STUDIES IN SWIRLING FLOW WITH SALT SOLUTION

A DISSERTATION
Submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF ENGINEERING
in
CHEMICAL ENGINEERING
(Plant and Equipment Design)

By
RAJ KUMAR SHARMA

DEPARTMENT OF CHEMICAL ENGINEERING
UNIVERSITY OF ROORKEE
ROORKEE (INDIA)
April, 1978

CERTIFICATE

CERTIFIED that the dissertation entitled "STUDIES IN SWIRLING FLOW WITH SALT SOLUTION" which is being submitted by Shri Raj Kumar Sharma in partial fulfilment of the requirements for the award of the DEGREE OF MASTER OF ENGINEERING IN CHEMICAL ENGINEERING (EQUIPMENT AND PLANT DESIGN) of the University of Roorkee, Roorkee is a record of candidate's own work carried out by him under the supervision and guidance of the undersigned. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

This is further certified that he has worked for a period of about six and half month for preparing this dissertation at this University.

B D Sharma

Dr.B.D.SHARMA
Reader
Chemical Engineering Deptt.
University of Roorkee,
Roorkee

Roorkee

28th April,1978.

ACKNOWLEDGEMENTS

The author expresses his deep sense of gratitude and indebtedness to Dr. B.D. Sharma, Reader in Chemical Engineering Department, University of Roorkee, Roorkee for providing inspirational guidance and encouragement throughout the duration of this work.

The author is greatful to Dr. H. Gopal Krishna, Professor and Head of Chemical Engineering Department, University of Roorkee, Roorkee for providing the necessary facilities and help.

The author is very much greatful to Dr. P.S. Panesar, Professor in Chemical Engineering Department, University of Roorkee, Roorkee, for his invaluable suggestions, whole hearted help and lab facilities.

Thanks are due to Dr. B.S. Varshney, Professor and to all the teachers of Chemical Engineering Department, University of Roorkee, Roorkee for their kind help and inspiration at various stages of this work.

Comperation of laboratory and fabrication staff in experimental work of the thesis is thankfully acknowledged.

At last the author is thankful to his friend Shri S.P. Singh, U.G.C. Research Fellow, for his kind help at every stage of this work.

ABSTRACT

Hydrodynamic studies of dilute sodium chloride salt solutions of one, two and three per cent concentration in swirling flow on long horizontal tubes and heat transfer studies in a swirl flow double pipe heat exchanger were conducted. Two tubes of 5.71 cms and 3.81 cms I.D., and 380 cms length and one tube of 2.54 cms I.D. and 185 cms length were employed for the hydrodynamic studies. Two swirl chambers one of mild steel having 11.50 cms I.D. and 1.60 cms I.D. tangential inlets and other of perspex having 10.30 cms I.D. and five different sets of tangential entries were used for generating swirling flow. An aluminium casted swirl chamber, having same dimensions as that of perspex swirl chamber, was used for the heat transfer studies. Only one set of tangential entries of 1.27 cms I.D. out of five sets was used for both hydrodynamic and heat transfer studies.

Predicted pressure drops for all the runs taken for hydrodynamic studies for various sets of parameters were calculated using Sharmas(21) generalised correlation for predicting pressure drops in long horizontal tubes for swirling flow without reversal.It was observed that correlation was applicable for dilute sodium chloride salt solutions also for the range of concentration studied with ± 20 percent accuracy.

Correlations for predicting pressure drops for swirling flow without reversal for all the three tubes were proposed, which could be applied with less percentage of errors.

(a) For D_T = 5.41 cms, D_s = 11.50 cms and D_i = 1.60 cms

$$\frac{\Delta P\, g_c}{V_i^2\, \rho} = 2.98 \times 10^{-2} \left[\frac{D_T V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g\, D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6}$$

Applicable with ± 4 % accuracy.

(b) For D_T = 3.81 cms, D_s = 11.50 cms and D_i = 1.60 cms

$$\frac{\Delta P\, g_c}{V_i^2\, \rho} = 2.16 \times 10^{-2} \left[\frac{D_T\, V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g\, D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6}$$

Applicable with ± 4% accuracy.

(c) For D_T = 2.54 cms, D_s = 10.30 cm and D_i = 1.27 cms.

$$\frac{\Delta P g_c}{V_i^2\, \rho} = 2.25 \times 10^{-2} \left[\frac{D_T V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6}$$

Applicable with ± 5% accuracy.

Effect of change of tube diameter, air rate, inlet velocity, salt concentrations on pressure drop, air core diameter and length were studied.

Overall heat transfer coefficients for all the three salt concentrations using swirling flow and axial flow on a double pipe heat exchanger were investigated. An average increase of 16 per cent and 32 per cent in overall heat transfer coefficients was observed for case of no induced air and induced air respectively.

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NOMENCLATURE

A	Heat transfer area	m^2
C_p	Specific heat	Kcal/kg °C
D_a	Average diameter of the air core	cm
D_h	Equivalent hydraulic radius	cm
D_i	Internal diameter of tangential entry	cm
D_s	Internal diameter of swirl chamber	cm
D_T	Inside diameter of the tube	cm
f	Friction factor (Blasius)	
g	Gravitational acceleration	cm/sec^2
g_c	Conversion factor	
L_a	Length of stable air core	cm
L_e	Lenear equivalent length of swirl flow	cm
ℓ	Length of feed pipe	cm
m	Mass flow rate	Kg/sec.
ΔP	Pressure drop of liquid measured at tangential inlets	Kg/cm^2
Q_w	Rate of flow of liquid	Lit/min
q	Heat flux per unit area	$KCal/hr.m^2$
R_a	Radius of air core	cm
R_s	Radius of swirl chamber	cm
S	Cross-sectional area of the channel	cm^2
$\bar{V}$	Average velocity of the liquid	cm/sec
V_a	Average axial component of velocity	cm/sec
V_i	Velocity of liquid at tangential inlets	cm/sec
V_T	Tangential component of velocity at any point	cm/sec

V_{Ta}	Tangential component of the velocity at the air core	cm/sec
V_{TT}	Tangential component of the velocity at the tube radius	cm/sec
V_{Tav}	Average tangential component of the velocity	cm/sec
ρ	Density of the liquid	gm/cc
ν	Kinematic viscosity of the liquid	cm^2/sec
	Circulation constant.	
μ	Viscosity of the liquid	cps

CHAPTER-I

INTRODUCTION

The overall economy of a Chemical process industry depends on how fast are its transport processes. The rate of heat transfer or/and mass transfer is a function of type of flow and boundary conditions of the fluid at the surface of the exchangers. There is an everlasting demand to increase the point velocities or the Reynold number to say more precisely to increase these transfer coefficients at minimum of pressure losses and by avoiding the costly equipment as far as possible. The point velocities can be increased by keeping the contact time (or residence time of the fluid in the equipment) nearly same by swirling flows.

The swirling flow inside a long tube can be generated by any one of the following methods.

(i) By rotating the tube through which the fluid is pumped.

(ii) By introducing fluid into the tube with the help of guided vanes.

(iii) By introducing twisted tape in the tube through which the fluid is pumped.

(iv) By introducing the fluid in the tube through tangential inlets.

All the above mentioned methods have been a subject of research workers interest. Some of them have been commercially used with success. Heat transfer studies (20,22) in double pipe heat exchangers while rotating inner or outer tube have shown an increase in convective heat transfer. In a constant power comparison between tape induced swirl flow and straight flow heat transfer studies (24) have indicated that an improvement of 20-25 percent can readily be obtained with the help of swirl flow. Gambil et al (11,25) have shown that in swirl flow generated by twisted tapes, burnout heat flux could be as much as two and half times larger than the axial flow values at the same pumping power. Kirov(26) has indicated that an overall boiler efficiency was improved by about six percent by utilizing inserts in the flue gas tubes of the air preheater.

A critical appraisal of the available literature and difficulties observed by various workers utilizing different techniques of swirl flow, have been discussed by Sharma(21). In case of rotating tube, maintenance of seals and replacement of moving parts because of wear and tear becomes very expensive. Since it is not possible to rotate the tube at a very high rpm, only low strength swirling motion can be produced. In case of guided vanes technique it is difficult to produce strong swirl.

Twisted tape mechanism presents a serious problem of alignment of twisted tapes in long tubes.

Tangential inlet technique for producing swirling flow appears to be good one(21) since it does not involve any moving parts and there is no obstruction in the path of the fluid flow. Principle of swirl flow generation can be understood by Figure 1.01, showing formation of swirling flow by two tangential inlets. As the liquid enters through a tangential, inlet No.1, it takes a swirling motion and as it meets the liquid from the tangential inlet no.2, it is pushed towards the centre of the tube and give rise to swirling motion. This swirling motion can be of two types.

(i) Forced vortex flow in which angular velocity is contant. The linear velocity at some point is directly proportinal to the radius from the centre of rotation.

(ii) Free vortex motion in which the moment of momentum is radially conserved such that the product of the tangential velocity component and radius at any point within the main body of the liquid is constant ie

$$V_T \times R = \Omega \qquad (1.01)$$

Where Ω is generally known as circulation constant

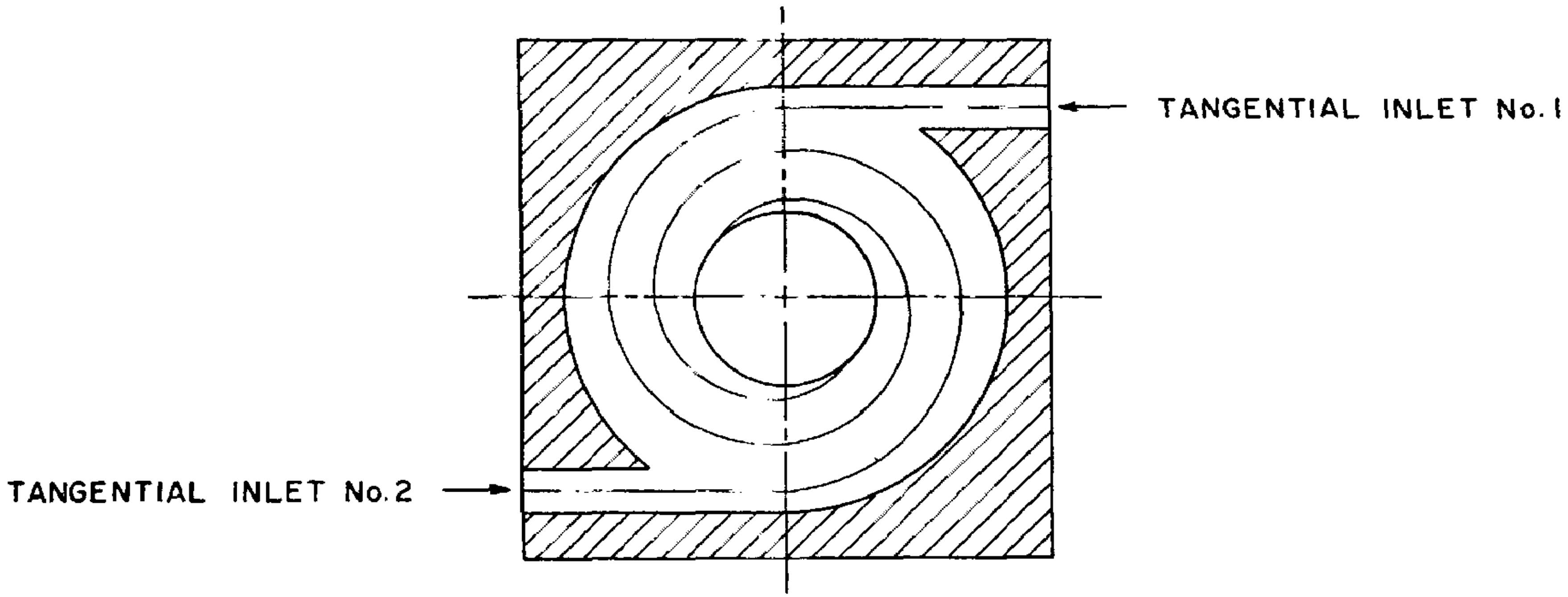


FIG. 1·01 PRODUCTION OF SWIRLING FLOW

The swirling flow produced by tangential inlets is more of free vortex in nature (9,10).

From equation 1.01, as the radius approaches zero, velocity approaches infinity which is hydrodynamically impossible. The axial component of velocity has been reported to cavitate near the central axis if the swirl strength is low. At higher values of swirl strength a complete reversal of axial component was observed. Higher swirl strength give rise to vaccum of such a degree that a central air core is produced, if the system is able to suck air at the axis of swirl from some source, if this air passage is sealed, the liquid itself vaporises to give rise to a vapor core.

The phenomenon of flow reversal in swirling flow had been detrimental to heat and mass transfer operations. Sharma (21) has proposed a technique to produce swirling flow in long tubes without any flow reversal, if natural or pneumatic air is allowed to enter at the axis of the tube.

Having overcome the flow reversal in swirling flow, this field has a great scope of studies for academic as well as industrial interests and applications. The present work was under taken for carrying out hydrodynamic and heat transfer studies and to investigate the flow characteristics in swirling flow of dilute sodium chloride solution in long horizontal tubes. Moreover, the aim of the present work was to generate data for marine industry.

Sodium chloride salt solutions of one, two and three per cent concentrations were used to study the effect of various parameters on pressure drop, air core diameter and length in long perspex tubes for hydrodynamic studies. Two tubes of 5.71 cms and 3.81 cms I.D. and 3.70 cms long and one tube of 2.54 cm I.D. and 185 cm long were employed for the purpose. Mild steel swirl chamber of 11.50 cm I.D. and a perspex swirl chamber of 10.30 cms I.D. were used. Mild steel swirl chamber was provided with one axial and two tangential inlets of 1.60 cm I.D. while perspex swirl chamber with one axial and five different size entires. Only 1.27 cm I.D. tangential inlets of perspex swirl chamber were used.

Emperical correlations for calculating pressure drops have been proposed which were found in confirmity with the general correlation developed by Sharma (21) with a maximum deviation of ± 20% . Preliminary heat transfer studies were conducted on a double pipe swirl flow heat exchanger. An aluminium swirl chamber, having same dimensiones as that of perspex swirl chamber used for hydrodynamic studies for generating swirling flow. was used. Compressed air at low rate was pumped through an air in let at the axis of the swirl. flow. Same set of tangential entries, i.e., 1.27 cm I.D. was used for heat transfer studies also.Heat transfer coefficients by using swirling flow and axial flow are calculatted for all the thee concentrations of salt solution on various flow rates and keeping steam pressure constant content. On comparison between overall heat transfer coefficients by swirling flow and axial flow it was observed that there was an increase of 16% in overall heat transfer coefficients by using swirling flow, when no air was induced and 32% by inducing air at the axis of swirling flow at the rate of 5 Lit/min.

CHAPTER - II

LITERATURE REVIEW

The flow characteristics of rotating systems are of very much theoretical and practical importance. In recent years, a large number of experimental and analytical studies has been conducted on different types of swirling flows. Sufficient work has been done by various workers on swirl flow atomizers, fluid flow between rotating cylinders and in curved channels.

Relatively much work has been done on compressible swirling flow in tubes than swirling incompressible flow in long tubes.

Swirling flow of water in a pipe was studied by Talbot (1) by using a long unperforated tube in which swirling motion was induced by rotating of a part of the tube. Swirl strength generated was insufficient to produce flow reversal but a dimpling of the axial velocity profile at the centre of the tube was reported.

Binnie and Teare (2) conducted the experiments on the flow of a swirling water through a pressure nozzle. Observations were recorded when swirling water was discharged downwards under pressure through a large perspex conical nozzle. It was observed that a boundary layer of forced vortex motion ~~at~~ existed around the free surface of the air core and when the swirl was sufficiently strong axial component of the velocity was reversed in the upper part of the nozzle close to the forced vortex zone.

Binnie(3) also observed the flow reversal in centre of the pipe when swirling flow was produced by rotating the pipe. Three alternative regimes were observed by dye injection technique.

(a) Down stream over the entire cross-section.

(b) Up stream near the axis and down stream near the tube wall.

(c) Down stream near the axis and the wall and upstream in the intermediate region.

Nuttal (4) conducted swirling fluid flow in a long perspex tube set vertically and surmounted by a cylinderical tank containing a ring of guided vanes for producing the swirl. Nuttal observed,

(a) At low rates of swirl, the axial velocity at the pipe centre was less than the expected maximum velocity.

(b) As average axial velocity increases, Centre line velocity decreases to a point where it reversed in direction.

(c) By further increase of the swirl by increasing the average vertical velocity, centre line axial velocity was positive at the centre but negative in a narrow region between the axis and the wall of the pipe.

Regime observed by Binnie (3) were also similar although Binnie's method of producing swirl was different than that of Nuttal.

Keith and Sonju(5) studied the decay of a liquid swirl induced by twisted metal strips in a one inch pipe. He observed that swirl decays to about 10-20 percent of its initial intensity in a distance of about 50 pipe diameters. The decay used to be more rapid at smaller than at larger Reynold numbers.

Place et al(6) studied the behaviour of air flowing through a spray drier by employing tracer technique. They found a region where a core of velocities, opposite in direction to the primary flow existed. The experiments revealed the presence of a zone of reversed flow and they observed a region of downward vertical velocity located between an upward central core and an upward velocity region adjacent to the wall.

Flow reversal is not limited to cylinders alone. it exists in swirl pressure nozzles and cyclone separators. Binnie(2) found that vertical velocity component would reverse itself in the upper section of the nozzles under proper conditions of feed pressure and swirl velocity.

Kelsall (7) obtained velocity measurements in cyclone separators showing a velocity core along the central axis opposite in direction to that which existed along the wall.

Swithberg and Landis(8) studied the convection heat transfer characteristics in tube and velocity distribution by using twisted tape swirl generators. They concluded that,

(a) The axial velocity remains nearly constant over most of the cross-section, while the in plane components appear to be tangential and increase linearly with radius.

(b) The velocity field is helicoidal and corresponds to a forced vortex in the core superimposed on an essentially uniform axial flow.

They explained that the twists were responsible for the double vortex flow pattern.

Bregan et al(9) studied the swirling of water in a vertical tube in which swirl was produced by tangential injection of water from the bottom of the tube. They studied the pressure and velocity profiles to elucidate some of the factors governing the phenomenon of reversed flow. There conclusions regarding pressure profile were as follows -

(a) The static pressure profile along any radius of the tube always showed a minimum at the centre with more or less steady increase towards the wall.

(b) The static pressure measured at the wall decreased steadily down stream from the inlet.

(c) The static pressure profile as well as the patterns of flow established by the axial velocities were primarily controlled by the variation of the tangential velocity and its decay along the axial direction. Boundary layer growth appears to be responsible for the doubly reversed flow.

Conclusion Regarding Velocity Profiles Were As Under

(a) Swirling flow produced by injecting water at constant rate and tangentially into a cylinder through two ports, situated diametrically opposite to each other is found to be steady and approximately cylinderical and coaxial to the tube. However, when injection of water was restricted through one hole only, a spiral core was produced and the cylinderical symmetry was destroyed.

(b) Radial velocities were always small compared to tangential and axial velocities except in narrow regions near the inlet and out let of the cylinder.

(c) The tangential velocity profile accross a radius showed the velocity to increase from zero at the centre to a maximum at a radius usually less than half the tube radius, to keep steady for a further distance and then to fall to zero again at the wall indicating that the flow was essentially forced vortex in nature.

(d) The mean tangential velocity, averaged accross a diameter, steadily decreased down stream from the inlet.

(e) At low rates of flow the vertical velocity was upward throughout the cylinder. However, at higher rates of flow there was a reversed of flow at the axis of the tube so that water flowed downwards at the centre, reversed direction near the inlet and flowed upward near the wall.

King et al (10) in their investigation in swirling in compressible tube flow took a system similar to Bregan(9), studies were carried out in a 2" I.D. test section of plexi-glass tubing 10 feet long held horizontally. Swirl was produced by injecting total fluid through two symmetrical tangential inlets,1/2 inch diameter. They obtained static pressure and velocity profiles by using probe technique. These profiles were determined for test section axial flow Reynold numbers of 10,000,15000,20,000, and 25,000. Following observation were concluded for velocity profiles.

(a) Flow could be roughly divided into free and forced vortex regions.

(b) At the centre of the tube a region of reverse axial flow was observed. The radius of this region decreases with increasing Z/Ro to zero.

(c) The curves of the tangential velocity/inlet velocity versus Z/R_0 were developed as representation of the swirl decay.

From pressure profiles, they concluded that the static pressure at a given Z/R_0 increases monotonically from the centre line to the wall. With increasing Z/R_0, the magnitude of this gradient decreases as the gradient producing swirl decays. At the centre line the axial pressure gradient is positive for considerable distance from the tube.

