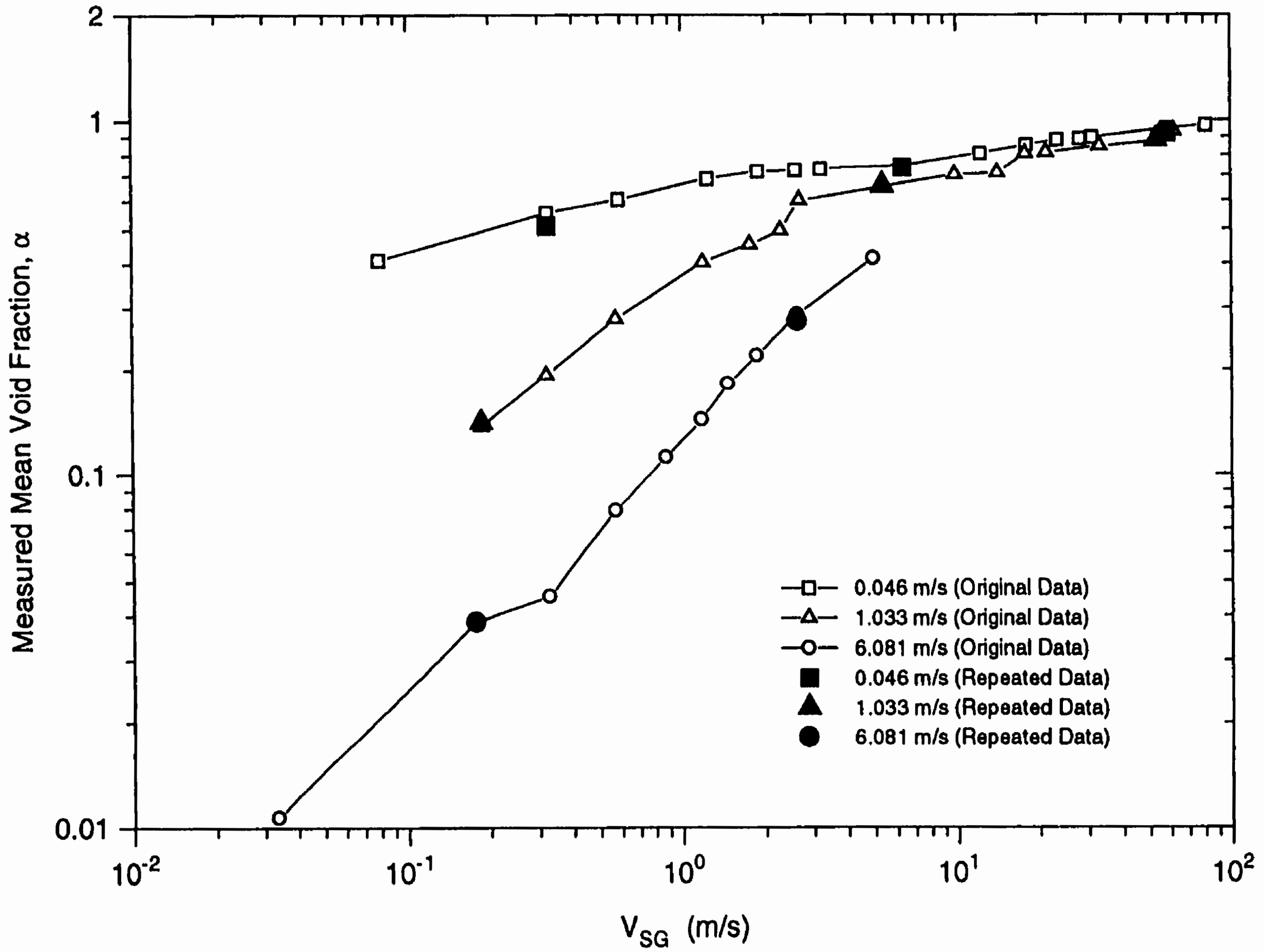


Figure E.8 Repeatability Results of Mean Void Fraction Measurement for Air - G1

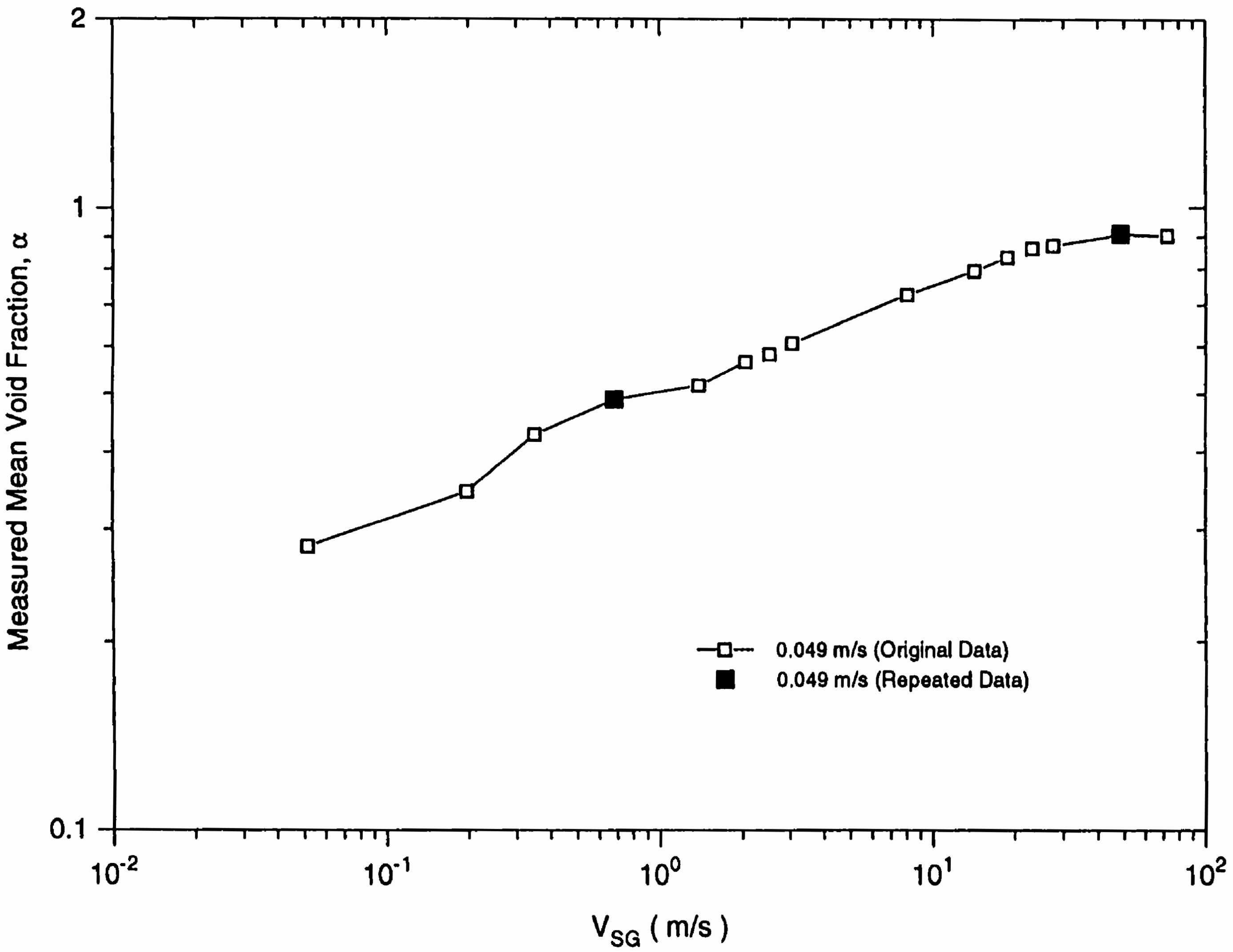


Figure E.9 Repeatability Results of Mean Void Fraction Measurement for Air-G2

REFERENCES FOR APPENDIX E

E.1 Kline, S.J. and McClintock, F. A., "Describing Uncertainties in Single-Sample Experiments," Mechanical Engineering, Vol. 75, pp.3-8, 1953.

E.2 Moffat, R. J., "Describing the Uncertainties in Experimental Results," Experimental Thermal and Fluid Science, pp.3-17, 1988.

E.3 Heineman, J. B., "An Experimental Investigation of Heat Rectangular Channels, "ANL-6213, U.S.A., 1960. As reported in Vijay (93).

Appendix F

ADAPTED SPALDING THEORY

In Chapter 8, the present two-phase results are used in a predictive method which was adapted by Vijay (93) from an original work proposed by Spalding (83) for single-phase boundary-layer flow. Although not considered a test of the single-phase data, it is nonetheless interesting to determine how well heat-transfer coefficients would be predicted in the limiting case of single-phase liquid flow.

The following equation proposed by Spalding (83) was used to predict local heat-transfer coefficients in the turbulent boundary layer.

$$S_q = \left\{ \left[\frac{Pr_L / Pr_T}{6.64\ (Z^+ / Pr_T)^{1/9} + P_{FN}} \right]^4 + \left[0.651\ (Z^+ / Pr_L)^{-1/3} \right]^4 \right\}^{1/4} \qquad \text{(F.1)}$$

where P_{FN} is the "P-Function" and is given by

$$P_{FN} = 11.57 \left[\left(\frac{Pr_L}{Pr_T} \right)^{0.75} - 1 \right] \qquad \text{(F.2)}$$

Pr_T is the turbulent Prandtl number which was given the value of 0.887 as recommended in the original work. The quantity Z^+ is defined by

$$Z^+ = \int_0^z (\tau_W \rho)^{1/2} \mu^{-1} dz \qquad \text{(F.3)}$$

which for a constant friction coefficient and fluid properties (present case) the Z^+ becomes,

$$Z^{*} = (Z/D)\ Re_{SL}\ (f_{sp}/2)^{1/2} \qquad (F.4)$$

$$Sq = \frac{Nu_{sp}}{Re_{SL}\ (f_{sp}/2)^{1/2}} \qquad (F.5)$$

The quantity S_q is called the "Spalding Function". The value of f_{sp} in Equations (F.4) and (F.5) was calculated from Equations (5.3), (5.4) or (5.5). Due to the viscosity of G2, all test conditions of this liquid fell only in laminar flow. Figures F.1 and F.2 show the results of water and G1, with the correction of variation of fluid properties, as recommended by Kays and Crawford (46). Table F.1 summarizes the deviation of experimental data from the predictions; very good agreement is noted.

Table F.1 Summary of Comparison of the Local Heat-Transfer Data in Turbulent Flow Compared with Spalding Theory (Equation F.1)

Liquid	No. of points	$\bar{e}$ (%)	$\bar{e}_{rms}$ (%)
Water	77	-1.2	7.1
G1	28	11.3	16.7
G2	-	-	-

From the material presented in this appendix, it can be seen that the experimental data agree well with the predictions.

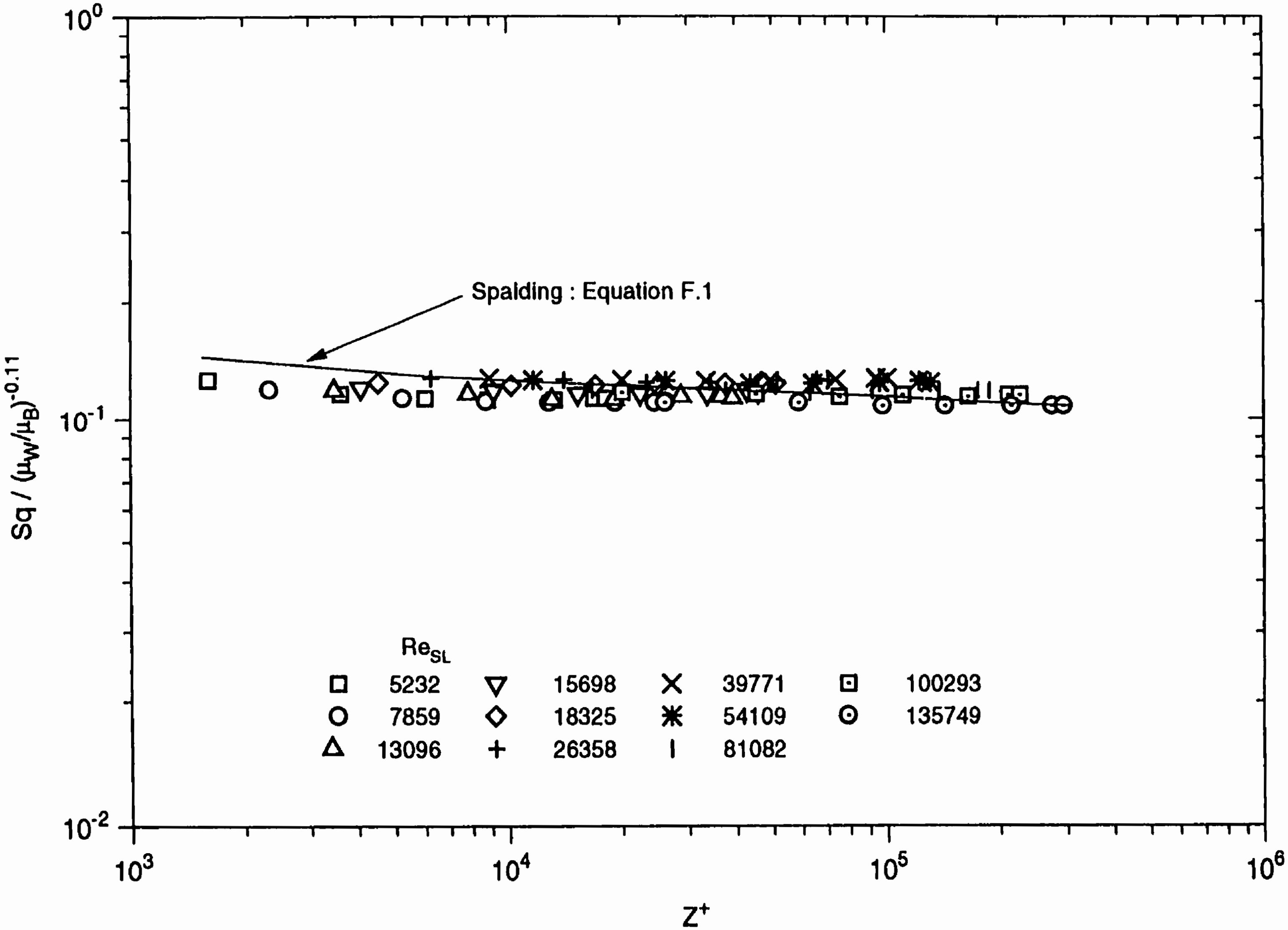


Figure F.1 Comparison of Present Single-Phase Water Data with Adapted Spalding Theory

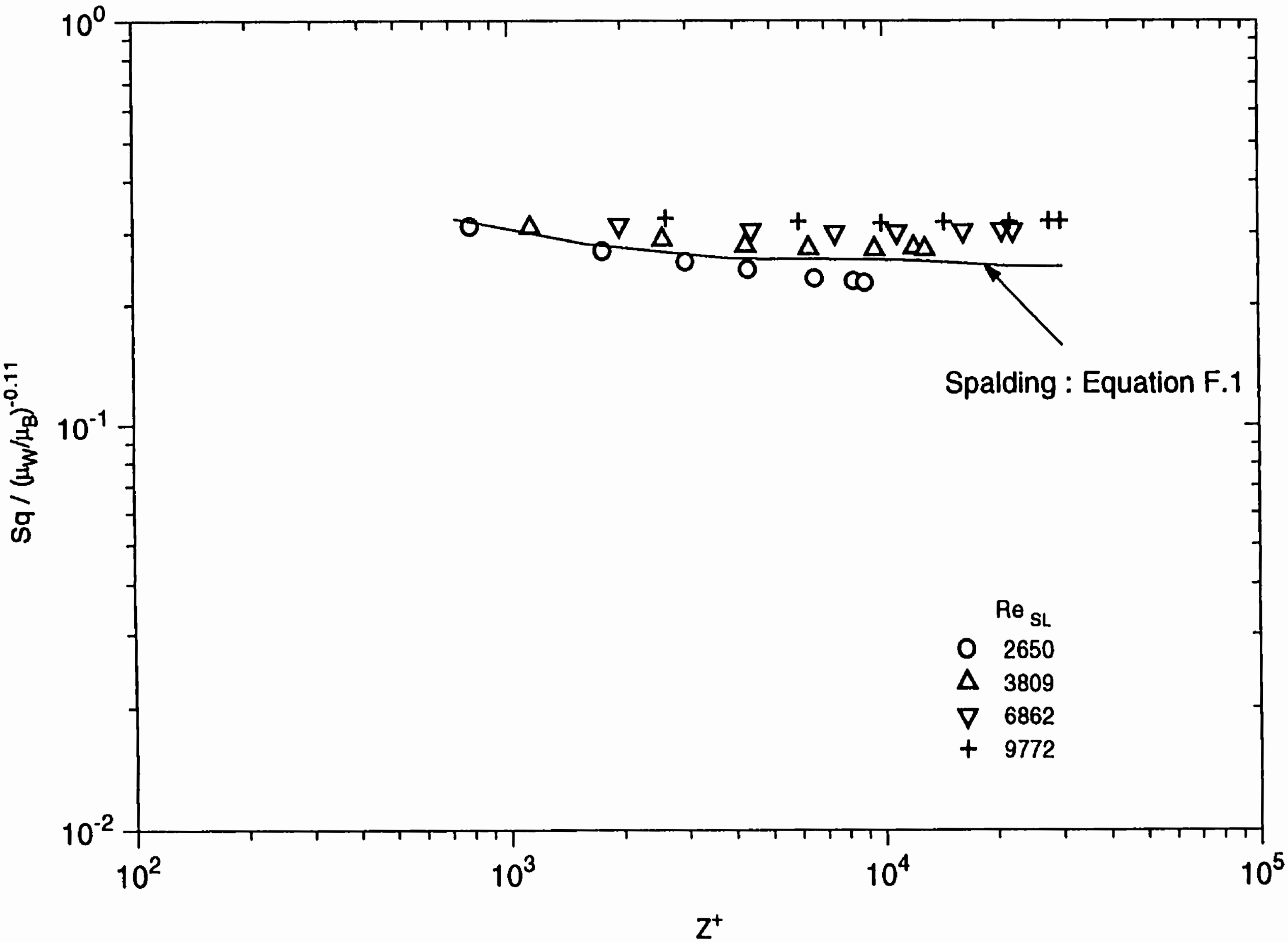


Figure F.2 Comparison of Single-Phase G1 Present Data with Spalding Theory

Appendix G

TABULATED DATA

This appendix presents the two-phase experimental data of the present investigation. Table G.1 gives the information of the bubble diameter for bubble flow. Table G.2 gives the data of mean void-fraction measurement which was done separately from the heat-transfer and pressure-drop test. The "Test No." appearing in all tables indicates the corresponding test data conducted under the same flow condition. Table G.3 presents the two-phase heat-transfer and hydrodynamic data of the present investigation. The data of a air-liquid mixture are given in the order of increasing air flow rate at each fixed liquid flow rate. For Table G.3, for each test, the data are tabulated in the following order:

The first line indicates the test no. and the flow pattern (in the bracket) which is using the same code as shown in Table 6.1.

The next two lines give the values of the following quantities:

ML	=	liquid mass flow rate	(kg/s)
MG	=	air mass flow rate	(kg/s)
QFLUX	=	average heat flux	(W/m^2)
HTP	=	average two-phase heat-transfer coefficient	($W/m^2 \cdot K$)
PDT	=	total pressure drop across the heated test section	(Pa)
PDF	=	frictional pressure drop across the heated test section	(Pa)
ALFA	=	measured void fraction	(-)
TOUT	=	measured outlet temperature of the mixture leaving the heated test	

section at centre line and wall locations (°C)

The next three lines give respectively the inlet, outlet and mean values [(inlet + outlet)/2] of the following quantities:

TMIX	=	mixture temperature [T_o (calculated)]	(°C)
RESL	=	superficial liquid Reynolds number	(-)
RESG	=	superficial gas Reynolds number	(-)
P	=	system pressure (absolute)	(Pa)
PRL	=	liquid Prandtl number	(-)
VSL	=	superficial liquid velocity	(m/s)
VSG	=	superficial gas velocity	(m/s)

All properties were taken at mean bulk temperature. Next, the local values of the quantities listed below are given at seven locations (Z cm) along the heated test section.

RESL	=	superficial liquid Reynolds number	(-)
VSG	=	superficial gas velocity	(m/s)
TBULK	=	bulk temperature of the mixture	(°C)
TWALL	=	wall temperature	(°C)
HTP	=	two-phase heat-transfer coefficient	($W/m^2 \cdot K$)

Due to the effect of evaporation at high V_{SG} and low V_{SL} the temperature of the mixture dropped slightly between the outlet of the heated test section and the temperature measuring station; this was due to the pressure drop between the two locations mentioned (a lower pressure allows for a larger vapour content in the air). The order of magnitude of this effect for water (largest effects with water) data with high V_{SL} and low V_{SG} (e.g., WR1.14, WR1.15, WR1.16, WR2.16) is in the range of 0.2 to 0.3 °C (meaning that the actual measured temperature right at the outlet from the heated section would have been 0.2 to 0.3 °C higher than the TOUT listed in the tables for these data).

Table G.1 Mean Horizontal Bubble Diameter for Bubble Flow

Test No.	Range of Diameter (mm)	No. of Samples (-)	Mean Diameter (mm)
WR4.01	0.42 - 4.98	26	0.94
WR4.02	0.30 - 7.00	52	1.04
WR5.01	0.17 - 2.71	97	0.83
WR5.02	0.30 - 7.21	52	2.11
WR6.01	0.14 - 1.23	80	0.61
WR6.02	0.37 - 1.18	64	0.64
WR6.03	0.27 - 1.39	70	0.55
WR6.04	0.30 - 1.00	54	0.53
WR6.05	0.20 - 1.16	60	0.55
WR7.01	0.10 - 0.51	92	0.19
WR7.02	0.10 - 0.60	84	0.25
WR7.03	0.10 - 0.72	82	0.25
WR7.04	0.10 - 0.80	72	0.28
G1R2.01	0.51 - 2.23	57	1.52
G1R2.02	0.88 - 3.51	33	1.80
G1R2.03	1.10 - 2.89	31	1.71
G1R3.01	0.20 - 1.51	104	0.75
G1R3.02	0.45 - 2.54	48	1.59
G1R3.03	1.07 - 2.58	32	1.57
G1R3.04	0.97 - 2.10	45	1.39
G1R4.01	0.21 - 1.09	100	0.46
G1R4.02	0.21 - 1.61	158	0.54
G1R4.03	0.19 - 1.39	129	0.40
G1R4.04	0.26 - 1.34	63	0.58

Table G.1 Mean Horizontal Bubble Diameter for Bubble Flow (con't)

Test No.	Range of Diameter (mm)	No. of Samples (-)	Mean Diameter (mm)
G1R5.01	0.68 - 1.52	38	0.68
G1R5.02	0.38 - 0.72	27	0.56
G1R5.03	0.37 - 0.99	27	0.57
G1R5.04	0.16 - 0.99	23	0.48
G2R3.01	0.46 - 2.19	73	0.68
G2R4.01	0.24 - 1.27	70	0.42

Table G.2 Tabulated Data for Void Measurement

Test No.	VSL (m/s)	VSG (m/s)	P (Pa)	T (C)	ALPHA (-)	No. of Samples (-)
WR1.01	0.0545	0.546	101351.35	28.19	0.6195	12
WR1.02		1.091	102027.03	30.09	0.7575	12
WR1.03		1.652	102371.76	29.77	0.7993	12
WR1.04		2.003	103281.85	29.60	0.8018	12
WR1.05		2.816	103075.01	26.71	0.8063	12
WR1.06		3.164	103075.01	28.78	0.7993	12
WR1.07		7.986	101351.35	27.02	0.8487	7
WR1.08		13.692	101351.35	28.23	0.9051	7
WR1.09		19.193	101351.35	28.52	0.9417	7
WR1.10		25.393	105419.20	27.29	0.9399	7
WR1.11		39.122	108246.00	24.58	0.9542	7
WR1.12		58.937	113037.78	22.04	0.9652	7
WR1.13		75.366	118546.61	20.63	0.9740	7
WR1.14		90.792	127551.02	19.86	0.9830	7
WR1.15		105.304	130274.41	19.23	0.9852	7
WR1.16	0.0545	113.104	131687.81	19.13	0.9858	7
WR2.01	0.1158	0.978	101351.35	26.26	0.6048	12
WR2.02		1.414	101351.35	26.01	0.6150	12
WR2.03		1.725	101351.35	25.99	0.7697	12
WR2.04		2.344	101351.35	26.48	0.7593	12
WR2.05		2.844	102385.55	26.63	0.7855	12
WR2.06		5.081	102730.28	26.09	0.7858	7
WR2.07		9.071	102730.28	28.55	0.8410	7
WR2.08		13.945	102730.28	28.48	0.8775	7
WR2.09		18.108	103419.75	29.76	0.8997	7
WR2.10		20.105	104109.21	30.27	0.8948	7
WR2.11		22.559	104798.68	32.13	0.9098	7
WR2.12		30.066	105488.14	30.47	0.9211	7
WR2.13		39.564	107556.54	28.15	0.9343	7
WR2.14		59.330	115140.65	26.02	0.9696	7
WR2.15		84.833	125482.63	23.46	0.9736	7
WR2.16	0.1158	118.358	146166.58	23.46	0.9820	7
WR3.01	0.311	0.585	103419.75	22.27	0.5250	12
WR3.02		0.884	102730.28	22.01	0.5950	12
WR3.03		1.433	102040.82	21.99	0.6110	12
WR3.04		2.621	102040.82	21.90	0.6767	12
WR3.05		5.465	102040.82	21.84	0.7460	7
WR3.06		10.769	102730.28	22.56	0.8013	7
WR3.07		13.097	104109.21	23.87	0.8280	7
WR3.08		18.910	106177.61	24.00	0.8675	7
WR3.09		37.073	115140.65	27.28	0.9176	7
WR3.10		49.022	122724.77	26.51	0.9470	7
WR3.11		75.046	138582.46	21.13	0.9738	7
WR3.12		96.775	154440.15	19.47	0.9825	7
WR3.13		103.353	164782.13	19.02	0.9834	7
WR3.14	0.311	108.123	179260.89	18.97	0.9840	7

WR4.01	1.04	0.040	110314.40	22.73	0.0308	7
WR4.02		0.098	110314.40	22.80	0.1088	7
WR4.03		0.183	109624.93	22.58	0.1493	12
WR4.04		0.415	109624.93	22.85	0.2272	12
WR4.05		0.454	109624.93	22.92	0.2526	12
WR4.06		0.732	109280.20	22.99	0.3278	12
WR4.07		1.414	109280.20	23.22	0.4560	12
WR4.08		1.823	108935.47	23.33	0.5038	12
WR4.09		2.505	108935.47	23.33	0.5694	12
WR4.10		3.399	111003.86	23.94	0.6256	7
WR4.11		4.642	111693.33	23.76	0.6408	7
WR4.12		8.013	113761.72	24.72	0.7151	7
WR4.13		15.134	122724.77	24.66	0.7718	7
WR4.14		31.611	138582.46	25.31	0.8364	7
WR4.15		55.368	184776.61	25.25	0.8981	7
WR4.16	1.04	69.136	233039.16	25.15	0.9467	7
WR5.01	3.17	0.064	117484.83	21.67	0.0174	7
WR5.02		0.204	118725.87	21.26	0.0581	7
WR5.03		0.360	119346.39	21.13	0.0954	12
WR5.04		0.835	120656.37	21.01	0.1738	12
WR5.05		1.658	123690.02	21.42	0.2996	12
WR5.06		2.082	125551.57	21.49	0.3420	12
WR5.07		4.282	134859.35	21.53	0.4878	12
WR5.08		6.559	146166.58	21.59	0.5930	12
WR5.09		8.516	154550.47	21.42	0.6385	7
WR5.10		10.132	163403.20	21.58	0.6430	7
WR5.11		11.644	172297.30	22.51	0.6674	7
WR5.12		15.664	182018.75	22.06	0.6971	7
WR5.13		20.510	202013.24	22.04	0.7663	7
WR5.14		27.445	240623.28	22.07	0.7665	7
WR5.15	3.17	31.879	259928.30	22.62	0.8044	7
WR6.01	6.34	0.277	137203.53	22.61	0.0573	7
WR6.02		0.491	141340.32	21.87	0.0725	7
WR6.03		0.668	144787.65	21.94	0.0922	7
WR6.04		0.930	148234.97	22.37	0.1204	7
WR6.05		1.122	150303.37	21.64	0.1414	7
WR6.06		1.515	155129.62	21.64	0.1829	7
WR6.07		1.670	160645.34	21.74	0.2007	7
WR6.08		2.786	176503.03	21.81	0.2736	7
WR6.09		3.615	187534.47	21.74	0.3232	7
WR6.10		7.114	233039.16	21.61	0.4743	7
WR6.11		7.995	244070.60	21.61	0.5137	7
WR6.12		11.031	268891.34	21.51	0.5647	7
WR6.13		14.173	304054.06	22.58	0.6160	7
WR6.14	6.34	18.313	342664.09	23.20	0.6509	7

WR7.01	8.46	0.460	162024.27	22.93	0.0258	7
WR7.02		0.716	168229.45	21.64	0.0775	7
WR7.03		0.911	175124.10	22.12	0.0957	7
WR7.04		1.131	178571.43	22.61	0.1134	7
WR7.05		1.250	182018.75	22.02	0.1262	7
WR7.06		1.402	186845.01	22.75	0.1409	7
WR7.07		1.637	190981.80	22.78	0.1527	7
WR7.08		3.164	227523.44	22.72	0.2546	7
WR7.09		4.862	266822.95	22.79	0.3403	7
WR7.10		6.797	306122.45	22.84	0.4128	7
WR7.11		7.968	330943.19	22.26	0.4276	7
WR7.12		8.044	318532.82	22.50	0.4314	7
WR7.13	8.46	9.339	342664.09	23.51	0.4497	7
G1R1.01	0.0457	0.079	106177.61	24.14	0.4101	6
G1R1.02		0.323	104109.21	24.08	0.5547	6
G1R1.03		0.588	103419.75	29.43	0.6039	6
G1R1.04		1.247	102040.82	30.95	0.6877	6
G1R1.05		1.896	103419.75	31.64	0.7187	6
G1R1.06		2.606	103419.75	31.34	0.7265	5
G1R1.07		3.222	102730.28	31.64	0.7312	5
G1R1.08		6.380	102385.55	30.69	0.7476	5
G1R1.09		12.323	102040.82	28.42	0.8084	5
G1R1.10		18.133	102040.82	28.28	0.8547	5
G1R1.11		23.458	104798.68	27.98	0.8827	5
G1R1.12		28.216	104109.21	24.44	0.8901	5
G1R1.13		31.373	104798.68	24.64	0.8987	5
G1R1.14		58.617	112382.79	22.36	0.9524	5
G1R1.15	0.0457	81.562	123414.23	20.83	0.9703	5
G1R2.01	0.418	0.046	111693.33	24.47	0.0967	5
G1R2.02		0.186	110314.40	23.96	0.2189	5
G1R2.03		0.329	109624.93	22.72	0.3093	5
G1R2.04		0.485	109624.93	24.26	0.3579	6
G1R2.05		1.039	107556.54	24.06	0.5109	6
G1R2.06		1.588	107556.54	24.90	0.5538	6
G1R2.07		2.146	105488.14	25.38	0.6186	6
G1R2.08		2.582	107556.54	24.56	0.6369	6
G1R2.09		2.923	108246.00	24.86	0.6586	6
G1R2.10		5.154	113072.26	23.82	0.6929	5
G1R2.11		9.836	113761.72	23.69	0.7237	5
G1R2.12		17.566	114451.19	24.20	0.8271	5
G1R2.13		21.187	115140.65	24.37	0.8139	5
G1R2.14		25.067	117898.51	24.21	0.8352	5
G1R2.15		65.722	153061.23	22.22	0.9406	5
G1R2.16	0.418	77.344	175124.10	22.48	0.9845	5