Gambil et al measured isothermal friction factor in their studies on swirl flow heat transfer of water (11) and ethylene glycol(12). For axial flow of glycol through a 1/4 inch I.D. tube, the friction factors were close to the standard Moody curve(13) for same relative roughness. In case of glycol, the isothermal friction factors were in reasonable agreement with the generalized swirl flow friction factor correlation developed for water and air data (14).

Bergles et al (15) carried out studies in rough tubes with tape generated swirl flow. Pressure drop data for a variety of tubular test sections, with a low pressure water system was taken and also various combinations of tube roughness and swirl flow were tried. They proposed an expression for the isothermal swirl flow friction factor.

Shirivastava et al (16) carried out the pressure studies in two phase flow using swirl generator metallic strips. They studied the effect of twisted tapes and liquid phase viscosity in the two phase flow in horizontal pipes. Water and Glycerine-water mixtures were employed.

Sharma et al (17) carried out studies on the stability of swirling flow in long horizontal tubes. On set and complete development of air core in swirling flow in long tubes have been shown photographically. They observed that injecting of air at the axial of the swirling flow in long tubes improves the length diameter and uniformity of air core.

Kumari N(18) studied the swirling flow in double pipe heat exchanger with a swirl chamber having five different inlet diameters entiries using water and three concentrations of water glycirine solutions and steam as the heating medium. She proposed a correlation to estimate heat transfer coefficient for the swirling flow.

Rao and Sharma(19) studied the performance of steel strips of different pitch to diameter ratios as swirl generator in forced convection heat transfer. The test section was electrically heated and fluid used was water. The heat transfer coefficient was found to be a function of pitch and Reynold number and its value increases with increased in the number of twists upto a particular value. They proposed a dimensionless correlation for heat transfer coefficient.

Becker and Kaye(20) obtained experimental data for different types of flow in an annulus with an inner rotating cylinder. The heat transfer data were subdivided into the following

(i) Axial flow with zero rotation

(ii) Rotation of inner cylinder with zero axial flow

(iii) General case of combined axial flow and rotation.

The heat transfer data were correlated in terms of Reynold number and Taylor number over a wide range of these variables in terms of fairly simple equations for the rotation of inner cylinder with zero axial flow.

Sharma (21) carried out investigations in horizontal tubes by taking different diameters ranging from 18 mm to 57 mm perpex tubes. He studied the effects of various parameters such as tube diameter, tangential entry diameter, flow rates and viscosity on the stability of swirling flow in horizontal tubes. Correlations for pressure drop, air core length and diameter of the air core have been proposed. He observed that higher rates of air do not help much in increasing the air core diameter along the length at the upstream side of the air core however, it increases the air core diameter towards the down stream side. High rates of flow of air cause the stratification of air core at the down stream side. Further, he observed that RPM of swirl decreases in the direction of the flow.

Singh and Ghosh (22) studied heat transfer in concentric heat exchanger with rotating inner pipe. They proposed a correlation for heat transfer coefficient using water and molasses.

Sharma (23) studied overall heat transfer coefficient in a double pipe heat exchanger using water and steam as heating medium and reported substantial increase in the overall heat transfer coefficient by swirling flow.

CHAPTER-III

EXPERIMENTAL SETUP AND PROCEDURE

3.01 EXPERIMENTAL SETUP FOR HYDRODYNAMIC STUDIES

The schematic diagram of the experimental set up used for the present studies is shown in figure 3.01 and a photograph of the same in plate 3.01.

It consists of two feed tanks (1 and 2) equipped with overflow and discharge connections. Salt solution ranging in concentration from 1 to 3 percent was prepared by dissolving sodium chloride in water in the feed tanks. Two tanks were so connected to the suction of the pump (3) that liquid could be sucked from any of the tank. Centrifugal pump of 3 HP and $1\frac{1}{2}$ " size was employed for the studies. The discharge line of the pump was divided into three parts, and all the three parts were connected to a swirl chamber (4). Mild steel swirl chamber of 11.50 cm I.D. and a perspex swirl chamber of 10.30 cm I.D. were used. Mild steel swirl chamber was provided with one axial (5) and two tangential inlet's (6) of 1.60 cms I.D. while perspex swirl chamber with one axial and five different size tangential entries. Only 1.27 cm I.D. tangential entires of perspex swirl chamber were used. An air inlet (7) was provided for pumping air at the axis of the swirling flow. One end of a long perspex tube (8) was fitted with the swirl chamber by stuffing box arrangements while other end was kept open to the atmosphere. Two tubes of I.D. 5.71 cms and 3.81 cms and 370 cms long and one tube of I.D. 2.54 cms and 185 cms long were used for the purpose of studies. Inlet liquid pressure were measured by means of the calibrated pressure gauges (9 and 10). Liquid discharge from the perspex tube was taken back in the feed tank. Globe valves were used to regulate the flow of the liquid in swirl chamber and tube.

A trolley mounted compressor of 1 HP and working pressure 9 atm was used to supply compressed air at the centre of the swirling flow. Flow rate of the air was measured by means of a wet gas meter (11).

3.02 PROCEDURE OF CARRYING OUT HYDRO DYNAMIC STUDIES

Sodium chloride salt solution ranging from 1 to 3% concentration was prepared in the feed tank by dissolving sodium chloride in water. Compressed air was kept ready before starting the pump. Pump was started after priming and opening all the appropriate valves of the flow path. The pressures, in the tangential inlet lines of the swirl chamber were equalised with the help of the globe valves and pressure gauges and provided for this purpose.

When tangential inlet velocities were high enough to give rise to a free vortex type of motion, a central air core coaxial to the tube was obtained to a long distance in the tube by supplying compressed air at the axis of the flow. The feed discharge rates were measured by collecting the liquid in a bucket for a known interval of time and then measuring the volume of the collected liquid.

Cathetometer was employed to measure the diameter of the air core al~~l~~ong the full length of the air core. Air core length was measured directly by a graduated scale fitted up at the top of theperspex tube along the length. Air flow rate was measured by wet gas flow meter.

3.03 EXPERIMENTAL SETUP FOR HEAT TRANSFER STUDIES

The schematic diagram of the experimental set up used for the heat transfer studies is shown in figure 3.02.

It consists of a feed tank (1) fitted with cooling coils(2). Liquid was recirculated to theheat exchanger after cooling in the tank. This tank also serves the purpose of receiving tank. Liquid was pumped by a 3 H.P. stainless steel centrifugal pump (3) to the swirl chamber. A by pass valve (4) and control valves (5,6,7) were used to control the flow. Inlet pressures to swirl chamber were recorded by calibrated pressure gauges (8,9 and 10). One end of the inner tube of the double pipe heat exchanger was connected with the swirl chamber (11). Swirl chamber made of aluminium, having 103 cms internal diameter and provided with five tangential inlets of different diameters located diametrically opposite to each other. Inner tube of double pipe heat exchanger was a stainless steel tube (12) having O.D. = 3.18 cms and I.D. 2.84 cms. A length of 114.5 cms of this tube was steam jacketed by using $1\frac{1}{2}$" steel pipe (13) along with other necessary fittings. Heat exchanger was insulated with asbestos rope and cemented with plaster of paris, to minimise the heat losses. The entire assembly was supported on a mild steel stand.

3.04 PROCEDURE FOR CARRYING OUT HEAT TRANSFER STUDIES

The sodium chloride salt solution (ranging in concentration from 1 to 3 %) was prepared by dissolving NaCl salt in water. The stainless steel pump was started after opening all the appropriate valves of flow path. Cooling water was allowed to pass in the cooling coils of the feed tank. Now steam was supplied from the oil fired boiler in the double pipe heat exchanger. Steam pressure was controlled by the help of valves and pressure

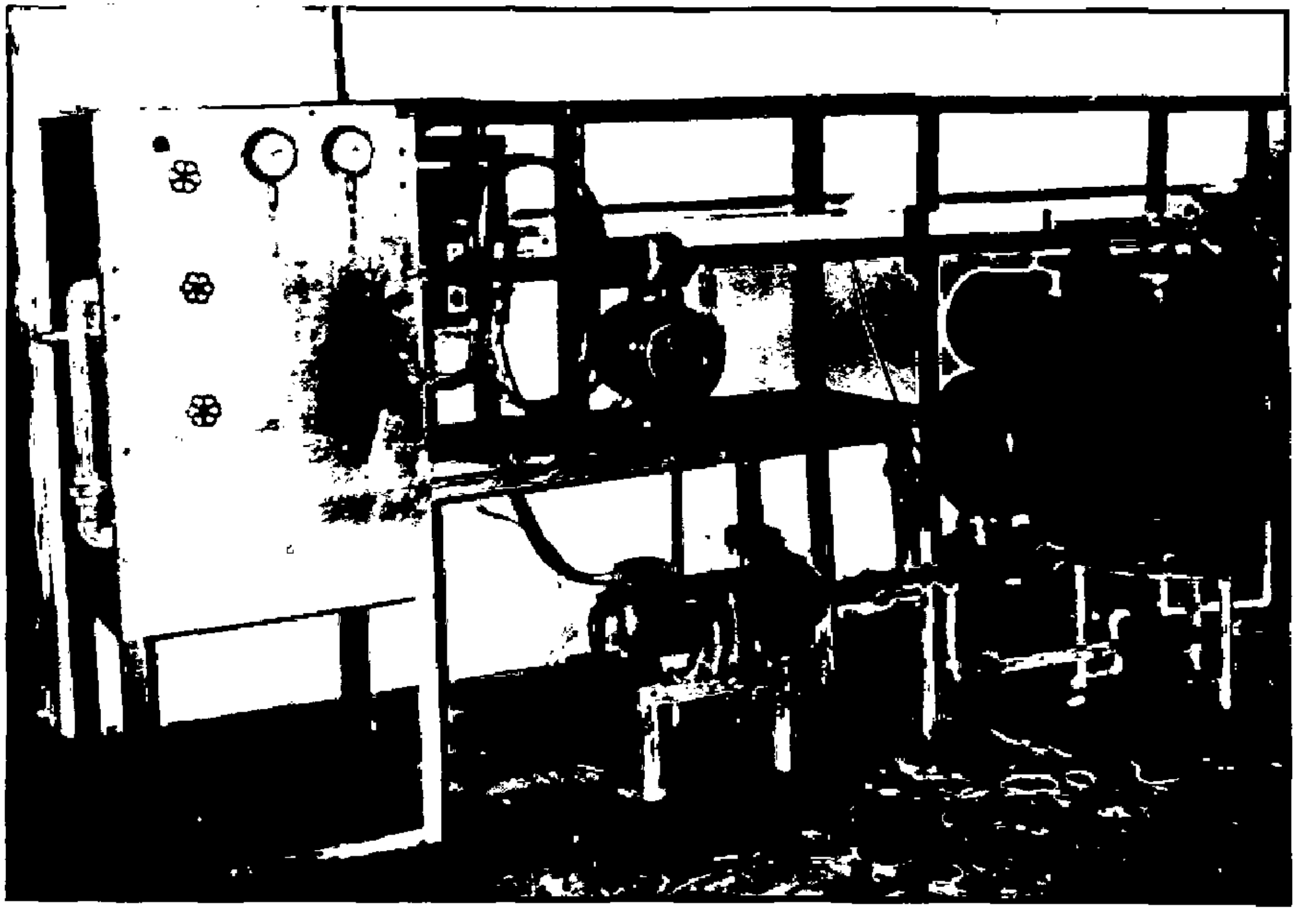


PLATE 3.01 EXPERIMENTAL SET UP FOR HYDRODYNAMIC STUDIES

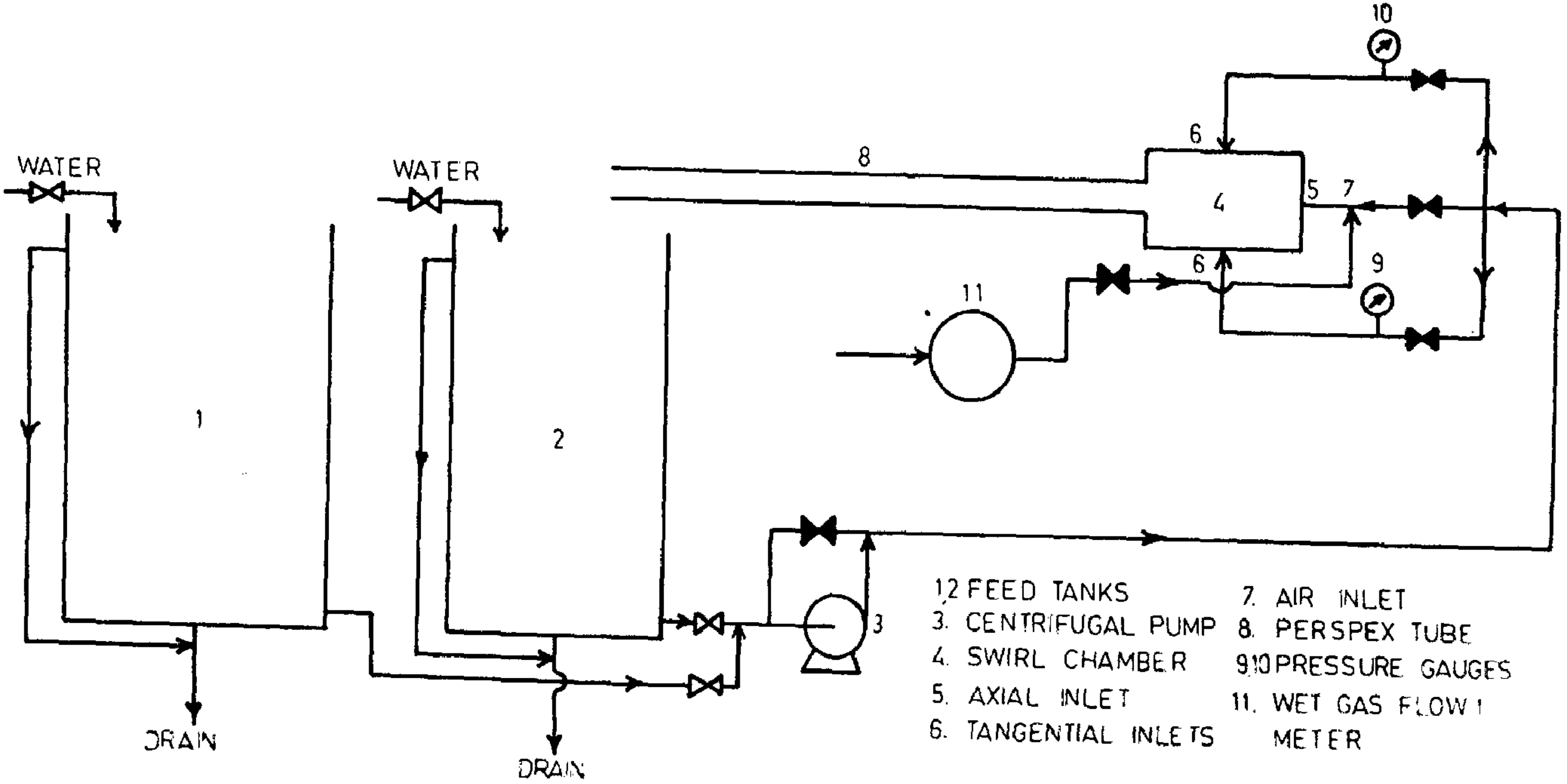


FIG 3.01 EXPERIMENTAL SET UP FOR HYDRODYNAMIC STUDIES

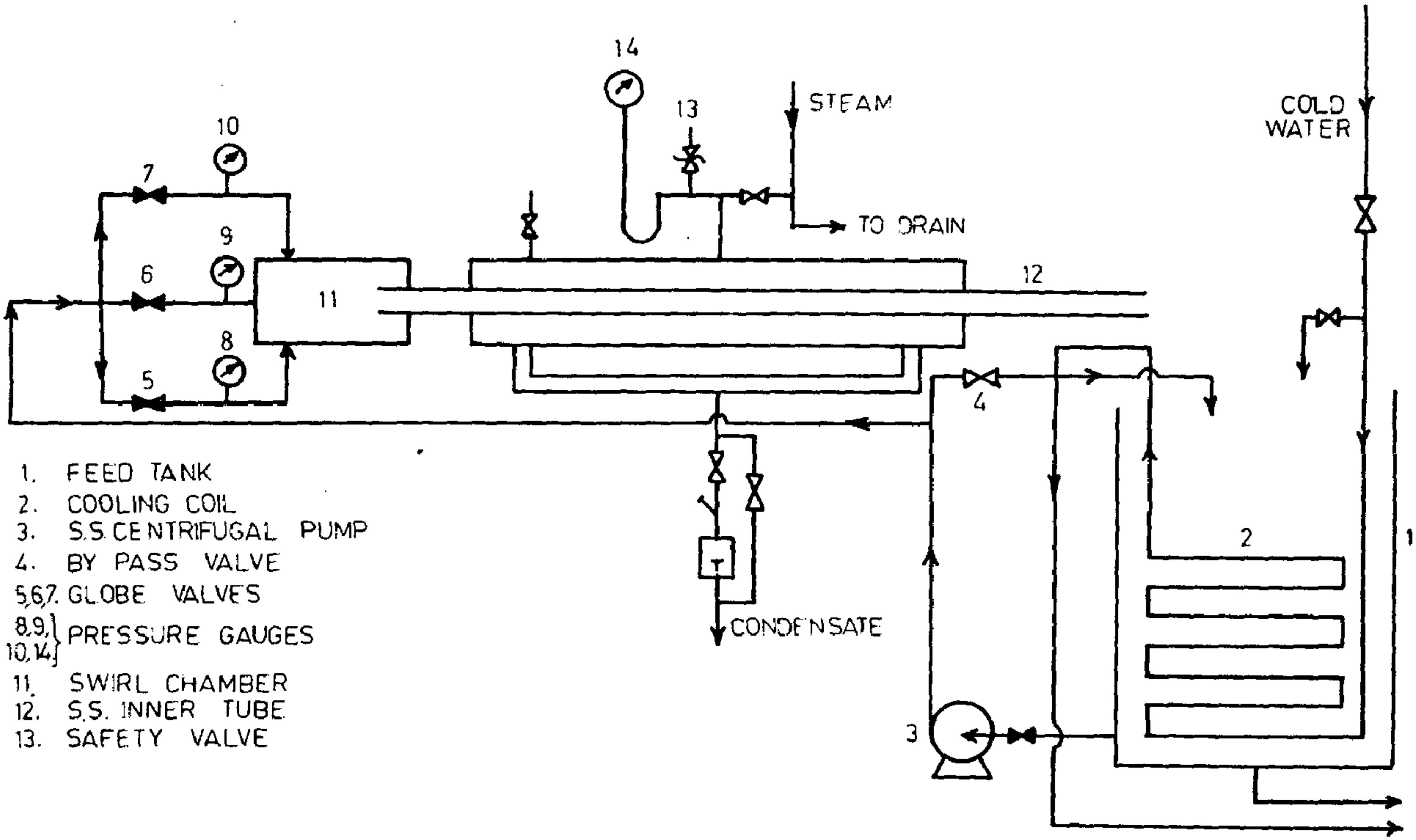


FIG. 3.02 EXPERIMENTAL SET UP FOR HEAT TRANSFER STUDIES

gauges provided for this purpose. Inlet pressures of the tangentially / axially entering liquid were noted by the help of pressure gauges. The inlet and outlet temperatures were recorded by means of a thermometer. Discharge rate of the liquid was measured by collecting the liquid for a known interval of time and then by measuring the volume of the collected liquid. Only one set of tangential entries was used for the studies.

CHAPTER-IV

THEORETICAL METHOD FOR COMPUTING PRESSURE DROP

In any flow system or process pressure drop is of vital importance from the point of view of design and economy of the system. In the present study total pressure drop was measured by measuring the inlet pressures of liquid to tangential entries with the help of calibrated pressure gauges. As the liquid is discharged to atmosphere, the inlet pressure of liquid to tangential entries gives the total pressure drop in the system.

The total pressure drop in the system can be divided into following-

(i) ΔP_1 = Pressure drop due to friction in the tangential entry pipes

(ii) ΔP_2 = Pressure drop due to sudden expansion of the liquid in the swirl chamber.