G1R3.01	1.033	0.046	115140.65	22.78	0.0196	5
G1R3.02		0.186	114726.97	22.78	0.1370	5
G1R3.03		0.320	113761.72	22.93	0.1933	5
G1R3.04		0.573	113761.72	23.02	0.2793	5
G1R3.05		1.192	114451.19	23.14	0.4038	6
G1R3.06		1.768	113761.72	22.47	0.4533	6
G1R3.07		2.280	114451.19	22.22	0.4951	6
G1R3.08		2.679	115140.65	22.75	0.5994	6
G1R3.09		5.377	119277.44	22.97	0.6507	5
G1R3.10		9.857	124793.16	22.75	0.7037	5
G1R3.11		14.125	130308.88	23.93	0.7124	5
G1R3.12		17.922	137893.00	24.52	0.8039	5
G1R3.13		21.318	153061.23	20.84	0.8129	5
G1R3.14		33.391	150992.83	21.22	0.8479	5
G1R3.15		53.460	192360.73	21.11	0.8775	5
G1R3.16	1.033	62.332	216629.90	21.20	0.9338	5
G1R4.01	2.68	0.040	124103.70	22.71	0.0204	5
G1R4.02		0.165	124793.16	22.68	0.0608	5
G1R4.03		0.296	124793.16	21.74	0.0891	5
G1R4.04		0.558	125482.63	21.49	0.1469	5
G1R4.05		1.045	126861.56	22.14	0.2417	5
G1R4.06		1.484	128240.49	21.01	0.3059	6
G1R4.07		2.015	133066.74	21.01	0.3587	6
G1R4.08		2.649	137893.00	21.00	0.3826	6
G1R4.09		4.133	153750.69	21.71	0.4744	6
G1R4.10		7.224	163403.20	20.99	0.6059	5
G1R4.11		9.763	181329.29	21.25	0.6695	5
G1R4.12		12.323	193739.66	21.10	0.7017	5
G1R4.13		14.292	202013.24	21.24	0.7104	5
G1R4.14		20.675	214423.61	21.00	0.7458	5
G1R4.15		25.070	243381.14	21.02	0.7659	5
G1R4.16	2.68	31.230	254412.58	21.66	0.7692	5
G1R5.01	6.08	0.034	163403.20	21.99	0.0107	5
G1R5.02		0.177	163403.20	21.52	0.0386	5
G1R5.03		0.326	166161.06	21.54	0.0455	5
G1R5.04		0.570	172366.24	22.02	0.0791	5
G1R5.05		0.875	178571.43	21.06	0.1119	5
G1R5.06		1.180	184087.15	22.21	0.1435	5
G1R5.07		1.469	190292.33	22.29	0.1825	5
G1R5.08		1.868	197186.98	21.30	0.2199	5
G1R5.09		2.621	208907.89	21.01	0.2879	5
G1R5.10		4.977	236486.49	21.01	0.4145	5
G1R5.11		6.460	262686.20	19.30	0.4220	5
G1R5.12		7.680	283370.10	19.54	0.4531	5
G1R5.13		8.720	304054.10	18.95	0.4773	5
G1R5.14	6.08	9.151	306812.00	20.45	0.4854	5

G2R1.01	0.0487	0.052	110314.40	22.24	0.2820	4
G2R1.02		0.198	103764.48	22.22	0.3452	4
G2R1.03		0.351	102040.82	22.23	0.4272	4
G2R1.04		0.683	101351.35	22.07	0.4844	4
G2R1.05		1.390	102040.82	22.10	0.5169	4
G2R1.06		2.051	102040.82	22.00	0.5664	3
G2R1.07		2.512	102040.82	23.02	0.5826	3
G2R1.08		3.048	102040.82	23.07	0.6076	3
G2R1.09		8.025	101351.35	22.69	0.7277	3
G2R1.10		14.146	102730.28	21.95	0.7946	3
G2R1.11		18.730	103419.75	21.28	0.8351	3
G2R1.12		23.061	105488.14	21.20	0.8635	3
G2R1.13		27.512	107556.54	21.15	0.8725	3
G2R1.14		48.430	119277.44	19.58	0.9089	3
G2R1.15		72.153	145477.11	19.32	0.9040	3
G2R1.16	0.0487	81.879	167264.20	19.85	0.9870	3
G2R2.01	0.366	0.046	120518.48	19.77	0.1503	4
G2R2.02		0.180	111693.33	19.77	0.2609	4
G2R2.03		0.308	110314.40	19.77	0.2915	4
G2R2.04		0.564	108935.47	19.77	0.3496	4
G2R2.05		1.170	108935.47	19.74	0.4088	4
G2R2.06		1.710	108935.47	19.76	0.4463	4
G2R2.07		2.310	110314.40	19.72	0.4842	4
G2R2.08		2.774	111003.86	19.74	0.5427	3
G2R2.09		5.005	113761.72	19.72	0.6046	3
G2R2.10		9.537	117898.51	19.67	0.6140	3
G2R2.11		14.051	123414.23	19.63	0.6519	3
G2R2.12		19.160	130998.35	19.58	0.6829	3
G2R2.13		22.025	135824.60	19.55	0.7186	3
G2R2.14		35.409	153061.23	19.45	0.7906	3
G2R2.15		51.125	186845.01	19.39	0.8120	3
G2R2.16	0.366	57.693	210976.30	17.35	0.9340	3
G2R3.01	2.877	0.034	155129.62	19.77	0.0087	3
G2R3.02		0.128	157198.01	19.77	0.0287	4
G2R3.03		0.229	158576.94	19.77	0.0540	4
G2R3.04		0.381	164092.66	19.77	0.0712	4
G2R3.05		0.728	172366.24	19.77	0.1265	4
G2R3.06		1.006	178571.43	19.77	0.1591	4
G2R3.07		1.362	185466.08	19.77	0.2239	4
G2R3.08		1.585	190981.80	19.77	0.2583	4
G2R3.09		2.868	210976.28	19.77	0.3521	4
G2R3.10		5.822	244760.07	19.77	0.4799	4
G2R3.11		7.827	261307.23	19.77	0.5245	3
G2R3.12		9.361	274407.06	19.77	0.5679	3
G2R3.13	2.877	10.747	281991.18	19.77	0.5606	3
G2R4.01	4.319	0.027	184776.61	19.77	0.0066	3
G2R4.02		0.110	186845.01	19.77	0.0233	4
G2R4.03		0.189	188223.94	19.77	0.0292	4
G2R4.04		0.360	194429.12	19.77	0.0557	4
G2R4.05		0.689	207528.96	19.77	0.0945	4
G2R4.06	4.319	0.911	217181.47	19.77	0.1282	4

Table G.3 Tabulated Data

WR1.01 (S)
ML= 0.00592 MG= 0.0000655 QFLUX= 19076 HTP= 2850.3
PDT= 1.427 PDF= -0.896 ALFA=0.620 TOUT= 37.05, 37.22

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	674.3	394.1	102.04	6.7	0.0548	0.51
OUTLET	38.3	957.0	393.9	100.66	4.5	0.0548	0.57
MEAN	29.9	815.7	394.0	101.35	5.6	0.0548	0.54

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	696.4	0.52	22.86	31.42	2217.2
11.4	724.6	0.52	24.61	33.28	2191.7
19.1	758.9	0.53	26.71	35.23	2237.7
27.9	799.5	0.54	29.17	37.31	2342.7
41.9	864.9	0.55	33.02	39.53	2936.6
53.3	919.7	0.56	36.17	40.68	4253.4
57.2	938.3	0.56	37.22	40.51	5836.4

WR1.02 (S)
ML= 0.00592 MG= 0.000133 QFLUX= 19111 HTP= 2945.2
PDT= 0.951 PDF= -0.552 ALFA=0.758 TOUT= 37.34, 37.22

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	682.3	798.0	102.73	6.6	0.0548	1.03
OUTLET	38.6	962.1	798.4	102.04	4.5	0.0548	1.14
MEAN	30.3	822.2	798.2	102.04	5.5	0.0548	1.09

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	704.1	1.05	23.35	35.40	1580.7
11.4	732.0	1.06	25.08	37.11	1587.6
19.1	766.0	1.07	27.16	37.63	1822.6
27.9	806.2	1.09	29.58	39.14	2000.9
41.9	871.0	1.11	33.39	39.93	2927.5
53.3	925.2	1.13	36.51	39.91	5634.8
57.2	943.6	1.14	37.54	39.44	10085.7

WR1.03 (S)
ML= 0.00592 MG= 0.000202 QFLUX= 17553 HTP= 2626.6
PDT= 0.724 PDF= -0.483 ALFA=0.799 TOUT= 37.03, 37.03

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.6	693.1	1209.4	102.73	6.5	0.0548	1.56
OUTLET	37.7	946.2	1212.2	102.04	4.5	0.0548	1.72
MEAN	30.2	819.7	1210.8	102.73	5.5	0.0548	1.64

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	712.8	1.60	23.90	36.25	1417.8
11.4	738.2	1.61	25.47	37.68	1436.5
19.1	769.0	1.62	27.36	38.63	1556.3
27.9	805.5	1.64	29.55	38.86	1887.9
41.9	864.1	1.67	33.01	39.48	2714.1
53.3	913.0	1.70	35.83	39.31	5055.1
57.2	929.5	1.71	36.77	39.03	7769.7

WR1.04 (S)
ML= 0.00592 MG= 0.000256 QFLUX= 14554 HTP= 2079.8
PDT= 0.951 PDF= -0.276 ALFA=0.802 TOUT= 32.39, 32.39

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.4	642.2	1537.4	103.42	7.1	0.0548	1.93
OUTLET	31.9	844.7	1532.4	102.73	5.2	0.0548	2.09
MEAN	25.7	743.5	1534.9	103.42	6.1	0.0548	2.01

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	658.0	1.97	20.45	30.92	1386.6
11.4	678.5	1.98	21.75	32.33	1374.1
19.1	703.2	2.00	23.31	33.46	1434.8
27.9	732.5	2.01	25.13	33.84	1671.6
41.9	779.3	2.05	27.98	34.56	2216.7
53.3	818.3	2.08	30.32	34.52	3472.6
57.2	831.4	2.08	31.11	34.28	4581.0

WR1.05 (S-C)
ML= 0.00592 MG= 0.000359 QFLUX= 14595 HTP= 2300.7
PDT= 1.158 PDF= 0.000 ALFA=0.806 TOUT= 31.71, 31.71

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.6	644.8	2159.6	103.42	7.0	0.0548	2.72
OUTLET	31.9	844.2	2153.8	102.73	5.2	0.0548	2.94
MEAN	25.7	744.5	2156.7	102.73	6.1	0.0548	2.83

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	660.3	2.77	20.61	28.16	1924.3
11.4	680.4	2.79	21.89	29.53	1903.2
19.1	704.8	2.81	23.42	31.22	1870.9
27.9	733.7	2.84	25.22	32.62	1974.2
41.9	779.8	2.88	28.04	34.50	2263.8
53.3	818.2	2.92	30.34	34.73	3336.4
57.2	831.2	2.93	31.11	34.51	4303.9

WR1.06 (S-C)
ML= 0.00592 MG= 0.000398 QFLUX= 16840 HTP= 2586.9
PDT= 1.172 PDF= -0.069 ALFA=0.799 TOUT= 34.08, 34.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.8	664.0	2385.6	103.42	6.8	0.0548	3.02
OUTLET	34.8	894.4	2382.4	102.73	4.9	0.0548	3.31
MEAN	27.8	779.2	2384.0	102.73	5.8	0.0548	3.17

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	681.7	3.08	21.97	28.22	2677.2
11.4	704.9	3.11	23.43	30.66	2323.4
19.1	733.1	3.14	25.18	32.25	2379.1
27.9	766.4	3.17	27.23	34.12	2443.2
41.9	819.7	3.23	30.44	36.67	2712.9
53.3	864.2	3.28	33.07	39.12	2797.0
57.2	879.2	3.30	33.94	38.81	3478.9

WR1.07 (C)
ML= 0.00592 MG= 0.000993 QFLUX= 16834 HTP= 4368.0
PDT= 1.096 PDF= 0.138 ALFA=0.849 TOUT= 32.80, 32.92

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	657.3	5958.0	102.04	6.9	0.0548	7.64
OUTLET	33.2	863.3	5951.1	100.66	5.0	0.0548	8.32
MEAN	26.8	760.3	5954.5	101.35	6.0	0.0548	7.98

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	672.3	7.80	21.44	25.24	4405.0
11.4	693.2	7.85	22.78	26.64	4335.7
19.1	718.6	7.92	24.38	28.31	4272.1
27.9	748.6	8.00	26.24	30.14	4314.7
41.9	796.5	8.14	29.18	33.05	4361.2
53.3	836.3	8.25	31.58	35.32	4522.5
57.2	849.7	8.29	32.38	36.06	4595.2

WR1.08 (C-A)
ML= 0.00592 MG= 0.00167 QFLUX= 33746 HTP= 4419.7
PDT= 1.151 PDF= 0.552 ALFA=0.905 TOUT= 40.44, 40.37

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.4	626.9	10074.6	102.04	7.3	0.0548	12.77
OUTLET	40.9	990.6	9991.1	100.66	4.2	0.0548	14.61
MEAN	29.7	808.7	10032.8	101.35	5.8	0.0548	13.69

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	653.3	13.05	20.29	26.98	4994.9
11.4	689.6	13.21	22.63	29.73	4714.4
19.1	734.0	13.39	25.44	32.89	4508.9
27.9	786.7	13.62	28.72	36.51	4327.7
41.9	871.4	14.02	33.87	41.90	4221.6
53.3	942.3	14.37	38.08	45.99	4303.9
57.2	966.0	14.50	39.48	47.36	4334.0

WR1.09 (A)
ML= 0.00592 MG= 0.00233 QFLUX= 36616 HTP= 4252.2
PDT= 1.427 PDF= 1.034 ALFA=0.942 TOUT= 40.92, 40.80

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.6	630.2	14062.4	102.04	7.2	0.0548	17.85
OUTLET	40.8	982.6	13955.5	100.66	4.3	0.0548	20.44
MEAN	29.7	806.4	14009.0	101.35	5.7	0.0548	19.14

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	655.0	18.25	20.48	27.01	5540.0
11.4	690.6	18.47	22.78	30.19	4898.9
19.1	733.9	18.73	25.55	33.74	4447.5
27.9	785.3	19.06	28.77	37.59	4147.7
41.9	867.6	19.61	33.84	43.37	3862.7
53.3	936.1	20.11	37.99	47.66	3824.1
57.2	958.9	20.29	39.37	49.04	3830.3

WR1.10 (A)
ML= 0.00592 MG= 0.00327 QFLUX= 34311 HTP= 3670.2
PDT= 1.944 PDF= 1.586 ALFA=0.940 TOUT= 36.43, 36.43

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.2	607.9	19807.8	106.18	7.5	0.0548	23.93
OUTLET	36.7	909.6	19555.2	104.11	4.6	0.0548	27.00
MEAN	26.9	758.7	19681.5	105.49	6.1	0.0548	25.47

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	628.3	24.42	18.81	26.06	4680.3
11.4	659.1	24.68	20.84	29.40	3976.8
19.1	696.4	25.00	23.27	32.45	3724.7
27.9	740.7	25.39	26.12	35.80	3541.9
41.9	811.2	26.05	30.58	40.71	3403.4
53.3	869.6	26.63	34.23	43.99	3546.4
57.2	889.2	26.83	35.45	44.88	3671.4

WR1.11 (A)
ML= 0.00592 MG= 0.00520 QFLUX= 33620 HTP= 3418.1
PDT= 3.103 PDF= 2.827 ALFA=0.954 TOUT= 33.94, 33.94

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.4	611.8	31449.4	109.62	7.4	0.0548	36.84
OUTLET	33.7	853.5	31097.5	106.87	5.0	0.0548	41.30
MEAN	25.6	732.6	31273.4	108.25	6.2	0.0548	39.07

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	625.7	37.57	18.80	25.29	5118.7
11.4	651.0	37.96	20.49	29.13	3864.4
19.1	681.6	38.43	22.53	32.07	3512.9
27.9	717.5	39.01	24.91	35.22	3258.0
41.9	774.5	39.95	28.64	39.53	3101.9
53.3	821.6	40.76	31.69	42.81	3049.6
57.2	837.2	41.04	32.71	43.72	3082.0

WR1.12 (A)
ML= 0.00592 MG= 0.00828 QFLUX= 33803 HTP= 3200.7
PDT= 5.778 PDF= 5.585 ALFA=0.965 TOUT= 29.73, 29.88

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	15.8	586.4	50325.0	115.83	7.8	0.0548	55.27
OUTLET	29.6	779.9	49698.7	110.31	5.5	0.0548	62.41
MEAN	22.7	683.1	50011.9	113.07	6.7	0.0548	58.84

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	594.9	56.32	16.92	22.87	5612.1
11.4	615.6	56.96	18.36	27.08	3847.9
19.1	640.8	57.74	20.08	30.34	3283.0
27.9	670.1	58.67	22.09	33.46	2976.4
41.9	716.4	60.21	25.26	37.56	2761.2
53.3	754.2	61.53	27.85	40.42	2709.5
57.2	766.7	61.99	28.71	41.36	2698.2

WR1.13 (A-M)
ML= 0.00592 MG= 0.01124 QFLUX= 32324 HTP= 3078.0
PDT= 8.598 PDF= 8.411 ALFA=0.974 TOUT= 26.18, 26.33

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	15.2	577.3	68434.9	122.72	8.0	0.0548	70.62
OUTLET	26.8	733.4	67646.0	114.45	5.8	0.0548	80.54
MEAN	21.0	655.4	68040.5	118.59	6.9	0.0548	75.58

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	581.4	71.95	16.14	21.51	5950.5
11.4	598.5	72.85	17.36	25.64	3873.5
19.1	619.2	73.96	18.82	29.08	3138.8
27.9	643.4	75.27	20.52	32.14	2782.2
41.9	681.2	77.45	23.19	35.89	2556.8
53.3	712.1	79.30	25.38	38.24	2532.9
57.2	722.5	79.93	26.12	38.94	2540.3

WR1.14 (A-M)
ML= 0.00592 MG= 0.01462 QFLUX= 28612 HTP= 2955.9
PDT= 11.473 PDF= 11.376 ALFA=0.983 TOUT= 23.03, 23.21

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	15.3	579.4	88973.2	133.07	7.9	0.0548	84.66
OUTLET	24.4	692.8	88237.5	122.04	6.2	0.0548	97.05
MEAN	19.8	636.1	88605.3	127.55	7.1	0.0548	90.86

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	578.1	86.24	16.06	20.73	6057.8
11.4	591.2	87.37	17.00	24.52	3783.2
19.1	606.8	88.76	18.13	27.64	3004.8
27.9	625.2	90.41	19.46	30.49	2595.4
41.9	653.9	93.13	21.53	33.36	2429.0
53.3	676.9	95.47	23.23	35.20	2405.7
57.2	684.6	96.27	23.80	35.74	2412.6

WR1.15 (A-M)
ML= 0.00592 MG= 0.01727 QFLUX= 34711 HTP= 2807.2
PDT= 13.362 PDF= 13.238 ALFA=0.985 TOUT= 23.28, 23.38

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	15.0	574.8	105180.4	136.51	8.0	0.0548	97.34
OUTLET	24.9	695.3	104109.1	123.41	6.1	0.0548	113.37
MEAN	19.9	635.0	104644.7	130.31	7.1	0.0548	105.36

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	573.0	99.24	15.82	21.84	5696.7
11.4	586.9	100.70	16.85	26.91	3430.6
19.1	603.7	102.50	18.09	30.72	2741.9
27.9	623.4	104.65	19.53	33.63	2465.9
41.9	654.0	108.20	21.79	36.46	2378.5
53.3	678.4	111.28	23.65	38.08	2420.5
57.2	686.5	112.34	24.27	38.56	2446.1

WR1.16 (A-M)
ML= 0.00592 MG= 0.01878 QFLUX= 34702 HTP= 2803.8
PDT= 17.457 PDF= 17.375 ALFA=0.986 TOUT= 22.68, 22.78

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	15.1	575.7	114327.6	140.65	8.0	0.0548	103.21
OUTLET	24.3	683.8	113310.7	122.72	6.2	0.0548	123.52
MEAN	19.7	629.7	113819.2	131.69	7.1	0.0548	113.37

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	572.1	105.42	15.82	21.86	5686.5
11.4	585.0	107.25	16.78	26.82	3438.6
19.1	600.4	109.51	17.93	30.46	2765.2
27.9	618.3	112.25	19.27	33.32	2473.3
41.9	646.4	116.79	21.38	36.15	2359.8
53.3	668.4	120.78	23.10	37.68	2395.0
57.2	675.7	122.16	23.68	38.08	2425.6

WR2.01 (S)
ML= 0.01222 MG= 0.000122 QFLUX= 28928 HTP= 3279.0
PDT= 1.358 PDF= -1.034 ALFA=0.605 TOUT= 33.19, 33.4

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	1345.6	737.2	102.04	6.9	0.113	0.94
OUTLET	32.9	1765.2	736.6	100.66	5.1	0.112	1.03
MEAN	26.6	1555.4	736.9	101.35	6.0	0.112	0.99

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1378.9	0.97	21.43	30.87	3049.6
11.4	1421.1	0.97	22.73	32.10	3076.9
19.1	1472.4	0.98	24.29	33.72	3063.3
27.9	1533.0	0.99	26.11	35.17	3192.1
41.9	1629.8	1.01	28.97	37.87	3261.4
53.3	1710.6	1.02	31.31	39.13	3717.9
57.2	1737.8	1.03	32.09	38.97	4226.1

WR2.02 (S)
ML= 0.01222 MG= 0.000175 QFLUX= 29193 HTP= 3132.5
PDT= 1.434 PDF= -0.896 ALFA=0.615 TOUT= 33.34, 33.31

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	1347.3	1053.7	102.04	6.9	0.113	1.35
OUTLET	33.0	1768.9	1052.9	100.66	5.1	0.112	1.48
MEAN	26.7	1558.1	1053.3	101.35	6.0	0.112	1.41

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1380.7	1.38	21.48	32.62	2611.9
11.4	1423.1	1.39	22.79	33.75	2657.8
19.1	1474.6	1.41	24.36	34.93	2757.8
27.9	1535.5	1.42	26.19	36.19	2920.7
41.9	1632.8	1.44	29.07	37.92	3305.1
53.3	1714.0	1.46	31.42	39.04	3842.3
57.2	1741.3	1.47	32.20	38.49	4654.8

WR2.03 (S)
ML= 0.01222 MG= 0.000215 QFLUX= 29104 HTP= 3172.3
PDT= 1.193 PDF= -0.207 ALFA=0.770 TOUT= 33.34, 33.32

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	1346.6	1289.5	102.04	6.9	0.113	1.65
OUTLET	32.9	1765.2	1288.3	100.66	5.1	0.112	1.80
MEAN	26.7	1555.9	1288.9	101.35	6.0	0.112	1.73

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1379.7	1.69	21.46	32.24	2689.1
11.4	1421.8	1.70	22.76	33.57	2684.5
19.1	1473.0	1.71	24.31	34.62	2820.8
27.9	1533.5	1.73	26.13	35.89	2980.9
41.9	1630.1	1.76	28.99	38.03	3227.3
53.3	1710.7	1.78	31.33	38.58	4025.1
57.2	1737.9	1.79	32.11	38.37	4661.0

WR2.04 (S)
ML= 0.01222 MG= 0.000292 QFLUX= 29026 HTP= 3149.0
PDT= 1.448 PDF= 0.000 ALFA=0.759 TOUT= 33.38, 33.38

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	1345.6	1755.5	102.04	6.9	0.113	2.25
OUTLET	32.7	1759.7	1754.1	100.66	5.1	0.112	2.45
MEAN	26.6	1552.7	1754.8	101.35	6.0	0.112	2.35

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1378.2	2.30	21.42	32.43	2624.3
11.4	1419.9	2.31	22.70	33.86	2596.0
19.1	1470.6	2.33	24.24	34.84	2736.2
27.9	1530.4	2.36	26.05	36.13	2881.0
41.9	1626.1	2.40	28.88	38.07	3165.5
53.3	1705.8	2.43	31.19	38.03	4259.0
57.2	1732.7	2.44	31.97	37.91	4893.8

WR2.05 (S-C)
ML= 0.01222 MG= 0.000359 QFLUX= 28603 HTP= 3290.4
PDT= 1.524 PDF= 0.207 ALFA=0.786 TOUT= 33.19, 33.19

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	1344.5	2153.9	103.42	6.9	0.113	2.72
OUTLET	32.5	1749.9	2151.4	102.04	5.1	0.112	2.96
MEAN	26.4	1547.2	2152.6	102.73	6.0	0.112	2.84

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1376.4	2.77	21.36	30.67	3059.3
11.4	1417.3	2.80	22.62	31.89	3076.3
19.1	1466.9	2.82	24.14	33.63	3007.0
27.9	1525.5	2.85	25.91	35.49	2986.6
41.9	1619.1	2.90	28.68	37.39	3293.8
53.3	1697.1	2.94	30.95	38.11	4013.2
57.2	1723.4	2.95	31.71	37.95	4599.1

WR2.06 (C)
ML= 0.01222 MG= 0.000641 QFLUX= 29067 HTP= 4784.8
PDT= 1.669 PDF= 0.345 ALFA=0.786 TOUT= 32.68, 32.68

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.1	1336.2	3848.0	103.42	7.0	0.113	4.85
OUTLET	32.1	1737.2	3842.3	102.04	5.2	0.112	5.29
MEAN	26.1	1536.7	3845.2	102.73	6.1	0.112	5.07

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1367.4	4.95	21.10	27.27	4683.2
11.4	1407.9	4.98	22.35	28.44	4751.3
19.1	1457.0	5.03	23.86	30.07	4666.1
27.9	1515.1	5.08	25.62	31.72	4756.4
41.9	1607.8	5.16	28.37	34.41	4833.6
53.3	1685.0	5.24	30.63	36.59	4900.1
57.2	1711.0	5.26	31.38	37.27	4970.5

WR2.07 (C)
ML= 0.01222 MG= 0.00113 QFLUX= 45591 HTP= 5611.5
PDT= 1.593 PDF= 0.621 ALFA=0.841 TOUT= 38.50, 38.50

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.9	1329.0	6782.9	103.42	7.0	0.113	8.53
OUTLET	37.9	1937.1	6747.5	102.04	4.5	0.112	9.58
MEAN	28.9	1633.0	6765.2	102.73	5.8	0.112	9.06

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1375.2	8.72	21.37	29.48	5573.5
11.4	1435.8	8.81	23.24	31.22	5676.8
19.1	1509.7	8.92	25.49	33.67	5549.6
27.9	1597.4	9.05	28.11	36.20	5634.8
41.9	1738.5	9.27	32.24	40.44	5575.2
53.3	1856.6	9.46	35.61	43.73	5659.8
57.2	1896.6	9.53	36.73	44.92	5617.2

WR2.08 (C-A)
ML= 0.01222 MG= 0.00173 QFLUX= 52583 HTP= 6463.2
PDT= 1.813 PDF= 1.034 ALFA=0.878 TOUT= 39.88, 39.88

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	1324.1	10391.2	103.42	7.0	0.113	13.06
OUTLET	39.3	1986.0	10333.1	102.04	4.4	0.112	14.83
MEAN	29.5	1655.1	10362.1	102.73	5.7	0.112	13.94

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1373.6	13.36	21.35	29.16	6674.4
11.4	1439.5	13.51	23.39	31.18	6707.9
19.1	1520.0	13.69	25.84	33.95	6465.5
27.9	1615.5	13.91	28.71	36.91	6405.9
41.9	1769.3	14.28	33.21	41.52	6354.2
53.3	1898.2	14.62	36.89	45.14	6422.9
57.2	1941.8	14.73	38.11	46.37	6430.3

WR2.09 (A)
ML= 0.01222 MG= 0.00225 QFLUX= 63595 HTP= 7284.2
PDT= 2.234 PDF= 1.586 ALFA=0.900 TOUT= 42.24, 42.22

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.5	1317.8	13535.3	104.80	7.1	0.113	16.85
OUTLET	42.0	2078.1	13456.9	102.04	4.1	0.112	19.52
MEAN	30.8	1697.9	13496.1	103.42	5.6	0.112	18.18

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1374.0	17.25	21.39	29.54	7720.9
11.4	1449.5	17.48	23.73	31.92	7702.1
19.1	1541.9	17.75	26.55	35.13	7375.1
27.9	1651.6	18.09	29.83	38.66	7193.4
41.9	1828.4	18.66	34.98	43.98	7100.8
53.3	1976.8	19.18	39.20	48.26	7092.9
57.2	2026.8	19.37	40.61	49.59	7162.2

WR2.10 (A)
ML= 0.01222 MG= 0.00250 QFLUX= 65030 HTP= 7643.7
PDT= 2.503 PDF= 1.862 ALFA=0.895 TOUT= 41.96, 41.92

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.5	1316.3	15044.3	104.80	7.1	0.113	18.63
OUTLET	42.0	2075.9	14953.1	102.73	4.1	0.112	21.63
MEAN	30.7	1696.1	14998.7	104.11	5.6	0.112	20.13

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1372.2	19.08	21.35	29.08	8313.6
11.4	1447.8	19.33	23.69	31.64	8116.6
19.1	1540.1	19.64	26.52	34.88	7732.2
27.9	1649.8	20.02	29.80	38.38	7576.7
41.9	1826.6	20.67	34.97	43.84	7366.0
53.3	1974.7	21.25	39.19	48.02	7438.7
57.2	2024.6	21.46	40.61	49.40	7477.9

WR2.11 (A)
ML= 0.01222 MG= 0.00280 QFLUX= 74797 HTP= 7812.3
PDT= 2.868 PDF= 2.344 ALFA=0.910 TOUT= 44.24, 44.21

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.3	1309.8	16859.9	106.18	7.1	0.113	20.70
OUTLET	44.3	2154.8	16756.0	102.73	4.0	0.112	24.45
MEAN	31.8	1732.3	16808.0	104.80	5.5	0.112	22.57

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1371.8	21.21	21.35	29.86	8677.0
11.4	1455.5	21.53	23.96	32.74	8432.3
19.1	1558.1	21.91	27.08	36.40	7983.8
27.9	1680.2	22.38	30.73	40.38	7744.2
41.9	1877.0	23.20	36.46	46.59	7431.3
53.3	2041.8	23.96	41.16	51.24	7496.6
57.2	2097.5	24.23	42.72	52.72	7574.9

WR2.12 (A)
ML= 0.01222 MG= 0.00378 QFLUX= 76840 HTP= 7777.1
PDT= 3.468 PDF= 2.965 ALFA=0.921 TOUT= 43.53, 43.48

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.0	1300.3	22780.8	106.87	7.2	0.113	27.58
OUTLET	43.0	2101.0	22602.6	103.42	4.1	0.112	32.53
MEAN	31.0	1700.7	22691.7	105.49	5.6	0.112	30.05

Z	RESL	VSG	TBULK	TWALL	NUTP	HTP
5.1	1358.2	28.25	20.97	29.11	9318.1	
11.4	1438.2	28.67	23.48	32.22	8707.1	
19.1	1536.0	29.18	26.49	35.99	8042.2	
27.9	1652.1	29.81	30.00	40.01	7668.6	
41.9	1838.7	30.90	35.52	46.21	7233.1	
53.3	1994.4	31.89	40.03	50.82	7204.2	
57.2	2046.8	32.24	41.54	52.32	7218.9	

WR2.13 (A-M)
ML= 0.01235 MG= 0.00517 QFLUX= 61949 HTP= 6094.1
PDT= 4.723 PDF= 4.344 ALFA=0.934 TOUT= 37.17, 37.42

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.6	1297.4	31212.0	109.62	7.2	0.114	36.79
OUTLET	37.0	1897.3	30913.7	104.80	4.6	0.113	42.44
MEAN	27.8	1597.4	31062.9	107.56	5.9	0.113	39.61

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1338.9	37.62	20.09	28.13	7620.9
11.4	1399.9	38.11	22.01	31.17	6710.8
19.1	1474.0	38.72	24.31	34.26	6204.9
27.9	1561.7	39.44	27.01	37.37	5970.9
41.9	1701.7	40.66	31.23	42.09	5729.0
53.3	1817.9	41.74	34.69	45.68	5681.9
57.2	1857.0	42.11	35.84	46.95	5632.5

WR2.14 (A-M)
ML= 0.01222 MG= 0.00838 QFLUX= 55787 HTP= 6185.6
PDT= 9.204 PDF= 8.963 ALFA=0.965 TOUT= 32.46, 32.92

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.8	1263.1	50665.3	119.28	7.4	0.114	54.65
OUTLET	32.6	1721.3	50133.8	110.31	5.1	0.112	63.98
MEAN	25.2	1492.2	50399.6	115.14	6.3	0.113	59.31

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1291.4	55.89	19.02	24.72	9686.6
11.4	1339.0	56.71	20.56	27.61	7850.3
19.1	1396.5	57.74	22.41	30.79	6626.7
27.9	1464.2	58.97	24.56	34.11	5844.3
41.9	1571.8	61.02	27.95	38.61	5261.8
53.3	1660.6	62.80	30.72	41.83	5063.0
57.2	1690.4	63.41	31.64	42.84	5031.8

WR2.15 (A-M)
ML= 0.01222 MG= 0.01328 QFLUX= 40558 HTP= 4147.7
PDT= 14.810 PDF= 14.617 ALFA=0.974 TOUT= 26.14, 25.99

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.2	1244.1	80391.6	133.07	7.5	0.114	77.75
OUTLET	26.5	1516.5	79891.5	117.90	5.9	0.112	92.00
MEAN	21.9	1380.3	80141.6	125.48	6.7	0.113	84.87

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1254.8	79.47	17.96	23.23	7630.6
11.4	1284.2	80.75	18.94	26.43	5382.1
19.1	1319.6	82.32	20.11	29.40	4352.1
27.9	1361.1	84.22	21.47	32.22	3774.7
41.9	1426.3	87.39	23.61	35.52	3422.1
53.3	1480.0	90.13	25.37	37.66	3322.7
57.2	1497.9	91.07	25.95	38.30	3308.0

WR2.16 (A-M)
ML= 0.01222 MG= 0.02169 QFLUX= 39789 HTP= 3509.0
PDT= 27.213 PDF= 27.096 ALFA=0.982 TOUT= 21.99, 21.99

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.9	1236.0	131374.6	159.96	7.5	0.114	105.46
OUTLET	24.1	1429.8	130746.7	132.38	6.3	0.112	132.14
MEAN	20.5	1332.9	131060.7	146.17	6.9	0.113	118.80

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1236.7	108.07	17.52	23.21	6932.8
11.4	1258.6	110.39	18.27	27.13	4465.1
19.1	1285.0	113.30	19.17	30.38	3544.7
27.9	1315.9	116.88	20.22	32.96	3128.5
41.9	1364.1	122.93	21.87	35.58	2913.4
53.3	1403.1	128.34	23.22	37.09	2885.5
57.2	1416.1	130.23	23.67	37.50	2894.0

WR3.01 (S)
ML= 0.03352 MG= 0.0000768 QFLUX= 40763 HTP= 4452.6
PDT= 3.020 PDF= 0.138 ALFA=0.525 TOUT= 24.54, 24.54

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.6	3440.0	464.9	104.80	7.4	0.311	0.57
OUTLET	24.1	4010.8	465.7	102.04	6.3	0.311	0.61
MEAN	20.9	3725.4	465.3	103.42	6.8	0.311	0.59

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3486.3	0.58	18.18	27.35	4431.6
11.4	3544.7	0.59	18.86	28.13	4387.3
19.1	3615.2	0.59	19.67	29.09	4323.2
27.9	3697.9	0.59	20.61	29.99	4348.2
41.9	3829.2	0.60	22.10	31.12	4523.1
53.3	3937.8	0.61	23.32	32.08	4663.9
57.2	3974.2	0.61	23.72	32.61	4601.4

WR3.02 (S)
ML= 0.03352 MG= 0.000116 QFLUX= 38821 HTP= 4471.4
PDT= 2.565 PDF= 0.069 ALFA=0.595 TOUT= 24.44, 24.44

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.7	3441.6	701.5	104.11	7.4	0.311	0.87
OUTLET	23.8	3984.0	703.1	101.35	6.3	0.311	0.93
MEAN	20.7	3712.8	702.3	102.73	6.9	0.311	0.90

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3485.6	0.88	18.17	26.98	4394.7
11.4	3541.1	0.89	18.82	27.57	4428.2
19.1	3608.1	0.89	19.59	28.38	4408.9
27.9	3686.8	0.90	20.49	29.19	4459.5
41.9	3811.6	0.91	21.90	30.51	4516.2
53.3	3914.7	0.92	23.06	31.64	4533.3
57.2	3949.3	0.92	23.44	31.99	4552.6

WR3.03 (S)
ML= 0.03352 MG= 0.000185 QFLUX= 38732 HTP= 4517.9
PDT= 2.248 PDF= -0.138 ALFA=0.611 TOUT= 24.44, 24.44

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.8	3455.7	1121.2	103.42	7.4	0.31	1.40
OUTLET	24.0	3996.4	1124.0	100.66	6.3	0.31	1.49
MEAN	20.9	3726.0	1122.6	102.04	6.8	0.31	1.44

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3499.5	1.42	18.33	27.12	4400.4
11.4	3554.9	1.43	18.98	27.71	4426.0
19.1	3621.7	1.44	19.74	28.43	4454.3
27.9	3700.2	1.45	20.64	29.23	4507.7
41.9	3824.6	1.47	22.05	30.54	4566.2
53.3	3927.4	1.48	23.20	31.61	4617.9
57.2	3961.8	1.48	23.58	31.90	4672.4

WR3.04 (S-C)
ML= 0.03352 MG= 0.000337 QFLUX= 38698 HTP= 4795.0
PDT= 2.379 PDF= 0.414 ALFA=0.677 TOUT= 24.22, 24.22

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.6	3440.6	2044.3	103.42	7.4	0.311	2.55
OUTLET	23.8	3977.6	2049.1	100.66	6.3	0.311	2.71
MEAN	20.7	3709.1	2046.7	102.04	6.9	0.311	2.63

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3483.9	2.59	18.16	26.26	4764.4
11.4	3539.0	2.61	18.79	26.87	4783.1
19.1	3605.3	2.62	19.56	27.72	4736.5
27.9	3683.3	2.64	20.45	28.62	4738.2
41.9	3806.9	2.67	21.86	30.01	4751.9
53.3	3909.0	2.70	23.00	30.83	4956.8
57.2	3943.3	2.71	23.38	30.96	5119.2

WR3.05 (C)
ML= 0.03352 MG= 0.000699 QFLUX= 53545 HTP= 6306.5
PDT= 3.020 PDF= 1.448 ALFA=0.746 TOUT= 26.82, 26.82

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.9	3459.0	4223.2	104.11	7.4	0.311	5.25
OUTLET	26.3	4202.0	4220.2	100.66	5.9	0.311	5.68
MEAN	22.1	3830.5	4221.7	102.04	6.6	0.311	5.46

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3518.2	5.34	18.56	26.95	6358.2
11.4	3593.9	5.38	19.43	27.92	6290.0
19.1	3685.4	5.42	20.48	29.07	6222.5
27.9	3793.1	5.47	21.71	30.27	6250.9
41.9	3964.4	5.56	23.63	32.05	6370.1
53.3	4106.4	5.63	25.20	33.63	6371.2
57.2	4154.1	5.66	25.72	34.27	6295.7

WR3.06 (C)
ML= 0.03352 MG= 0.00138 QFLUX= 76383 HTP= 9380.5
PDT= 3.316 PDF= 2.068 ALFA=0.801 TOUT= 29.42, 29.42

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.6	3432.6	8330.3	104.80	7.4	0.311	10.24
OUTLET	29.3	4481.0	8286.9	101.35	5.5	0.311	11.29
MEAN	23.4	3956.8	8308.6	102.73	6.5	0.311	10.77

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3514.8	10.44	18.53	26.95	9029.1
11.4	3620.7	10.53	19.76	28.13	9082.4
19.1	3749.1	10.64	21.22	29.55	9151.7
27.9	3900.7	10.77	22.93	31.15	9287.4
41.9	4142.9	10.99	25.62	33.64	9539.5
53.3	4344.6	11.17	27.82	35.63	9821.7
57.2	4412.6	11.23	28.55	36.39	9792.2

WR3.07 (C-A)
ML= 0.03352 MG= 0.00169 QFLUX= 83491 HTP= 10223.7
PDT= 3.682 PDF= 2.620 ALFA=0.828 TOUT= 30.48, 30.48

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.5	3430.6	10213.7	105.49	7.4	0.311	12.43
OUTLET	30.2	4569.5	10147.8	102.04	5.4	0.311	13.81
MEAN	23.9	4000.1	10180.7	104.11	6.4	0.311	13.12

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3519.5	12.68	18.59	26.94	9939.2
11.4	3634.2	12.80	19.92	28.28	9936.4
19.1	3773.5	12.94	21.50	29.84	9993.8
27.9	3938.1	13.12	23.36	31.57	10157.3
41.9	4201.4	13.40	26.27	34.35	10360.5
53.3	4420.9	13.65	28.65	36.56	10609.8
57.2	4494.9	13.73	29.44	37.30	10692.7

WR3.08 (A)
ML= 0.03352 MG= 0.00247 QFLUX=106402 HTP= 12772.0
PDT= 5.026 PDF= 4.206 ALFA=0.868 TOUT= 33.43, 33.43

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.7	3440.8	14943.6	108.94	7.4	0.311	17.68
OUTLET	33.5	4871.4	14799.7	104.11	5.0	0.311	20.16
MEAN	25.6	4156.1	14871.7	106.18	6.2	0.311	18.92

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3551.0	18.06	18.97	27.46	12438.7
11.4	3694.1	18.27	20.61	29.19	12334.8
19.1	3868.2	18.54	22.59	31.18	12352.9
27.9	4074.6	18.86	24.89	33.29	12656.1
41.9	4405.8	19.39	28.52	36.74	12979.8
53.3	4683.1	19.85	31.48	39.46	13414.1
57.2	4776.8	20.01	32.47	40.41	13492.5

WR3.09 (A)
ML= 0.03352 MG= 0.00521 QFLUX=139700 HTP= 15643.9
PDT= 10.177 PDF= 9.653 ALFA=0.918 TOUT= 36.28, 36.76

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.4	3421.3	31546.2	120.66	7.5	0.311	33.69
OUTLET	36.6	5164.4	31097.7	110.31	4.6	0.311	40.64
MEAN	27.0	4292.8	31321.9	115.14	6.0	0.311	37.16

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3552.7	34.52	19.02	27.16	16994.7
11.4	3726.4	35.12	21.02	29.55	16271.9
19.1	3937.9	35.88	23.42	32.24	15781.3
27.9	4189.5	36.79	26.23	35.22	15525.8
41.9	4594.0	38.34	30.63	39.81	15278.2
53.3	4933.2	39.71	34.23	43.46	15256.1
57.2	5047.8	40.20	35.43	44.71	15198.7

WR3.10 (A-M)
ML= 0.03352 MG= 0.00734 QFLUX=131835 HTP= 14018.9
PDT= 13.927 PDF= 13.582 ALFA=0.947 TOUT= 34.30, 35.00

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.5	3431.1	44415.4	129.62	7.4	0.311	44.13
OUTLET	34.9	4987.5	43779.5	115.83	4.8	0.311	54.02
MEAN	26.2	4209.3	44097.5	122.72	6.1	0.311	49.08

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3547.1	45.25	18.98	26.39	17610.7
11.4	3703.4	46.10	20.79	28.94	16038.5
19.1	3893.4	47.19	22.96	31.82	14820.0
27.9	4118.8	48.50	25.48	34.96	13901.3
41.9	4480.1	50.72	29.46	39.74	12887.2
53.3	4782.2	52.67	32.71	43.51	12320.0
57.2	4883.9	53.37	33.79	44.72	12196.2

WR3.11 (A-M)
ML= 0.03352 MG= 0.01296 QFLUX= 80243 HTP= 8130.3
PDT= 21.739 PDF= 21.580 ALFA=0.974 TOUT= 25.92, 26.55

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.6	3350.9	78570.2	149.61	7.6	0.311	67.19
OUTLET	26.4	4191.9	77858.5	127.55	5.9	0.311	82.65
MEAN	21.5	3771.4	78214.3	138.58	6.8	0.311	74.92

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3409.4	68.79	17.42	22.93	14417.4
11.4	3496.0	70.16	18.44	25.79	10851.1
19.1	3600.9	71.86	19.67	28.48	9075.6
27.9	3724.3	73.93	21.10	31.58	7660.1
41.9	3920.0	77.43	23.35	35.69	6531.3
53.3	4082.2	80.51	25.19	38.81	5943.1
57.2	4136.7	81.58	25.81	39.74	5812.5

WR3.12 (A-M)
ML= 0.03352 MG= 0.01884 QFLUX= 43308 HTP= 4836.5
PDT= 28.227 PDF= 28.130 ALFA=0.983 TOUT= 20.56, 20.66

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.6	3350.8	114256.1	168.92	7.6	0.311	86.66
OUTLET	21.4	3744.0	114082.7	140.65	6.7	0.311	107.01
MEAN	19.0	3547.4	114169.4	154.44	7.2	0.311	96.84

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3370.8	88.66	16.99	21.17	10314.0
11.4	3412.8	90.45	17.50	23.97	6666.5
19.1	3463.2	92.68	18.10	26.37	5226.6
27.9	3522.3	95.42	18.80	28.86	4310.1
41.9	3615.6	100.03	19.91	31.61	3716.8
53.3	3692.4	104.12	20.81	33.38	3466.4
57.2	3718.0	105.55	21.11	33.90	3407.3

WR3.13 (A-M)
ML= 0.03352 MG= 0.02150 QFLUX= 32485 HTP= 4374.9
PDT= 30.681 PDF= 30.543 ALFA=0.983 TOUT= 18.33, 18.43

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.1	3308.9	130555.2	179.95	7.7	0.311	92.58
OUTLET	19.5	3580.8	130606.9	148.92	7.1	0.311	114.03
MEAN	17.8	3444.8	130581.1	164.78	7.4	0.311	103.30

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3318.8	94.63	16.39	19.74	9623.6
11.4	3348.4	96.52	16.74	22.19	5944.2
19.1	3383.9	98.88	17.17	24.17	4633.8
27.9	3425.5	101.76	17.67	26.11	3856.5
41.9	3490.9	106.64	18.46	28.06	3392.0
53.3	3544.6	110.97	19.10	29.32	3191.0
57.2	3562.6	112.49	19.31	29.67	3150.1

WR3.14 (A-M)
ML= 0.03352 MG= 0.02443 QFLUX= 42277 HTP= 4161.4
PDT= 34.260 PDF= 34.129 ALFA=0.984 TOUT= 18.53, 18.55

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	3304.2	148363.7	196.50	7.8	0.311	96.19
OUTLET	20.5	3662.7	147975.2	162.02	6.9	0.311	119.38
MEAN	18.3	3483.4	148169.4	179.26	7.3	0.311	107.79

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3320.8	98.33	16.42	21.31	8571.4
11.4	3359.2	100.37	16.88	24.52	5512.2
19.1	3405.5	102.92	17.44	27.22	4315.8
27.9	3459.7	106.05	18.08	29.52	3702.0
41.9	3545.2	111.34	19.11	31.83	3335.8
53.3	3615.4	116.05	19.94	33.12	3222.8
57.2	3638.8	117.70	20.22	33.47	3206.9

WR4.01 (B)
ML= 0.11163 MG= 0.00000252 QFLUX= 42810 HTP= 5147.1
PDT= 6.819 PDF= 0.896 ALFA=0.031 TOUT= 23.82

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12646.0	16.4	113.76	6.7	1.04	0.02
OUTLET	23.7	13255.8	16.6	106.87	6.3	1.04	0.02
MEAN	22.7	12950.9	16.5	110.31	6.5	1.04	0.02

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12696.4	0.02	21.81	30.01	5220.3
11.4	12759.6	0.02	22.03	30.34	5145.9
19.1	12835.5	0.02	22.28	30.66	5107.3
27.9	12924.3	0.02	22.58	30.95	5117.5
41.9	13064.2	0.02	23.05	31.34	5166.4
53.3	13179.1	0.02	23.43	31.72	5174.9
57.2	13217.4	0.02	23.56	31.89	5145.9

WR4.02 (B)
ML= 0.11163 MG= 0.0000101 QFLUX= 43456 HTP= 5550.8
PDT= 6.702 PDF= 1.241 ALFA=0.109 TOUT= 23.79

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	12610.1	59.7	113.76	6.7	1.04	0.07
OUTLET	23.6	13228.6	60.4	106.87	6.3	1.04	0.08
MEAN	22.6	12919.4	60.0	110.31	6.5	1.04	0.07

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12661.3	0.07	21.69	29.44	5607.0
11.4	12725.3	0.07	21.91	29.80	5506.5
19.1	12802.3	0.07	22.17	30.07	5499.7
27.9	12892.4	0.07	22.47	30.29	5561.5
41.9	13034.3	0.07	22.95	30.76	5567.2
53.3	13150.8	0.08	23.34	31.14	5578.6
57.2	13189.7	0.08	23.47	31.31	5553.6

WR4.03 (B-S)
ML= 0.11163 MG= 0.0000214 QFLUX= 43835 HTP= 5927.8
PDT= 6.515 PDF= 1.310 ALFA=0.149 TOUT= 23.96

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	12667.7	124.5	113.07	6.6	1.04	0.15
OUTLET	23.8	13292.5	126.0	106.87	6.3	1.04	0.16
MEAN	22.8	12980.1	125.3	109.62	6.5	1.04	0.15

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12719.3	0.15	21.89	29.42	5818.2
11.4	12784.0	0.15	22.11	29.51	5919.3
19.1	12861.8	0.15	22.37	29.75	5940.3
27.9	12952.8	0.15	22.68	30.06	5934.6
41.9	13096.1	0.16	23.16	30.54	5939.7
53.3	13213.8	0.16	23.55	30.93	5941.4
57.2	13253.1	0.16	23.68	31.10	5915.9

WR4.04 (S)
ML= 0.11163 MG= 0.0000566 QFLUX= 51290 HTP= 6428.0
PDT= 5.964 PDF= 1.241 ALFA=0.227 TOUT= 24.22

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12623.5	339.7	112.38	6.7	1.04	0.40
OUTLET	24.0	13354.4	343.6	106.18	6.3	1.04	0.43
MEAN	22.8	12988.9	341.6	108.94	6.5	1.04	0.42

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12683.8	0.41	21.77	29.66	6495.0
11.4	12759.4	0.41	22.03	29.98	6445.0
19.1	12850.3	0.41	22.33	30.35	6392.8
27.9	12956.7	0.42	22.69	30.72	6387.1
41.9	13124.4	0.42	23.25	31.21	6449.0
53.3	13262.2	0.43	23.71	31.67	6453.0
57.2	13308.3	0.43	23.87	31.87	6412.1

WR4.05 (S)
ML= 0.11163 MG= 0.0000617 QFLUX= 52182 HTP= 6538.7
PDT= 5.909 PDF= 1.379 ALFA=0.253 TOUT= 24.24

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	12616.3	372.5	111.69	6.7	1.04	0.44
OUTLET	24.0	13359.8	376.8	106.18	6.3	1.04	0.48
MEAN	22.8	12988.0	374.6	108.94	6.5	1.04	0.46

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12677.6	0.45	21.75	29.67	6577.9
11.4	12754.5	0.45	22.01	29.99	6535.3
19.1	12847.0	0.45	22.32	30.37	6478.0
27.9	12955.2	0.46	22.68	30.64	6554.6
41.9	13125.9	0.47	23.26	31.24	6537.6
53.3	13266.0	0.47	23.72	31.68	6567.7
57.2	13312.9	0.47	23.88	31.87	6543.3

WR4.06 (S)
ML= 0.11163 MG= 0.000100 QFLUX= 60284 HTP= 7527.8
PDT= 5.633 PDF= 1.517 ALFA=0.328 TOUT= 24.54

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12644.1	593.2	111.69	6.7	1.04	0.70
OUTLET	24.5	13504.6	599.7	105.49	6.2	1.04	0.76
MEAN	23.1	13074.3	596.5	108.25	6.4	1.04	0.73

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12714.9	0.72	21.88	29.86	7539.2
11.4	12803.8	0.72	22.18	30.25	7462.0
19.1	12910.8	0.73	22.53	30.59	7479.6
27.9	13036.0	0.73	22.96	30.99	7502.8
41.9	13233.6	0.75	23.62	31.61	7543.7
53.3	13396.0	0.76	24.16	32.06	7636.8
57.2	13450.2	0.76	24.34	32.31	7574.4

WR4.07 (S)
ML= 0.11189 MG= 0.000188 QFLUX= 69306 HTP= 8410.2
PDT= 5.357 PDF= 2.068 ALFA=0.456 TOUT= 24.95

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12660.6	1129.1	111.00	6.7	1.05	1.34
OUTLET	24.9	13650.3	1140.9	105.49	6.1	1.05	1.46
MEAN	23.3	13155.4	1135.0	108.25	6.4	1.05	1.40

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12741.8	1.37	21.88	30.21	8309.1
11.4	12844.0	1.38	22.22	30.50	8366.5
19.1	12966.9	1.39	22.64	30.92	8360.2
27.9	13110.9	1.41	23.12	31.39	8381.8
41.9	13338.2	1.43	23.88	32.12	8415.3
53.3	13525.1	1.44	24.49	32.61	8548.1
57.2	13587.7	1.45	24.70	32.82	8545.3

WR4.08 (S)
ML= 0.11163 MG= 0.000243 QFLUX= 70019 HTP= 8539.6
PDT= 5.336 PDF= 2.344 ALFA=0.504 TOUT= 25.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12633.8	1452.9	110.31	6.7	1.04	1.74
OUTLET	24.9	13633.2	1468.1	104.80	6.1	1.04	1.88
MEAN	23.3	13133.5	1460.5	107.56	6.4	1.04	1.81

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12715.7	1.77	21.88	30.08	8531.1
11.4	12818.9	1.79	22.23	30.46	8497.0
19.1	12943.1	1.80	22.64	30.97	8406.8
27.9	13088.5	1.82	23.13	31.41	8465.8
41.9	13318.0	1.84	23.90	32.05	8598.7
53.3	13506.8	1.87	24.52	32.57	8710.5
57.2	13570.0	1.87	24.73	32.83	8658.3

WR4.09 (S-C)
ML= 0.11163 MG= 0.000338 QFLUX= 70101 HTP= 9022.8
PDT= 5.523 PDF= 2.896 ALFA=0.569 TOUT= 25.03

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	12617.6	2026.4	111.00	6.7	1.04	2.41
OUTLET	24.9	13616.7	2047.4	105.49	6.1	1.04	2.61
MEAN	23.2	13117.2	2036.9	108.25	6.4	1.04	2.51

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12699.4	2.46	21.82	29.63	8965.5
11.4	12802.5	2.48	22.17	29.88	9079.6
19.1	12926.7	2.50	22.59	30.44	8926.9
27.9	13072.0	2.52	23.08	30.89	8972.9
41.9	13301.5	2.56	23.84	31.63	9006.9
53.3	13490.3	2.59	24.47	32.12	9176.1
57.2	13553.4	2.60	24.68	32.38	9112.0

WR4.10 (C)
ML= 0.11163 MG= 0.000467 QFLUX= 78925 HTP= 10077.2
PDT= 6.109 PDF= 3.792 ALFA=0.626 TOUT= 25.56

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	12673.2	2795.1	113.76	6.6	1.04	3.25
OUTLET	25.5	13800.0	2821.7	107.56	6.0	1.04	3.54
MEAN	23.6	13236.6	2808.4	110.31	6.3	1.04	3.40

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12765.2	3.32	22.05	30.02	9880.8
11.4	12881.4	3.34	22.44	30.42	9876.8
19.1	13021.3	3.37	22.91	30.78	10015.9
27.9	13185.2	3.41	23.46	31.30	10065.9
41.9	13444.2	3.47	24.32	32.09	10166.4
53.3	13657.3	3.51	25.02	32.77	10211.8
57.2	13728.6	3.53	25.26	32.91	10341.8

WR4.11 (C)
ML= 0.11163 MG= 0.000636 QFLUX= 77805 HTP= 10720.5
PDT= 6.791 PDF= 4.619 ALFA=0.641 TOUT= 25.45

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12640.3	3810.1	113.76	6.7	1.04	4.43
OUTLET	25.3	13747.6	3846.7	106.87	6.1	1.04	4.86
MEAN	23.5	13194.0	3828.4	110.31	6.4	1.04	4.64

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12730.4	4.52	21.93	29.17	10731.9
11.4	12844.6	4.56	22.32	29.59	10682.5
19.1	12982.2	4.60	22.78	30.11	10602.4
27.9	13143.3	4.65	23.32	30.60	10688.7
41.9	13397.9	4.74	24.17	31.44	10711.4
53.3	13607.4	4.81	24.86	32.00	10915.3
57.2	13677.4	4.83	25.09	32.29	10829.5

WR4.12 (C-A)
ML= 0.11151 MG= 0.00113 QFLUX= 97521 HTP= 13287.5
PDT= 9.901 PDF= 8.136 ALFA=0.715 TOUT= 26.30

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	12628.0	6779.6	118.59	6.7	1.04	7.53
OUTLET	26.3	14014.2	6832.5	108.94	5.9	1.04	8.51
MEAN	24.0	13321.1	6806.0	113.76	6.3	1.04	8.02

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12740.1	7.70	22.06	29.55	12985.5
11.4	12882.8	7.79	22.53	29.92	13195.5
19.1	13054.7	7.89	23.11	30.53	13143.3
27.9	13256.3	8.02	23.79	31.18	13183.1
41.9	13575.2	8.22	24.85	32.12	13421.5
53.3	13838.0	8.39	25.72	32.94	13512.9
57.2	13926.0	8.45	26.01	33.20	13586.8

WR4.13 (A)
ML= 0.11151 MG= 0.00229 QFLUX=135355 HTP= 18025.2
PDT= 13.362 PDF= 11.997 ALFA=0.772 TOUT= 27.95

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	12608.6	13721.0	128.93	6.7	1.04	14.00
OUTLET	28.0	14522.8	13776.6	115.83	5.7	1.04	16.28
MEAN	24.8	13565.7	13748.8	122.72	6.2	1.04	15.14

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12761.6	14.33	22.13	29.69	17850.3
11.4	12957.8	14.53	22.79	30.38	17803.2
19.1	13194.7	14.78	23.59	31.22	17729.4
27.9	13472.8	15.08	24.52	32.06	17938.9
41.9	13913.8	15.57	25.97	33.47	18087.1
53.3	14278.1	15.99	27.16	34.48	18532.3
57.2	14400.2	16.14	27.56	34.90	18491.9

WR4.14 (A)
ML= 0.11163 MG= 0.00534 QFLUX=175229 HTP= 22652.7
PDT= 23.745 PDF= 22.752 ALFA=0.836 TOUT= 29.12

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	12591.8	31975.5	150.30	6.7	1.04	28.04
OUTLET	29.5	15012.6	31968.6	126.17	5.5	1.04	34.92
MEAN	25.5	13802.2	31972.0	138.58	6.1	1.04	31.48

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12782.1	28.80	22.13	29.71	23020.7
11.4	13029.5	29.40	22.96	30.60	22869.6
19.1	13328.5	30.15	23.96	31.72	22532.9
27.9	13680.2	31.06	25.13	32.89	22568.7
41.9	14238.9	32.59	26.96	34.72	22618.7
53.3	14701.3	33.96	28.46	36.23	22622.1
57.2	14856.5	34.44	28.96	36.74	22620.4

WR4.15 (A-M)
ML= 0.11151 MG= 0.01251 QFLUX=204664 HTP= 23388.0
PDT= 39.327 PDF= 38.679 ALFA=0.898 TOUT= 29.54

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.2	12492.5	74955.2	204.77	6.7	1.04	48.23
OUTLET	30.2	15197.9	74432.7	164.78	5.4	1.04	62.55
MEAN	25.7	13845.2	74693.9	184.78	6.1	1.04	55.39

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12701.3	49.55	21.96	29.49	27024.2
11.4	12977.7	50.78	22.89	30.79	25804.0
19.1	13311.9	52.32	24.02	32.30	24644.0
27.9	13705.2	54.23	25.33	33.98	23641.3
41.9	14330.6	57.49	27.38	36.72	21973.7
53.3	14848.6	60.45	29.07	38.89	20940.3
57.2	15022.6	61.49	29.63	39.56	20725.1

WR4.16 (A-M)
ML= 0.11151 MG= 0.01972 QFLUX=190164 HTP= 21009.0
PDT= 54.109 PDF= 53.778 ALFA=0.947 TOUT= 28.07

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.2	12480.4	118150.3	259.93	6.7	1.04	59.75
OUTLET	29.3	14901.7	117129.8	206.15	5.5	1.04	78.49
MEAN	25.2	13691.0	117640.0	233.04	6.1	1.04	69.12

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	12664.6	61.34	21.84	28.97	26531.3
11.4	12913.0	62.94	22.68	29.93	26133.3
19.1	13213.1	64.95	23.69	31.82	23359.6
27.9	13566.0	67.46	24.88	33.93	21004.4
41.9	14126.4	71.76	26.73	37.09	18421.5
53.3	14589.6	75.68	28.25	39.56	16925.4
57.2	14745.0	77.07	28.76	40.41	16439.4

WR5.01 (B)
ML= 0.33957 MG= 0.0000063 QFLUX=101094 HTP= 13122.3
PDT= 11.707 PDF= 5.723 ALFA=0.017 TOUT= 21.62, 21.62

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.9	36908.6	39.0	124.10	7.0	3.17	0.04
OUTLET	21.5	38326.5	39.4	112.38	6.7	3.17	0.05
MEAN	20.7	37617.6	39.2	117.90	6.8	3.17	0.04

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37026.1	0.04	20.06	27.52	13535.7
11.4	37173.1	0.04	20.22	27.87	13221.7
19.1	37349.8	0.04	20.42	28.17	13046.2
27.9	37556.3	0.04	20.65	28.42	13016.1
41.9	37881.5	0.05	21.02	28.76	13072.3
53.3	38148.3	0.05	21.32	28.99	13176.2
57.2	38237.4	0.05	21.42	29.11	13155.8