(iii) ΔP_3 = Radial pressure drop at the swirl chamber

(iv) ΔP_4 = Pressure drop due to sudden contraction of cross-section

(v) ΔP_5 = Pressure drop due to liquid flow inside the tube

Thus total pressure drop

$$\Delta P = \Delta P_1 + \Delta P_2 + \Delta P_3 + \Delta P_4 + \Delta P_5 \quad \ldots\ldots \quad (4.01)$$

(i) Pressure Drop Due To Friction In Tangential Entry Pipes

Pressure drop in the line, though which liquid is fed in the swirl chamber, can be calculated by the help of Blausius friction factor equations

$$\frac{\Delta P}{\rho} = f \, \frac{\ell}{D_i} \cdot \frac{V_i^2}{2g_c} \quad \ldots\ldots\ldots \qquad (4.02)$$

Where ℓ is the length of the feed pipe

(ii) Pressure Drop Due To Sudden Expansion Of The Liquid In the Swirl Chamber

As the cross-section of the inlet feed pipe suddenly enlarges in the swirl chamber, the fluid stream seperates from the wall and issues a jet into the enlarged section of the swirl chamber. The get then expands to fill the entire cross-section of the swirl chamber. The space between the expanding jet and swirl chamber wall is filled with the fluid in vortex motion and considerable friction is generated within this space. If the velocities at the two cross-sections are V_i and $\bar{V}$, then the pressure drop can be find out from the following equations.

$$\frac{\Delta P}{\rho} = \frac{(V_i - \bar{V})^2}{2g_c} \quad \ldots\ldots\ldots \qquad (4.03)$$

(iii) Radial Pressure Drop At The Swirl Chamber

Radial pressure drop at the swirl chamber can be calculated from Navier-Stokes equation as

$$\frac{\Delta P}{\rho} = \frac{\Omega^2}{2g_c}\left[\frac{1}{R_a^2} - \frac{1}{R_s^{22}}\right] \qquad \ldots\ldots(4.04)$$

Where Ω is a circulation constant and given as

$$\Omega = V_{Ta} \times R_a \qquad \ldots\ldots(4.05)$$

and V_{Ta} is tangential component of velocity at the air core.

(iv) <u>Pressure Drop Due To Sudden Contraction Of Cross-Section</u>

When the liquid enters in to the pipe from swirl chamber, the cross-section of the pipe is suddenly reduced. The fluid stream can not follow around the sharp corner, and stream breaks contact with the wall of the pipe. A jet is formed, which flows into the stagnant fluid in the smaller section. The jet first contracts and then expands to fill the smaller cross-section.

The loss from sudden contraction is proportional to the velocity head in the smaller pipe and can be calculated from the equation:-

$$\frac{\Delta P}{\rho} = K_c \; \frac{\bar{V}_b^2}{2g_c} \qquad \ldots\ldots \quad (4.06)$$

For tubulent flow $K_c = 0.4\,(1 - S_{b/Sa})$ $\ldots$ (4.07)

Where V_b is the average velocity in the downstream section.

(v) <u>Pressure Drop Due To Liquid Flow Inside the Tube</u>

Frictional pressure drop due to liquid flow inside the tube can be find out from Blausius friction factor equation as-

$$\frac{\Delta p}{\rho} = f \quad \frac{L_a}{D_h} \cdot \frac{\bar{V}^2}{2g_c} \qquad \ldots(4.08)$$

The average velocity $\bar{V}$ can be calculated from the average tangential component (V_{Ta}) and average axial component (Va) as under:

$$\bar{V} = (V_a^2 + V_{Tav}^2)^{1/2} \qquad \ldots\ldots(4.09)$$

Average axial component of velocity can be calculated from the total liquid flow rate divided by the cross-sectional area of the annulus.

$$V_a = \frac{Q_L}{a} \qquad \ldots\ldots(4.10)$$

The average tangential component can be find out by taking the average of the tangential component of velocity at the air core(V_{Ta}) and tangential component of the velocity at the tube radius (V_{T_T}).

$$V_{Tav} = \frac{V_{Ta} + V_{TT}}{2} \qquad \ldots(4.11)$$

The tangential component of velocity at the air core can be evaluated by taking rpm of swirl with the help of a strobscope.

$$V_{Ta} = D_a \times \Pi \times \frac{rpm}{60} \qquad \ldots(4.12)$$

Tangential component of velocity at the tube radius can be calculated as:

$$V_{T_T} = V_{Ta} \times \frac{D_a}{D_T} \qquad \ldots (4.13)$$

Now knowing the value of average velocity ($\bar{V}$) the Reynold number ($Re = D_h \bar{V} \rho/\mu$) can be calculated. Blausius friction factor can be calculated from the equation given below :

$$f = 0.079 / Re^{0.25} \qquad \ldots (4.14)$$

Linear equivalent length for swirl flow is given by

$$L_e = L_a \cdot \frac{\bar{V}}{V_a} \qquad \ldots (4.15)$$

CHAPTER-V

EXPERIMENTAL DATA RESULTS AND DISCUSSION

Experimental runs were taken for dilute sodium chloride solution of one, two and three percent concentrations. Effect of tangential inlet velocity and air rate on pressure drop, aircore diameter and length were studied for all the three solutions, employing three tubes of 5.71 cm 3.81 cms and 2.54 cms I.D. Effect of tube diameter and swirl chamber diameter on pressure drop and air core dimensions were also investigated. Heat transfer studies on a double pipe heat exchanger were also carried out to study the effect of swirling flow on heat transfer coefficients.

All the data collected for swirling flow in long horizontal tube for hydrodynamic studies can be divided in three groups for the purpose of discussion.

(i) Effect of various parameters on pressure drop

(ii) Effect of various parameters on aircore diameter

(iii) Effect of various parameters on aircore length.

5.01 EFFECT OF VARIOUS PARAMETERS ON PRESSURE DROP

Pressure drop data for various inlet velocities and air rates for 1 to 3 per cent solutions are recorded on tables 5.01 to 5.03 and tables 5.04 to 5.06 for 370 cm long tubes of ID 5.71 cms and 3.81 cms respectively. Swirl

Chamber of 11.50 cm I.D. and 1.60 cms tangential inlet diameters was used for these experiments.

Similarly in tables 5.07 to 5.09 pressure drop data for various inlet velocities and air rates are tabulated for 1 to 5% solution concentrations using 2.54 cms I.D. and 185 cms long perspex tube. Swirl chamber of 10.30 cm I.D. and 1.27 cm tangential inlet diameter was used for these runs.

Effect of liquid inlet velocity on pressure drop for different sets of operating conditions are shown graphically in figures 5.01 to 5.03. It is clear from these graphs that pressure drop increases with increase in liquid inlet velocity. The effect of change of tube diameter is shown in figure 5.01. It can be seen from this plot that for a particular value of tangential inlet velocity, pressure drop in a smaller diameter tube (3.81 cm I.D) is more than the bigger diameter tube (5.71 cms).

Effect of air rates on pressure drop for various operating conditions are shown in tabular form in table 5.01 to 5.09 for all the three salt concentrations studied. Effect of air rate on pressure drop is also shown graphically in figures 5.02 and 5.03 for only 1 percent salt concentration and different sets of various operating conditions, it can be seen from these plots figure 5.02 and 5.03, that air rate does not seem to have any significant effect on pressure drop within the range of experimental conditions studied.

(b) For 3.81 cms I.D. tube, 11.50 cms I.D. swirl chamber diameter, 1.60 cms tangential inlts diameters and for 1 to 5 percent salt concentrations the the following correlation is proposed, which is applicable for the above set of variables with ±4% accuracy.

$$\frac{\Delta P \cdot g_c}{V_i^2 \cdot \rho} = 2.16 \times 10^{-2} \left[\frac{D_T V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6} \quad \ldots\ldots \quad (9.05)$$

(c) For 2.54 cms I.D. tube, 10.50 cm I.D. swirl chamber diameter, 1.27 cms tangential inlets diameters and for 1 to 5 percent salt concentration the following correlation is proposed, which is applicable for the above set of variables with ± 5% accuracy.

$$\frac{\Delta P \cdot g_c}{V_i^2 \cdot \rho} = 2.25 \times 10^{-2} \left[\frac{D_T V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6} \quad \ldots.(9.06)$$

9.02 EFFECT OF VARIOUS PARAMETERS ON AIR CORE DIAMETER

Tables 9.01 to 9.03 and 9.04 to 9.06 give the average air core diameter for various inlt velocities, pressure drips and air rates for 1 to 5%.salt. concentration, using 5.71 cm and 3.81 cms I.D. and 370 cms long perspex tube. Swirl chamber of 11.50 cms diameter and 1.60 cms tangential inlet diameters was used for these data.

Tables 5.07 to 5.09 give the similar information for 2.54 cms I.D. and 185 cms long perspex tube for 1 to 5 percent salt concentrations. Swirl chamber of 10.30 cms I.D. and 1.27 cms tangential inlets was employed.

Air core diameters measured along the tube axis by cathetometer for all the three tubes are tabulated in tables . 5.13 to 5.15. Average air core diameters have been calculated from these tables only.

Variation of air core diameters along the tube axis are shown in figure 5.08a . It can readily be seen from this figure the air core diameter decreases from upstream to downstream side and finally reduces to zero.

Effect of liquid inlet velocity on air core diameter for different sets of operating conditions are shown graphically in figures 5.09 to 5.11. It can be seen that liquid inlet velocity has no significant effect on air core diameter.

Figure 5.09 shows the effect of tube diameter on air core diameter. It is clear from this plot that air core diameter reduces with the reduction in diameter of the tube.

Effect of salt concentrations on air core diameter is graphically shown in figure 5.10.It is clear from this curve that salt concentration or kinematic viscosity does not have any appreciable effect on air core diameter.

The data tabulated in table 5.01, 5.04 and 5.07 showing effect of air rate an air core diameter are plotted in figure 5.11. It can be noted from fig.5.11 that air rate does not seen to have any effect on air core diameter.

(c) EFFECT OF VARIOUS PARAMETERS ON AIRCORE LENGTH

Tables 5.01 to 5.03 and 5.04 to 5.06 give the air core length for various inlet velocities, pressure drops and air rates for 1 to 3% salt concentration, using 5.71 cms and 3.81 cms I.D. and 370 cms long perspex tube. Swirl chamber of 10.30 cms diameter and 1.60 cms tangential inlet diameters was used for these data. Similar informations are tabulated in table 5.07 to 5.09 for 2.54 cms I.D. and 185 cms long perspex tube. Swirl chamber of 10.30 cms I.D. and 1.27 cms tangential inlets diameter was used for the runs tabulated in table 5.07 to 5.09.

Data for air core length for different sets of operating conditions at various liquid inlet velocities are plotted in figures 5.12 to 5.14. It can be seen that air core length increases with increase in liquid inlet velocity.

Effect of tube diameter is shown in figure 5.12. It is observed that the air core length increases with increase in tube diameter.

To shown the effect of air rate on air core length, data were plotted in figures 5.13 and 5.14 and it was observed that change of air rate did not have any appreciable effect on air core length.

Pressure drop as a function of concentration of solution ploted in figure 5.04. The figure shows that the pressure drop increases with increase in salt concentration.

Higher percentage of salt concentration could not be studied because of corrosion problems of the pump and other parts of the equipment. By increasing salt concentration from 1 to 3 percent any marked effect could not be noticed either in change of pressure drops or on aircore length and diameters.

Emperical correlation for pressure drop proposed by Sharma(21) for swirling flow without reversal-in long horizontal tubes is-

$$\frac{\Delta P \cdot g_c}{V_i^2 \, \rho} = 2.57\times10^{-2} \left[\frac{D_T \, V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6} \quad \text{.. (5.01)}$$

On rearranging the above correlation can be written as

$$\Delta P = K . V_i^{1.72} \quad \text{....... (5.02)}$$

Where,

$$K = \frac{2.57.10^2.\rho}{g_c} \left[\frac{D_T}{\nu}\right]^{-0.15} \left[\frac{1}{g D_T}\right]^{-0.065} \left[\frac{D_g}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6} V_i^{1.72} \quad \text{...(5.03)}$$

Predicted pressure drop for all the runs for various sets of parameters are calculated by the help of above correlations and values have been tabulated in table 5.10, 5.11 and 5.12 under the head predicted pressure drop.

Figure 5.05 to 5.07 show the variation of predicted pressure drop from experimental pressure drop. It has been observed that all the data fall in between ±20% deviation lines, as said by Sharma.

The correlation developed by Sharma (21) for the calculation of pressure drop for swirling flow without reversal in long horizontal tubes is applicable for all sets of variable- i.e. tube diameter, swirl chamber diameter tangential inlet diameter, kinematic viscosity and density with ± 20% accuracy.

For all the three tubes studied following correlations are proposed which can safely be applied with less percentage of errors as shown against each correlation/

(a) For 5.71 cms I.D. tube, 11.50 cms I.D. Swirl chamber diameter, 1.60 cms tangential inlets diameters and for 1 to 5 percent salt concentrations the following correlation is proposed, which is applicable. for the above set of variables with ±4% accuracy.

$$\frac{\Delta P \cdot g_c}{V_1^2 \cdot \rho} = 2.98 \times 10^{-2} \left[\frac{D_T V_1}{\nu}\right]^{-0.15} \left[\frac{V_1^2}{g D_T}\right]^{-0.065} \left[\frac{D_s}{D_T}\right]^{4.18}$$

$$\left[\frac{D_T}{D_1}\right]^{2.6} \qquad \ldots\ldots \quad (5.04)$$

The higher flow rates of air does not seem to have any advantage. The air core length and diameter remain more or less same with the change of air flow rate. However, stratification of air core length at the downstream side starts at higher flow rates of air.

To test whether the rates of heat transfer are enhanced in swirl flow, overall heat transfer coefficients were experimentally determined in a double pipe heat exchanger for axial and swirl flows. Inside tube of ID 2.84 cms and length 114.5 cms and a swirl chamber of ID10.50 and tangential inlets 1.27 cms were used in the heat exchanger. The operating variables were adjusted to give astable air core of length nearly equal to the length of heat exchanger. The experimental data are recorded in Tables 5.16 and 5.17. Figure 5.15 gives a comparison of over all heat transfer coefficients for swirling flow and linear flow. An average increase of 16 percent and 32 percent in over all heat transfer coefficients was observed for case of no induced air and induced air respectively.

TABLE - 5.01

DATA OF PRESSURE DROP

Inside diameter of perspex tube	..	5.71 Cms
Length of perspex tube	..	370. Cms
Inside diameter of swirl chamber	..	11.50 Cms
Inside diameter of tangential entry	..	1.6 Cms
Concentration of NaCl salt solution	..	1 percent by weight
Kinematic viscosity of the solution	..	1.089×10^{-2} cm^2/se
Density of the solution	..	1.004 gm/cc.

Run No.	Experimental pressure drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec.
		Length	Average diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0101	0.07	105	4.62	6.00	38.70	160.48
5.0102	0.14	150	4.64	4.35	58.50	242.59
5.0103	0.21	180	4.27	4.40	72.00	298.57
5.0104	0.28	210	4.46	4.50	87.00	360.77
5.0105	0.35	230	4.52	5.00	99.50	412.60
5.0106	0.07	105	4.61	10.00	38.00	157.58
5.0107	0.14	148	4.59	8.20	58.00	240.51
5.0108	0.21	178	4.33	9.00	73.00	302.70
5.0109	0.28	208	4.48	10.00	85.00	352.47
5.0110	0.35	228	4.46	9.95	97.50	404.31
5.0111	0.07	104	4.59	12.00	38.70	160.48
5.0112	0.14	147	4.56	11.25	57.50	238.44
5.0013	0.21	178	4.36	12.85	72.00	298.57
5.0114	0.28	208	4.50	14.10	87.90	364.50

Table - 5.01 (Contd.)

1	2	3	4	5	6	7
5.0115	0.35	225	4.47	15.00	99.50	412.60
5.0116	0.07	103	4.66	19.75	39.50	163.80
5.0117	0.14	148	4.58	20.00	59.60	247.15
5.0118	0.21	176	4.34	20.00	74.50	308.93
5.0119	0.28	207	4.45	17.50	87.00	360.77
5.0120	0.35	224	4.47	19.15	101.00	418.82
5.0121	0.07	102	4.63	25.00	38.65	160.27
5.0122	0.14	145	4.57	22.50	59.50	246.73
5.0123	0.21	175	4.42	25.70	73.80	306.03
5.0124	0.28	205	4.40	24.85	88.20	365.74
5.0125	0.35	220	4.49	22.50	98.50	408.46

TABLE - 5.02

DATA ON PRESSURE DROP

Inside diameter of perspex tube	.. 5.71 Cms
Length of perspex tube	.. 370 Cms
Inside diameter of swril chamber	.. 11.50 Cms
Inside diameter of tangential entry	.. 1.6 Cms
Concentration of NaCl salt solution	.. 2 percent by weight.
Kinematic Viscosity of the solution	.. 1.192×10^{-2} cm^2/sec.
Density of the solution	.. 1.011 gm/cc.

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates Lt/min		Liquid Inlet Velocity cm/sec
		Length	Average Diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0201	0.07	105	4.67	5.60	37.50	155.50
5.0202	0.14	150	4.64	5.15	57.500	238.44
5.0203	0.21	180	4.33	4.60	72.00	298.57
5.0204	0.28	212	4.50	4.55	84.50	350.40
5.0205	0.35	230	4.61	5.10	97.50	404.31
5.0206	0.07	104	4.68	10.00	38.00	157.58
5.0207	0.14	150	4.63	9.75	59.00	244.66
5.0208	0.21	180	4.33	10.15	71.10	294.83
5.0209	0.28	210	4.51	10.60	86.00	356.62
5.0210	0.35	227	4.55	9.70	96.00	398.09
5.0211	0.07	104	4.69	13.35	39.00	161.72
5.0212	0.14	146	4.63	15.00	59.00	244.66
5.0213	0.21	175	4.30	15.65	71.10	294.83
5.0214	0.28	209	4.54	15.00	84.50	350.40

Table - 5.02 (Contd.)

1	2	3	4	5	6	7
5.0215	0.35	227	4.56	14.50	96.00	398.09
5.0216	0.07	103	4.67	20.00	38.50	159.65
5.0217	0.14	147	4.57	22.20	57.50	238.44
5.0218	0.21	180	4.35	20.00	72.90	302.30
5.0219	0.28	208	4.46	18.45	88.00	364.91
5.0220	0.35	225	4.51	27.70	98.50	408.46
5.0221	0.07	103	4.68	25.00	38.50	159.65
5.0222	0.14	146	4.67	27.10	58.00	240.51
5.0223	0.21	180	4.43	24.85	72.00	298.57
5.0224	0.28	205	4.40	27.70	87.50	362.84
5.0225	0.35	224	4.48	30.00	99.50	412.60

TABLE - 5.03

DATA ON PRESSURE DROP

Inside diameter of perspex tube .. 5.71 Cms
Length of perspex tube .. 370 Cms
Inside diameter of swirl chamber .. 11.50 Cms
Inside diameter of tangential entry .. 1.6 Cms
Concentration of NaCl salt solution .. 3 percent by weight.
Kinematic Viscosity of the solution .. 1.315×10^{2} cm^2/sec.
Density of the solution .. 1.020 gm/cc.

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec.
		Length	Average Diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0301	0.07	105	4.70	4.60	37.90	157.16
5.0302	0.14	150	4.65	4.55	56.95	236.16
5.0303	0.21	180	4.33	5.00	70.20	291.10
5.0304	0.28	212	4.50	4.30	84.50	350.40
5.0305	0.35	230	4.54	4.80	97.70	405.14
5.0306	0.07	105	4.67	9.45	37.90	157.16
5.0307	0.14	150	4.63	9.85	57.75	239.48
5.0308	0.21	180	4.33	9.75	72.00	298.57
5.0309	0.28	210	4.50	9.50	83.30	345.43
5.0310	0.35	227	4.54	10.00	98.00	406.38
5.0311	0.07	105	4.67	14.40	38.50	160.07
5.0312	0.14	150	4.63	14.70	56.50	234.29
5.0313	0.21	180	4.34	16.00	70.20	291.10
5.0314	0.28	210	4.56	14.40	87.00	360.77
5.0315	0.35	227	4.55	24.00	95.00	393.94

Table - 5.03 (Contd.)

1	2	3	4	5	6	7
5.0316	0.07	103	4.67	19.00	38.00	157.58
5.0317	0.14	147	4.58	17.80	58.00	240.51
5.0318	0.21	180	4.34	20.00	71.90	298.15
5.0319	0.28	208	4.46	18.95	84.50	350.40
5.0320	0.35	226	4.50	20.70	94.50	391.87
5.0321	0.07	103	4.69	24.00	38.60	160.07
5.0322	0.14	146	4.68	23.10	56.50	234.29
5.0323	0.21	180	4.43	24.00	72.50	300.64
5.0324	0.28	205	4.40	24.85	86.50	358.69
5.0325	0.35	224	4.49	25.35	97.00	402.24

TABLE - 5.04

DATA ON PRESSURE DROP

Inside diameter of perspex tube .. 3.81 Cms
Length of perspex tube .. 370 Cms
Inside diameter of swirl chamber .. 11.50 Cms
Inside diameter of tangential entry .. 1.60 Cms
Concentration of NaCl Salt solution .. 1 percent by weight.
Kinematic viscosity of the solution .. 1.089×10^{-2} cm^2/sec
Density of the solution .. 1.004 gm/cc.