WR5.02 (B)
ML= 0.33957 MG= 0.0000277 QFLUX=101435 HTP= 13460.1
PDT= 12.010 PDF= 6.274 ALFA=0.058 TOUT= 21.38, 21.38

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	36751.8	163.1	125.48	7.0	3.17	0.17
OUTLET	21.3	38172.2	164.7	113.07	6.7	3.17	0.19
MEAN	20.5	37462.0	163.9	119.28	6.9	3.17	0.18

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	36869.4	0.17	19.88	27.21	13825.8
11.4	37016.7	0.17	20.04	27.55	13513.5
19.1	37193.7	0.18	20.24	27.84	13349.4
27.9	37400.6	0.18	20.48	28.08	13345.4
41.9	37726.4	0.19	20.84	28.39	13451.1
53.3	37993.7	0.19	21.14	28.63	13558.4
57.2	38082.9	0.19	21.24	28.77	13493.1

WR5.03 (B-S)
ML= 0.33957 MG= 0.0000554 QFLUX=101410 HTP= 14242.6
PDT= 12.417 PDF= 6.895 ALFA=0.095 TOUT= 21.57, 21.57

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.0	36930.3	329.6	126.17	7.0	3.17	0.34
OUTLET	21.5	38352.5	332.9	113.76	6.7	3.17	0.39
MEAN	20.7	37641.4	331.2	119.97	6.8	3.17	0.36

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37048.0	0.35	20.08	27.04	14548.0
11.4	37195.5	0.35	20.25	27.34	14282.9
19.1	37372.8	0.36	20.44	27.64	14094.4
27.9	37579.9	0.36	20.68	27.87	14103.5
41.9	37906.1	0.37	21.04	28.16	14270.4
53.3	38173.8	0.38	21.34	28.41	14372.0
57.2	38263.1	0.38	21.44	28.51	14355.6

WR5.04 (B-S)
ML= 0.33957 MG= 0.000128 QFLUX=101328 HTP= 14892.7
PDT= 13.065 PDF= 7.998 ALFA=0.174 TOUT= 21.18, 21.18

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.5	36549.3	775.0	127.55	7.1	3.17	0.79
OUTLET	21.1	37965.0	782.4	114.45	6.8	3.17	0.90
MEAN	20.3	37257.1	778.7	121.35	6.9	3.17	0.84

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	36666.5	0.81	19.65	26.33	15156.1
11.4	36813.3	0.82	19.82	26.62	14891.6
19.1	36989.7	0.83	20.02	26.87	14777.4
27.9	37195.9	0.84	20.25	27.11	14774.6
41.9	37520.6	0.87	20.61	27.42	14898.9
53.3	37787.0	0.88	20.91	27.64	15053.9
57.2	37875.9	0.89	21.01	27.78	14975.6

WR5.05 (B-S)
ML= 0.33957 MG= 0.000261 QFLUX=123715 HTP= 17014.0
PDT= 14.403 PDF= 10.135 ALFA=0.300 TOUT= 21.67, 21.67

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	36748.4	1566.6	131.69	7.0	3.17	1.55
OUTLET	21.7	38481.5	1580.4	117.21	6.7	3.17	1.78
MEAN	20.7	37615.0	1573.5	124.79	6.8	3.17	1.66

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	36891.5	1.58	19.91	27.08	17216.1
11.4	37071.1	1.60	20.11	27.42	16919.1
19.1	37286.9	1.63	20.35	27.71	16809.6
27.9	37539.3	1.66	20.63	27.96	16882.8
41.9	37937.0	1.71	21.08	28.33	17062.2
53.3	38263.4	1.75	21.44	28.60	17303.5
57.2	38372.4	1.76	21.57	28.76	17213.8

WR5.06 (S-F)
ML= 0.33957 MG= 0.000331 QFLUX=133869 HTP= 17886.7
PDT= 15.251 PDF= 11.238 ALFA=0.342 TOUT= 21.72, 21.72

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.6	36635.8	1994.4	134.45	7.0	3.17	1.93
OUTLET	21.7	38510.0	2010.7	119.28	6.6	3.17	2.22
MEAN	20.7	37572.9	2002.5	126.86	6.8	3.17	2.08

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	36790.5	1.97	19.79	27.17	18116.6
11.4	36984.6	2.00	20.01	27.52	17808.9
19.1	37217.9	2.03	20.27	27.86	17639.1
27.9	37490.8	2.07	20.58	28.13	17740.2
41.9	37920.9	2.13	21.06	28.52	17965.6
53.3	38274.0	2.19	21.46	28.83	18158.6
57.2	38391.9	2.20	21.59	28.98	18133.1

WR5.07 (S-F)
ML= 0.33957 MG= 0.000734 QFLUX=157698 HTP= 20688.7
PDT= 19.284 PDF= 16.133 ALFA=0.488 TOUT= 22.10, 22.10

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.6	36631.1	4418.1	146.17	7.0	3.17	3.94
OUTLET	22.1	38838.8	4447.6	126.86	6.6	3.17	4.63
MEAN	20.9	37735.0	4432.8	136.51	6.8	3.17	4.29

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	36812.7	4.02	19.82	27.32	20980.6
11.4	37041.2	4.08	20.07	27.70	20656.9
19.1	37315.9	4.16	20.38	28.12	20370.8
27.9	37637.3	4.26	20.74	28.46	20448.6
41.9	38144.1	4.41	21.31	28.91	20766.5
53.3	38560.4	4.54	21.78	29.26	21089.0
57.2	38699.5	4.59	21.93	29.44	21027.1

WR5.08 (S-F)
ML= 0.33957 MG= 0.00121 QFLUX=168527 HTP= 22514.8
PDT= 23.876 PDF= 21.373 ALFA=0.593 TOUT= 22.49, 22.49

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.9	36849.3	7254.1	158.58	7.0	3.17	5.96
OUTLET	22.5	39210.9	7296.1	135.14	6.5	3.17	7.17
MEAN	21.2	38030.1	7275.1	146.86	6.8	3.17	6.57

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37043.1	6.10	20.08	27.39	23015.6
11.4	37287.4	6.20	20.35	27.86	22438.1
19.1	37581.3	6.34	20.68	28.26	22234.8
27.9	37925.0	6.50	21.07	28.62	22305.8
41.9	38467.3	6.77	21.67	29.16	22538.0
53.3	38912.9	7.00	22.17	29.54	22867.4
57.2	39061.8	7.09	22.33	29.71	22868.5

WR5.09 (A-F)
ML= 0.33957 MG= 0.00165 QFLUX=180429 HTP= 24081.3
PDT= 28.792 PDF= 26.613 ALFA=0.639 TOUT= 22.66, 22.66

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.9	36845.5	9900.7	169.61	7.0	3.17	7.62
OUTLET	22.7	39371.9	9949.2	140.65	6.5	3.17	9.39
MEAN	21.3	38108.7	9925.0	155.13	6.7	3.17	8.50

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37052.5	7.81	20.09	27.42	24575.3
11.4	37313.7	7.96	20.38	27.92	23901.3
19.1	37628.0	8.15	20.73	28.37	23614.0
27.9	37995.7	8.39	21.14	28.72	23826.9
41.9	38576.0	8.78	21.79	29.24	24236.9
53.3	39052.9	9.14	22.32	29.68	24549.2
57.2	39212.2	9.26	22.50	29.86	24566.8

WR5.10 (A-F)
ML= 0.33957 MG= 0.00207 QFLUX=195333 HTP= 25025.6
PDT= 32.177 PDF= 29.992 ALFA=0.643 TOUT= 23.08, 23.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.1	37018.1	12447.5	180.64	7.0	3.17	9.01
OUTLET	23.1	39756.6	12496.9	148.23	6.4	3.17	11.21
MEAN	21.6	38387.3	12472.2	164.09	6.7	3.17	10.11

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37242.1	9.23	20.30	28.02	25264.0
11.4	37525.1	9.42	20.62	28.46	24906.3
19.1	37865.6	9.66	21.00	28.92	24659.9
27.9	38264.2	9.95	21.44	29.29	24891.6
41.9	38893.3	10.45	22.14	29.94	25084.0
53.3	39410.5	10.90	22.72	30.42	25411.7
57.2	39583.4	11.05	22.91	30.58	25518.4

WR5.11 (A-F)
ML= 0.33957 MG= 0.00248 QFLUX=195005 HTP= 26061.8
PDT= 35.177 PDF= 33.163 ALFA=0.667 TOUT= 23.03, 23.03

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.0	37015.4	14901.0	188.91	7.0	3.17	10.30
OUTLET	23.1	39745.8	14953.8	153.75	6.4	3.17	12.93
MEAN	21.6	38380.6	14927.4	171.68	6.7	3.17	11.61

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37238.5	10.55	20.30	27.57	26758.5
11.4	37520.7	10.78	20.62	28.11	26016.4
19.1	37860.3	11.06	20.99	28.61	25618.9
27.9	38257.7	11.41	21.44	28.98	25875.5
41.9	38884.9	12.01	22.14	29.63	26032.8
53.3	39400.6	12.55	22.71	30.08	26493.3
57.2	39573.1	12.74	22.90	30.25	26572.8

WR5.12 (A-F)
ML= 0.33957 MG= 0.00353 QFLUX=194986 HTP= 26483.1
PDT= 38.872 PDF= 37.024 ALFA=0.697 TOUT= 23.11, 23.11

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.1	37071.4	21218.6	201.32	6.9	3.17	13.76
OUTLET	23.1	39794.0	21281.6	162.71	6.4	3.17	17.42
MEAN	21.6	38432.7	21250.1	182.02	6.7	3.17	15.59

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37293.2	14.11	20.36	27.41	27610.7
11.4	37574.7	14.42	20.68	27.98	26672.2
19.1	37913.4	14.82	21.06	28.50	26185.0
27.9	38309.8	15.30	21.50	28.94	26197.5
41.9	38935.4	16.14	22.19	29.62	26268.5
53.3	39449.8	16.89	22.77	30.04	26845.9
57.2	39621.8	17.15	22.96	30.21	26899.3

WR5.13 (A-F)
ML= 0.33957 MG= 0.00515 QFLUX=207465 HTP= 28234.7
PDT= 45.801 PDF= 44.333 ALFA=0.766 TOUT= 23.13, 23.23

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.1	37083.3	30955.8	224.77	6.9	3.17	17.97
OUTLET	23.3	39971.2	31004.6	179.26	6.4	3.17	23.05
MEAN	21.7	38527.2	30980.2	202.01	6.7	3.17	20.51

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37317.8	18.43	20.39	27.24	30211.8
11.4	37616.3	18.86	20.72	27.96	28641.3
19.1	37975.5	19.41	21.13	28.56	27901.4
27.9	38396.0	20.08	21.59	29.03	27904.8
41.9	39059.8	21.24	22.33	29.76	27987.2
53.3	39605.7	22.29	22.94	30.28	28301.2
57.2	39788.3	22.67	23.14	30.49	28259.7

WR5.14 (A-F)
ML= 0.33957 MG= 0.00817 QFLUX=218076 HTP= 29159.1
PDT= 59.191 PDF= 57.777 ALFA=0.767 TOUT= 23.18, 23.45

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.3	37198.8	49036.8	270.27	6.9	3.17	23.71
OUTLET	23.6	40220.0	49027.0	211.67	6.3	3.17	30.97
MEAN	21.9	38709.4	49031.9	240.62	6.6	3.17	27.33

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37443.1	24.31	20.53	27.27	32276.3
11.4	37755.4	24.92	20.88	28.16	29952.9
19.1	38131.3	25.70	21.30	28.83	28957.0
27.9	38571.3	26.67	21.79	29.41	28638.4
41.9	39266.0	28.34	22.57	30.18	28673.6
53.3	39837.5	29.86	23.19	30.73	28968.3
57.2	40028.5	30.40	23.41	30.92	29061.4

WR5.15 (A-F)
ML= 0.33957 MG= 0.01024 QFLUX=218165 HTP= 29367.5
PDT= 66.120 PDF= 64.948 ALFA=0.804 TOUT=23.48, 23.82

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.7	37560.4	61411.6	293.02	6.8	3.17	27.46
OUTLET	24.0	40577.9	61376.8	226.83	6.3	3.17	36.15
MEAN	22.3	39069.2	61394.2	259.93	6.6	3.17	31.80

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	37803.6	28.16	20.94	27.51	33101.3
11.4	38115.6	28.89	21.28	28.41	30576.9
19.1	38491.1	29.82	21.71	29.17	29192.0
27.9	38930.7	30.98	22.19	29.75	28872.4
41.9	39624.8	32.99	22.96	30.58	28665.7
53.3	40195.7	34.82	23.59	31.14	28939.4
57.2	40386.6	35.48	23.80	31.38	28836.6

WR6.01 (B)
ML= 0.67964 MG= 0.0000478 QFLUX=168253 HTP= 23389.7
PDT= 26.400 PDF= 20.615 ALFA=0.048 TOUT= 21.87, 21.87

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.5	74875.8	284.1	150.30	6.9	6.34	0.25
OUTLET	21.8	77243.5	286.9	124.10	6.6	6.35	0.30
MEAN	21.1	76059.7	285.5	137.20	6.8	6.35	0.28

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75072.1	0.25	20.59	27.69	23702.6
11.4	75317.8	0.26	20.73	27.87	23555.5
19.1	75613.1	0.27	20.89	28.13	23237.6
27.9	75957.9	0.27	21.09	28.32	23272.2
41.9	76501.0	0.29	21.39	28.60	23343.7
53.3	76946.2	0.30	21.64	28.80	23519.8
57.2	77094.8	0.30	21.72	28.92	23406.2

WR6.02 (B)
ML= 0.67964 MG= 0.0000894 QFLUX=164128 HTP= 23914.4
PDT= 27.420 PDF= 21.787 ALFA=0.073 TOUT= 21.99, 21.99

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	75139.6	536.0	155.13	6.8	6.34	0.45
OUTLET	21.9	77451.4	541.2	127.55	6.6	6.35	0.56
MEAN	21.3	76295.5	538.6	141.34	6.7	6.35	0.51

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75331.3	0.47	20.74	27.53	24152.9
11.4	75571.2	0.48	20.87	27.68	24093.8
19.1	75859.5	0.48	21.03	27.92	23815.6
27.9	76196.3	0.50	21.22	28.12	23782.6
41.9	76726.5	0.52	21.52	28.40	23851.4
53.3	77161.2	0.55	21.76	28.58	24055.8
57.2	77306.3	0.55	21.84	28.70	23939.4

WR6.03 (B)
ML= 0.67964 MG= 0.000121 QFLUX=172103 HTP= 24089.3
PDT= 27.972 PDF= 22.408 ALFA=0.092 TOUT= 21.99, 21.99

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	75004.2	723.5	158.58	6.9	6.34	0.60
OUTLET	21.9	77427.3	730.1	130.31	6.6	6.35	0.74
MEAN	21.2	76215.7	726.8	144.79	6.7	6.35	0.67

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75205.0	0.61	20.67	27.75	24281.2
11.4	75456.5	0.62	20.81	27.91	24215.9
19.1	75758.6	0.64	20.98	28.17	23938.2
27.9	76111.5	0.66	21.17	28.36	23964.9
41.9	76667.3	0.69	21.48	28.64	24037.6
53.3	77123.0	0.72	21.74	28.83	24290.3
57.2	77275.1	0.73	21.82	28.93	24237.5

WR6.04 (B)
ML= 0.67964 MG= 0.000171 QFLUX=178546 HTP= 24580.4
PDT= 29.082 PDF= 23.718 ALFA=0.120 TOUT= 21.97, 21.97

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.5	74917.6	1029.2	162.71	6.9	6.34	0.83
OUTLET	21.9	77430.5	1038.2	133.07	6.6	6.35	1.03
MEAN	21.2	76174.0	1033.7	148.23	6.7	6.35	0.93

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75125.8	0.85	20.62	27.82	24782.5
11.4	75386.5	0.87	20.77	28.01	24665.6
19.1	75699.8	0.89	20.94	28.26	24414.6
27.9	76065.8	0.91	21.15	28.46	24446.4
41.9	76642.2	0.96	21.47	28.74	24566.8
53.3	77114.9	1.00	21.73	28.94	24793.3
57.2	77272.7	1.01	21.82	29.06	24694.0

WR6.05 (B)
ML= 0.67964 MG= 0.000209 QFLUX=186298 HTP= 24869.4
PDT= 29.633 PDF= 24.407 ALFA=0.141 TOUT= 22.22, 22.22

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.7	75183.4	1257.2	164.78	6.8	6.34	1.00
OUTLET	22.1	77809.1	1268.0	135.14	6.6	6.35	1.24
MEAN	21.4	76496.3	1262.6	150.30	6.7	6.35	1.12

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75400.9	1.02	20.78	28.18	25149.3
11.4	75673.3	1.05	20.93	28.38	25002.8
19.1	76000.6	1.07	21.11	28.67	24665.0
27.9	76383.0	1.10	21.33	28.86	24734.8
41.9	76985.3	1.16	21.66	29.17	24822.3
53.3	77479.2	1.21	21.93	29.36	25099.4
57.2	77644.1	1.22	22.03	29.48	25004.0

WR6.06 (B-F)
ML= 0.67964 MG= 0.000294 QFLUX=186247 HTP= 25377.0
PDT= 32.039 PDF= 27.027 ALFA=0.183 TOUT= 22.12, 22.12

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	75047.6	1767.2	170.99	6.9	6.34	1.35
OUTLET	22.0	77670.2	1781.6	139.27	6.6	6.35	1.69
MEAN	21.3	76358.9	1774.4	155.13	6.7	6.35	1.52

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75264.7	1.39	20.70	27.95	25667.2
11.4	75536.8	1.42	20.86	28.16	25474.7
19.1	75863.7	1.45	21.04	28.46	25107.9
27.9	76245.7	1.50	21.25	28.64	25202.1
41.9	76847.3	1.58	21.58	28.92	25385.0
53.3	77340.7	1.64	21.86	29.12	25654.7
57.2	77505.4	1.67	21.95	29.23	25586.5

WR6.07 (B-F)
ML= 0.67964 MG= 0.000333 QFLUX=186263 HTP= 25415.6
PDT= 32.315 PDF= 27.441 ALFA=0.201 TOUT= 22.25, 22.25

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.7	75205.0	1999.0	177.19	6.8	6.34	1.48
OUTLET	22.1	77829.6	2014.5	144.79	6.6	6.35	1.84
MEAN	21.4	76517.3	2006.7	160.65	6.7	6.35	1.66

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75422.2	1.52	20.79	28.06	25603.0
11.4	75694.5	1.55	20.94	28.26	25446.9
19.1	76021.7	1.59	21.12	28.53	25143.1
27.9	76404.0	1.64	21.34	28.71	25290.7
41.9	77006.1	1.72	21.67	29.01	25414.5
53.3	77499.8	1.79	21.94	29.19	25725.6
57.2	77664.6	1.82	22.04	29.30	25676.2

WR6.08 (B-F)
ML= 0.67964 MG= 0.000613 QFLUX=189436 HTP= 27455.7
PDT= 37.486 PDF= 33.025 ALFA=0.274 TOUT= 22.20, 22.20

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	75135.4	3682.2	195.12	6.8	6.34	2.47
OUTLET	22.1	77802.4	3706.9	157.89	6.6	6.35	3.11
MEAN	21.4	76468.9	3694.6	176.50	6.7	6.35	2.79

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75356.0	2.54	20.75	27.58	27726.6
11.4	75632.7	2.59	20.91	27.82	27403.5
19.1	75965.1	2.66	21.09	28.08	27101.4
27.9	76353.6	2.74	21.31	28.26	27260.4
41.9	76965.5	2.89	21.65	28.53	27537.5
53.3	77467.3	3.02	21.93	28.74	27839.0
57.2	77634.8	3.06	22.02	28.84	27817.4

WR6.09 (B-F)
ML= 0.67964 MG= 0.000844 QFLUX=186121 HTP= 27694.8
PDT= 41.506 PDF= 37.369 ALFA=0.323 TOUT= 22.20, 22.20

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	75089.0	5066.5	208.22	6.9	6.34	3.19
OUTLET	22.1	77707.1	5097.7	166.85	6.6	6.35	4.04
MEAN	21.3	76398.0	5082.1	187.53	6.7	6.35	3.61

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75305.4	3.27	20.72	27.36	28040.5
11.4	75577.0	3.34	20.88	27.58	27749.3
19.1	75903.5	3.43	21.06	27.84	27435.3
27.9	76284.9	3.55	21.27	28.05	27465.4
41.9	76885.5	3.74	21.61	28.34	27632.9
53.3	77378.1	3.92	21.88	28.50	28133.1
57.2	77542.6	3.98	21.97	28.60	28087.7

WR6.10 (F)
ML= 0.67964 MG= 0.00206 QFLUX=204648 HTP= 30190.8
PDT= 57.812 PDF= 54.606 ALFA=0.474 TOUT= 22.25, 22.25

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	74993.9	12350.4	261.31	6.9	6.34	6.18
OUTLET	22.2	77867.1	12399.5	204.08	6.6	6.35	8.05
MEAN	21.4	76430.5	12375.0	233.04	6.7	6.35	7.12

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75230.8	6.34	20.68	27.37	30599.6
11.4	75528.9	6.50	20.85	27.61	30289.6
19.1	75887.1	6.70	21.05	27.88	29937.5
27.9	76305.7	6.95	21.28	28.13	29912.0
41.9	76965.0	7.38	21.65	28.43	30195.3
53.3	77505.8	7.77	21.95	28.66	30539.4
57.2	77686.4	7.91	22.05	28.77	30496.3

WR6.11 (F)
ML= 0.67964 MG= 0.00243 QFLUX=217884 HTP= 30990.2
PDT= 61.038 PDF= 58.053 ALFA=0.514 TOUT= 22.54, 22.54

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.8	75352.7	14560.2	275.10	6.8	6.34	6.95
OUTLET	22.5	78416.4	14610.8	213.73	6.5	6.35	9.06
MEAN	21.6	76884.5	14585.5	244.07	6.7	6.35	8.00

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75605.1	7.12	20.89	27.78	31614.2
11.4	75922.8	7.30	21.07	28.07	31094.1
19.1	76304.7	7.53	21.28	28.38	30690.4
27.9	76751.0	7.81	21.53	28.62	30727.9
41.9	77454.2	8.29	21.92	28.96	30997.0
53.3	78031.0	8.73	22.24	29.21	31284.9
57.2	78223.6	8.89	22.35	29.33	31223.0

WR6.12 (F)
ML= 0.67964 MG= 0.00369 QFLUX=216752 HTP= 31216.8
PDT= 69.815 PDF= 67.154 ALFA=0.565 TOUT= 22.44, 22.44

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.7	75236.2	22117.3	304.05	6.8	6.34	9.54
OUTLET	22.4	78276.3	22178.3	234.42	6.5	6.35	12.54
MEAN	21.5	76756.2	22147.8	268.89	6.7	6.35	11.04

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	75486.1	9.78	20.83	27.63	31827.2
11.4	75801.5	10.03	21.00	27.91	31387.1
19.1	76180.5	10.35	21.22	28.24	30819.3
27.9	76623.5	10.75	21.46	28.47	30920.4
41.9	77321.3	11.44	21.85	28.79	31236.1
53.3	77893.8	12.08	22.17	29.03	31583.0
57.2	78085.0	12.30	22.27	29.17	31480.8

WR6.13 (F)
ML= 0.67964 MG= 0.00533 QFLUX=231457 HTP= 32486.4
PDT= 80.440 PDF= 78.116 ALFA=0.616 TOUT= 22.88, 22.88

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.0	75853.9	31945.2	344.04	6.8	6.34	12.20
OUTLET	22.8	79104.2	32004.3	264.07	6.5	6.35	16.12
MEAN	21.9	77479.1	31974.7	304.05	6.6	6.35	14.16

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	76120.6	12.50	21.18	28.09	33436.9
11.4	76457.7	12.83	21.37	28.41	32860.0
19.1	76863.0	13.25	21.59	28.78	32213.3
27.9	77336.6	13.77	21.86	29.04	32205.3
41.9	78082.8	14.68	22.27	29.41	32424.5
53.3	78695.1	15.51	22.61	29.72	32578.9
57.2	78899.5	15.81	22.72	29.86	32451.7

WR6.14 (F)
ML= 0.67964 MG= 0.00775 QFLUX=233245 HTP= 32624.9
PDT= 93.367 PDF= 91.216 ALFA=0.651 TOUT= 23.18, 23.18

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.4	76501.1	46400.5	389.55	6.7	6.35	15.70
OUTLET	23.2	79775.9	46458.6	295.78	6.4	6.35	20.91
MEAN	22.3	78138.5	46429.5	342.66	6.6	6.35	18.30

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	76769.0	16.09	21.54	28.26	34701.9
11.4	77108.8	16.53	21.73	28.72	33359.6
19.1	77517.2	17.08	21.96	29.13	32504.5
27.9	77994.5	17.77	22.22	29.42	32391.6
41.9	78746.6	18.98	22.64	29.88	32230.3
53.3	79363.6	20.09	22.98	30.21	32303.5
57.2	79569.7	20.49	23.09	30.32	32304.7

WR7.01 (B)
ML= 0.90656 MG= 0.0000919 QFLUX=165244 HTP= 29487.8
PDT= 41.085 PDF= 35.370 ALFA=0.059 TOUT= 22.78, 22.78

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	102872.6	552.5	182.02	6.6	8.46	0.40
OUTLET	22.7	105218.2	557.9	141.34	6.5	8.46	0.52
MEAN	22.2	104045.4	555.2	162.02	6.6	8.46	0.46

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103067.3	0.41	21.82	27.22	30609.8
11.4	103311.0	0.42	21.92	27.49	29648.0
19.1	103603.6	0.44	22.04	27.67	29356.7
27.9	103945.4	0.45	22.19	27.86	29175.6
41.9	104483.3	0.48	22.41	28.03	29396.4
53.3	104924.0	0.51	22.59	28.18	29619.0
57.2	105071.1	0.52	22.66	28.25	29560.0

WR7.02 (B)
ML= 0.90656 MG= 0.000150 QFLUX=166664 HTP= 30387.8
PDT= 43.305 PDF= 37.714 ALFA=0.078 TOUT= 22.73, 22.73

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	102690.3	899.1	189.60	6.7	8.46	0.62
OUTLET	22.7	105054.3	907.5	146.86	6.5	8.46	0.82
MEAN	22.2	103872.3	903.3	168.23	6.6	8.46	0.72

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	102886.5	0.64	21.75	27.00	31714.2
11.4	103132.1	0.66	21.85	27.29	30637.6
19.1	103427.0	0.68	21.97	27.50	30167.5
27.9	103771.5	0.70	22.12	27.67	30029.5
41.9	104313.6	0.75	22.34	27.84	30311.2
53.3	104757.8	0.79	22.53	27.99	30476.9
57.2	104906.0	0.80	22.59	28.05	30518.4

WR7.03 (B)
ML= 0.90946 MG= 0.000196 QFLUX=167196 HTP= 30886.3
PDT= 44.877 PDF= 39.368 ALFA=0.096 TOUT= 23.08, 23.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	103880.4	1176.4	197.19	6.6	8.49	0.79
OUTLET	23.0	106258.3	1187.1	152.37	6.4	8.49	1.03
MEAN	22.5	105069.3	1181.7	175.12	6.5	8.49	0.91

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	104077.7	0.81	22.10	27.30	32136.6
11.4	104324.7	0.83	22.21	27.58	31056.1
19.1	104621.4	0.86	22.33	27.78	30651.8
27.9	104967.9	0.89	22.47	27.93	30623.4
41.9	105513.2	0.94	22.69	28.13	30796.0
53.3	105960.1	1.00	22.88	28.27	31004.4
57.2	106109.2	1.01	22.94	28.36	30898.8

WR7.04 (B)
ML= 0.90883 MG= 0.000248 QFLUX=172532 HTP= 31036.2
PDT= 44.919 PDF= 39.506 ALFA=0.113 TOUT= 23.08, 23.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	103740.3	1486.2	201.32	6.6	8.49	0.98
OUTLET	23.0	106193.6	1499.1	156.51	6.4	8.49	1.28
MEAN	22.5	104967.0	1492.7	178.57	6.5	8.49	1.13

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103943.8	1.00	22.08	27.41	32373.4
11.4	104198.6	1.03	22.18	27.69	31288.3
19.1	104504.7	1.06	22.31	27.91	30843.2
27.9	104862.2	1.10	22.46	28.07	30745.5
41.9	105424.8	1.17	22.69	28.28	30888.6
53.3	105885.9	1.23	22.88	28.43	31125.4
57.2	106039.7	1.25	22.94	28.49	31097.0

WR7.05 (B-F)
ML= 0.90719 MG= 0.000282 QFLUX=178133 HTP= 30550.8
PDT= 46.587 PDF= 41.230 ALFA=0.126 TOUT= 22.98, 22.98

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.8	103192.0	1687.2	205.46	6.6	8.47	1.09
OUTLET	22.9	105722.1	1701.3	158.58	6.5	8.47	1.43
MEAN	22.4	104457.1	1694.2	182.02	6.5	8.47	1.26

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103401.8	1.12	21.93	27.51	31925.4
11.4	103664.6	1.14	22.04	27.82	30806.3
19.1	103980.3	1.18	22.17	28.04	30317.4
27.9	104349.0	1.23	22.32	28.21	30274.2
41.9	104929.2	1.30	22.56	28.42	30421.9
53.3	105404.7	1.37	22.76	28.58	30647.3
57.2	105563.4	1.40	22.83	28.67	30471.8

WR7.06 (B-F)
ML= 0.90946 MG= 0.000326 QFLUX=194396 HTP= 31452.4
PDT= 48.200 PDF= 42.954 ALFA=0.141 TOUT= 23.16, 23.16

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.9	103696.6	1947.7	210.98	6.6	8.49	1.22
OUTLET	23.1	106460.8	1963.2	162.71	6.4	8.49	1.61
MEAN	22.5	105078.7	1955.4	186.85	6.5	8.49	1.41

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103925.8	1.25	22.04	27.97	32778.8
11.4	104212.8	1.29	22.16	28.31	31619.4
19.1	104557.6	1.33	22.30	28.52	31229.3
27.9	104960.4	1.38	22.47	28.71	31153.8
41.9	105594.3	1.47	22.73	28.93	31344.0
53.3	106113.9	1.55	22.94	29.09	31618.8
57.2	106287.3	1.58	23.01	29.20	31441.6

WR7.07 (B-F)
ML= 0.90719 MG= 0.000386 QFLUX=203444. NUTP= 603.2 HTP= 31197.5
PDT= 49.338 PDF= 44.195 ALFA=0.153 TOUT= 23.21, 23.21

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.9	103434.2	2315.9	215.80	6.6	8.47	1.42
OUTLET	23.1	106327.3	2333.5	166.85	6.4	8.47	1.86
MEAN	22.5	104880.7	2324.7	190.98	6.5	8.47	1.64

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103673.9	1.46	22.04	28.24	32800.4
11.4	103974.3	1.49	22.17	28.66	31355.3
19.1	104335.2	1.54	22.32	28.88	30997.0
27.9	104756.7	1.60	22.49	29.07	30947.1
41.9	105420.2	1.70	22.77	29.33	30989.7
53.3	105964.1	1.80	22.99	29.49	31331.5
57.2	106145.7	1.83	23.07	29.59	31170.2