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec
		Length	Average Diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0401	0.07	85	2.49	5.00	31.85	132.07
5.0402	0.14	123	2.49	4.80	46.90	194.48
5.0403	0.21	145	2.43	4.50	60.55	251.09
5.0404	0.28	165	2.27	5.00	71.30	295.66
5.0405	0.35	187	2.26	4.35	81.90	339.62
5.0406	0.07	85	2.58	10.00	31.30	129.79
5.0407	0.14	122	2.47	9.50	48.75	202.15
5.0408	0.21	145	2.48	9.30	59.30	245.90
5.0409	0.28	165	2.28	8.25	70.20	291.10
5.0410	0.35	185	227	10.00	80.00	331.74
5.0411	0.07	87	2.56	16.00	31.85	132.07
5.0412	0.14	123	2.52	15.00	47.35	196.35
5.0413	0.21	144	2.46	14.75	61.70	255.86

Table - 5.04 (Contd.)

1	2	3	4	5	6	7
5.0414	0.28	160	2.45	15.00	71.30	296.91
5.0415	0.35	180	2.42	15.25	83.00	344.18
5.0416	0.07	86	2.56	20.00	32.40	135.60
5.0417	0.14	124	2.51	21.25	48.10	199.46
5.0418	0.21	145	2.43	20.50	60.90	252.54
5.0419	0.28	160	2.48	20.00	72.90	302.30
5.0420	0.35	180	2.43	19.50	80.00	331.74

TABLE - 5.05

DATA ON PRESSURE DROP

Inside diameter of perspex tube	..	3.81 Cms
Length of perspex tube	..	370 Cms
Inside diameter of swirl chamber	..	11.50 Cms
Inside diameter of tangential entry	..	1.60 cms
Concentration of NaCl Salt Solution	..	2 percent by weight.
Kinematic viscosity of the solution	..	1.192x10^{-2} cm^2/sec
Density of the solution	..	1.011 gm/cc.

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec
		Length	Average Diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0501	0.07	85	2.55	5.00	31.00	128.55
5.0502	0.14	123	2.42	4.80	47.00	194.90
5.0503	0.21	145	2.34	5.00	58.70	243.41
5.0504	0.28	165	2.35	4.65	70.40	291.93
5.0505	0.35	187	2.26	5.50	78.80	326.76
5.0506	0.07	85	2.57	10.50	31.50	130.62
5.0507	0.14	122	2.50	11.20	46.30	192.00
5.0508	0.21	145	2.40	10.00	59.50	246.43
5.0509	0.28	165	2.39	9.75	72.00	298.57
5.0510	0.35	185	2.27	10.00	30.00	331.74
5.0511	0.07	85	2.62	15.00	32.10	133.11
5.0512	0.14	125	2.56	15.50	47.50	196.97
5.0513	0.21	144	2.46	16.15	60.80	252.12

Table - 5.05 (Contd.)

1	2	3	4	5	6	7
5.0514	0.28	160	2.47	14.90	71.00	294.42
5.0515	0.35	180	2.39	14.50	81.70	338.79
5.0516	0.07	85	2.61	20.00	31.00	128.55
5.0517	0.14	123	2.62	19.50	48.00	199.04
5.0518	0.21	144	2.46	20.80	59.50	246.73
5.0519	0.28	159	2.47	21.35	70.75	293.38
5.0520	0.35	181	2.44	20.00	78.80	326.76

TABLE - 5.06

DATA ON PRESSURE DROP'

Inside diameter of perspex tube .. 3.81 Cms
Length of perspex tube .. 370 Cms
Inside diameter swirl chamber .. 11.50 Cms
Inside diameter of tangential entry .. 1.60 Cms
Concentration of NaCl salt solution .. 3 percent by weight.
Kinematic viscosity of the solution .. 1.315×10^{-2} cm²/sec
Density of the solution .. 1.020 gm/cc.

Run No.	Experimental Pressure Drop kg/cm²	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet velocity, cm/sec
		Length	Average diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0601	0.07	85	2.56	4.85	31.00	128.55
5.0602	0.14	124	2.44	4.50	45.80	189.92
5.0603	0.21	145	2.34	5.00	60.20	249.64
5.0604	0.28	165	2.34	5.50	68.50	284.05
5.0605	0.35	187	2.28	5.00	80.50	333.81
5.0606	0.07	85	2.58	10.00	31.75	131.66
5.0607	0.14	125	2.43	11.50	46.50	192.82
5.0608	0.21	145	2.40	9.50	59.50	246.73
5.0609	0.28	165	2.40	10.00	69.75	289.24
5.0610	0.35	185	2.29	12.00	81.00	335.89
5.0611	0.07	65	2.62	15.00	30.50	126.48
5.0612	0.14	125	2.44	15.50	47.50	196.97
5.0613	0.21	144	2.46	14.70	57.90	240.10

Table - 5.06 (Contd.)

1	2	3	4	5	6	7
5.0614	0.28	158	2.47	15.00	71.00	294.42
5.0615	0.35	182	2.41	16.00	77.90	323.03
5.0616	0.07	85	2.60	20.00	31.75	130.62
5.0617	0.14	124	2.49	21.00	46.80	194.07
5.0618	0.21	144	2.47	19.50	59.35	246.11
5.0619	0.28	158	2.49	18.75	69.75	289.24
5.0620	0.35	179	2.45	20.00	79.80	330.91

TABLE - 5.07

DATA ON PRESSURE DROP

Inside diameter of perspex tube	..	2.54 Cms
Length of perspex tube	..	185 Cms
Inside diameter of swirl chamber	..	10.30 Cms
Inside diameter of tangential entry	..	1.27 Cms
Concentration of NaCl salt solution	..	1 percent by weight.
Kinematic viscosity of the solution	..	1.089×10^{-2} cm^2/sec
Density of the solution	..	1.004 gm/cc.

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec
		Length	Average diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0701	0.07	60	1.42	490	12.50	82.23
5.0702	0.14	70	1.43	5.30	18.50	121.76
5.0703	0.21	85	1.40	5.20	23.85	156.90
5.0704	0.28	100	1.35	5.15	27.20	179.04
5.0705	0.35	110	1.27	4.85	32.10	211.17
5.0706	0.07	60	1.43	8.90	12.10	79.60
5.0707	0.14	70	1.47	9.70	18.85	124.04
5.0708	0.21	88	1.43	8.80	23.50	154.60
5.0709	0.28	100	1.35	10.00	27.10	178.28
5.0710	0.35	110	1.33	8.90	31.50	207.22
5.0711	0.07	58	1.46	13.85	12.50	82.23
5.0712	0.14	68	1.51	14.90	18.50	121.76
5.0713	0.21	86	1.44	15.65	23.00	151.30
5.0714	0.28	97	1.45	14.70	27.50	180.91

Table - 5.07 (Contd.)

1	2	3	4	5	6	7
5.0715	0.35	109	1.31	15.00	32.10	211.17
5.0716	0.07	56	1.47	20.80	12.20	80.26
5.0717	0.14	67	1.50	20.00	18.20	119.73
5.0718	0.21	90	1.52	19.50	22.90	150.65
5.0719	0.28	95	1.44	20.00	28.20	185.51
5.0720	0.35	108	1.32	20.00	30.85	202.94

TABLE - 5.08

DATA ON PRESSURE DROP

Inside diameter of perspex tube	..	2.54 Cms
Length of perspex tube	..	185 Cms
Inside diameter of swril chamber	..	10.30 Cms
Inside diameter of tangential entry.		1.27 Cms
Concentration of NaCl salt solution.		2 percent by weight.
Kinematic Viscosity of the solution.		1.192 x 10^{-2} cm^2/sec
Density of the solution	..	1.011 gm/cc.

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec.
		Length	Average Diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0801	0.07	59	1.41	4.80	12.00	78.94
5.0802	0.14	70	1.37	4.85	18.50	121.76
5.0803	0.21	85	1.36	5.05	23.20	152.62
5.0804	0.28	100	1.30	5.00	27.80	182.88
5.0805	0.35	110	1.30	5.00	31.40	206.56
5.0806	0.07	60	1.41	9.25	12.20	80.26
5.0807	0.14	70	1.39	10.00	17.90	117.75
5.0808	0.21	88	1.38	10.00	22.60	148.67
5.0809	0.28	100	1.34	10.00	26.75	176.07
5.0810	0.35	110	1.32	9.75	31.70	208.54
5.0811	0.07	57	1.44	14.70	12.20	80.26
5.0812	0.14	67	1.43	15.00	18.60	122.42
5.0813	0.21	90	1.37	15.05	23.20	152.62

Table - 5.08 (Contd.)

1	2	3	4	5	6	7
5.0814	0.28	95	1.34	14.40	27.50	180.91
5.0815	0.35	107	1.30	15.00	31.40	206.56
5.0816	0.07	55	1.52	24.00	12.45	81.90
5.0817	0.14	67	1.47	22.50	18.20	119.73
5.0818	0.21	90	1.33	21.20	23.60	155.33
5.0819	0.28	98	1.44	20.70	26.90	177.05
5.0820	0.35	107	1.33	20.00	30.45	200.31

TABLE - 5.09

DATA ON PRESSURE DROP

Inside diameter of perspex tube .. 2.54 Cms
Length of perspex tube .. 185 Cms
Inside diameter of swirl chamber .. 10.30 Cms
Inside diameter of tangential entry .. 1.27 Cms
Concentration of NaCl salt solution .. 3 percent by weight.
Kinematic Viscosity of the solution .. 1.315×10^{-2} cm^2/sec
Density of the solution .. 1.020 gm/cc

Run No.	Experimental Pressure Drop kg/cm^2	Air Core, Cms		Flow Rates, Lt/min		Liquid Inlet Velocity cm/sec
		Length	Average diameter	Air	Liquid	
1	2	3	4	5	6	7
5.0901	0.07	60	1.39	5.00	11.80	77.63
5.0902	0.14	71	1.43	4.80	18.10	119.13
5.0903	0.21	85	1.33	4.50	23.20	152.40
5.0904	0.28	100	1.31	4.55	26.40	173.67
5.0905	0.35	110	1.29	5.15	30.80	202.62
5.0906	0.07	60	1.42	8.20	12.10	79.60
5.0907	0.14	70	1.46	9.75	17.70	116.44
5.0908	0.21	88	1.36	9.00	22.40	147.36
5.0909	0.28	100	1.30	9.00	26.80	176.30
5.0910	0.35	109	1.29	9.00	31.30	205.90
5.0911	0.07	60	1.52	14.40	12.25	80.59
5.0912	0.14	70	1.42	15.00	18.00	118.50
5.0913	0.21	88	1.38	15.00	23.20	152.70

Table - 5.09 (Contd.)

1	2	3	4	5	6	7
50914	0.28	100	1.32	15.00	27.50	180.91
5.0915	0.35	108	1.38	16.75	30.50	200.64
5.0916	0.07	60	1.42	24.00	12.10	79.60
5.0917	0.14	70	1.50	18.00	18.30	120.45
5.0918	0.21	88	1.48	23.25	23.00	151.38
5.0919	0.28	100	1.32	24.00	26.40	173.76
5.0920	0.35	108	1.35	20.00	29.95	197.13

TABLE - 5.10

CALCULATIONS FOR PREDICTED PRESSURE DROP

Sharma's Correlation(21) for Predicting Pressure Drop for Swirling Flow in Long Horizontal Tube is -

$$\frac{\Delta P\ g_c}{V_i^{2}\ \rho} = 2.57\text{x}10^{-2}\left[\frac{D_T\ V_i}{\nu}\right]^{-0.15}\left[\frac{V_i^{2}}{g\ D_T}\right]^{-0.065}\left[\frac{D_B}{D_T}\right]^{4.18}\left[\frac{D_T}{D_i}\right]^{2.6}$$

On rearraning

$$\Delta P = \left[\frac{2.57\text{x}\ \rho\ \text{x}\ 10^{-2}}{g_c}\right]\left[\frac{D_T}{\nu}\right]^{-0.15}\left[\frac{1}{g\ D_T}\right]^{-0.065}\left[\frac{D_B}{D_T}\right]^{4.18}\left[\frac{D_T}{D_i}\right]^{2.6} V_i^{1.7}$$

or $\Delta P = K\ V_i^{1.72}$

Run No.	Experimental Pressure Drop kg/cm^2	$\frac{2.57\text{x}\rho\text{x}10^{-2}}{g_c}$	$\left[\frac{D_T}{\nu}\right]^{-0.15}$	$\left[\frac{1}{g\ D_T}\right]^{-0.065}$	$\left[\frac{D_B}{D_T}\right]^{4.18}$	$\left[\frac{D_T}{D_i}\right]^{2.6}$	$V_i^{1.72}$	Predicted Pressure Drop kg/cm^2
1	2	3	4	5	6	7	8	9
5.0101	0.07	2.63x10^{-5}	0.391	1.752	18.663	27.324	6213.32	0.0571
5.0102	0.14	2.63	0.391	1.752	18.663	27.324	12646.80	0.1162
5.0103	0.21	2.63	0.391	1.752	18.663	27.324	18075.00	0.1661
5.0104	0.28	2.63	0.391	1.752	18.663	27.324	25028.60	0.2299
5.0105	0.35	2.63	0.391	1.752	18.663	27.324	31529.00	0.2897
5.0106	0.07	2.63	0.391	1.752	18.663	27.324	6021.46	0.0553
5.0107	0.14	2.63	0.391	1.752	18.663	27.324	12460.90	0.1145
5.0108	0.21	2.63	0.391	1.752	18.663	27.324	18507.20	0.1700
5.0109	0.28	2.63	0.391	1.752	18.663	27.324	24046.40	0.2209

Table - 5.10 (Contd.)

1	2	3	4	5	6	7	8	9
5.0110	0.35	2.63×10^{-5}	0.391	1.752	18.663	27.324	30447.30	0.2797
5.0111	0.07	2.63	0.391	1.752	18.633	27.324	6213.32	0.0571
5.0112	0.14	2.63	0.391	1.752	18.663	27.324	12277.0	0.1128
5.0113	0.21	2.63	0.391	1.752	18.663	27.324	18075.00	0.1661
5.0114	0.28	2.63	0.391	1.752	18.663	27.324	25475.30	0.2341
5.0115	0.35	2.63	0.391	1.752	18.663	27.324	31529.0	0.2897
5.0116	0.07	2.63	0.391	1.752	18.663	27.324	6436.06	0.0591
5.0117	0.14	2.63	0.391	1.752	18.663	27.324	13058.50	0.1200
5.0118	0.21	2.63	0.391	1.752	18.663	27.324	19167.20	0.1761
5.0119	0.28	2.63	0.391	1.752	18.663	27.324	25028.60	0.2300
5.0120	0.35	2.63	0.391	1.752	18.663	27.324	32351.0	0.2972
5.0121	0.07	2.63	0.391	1.752	18.663	27.324	6199.34	0.5696
5.0122	0.14	2.63	0.391	1.752	18.663	27.324	13020.30	0.1196
5.0123	0.21	2.63	0.391	1.752	18.663	27.324	18858.80	0.1733
5.0124	0.28	2.63	0.391	1.752	18.663	27.324	25624.60	0.2354
5.0125	0.35	2.63	0.391	1.752	18.663	27.324	30986.80	0.2847
5.0201	0.07	2.65	0.396	1.752	18.663	27.324	5885.40	0.0552
5.0202	0.14	2.65	0.396	1.752	18.663	27.324	12277.0	0.1151
5.0203	0.21	2.65	0.396	1.752	18.663	27.324	18075.0	0.1695
5.0204	0.28	2.65	0.396	1.752	18.663	27.324	23804.0	0.2232
5.0205	0.35	2.65	0.396	1.752	18.663	27.324	30447.30	0.2855
5.0206	0.07	2.65	0.396	1.752	18.663	27.324	6021.46	0.0565
5.0207	0.14	2.65	0.396	1.752	18.663	27.324	12833.0	0.1203
5.0208	0.21	2.65	0.396	1.752	18.663	27.324	17687.40	0.1658
5.0209	0.28	2.65	0.396	1.752	18.663	27.324	24535.40	0.2300
5.0210	0.35	2.65	0.396	1.752	18.663	27.324	29646.00	0.2780

Table-5.10 (Contd.)

1	2	3	4	5	6	7	8	9
5.0211	0.07	2.65×10^{-5}	0.396	1.752	18.663	27.324	6296.13	0.0590
5.0212	0.14	2.65	0.396	1.752	18.663	27.324	12833.0	0.1208
5.0213	0.21	2.65	0.396	1.752	18.663	27.324	17687.4	0.1658
5.0214	0.28	2.65	0.396	1.752	18.663	27.324	23804.0	0.2232
5.0215	0.35	2.65	0.396	1.752	18.663	27.324	29646.10	0.2780
5.0216	0.07	2.65	0.396	1.752	18.663	27.324	6158 .15	0.0577
5.0217	0.14	2.65	0.396	1.752	18.663	27.324	12277.00	0.1151
5.0218	0.21	2.65	0.396	1.752	18.663	27.324	18465.20	0.1731
5.0219	0.28	2.65	0.396	1.752	18.663	27.324	25524.60	0.2393
5.0220	0.35	2.65	0.396	1.752	18.663	27.324	30986.80	0.2905
5.0221	0.07	2.65	0.396	1.752	18.663	27.324	6158.150	0.0577
5.0222	0.14	2.65	0.396	1.752	18.663	27.324	12460.90	0.1168
5.0223	0.21	2.65	0.396	1.752	18.663	27.324	18075.00	0.1695
5.0224	0.28	2.65	0.396	1.752	18.663	27.324	25276.100	0.2370
5.0225	0.35	2.65	0.396	1.752	18.663	27.324	31529.00	0.2956
5.0301	0.07	2.67	0.402	1.752	18.663	27.324	5993.88	0.0575
5.0302	0.14	2.67	0.402	1.752	18.663	27.324	12075.80	0.1158
5.0303	0.21	2.67	0.402	1.752	18.663	27.324	17304.20	0.1659
5.0304	0.28	2.67	0.402	1.752	18.663	27.324	23804.00	0.2283
5.0305	0.35	2.67	0.402	1.752	18.663	27.324	30554.90	0.2930
5.0306	0.07	2.67	0.402	1.752	18.663	27.324	5993.88	0.0575
5.0307	0.14	2.67	0.402	1.752	18.663	27.324	12369.20	0.1186
5.0308	0.21	2.67	0.402	1.752	18.663	27.324	18075.00	0.1733
5.0309	0.28	2.67	0.402	1.752	18.663	27.324	23226.20	0.2227
5.0310	0.35	2.67	0.402	1.752	18.663	27.324	30715.90	0.2950
5.0311	0.07	2.67	0.402	1.752	18.663	27.324	6186.04	0.05932
5.0312	0.14	2.67	0.402	1.752	18.663	27.324	11911.80	0.1142

Table - 5.10 (Contd.)

1	2	3	4	5	6	7	8	9
5.0313	0.21	2.67×10^{-5}	0.402	1.752	18.663	27.324	17304.20	0.1659
5.0314	0.28	2.67	0.402	1.752	18.663	27.324	25028.60	0.2400
5.0315	0.35	2.67	0.402	1.752	18.663	27.324	29116.50	0.2792
5.0316	0.07	2.67	0.402	1.752	18.663	27.324	602146	0.0577
5.0317	0.14	2.67	0.402	1.752	18.663	27.324	12460.0	0.1195
5.0318	0.21	2.67	0.402	1.752	18.663	27.324	18031.30	0.1729
5.0319	0.28	2.67	0.402	1.752	18.663	27.324	23804.00	0.2283
5.0320	0.35	2.67	0.402	1.752	18.663	27.324	28853.90	0.2769
5.0321	0.07	2.67	0.402	1.752	18.663	27.324	6186.04	0.0593
5.0322	0.14	2.67	0.402	1.752	18.663	27.324	11911.80	0.1142
5.0323	0.21	2.67	0.402	1.752	18.663	27.324	18291.10	0.1754
5.0324	0.28	2.67	0.402	1.752	18.663	27.324	24730.90	0.2376
5.0325	0.35	2.67	0.402	1.752	18.663	27.324	30179.70	0.2984

TABLE-5.11

CALCULATIONS FOR PREDICTED PRESSURE DROP

Sharma's correlation (21) for predicting pressure drop for swirling flow in long horizontal tube is-

$$\frac{\Delta P\ g_c}{V_1^2\ \rho} = .2.57\times10^{-2}\left[\frac{D_T\ V_1}{v}\right]^{-0.15}\left[\frac{V_1^2}{gD_T}\right]^{-0.065}\left[\frac{D_S}{D_T}\right]^{4.18}\left[\frac{D_T}{D_1}\right]^{2.6}$$

on rearranging

$$\Delta P = \left[\frac{2.57\times\rho\times10^{-2}}{g_c}\right]\left[\frac{D_T}{v}\right]^{-0.15}\left[\frac{1}{gD_T}\right]^{-0.065}\left[\frac{D_S}{D_T}\right]^{4.18}\left[\frac{D_T}{D_1}\right]^{2.6} V_1^{1.72}$$

or $\Delta P = K\ V_1^{1.72}$

Run No.	Experiment at Pressure Drop Kg/cm^2	$\frac{2.57\times10^{-2}\times\rho}{g_c}$	$\left[\frac{D_T}{v}\right]^{-0.15}$	$\left[\frac{1}{gD_T}\right]^{-0.065}$	$\left[\frac{D_S}{D_T}\right]^{4.18}$	$\left[\frac{D_T}{D_1}\right]^{2.6}$	$V_1^{1.72}$	Predicte pressure drop kg/cm^2
5.0401	0.07	2.63×10^{-5}	0.415	1.707	101.263	9.543	4444.09	0.080
5.0402	0.14	2.63	0.415	1.707	101.263	9.543	8671.47	0.156
5.0403	0.21	2.63	0.415	1.707	101.263	9.543	13418.60	0.241
5.0404	0.28	2.63	0.415	1.707	101.263	9.543	17773.10	0.320
5.0405	0.35	2.63	0.415	1.707	101.263	9.543	22558.40	0.406
5.0406	0.07	2.63	0.415	1.707	101.263	9.543	4312.95	0.077
5.0407	0.14	2.63	0.415	1.707	101.263	9.543	9241.85	0.1664
5.0408	0.21	2.63	0.415	1.707	101.263	9.543	12945.10	0.233
5.0409	0.28	2.63	0.415	1.707	101.263	9.543	17304.20	0.311
5.0410	0.35	2.63	0.415	1.707	101.263	9.543	21665.70	0.390
5.0411	0.07	2.63	0.415	1.707	101.263	9.543	4444.09	0.080
5.0412	0.14	2.63	0.415	1.707	101.263	9.543	8790.49	0.158

Table No.5.11 contd....

1	2	3	4	5	6	7	8	9
5.0413	0.21	2.63	0.415	1.707	101.263	9.543	13860.00	0.2495
5.0414	0.28	2.63	0.415	1.707	101.263	9.543	17902.50	0.3223
5.0415	0.35	2.63	0.415	1.707	101.213	9.543	23081.90	0.4156
5.0416	0.07	2.63	0.415	1.707	101.263	9.543	4650.36	0.0837
5.0417	0.14	2.63	0.415	1.707	101.263	9.543	9031.34	0.1626
5.0418	0.21	2.63	0.415	1.707	101.263	9.543	13552.10	0.2440
5.0419	0.28	2.63	0.415	1.707	101.263	9.543	18465.20	0.3325
5.0420	0.35	2.63	0.415	1.707	101.263	9.543	21665.70	0.3901
5.0501	0.07	2.65	0.421	1.707	101.263	9.543	4242.32	0.0781
5.0502	0.14	2.65	0.421	1.707	101.263	9.543	8679.13	0.1597
5.0503	0.21	2.65	0.421	1.707	101.263	9.543	12720.40	0.2341
5.0504	0.28	2.65	0.421	1.707	101.263	9.543	17389.20	0.3200
5.0505	0.35	2.65	0.421	1.707	101.263	9.543	21109.30	0.3885
5.0506	0.07	2.65	0.421	1.707	101.263	9.543	4360.50	0.0802
5.0507	0.14	2.65	0.421	1.707	101.263	9.543	8458.20	0.1557
5.0508	0.21	2.65	0.421	1.707	101.263	9.543	13020.30	0.2396
5.0509	0.28	2.65	0.421	1.707	101.263	9.543	18075.00	0.3326
5.0510	0.35	2.65	0.421	1.707	101.263	9.543	21665.70	0.3987
5.0511	0.07	2.65	0.421	1.707	101.263	9.543	4504.46	0.08290
5.0512	0.14	2.65	0.421	1.707	101.263	9.543	8838.29	0.1627
5.0513	0.21	2.65	0.421	1.707	101.263	9.543	13513.40	0.2487
5.0514	0.28	2.65	0.421	1.707	101.263	9.543	17649.10	0.3247
5.0515	0.35	2.65	0.421	1.707	101.263	9.543	22463.70	0.4134
5.0516	0.07	2.65	0.421	1.707	101.263	9.543	4242.32	0.0781
5.0517	0.14	2.65	0.421	1.707	101.263	9.543	8998.65	0.1656

Table No.5.11 contd........

1	2	3	4	5	6	7	8	9
5.0518	0.21	2.65	0.421	1.707	101.263	9.543	13020.30	0.2396
5.0519	0.28	2.65	0.421	1.707	101.263	9.543	17538.0	0.3228
5.0520	0.35	2.65	0.421	1.707	101.263	9.543	21109.30	0.3885
5.0601	0.07	2.67	0.427	1.707	101.263	9.543	4242.32	0.0798
5.0602	0.14	2.67	0.427	1.707	101.263	9.543	8301.21	0.1561
5.0603	0.21	2.67	0.427	1.707	101.263	9.543	13285.60	0.2499
5.0604	0.28	2.67	0.427	1.707	101.263	9.543	16589.70	0.3120
5.0605	0.35	2.67	0.427	1.707	101.263	9.543	21898.70	0.4118
5.0606	0.07	2.67	0.427	1.707	101.263	9.543	4420.39	0.0831
5.0607	0.14	2.67	0.427	1.707	101.263	9.543	8520.43	0.1602
5.0608	0.21	2.67	0.427	1.707	101.263	9.543	13020.30	0.2449
5.0609	0.28	2.67	0.427	1.707	101.263	9.543	17114.5	0.3219
5.0610	0.35	2.67	0.427	1.707	101.263	9.543	22133.90	0.4163
5.0611	0.07	2.67	0.427	1.707	101.263	9.543	4125.51	0.0776
5.0612	0.14	2.67	0.427	1.707	101.263	9.543	8818.29	0.1662
5.0613	0.21	2.67	0.427	1.707	101.263	9.543	12964.10	0.2438
5.0614	0.28	2.67	0.427	1.707	101.263	0.543	17645.10	0.3318
5.0615	0.35	2.67	0.427	1.707	101.263	0.543	20696.50	0.3892
5.0616	0.07	2.67	0.427	1.707	101.263	9.543	4360.50	0.0820
5.0617	0.14	2.67	0.427	1.707	101.263	9.543	8615.66	0.1620
5.0618	0.21	2.67	0.427	1.707	101.263	9.543	12964.10	0.2438
5.0619	0.28	2.67	0.427	1.707	101.263	9.543	17114.50	0.3219
5.0620	0.35	2.67	0.427	1.707	101.263	9.543	21572.50	0.4057

TABLE -5.12

CALCULATIONS FOR PREDICTED PRESSURE DROP

Sharma's Correlation (21) for Predicting Pressure Drop for Swirling Flow in Long Horizontal Tube is-

$$\frac{\Delta P\, g_c}{V_i^2\, \rho} = 2.57\times10^{-2} \left[\frac{D_T\, V_i}{\nu}\right]^{-0.15} \left[\frac{V_i^2}{g D_T}\right]^{-0.065} \left[\frac{D_S}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6}$$

on rearranging

$$\Delta P = \left[\frac{2.57\rho\times10^{-2}}{g_c}\right] \left[\frac{D_T}{\nu}\right]^{-0.15} \left[\frac{1}{g\, D_T}\right]^{-0.065} \left[\frac{D_S}{D_T}\right]^{4.18} \left[\frac{D_T}{D_i}\right]^{2.6} V_i^{1.72}$$

or $\Delta P = K\, V_i^{1.72}$

Run No.	Experimental Pressure Drop kg/cm^2	$\frac{2.57\rho\times10^{-2}}{g_c}$	$\left[\frac{D_T}{\nu}\right]^{-0.15}$	$\left[\frac{1}{g\, D_T}\right]^{-0.065}$	$\left[\frac{D_S}{D_T}\right]^{4.18}$	$\left[\frac{D_T}{D_i}\right]^{2.6}$	$V_i^{1.72}$	Predicted pressure Drop kg/cm^2
1	2	3	4	5	6	7	8	9
5.0701	0.07	2.63×10^{-5}	0.441	1.663	347.900	6.063	1967.22	0.08
5.0702	0.14	263	0.441	1.663	347.900	6.063	4015.61	0.16
5.0703	0.21	2.63	0.441	1.663	347.900	6.063	5976.84	0.24
5.0704	0.28	2.63	0.441	1.663	347.900	6.063	7500.22	0.30
5.0705	0.35	2.63	0.441	1.663	347.900	6.063	9962.48	0.40
5.0706	0.07	2.63	0.441	1.663	347.900	6.063	1860.25	0.07
5.0707	0.14	2.63	0.441	1.663	347.900	6.063	3991.23	00.16
5.0708	0.21	2.63	0.441	1.663	347.900	6.063	5826.94	0.23
5.0709	0.28	2.63	0.441	1.663	347.900	6.063	7445.54	0.30
5.0710	0.35	2.63	0.441	1.663	347.900	6.063	9644.12	0.39

Table No.5.12 contd.....

1	2	3	4	5	6	7	8	9
5.0711	0.07	2.63	0.441	1.663	347.900	6.063	1967.22	0.0800
5.0712	0.14	2.63	0.441	1.663	347.900	6.063	3864.27	0.1572
5.0713	0.21	2.63	0.441	1.663	347.900	6.063	5614.65	0.2284
5.0714	0.28	2.63	0.441	1.663	347.900	6.063	7634.47	0.3106
5.0715	0.35	2.63	0.441	1.663	347.900	6.063	9962.48	0.4058
5.0716	0.07	2.63	0.441	1.663	347.900	6.063	1886.85	0.0768
5.0717	0.14	2.63	0.441	1.663	347.900	6.063	3754.13	0.1527
5.0718	0.21	2.63	0.441	1.663	347.900	6.063	5573.23	0.2267
5.0719	0.28	2.63	0.441	1.663	347.900	6.063	7972.45	0.3244
5.0420	0.35	2.63	0.441	1.663	3479.00	6.063	9304.06	0.3785
5.0801	0.07	2.65	0.447	1.663	347.900	6.063	1833.80	0.07620
5.0802	0.14	2.65	0.447	1.663	347.900	6.063	3864.27	0.1606
5.0803	0.21	2.65	0.447	1.663	347.900	6.063	5699.17	0.2368
5.0804	0.28	2.65	0.447	1.668	347.900	6.063	7779.03	0.3232
5.0805	0.35	2.65	0.447	1.663	347.900	6.063.	9591.34	0.3985
5.0806	0.07	2.65	0.447	1.663	347.900	6.063	1886.85	0.0784
5.0807	0.14	2.65	0.447	1.663	347.900	6.063	3647.98	0.1516
5.0808	0.21	2.65	0.447	1.669	347.900	6.063	5447.84	0.2264
5.0809	0.28	2.65	0.447	1.669	347.900	6.063	7287.50	0.3028
5.0810	0.35	2.65	0.447	1.663	347.900	6.063	9750.02	0.4051
5.0811	0.07	2.65	0.447	1.663	347.900	6.063	1886.85	0.0784
5.0812	0.14	2.65	0.447	1.663	347.900	6.063	3900.37	0.1621
5.0813	0.21	2.65	0.447	1.663	347.900	6.063	5699.17	0.2368
5.0814	0.28	2.65	0.447	1.663	347.900	6.063	7635.47	0.3173
5.0815	0.35	2.65	0.447	1.663	347.900	6.063	9591.34	0.3985
5.0816	0.07	2.65	0.447	1.663	347.900	6.063	1953.66	0.0812

Table No.5.12 contd.....

1	2	3	4	5	6	7	8	9
5.0817	0.14	2.65	0.447	1.663	347.9	6.063	3754.13	0.1560
5.0818	0.21	2.65	0.447	1.663	347.9	6.063	5874.34	0.2441
5.0819	0.28	2.65	0.447	1.663	347.9	6.063	7357.41	0.3057
5.0820	0.35	2.65	0.447	1.663	347.9	6.063	9096.85	0.3780
5.0901	0.07	2.67×10^{-5}	0.454	1.663	347.9	6.063	1781.77	0.0758
5.0902	0.14	2.67	0.454	1.663	347.9	6.063	3721.88	0.1583
5.0903	0.21	2.67	0.454	1.663	347.9	6.063	5704.31	0.2426
5.0904	0.28	2.67	0.454	1.663	347.9	6.063	7117.49	0.3026
5.0905	0.35	2.67	0.454	1.663	347.9	6.063	9278.84	0.3945
5.0906	0.07	2.67	0.454	1.663	347.9	6.063	1860.25	0.0791
5.0907	0.14	2.67	0.454	1.663	347.9	6.063	3578.46	0.1522
5.0908	0.21	2.67	0.454	1.663	347.9	6.063	5365.53	0.2281
5.0909	0.28	2.67	0.454	1.663	347.9	6.063	7303.88	0.3106
5.0910	0.35	2.67	0.454	1.663	347.9	6.063	9538.69	0.4056
5.0911	0.07	2.67	0.454	1.663	347.9	6.063	1900.22	0.0808
5.0912	0.14	2.67	0.454	1.663	347.9	6.063	3688.04	0.0168
5.0913	0.21	2.67	0.454	1.663	347.9	6.063	5704.31	0.2426
5.0914	0.28	2.67	0.454	1.663	347.9	6.063	7635.47	0.3247
5.0915	0.35	2.67	0.454	1.663	347.9	6.063	9123.43	0.3879
5.0916	0.07	2.67	0.454	1.663	347.9	6.063	1860.25	0.0791
5.0917	0.14	2.67	0.459	1.663	347.9	6.063	3793.04	0.1613
5.0918	0.21	2.67	0.454	1.663	347.9	6.063	5619.76	0.2390
5.0919	0.28	2.67	0.454	1.663	347.9	6.063	7123.83	0.3029
5.0920	0.35	2.67	0.454	1.663	347.9	6.063	8850.64	0.3763

TABLE-5.13

DATA ON AIR CORE DIAMETER ALONG THE TUBE AXIS

Inside diameter of perspex tube	- 5.71 cms
Length of perspex tube	- 370 cms
Inside diameter of swirl chamber	-11.50 cms
Inside diameter of tangential entry	- 1.60 cms
Correction factor for refraction	- 0.85

Run No.	Distance along the tube Axis cms.	Air Core Diameter cms.	Average Air Core Diameter after applying Refraction Correction cms.
1	2	3	4
5.0101	0	5.867	4.62
	20	5.638	
	40	5.571	
	60	5.450	
	80	5.145	
	105	4.985	
5.0102	0	5.969	4.64
	20	5.957	
	40	5.877	
	60	5.851	
	80	5.790	
	100	5.350	
	120	4.996	
	140	4.980	
	150	4.364	
5.0103	0	6.012	4.27
	20	5.848	
	40	5.374	
	60	5.175	
	80	5.050	
	100	4.850	
	120	4.790	
	140	4.570	
	170	4.350	
	180	4.264	

1	2	3	4
5.0104	0	5.980	4.46
	20	5.940	
	40	5.795	
	60	5.728	
	80	5.625	
	100	5.350	
	120	5.080	
	140	4.850	
	190	4.424	
	210	4.300	
5.0105	0	6.005	4.52
	20	5.950	
	40	5.890	
	60	5.628	
	80	5.515	
	100	5.378	
	120	5.295	
	140	5.088	
	170	4.950	
	190	4.818	
	210	4.715	
	230	4.525	
5.0106	0	5.905	4.61
	20	5.610	
	40	5.524	
	60	5.385	
	80	5.095	
	105	4.995	
5.0107	0	5.890	4.59
	20	5.850	
	40	5.790	
	60	5.790	
	80	5.688	
	100	5.415	
	120	4.925	
	140	4.850	
	148	4.452	
5.0108	0	6.025	4.33
	20	5.915	
	40	5.525	
	60	5.280	
	80	5.090	
	100	4.980	
	120	4.825	
	140	4.610	
	170	4.375	
	178	4.374	
5.0109	0	6.015	4.48
	20	5.895	
	40	5.755	

1	2	3	4
	60	5.700	
	80	5.629	
	100	5.250	
	120	5.150	
	140	4.950	
	170	4.775	
	190	4.425	
	208	4.385	
5.0110	0	5.950	4.46
	20	5.915	
	40	5.845	
	60	5.578	
	80	5.500	
	100	5.295	
	120	5.225	
	140	4.985	
	170	4.850	
	190	4.780	
	210	4.628	
	225	4.433	
5.0111	0	5.925	4.59
	20	5.625	
	40	5.495	
	60	5.415	
	80	5.205	
	104	4.850	
5.0112	0	5.910	4.56
	20	5.835	
	40	5.695	
	60	5.645	
	80	5.578	
	100	5.438	
	120	4.955	
	140	4.849	
	147	4.354	
5.0113	0	5.995	4.36
	20	5.950	
	40	5.650	
	60	5.433	
	80	5.113	
	100	4.951	
	120	4.868	
	140	4.627	
	170	4.398	
	178	4.292	
5.0114	0	5.978	4.50
	20	5.858	
	40	5.725	
	60	5.695	
	80	5.658	
	100	5.350	
	120	5.195	

1	2	3	4
	140	5.013	
	170	4.870	
	190	4.525	
	208	4.338	
5.0115	0	6.005	4.47
	20	5.890	
	40	5.823	
	60	5.535	
	80	5.478	
	100	5.308	
	120	5.235	
	140	5.005	
	170	4.945	
	190	4.810	
	210	4/613	
	225	4.395	
5.0116	0	5.910	4.66
	20	5.731	
	40	5.613	
	60	5.515	
	80	5.140	
	103	4.950	
5.0117	0	5.948	4.58
	20	5.895	
	40	5.795	
	60	5.738	
	80	5.715	
	100	5.345	
	120	4.890	
	140	4.835	
	148	4.290	
5.0118	0	6.000	4.34
	20	5.938	
	40	5.378	
	60	5.313	
	80	5.112	
	100	4.997	
	120	4.807	
	140	4.597	
	170	4.415	
	176	4.415	
5.0119	0	5.985	4.45
	20	5.823	
	40	5.715	
	60	5.638	
	80	5.592	
	100	5.178	
	120	5.105	

1	2	3	4
	40	5.795	
	60	5.738	
	80	5.715	
	100	5.345	
	120	4.890	
	140	4.835	
	148	4.290	
5.0118	0	6.000	4.34
	20	5.938	
	40	4.478	
	60	5.313	
	80	5.122	
	100	4.997	
	120	4.807	
	140	4.597	
	170	4.415	
	176	4.415	
5.0119	0	5.985	4.45
	20	5.823	
	40	5.715	
	60	5.638	
	80	5.592	
	100	5.178	
	120	5.105	
	140	4.995	
	170	4.708	
	190	4.448	
	207	4.405	
5.0120	0	5.995	4.4[illegible]
	20	5.905	
	40	5.835	
	60	5.9[illegible]8	
	80	5.505	
	100	5.329	
	120	5.215	
	140	4.871	
	170	4.877	
	190	4.792	
	210	4.650	
	226	4.495	
5.0121	0	5.955	4.63
	20	5.633	
	40	5.575	
	60	5.405	
	80	5.138	
	102	4.950	
5.0122	0	5.900	4.57
	20	5.835	
	40	5.738	

1	2	3	4
	60	5.689	
	80	5.635	
	100	5.395	
	120	5.005	
	140	4.895	
	145	4.375	
5.0123	0	6.030	4.42
	20	5.960	
	40	5.678	
	60	5.419	
	80	5.325	
	100	5.105	
	120	4.920	
	140	4.613	
	170	4.555	
	175	4.435	
5.0124	0	5.915	4.40
	20	5.800	
	40	5.689	
	60	5.615	
	80	5.485	
	100	5.269	
	120	5.018	
	140	4.875	
	160	4.698	
	190	4.378	
	205	4.310	
5.0125	0	6.000	4.49
	20	5.895	
	40	5.800	
	60	5.651	
	80	5.615	
	100	5.358	
	120	5.235	
	140	5.038	
	170	4.910	
	190	4.815	
	210	4.680	
	220	4.523	
5.0201	0	5.900	4.67
	20	5.725	
	40	5.550	
	60	5.478	
	80	5.210	
	105	5.092	
5.0202	0	5.985	4.64
	20	5.947	
	40	5.905	
	60	5.872	