WR7.08 (F)
ML= 0.90719 MG= 0.000892 QFLUX=206392 HTP= 33275.6
PDT= 58.405 PDF= 53.847 ALFA=0.255 TOUT= 23.26, 23.26

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.9	103370.7	5335.8	257.17	6.6	8.47	2.74
OUTLET	23.1	106302.8	5366.7	198.57	6.4	8.47	3.60
MEAN	22.5	104836.8	5351.3	227.52	6.5	8.47	3.17

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103613.4	2.82	22.02	28.11	33895.1
11.4	103917.9	2.89	22.14	28.32	33394.8
19.1	104283.6	2.98	22.29	28.56	32954.2
27.9	104710.8	3.09	22.47	28.73	32961.6
41.9	105383.4	3.29	22.75	28.97	33197.3
53.3	105934.7	3.47	22.98	29.10	33748.6
57.2	106118.7	3.53	23.06	29.18	33714.5

WR7.09 (F)
ML= 0.90719 MG= 0.00162 QFLUX=207130 HTP= 35067.6
PDT= 69.195 PDF= 65.154 ALFA=0.340 TOUT= 23.28, 23.28

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.9	103428.9	9662.5	301.30	6.6	8.47	4.23
OUTLET	23.2	106369.0	9705.8	232.35	6.4	8.47	5.56
MEAN	22.6	104898.9	9684.2	266.82	6.5	8.47	4.90

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103671.9	4.34	22.04	27.85	35635.4
11.4	103977.2	4.45	22.17	28.05	35193.6
19.1	104344.0	4.59	22.32	28.29	34712.1
27.9	104772.5	4.77	22.50	28.47	34687.7
41.9	105446.9	5.07	22.78	28.68	35079.5
53.3	105999.8	5.36	23.01	28.84	35524.6
57.2	106184.3	5.45	23.08	28.91	35575.7

WR7.10 (F)
ML= 0.90719 MG= 0.00257 QFLUX=229199 HTP= 35608.1
PDT= 79.978 PDF= 76.393 ALFA=0.413 TOUT= 23.10, 23.10

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.9	103304.9	15391.8	346.11	6.6	8.47	5.87
OUTLET	23.2	106555.4	15440.9	266.13	6.4	8.47	7.73
MEAN	22.6	104930.1	15416.3	306.12	6.5	8.47	6.80

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103573.2	6.02	22.00	28.24	36674.4
11.4	103910.7	6.18	22.14	28.52	35929.5
19.1	104316.1	6.38	22.31	28.80	35318.5
27.9	104789.8	6.62	22.51	29.01	35261.2
41.9	105535.6	7.05	22.82	29.28	35473.0
53.3	106147.1	7.44	23.07	29.46	35875.5
57.2	106351.2	7.58	23.15	29.56	35826.1

WR7.11 (F)
ML= 0.90719 MG= 0.00325 QFLUX=245213 HTP= 37212.7
PDT= 87.362 PDF= 83.839 ALFA=0.428 TOUT= 23.60, 23.60

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	103545.9	19441.2	375.07	6.6	8.47	6.86
OUTLET	23.4	107025.6	19490.1	287.51	6.4	8.47	9.04
MEAN	22.7	105285.7	19465.6	330.94	6.5	8.47	7.95

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103832.9	7.03	22.11	28.52	38212.6
11.4	104194.0	7.21	22.26	28.79	37547.1
19.1	104628.0	7.44	22.44	29.08	36904.4
27.9	105135.1	7.74	22.65	29.29	36905.5
41.9	105933.5	8.24	22.98	29.58	37175.2
53.3	106588.3	8.70	23.25	29.83	37278.0
57.2	106806.9	8.87	23.34	29.88	37483.5

WR7.12 (F)
ML= 0.90719 MG= 0.00317 QFLUX=256121 HTP= 37355.2
PDT= 83.673 PDF= 80.185 ALFA=0.431 TOUT= 23.60, 23.53

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	103454.2	18938.3	360.59	6.6	8.47	6.94
OUTLET	23.5	107088.9	18987.5	277.16	6.4	8.47	9.14
MEAN	22.7	105271.5	18962.9	318.53	6.5	8.47	8.04

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	103753.9	7.11	22.08	28.73	38451.1
11.4	104131.1	7.30	22.23	29.03	37643.1
19.1	104584.4	7.53	22.42	29.33	37067.9
27.9	105114.0	7.83	22.64	29.57	36991.3
41.9	105948.0	8.34	22.98	29.87	37233.1
53.3	106632.0	8.80	23.27	30.09	37561.9
57.2	106860.4	8.97	23.36	30.13	37884.4

WR7.13 (F)
ML= 0.90719 MG= 0.00395 QFLUX=257758 HTP= 38195.5
PDT= 90.830 PDF= 87.493 ALFA=0.450 TOUT= 24.24, 24.24

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.6	104992.5	23567.2	388.17	6.5	8.47	8.05
OUTLET	24.1	108665.9	23623.1	297.16	6.3	8.47	10.63
MEAN	23.3	106829.2	23595.1	342.66	6.4	8.47	9.34

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	105295.1	8.25	22.72	28.86	41941.3
11.4	105676.4	8.47	22.87	29.56	38531.1
19.1	106134.5	8.74	23.06	29.88	37772.0
27.9	106669.8	9.09	23.28	30.13	37633.4
41.9	107512.8	9.68	23.63	30.46	37760.6
53.3	108204.2	10.23	23.91	30.64	38343.2
57.2	108435.0	10.43	24.01	30.76	38233.6

G1R1.01 (S)
ML= 0.00580 MG= 0.0000101 QFLUX= 2690 NUTP= 12.7 HTP= 420.7
PDT= 4.482 PDF= 0.345 ALFA=0.410 TOUT= 24.90, 24.90

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.2	68.2	63.4	108.25	77.3	0.0457	0.08
OUTLET	25.4	78.5	63.9	104.11	66.8	0.0457	0.08
MEAN	23.8	73.4	63.7	106.18	72.0	0.0457	0.08

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	69.0	0.09	22.42	30.22	345.0
11.4	70.1	0.09	22.76	31.12	322.2
19.1	71.3	0.09	23.16	31.55	321.3
27.9	72.8	0.09	23.63	31.46	344.6
41.9	75.2	0.09	24.37	30.17	463.9
53.3	77.2	0.09	24.98	29.32	618.6
57.2	77.8	0.09	25.18	28.90	722.3

G1R1.02 (S)
ML= 0.00580 MG= 0.0000428 QFLUX= 2706 NUTP= 26.1 HTP= 861.9
PDT= 2.303 PDF= -0.827 ALFA=0.555 TOUT= 25.70, 25.70

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.5	69.2	254.1	105.49	76.1	0.0457	0.32
OUTLET	25.7	79.6	256.0	103.42	65.8	0.0457	0.34
MEAN	24.1	74.4	255.0	104.11	70.9	0.0457	0.33

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	70.1	0.34	22.76	26.03	826.0
11.4	71.1	0.34	23.09	26.38	824.2
19.1	72.4	0.34	23.50	26.78	823.5
27.9	73.9	0.34	23.97	27.29	814.9
41.9	76.3	0.34	24.71	27.94	839.1
53.3	78.3	0.34	25.32	28.08	981.8
57.2	79.0	0.34	25.52	27.81	1184.7

G1R1.03 (S)
ML= 0.00580 MG= 0.0000743 QFLUX= 9877. NUTP= 36.7 HTP= 1219.1
PDT= 1.517 PDF= -1.241 ALFA=0.604 TOUT= 33.96, 33.96

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.1	71.1	441.2	104.11	74.1	0.0457	0.56
OUTLET	34.8	113.1	439.8	102.73	45.7	0.0457	0.61
MEAN	28.9	92.1	440.5	103.42	59.9	0.0457	0.59

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	74.1	0.58	24.05	33.75	1014.8
11.4	78.1	0.58	25.27	35.07	1006.1
19.1	83.1	0.58	26.73	36.42	1018.6
27.9	89.1	0.58	28.43	37.34	1108.8
41.9	99.0	0.61	31.12	38.91	1271.0
53.3	107.4	0.61	33.31	39.51	1597.6
57.2	110.3	0.61	34.04	38.97	2009.2

G1R1.04 (S)
ML= 0.00580 MG= 0.000152 QFLUX= 12986. NUTP= 38.2 HTP= 1270.7
PDT= 1.179 PDF= -1.034 ALFA=0.688 TOUT= 38.16, 38.16

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.4	72.2	908.4	102.73	72.9	0.0457	1.18
OUTLET	38.5	127.7	904.0	101.35	40.2	0.0457	1.30
MEAN	31.0	100.0	906.2	102.04	56.5	0.0457	1.24

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	76.2	1.22	24.69	36.22	1120.5
11.4	81.5	1.22	26.27	37.73	1128.4
19.1	88.1	1.22	28.16	39.48	1143.8
27.9	96.2	1.25	30.35	41.41	1174.8
41.9	109.3	1.28	33.81	44.18	1255.7
53.3	120.4	1.28	36.64	44.81	1594.8
57.2	124.1	1.28	37.58	44.19	1969.7

G1R1.05 (S-C)
ML= 0.00580 MG= 0.000235 QFLUX= 14068. NUTP= 41.2 HTP= 1372.9
PDT= 1.289 PDF= -0.689 ALFA=0.719 TOUT= 39.20, 39.20

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.7	73.0	1399.9	104.11	72.1	0.0457	1.80
OUTLET	39.7	132.3	1392.5	102.73	38.7	0.0457	1.98
MEAN	31.7	102.6	1396.2	103.42	55.4	0.0457	1.89

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	77.3	1.83	25.02	36.99	1168.5
11.4	82.9	1.86	26.69	38.63	1174.3
19.1	90.0	1.86	28.69	40.30	1209.9
27.9	98.7	1.89	31.03	42.17	1263.9
41.9	112.8	1.92	34.71	44.93	1379.6
53.3	124.5	1.95	37.71	45.64	1781.3
57.2	128.4	1.98	38.71	45.37	2122.0

G1R1.06 (C)
ML= 0.00580 MG= 0.000323 QFLUX= 14065. NUTP= 41.9 HTP= 1394.5
PDT= 1.489 PDF= -0.414 ALFA=0.727 TOUT= 39.81, 39.71

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.9	73.6	1927.3	104.11	71.4	0.0457	2.47
OUTLET	39.6	131.8	1918.4	102.73	38.9	0.0457	2.74
MEAN	31.7	102.7	1922.9	103.42	55.1	0.0457	2.61

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	77.8	2.53	25.19	35.87	1309.1
11.4	83.4	2.56	26.83	37.72	1286.2
19.1	90.4	2.56	28.79	39.53	1307.5
27.9	98.9	2.62	31.09	41.81	1311.5
41.9	112.7	2.65	34.69	44.92	1380.2
53.3	124.1	2.71	37.63	46.28	1634.8
57.2	128.0	2.71	38.62	45.91	1938.3

G1R1.07 (C)
ML= 0.00580 MG= 0.000393 QFLUX= 15724. NUTP= 43.5 HTP= 1449.0
PDT= 1.600 PDF= -0.276 ALFA=0.731 TOUT= 41.35, 41.35

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.8	73.2	2337.1	103.42	71.8	0.0457	3.02
OUTLET	41.0	137.2	2325.0	102.04	37.2	0.0457	3.37
MEAN	32.4	105.2	2331.0	102.73	54.5	0.0457	3.19

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	77.8	3.08	25.20	36.69	1358.3
11.4	83.9	3.11	26.99	38.43	1368.4
19.1	91.6	3.14	29.15	40.57	1373.9
27.9	101.0	3.20	31.67	42.79	1413.2
41.9	116.2	3.26	35.62	46.48	1453.9
53.3	128.8	3.32	38.85	48.82	1586.9
57.2	133.0	3.35	39.93	48.45	1856.9

G1R1.08 (C)
ML= 0.00580 MG= 0.000777 QFLUX= 18846. NUTP= 53.6 HTP= 1782.9
PDT= 1.620 PDF= -0.138 ALFA=0.748 TOUT= 41.35, 41.35

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.4	65.8	4655.6	102.73	80.1	0.0457	5.97
OUTLET	40.5	134.9	4603.7	101.35	37.8	0.0457	6.70
MEAN	30.9	100.4	4629.7	102.04	59.0	0.0457	6.33

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	70.5	6.10	22.96	33.33	1799.3
11.4	76.9	6.16	24.95	35.45	1782.5
19.1	85.0	6.22	27.34	38.01	1760.1
27.9	95.1	6.31	30.13	40.80	1765.6
41.9	111.8	6.46	34.52	45.01	1803.7
53.3	125.7	6.61	38.11	48.73	1788.9
57.2	130.3	6.64	39.31	49.90	1795.3

G1R1.09 (A)
ML= 0.00580 MG= 0.00152 QFLUX= 18887. NUTP= 52.4 HTP= 1738.6
PDT= 1.641 PDF= 0.276 ALFA=0.808 TOUT= 38.84, 38.72

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.8	64.2	9123.1	102.73	82.2	0.0457	11.67
OUTLET	37.9	124.2	9019.5	100.66	41.1	0.0457	12.96
MEAN	29.3	94.2	9071.3	102.04	61.6	0.0457	12.31

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	68.2	11.89	22.23	31.80	1955.4
11.4	73.7	12.01	24.01	34.07	1864.6
19.1	80.7	12.13	26.14	36.79	1765.6
27.9	89.4	12.31	28.63	39.58	1723.8
41.9	103.8	12.56	32.54	43.92	1666.0
53.3	116.0	12.80	35.73	47.16	1666.6
57.2	120.1	12.89	36.80	48.26	1663.6

G1R1.10 (A)
ML= 0.00580 MG= 0.00225 QFLUX= 21839. NUTP= 56.5 HTP= 1876.0
PDT= 2.048 PDF= 1.034 ALFA=0.855 TOUT= 38.79, 38.70

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	63.1	13483.3	103.42	83.7	0.0457	17.09
OUTLET	38.1	124.5	13312.7	101.35	40.8	0.0457	19.09
MEAN	29.3	93.8	13398.0	102.04	62.2	0.0457	18.09

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	67.1	17.43	21.89	31.63	2219.9
11.4	72.7	17.59	23.73	34.19	2073.4
19.1	79.9	17.80	25.94	37.23	1927.3
27.9	88.8	18.07	28.51	40.31	1850.5
41.9	103.6	18.47	32.56	45.05	1756.6
53.3	116.1	18.87	35.87	48.36	1762.5
57.2	120.3	18.99	36.97	49.46	1765.8

G1R1.11 (A)
ML= 0.00580 MG= 0.00298 QFLUX= 26197. NUTP= 60.4 HTP= 2006.6
PDT= 2.627 PDF= 1.793 ALFA=0.883 TOUT= 39.81, 39.71

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.0	61.8	17929.7	106.18	85.5	0.0457	22.03
OUTLET	39.1	127.7	17656.4	103.42	39.5	0.0457	24.88
MEAN	29.5	94.8	17793.0	104.80	62.5	0.0457	23.45

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	66.0	22.46	21.55	31.80	2524.9
11.4	72.0	22.71	23.54	34.89	2287.6
19.1	79.7	23.01	25.93	38.48	2076.8
27.9	89.3	23.38	28.71	42.08	1958.7
41.9	105.3	23.99	33.09	47.36	1845.5
53.3	118.7	24.54	36.68	51.08	1836.2
57.2	123.2	24.72	37.87	52.23	1844.2

G1R1.12 (A)
ML= 0.00580 MG= 0.00364 QFLUX= 22763. NUTP= 59.5 HTP= 1966.8
PDT= 3.309 PDF= 2.551 ALFA=0.890 TOUT= 34.78, 34.78

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.1	54.3	22058.7	106.18	97.7	0.0457	26.68
OUTLET	33.5	106.4	21667.7	102.73	47.9	0.0457	29.81
MEAN	25.3	80.4	21863.2	104.11	72.8	0.0457	28.24

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	57.5	27.13	18.48	27.04	2632.1
11.4	62.0	27.43	20.18	29.93	2318.3
19.1	67.9	27.77	22.23	33.21	2065.9
27.9	75.3	28.16	24.61	36.52	1912.3
41.9	87.8	28.86	28.36	41.32	1766.0
53.3	98.8	29.41	31.43	44.64	1738.1
57.2	102.6	29.63	32.45	45.75	1728.8

G1R1.13 (A)
ML= 0.00580 MG= 0.00402 QFLUX= 25153. NUTP= 59.6 HTP= 1971.4
PDT= 3.516 PDF= 2.827 ALFA=0.899 TOUT= 36.28, 36.28

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.3	54.7	24347.3	106.18	97.0	0.0457	29.42
OUTLET	34.4	109.8	23903.9	102.73	46.2	0.0457	33.07
MEAN	25.9	82.3	24125.6	104.80	71.6	0.0457	31.24

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	58.0	29.93	18.71	27.97	2685.0
11.4	62.9	30.27	20.49	31.13	2344.8
19.1	69.1	30.66	22.64	34.69	2077.2
27.9	76.9	31.15	25.14	38.28	1912.9
41.9	90.2	31.94	29.07	43.44	1759.7
53.3	101.8	32.61	32.29	47.03	1721.5
57.2	105.8	32.86	33.36	48.17	1716.3

G1R1.14 (A)
ML= 0.00580 MG= 0.00821 QFLUX= 26887. NUTP= 63.7 HTP= 2100.3
PDT= 8.453 PDF= 8.136 ALFA=0.952 TOUT= 31.35, 31.35

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.3	52.5	49823.0	117.21	101.4	0.0457	54.43
OUTLET	29.9	92.1	49005.1	108.25	55.0	0.0457	62.60
MEAN	23.1	72.3	49414.1	112.38	78.2	0.0457	58.52

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	54.6	55.44	17.48	25.41	3351.5
11.4	58.1	56.18	18.89	29.13	2606.2
19.1	62.7	57.09	20.59	32.87	2183.3
27.9	68.3	58.19	22.58	36.28	1962.4
41.9	77.9	60.02	25.69	40.60	1813.1
53.3	86.3	61.57	28.24	43.40	1788.6
57.2	89.1	62.09	29.09	44.23	1793.4

G1R1.15 (A-M)
ML= 0.00580 MG= 0.01265 QFLUX= 25954. NUTP= 56.6 HTP= 1865.8
PDT= 14.334 PDF= 14.134 ALFA=0.970 TOUT= 26.97, 27.05

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.1	51.8	76797.8	131.00	102.8	0.0457	74.80
OUTLET	26.7	80.4	75762.9	116.52	63.0	0.0457	88.36
MEAN	21.4	66.1	76280.3	123.41	82.9	0.0457	81.57

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	53.1	76.26	16.94	25.16	3126.2
11.4	55.7	77.51	18.05	29.68	2217.9
19.1	59.1	79.04	19.38	33.32	1859.2
27.9	63.2	80.86	20.94	36.12	1711.2
41.9	70.1	83.91	23.38	39.18	1649.1
53.3	76.2	86.56	25.37	41.08	1663.5
57.2	78.2	87.45	26.04	41.62	1677.2

G1R2.01 (B)
ML= 0.05116 MG= 0.0000063 QFLUX= 8335. NUTP= 29.1 HTP= 951.1
PDT= 7.039 PDF= 0.689 ALFA=0.097 TOUT= 23.62, 23.70

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.5	584.9	38.9	115.83	79.8	0.417	0.05
OUTLET	23.7	615.2	39.3	108.25	75.7	0.417	0.05
MEAN	23.1	600.0	39.1	111.69	77.8	0.417	0.05

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	587.4	0.03	22.61	29.77	1160.3
11.4	590.5	0.06	22.72	31.09	994.9
19.1	594.2	0.06	22.87	31.76	937.7
27.9	598.6	0.06	23.03	32.04	925.2
41.9	605.6	0.06	23.29	32.32	924.1
53.3	611.3	0.06	23.51	32.49	929.0
57.2	613.3	0.06	23.58	32.57	928.2

G1R2.02 (B)
ML= 0.05116 MG= 0.0000264 QFLUX= 8493. NUTP= 38.5 HTP= 1257.7
PDT= 6.378 PDF= 0.896 ALFA=0.219 TOUT= 23.41, 23.41

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.3	578.5	156.6	113.76	80.7	0.417	0.18
OUTLET	23.4	609.1	158.2	107.56	76.5	0.417	0.20
MEAN	22.8	593.8	157.4	110.31	78.6	0.417	0.19

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	581.0	0.18	22.36	28.61	1358.2
11.4	584.2	0.18	22.48	29.16	1272.3
19.1	588.0	0.18	22.63	29.45	1245.5
27.9	592.4	0.18	22.80	29.66	1238.2
41.9	599.4	0.18	23.07	29.87	1249.1
53.3	605.2	0.18	23.28	30.03	1259.5
57.2	607.2	0.18	23.36	30.10	1260.0

G1R2.03 (B)
ML= 0.05116 MG= 0.0000453 QFLUX= 8524. NUTP= 40.5 HTP= 1324.1
PDT= 5.978 PDF= 1.103 ALFA=0.309 TOUT= 22.39, 22.39

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.1	549.1	273.0	113.07	85.2	0.417	0.32
OUTLET	22.3	578.6	275.5	106.87	80.7	0.417	0.34
MEAN	21.7	563.8	274.2	109.62	82.9	0.417	0.33

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	551.5	0.34	21.20	27.32	1392.1
11.4	554.5	0.34	21.32	27.68	1340.9
19.1	558.2	0.34	21.47	27.93	1318.1
27.9	562.4	0.34	21.64	28.17	1304.7
41.9	569.2	0.34	21.91	28.37	1318.1
53.3	574.8	0.34	22.12	28.56	1325.6
57.2	576.7	0.34	22.19	28.65	1322.2

G1R2.04 (B-S)
ML= 0.05116 MG= 0.0000667 QFLUX= 15036. NUTP= 48.2 HTP= 1575.1
PDT= 5.640 PDF= 1.103 ALFA=0.358 TOUT= 24.44, 24.44

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.2	577.7	396.3	112.38	80.8	0.417	0.47
OUTLET	24.3	632.6	399.8	106.18	73.6	0.417	0.50
MEAN	23.3	605.2	398.0	109.62	77.2	0.417	0.48

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	582.1	0.49	22.41	31.63	1628.2
11.4	587.7	0.49	22.62	32.14	1577.7
19.1	594.5	0.49	22.88	32.49	1563.6
27.9	602.4	0.49	23.18	32.78	1565.7
41.9	615.1	0.49	23.64	33.24	1569.0
53.3	625.6	0.49	24.03	33.52	1585.5
57.2	629.1	0.49	24.16	33.64	1587.7

G1R2.05 (S)
ML= 0.05116 MG= 0.000138 QFLUX= 20063. NUTP= 54.9 HTP= 1794.2
PDT= 5.088 PDF= 1.655 ALFA=0.511 TOUT= 25.03, 25.03

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	563.9	830.6	109.62	82.9	0.417	1.00
OUTLET	24.4	636.5	836.6	104.80	73.1	0.417	1.07
MEAN	23.1	600.2	833.6	107.56	78.0	0.417	1.03

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	569.7	1.01	21.92	32.56	1883.5
11.4	577.0	1.01	22.21	33.23	1818.5
19.1	585.9	1.04	22.55	33.68	1801.2
27.9	596.3	1.04	22.95	34.19	1784.6
41.9	613.1	1.04	23.57	34.88	1776.5
53.3	627.1	1.07	24.09	35.38	1778.7
57.2	631.8	1.07	24.26	35.63	1766.6

G1R2.06 (S)
ML= 0.05116 MG= 0.000211 QFLUX= 21378. NUTP= 59.7 HTP= 1954.3
PDT= 4.971 PDF= 1.862 ALFA=0.554 TOUT= 25.43, 25.49

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.4	582.1	1266.6	109.62	80.2	0.417	1.53
OUTLET	25.3	661.4	1276.2	104.80	70.3	0.417	1.64
MEAN	23.9	621.7	1271.4	107.56	75.2	0.417	1.58

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	588.4	1.55	22.64	33.00	2060.7
11.4	596.3	1.55	22.95	33.68	1989.7
19.1	606.0	1.58	23.31	34.24	1956.1
27.9	617.5	1.58	23.74	34.74	1943.2
41.9	635.8	1.62	24.41	35.49	1929.8
53.3	651.1	1.62	24.95	35.98	1941.8
57.2	656.2	1.65	25.13	36.23	1929.0

G1R2.07 (S-C)
ML= 0.05116 MG= 0.000279 QFLUX= 21384. NUTP= 62.8 HTP= 2056.0
PDT= 4.716 PDF= 2.068 ALFA=0.619 TOUT= 26.16, 26.16

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.2	602.5	1670.0	108.25	77.4	0.417	2.06
OUTLET	26.1	683.7	1684.3	103.42	67.9	0.417	2.21
MEAN	24.6	643.1	1677.1	105.49	72.6	0.417	2.13

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	609.0	2.10	23.42	33.59	2099.0
11.4	617.1	2.10	23.72	34.11	2058.1
19.1	627.1	2.13	24.09	34.56	2041.5
27.9	638.8	2.13	24.51	35.00	2038.9
41.9	657.5	2.16	25.18	35.63	2048.7
53.3	673.2	2.19	25.72	35.99	2086.1
57.2	678.4	2.19	25.91	36.28	2065.4

G1R2.08 (S-C)
ML= 0.05116 MG= 0.000347 QFLUX= 20120. NUTP= 63.4 HTP= 2073.0
PDT= 4.316 PDF= 1.793 ALFA=0.637 TOUT= 24.78, 24.78

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.9	569.4	2075.3	109.62	82.0	0.417	2.50
OUTLET	24.6	642.5	2090.8	105.49	72.4	0.417	2.67
MEAN	23.3	606.0	2083.1	107.56	77.2	0.417	2.59

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	575.2	2.53	22.14	31.53	2139.7
11.4	582.6	2.56	22.42	32.04	2090.6
19.1	591.5	2.56	22.77	32.48	2071.2
27.9	602.1	2.59	23.17	32.88	2070.2
41.9	618.9	2.62	23.79	33.59	2055.6
53.3	633.0	2.65	24.31	34.06	2064.6
57.2	637.7	2.65	24.47	34.21	2069.6

G1R2.09 (S-C)
ML= 0.05116 MG= 0.000394 QFLUX= 20555. NUTP= 60.9 HTP= 1992.4
PDT= 4.957 PDF= 2.551 ALFA=0.659 TOUT= 25.10, 25.10

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.4	582.5	2356.4	111.00	80.1	0.41	2.82
OUTLET	25.2	658.4	2374.7	105.49	70.6	0.41	3.03
MEAN	23.8	620.4	2365.6	108.25	75.4	0.41	2.92

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	588.5	2.87	22.65	32.37	2110.8
11.4	596.2	2.90	22.94	32.84	2073.8
19.1	605.5	2.90	23.29	33.38	2035.4
27.9	616.4	2.93	23.70	34.08	1980.2
41.9	633.9	2.96	24.34	34.89	1949.2
53.3	648.5	3.02	24.86	35.53	1929.0
57.2	653.4	3.02	25.03	35.74	1923.2

G1R2.10 (C)
ML= 0.05116 MG= 0.000729 QFLUX= 21826. NUTP= 66.9 HTP= 2188.8
PDT= 5.509 PDF= 3.378 ALFA=0.693 TOUT= 24.73, 24.81

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	564.3	4360.6	115.83	82.8	0.417	4.96
OUTLET	24.7	642.5	4387.6	110.31	72.4	0.417	5.33
MEAN	23.2	603.4	4374.1	113.07	77.6	0.417	5.15

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	570.4	5.03	21.96	31.31	2329.8
11.4	578.3	5.06	22.26	31.96	2249.2
19.1	587.8	5.12	22.63	32.48	2214.6
27.9	599.1	5.15	23.06	33.03	2188.1
41.9	617.2	5.24	23.73	33.88	2152.1
53.3	632.3	5.30	24.28	34.56	2127.4
57.2	637.4	5.30	24.47	34.81	2114.9

G1R2.11 (C)
ML= 0.05116 MG= 0.00140 QFLUX= 21968. NUTP= 80.5 HTP= 2633.4
PDT= 7.350 PDF= 5.378 ALFA=0.724 TOUT= 24.98, 25.00

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	572.5	8372.8	117.90	81.6	0.417	9.40
OUTLET	24.9	650.8	8427.4	110.31	71.4	0.417	10.27
MEAN	23.5	611.6	8400.1	113.76	76.5	0.417	9.84

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	578.5	9.57	22.27	30.14	2789.5
11.4	586.4	9.63	22.58	30.73	2691.4
19.1	596.0	9.72	22.94	31.22	2653.4
27.9	607.3	9.85	23.37	31.88	2582.6
41.9	625.4	10.03	24.03	32.44	2615.8
53.3	640.5	10.18	24.58	33.01	2611.7
57.2	645.6	10.21	24.76	33.29	2581.5

G1R2.12 (A)
ML= 0.05116 MG= 0.00249 QFLUX= 26783. NUTP= 98.0 HTP= 3207.5
PDT= 10.252 PDF= 9.032 ALFA=0.827 TOUT= 26.04, 26.14

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.6	586.7	14880.6	119.28	79.5	0.417	16.52
OUTLET	26.0	682.0	14971.9	108.94	68.0	0.417	18.57
MEAN	24.3	634.4	14926.2	114.45	73.8	0.417	17.54

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	593.9	16.86	22.87	30.69	3415.1
11.4	603.5	17.04	23.23	31.33	3304.0
19.1	615.1	17.25	23.66	31.97	3222.3
27.9	628.9	17.53	24.17	32.59	3181.4
41.9	651.0	17.95	24.96	33.49	3145.3
53.3	669.5	18.32	25.61	34.07	3173.6
57.2	675.7	18.44	25.83	34.34	3154.7

G1R2.13 (A)
ML= 0.05116 MG= 0.00304 QFLUX= 34838. NUTP= 102.9 HTP= 3369.3
PDT= 10.507 PDF= 9.170 ALFA=0.814 TOUT= 26.55, 26.62

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	562.5	18157.9	120.66	83.1	0.417	19.90
OUTLET	26.1	683.8	18220.2	109.62	67.8	0.417	22.47
MEAN	23.9	623.1	18189.0	115.14	75.5	0.417	21.19

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	571.6	20.30	22.01	31.77	3560.0
11.4	583.6	20.51	22.48	32.54	3456.4
19.1	598.3	20.82	23.04	33.32	3384.7
27.9	615.8	21.15	23.69	34.06	3359.0
41.9	643.9	21.70	24.71	35.25	3310.8
53.3	667.7	22.16	25.55	36.08	3316.0
57.2	675.7	22.31	25.83	36.34	3323.3

G1R2.14 (A)
ML= 0.05116 MG= 0.00367 QFLUX= 41006. NUTP= 116.5 HTP= 3816.1
PDT= 12.397 PDF= 11.238 ALFA=0.835 TOUT= 27.49, 27.71

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.1	573.7	21905.5	124.10	81.4	0.417	23.39
OUTLET	27.3	717.9	21958.0	111.69	64.5	0.417	26.87
MEAN	24.7	645.8	21931.8	117.90	72.9	0.417	25.13

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	584.4	23.90	22.51	32.90	3936.8
11.4	598.6	24.20	23.05	33.69	3847.3
19.1	616.0	24.57	23.70	34.48	3799.9
27.9	636.7	25.02	24.46	35.22	3810.4
41.9	670.3	25.79	25.64	36.51	3781.2
53.3	698.6	26.43	26.62	37.38	3820.2
57.2	708.2	26.64	26.94	37.72	3816.5

G1R2.15 (A)
ML= 0.05116 MG= 0.01256 QFLUX= 43781. NUTP= 127.5 HTP= 4167.6
PDT= 28.771 PDF= 28.337 ALFA=0.941 TOUT= 25.18, 25.56

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.2	526.1	75454.4	167.54	89.0	0.417	58.87
OUTLET	25.0	649.5	75342.3	138.58	71.4	0.417	73.04
MEAN	22.6	587.8	75398.4	153.06	80.2	0.417	65.96

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	534.8	60.23	20.56	29.38	4946.5
11.4	547.0	61.48	21.06	30.41	4672.1
19.1	561.9	63.03	21.66	31.61	4396.0
27.9	579.7	64.92	22.36	32.88	4161.4
41.9	608.5	68.15	23.46	34.73	3890.2
53.3	632.9	71.02	24.36	36.14	3729.1
57.2	641.2	72.03	24.66	36.63	3672.2

G1R2.16 (A-M)
ML= 0.05116 MG= 0.01659 QFLUX= 46913. NUTP= 128.3 HTP= 4196.0
PDT= 36.659 PDF= 36.542 ALFA=0.985 TOUT= 25.18, 24.93

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	531.8	99553.0	193.74	88.0	0.417	67.32
OUTLET	25.3	659.0	99267.9	157.20	70.3	0.417	85.27
MEAN	22.9	595.4	99410.4	175.12	79.2	0.417	76.30

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	540.7	68.92	20.81	29.32	5486.0
11.4	553.2	70.47	21.32	30.78	4938.8
19.1	568.6	72.42	21.93	32.34	4500.8
27.9	587.0	74.86	22.64	34.07	4108.7
41.9	616.7	78.94	23.77	36.19	3787.5
53.3	641.8	82.63	24.69	37.71	3617.7
57.2	650.3	83.94	24.99	38.21	3568.6

G1R3.01 (B)
ML= 0.12701 MG= 0.0000063 QFLUX= 7487. NUTP= 35.0 HTP= 1144.1
PDT= 8.515 PDF= 1.655 ALFA=0.020 TOUT= 21.99, 21.99

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	1387.4	39.8	119.28	83.5	1.03	0.04
OUTLET	21.9	1413.4	40.2	111.00	82.0	1.03	0.05
MEAN	21.7	1400.4	40.0	115.14	82.7	1.03	0.05

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1389.6	0.03	21.56	26.67	1462.8
11.4	1392.3	0.03	21.60	27.66	1234.8
19.1	1395.5	0.03	21.65	28.18	1146.6
27.9	1399.3	0.06	21.71	28.51	1101.7
41.9	1405.3	0.06	21.81	28.71	1086.4
53.3	1410.1	0.06	21.88	28.71	1098.1
57.2	1411.8	0.06	21.91	28.74	1096.2

G1R3.02 (B)
ML= 0.12701 MG= 0.0000265 QFLUX= 8713. NUTP= 38.7 HTP= 1266.2
PDT= 8.294 PDF= 2.206 ALFA=0.137 TOUT= 22.49, 22.49

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	1415.6	159.8	118.59	81.8	1.03	0.18
OUTLET	22.5	1446.3	161.6	110.31	80.0	1.03	0.20
MEAN	22.2	1430.9	160.7	114.45	80.9	1.03	0.19

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1418.1	0.18	22.01	27.46	1595.8
11.4	1421.3	0.18	22.06	28.48	1356.1
19.1	1425.1	0.18	22.12	28.99	1267.1
27.9	1429.6	0.18	22.19	29.31	1224.5
41.9	1436.6	0.18	22.30	29.50	1210.6
53.3	1442.4	0.18	22.39	29.58	1213.2
57.2	1444.4	0.18	22.42	29.59	1215.7

G1R3.03 (B)
ML= 0.12701 MG= 0.0000453 QFLUX= 9896. NUTP= 42.1 HTP= 1376.3
PDT= 8.012 PDF= 2.344 ALFA=0.193 TOUT= 23.18, 23.18

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.7	1459.6	272.3	117.90	79.3	1.03	0.31
OUTLET	23.2	1495.4	275.4	109.62	77.3	1.03	0.34
MEAN	22.9	1477.5	273.8	113.76	78.3	1.03	0.32

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1462.6	0.30	22.70	28.44	1719.7
11.4	1466.3	0.30	22.76	29.53	1460.9
19.1	1470.7	0.30	22.82	30.03	1374.2
27.9	1475.9	0.34	22.91	30.30	1338.3
41.9	1484.1	0.34	23.03	30.53	1321.0
53.3	1490.9	0.34	23.13	30.62	1322.8
57.2	1493.1	0.34	23.17	30.67	1320.7

G1R3.04 (B)
ML= 0.12701 MG= 0.0000806 QFLUX= 11864. NUTP= 50.4 HTP= 1648.3
PDT= 7.825 PDF= 2.758 ALFA=0.279 TOUT= 23.77, 23.72

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	23.0	1483.8	482.5	117.21	77.9	1.03	0.55
OUTLET	23.7	1527.3	488.0	109.62	75.6	1.03	0.59
MEAN	23.4	1505.6	485.2	113.76	76.8	1.03	0.57

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1487.4	0.55	23.08	28.66	2123.2
11.4	1491.9	0.55	23.15	29.87	1762.8
19.1	1497.3	0.58	23.23	30.44	1644.1
27.9	1503.7	0.58	23.32	30.81	1586.2
41.9	1513.6	0.58	23.47	30.99	1579.0
53.3	1521.9	0.58	23.59	31.13	1577.2
57.2	1524.6	0.58	23.64	31.17	1576.1

G1R3.05 (S)
ML= 0.12701 MG= 0.000168 QFLUX= 11980. NUTP= 58.8 HTP= 1922.6
PDT= 7.977 PDF= 3.792 ALFA=0.404 TOUT= 23.23, 23.26

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.5	1449.7	1007.3	117.90	79.8	1.03	1.13
OUTLET	23.2	1492.8	1018.5	110.31	77.5	1.03	1.23
MEAN	22.8	1471.2	1012.9	114.45	78.6	1.03	1.18

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1453.2	1.16	22.56	27.53	2407.0
11.4	1457.7	1.16	22.62	28.54	2022.7
19.1	1463.0	1.16	22.71	29.07	1884.6
27.9	1469.3	1.19	22.81	29.32	1838.4
41.9	1479.2	1.19	22.96	29.42	1856.0
53.3	1487.3	1.22	23.08	29.37	1906.7
57.2	1490.1	1.22	23.12	29.33	1928.5

G1R3.06 (S)
ML= 0.12701 MG= 0.000257 QFLUX= 13311. NUTP= 69.0 HTP= 2253.6
PDT= 8.439 PDF= 4.619 ALFA=0.453 TOUT= 22.51, 22.51

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.7	1395.6	1539.5	118.59	83.0	1.03	1.72
OUTLET	22.4	1442.0	1555.3	109.62	80.3	1.03	1.87
MEAN	22.0	1418.8	1547.4	113.76	81.7	1.03	1.80

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1399.4	1.74	21.71	27.08	2478.4
11.4	1404.2	1.77	21.79	27.53	2319.2
19.1	1409.9	1.77	21.88	27.74	2269.5
27.9	1416.7	1.80	21.99	28.00	2215.1
41.9	1427.4	1.83	22.16	28.16	2217.9
53.3	1436.2	1.86	22.29	28.31	2214.0
57.2	1439.1	1.86	22.34	28.39	2199.4

G1R3.07 (S)
ML= 0.12701 MG= 0.000325 QFLUX= 19193. NUTP= 69.6 HTP= 2274.0
PDT= 8.563 PDF= 5.033 ALFA=0.495 TOUT= 21.87, 21.87

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.7	1334.8	1949.0	118.59	86.9	1.03	2.15
OUTLET	21.7	1399.8	1966.2	110.31	82.8	1.03	2.36
MEAN	21.2	1367.3	1957.6	114.45	84.9	1.03	2.26

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1340.1	2.19	20.75	28.46	2488.9
11.4	1346.8	2.19	20.86	29.14	2316.1
19.1	1354.8	2.23	20.99	29.48	2262.8
27.9	1364.2	2.26	21.15	29.69	2246.5
41.9	1379.2	2.29	21.39	29.93	2248.2
53.3	1391.5	2.35	21.59	30.12	2250.3
57.2	1395.6	2.35	21.65	30.22	2243.8

G1R3.08 (S-C)
ML= 0.12701 MG= 0.000388 QFLUX= 22015. NUTP= 75.7 HTP= 2473.9
PDT= 8.880 PDF= 6.067 ALFA=0.599 TOUT= 22.71, 22.71

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.4	1378.6	2321.4	119.28	84.1	1.03	2.56
OUTLET	22.6	1455.2	2342.5	110.31	79.5	1.03	2.81
MEAN	22.0	1416.9	2332.0	115.14	81.8	1.03	2.69

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1384.8	2.59	21.48	29.67	2686.9
11.4	1392.7	2.62	21.61	30.30	2531.6
19.1	1402.2	2.65	21.76	30.63	2480.4
27.9	1413.3	2.68	21.93	30.93	2448.2
41.9	1430.9	2.74	22.21	31.27	2430.4
53.3	1445.5	2.77	22.44	31.44	2445.6
57.2	1450.4	2.80	22.51	31.58	2430.2

G1R3.09 (C)
ML= 0.12701 MG= 0.000800 QFLUX= 22056. NUTP= 92.3 HTP= 3019.0
PDT= 11.459 PDF= 9.032 ALFA=0.651 TOUT= 23.43, 23.43

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.1	1424.0	4780.0	124.79	81.3	1.03	5.06
OUTLET	23.3	1502.3	4824.6	113.76	76.9	1.03	5.66
MEAN	22.7	1463.1	4802.3	119.28	79.1	1.03	5.36

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1430.3	5.15	22.20	29.12	3186.6
11.4	1438.3	5.21	22.33	29.56	3047.9
19.1	1448.0	5.27	22.48	29.83	3000.8
27.9	1459.4	5.33	22.65	30.03	2991.1
41.9	1477.4	5.49	22.93	30.27	3006.0
53.3	1492.3	5.58	23.16	30.50	3006.0
57.2	1497.3	5.61	23.23	30.56	3011.9

G1R3.10 (C-A)
ML= 0.12701 MG= 0.00154 QFLUX= 25434. NUTP= 105.3 HTP= 3438.6
PDT= 17.250 PDF= 15.168 ALFA=0.704 TOUT= 22.56, 22.56

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.1	1358.3	9223.0	133.76	85.4	1.03	9.09
OUTLET	22.4	1444.6	9295.6	115.83	80.1	1.03	10.60
MEAN	21.7	1401.5	9259.3	124.79	82.7	1.03	9.85

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1365.2	9.27	21.17	28.33	3548.7
11.4	1374.1	9.42	21.31	28.67	3453.9
19.1	1384.7	9.57	21.48	28.94	3408.8
27.9	1397.3	9.78	21.68	29.18	3393.1
41.9	1417.1	10.12	21.99	29.39	3440.7
53.3	1433.6	10.39	22.26	29.59	3470.5
57.2	1439.1	10.52	22.34	29.71	3456.2

G1R3.11 (C-A)
ML= 0.12701 MG= 0.00230 QFLUX= 28332. NUTP= 119.3 HTP= 3899.6
PDT= 21.656 PDF= 19.650 ALFA=0.712 TOUT= 23.62, 23.65

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.1	1423.5	13730.5	141.34	81.4	1.03	12.85
OUTLET	23.6	1522.3	13841.0	119.97	75.9	1.03	15.44
MEAN	22.9	1472.9	13785.7	130.31	78.6	1.03	14.15

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1431.3	13.14	22.22	29.26	4024.8
11.4	1441.5	13.38	22.38	29.59	3927.9
19.1	1453.7	13.66	22.57	29.86	3882.2
27.9	1468.0	13.99	22.79	30.11	3868.8
41.9	1490.8	14.57	23.13	30.42	3892.9
53.3	1509.6	15.09	23.42	30.69	3900.7
57.2	1516.0	15.27	23.51	30.80	3893.0

G1R3.12 (A)
ML= 0.12701 MG= 0.00306 QFLUX= 32113. NUTP= 126.4 HTP= 4137.0
PDT= 22.911 PDF= 21.511 ALFA=0.804 TOUT= 24.42, 24.49

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.7	1462.0	18260.3	148.92	79.1	1.03	16.25
OUTLET	24.4	1575.8	18396.6	126.17	73.2	1.03	19.54
MEAN	23.5	1518.9	18328.4	137.89	76.2	1.03	17.90

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1471.0	16.61	22.83	30.36	4261.1
11.4	1482.6	16.92	23.01	30.69	4180.3
19.1	1496.7	17.28	23.22	31.07	4091.0
27.9	1513.2	17.71	23.47	31.27	4119.8
41.9	1539.5	18.44	23.86	31.66	4123.9
53.3	1561.2	19.08	24.18	31.95	4139.3
57.2	1568.5	19.32	24.29	32.04	4146.3

G1R3.13 (A)
ML= 0.12701 MG= 0.00363 QFLUX= 37244. NUTP= 120.6 HTP= 3931.4
PDT= 25.441 PDF= 24.131 ALFA=0.813 TOUT= 20.81, 21.04

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.7	1223.0	21886.4	151.68	95.2	1.03	18.69
OUTLET	20.7	1338.0	21977.1	126.17	86.7	1.03	22.82
MEAN	19.7	1280.5	21931.7	139.27	90.9	1.03	20.75

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1232.0	19.11	18.91	28.02	4085.9
11.4	1243.6	19.48	19.12	28.49	3969.3
19.1	1257.8	19.90	19.36	28.88	3913.4
27.9	1274.4	20.48	19.65	29.18	3907.5
41.9	1301.0	21.40	20.11	29.61	3922.0
53.3	1323.1	22.22	20.48	30.01	3911.7
57.2	1330.5	22.52	20.60	30.15	3905.3

G1R3.14 (A)
ML= 0.12701 MG= 0.00634 QFLUX= 43661. NUTP= 133.9 HTP= 4370.3
PDT= 32.874 PDF= 31.784 ALFA=0.848 TOUT= 22.77, 23.00

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.5	1266.7	38127.3	167.54	91.8	1.03	29.64
OUTLET	21.8	1402.6	38257.8	134.45	82.6	1.03	37.51
MEAN	20.6	1334.6	38192.5	150.99	87.2	1.03	33.57

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1277.2	30.36	19.70	29.22	4580.2
11.4	1290.9	31.03	19.94	29.72	4460.3
19.1	1307.6	31.88	20.22	30.19	4378.3
27.9	1327.3	32.95	20.55	30.61	4340.6
41.9	1358.7	34.72	21.07	31.14	4335.1
53.3	1384.9	36.36	21.49	31.62	4314.4
57.2	1393.7	36.91	21.63	31.81	4296.8

G1R3.15 (A)
ML= 0.12701 MG= 0.01283 QFLUX= 44664. NUTP= 147.7 HTP= 4822.3
PDT= 42.574 PDF= 41.713 ALFA=0.878 TOUT= 22.22, 22.37

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.1	1300.1	77073.9	213.73	89.3	1.03	47.09
OUTLET	22.3	1435.3	77212.6	170.99	80.6	1.03	59.70
MEAN	21.2	1367.7	77143.3	192.36	85.0	1.03	53.40

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1310.3	48.19	20.27	28.77	5245.8
11.4	1324.1	49.26	20.50	29.32	5057.3
19.1	1340.7	50.63	20.78	29.83	4928.7
27.9	1360.3	52.33	21.10	30.41	4797.5
41.9	1391.7	55.23	21.61	31.13	4693.5
53.3	1417.7	57.82	22.02	31.70	4620.4
57.2	1426.5	58.74	22.16	31.87	4608.3

G1R3.16 (A)
ML= 0.12701 MG= 0.01675 QFLUX= 44872. NUTP= 152.8 HTP= 4992.1
PDT= 53.654 PDF= 53.158 ALFA=0.934 TOUT= 22.63, 22.63

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	1333.1	100457.1	243.38	87.1	1.03	54.07
OUTLET	22.8	1466.9	100600.9	189.60	78.8	1.03	70.35
MEAN	21.7	1400.0	100529.0	216.49	82.9	1.03	62.21

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	1343.1	55.38	20.82	28.83	5591.4
11.4	1356.7	56.78	21.04	29.43	5342.3
19.1	1373.2	58.52	21.31	30.02	5149.8
27.9	1392.7	60.69	21.62	30.63	4979.4
41.9	1423.7	64.44	22.12	31.49	4793.4
53.3	1449.5	67.88	22.52	32.10	4690.2
57.2	1458.1	69.10	22.65	32.36	4635.0

G1R4.01 (B)
ML= 0.32949 MG= 0.0000063 QFLUX= 18196. NUTP= 79.6 HTP= 2601.6
PDT= 15.830 PDF= 8.963 ALFA=0.020 TOUT= 22.51, 22.51

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.1	3694.5	36.2	132.38	81.3	2.67	0.04
OUTLET	22.5	3758.9	36.6	116.52	79.9	2.67	0.04
MEAN	22.3	3726.7	36.4	124.10	80.6	2.67	0.04

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3699.8	0.03	22.13	28.46	2871.9
11.4	3706.5	0.03	22.17	28.94	2686.8
19.1	3714.5	0.03	22.22	29.27	2581.0
27.9	3723.9	0.03	22.27	29.41	2552.0
41.9	3738.7	0.03	22.36	29.45	2568.6
53.3	3750.8	0.03	22.43	29.52	2568.4
57.2	3754.8	0.03	22.46	29.52	2576.5

G1R4.02 (B)
ML= 0.32949 MG= 0.0000252 QFLUX= 18161. NUTP= 82.3 HTP= 2690.2
PDT= 16.154 PDF= 9.584 ALFA=0.061 TOUT= 23.01, 23.01

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.6	3775.9	152.5	133.07	79.5	2.67	0.15
OUTLET	23.0	3841.3	154.2	116.52	78.1	2.67	0.18
MEAN	22.8	3808.6	153.3	124.79	78.8	2.67	0.16

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3781.3	0.15	22.62	28.76	2954.5
11.4	3788.1	0.15	22.66	29.22	2766.1
19.1	3796.2	0.15	22.71	29.46	2689.2
27.9	3805.8	0.15	22.76	29.63	2643.4
41.9	3820.8	0.18	22.85	29.72	2642.9
53.3	3833.1	0.18	22.92	29.74	2666.1
57.2	3837.2	0.18	22.94	29.77	2662.4

G1R4.03 (B)
ML= 0.32949 MG= 0.0000466 QFLUX= 22201. NUTP= 75.5 HTP= 2463.1
PDT= 15.975 PDF= 9.584 ALFA=0.089 TOUT= 21.14, 21.16

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	3452.5	280.3	133.07	87.2	2.67	0.28
OUTLET	21.1	3526.9	282.9	117.21	85.3	2.67	0.32
MEAN	20.8	3489.7	281.6	124.79	86.3	2.67	0.30

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3458.7	0.27	20.63	28.72	2742.5
11.4	3466.4	0.27	20.68	29.42	2541.2
19.1	3475.6	0.30	20.74	29.63	2498.1
27.9	3486.5	0.30	20.81	30.02	2411.7
41.9	3503.6	0.30	20.92	30.13	2410.1
53.3	3517.6	0.30	21.01	30.21	2412.8
57.2	3522.3	0.30	21.03	30.21	2420.1

G1R4.04 (B)
ML= 0.32949 MG= 0.0000882 QFLUX= 22280. NUTP= 77.0 HTP= 2515.9
PDT= 15.582 PDF= 9.584 ALFA=0.147 TOUT= 21.74, 21.74

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.1	3540.0	529.2	133.07	85.0	2.67	0.52
OUTLET	21.6	3616.2	534.2	117.90	83.2	2.67	0.60
MEAN	21.4	3578.1	531.7	125.48	84.1	2.67	0.56

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3546.3	0.52	21.18	29.11	2810.8
11.4	3554.2	0.55	21.23	29.77	2609.1
19.1	3563.7	0.55	21.29	30.15	2516.5
27.9	3574.8	0.55	21.36	30.41	2464.8
41.9	3592.3	0.58	21.47	30.50	2468.8
53.3	3606.6	0.58	21.56	30.58	2470.1
57.2	3611.4	0.58	21.59	30.59	2478.0

G1R4.05 (B-F)
ML= 0.32949 MG= 0.000166 QFLUX= 22271. NUTP= 81.1 HTP= 2649.9
PDT= 16.058 PDF= 10.756 ALFA=0.242 TOUT= 22.54, 22.54

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.0	3683.5	996.2	134.45	81.6	2.67	0.98
OUTLET	22.5	3762.1	1006.3	118.59	79.8	2.67	1.12
MEAN	22.3	3722.8	1001.2	126.86	80.7	2.67	1.05

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3690.0	1.01	22.07	29.62	2945.4
11.4	3698.1	1.01	22.12	30.23	2746.7
19.1	3707.9	1.04	22.18	30.57	2654.7
27.9	3719.4	1.04	22.24	30.78	2612.3
41.9	3737.4	1.07	22.36	30.95	2592.7
53.3	3752.2	1.10	22.44	31.03	2595.8
57.2	3757.2	1.13	22.47	31.04	2599.3

G1R4.06 (S-F)
ML= 0.32949 MG= 0.000242 QFLUX= 22274. NUTP= 74.4 HTP= 2423.9
PDT= 16.761 PDF= 11.859 ALFA=0.306 TOUT= 18.96, 18.96

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.4	3126.0	1462.6	136.51	96.7	2.66	1.38
OUTLET	18.9	3194.3	1473.8	119.97	94.5	2.66	1.59
MEAN	18.7	3160.1	1468.2	128.24	95.6	2.66	1.49

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3131.6	1.40	18.46	26.51	2761.6
11.4	3138.7	1.43	18.51	27.27	2538.8
19.1	3147.2	1.46	18.56	27.74	2427.8
27.9	3157.1	1.49	18.63	28.03	2371.4
41.9	3172.8	1.52	18.74	28.18	2361.3
53.3	3185.7	1.55	18.83	28.22	2373.0
57.2	3190.0	1.58	18.86	28.29	2363.9

G1R4.07 (S-F)
ML= 0.32949 MG= 0.000337 QFLUX= 22400. NUTP= 91.8 HTP= 2993.4
PDT= 19.339 PDF= 14.823 ALFA=0.359 TOUT= 20.17, 20.17

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.6	3302.6	2034.5	142.72	91.3	2.67	1.86
OUTLET	20.1	3374.7	2051.0	123.41	89.3	2.67	2.17
MEAN	19.9	3338.7	2042.7	133.07	90.3	2.67	2.01

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3308.6	1.89	19.66	26.62	3214.3
11.4	3316.0	1.92	19.71	27.08	3039.5
19.1	3325.0	1.95	19.77	27.28	2981.1
27.9	3335.5	2.01	19.83	27.44	2944.8
41.9	3352.0	2.07	19.94	27.51	2963.8
53.3	3365.6	2.13	20.03	27.52	2993.1
57.2	3370.2	2.16	20.06	27.54	2994.2

G1R4.08 (S-F)
ML= 0.32949 MG= 0.000461 QFLUX= 25383. NUTP= 102.5 HTP= 3340.3
PDT= 21.856 PDF= 17.512 ALFA=0.383 TOUT= 19.87, 19.87

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.3	3247.7	2775.5	148.92	92.9	2.67	2.42
OUTLET	19.8	3328.3	2796.2	127.55	90.6	2.67	2.87
MEAN	19.5	3288.0	2785.8	137.89	91.8	2.67	2.64

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3254.4	2.47	19.29	26.48	3532.4
11.4	3262.7	2.50	19.35	26.85	3384.5
19.1	3272.7	2.56	19.42	27.03	3334.4
27.9	3284.4	2.62	19.49	27.19	3299.1
41.9	3302.9	2.71	19.62	27.27	3318.1
53.3	3318.1	2.80	19.72	27.35	3329.3
57.2	3323.2	2.83	19.75	27.38	3329.0

G1R4.09 (S-F)
ML= 0.32949 MG= 0.000762 QFLUX= 25465. NUTP= 115.4 HTP= 3766.2
PDT= 25.758 PDF= 22.063 ALFA=0.474 TOUT= 20.86, 20.86

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.2	3396.4	4574.3	159.27	88.7	2.67	3.75
OUTLET	20.8	3480.1	4608.7	133.76	86.5	2.67	4.52
MEAN	20.5	3438.3	4591.5	146.86	87.6	2.67	4.14

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3403.3	3.84	20.28	26.76	3929.8
11.4	3411.9	3.90	20.33	27.01	3811.2
19.1	3422.4	3.99	20.40	27.17	3761.3
27.9	3434.5	4.08	20.48	27.33	3717.5
41.9	3453.8	4.27	20.60	27.41	3741.2
53.3	3469.6	4.42	20.70	27.45	3774.8
57.2	3474.8	4.48	20.73	27.48	3774.5

G1R4.10 (A-F)
ML= 0.32949 MG= 0.00148 QFLUX= 28565. NUTP= 125.7 HTP= 4098.3
PDT= 33.804 PDF= 31.026 ALFA=0.606 TOUT= 19.97, 19.97

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.3	3248.4	8938.0	180.64	92.9	2.67	6.43
OUTLET	19.9	3338.4	8992.7	146.86	90.3	2.67	8.00
MEAN	19.6	3293.4	8965.3	163.40	91.6	2.67	7.21

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3255.7	6.58	19.31	26.08	4212.0
11.4	3265.0	6.71	19.37	26.34	4096.9
19.1	3276.2	6.89	19.44	26.47	4062.9
27.9	3289.3	7.10	19.53	26.59	4043.3
41.9	3310.0	7.44	19.67	26.63	4105.2
53.3	3327.0	7.77	19.78	26.67	4145.7
57.2	3332.7	7.89	19.82	26.68	4161.1

G1R4.11 (A-F)
ML= 0.32949 MG= 0.00223 QFLUX= 28565. NUTP= 134.2 HTP= 4377.7
PDT= 39.810 PDF= 37.507 ALFA=0.670 TOUT= 20.36, 20.36

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.8	3323.3	13395.2	201.32	90.7	2.67	8.68
OUTLET	20.4	3414.6	13470.4	161.33	88.2	2.67	10.92
MEAN	20.1	3368.9	13432.8	181.33	89.5	2.67	9.80

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3330.7	8.87	19.81	26.13	4514.0
11.4	3340.2	9.08	19.87	26.37	4392.7
19.1	3351.5	9.33	19.94	26.54	4324.3
27.9	3364.8	9.60	20.03	26.67	4301.8
41.9	3385.8	10.12	20.16	26.69	4376.7
53.3	3403.0	10.58	20.28	26.69	4453.4
57.2	3408.8	10.76	20.31	26.69	4479.4

G1R4.12 (A)
ML= 0.32949 MG= 0.00299 QFLUX= 33910. NUTP= 142.8 HTP= 4659.3
PDT= 43.498 PDF= 41.368 ALFA=0.702 TOUT= 21.14, 21.21

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	3425.6	17941.8	215.80	87.9	2.67	10.90
OUTLET	21.1	3536.7	18034.5	172.37	85.1	2.67	13.78
MEAN	20.8	3481.2	17988.1	193.74	86.5	2.67	12.34

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3434.6	11.16	20.48	27.62	4750.9
11.4	3446.1	11.40	20.55	27.84	4652.1
19.1	3459.9	11.70	20.64	28.03	4591.9
27.9	3476.1	12.10	20.74	28.14	4584.1
41.9	3501.6	12.77	20.91	28.18	4660.9
53.3	3522.7	13.35	21.04	28.13	4779.3
57.2	3529.7	13.56	21.08	28.17	4787.7

G1R4.13 (A)
ML= 0.32949 MG= 0.00360 QFLUX= 35840. NUTP= 148.6 HTP= 4854.1
PDT= 44.884 PDF= 42.816 ALFA=0.710 TOUT= 21.50, 21.62

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.9	3505.1	21578.5	224.08	85.9	2.67	12.63
OUTLET	21.7	3624.4	21687.3	179.26	83.0	2.67	15.95
MEAN	21.3	3564.7	21632.9	202.01	84.4	2.67	14.29

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3514.7	12.92	20.99	28.17	4989.3
11.4	3527.0	13.20	21.07	28.44	4862.4
19.1	3541.9	13.56	21.16	28.68	4767.5
27.9	3559.2	14.02	21.27	28.80	4759.4
41.9	3586.7	14.78	21.44	28.81	4861.9
53.3	3609.3	15.45	21.58	28.78	4975.5
57.2	3616.8	15.70	21.62	28.80	4996.4

G1R4.14 (A)
ML= 0.32949 MG= 0.00553 QFLUX= 41362. NUTP= 154.6 HTP= 5043.2
PDT= 58.280 PDF= 56.467 ALFA=0.746 TOUT= 19.97, 20.24

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.4	3271.9	33283.6	243.38	92.2	2.67	17.79
OUTLET	20.3	3400.9	33415.1	185.47	88.6	2.67	23.59
MEAN	19.8	3336.4	33349.3	214.42	90.4	2.67	20.69

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3282.3	18.23	19.48	27.47	5173.3
11.4	3295.6	18.71	19.57	27.79	5033.3
19.1	3311.6	19.32	19.68	27.93	5010.6
27.9	3330.4	20.12	19.80	28.13	4966.5
41.9	3360.1	21.46	19.99	28.21	5041.1
53.3	3384.5	22.68	20.16	28.22	5132.4
57.2	3392.7	23.13	20.21	28.29	5120.9

G1R4.15 (A)
ML= 0.32949 MG= 0.00764 QFLUX= 41520. NUTP= 163.7 HTP= 5336.7
PDT= 61.052 PDF= 59.363 ALFA=0.766 TOUT= 19.32, 19.82

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.1	3226.9	46042.5	274.41	93.5	2.67	21.82
OUTLET	20.0	3354.1	46182.6	213.04	89.9	2.67	28.30
MEAN	19.5	3290.5	46112.6	243.38	91.7	2.67	25.06

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3237.1	22.31	19.18	26.78	5461.2
11.4	3250.2	22.86	19.27	27.03	5349.5
19.1	3266.0	23.56	19.37	27.22	5293.8
27.9	3284.5	24.45	19.50	27.38	5268.5
41.9	3313.8	25.94	19.69	27.48	5335.5
53.3	3338.0	27.31	19.85	27.53	5410.1
57.2	3346.0	27.80	19.91	27.62	5384.8

G1R4.16 (A)
ML= 0.32949 MG= 0.00981 QFLUX= 44677. NUTP= 174.0 HTP= 5679.7
PDT= 76.751 PDF= 75.083 ALFA=0.769 TOUT= 20.63, 21.07

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.4	3419.4	58883.6	292.33	88.1	2.67	26.35
OUTLET	21.3	3561.1	59075.1	215.80	84.5	2.67	36.04
MEAN	20.8	3490.3	58979.3	254.41	86.3	2.67	31.20

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	3430.7	27.07	20.46	28.07	5866.6
11.4	3445.3	27.86	20.55	28.37	5710.1
19.1	3462.9	28.86	20.66	28.61	5626.4
27.9	3483.6	30.15	20.79	28.81	5579.3
41.9	3516.2	32.37	21.00	28.87	5679.4
53.3	3543.1	34.47	21.17	28.93	5761.9
57.2	3552.1	35.24	21.23	28.99	5756.2

G1R5.01 (B)
ML= 0.74742 MG= 0.0000063 QFLUX= 43261. NUTP= 167.0 HTP= 5436.1
PDT= 43.691 PDF= 36.748 ALFA=0.011 TOUT= 21.45, 21.45