1	2	3	4
	60	5.872	
	80	5.805	
	100	5.374	
	120	5.025	
	140	4.925	
	150	4.275	
5.0203	0	6.059	4.33
	20	5.957	
	40	5.438	
	60	5.288	
	80	5.102	
	100	4.985	
	120	4.828	
	140	4.605	
	170	4.378	
	180	4.278	
5.0204	0	6.025	4.50
	20	5.975	
	40	5.835	
	60	5.755	
	80	5.685	
	100	5.480	
	120	5.035	
	140	4.875	
	170	4.731	
	190	4.495	
	212	4.383	
5.0205	0	6.105	4.61
	20	5.995	
	40	5.905	
	60	5.648	
	80	5.532	
	100	5.415	
	120	5.318	
	140	5.125	
	170	4.925	
	190	4.848	
	210	4.738	
	230	4.490	
5.0206	0	6.005	4.68
	20	5.735	
	40	5.558	
	60	5.495	
	80	5.228	
	104	5.024	
5.0207	0	5.950	4.63
	20	5.903	
	40	5.875	

1	2	3	4
	60	5.835	
	80	5.785	
	100	5.405	
	120	5.038	
	140	4.948	
	150	4.305	
5.0208	0	6.040	4.33
	20	5.970	
	40	5.445	
	60	5.305	
	80	5.088	
	100	4.945	
	120	4.800	
	140	4.578	
	170	4.405	
	180	4.305	
5.0209	0	5.985	4.51
	20	5.955	
	40	5.890	
	60	5.785	
	80	5.635	
	100	5.515	
	120	5.000	
	140	4.905	
	170	4.775	
	190	4.513	
	210	4.348	
5.0210	0	6.085	4.55
	20	6.005	
	40	5.915	
	60	5.712	
	80	5.572	
	100	5.392	
	120	5.325	
	140	5.178	
	170	4.955	
	190	4.855	
	210	4.790	
	227	4.408	
5.0211	0	5.995	4.69
	20	5.795	
	40	5.601	
	60	5.505	
	80	5.195	
	104	5.038	
5/0212	0	5.982	4.63
	20	5.885	
	40	5.865	
	60	5.843	
	80	5.748	

1	2	3	4
	100	5.444	
	120	5.000	
	140	4.915	
	146	4.295	
5.0213	0	6.000	4.30
	20	5.950	
	40	4.445	
	60	5.328	
	80	5.015	
	100	4.908	
	120	4.823	
	140	4.538	
	170	4.380	
	175	4.255	
5.0214	0	6.038	4.54
	20	5.985	
	40	5.905	
	60	5.823	
	80	5.638	
	100	5.498	
	120	5.125	
	140	4.988	
	170	4.805	
	190	4.544	
	209	4.355	
5.0215	0	6.052	4.56
	20	5.992	
	40	5.923	
	60	5.745	
	80	5.585	
	100	5.405	
	120	5.342	
	140	5.195	
	170	5.000	
	190	4.895	
	210	4.805	
	227	4.435	
5.0216	0	5.985	4.67
	20	5.828	
	40	5.615	
	60	5.485	
	80	5.203	
	105	4.825	
5.0217	0	5.972	4.57
	20	5.905	
	40	5.813	
	60	5.775	
	80	5.690	
	100	5.338	
	120	4.832	

1	2	3	4
	140	4.765	
	147	4.250	
5.0218	0	5.993	4.35
	20	5.928	
	40	5.500	
	60	5.119	
	100	5.000	
	120	4.785	
	140	4.608	
	170	4.475	
	180	4.465	
5.0219	0	6.000	4.46
	20	5.855	
	40	5.738	
	60	5.600	
	80	5.625	
	100	5.200	
	120	5.128	
	140	5.000	
	170	4.719	
	190	4.458	
	208	4.395	
5.0220	0	6.085	4.51
	20	6.010	
	40	5.903	
	60	5.612	
	80	5.498	
	100	5.355	
	120	5.248	
	140	5.072	
	170	4.903	
	190	4.825	
	210	4.708	
	225	4.502	
5.0221	0	5.990	4.68
	20	5.850	
	40	5.668	
	60	5.508	
	80	5.195	
	103	4.838	
5.0222	0	5.980	4.67
	20	5.890	
	40	5.805	
	60	5.790	
	80	5.713	
	100	5.375	
	120	4.848	
	140	5.778	
	146	4.295	

1	2	3	4
5.0223	0	6,005	4,43
	20	5.980	
	40	5.708	
	60	5,423	
	80	5,348	
	100	5,085	
	120	4,905	
	140	4,658	
	170	4,505	
	180	4,490	
5.0224	0	5.985	4.40
	20	5.805	
	40	5.713	
	60	5,625	
	80	5.505	
	100	5.095	
	120	5.000	
	140	4.905	
	170	4/678	
	205	4.245	
5.0225	0	6.013	4.48
	20	5.913	
	40	5.823	
	60	5.585	
	80	5.500	
	100	5.362	
	120	5.222	
	140	5.000	
	170	4.903	
	190	4.800	
	210	4.668	
	224	4.509	
5.0301	0	5.985	4.70
	20	5.772	
	40	5.563	
	60	5.505	
	80	5.218	
	105	5.113	
5.0302	0	6.000	4.65
	20	5.950	
	40	5.915	
	60	5.850	
	80	5.813	
	100	5.405	
	120	5.048	
	140	4.955	
	150	4.305	

1	2	3	4
5.0303	0	6.013	4.33
	20	5.962	
	40	5.455	
	60	5.310	
	80	5.085	
	100	4.963	
	120	4.842	
	140	4.585	
	170	4.382	
	180	4.305	
5.0304	0	6.000	4.50
	20	5.958	
	40	5.845	
	60	5.695	
	80	5.633	
	100	5.501	
	120	5.100	
	140	4.900	
	170	4.748	
	190	4.509	
	212	4.305	
5.0305	0	6.085	4.54
	20	5.990	
	40	5.913	
	60	5.672	
	80	5.566	
	100	5.448	
	120	5.324	
	140	5.143	
	170	4.908	
	190	4.852	
	210	4.752	
	230	4.501	
5.0306	0	6.035	4.67
	20	5.715	
	40	5.490	
	60	5.478	
	80	5.238	
	105	5.005	
5.0307	0	5.973	4.63
	20	5.913	
	40	5.885	
	60	5.812	
	80	5.795	
	100	5.390	
	120	5.014	
	140	4.963	
	150	4.278	

1	2	3	4
5.0308	0	6.005	4.33
	20	5.958	
	40	5.503	
	60	5.300	
	80	51112	
	100	4.968	
	120	4.808	
	140	4.585	
	170	4.417	
	180	4.285	
5.0309	0	5.968	4.50
	20	5.934	
	40	5.885	
	60	5.803	
	80	5.643	
	100	5.524	
	120	4.980	
	140	4.880	
	170	4.755	
	190	4.495	
	210	4.315	
5.0310	0	6.045	4.54
	20	5.948	
	40	5.900	
	60	5.684	
	80	5.513	
	100	5.464	
	120	5.338	
	140	5.165	
	170	4.936	
	190	4.895	
	210	4.757	
	227	4.475	
5.0311	0	6.000	4.67
	20	5.723	
	40	5.508	
	60	5.488	
	80	5.265	
	105	4.990	
5.0312	0	5.990	4.63
	20	5.925	
	40	5.905	
	60	5.828	
	80	5.800	
	100	5.388	
	120	5.005	
	140	4.917	
	150	4.308	

1	2	3	4
5.0313	0	5.985	4.34
	20	5.923	
	40	5.542	
	60	5.325	
	80	5.123	
	100	5.020	
	120	4.823	
	140	4.625	
	170	4.423	
	180	4.265	
5.0314	0	5.982	4.56
	20	5.943	
	40	5.895	
	60	5.800	
	80	5.658	
	100	5.518	
	120	4.973	
	140	4.865	
	190	4.715	
	210	4.318	
5.0315	0	6.005	4.55
	20	5.965	
	40	5.888	
	60	5.657	
	80	5.570	
	100	5.385	
	120	5.335	
	140	5.212	
	170	5.085	
	190	4.913	
	210	4.822	
	227	4.445	
5.0316	0	5.995	4.67
	20	5.775	
	40	5.620	
	60	5.498	
	80	5.200	
	103	4.863	
5.0317	0	5.988	4.58
	20	5.900	
	40	5.830	
	60	5.800	
	80	5.717	
	100	5.356	
	120	4.849	
	140	4.773	
	147	4.235	
5.0318*			
5.0319	0	6.070	4.46

1	2	3	4
	20	5.885	
	40	5.763	
	60	5.625	
	80	5.580	
	100	5.213	
	120	5.138	
	140	4.942	
	170	4.723	
	190	4.468	
	208	4.305	
5.0320	0	6.038	4.50
	20	6.000	
	40	5.928	
	60	5.658	
	80	5.475	
	100	5.323	
	120	5.303	
	140	5.014	
	170	4.900	
	190	4.805	
	210	4.688	
	226	4.473	
5.0321	0	6.000	4.69
	20	5.795	
	40	5.700	
	60	5.525	
	80	5.203	
	103	4.905	
5.0322	0	5.985	4.68
	20	5.888	
	40	5.812	
	60	5.790	
	80	5.723	
	100	5.372	
	120	4.863	
	140	5.772	
	146	4.317	
5.0323	0	6.000	4.43
	20	5.978	
	40	5.713	
	60	5.428	
	80	5.363	
	100	5.105	
	120	4.912	
	140	4.605	
	170	4.495	
	180	4.475	
5.0324	0	5.975	4.40
	20	5.823	
	40	5.734	

1	2	3	4	1	2	3	4
	60	5.608			80	5.115	
	80	5.488			100	5.012	
	100	5.123			120	4.800	
	120	5.029			140	4.638	
	140	4.917			170	4.428	
	170	4.682			180	4.205	
	190	4.335					
	205	4.275					
5.0325	0	6.028	4.49				
	20	5.948					
	40	5.835					
	60	5.600					
	80	5.513					
	100	5.340					
	120	5.200					
	140	4.963					
	170	4.895					
	190	4.808					
	210	4.705					
	224	4.483					
5.0318	0	5.978	4.34				
	20	5.905					
	40	5.572					
	60	5.348					

TABLE - 5.14

DATA ON AIR CORE DIAMETER ALONG THE TUBE AXIS

Inside diameter of perspex tube	..	3.81	Cms
Length of perspex tube	..	370	Cms
Inside diameter of swirl chamber	..	11.50	Cms
Inside diameter of tangential entry	..	1.60	Cms
Correction factor for refraction	..	0.87	Cms

Run No.	Distance Along the Tube Axis Cms	Air Core Diameter Cms	Average Air Core Diameter after Applying refraction correction. Cms	Run No.	Distance Along the Tube Axis Cms	Air Core Diameter Cms	Average Air Cor Diameter after Applyin refraction co rrectio Cms
1	2	3	4	1	2	3	4
5.0401	10	3.121	2.49	5.0403	10	3.300	2.43
	25	3.075			25	3.210	
	40	2.935			40	3.050	
	55	2.900			55	2.988	
	70	2.900			70	2.832	
	80	2.540			85	2.761	
	85	2.530			100	2.683	
5.0402	10	3.276	2.49		115	2.438	
	25	3.100			130	2.650	
	40	3.033			145	1.750	
	55	3.020		5.0404	10	3.273	2.27
	70	2.881			30	3.0[illegible]0	
	85	2.866			50	2.940	
	100	2.619			70	2.748	
	123	2.140			90	2.560	

Table - 5.14 (Contd.)

1	2	3	4
	110	2.471	
	130	2.375	
	150	2.184	
	165	1.884	
5.0405	10	3.315	2.26
	30	3.132	
	50	3.015	
	70	2.781	
	90	2.640	
	110	2.494	
	130	2.378	
	150	2.230	
	187	1.450	
5.0406	10	3.150	2.58
	25	3.093	
	40	3.004	
	55	2.985	
	70	3.000	
	85	2.590	
5.0407	10	3.270	2.47
	25	3.125	
	40	3.050	
	55	3.015	
	70	2.890	
	85	2.720	
	100	2.610	
	122	2.036	
5.0408	10	3.255	2.48
	25	3.216	
	40	3.054	
	55	3.050	
	70	2.884	
	85	2.881	
	100	2.674	
	115	2.795	
	130	2.454	
	145	1.470	
5.0409	10	3.260	2.28
	30	3.065	
	50	2.950	
	70	2.850	
	90	2.577	
	110	2.395	
	130	2.365	
	150	2.200	
	165	1.875	
5.0410	10	3.300	2.27
	30	3.129	
	50	3.084	

Table - 5.14 (Contd.)

1	2	3	4
	70	2.874	
	90	2.760	
	110	2.570	
	130	2.430	
	150	2.393	
	165	2.075	
	185	1.505	
5.0411	10	3.162	2.56
	25	3.050	
	40	3.015	
	55	2.995	
	70	2.900	
	87	2.550	
5.0412	10	3.288	2.52
	25	3.094	
	40	3.072	
	55	3.010	
	70	2.981	
	85	2.950	
	100	2.828	
	123	1.998	
4.0413	10	3.290	2.46
	25	3.185	
	40	3.115	
	55	3.080	
	70	2.993	
	85	2.942	
	100	2.815	
	115	2.770	
	130	2.520	
	144	1.525	
5.0414	10	3.324	2.45
	30	3.125	
	50	3.056	
	70	2.858	
	90	2.725	
	110	2.569	
	130	2.485	
	160	2.362	
5.0415	10	3.335	2.42
	30	3.220	
	50	3.040	

Table - 5.14 (Contd.)

1	2	3	4
	70	2.875	
	90	2.725	
	110	2.600	
	130	2.530	
	150	2.390	
	180	2.330	
5.0416	10	3.155	2.58
	25	3.080	
	40	3.060	
	55	3.000	
	70	2.955	
	86	2.545	
5.0417	10	3.260	2.51
	25	3.070	
	40	3.005	
	55	2.982	
	70	2.949	
	85	2.941	
	100	2.800	
	124	2.075	
5.0418	10	3.303	2.43
	25	3.180	
	40	3.150	
	55	3.030	
	70	2.996	
	85	2.946	
	100	2.825	
	115	2.780	
	130	2.550	
	145	1.495	
5.0419	10	3.339	2.48
	30	3.180	
	50	3.021	
	70	2.920	
	90	2.840	
	110	2.525	
	130	2.480	
	160	2.475	
5.0420	10	3.350	2.43
	30	3.234	
	50	3.045	
	70	2.879	
	90	2.710	
	110	2.550	
	130	2.530	
	150	2.550	
	180	2.295	

Table - 5.14 (Contd.)

1	2	3	4
5.0501	10	3.228	2.55
	25	3.001	
	40	2.956	
	55	2.932	
	70	2.840	
	85	2.632	
5.0502	10	3.315	2.42
	30	3.150	
	50	3.005	
	70	2.762	
	90	2.777	
	110	2.530	
	123	1.909	
5.0503	10	3.282	2.34
	30	3.125	
	50	3.074	
	70	2.825	
	90	2.632	
	110	2.350	
	130	2.300	
	145	1.955	
5.0504	10	3.280	2.35
	30	3.225	
	50	3.109	
	70	2.839	
	90	2.798	
	110	2.475	
	130	2.300	
	150	2.480	
	165	1.765	
5.0505	10	3.225	2.26
	30	3.140	
	50	2.970	
	70	2.854	
	90	2.720	
	110	2.495	
	130	2.280	
	150	2.225	
	187	1.510	
5.0506	10	3.241	2.57
	25	3.053	
	40	3.013	
	55	3.020	
	70	2.841	
	85	2.525	
5.0507	10	3.280	2.50
	30	3.185	
	50	3.120	

Table - 5.14 (Contd.)

1	2	3	4	1	2	3	4
	70	3.065			70	2.859	
	90	2.950			90	2.680	
	110	2.555			110	2.475	
	122	1.990			130	2.300	
					150	2.220	
5.0503	10	3.280	2.40		185	1.550	
	30	3.103					
	50	3.025		5.0511	10	3.225	262
	70	2.860			25	3.211	
	90	2.433			40	3.100	
	110	2.695			55	3.125	
	130	2.480			70	2.845	
	145	1.925			85	2.545	
5.0509	10	3.257	2.39	5.0512	10	3.214	2.56
	30	3.150			30	3.212	
	50	2.950			50	3.125	
	70	2.911			70	3.050	
	90	2.777			90	2.971	
	110	2.690			110	2.680	
	130	2.575			125	2.355	
	150	2.550					
	165	1.890		5.0513	10	3.340	2.46
					30	3.170	
5.0510	10	3.220	2.27		50	3.120	
	30	3.160			70	2.880	
	50	2.980			90	8.700	

Table - 5.14 (Contd.)

1	2	3	4
	110	2.700	
	130	2.565	
	144	2.150	
5.0514	10	3.255	2.47
	30	3.140	
	50	3.090	
	70	2.920	
	90	2.815	
	110	2.590	
	130	2.505	
	160	2.435	
5.0515	10	3.213	2.39
	30	3.117	
	50	3.025	
	70	2.835	
	90	2.844	
	110	2.650	
	130	2.530	
	150	2.525	
	180	2.030	
5.0516	10	3.225	2.61
	25	3.200	
	40	3.110	
	55	3.100	
	70	2.830	
	85	2.550	
5.0517	10	3.270	2.62
	30	3.225	
	50	3.200	
	70	3.065	
	90	3.000	
	110	2.935	
	123	2.440	
5.0518	10	3.350	2.46
	30	3.160	
	50	3.135	
	70	2.915	
	90	2.725	
	110	2.705	
	130	2.538	
	144	2.050	
5.0519	10	3.258	2.47
	30	3.125	
	50	3.075	
	70	2.870	
	90	2.780	
	110	2.600	
	130	2.525	

Table - 5.14 (Contd.)

1	2	3	4
	159	2.455	
5.0520	10	3.313	2.44
	30	3.191	
	50	3.040	
	70	2.975	
	90	2.791	
	110	2.720	
	130	2.530	
	150	2.520	
	181	2.155	
5.0601	10	3.230	2.56
	25	3.085	
	40	2.954	
	55	2.909	
	70	2.855	
	85	2.595	
5.0602	10	3.350	2.44
	30	3.140	
	50	3.015	
	70	2.485	
	90	2.785	
	110	2.575	
	124	2.005	
5.0603	10	3.295	2.34
	30	3.175	
	50	3.050	
	70	2.845	
	90	2.650	
	110	2.325	
	130	2.315	
	145	1.850	
5.0604	10	3.290	2.34
	30	3.195	
	50	3.125	
	70	2.865	
	90	2.800	
	110	2.465	
	130	2.325	
	150	2.280	
	165	1.825	
5.0605	10	3.228	2.28
	30	3.155	
	50	3.005	
	70	2.890	
	90	2.705	
	110	2.490	
	130	2.348	

Table - 5.14 (Contd.)

1	2	3	4
	150	2.235	
	187	1.485	
5.0606	10	3.258	2.58
	25	3.105	
	40	2.975	
	55	2.935	
	70	2.865	
	85	2.650	
5.0607	10	3.378	2.43
	30	3.125	
	50	2.995	
	70	2.790	
	90	2.765	
	110	2.540	
	125	1.995	
5.0608	10	3.300	2.40
	30	3.118	
	50	3.046	
	70	2.850	
	90	2.720	
	110	2.675	
	130	2.358	
	145	1.980	
5.0609	10	3.280	2.40
	30	3.175	
	50	2.940	
	70	2.895	
	90	2.780	
	110	2.710	
	130	2.610	
	150	2.575	
	165	1.915	
5.0610	10	3.250	2.29
	30	3.190	
	50	2.985	
	70	2.870	
	90	2.700	
	110	2.480	
	130	2.305	
	150	2.205	
	185	1.420	
5.0611	10	3.250	2.62
	25	3.205	
	40	3.089	
	55	3.105	
	70	2.856	

Table - 5.14 (Contd.)

1	2	3	4
	85	2.590	
5.0612	10	3.290	2.44
	30	3.115	
	50	3.007	
	70	2.890	
	90	2.748	
	110	2.590	
	125	2.025	
5.0613	10	3.345	2.46
	30	3.185	
	50	3.128	
	70	2.850	
	90	2.715	
	110	2.710	
	130	2.590	
	144	2.185	
5.0614	10	3.270	2.47
	30	3.165	
	50	3.000	
	70	2.915	
	90	2.025	
	220	2.583	
	130	2.515	
	150	2.408	
5.0615	10	3.228	2.41
	30	3.120	
	50	3.048	
	70	2.865	
	90	2.870	
	110	2.668	
	130	2.528	
	150	2.505	
	182	2.076	
5.0616	10	3.240	2.60
	25	3.205	
	40	3.059	
	55	3.089	
	70	2.810	
	85	2.525	
5.0617	10	3.295	2.49
	30	2.215	
	50	3.168	
	70	3.034	
	90	2.956	
	110	2.924	
	124	2.438	
5.0618	10	3.375	2.47
	30	3.145	

Table - 5.14 (Contd.)