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.9	7782.7	41.5	184.78	87.8	6.04	0.03
OUTLET	21.4	7927.3	41.8	141.34	86.2	6.05	0.04
MEAN	21.2	7855.0	41.7	163.40	87.0	6.04	0.03

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7794.7	0.03	20.98	28.62	5663.0
11.4	7809.7	0.03	21.02	28.96	5450.7
19.1	7827.7	0.03	21.07	29.09	5397.3
27.9	7848.7	0.03	21.13	29.16	5391.6
41.9	7881.9	0.03	21.23	29.19	5430.3
53.3	7909.1	0.03	21.30	29.25	5446.7
57.2	7918.2	0.03	21.33	29.29	5431.0

G1R5.02 (B)
ML= 0.74742 MG= 0.0000365 QFLUX= 43441. NUTP= 166.0 HTP= 5403.1
PDT= 44.705 PDF= 37.921 ALFA=0.039 TOUT= 21.11, 21.11

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.6	7658.6	216.7	186.16	89.2	6.04	0.15
OUTLET	21.0	7801.8	218.3	141.34	87.6	6.04	0.20
MEAN	20.8	7730.2	217.5	163.40	88.4	6.04	0.18

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7670.4	0.15	20.63	28.51	5510.8
11.4	7685.3	0.15	20.67	28.69	5418.7
19.1	7703.1	0.15	20.72	28.79	5381.6
27.9	7723.9	0.18	20.78	28.87	5370.6
41.9	7756.8	0.18	20.87	28.92	5402.6
53.3	7783.8	0.18	20.95	28.98	5414.1
57.2	7792.8	0.21	20.98	28.99	5417.6

G1R5.03 (B)
ML= 0.74742 MG= 0.0000668 QFLUX= 43683. NUTP= 168.0 HTP= 5469.6
PDT= 45.608 PDF= 38.886 ALFA=0.046 TOUT= 21.38, 21.38

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.9	7760.3	403.3	188.91	88.1	6.04	0.28
OUTLET	21.3	7905.9	406.3	143.41	86.4	6.05	0.37
MEAN	21.1	7833.1	404.8	166.16	87.2	6.04	0.33

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7772.4	0.27	20.92	28.74	5580.8
11.4	7787.5	0.30	20.96	28.90	5502.7
19.1	7805.6	0.30	21.01	29.03	5445.0
27.9	7826.8	0.30	21.07	29.12	5432.4
41.9	7860.2	0.34	21.17	29.16	5462.9
53.3	7887.6	0.37	21.24	29.21	5481.9
57.2	7896.8	0.37	21.27	29.24	5482.3

G1R5.04 (B)
ML= 0.74742 MG= 0.000122 QFLUX= 43510. NUTP= 172.7 HTP= 5622.9
PDT= 46.856 PDF= 40.403 ALFA=0.079 TOUT= 22.05, 22.05

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.5	7987.8	727.7	195.81	85.5	6.05	0.49
OUTLET	21.9	8136.3	733.2	148.92	83.9	6.05	0.65
MEAN	21.7	8062.1	730.4	172.37	84.7	6.05	0.57

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8000.1	0.52	21.56	29.15	5728.1
11.4	8015.5	0.52	21.60	29.30	5649.7
19.1	8034.0	0.55	21.65	29.42	5600.2
27.9	8055.6	0.55	21.71	29.50	5584.0
41.9	8089.7	0.58	21.80	29.55	5615.2
53.3	8117.6	0.64	21.88	29.58	5647.5
57.2	8127.0	0.64	21.91	29.63	5633.3

G1R5.05 (B-F)
ML= 0.74742 MG= 0.000194 QFLUX= 43620. NUTP= 160.2 HTP= 5212.9
PDT= 49.193 PDF= 42.954 ALFA=0.112 TOUT= 19.77, 19.77

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.2	7187.1	1171.1	202.70	95.2	6.04	0.75
OUTLET	19.6	7323.1	1178.4	153.75	93.4	6.04	1.00
MEAN	19.4	7255.1	1174.7	178.57	94.3	6.04	0.87

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7198.4	0.76	19.24	27.39	5346.5
11.4	7212.4	0.79	19.28	27.61	5237.8
19.1	7229.4	0.82	19.33	27.73	5197.3
27.9	7249.1	0.85	19.39	27.84	5164.0
41.9	7280.3	0.91	19.48	27.86	5209.6
53.3	7305.9	0.98	19.56	27.91	5227.9
57.2	7314.5	0.98	19.59	27.95	5218.8

G1R5.06 (B-F)
ML= 0.74742 MG= 0.000270 QFLUX= 44652. NUTP= 178.7 HTP= 5819.3
PDT= 50.200 PDF= 44.195 ALFA=0.144 TOUT= 22.68, 22.68

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	22.2	8225.0	1616.9	209.60	83.0	6.05	1.02
OUTLET	22.6	8380.9	1628.7	159.27	81.4	6.05	1.36
MEAN	22.4	8302.9	1622.8	184.09	82.2	6.05	1.19

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8237.9	1.04	22.21	29.71	5950.4
11.4	8254.0	1.07	22.25	29.87	5859.6
19.1	8273.5	1.10	22.30	30.01	5791.6
27.9	8296.2	1.16	22.36	30.09	5780.8
41.9	8331.9	1.22	22.46	30.14	5814.3
53.3	8361.3	1.31	22.54	30.20	5828.0
57.2	8371.1	1.34	22.56	30.26	5805.6

G1R5.07 (F)
ML= 0.74742 MG= 0.000345 QFLUX= 44828. NUTP= 173.7 HTP= 5654.7
PDT= 52.048 PDF= 46.263 ALFA=0.183 TOUT= 22.20, 22.20

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	21.6	8022.4	2066.3	215.80	85.1	6.05	1.26
OUTLET	22.0	8175.7	2080.2	164.09	83.5	6.05	1.68
MEAN	21.8	8099.1	2073.3	190.29	84.3	6.05	1.47

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8035.1	1.28	21.65	29.36	5811.4
11.4	8050.9	1.34	21.69	29.56	5704.0
19.1	8070.0	1.37	21.75	29.69	5642.8
27.9	8092.4	1.43	21.81	29.79	5613.8
41.9	8127.6	1.52	21.91	29.86	5639.9
53.3	8156.4	1.62	21.98	29.92	5648.7
57.2	8166.1	1.65	22.01	29.96	5639.3

G1R5.08 (F)
ML= 0.74742 MG= 0.000458 QFLUX= 44967. NUTP= 165.2 HTP= 5378.2
PDT= 54.364 PDF= 48.883 ALFA=0.220 TOUT= 20.58, 20.58

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.0	7457.6	2756.9	224.08	91.7	6.04	1.61
OUTLET	20.4	7602.2	2772.8	169.61	89.9	6.04	2.14
MEAN	20.2	7529.9	2764.8	197.19	90.8	6.04	1.87

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7469.6	1.65	20.04	28.11	5576.1
11.4	7484.6	1.71	20.09	28.32	5466.5
19.1	7502.6	1.74	20.14	28.52	5369.0
27.9	7523.6	1.83	20.21	28.63	5339.5
41.9	7556.8	1.95	20.30	28.72	5339.7
53.3	7584.0	2.04	20.38	28.77	5358.3
57.2	7593.1	2.10	20.41	28.83	5338.1

G1R5.09 (F)
ML= 0.74742 MG= 0.000684 QFLUX= 45036. NUTP= 157.8 HTP= 5132.9
PDT= 56.860 PDF= 51.848 ALFA=0.288 TOUT= 19.62, 19.62

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.0	7128.6	4124.0	237.18	96.0	6.04	2.26
OUTLET	19.4	7267.7	4144.5	179.95	94.1	6.04	2.99
MEAN	19.2	7198.1	4134.3	208.91	95.1	6.04	2.62

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7140.1	2.32	19.06	27.41	5391.1
11.4	7154.5	2.38	19.11	27.70	5238.5
19.1	7171.8	2.47	19.16	27.91	5147.2
27.9	7192.0	2.56	19.22	28.06	5098.3
41.9	7224.0	2.71	19.32	28.19	5076.9
53.3	7250.2	2.87	19.39	28.28	5072.4
57.2	7258.9	2.93	19.42	28.31	5067.5

G1R5.10 (F)

ML= 0.74742 MG= 0.00147 QFLUX= 43617. NUTP= 158.3 HTP= 5151.0
PDT= 63.789 PDF= 59.639 ALFA=0.415 TOUT= 19.65, 19.67

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.1	7136.5	8860.6	268.20	95.9	6.04	4.29
OUTLET	19.5	7270.8	8898.6	204.77	94.1	6.04	5.66
MEAN	19.3	7203.6	8879.6	236.49	95.0	6.04	4.98

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7147.5	4.39	19.08	27.08	5453.8
11.4	7161.4	4.51	19.13	27.41	5268.5
19.1	7178.2	4.66	19.18	27.63	5162.2
27.9	7197.7	4.85	19.24	27.79	5098.7
41.9	7228.6	5.15	19.33	27.91	5086.2
53.3	7253.9	5.46	19.41	27.95	5105.6
57.2	7262.3	5.55	19.43	28.01	5088.6

G1R5.11 (F)

ML= 0.74742 MG= 0.00211 QFLUX= 43595. NUTP= 165.9 HTP= 5398.6
PDT= 72.380 PDF= 68.326 ALFA=0.422 TOUT= 19.55, 19.55

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.0	7123.9	12731.3	298.54	96.1	6.04	5.53
OUTLET	19.4	7257.7	12779.1	226.14	94.3	6.04	7.35
MEAN	19.2	7190.8	12755.2	262.69	95.2	6.04	6.44

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7134.9	5.67	19.04	26.78	5630.5
11.4	7148.8	5.82	19.09	27.06	5472.9
19.1	7165.4	6.00	19.14	27.26	5367.5
27.9	7184.9	6.25	19.20	27.36	5344.7
41.9	7215.6	6.68	19.29	27.41	5370.0
53.3	7240.9	7.07	19.37	27.45	5395.5
57.2	7249.3	7.19	19.39	27.47	5396.4

G1R5.12 (F)

ML= 0.74742 MG= 0.00271 QFLUX= 43605. NUTP= 168.5 HTP= 5482.1
PDT= 78.613 PDF= 74.738 ALFA=0.453 TOUT= 19.85, 19.85

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.3	7223.5	16298.6	322.67	94.7	6.04	6.57
OUTLET	19.7	7358.7	16355.3	244.07	92.9	6.04	8.73
MEAN	19.5	7291.1	16326.9	283.37	93.8	6.04	7.65

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7234.6	6.74	19.35	26.96	5723.8
11.4	7248.6	6.92	19.39	27.23	5559.7
19.1	7265.5	7.13	19.44	27.44	5452.2
27.9	7285.2	7.44	19.50	27.57	5404.4
41.9	7316.2	7.92	19.59	27.59	5449.7
53.3	7341.7	8.38	19.67	27.59	5505.7
57.2	7350.2	8.56	19.69	27.60	5517.0

G1R5.13 (F)
ML= 0.74742 MG= 0.00332 QFLUX= 44292. NUTP= 171.8 HTP= 5589.9
PDT= 83.322 PDF= 79.633 ALFA=0.477 TOUT= 19.27, 19.27

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.7	7031.8	20026.0	346.11	97.4	6.04	7.50
OUTLET	19.1	7165.8	20086.1	262.69	95.5	6.04	9.93
MEAN	18.9	7098.8	20056.1	304.05	96.4	6.04	8.72

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7042.8	7.68	18.76	26.43	5777.9
11.4	7056.6	7.89	18.81	26.70	5611.2
19.1	7073.3	8.14	18.86	26.88	5519.1
27.9	7092.9	8.47	18.92	27.01	5479.5
41.9	7123.6	9.02	19.01	26.94	5587.6
53.3	7148.9	9.54	19.09	26.85	5706.3
57.2	7157.3	9.72	19.11	26.86	5721.8

G1R5.14 (F)
ML= 0.74742 MG= 0.00349 QFLUX= 44453. NUTP= 177.7 HTP= 5783.0
PDT= 83.508 PDF= 79.840 ALFA=0.485 TOUT= 20.81, 20.80

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.3	7542.8	20981.8	348.18	90.6	6.04	7.88
OUTLET	20.7	7685.7	21051.8	264.75	88.9	6.04	10.42
MEAN	20.5	7614.2	21016.8	306.81	89.8	6.04	9.15

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7554.5	8.08	20.29	27.69	6003.5
11.4	7569.3	8.29	20.34	27.99	5804.3
19.1	7587.1	8.53	20.39	28.16	5724.7
27.9	7607.9	8.90	20.45	28.27	5681.9
41.9	7640.7	9.48	20.54	28.24	5776.6
53.3	7667.7	10.03	20.62	28.19	5870.4
57.2	7676.7	10.21	20.64	28.19	5890.5

G2R1.01 (S)

ML= 0.00630 MG= 0.00000756 QFLUX= 2453 NUTP= 6.5 HTP= 177.7

PDT= 4.868 PDF= -0.414 ALFA=0.282 TOUT= 22.83, 23.01

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	20.2	9.1	42.2	113.07	653.2	0.0487	0.05
OUTLET	23.3	11.3	42.2	108.25	528.5	0.0487	0.05
MEAN	21.8	10.2	42.2	110.31	590.9	0.0487	0.05

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	9.3	0.06	20.47	34.62	173.3
11.4	9.5	0.06	20.80	36.23	159.3
19.1	9.7	0.06	21.19	37.28	152.9
27.9	10.0	0.06	21.65	37.68	153.5
41.9	10.5	0.06	22.37	36.42	174.9
53.3	11.0	0.06	22.96	33.25	237.8
57.2	11.1	0.06	23.15	31.77	283.6

G2R1.02 (S)

ML= 0.00630 MG= 0.0000264 QFLUX= 2447 NUTP= 8.2 HTP= 226.6

PDT= 2.606 PDF= -2.206 ALFA=0.345 TOUT= 22.83, 23.38

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.8	8.8	155.8	104.11	673.7	0.0487	0.20
OUTLET	22.9	10.9	155.7	102.04	545.8	0.0487	0.20
MEAN	21.3	9.9	155.7	103.42	609.8	0.0487	0.20

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	9.0	0.18	20.01	33.82	177.5
11.4	9.2	0.18	20.34	34.09	178.2
19.1	9.4	0.18	20.73	34.22	181.7
27.9	9.7	0.21	21.18	33.98	191.5
41.9	10.2	0.21	21.89	32.53	230.1
53.3	10.6	0.21	22.48	29.74	336.0
57.2	10.7	0.21	22.68	28.28	434.6

G2R1.03 (S)

ML= 0.00630 MG= 0.0000453 QFLUX= 2469 NUTP= 8.8 HTP= 241.9

PDT= 1.979 PDF= -2.275 ALFA=0.427 TOUT= 22.61, 23.70

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	8.8	275.2	103.42	675.6	0.0487	0.35
OUTLET	22.9	10.9	275.1	101.35	546.5	0.0487	0.36
MEAN	21.3	9.8	275.2	102.04	611.1	0.0487	0.35

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8.9	0.34	19.97	33.54	182.3
11.4	9.1	0.37	20.30	33.56	186.6
19.1	9.4	0.37	20.69	33.54	192.6
27.9	9.7	0.37	21.15	33.13	206.5
41.9	10.2	0.37	21.87	31.71	251.0
53.3	10.6	0.37	22.46	29.35	357.3
57.2	10.7	0.37	22.66	28.11	451.1

G2R1.04 (S)
ML= 0.00630 MG= 0.0000882 QFLUX= 2466 NUTP= 9.8 HTP= 270.3
PDT= 1.682 PDF= -2.137 ALFA=0.484 TOUT= 22.44, 23.84

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.6	8.7	528.0	102.73	679.4	0.0487	0.67
OUTLET	22.7	10.8	527.9	100.66	550.4	0.0487	0.69
MEAN	21.2	9.8	528.0	101.35	614.9	0.0487	0.68

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8.9	0.67	19.89	30.31	236.7
11.4	9.1	0.67	20.21	30.45	240.9
19.1	9.3	0.67	20.60	30.88	240.0
27.9	9.6	0.67	21.06	31.11	245.5
41.9	10.1	0.70	21.77	30.95	268.7
53.3	10.5	0.70	22.36	29.48	346.0
57.2	10.7	0.70	22.55	28.41	420.2

G2R1.05 (S-C)
ML= 0.00630 MG= 0.000179 QFLUX= 2457 NUTP= 14.0 HTP= 385.0
PDT= 2.055 PDF= -1.517 ALFA=0.517 TOUT= 22.71, 23.91

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	8.8	1076.4	102.73	675.6	0.0487	1.37
OUTLET	22.8	10.8	1076.3	100.66	549.0	0.0487	1.42
MEAN	21.2	9.8	1076.3	102.04	612.3	0.0487	1.39

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8.9	1.37	19.97	25.93	411.5
11.4	9.1	1.37	20.29	26.29	409.0
19.1	9.4	1.37	20.67	26.89	395.2
27.9	9.7	1.40	21.12	27.60	379.3
41.9	10.1	1.40	21.82	28.48	369.7
53.3	10.5	1.40	22.40	29.08	368.2
57.2	10.7	1.40	22.59	28.67	404.9

G2R1.06 (C)
ML= 0.00630 MG= 0.000264 QFLUX= 3510 NUTP= 17.9 HTP= 492.8
PDT= 2.199 PDF= -1.034 ALFA=0.566 TOUT= 24.17, 24.73

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	8.8	1592.4	102.73	674.0	0.0487	2.01
OUTLET	24.1	11.8	1588.0	100.66	502.8	0.0487	2.11
MEAN	21.9	10.3	1590.2	102.04	588.4	0.0487	2.06

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	9.0	2.04	20.11	26.69	532.1
11.4	9.3	2.04	20.56	27.22	525.7
19.1	9.7	2.04	21.10	27.91	514.9
27.9	10.1	2.07	21.73	28.82	495.2
41.9	10.8	2.07	22.73	30.18	471.6
53.3	11.4	2.10	23.54	31.21	459.1
57.2	11.6	2.10	23.81	31.18	477.5

G2R1.07 (C)
ML= 0.00630 MG= 0.000323 QFLUX= 5437. NUTP= 20.3 HTP= 557.0
PDT= 2.213 PDF= -0.896 ALFA=0.583 TOUT= 26.77, 27.58

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.7	8.8	1947.9	102.73	674.9	0.0487	2.47
OUTLET	26.4	13.8	1933.1	100.66	430.8	0.0487	2.61
MEAN	23.1	11.3	1940.5	102.04	552.9	0.0487	2.54

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	9.1	2.50	20.28	29.38	594.9
11.4	9.6	2.50	20.98	30.12	593.0
19.1	10.1	2.53	21.81	31.33	570.5
27.9	10.8	2.53	22.78	32.38	566.4
41.9	12.0	2.56	24.31	34.41	539.7
53.3	13.1	2.59	25.56	36.18	514.0
57.2	13.4	2.59	25.98	36.32	527.8

G2R1.08 (C)
ML= 0.00630 MG= 0.000386 QFLUX= 6676 NUTP= 20.8 HTP= 571.2
PDT= 2.579 PDF= -0.345 ALFA=0.608 TOUT= 27.34, 28.45

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.3	8.6	2330.0	103.42	693.6	0.0487	2.92
OUTLET	27.4	14.8	2304.9	101.35	402.0	0.0487	3.11
MEAN	23.4	11.7	2317.4	102.04	547.8	0.0487	3.02

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	9.0	2.96	20.00	30.73	619.0
11.4	9.5	2.99	20.84	31.78	608.4
19.1	10.2	2.99	21.86	33.17	589.1
27.9	11.0	3.02	23.04	34.67	574.0
41.9	12.5	3.05	24.91	37.10	548.8
53.3	13.8	3.08	26.43	38.87	539.2
57.2	14.3	3.11	26.94	39.44	536.7

G2R1.09 (A)
ML= 0.00630 MG= 0.00102 QFLUX= 8467 NUTP= 25.0 HTP= 687.0
PDT= 2.096 PDF= 0.069 ALFA=0.728 TOUT= 28.36, 29.64

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	19.2	8.5	6123.6	102.73	697.9	0.0487	7.75
OUTLET	28.8	16.1	6041.6	100.66	369.4	0.0487	8.27
MEAN	24.0	12.3	6082.6	101.35	533.7	0.0487	8.01

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	9.0	7.83	20.02	30.84	778.1
11.4	9.6	7.89	21.01	32.28	748.4
19.1	10.4	7.96	22.21	34.02	714.9
27.9	11.4	8.02	23.59	35.93	685.8
41.9	13.2	8.11	25.78	38.75	654.3
53.3	14.9	8.20	27.56	41.00	633.3
57.2	15.5	8.23	28.16	41.76	626.5

G2R1.10 (A)

ML= 0.00630 MG= 0.00182 QFLUX= 8575 NUTP= 29.4 HTP= 809.1
PDT= 3.041 PDF= 1.517 ALFA=0.795 TOUT= 27.54, 27.95

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	18.4	8.1	10970.8	104.11	735.7	0.0487	13.59
OUTLET	27.3	14.7	10829.2	101.35	405.2	0.0487	14.58
MEAN	22.9	11.4	10900.0	102.73	570.5	0.0487	14.08

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8.5	13.75	19.18	27.96	970.5
11.4	9.0	13.84	20.11	29.55	904.0
19.1	9.7	13.96	21.22	31.28	850.2
27.9	10.6	14.08	22.51	33.16	805.1
41.9	12.2	14.30	24.54	35.92	756.3
53.3	13.6	14.45	26.21	38.09	725.8
57.2	14.1	14.51	26.77	38.76	719.2

G2R1.11 (A)

ML= 0.00630 MG= 0.00244 QFLUX= 9748 NUTP= 30.9 HTP= 848.9
PDT= 3.606 PDF= 2.413 ALFA=0.835 TOUT= 27.37, 28.2

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.7	7.7	14778.5	105.49	774.5	0.0487	18.04
OUTLET	27.2	14.5	14560.4	102.04	409.0	0.0487	19.48
MEAN	22.4	11.1	14669.5	103.42	591.7	0.0487	18.76

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	8.1	18.26	18.46	27.22	1105.3
11.4	8.6	18.38	19.45	29.14	1000.3
19.1	9.3	18.53	20.64	31.32	910.0
27.9	10.3	18.75	22.03	33.64	838.9
41.9	11.9	19.05	24.21	36.98	765.7
53.3	13.4	19.32	25.99	39.53	724.6
57.2	13.9	19.39	26.59	40.36	712.8

G2R1.12 (A)

ML= 0.00630 MG= 0.00307 QFLUX= 9880 NUTP= 33.2 HTP= 913.0
PDT= 4.730 PDF= 3.723 ALFA=0.864 TOUT= 26.56, 27.56

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.5	7.6	18567.3	107.56	785.4	0.0487	22.15
OUTLET	26.6	13.9	18302.6	102.73	425.2	0.0487	24.13
MEAN	22.0	10.7	18435.0	105.49	605.3	0.0487	23.14

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7.9	22.43	18.22	26.32	1211.0
11.4	8.5	22.62	19.17	28.22	1086.5
19.1	9.1	22.83	20.31	30.39	977.5
27.9	10.0	23.10	21.64	32.64	897.9
41.9	11.5	23.53	23.74	35.86	817.7
53.3	12.9	23.90	25.45	38.24	777.0
57.2	13.4	24.02	26.02	39.04	764.2

G2R1.13 (A)
ML= 0.00630 MG= 0.00372 QFLUX= 10864 NUTP= 36.4 HTP= 1001.6
PDT= 6.191 PDF= 5.240 ALFA=0.873 TOUT= 26.37, 27.27

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.9	7.3	22525.8	111.00	815.4	0.0487	26.08
OUTLET	26.4	13.8	22176.2	104.80	430.5	0.0487	28.80
MEAN	21.7	10.5	22351.0	107.56	623.0	0.0487	27.44

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7.6	26.40	17.68	25.96	1303.4
11.4	8.2	26.67	18.67	27.86	1176.4
19.1	8.9	26.98	19.87	30.07	1061.6
27.9	9.7	27.34	21.25	32.29	983.6
41.9	11.3	27.95	23.43	35.42	908.8
53.3	12.7	28.47	25.22	37.78	869.3
57.2	13.2	28.62	25.81	38.53	859.4

G2R1.14 (A)
ML= 0.00630 MG= 0.00728 QFLUX= 10874 NUTP= 44.3 HTP= 1217.4
PDT= 13.121 PDF= 12.410 ALFA=0.909 TOUT= 24.52, 24.61

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.5	7.1	44165.2	125.48	838.6	0.0487	44.91
OUTLET	23.9	11.5	43636.9	112.38	510.7	0.0487	51.82
MEAN	20.2	9.3	43901.1	119.28	674.7	0.0487	48.37

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7.3	45.60	17.08	23.96	1571.9
11.4	7.7	46.24	17.85	25.54	1408.5
19.1	8.2	47.03	18.77	27.26	1279.0
27.9	8.8	47.98	19.85	29.03	1185.1
41.9	9.9	49.56	21.54	31.31	1116.2
53.3	10.8	50.90	22.93	33.05	1079.5
57.2	11.2	51.36	23.39	33.56	1074.6

G2R1.15 (A)
ML= 0.00630 MG= 0.01316 QFLUX= 12822 NUTP= 51.2 HTP= 1407.6
PDT= 26.310 PDF= 25.579 ALFA=0.904 TOUT= 23.13, 23.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.8	7.2	79780.7	158.58	821.1	0.0487	64.54
OUTLET	23.2	11.0	78916.8	131.69	533.3	0.0487	79.61
MEAN	20.0	9.1	79348.7	145.48	677.2	0.0487	72.07

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7.4	65.81	17.32	23.54	2048.7
11.4	7.8	67.15	17.99	25.59	1681.0
19.1	8.2	68.82	18.79	27.54	1462.8
27.9	8.7	70.90	19.73	29.32	1337.6
41.9	9.6	74.34	21.21	31.42	1259.2
53.3	10.4	77.42	22.41	32.90	1227.8
57.2	10.7	78.52	22.81	33.34	1223.5

G2R1.16 (A)
ML= 0.00630 MG= 0.01713 QFLUX= 13441 NUTP= 53.4 HTP= 1467.2
PDT= 35.094 PDF= 34.956 ALFA=0.987 TOUT= 22.22, 22.20

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.9	7.3	103770.9	184.09	812.9	0.0487	72.24
OUTLET	22.8	10.7	102721.3	148.92	549.9	0.0487	91.52
MEAN	19.9	9.0	103246.1	166.85	681.4	0.0487	81.88

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	7.5	73.76	17.42	23.57	2175.1
11.4	7.8	75.44	18.03	25.77	1731.3
19.1	8.2	77.57	18.76	27.69	1503.0
27.9	8.6	80.19	19.61	29.16	1407.5
41.9	9.4	84.64	20.94	31.22	1311.1
53.3	10.2	88.67	22.03	32.51	1288.3
57.2	10.4	90.07	22.39	32.91	1284.2

G2R2.01 (B-S)
ML= 0.04750 MG= 0.0000063 QFLUX= 2425 NUTP= 13.2 HTP= 361.7
PDT= 9.011 PDF= 2.689 ALFA=0.150 TOUT= 17.07, 18.01

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.1	52.9	40.3	118.59	844.4	0.365	0.04
OUTLET	17.5	54.4	40.5	109.62	821.4	0.365	0.05
MEAN	17.3	53.6	40.4	113.76	832.9	0.365	0.05

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	53.0	0.03	17.13	21.66	533.4
11.4	53.2	0.03	17.17	22.57	448.6
19.1	53.4	0.03	17.22	23.39	392.5
27.9	53.6	0.03	17.28	24.23	349.1
41.9	53.9	0.06	17.38	25.09	314.6
53.3	54.2	0.06	17.46	25.74	293.2
57.2	54.3	0.06	17.48	25.93	287.5

G2R2.02 (S)
ML= 0.04750 MG= 0.0000252 QFLUX= 2422 NUTP= 13.2 HTP= 360.5
PDT= 7.488 PDF= 1.999 ALFA=0.261 TOUT= 16.79, 17.27

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.6	51.3	156.2	115.14	870.3	0.365	0.17
OUTLET	17.1	52.8	156.8	107.56	846.8	0.365	0.19
MEAN	16.8	52.0	156.5	111.69	858.5	0.365	0.18

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	51.4	0.18	16.67	21.35	517.0
11.4	51.6	0.18	16.72	22.22	440.0
19.1	51.8	0.18	16.77	23.00	388.4
27.9	52.0	0.18	16.83	23.78	348.7
41.9	52.3	0.18	16.92	24.57	317.3
53.3	52.6	0.18	17.00	25.14	298.1
57.2	52.7	0.18	17.03	25.33	292.4

G2R2.03 (S)

ML= 0.04750 MG= 0.0000440 QFLUX= 2422 NUTP= 13.4 HTP= 366.2

PDT= 6.584 PDF= 1.310 ALFA=0.292 TOUT= 17.05, 17.60

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.0	52.6	269.5	113.07	848.8	0.3	0.30
OUTLET	17.4	54.1	270.7	106.87	825.7	0.3	0.33
MEAN	17.2	53.4	270.1	110.31	837.3	0.3	0.32

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	52.8	0.30	17.05	21.64	527.1
11.4	52.9	0.30	17.09	22.59	440.2
19.1	53.1	0.30	17.14	23.36	389.6
27.9	53.3	0.30	17.21	24.07	353.1
41.9	53.6	0.30	17.30	24.76	325.3
53.3	53.9	0.34	17.38	25.23	309.1
57.2	54.0	0.34	17.41	25.37	304.8

G2R2.04 (S)

ML= 0.04750 MG= 0.0000768 QFLUX= 3794 NUTP= 15.3 HTP= 419.6

PDT= 5.709 PDF= 0.896 ALFA=0.350 TOUT= 17.88, 18.48

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.5	54.3	467.6	111.69	822.2	0.365	0.54
OUTLET	18.1	56.8	469.4	106.18	787.4	0.365	0.57
MEAN	17.8	55.5	468.5	108.94	804.8	0.365	0.55

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	54.5	0.55	17.55	24.32	558.4
11.4	54.8	0.55	17.62	25.57	476.0
19.1	55.1	0.55	17.69	26.46	432.7
27.9	55.4	0.55	17.79	27.16	405.0
41.9	56.0	0.55	17.94	27.71	388.6
53.3	56.4	0.58	18.06	28.07	379.3
57.2	56.6	0.58	18.10	28.21	376.0

G2R2.05 (S)

ML= 0.04750 MG= 0.000163 QFLUX= 3781 NUTP= 18.9 HTP= 518.4

PDT= 5.647 PDF= 1.241 ALFA=0.409 TOUT= 17.05, 17.78

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.7	51.5	983.4	111.69	867.8	0.365	1.13
OUTLET	17.3	53.7	987.0	105.49	831.5	0.365	1.20
MEAN	17.0	52.6	985.2	108.94	849.7	0.365	1.16

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	51.7	1.13	16.74	22.99	603.3
11.4	51.9	1.16	16.81	23.67	550.4
19.1	52.2	1.16	16.88	24.02	529.9
27.9	52.5	1.16	16.98	24.46	505.5
41.9	53.0	1.19	17.12	24.66	502.0
53.3	53.4	1.19	17.24	24.89	495.1
57.2	53.6	1.19	17.28	24.97	493.0

G2R2.06 (S-C)
ML= 0.04750 MG= 0.000236 QFLUX= 5393 NUTP= 23.6 HTP= 647.3
PDT= 5.957 PDF= 1.862 ALFA=0.446 TOUT= 17.63, 18.13