1	2	3	4
	50	3.120	
	70	2.938	
	90	2.895	
	110	2.750	
	130	2.505	
	144	2.028	
5.0619	10	3.300	2.49
	30	3.145	
	50	3.095	
	70	2.900	
	90	2.796	
	110	2.638	
	130	2.536	
	158	2.485	
5.0620	10	3.340	2.45
	30	3.215	
	50	3.085	
	70	2.998	
	90	2.815	
	110	2.765	
	130	2.535	
	150	2.505	
	179	2.125	

TABLE - 5.15

DATA ON AIR CORE DIAMETER ALONG THE TUBE AXIS

Inside diameter of perspex tube	..	2.54	Cms
Length of perspex tube	..	185	Cms
Inside diameter of swirl chamber	..	10.30	Cms
Inside diameter of tangential entry	..	1.27	Cms
Correction factor for refraction	..	0.757	Cms.

Run No.	Distance Along the Tube Axis Cms	Air Core Diameter Cms	Average Air Core Diameter after Applying refraction correction Cms	Run No.	Distance Along the Tube Axis Cms	Air Core Diameter Cms	Average Air Core Diameter after Applying refraction correction. Cms
1	2	3	4	1	2	3	4
5.0701	0	2.141	1.42	5.0703	0	2.262	1.40
	10	2.055			15	2.125	
	20	2.012			30	1.959	
	30	1.885			45	1.902	
	40	1.786			60	1.725	
	50	1.650			70	1.650	
	60	1.644			85	1.299	
5.0702	0	2.133	1.43	5.0704	0	2.183	1.35
	15	2.090			15	2.152	
	30	1.933			30	1.975	
	45	1.832			45	1.924	
	60	1.665			60	1.769	
	70	1.665			70	1.730	

Table - 5.15 (Contd.)

1	2	3	4
	85	1.348	
	100	1.163	
5.0705	0	2.235	1.27
	15	2.180	
	30	1.980	
	45	1.800	
	60	1.740	
	70	1.655	
	85	1.319	
	100	1.174	
	110	1.050	
5.0706	0	2.110	1.43
	10	2.030	
	20	2.024	
	30	1.941	
	40	1.810	
	50	1.675	
	60	1.675	
5.0707	0	2.198	1.47
	15	2.176	
	30	1.980	
	45	1.794	
	60	1.747	
	70	1.741	
5.0708	0	2.175	1.43
	15	2.108	
	30	1.986	
	45	1.934	
	60	1.860	
	70	1.700	
	88	1.450	
5.0809	0	2.185	1.35
	15	2.151	
	30	1.970	
	45	1.920	
	60	1.750	
	70	1.722	
	85	1.375	
	100	1.150	
5.0710	0	2.265	1.33
	15	2.194	
	30	1.994	
	45	1.898	
	60	1.825	
	70	1.760	
	85	1.370	
	100	1.368	
	110	1.105	

Table - 5.15 (Contd.)

1	2	3	4
5.0711	0	2.177	1.46
	10	2.083	
	20	1.995	
	30	1.942	
	40	1.873	
	50	1.745	
	58	1.650	
5.0712	0	2.198	1.51
	15	2.183	
	30	2.025	
	45	1.924	
	60	1.830	
	68	1.790	
5.0713	0	2.270	1.44
	15	2.225	
	30	1.930	
	45	1.920	
	60	1.840	
	70	1.760	
	86	1.390	
5.0714	0	2.272	1.45
	15	2.222	
	30	2.038	
	45	1.856	
	60	1.807	
	70	1.750	
	85	1.722	
	97	1.650	
5.0715	0	2.288	1.31
	15	2.203	
	30	1.955	
	45	1.900	
	60	1.911	
	70	1.642	
	85	1.350	
	100	1.240	
	109	1.095	
5.0716	0	2.261	1.47
	10	2.149	
	20	2.089	
	30	1.915	
	40	1.900	
	50	1.665	
	56	1.575	
5.0717	0	2.236	1.50
	15	2.158	
	30	2.033	
	45	1.925	

Table - 5.15 (Contd.)

1	2	3	4	1	2	3	4
	60	1.800			85	1.350	
	67	1.775			100	1.280	
					108	1.115	
5.0718	0	2.275	1.52				
	15	2.256		5.0801	0	2.104	1.41
	30	2.050			10	1.982	
	45	2.015			20	1.940	
	60	1.967			30	1.875	
	70	1.900			40	1.799	
	85	1.870			50	1.674	
	90	1.780			59	1.625	
5.0719	0	2.190	1.44	5.0802	0	2.110	1.37
	15	2.125			15	2.015	
	30	2.042			30	1.850	
	45	1.900			45	1.794	
	60	1.815			60	1.620	
	70	1.790			70	1.490	
	85	1.735					
				5.0803	0	2.128	1.36
	95	1.620			15	2.062	
5.0720	0	2.270	1.32		30	1.940	
	15	2.250			45	1.768	
	30	2.060			60	1.682	
	45	1.890			70	1.669	
	60	1.830			85	1.300	
	70	1.690					

Table - 5.15 (Contd.)

1	2	3	4
5.0804	0	2.154	1.30
	15	2.050	
	30	1.903	
	45	1.843	
	60	1.640	
	70	1.591	
	85	1.325	
	100	1.188	
5.0805	0	2.206	1.30
	15	2.130	
	30	1.999	
	45	1.950	
	60	1.790	
	70	1.652	
	85	1.399	
	100	1.190	
	110	1.090	
5.0806	0	2.100	1.41
	10	1.980	
	20	1.975	
	30	1.872	
	40	1.790	
	50	1.688	
	60	1.590	
5.0807	0	2.120	1.39
	15	2.020	
	30	1.855	
	45	1.800	
	60	1.615	
	70	1.600	
5.0808	0	2.120	1.38
	15	2.023	
	30	1.916	
	45	1.820	
	60	1.725	
	70	1.700	
	88	1.415	
5.0809	0	2.130	1.34
	15	2.090	
	30	1.950	
	45	1.902	
	60	1.745	
	70	1.645	
	85	1.400	
	100	1.250	
5.0810	0	2.195	1.32
	15	2.175	
	30	1.969	

Table - 5.15 (Contd.)

1	2	3	4
	45	1.875	
	60	1.764	
	70	1.720	
	85	1.475	
	100	1.375	
	110	1.127	
5.0811	0	2.166	1.44
	10	2.073	
	20	2.080	
	30	1.900	
	40	1.821	
	50	1.686	
	57	1.615	
5.0812	0	2.190	1.43
	15	2.050	
	30	1.875	
	45	1.875	
	60	1.675	
	67	1.650	
5.0813	0	2.215	1.37
	15	2.150	
	30	1.893	
	45	1.825	
	60	1.766	
	70	1.700	
	85	1.477	
	90	1.415	
5.0814	0	2.227	1.34
	15	2.163	
	30	1.960	
	45	1.937	
	60	1.704	
	70	1.640	
	85	1.355	
	95	1.220	
5.0815	0	2.132	1.30
	15	2.174	
	30	1.955	
	45	1.907	
	60	1.783	
	70	1.713	
	85	1.380	
	100	1.237	
	107	1.115	
5.0816	0	2.225	1.52
	10	2.085	

Table - 5.15 (Contd.)

1	2	3	4
	20	2.124	
	30	2.080	
	40	1.950	
	50	1.826	
	55	1.795	
5.0817	0	2.190	1.47
	15	2.095	
	30	2.000	
	45	1.950	
	60	1.730	
	67	1.695	
5.0818	0	2.205	1.33
	15	2.155	
	30	1.890	
	45	1.780	
	60	1.740	
	70	1.695	
	85	1.480	
	90	1.1415	
5.0819	0	2.175	1.44
	15	2.155	
	30	2.005	
	45	1.950	
	60	1.870	
	70	1.759	
	85	1.705	
	98	1.625	
5.0820	0	2.285	1.33
	15	2.260	
	30	2.075	
	45	1.910	
	60	1.848	
	70	1.675	
	85	1.340	
	100	1.300	
	107	1.120	
5.0901	0	2.150	1.39
	10	2.075	
	20	2.000	
	30	1.851	
	40	1.695	
	50	1.656	
	60	1.400	
5.0902	0	2.115	1.43
	15	2.111	
	30	1.975	
	45	1.797	
	60	1.712	

Table - 5.15 (Contd.)

1	2	3	4	1	2	3	4
	71	1.650			100	1.166	
5.0903	0	2.172	1.33		110	1.005	
	15	2.145		5.0906	0	2.075	1.42
	30	1.925			10	2.037	
	45	1.830			20	1.908	
	60	1.600			30	1.906	
	70	1.500			40	1.750	
	85	1.168			50	1.735	
5.0904	0	2.241	1.31		60	1.703	
	15	2.094		5.0907	0	2.189	1.46
	30	2.056			10	2.117	
	45	1.888			20	1.975	
	60	1.865			30	1.902	
	70	1.500			40	1.845	
	85	1.250			50	1.833	
	100	1.000			60	1.775	
5.0905	0	2.283	1.29		70	1.730	
	15	2.120		5.0908	0	2.230	1.36
	30	2.039			15	2.174	
	45	1.875			30	1.955	
	60	1.812			45	1.870	
	70	1.628			60	1.516	
	85	1.400			70	1.490	

Table - 5.15 (Contd.)

1	2	3	4	1	2	3	4
	88	1.370			50	1.805	
					60	1.800	
5.0909	0	2.219	1.30				
	15	2.088		5.0912	0	2.196	1.42
	30	1.999			15	2.000	
	45	1.863			30	1.855	
	60	1.775			45	1.782	
	70	1.501			60	1.751	
	85	1.258			70	1.710	
	100	1.035					
				5.0913	0	2.240	1.38
5.0910	0	2.347	1.29		15	2.200	
	15	2.158			30	2.040	
	30	2.030			45	1.870	
	45	1.925			60	1.535	
	60	1.808			70	1.475	
	70	1.680			88	1.410	
	85	1.355		5.0914	0	2.235	1.32
	100	1.044			15	2.195	
	109	0.995			30	2.050	
5.0911	0	0.285	1.52		45	1.880	
	10	0.175			60	1.780	
	20	2.114			70	1.520	
	30	2.030			85	1.350	
	40	1.892			100	0.990	

Table - 5.15 (Contd.)

1	2	3	4
5.0915	0	2.235	1.38
	15	2.140	
	30	2.139	
	45	1.974	
	60	1.875	
	70	1.712	
	85	1.580	
	100	1.535	
	108	1.250	
5.0916	0	2.105	1.42
	10	2.035	
	20	1.950	
	30	1.902	
	40	1.805	
	50	1.745	
	60	1.595	
5.0917	0	2.155	1.50
	15	2.122	
	30	1.942	
	45	1.920	
	60	1.750	
	70	2.000	
5.0918	0	2.280	1.48
	15	2.250	
	30	2.104	
	45	2.013	
	60	1.980	
	70	1.875	
	85	1.830	
	88	1.350	
5.0919	0	2.240	1.32
	15	2.190	
	30	1.995	
	45	1.875	
	60	1.805	
	70	1.525	
	85	1.365	
	100	0.970	
5.0920	0	2.207	1.35
	15	2.095	
	30	2.140	
	45	1.975	
	60	1.845	
	70	1.725	
	85	1.575	
	90	1.540	
	100	1.505	
	108	1.290	

TABLE 5.16

HEAT TRANSFER DATA FOR SWIRLING FLOW

Inside diameter of the inner tube - 2.84 cms

Outside diameter of the inner tube - 3.18 cms

Inside diameter of swirl chamber -10.30 cms

Inside diameter of the tangential entry - 1.27 cms

Length of the inner tube (test section)-114.5 cms

Pressure of stream - 1.5 kg/cm^2

Run No.	Concentration of Salt Soln. (% by Weight)	Solution Temperature°C		Steam Temp. °C	Liquid Flow Rate Lit/sec.	Air Rate Lit/min.	U KCal/hr.m^2
		Inlet	Outlet				
5.1601	1	40.0	45.0	111.37	0.68	Nil	1555.5
5.1602	1	40.5	44.5	111.37	0.87	Nil	1591.9
5.1603	1	40.3	44.0	111.37	1.02	Nil	1717.7
5.1604	1	40.0	43.5	111.37	1.13	Nil	1789.4
5.1605	1	40.3	43.4	111.37	1.35	Nil	1896.2
5.1606	2	41.0	46.5	111.37	0.69	5.0	1768.6
5.1607	2	41.5	46.5	111.37	0.79	5.0	1847.4
5.1608	2	42.0	46.5	111.37	0.92	5.0	1943.5
5.1609	2	42.5	46.5	111.37	1.06	5.0	1997.6
5.1610	2	42.7	46.5	111.37	1.18	5.0	2115.7
5.1611	3	41.2	46.5	111.37	0.73	5.0	1805.5
5.1612	3	41.6	46.0	111.37	0.92	5.0	1887.4

Table No.16 contd......

1	2	3	4	5	6	7	8
5.1613	3	42.2	46.0	111.37	1.10	5.0	1957.67
5.1614	3	43.0	46.5	111.37	1.24	5.0	2052.40
5.1615	3	43.0	46.3	111.37	1.38	5.0	2150.00

TABLE 5.17

HEAT TRANSFER DATA FOR AXIAL FLOW

Inside diameter of the inner tube - 2.84 cms

Outside diameter of the inner tube - 3.18 cms

Inside diameter of axial inlet - 2.6 cms

Length of the inner tube (test section)-114.5 cms

Pressure of stream - 1.5 kg/cm^2

Run No.	Concentration of Salt Soln. (% By Weight)	Solution Temperature °C		Steam Temp. °C	Liquid Flow Rate Lit/sec.	U KCal/hr m^2 °C
		Inlet	Outlet			
1	2	3	4	5	6	7
5.1701	1	40.5	46.0	111.37	0.51	1297.68
5.1702	1	40.5	44.5	111.37	0.73	1335.78
5.1703	1	40.5	43.6	111.37	1.02	1493.23
5.1704	1	40.3	43.0	111.37	1.19	1561.47
5.1705	2	40.5	46.0	111.37	0.51	1297.68
5.1706	2	40.5	44.5	111.37	0.76	1390.67
5.1707	2	40.5	43.5	111.37	1.08	1471.27
5.1708	2	40.2	43.0	111.37	1.23	1554.93
5.1709	3	40.5	46.0	111.37	0.50	1272.24
5.1710	3	40.5	44.5	111.37	0.75	1372.37
5.1711	3	40.5	43.7	111.37	0.99	1440.65
5.1712	3	41.2	44.1	111.37	1.16	1542.03