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.6	51.3	1438.6	111.69	871.0	0.365	1.65
OUTLET	17.5	54.5	1442.9	106.18	819.5	0.365	1.75
MEAN	17.1	52.9	1440.7	108.94	845.2	0.365	1.70

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	51.5	1.65	16.71	24.09	729.4
11.4	51.9	1.68	16.80	24.82	672.2
19.1	52.3	1.68	16.92	25.21	650.0
27.9	52.7	1.71	17.05	25.49	638.7
41.9	53.5	1.71	17.26	25.76	634.7
53.3	54.1	1.74	17.43	26.03	627.5
57.2	54.3	1.74	17.49	26.07	628.6

G2R2.07 (S-C)
ML= 0.04750 MG= 0.000327 QFLUX= 5383 NUTP= 26.1 HTP= 713.7
PDT= 6.619 PDF= 2.827 ALFA=0.484 TOUT= 17.50, 17.78

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.3	50.2	1985.5	113.07	890.3	0.365	2.24
OUTLET	17.2	53.3	1991.1	106.87	837.9	0.365	2.40
MEAN	16.8	51.7	1988.3	110.31	864.1	0.365	2.32

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	50.4	2.26	16.37	23.17	792.1
11.4	50.7	2.29	16.47	23.75	739.3
19.1	51.1	2.29	16.58	24.02	724.5
27.9	51.6	2.32	16.72	24.43	698.3
41.9	52.3	2.35	16.93	24.56	706.0
53.3	52.9	2.38	17.09	24.92	689.1
57.2	53.1	2.38	17.16	25.04	683.6

G2R2.08 (C)
ML= 0.04750 MG= 0.000394 QFLUX= 6112 NUTP= 28.8 HTP= 788.1
PDT= 6.991 PDF= 3.585 ALFA=0.543 TOUT= 17.98, 18.16

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.8	51.9	2390.8	114.45	861.3	0.365	2.67
OUTLET	17.8	55.6	2397.3	107.56	803.9	0.365	2.87
MEAN	17.3	53.7	2394.1	111.00	832.6	0.365	2.77

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	52.2	2.71	16.88	23.81	881.8
11.4	52.5	2.71	16.99	24.48	815.6
19.1	53.0	2.74	17.12	24.80	795.7
27.9	53.5	2.77	17.27	25.12	778.8
41.9	54.4	2.80	17.51	25.40	774.9
53.3	55.1	2.83	17.71	25.77	759.0
57.2	55.3	2.87	17.77	25.91	751.8

G2R2.09 (C)
ML= 0.04750 MG= 0.000728 QFLUX= 6033 NUTP= 29.8 HTP= 815.9
PDT= 8.846 PDF= 5.929 ALFA=0.605 TOUT= 17.80, 18.08

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.6	51.2	4419.0	117.90	872.2	0.365	4.79
OUTLET	17.6	54.8	4430.5	108.94	815.3	0.365	5.22
MEAN	17.1	53.0	4424.8	113.76	843.8	0.365	5.00

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	51.5	4.85	16.69	23.23	921.0
11.4	51.9	4.88	16.79	23.84	855.9
19.1	52.3	4.94	16.92	24.27	821.8
27.9	52.8	5.00	17.07	24.62	799.7
41.9	53.6	5.09	17.31	24.86	799.5
53.3	54.3	5.18	17.49	25.13	790.1
57.2	54.6	5.18	17.56	25.26	784.5

G2R2.10 (A)
ML= 0.04750 MG= 0.00144 QFLUX= 7748 NUTP= 33.7 HTP= 921.5
PDT= 11.521 PDF= 8.687 ALFA=0.614 TOUT= 17.80, 18.03

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.1	49.6	8734.6	123.41	899.9	0.365	9.02
OUTLET	17.4	54.1	8749.0	111.69	826.4	0.365	10.04
MEAN	16.8	51.8	8741.8	117.90	863.2	0.365	9.53

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	50.0	9.14	16.24	23.55	1058.6
11.4	50.4	9.24	16.37	24.38	967.3
19.1	51.0	9.33	16.53	24.83	933.5
27.9	51.6	9.48	16.72	25.29	905.0
41.9	52.6	9.72	17.02	25.66	897.6
53.3	53.5	9.91	17.26	26.02	885.4
57.2	53.8	9.97	17.34	26.16	879.2

G2R2.11 (A)
ML= 0.04750 MG= 0.00222 QFLUX= 8149 NUTP= 38.5 HTP= 1054.4
PDT= 14.858 PDF= 12.272 ALFA=0.652 TOUT= 17.88, 18.03

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.3	50.1	13475.7	131.00	890.9	0.365	13.16
OUTLET	17.6	54.8	13495.0	115.83	815.6	0.365	14.99
MEAN	17.0	52.5	13485.3	123.41	853.2	0.365	14.08

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	50.5	13.35	16.40	23.18	1200.1
11.4	51.0	13.50	16.54	23.91	1105.6
19.1	51.5	13.72	16.70	24.35	1065.3
27.9	52.2	13.99	16.89	24.73	1040.1
41.9	53.3	14.39	17.20	25.14	1026.9
53.3	54.2	14.75	17.45	25.51	1012.2
57.2	54.5	14.87	17.53	25.63	1007.9

G2R2.12 (A)
ML= 0.04750 MG= 0.00318 QFLUX= 9382 NUTP= 47.2 HTP= 1292.3
PDT= 19.188 PDF= 16.823 ALFA=0.683 TOUT= 18.91, 18.99

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.1	53.1	19274.0	139.96	841.6	0.365	17.64
OUTLET	18.6	58.7	19295.0	121.35	761.3	0.365	20.64
MEAN	17.9	55.9	19284.5	131.00	801.4	0.365	19.14

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	53.5	17.92	17.27	23.74	1447.3
11.4	54.1	18.20	17.43	24.42	1341.5
19.1	54.8	18.53	17.61	24.79	1307.1
27.9	55.6	18.96	17.83	25.20	1273.3
41.9	56.9	19.63	18.18	25.60	1264.3
53.3	58.0	20.24	18.46	25.95	1253.1
57.2	58.3	20.42	18.55	26.11	1242.2

G2R2.13 (A)
ML= 0.04750 MG= 0.00381 QFLUX= 9372 NUTP= 47.9 HTP= 1312.7
PDT= 22.118 PDF= 19.994 ALFA=0.719 TOUT= 18.26, 18.33

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.2	50.0	23129.7	146.86	893.6	0.365	20.13
OUTLET	17.7	55.1	23145.9	124.79	810.0	0.365	23.94
MEAN	17.0	52.6	23137.8	135.82	851.8	0.365	22.03

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	50.4	20.48	16.37	22.78	1458.8
11.4	50.9	20.82	16.52	23.34	1371.6
19.1	51.5	21.24	16.71	23.72	1336.2
27.9	52.3	21.76	16.92	24.16	1295.9
41.9	53.5	22.65	17.26	24.57	1282.4
53.3	54.5	23.41	17.53	24.96	1264.6
57.2	54.8	23.65	17.63	25.12	1252.7

G2R2.14 (A)
ML= 0.04750 MG= 0.00690 QFLUX= 10773 NUTP= 55.9 HTP= 1531.9
PDT= 31.777 PDF= 30.199 ALFA=0.791 TOUT= 18.13, 18.18

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	49.2	41935.6	168.92	908.3	0.365	31.62
OUTLET	17.6	54.7	41930.6	137.20	816.6	0.365	39.32
MEAN	16.8	51.9	41933.1	153.06	862.4	0.365	35.47

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	49.6	32.25	16.13	22.51	1685.7
11.4	50.1	32.92	16.29	22.99	1608.9
19.1	50.8	33.77	16.49	23.39	1561.7
27.9	51.6	34.81	16.73	23.82	1519.0
41.9	52.9	36.58	17.09	24.32	1493.5
53.3	54.0	38.19	17.40	24.75	1467.6
57.2	54.3	38.74	17.50	24.91	1455.9

G2R2.15 (A)
ML= 0.04750 MG= 0.01206 QFLUX= 10896 NUTP= 65.3 HTP= 1788.6
PDT= 48.180 PDF= 46.746 ALFA=0.812 TOUT= 17.95, 17.95

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.1	49.7	73189.9	210.98	899.3	0.365	44.27
OUTLET	17.6	54.8	73157.4	162.71	815.2	0.365	57.88
MEAN	16.9	52.2	73173.7	186.85	857.3	0.365	51.08

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	50.0	45.26	16.27	21.81	1965.1
11.4	50.5	46.42	16.42	22.17	1895.4
19.1	51.2	47.88	16.61	22.53	1839.1
27.9	51.9	49.71	16.82	22.98	1768.5
41.9	53.1	52.88	17.16	23.44	1736.9
53.3	54.1	55.78	17.44	23.84	1703.4
57.2	54.4	56.82	17.53	23.99	1689.5

G2R2.16 (A)
ML= 0.04750 MG= 0.01532 QFLUX= 12529 NUTP= 72.0 HTP= 1970.8
PDT= 57.887 PDF= 57.363 ALFA=0.934 TOUT= 18.45, 18.43

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.5	51.0	92878.9	239.93	876.5	0.365	49.52
OUTLET	18.2	56.8	92773.3	182.02	785.7	0.365	65.87
MEAN	17.4	53.9	92826.1	210.98	831.1	0.365	57.70

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	51.4	50.69	16.67	22.42	2176.7
11.4	52.0	52.06	16.84	22.80	2099.7
19.1	52.7	53.80	17.04	23.23	2023.3
27.9	53.5	55.99	17.28	23.71	1950.7
41.9	54.9	59.77	17.66	24.24	1906.4
53.3	56.0	63.31	17.97	24.65	1876.9
57.2	56.4	64.56	18.07	24.82	1858.3

G2R3.01 (B)
ML= 0.37409 MG= 0.0000063 QFLUX= 9413 NUTP= 32.4 HTP= 887.5
PDT= 34.715 PDF= 27.372 ALFA=0.009 TOUT= 17.32, 17.98

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.2	419.9	40.8	172.37	837.3	2.87	0.03
OUTLET	17.4	425.6	40.9	137.89	826.0	2.87	0.04
MEAN	17.3	422.7	40.9	155.13	831.6	2.87	0.03

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	420.3	0.03	17.24	24.18	1350.2
11.4	420.9	0.03	17.26	25.76	1104.6
19.1	421.7	0.03	17.28	27.12	956.8
27.9	422.5	0.03	17.32	28.32	856.2
41.9	423.8	0.03	17.36	29.68	765.7
53.3	424.9	0.03	17.40	30.58	716.7
57.2	425.3	0.03	17.41	30.87	701.8

G2R3.02 (B-S)
ML= 0.37409 MG= 0.0000252 QFLUX= 9413 NUTP= 32.4 HTP= 888.0
PDT= 35.928 PDF= 28.751 ALFA=0.029 TOUT= 17.02, 17.70

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.0	414.9	153.6	175.12	847.2	2.87	0.11
OUTLET	17.3	420.6	154.1	139.27	835.8	2.87	0.14
MEAN	17.2	417.8	153.8	157.20	841.5	2.87	0.13

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	415.4	0.12	17.06	24.01	1348.6
11.4	416.0	0.12	17.08	25.61	1101.7
19.1	416.7	0.12	17.11	26.94	956.5
27.9	417.5	0.12	17.14	28.11	858.6
41.9	418.8	0.12	17.18	29.48	767.1
53.3	419.9	0.15	17.22	30.37	717.8
57.2	420.3	0.15	17.24	30.65	703.8

G2R3.03 (S)
ML= 0.37409 MG= 0.0000466 QFLUX= 9451 NUTP= 32.4 HTP= 887.5
PDT= 36.680 PDF= 29.647 ALFA=0.054 TOUT= 16.64, 17.15

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.5	399.1	282.6	177.19	880.5	2.87	0.20
OUTLET	16.7	404.6	283.6	140.65	868.6	2.87	0.26
MEAN	16.6	401.9	283.1	158.58	874.5	2.87	0.23

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	399.6	0.21	16.48	23.53	1336.0
11.4	400.2	0.21	16.51	25.11	1096.5
19.1	400.8	0.21	16.53	26.42	955.4
27.9	401.6	0.21	16.56	27.60	856.3
41.9	402.9	0.24	16.61	28.89	770.7
53.3	403.9	0.24	16.64	29.76	723.0
57.2	404.3	0.24	16.66	30.03	709.2

G2R3.04 (S)
ML= 0.37409 MG= 0.0000794 QFLUX= 9445 NUTP= 33.0 HTP= 905.1
PDT= 39.093 PDF= 32.198 ALFA=0.071 TOUT= 15.82, 16.62

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	387.4	484.1	183.40	907.1	2.87	0.34
OUTLET	16.2	392.7	485.6	144.10	894.9	2.87	0.43
MEAN	16.1	390.0	484.9	164.09	901.0	2.87	0.38

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	387.8	0.34	16.03	23.04	1343.0
11.4	388.4	0.37	16.06	24.57	1106.8
19.1	389.0	0.37	16.08	25.84	967.2
27.9	389.8	0.37	16.11	26.94	872.0
41.9	391.0	0.40	16.16	28.11	791.7
53.3	392.0	0.43	16.19	28.82	749.8
57.2	392.3	0.43	16.21	29.04	737.9

G2R3.05 (S)
ML= 0.37409 MG= 0.000158 QFLUX= 8489 NUTP= 35.8 HTP= 980.6
PDT= 43.105 PDF= 36.611 ALFA=0.127 TOUT= 16.01, 16.41

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	386.1	967.2	193.74	909.9	2.87	0.63
OUTLET	16.2	390.9	970.1	150.99	899.0	2.87	0.82
MEAN	16.1	388.5	968.6	172.37	904.5	2.87	0.73

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	386.5	0.64	15.98	22.08	1388.5
11.4	387.0	0.67	16.00	23.33	1157.4
19.1	387.6	0.67	16.02	24.31	1024.5
27.9	388.3	0.70	16.05	25.09	939.5
41.9	389.4	0.76	16.09	25.72	882.8
53.3	390.3	0.79	16.13	26.04	857.8
57.2	390.6	0.79	16.14	26.10	854.1

G2R3.06 (S)
ML= 0.37409 MG= 0.000228 QFLUX= 8486 NUTP= 38.3 HTP= 1048.1
PDT= 46.173 PDF= 39.920 ALFA=0.159 TOUT= 15.89, 16.31

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	15.9	384.9	1385.0	202.01	912.8	2.87	0.87
OUTLET	16.1	389.6	1388.9	155.82	901.9	2.87	1.14
MEAN	16.0	387.3	1387.0	178.57	907.4	2.87	1.01

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	385.3	0.88	15.93	21.88	1424.7
11.4	385.8	0.91	15.95	23.02	1199.7
19.1	386.4	0.94	15.98	23.84	1078.4
27.9	387.1	0.98	16.00	24.48	1001.4
41.9	388.1	1.04	16.04	24.85	965.0
53.3	389.0	1.10	16.08	25.01	951.9
57.2	389.3	1.13	16.09	25.01	953.2

G2R3.07 (S)
ML= 0.37409 MG= 0.000321 QFLUX= 8616 NUTP= 41.8 HTP= 1145.2
PDT= 49.614 PDF= 43.850 ALFA=0.224 TOUT= 16.04, 16.41

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	386.8	1951.2	210.29	908.5	2.87	1.18
OUTLET	16.2	391.6	1956.5	160.65	897.4	2.87	1.55
MEAN	16.1	389.2	1953.8	185.47	903.0	2.87	1.37

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	387.2	1.22	16.01	21.76	1494.5
11.4	387.7	1.25	16.03	22.78	1274.5
19.1	388.3	1.28	16.05	23.47	1160.5
27.9	389.0	1.34	16.08	23.94	1095.3
41.9	390.1	1.40	16.12	24.16	1072.2
53.3	391.0	1.49	16.16	24.16	1076.8
57.2	391.3	1.52	16.17	24.17	1076.7

G2R3.08 (S-A)
ML= 0.37409 MG= 0.000383 QFLUX= 8612 NUTP= 43.9 HTP= 1200.9
PDT= 51.910 PDF= 46.401 ALFA=0.258 TOUT= 16.39, 16.62

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.2	391.8	2322.8	216.49	896.8	2.87	1.37
OUTLET	16.4	396.7	2329.0	164.78	885.8	2.87	1.80
MEAN	16.3	394.3	2325.9	190.98	891.3	2.87	1.59

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	392.2	1.40	16.20	21.79	1539.7
11.4	392.7	1.43	16.22	22.74	1320.7
19.1	393.4	1.49	16.24	23.38	1207.4
27.9	394.1	1.55	16.27	23.78	1147.6
41.9	395.2	1.65	16.32	23.89	1137.6
53.3	396.1	1.74	16.35	23.89	1143.2
57.2	396.4	1.77	16.36	23.93	1139.3

G2R3.09 (S-A)
ML= 0.37409 MG= 0.000769 QFLUX= 9858 NUTP= 51.9 HTP= 1420.6
PDT= 61.362 PDF= 56.536 ALFA=0.352 TOUT= 16.64, 16.67

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.2	391.2	4672.7	242.00	898.3	2.87	2.46
OUTLET	16.4	396.8	4683.6	180.64	885.7	2.87	3.31
MEAN	16.3	394.0	4678.2	210.98	892.0	2.87	2.89

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	391.7	2.53	16.18	21.99	1694.5
11.4	392.2	2.59	16.20	22.74	1507.0
19.1	392.9	2.68	16.23	23.24	1407.4
27.9	393.7	2.80	16.26	23.48	1366.6
41.9	395.0	2.99	16.31	23.46	1379.0
53.3	396.1	3.17	16.35	23.40	1398.5
57.2	396.4	3.23	16.36	23.43	1395.5

G2R3.10 (S-A)
ML= 0.37409 MG= 0.00179 QFLUX= 9953 NUTP= 60.2 HTP= 1648.3
PDT= 77.834 PDF= 73.980 ALFA=0.480 TOUT= 17.02, 17.17

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.7	406.0	10828.9	283.37	865.8	2.87	4.89
OUTLET	16.9	411.7	10851.4	206.15	853.7	2.87	6.75
MEAN	16.8	408.9	10840.1	244.76	859.7	2.87	5.82

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	406.4	5.00	16.74	22.04	1874.4
11.4	407.0	5.15	16.76	22.62	1697.0
19.1	407.8	5.36	16.78	22.90	1628.8
27.9	408.6	5.61	16.82	23.06	1596.4
41.9	409.9	6.04	16.87	23.01	1621.6
53.3	411.0	6.46	16.91	22.93	1651.3
57.2	411.4	6.61	16.92	22.91	1660.7

G2R3.11 (A)
ML= 0.37409 MG= 0.00257 QFLUX= 12274 NUTP= 63.0 HTP= 1726.1
PDT= 84.990 PDF= 81.426 ALFA=0.525 TOUT= 16.21, 16.52

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	385.7	15621.8	304.05	911.1	2.87	6.55
OUTLET	16.2	392.4	15647.9	218.56	895.5	2.87	9.13
MEAN	16.1	389.0	15634.8	261.31	903.3	2.87	7.84

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	386.2	6.71	15.97	22.31	1936.4
11.4	386.9	6.92	15.99	22.96	1763.7
19.1	387.8	7.19	16.03	23.23	1704.4
27.9	388.7	7.53	16.07	23.38	1680.2
41.9	390.3	8.14	16.13	23.36	1699.3
53.3	391.6	8.69	16.18	23.24	1737.3
57.2	392.0	8.90	16.19	23.25	1739.4

G2R3.12 (A)
ML= 0.37409 MG= 0.00321 QFLUX= 12390 NUTP= 67.5 HTP= 1848.7
PDT= 90.534 PDF= 87.286 ALFA=0.568 TOUT= 17.60, 17.68

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	17.1	415.7	19452.0	319.91	845.6	2.87	7.80
OUTLET	17.3	423.1	19485.9	229.59	830.9	2.87	10.92
MEAN	17.2	419.4	19469.0	274.41	838.3	2.87	9.36

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	416.3	8.02	17.09	23.12	2056.1
11.4	417.1	8.26	17.12	23.71	1881.8
19.1	418.0	8.56	17.16	23.95	1824.4
27.9	419.1	8.99	17.19	24.10	1795.3
41.9	420.7	9.72	17.26	24.01	1836.2
53.3	422.1	10.39	17.31	23.98	1855.6
57.2	422.6	10.64	17.32	23.97	1864.9

G2R3.13 (A)
ML= 0.37409 MG= 0.00379 QFLUX= 12491 NUTP= 68.5 HTP= 1876.0
PDT= 95.843 PDF= 92.595 ALFA=0.561 TOUT= 17.17, 17.27

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.7	406.0	22989.2	330.25	865.6	2.87	8.92
OUTLET	17.0	413.2	23026.7	234.42	850.6	2.87	12.61
MEAN	16.9	409.6	23008.0	281.99	858.1	2.87	10.76

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	406.6	9.14	16.74	22.73	2083.4
11.4	407.4	9.45	16.77	23.33	1904.7
19.1	408.3	9.81	16.81	23.57	1847.1
27.9	409.3	10.30	16.84	23.73	1815.4
41.9	411.0	11.19	16.90	23.61	1864.4
53.3	412.3	11.98	16.95	23.53	1898.1
57.2	412.8	12.28	16.97	23.51	1910.3

G2R4.01 (B)
ML= 0.56183 MG= 0.0000063 QFLUX= 7701 NUTP= 34.3 HTP= 938.0
PDT= 53.151 PDF= 45.780 ALFA=0.007 TOUT= 16.04, 17.05

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.3	580.1	39.1	211.67	909.6	4.31	0.02
OUTLET	16.4	584.5	39.2	157.89	902.9	4.31	0.03
MEAN	16.3	582.3	39.2	184.78	906.2	4.31	0.03

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	580.5	0.03	16.27	21.81	1387.0
11.4	580.9	0.03	16.28	22.93	1157.2
19.1	581.5	0.03	16.30	23.91	1011.2
27.9	582.1	0.03	16.31	24.81	906.8
41.9	583.1	0.03	16.34	25.77	817.2
53.3	583.9	0.03	16.36	26.44	765.6
57.2	584.2	0.03	16.37	26.65	750.7

G2R4.02 (B-S)
ML= 0.56183 MG= 0.0000252 QFLUX= 7701 NUTP= 34.5 HTP= 943.1
PDT= 54.282 PDF= 47.022 ALFA=0.023 TOUT= 16.34, 16.77

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.3	582.1	154.9	213.73	906.5	4.31	0.09
OUTLET	16.4	586.4	155.4	159.27	899.9	4.31	0.12
MEAN	16.4	584.3	155.2	186.85	903.2	4.31	0.11

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	582.4	0.09	16.32	21.79	1404.6
11.4	582.9	0.09	16.33	22.92	1167.8
19.1	583.4	0.09	16.35	23.92	1016.9
27.9	584.1	0.09	16.37	24.83	909.4
41.9	585.1	0.12	16.39	25.79	819.7
53.3	585.9	0.12	16.41	26.46	768.1
57.2	586.2	0.12	16.42	26.68	752.1

G2R4P03 (B-S)
ML= 0.56183 MG= 0.0000453 QFLUX= 7701. NUTP= 34.7 HTP= 949.4
PDT= 55.323 PDF= 48.125 ALFA=0.029 TOUT= 16.39, 16.77

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.4	584.0	271.9	216.49	903.5	4.31	0.16
OUTLET	16.5	588.4	272.7	160.65	896.9	4.31	0.22
MEAN	16.4	586.2	272.3	188.22	900.2	4.31	0.19

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	584.4	0.15	16.37	21.78	1418.4
11.4	584.9	0.18	16.38	22.92	1176.1
19.1	585.4	0.18	16.40	23.91	1024.9
27.9	586.0	0.18	16.42	24.83	915.1
41.9	587.0	0.18	16.44	25.79	824.5
53.3	587.9	0.21	16.46	26.47	771.2
57.2	588.1	0.21	16.47	26.66	757.3

G2R4.04 (S)
ML= 0.56183 MG= 0.0000894 QFLUX= 7739 NUTP= 35.3 HTP= 965.3
PDT= 57.743 PDF= 50.745 ALFA=0.056 TOUT= 16.01, 16.46

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.1	574.3	542.9	223.39	918.7	4.31	0.31
OUTLET	16.2	578.6	544.4	165.47	912.0	4.31	0.42
MEAN	16.2	576.5	543.7	194.43	915.4	4.31	0.37

Z	RESL	VSG	TBULK	TWALL	HTP
5.1	574.7	0.30	16.12	21.52	1429.5
11.4	575.1	0.34	16.13	22.63	1189.9
19.1	575.6	0.34	16.14	23.58	1040.0
27.9	576.3	0.37	16.16	24.48	931.1
41.9	577.3	0.37	16.19	25.43	838.6
53.3	578.1	0.40	16.21	25.97	794.5
57.2	578.3	0.40	16.22	26.16	780.5

G2R4.05 (S)
ML= 0.56183 MG= 0.000180 QFLUX= 8486 NUTP= 38.1 HTP= 1042.5
PDT= 62.914 PDF= 56.191 ALFA=0.095 TOUT= 15.94, 16.31

	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.0	569.7	1092.3	238.55	926.1	4.31	0.58
OUTLET	16.1	574.4	1095.2	175.81	918.6	4.31	0.79
MEAN	16.1	572.0	1093.8	207.53	922.4	4.31	0.69

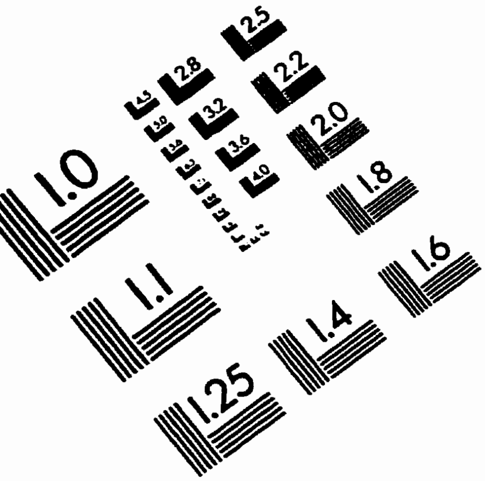
Z	RESL	VSG	TBULK	TWALL	HTP
5.1	570.1	0.61	16.00	21.63	1502.5
11.4	570.6	0.61	16.01	22.79	1250.6
19.1	571.2	0.64	16.03	23.74	1100.0
27.9	571.8	0.67	16.04	24.53	1001.4
41.9	572.9	0.70	16.07	25.25	926.2
53.3	573.8	0.76	16.10	25.64	891.0
57.2	574.1	0.76	16.11	25.72	884.2

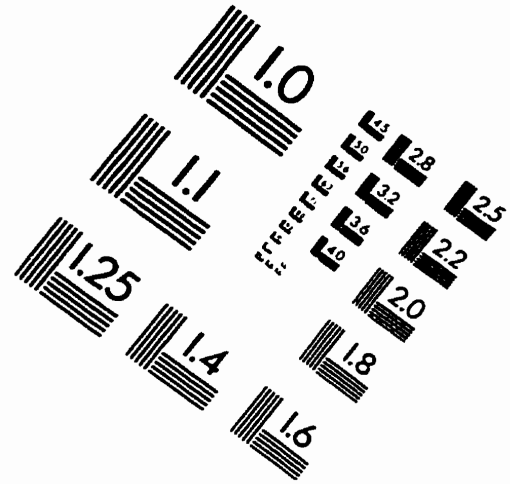
G2R4.06 (S-F)
ML= 0.56183 MG= 0.000253 QFLUX= 8575 NUTP= 41.5 HTP= 1135.0
PDT= 67.230 PDF= 60.742 ALFA=0.128 TOUT= 16.21, 16.64

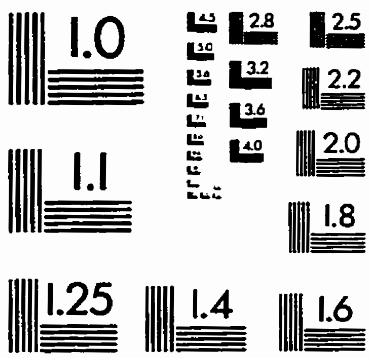
	TMIX	RESL	RESG	P	PRL	VSL	VSG
INLET	16.3	582.1	1533.4	250.97	906.5	4.31	0.78
OUTLET	16.4	586.9	1537.3	184.09	899.1	4.31	1.07
MEAN	16.4	584.5	1535.3	217.18	902.8	4.31	0.92

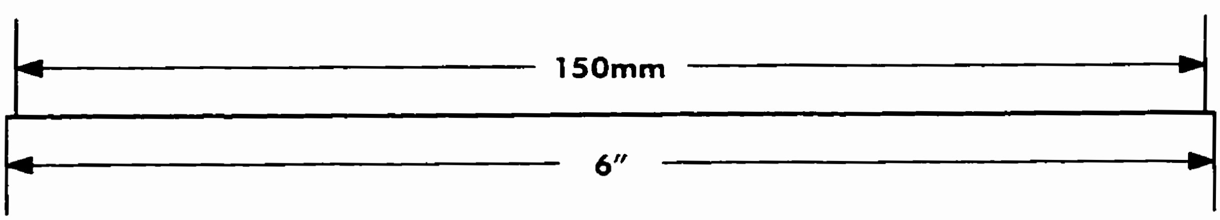
Z	RESL	VSG	TBULK	TWALL	HTP
5.1	582.5	0.79	16.32	21.70	1591.0
11.4	583.0	0.82	16.34	22.77	1330.3
19.1	583.6	0.85	16.35	23.62	1178.7
27.9	584.3	0.88	16.37	24.29	1083.6
41.9	585.4	0.94	16.40	24.75	1027.8
53.3	586.3	1.04	16.42	24.95	1006.8
57.2	586.6	1.04	16.43	25.01	1000.2

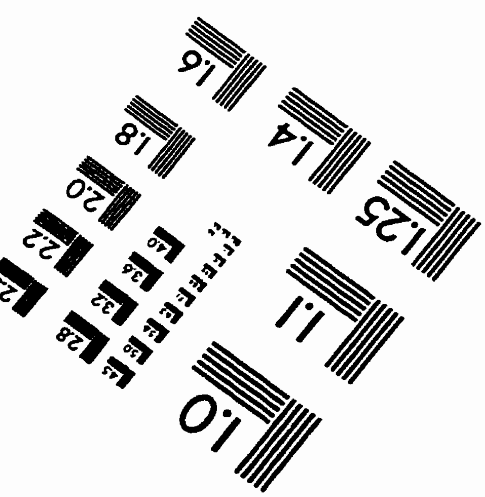
IMAGE EVALUATION TEST TARGET (QA-3)

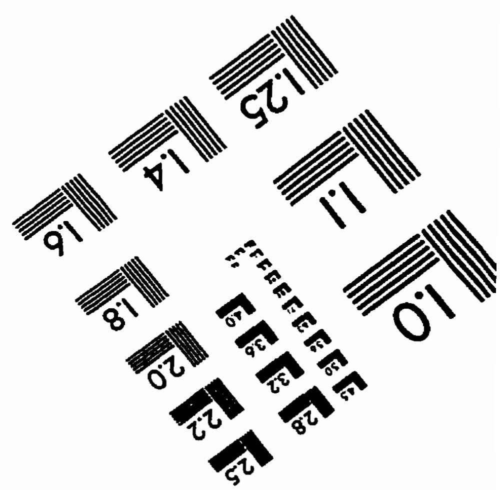












APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989