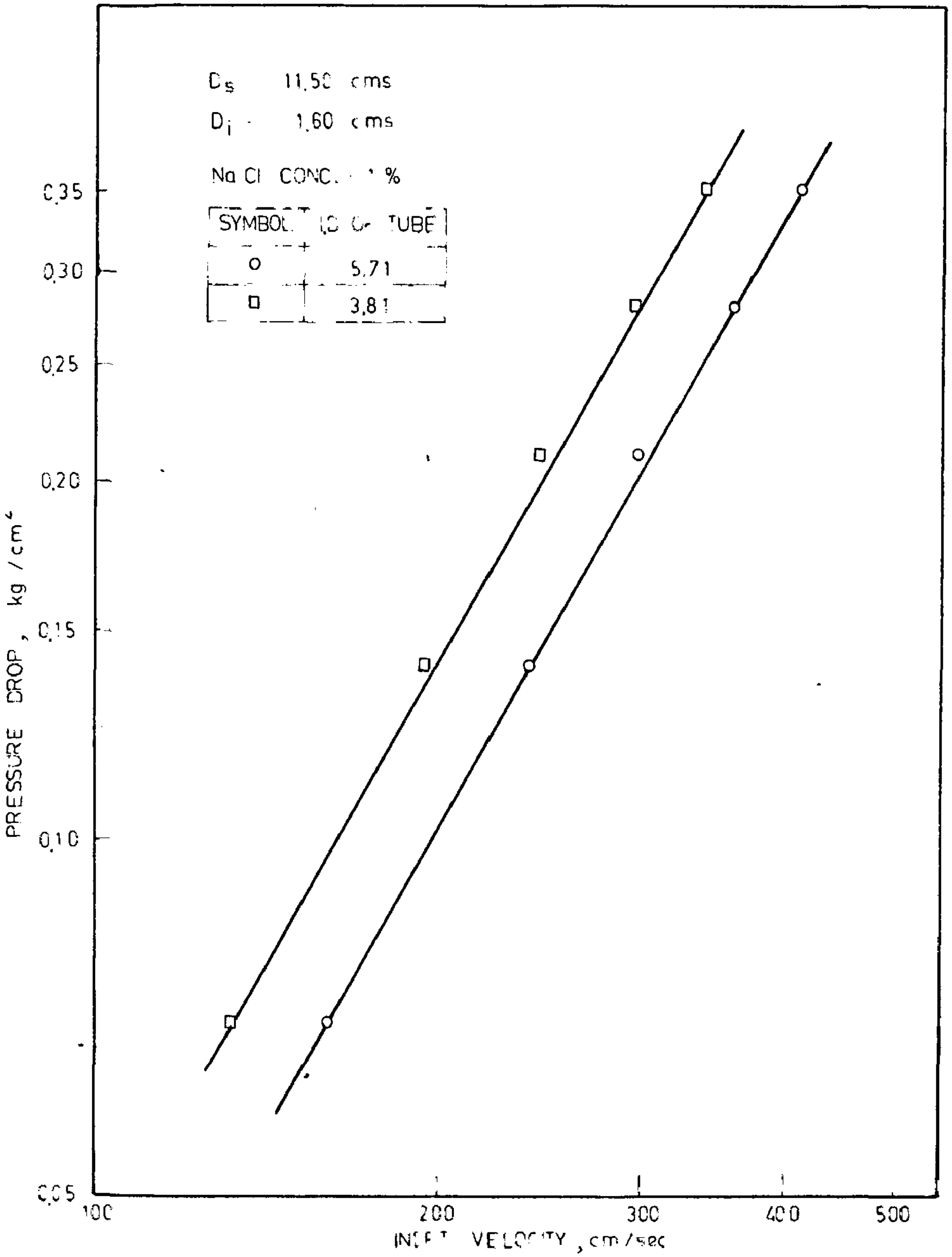


FIG 5.01 EFFECT OF TUBE DIAMETER ON PRESSURE DROP

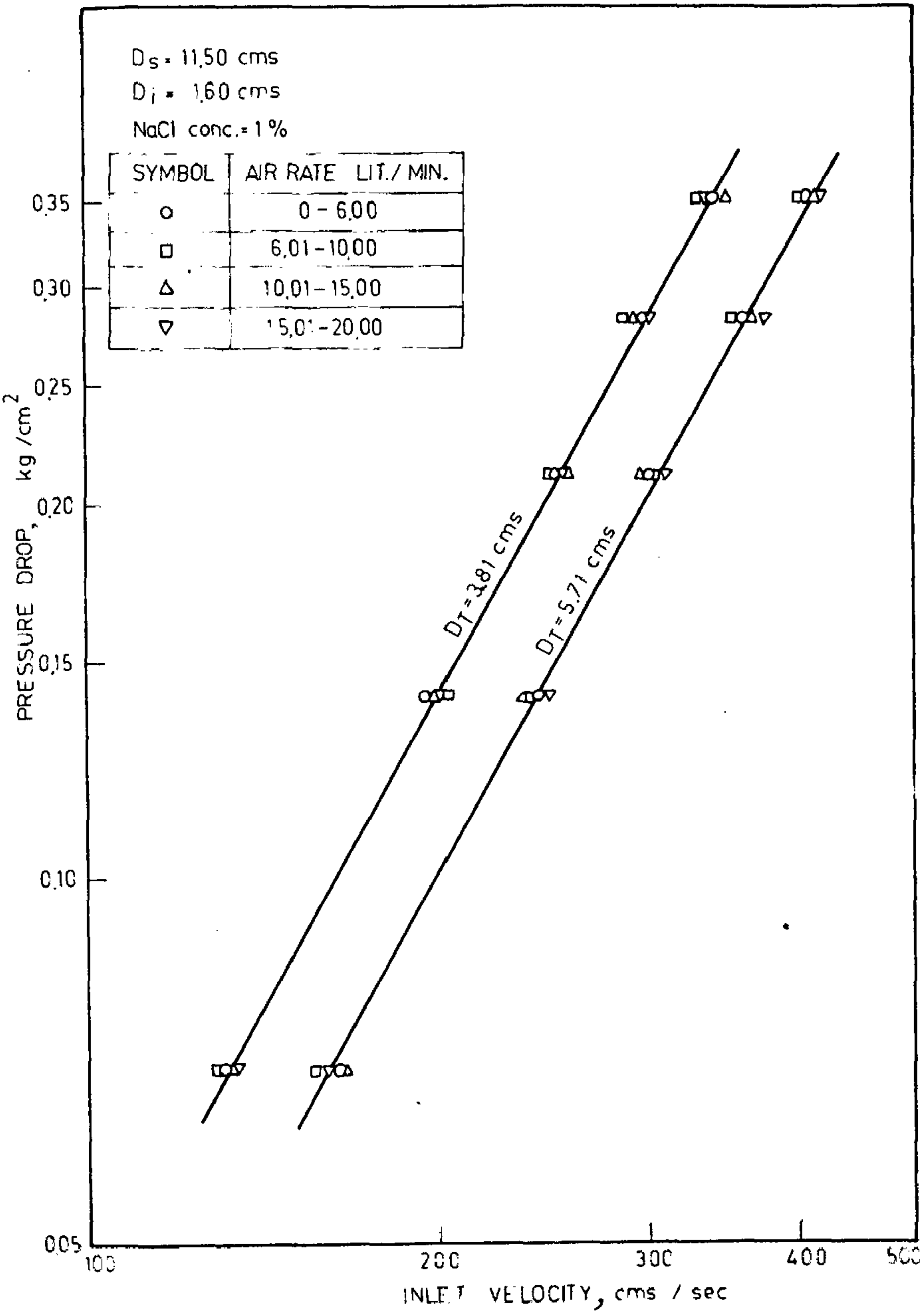


FIG. 5.02 EFFECT OF AIR RATE ON PRESSURE DROP

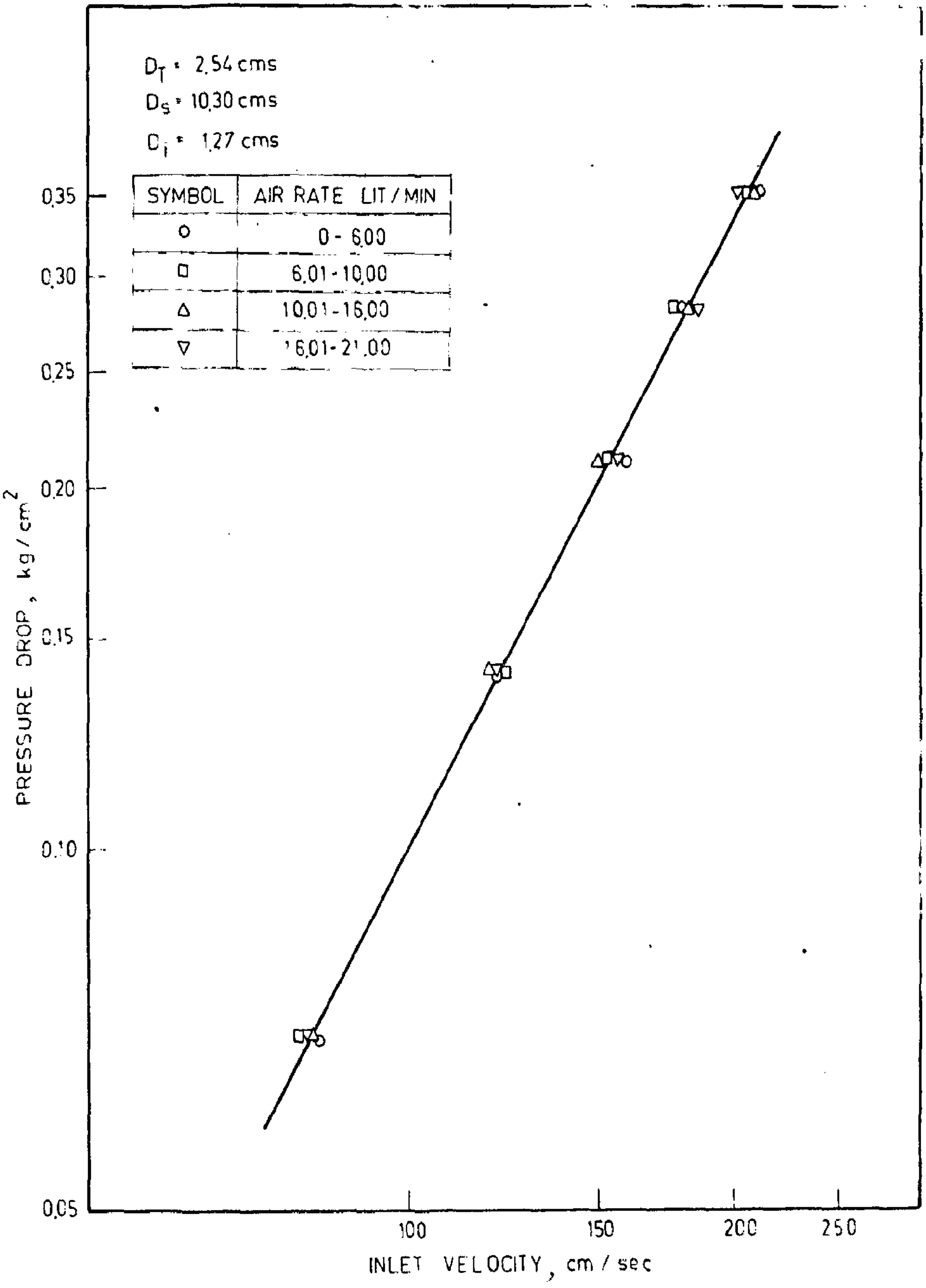


FIG. 5.03 EFFECT OF AIR RATE ON PRESSURE DROP

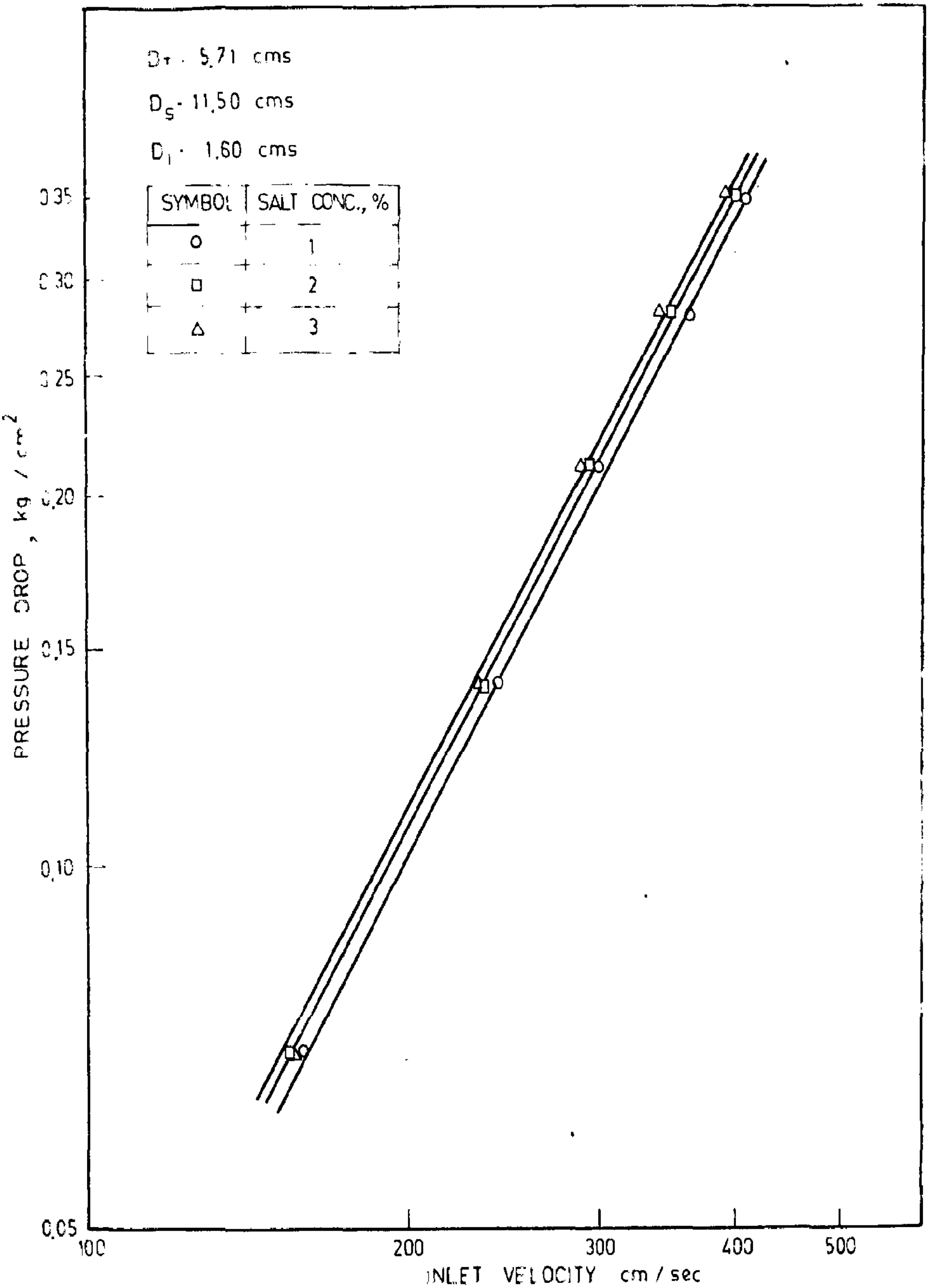


FIG. 5.04 EFFECT OF SALT CONCENTRATION ON PRESSURE DROP

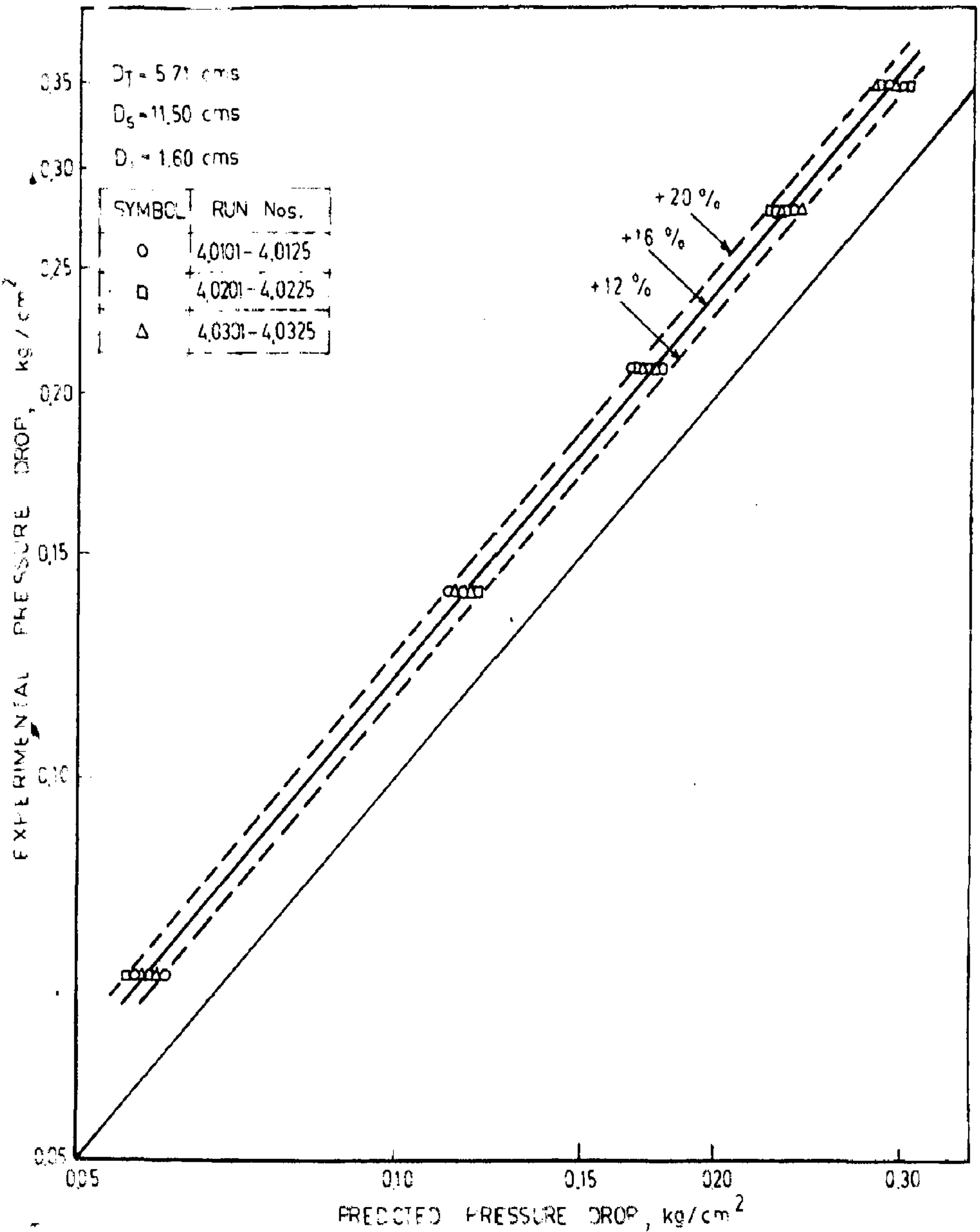


FIG. 505 COMPARISON BETWEEN EXPERIMENTAL AND PREDICTED PRESSURE DROPS

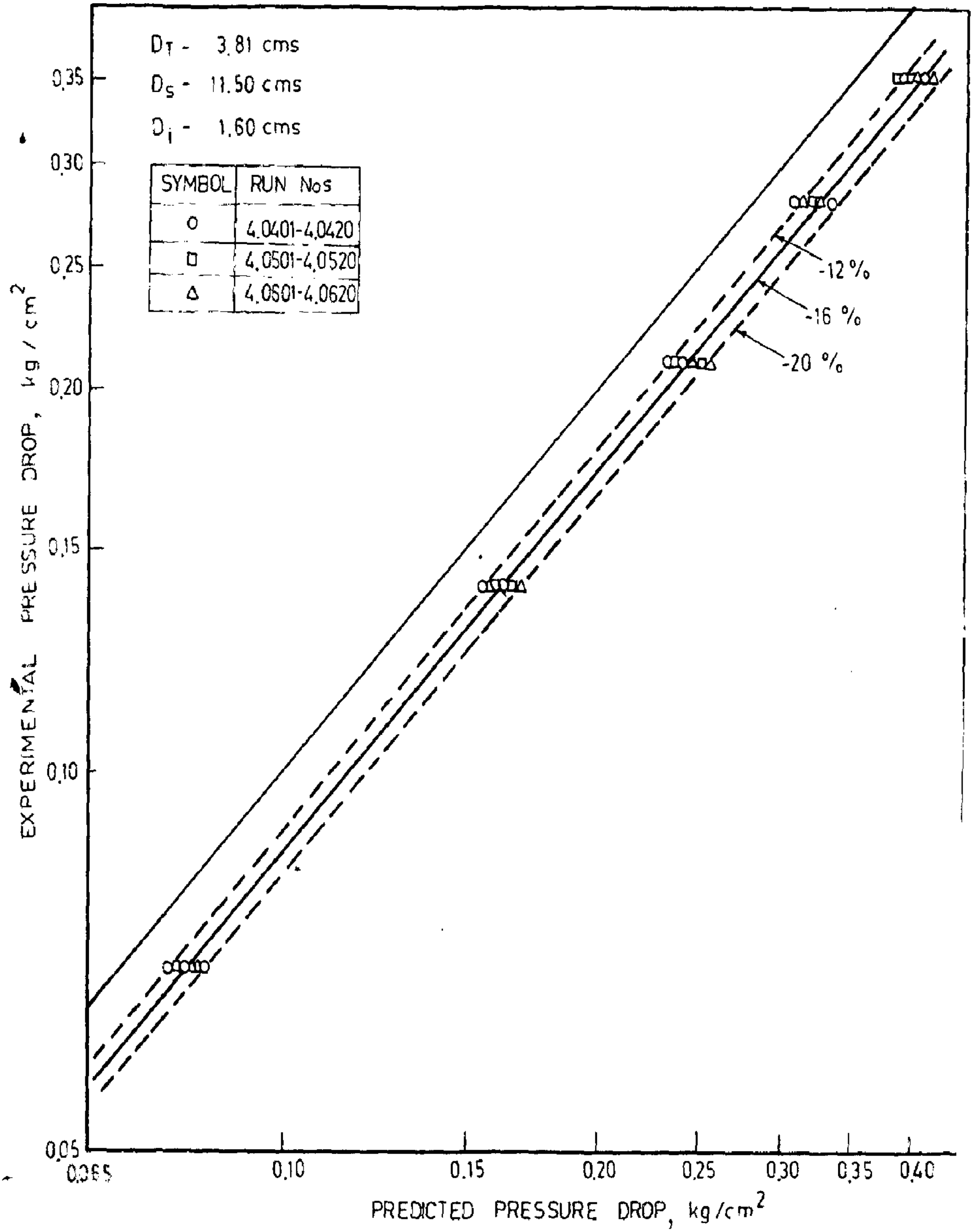


FIG 5.06 COMPARISON BETWEEN EXPERIMENTAL AND PREDICTED PRESSURE DROPS

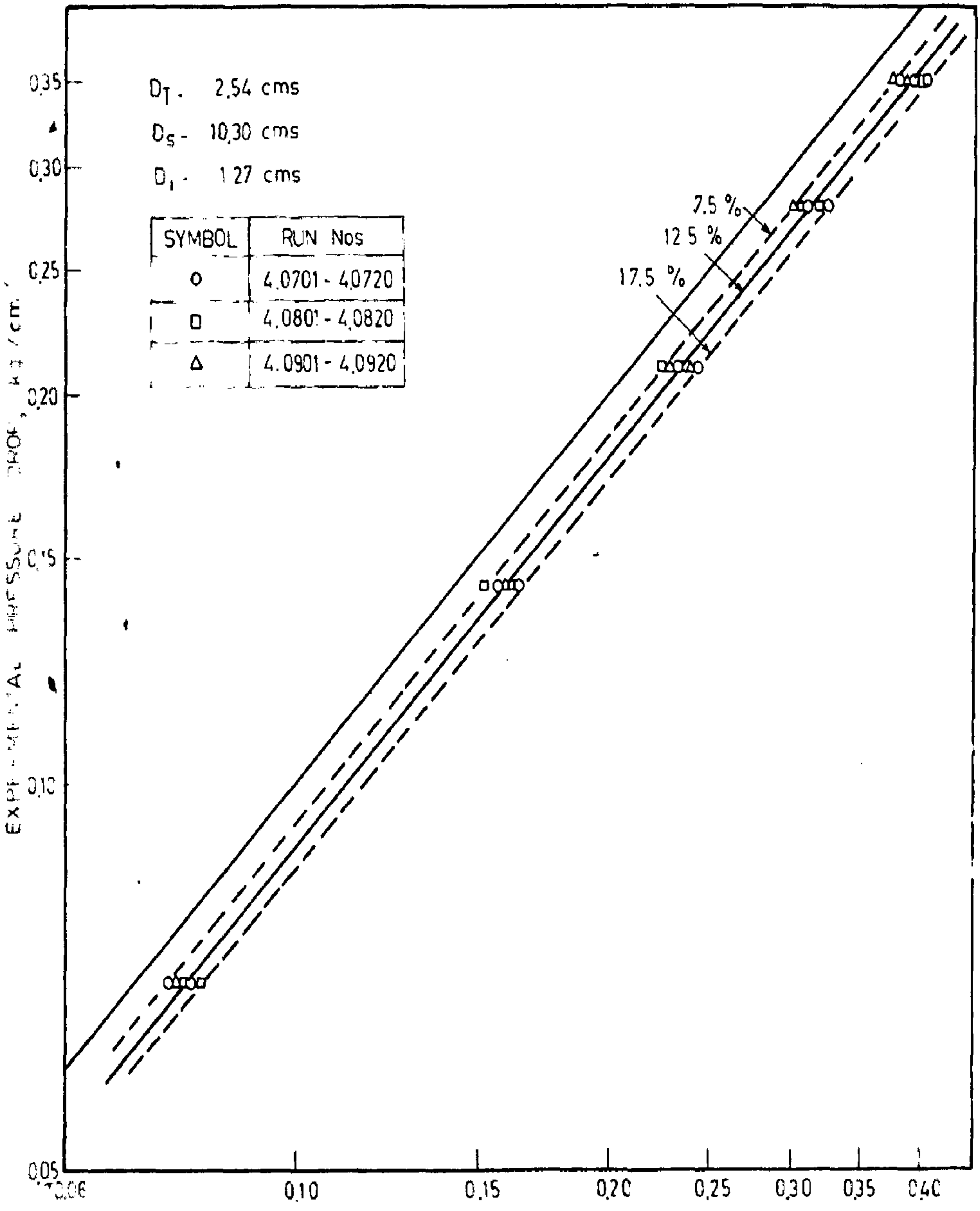


FIG. 5.07 COMPARISON BETWEEN EXPERIMENTAL AND PREDICTED PRESSURE DROP

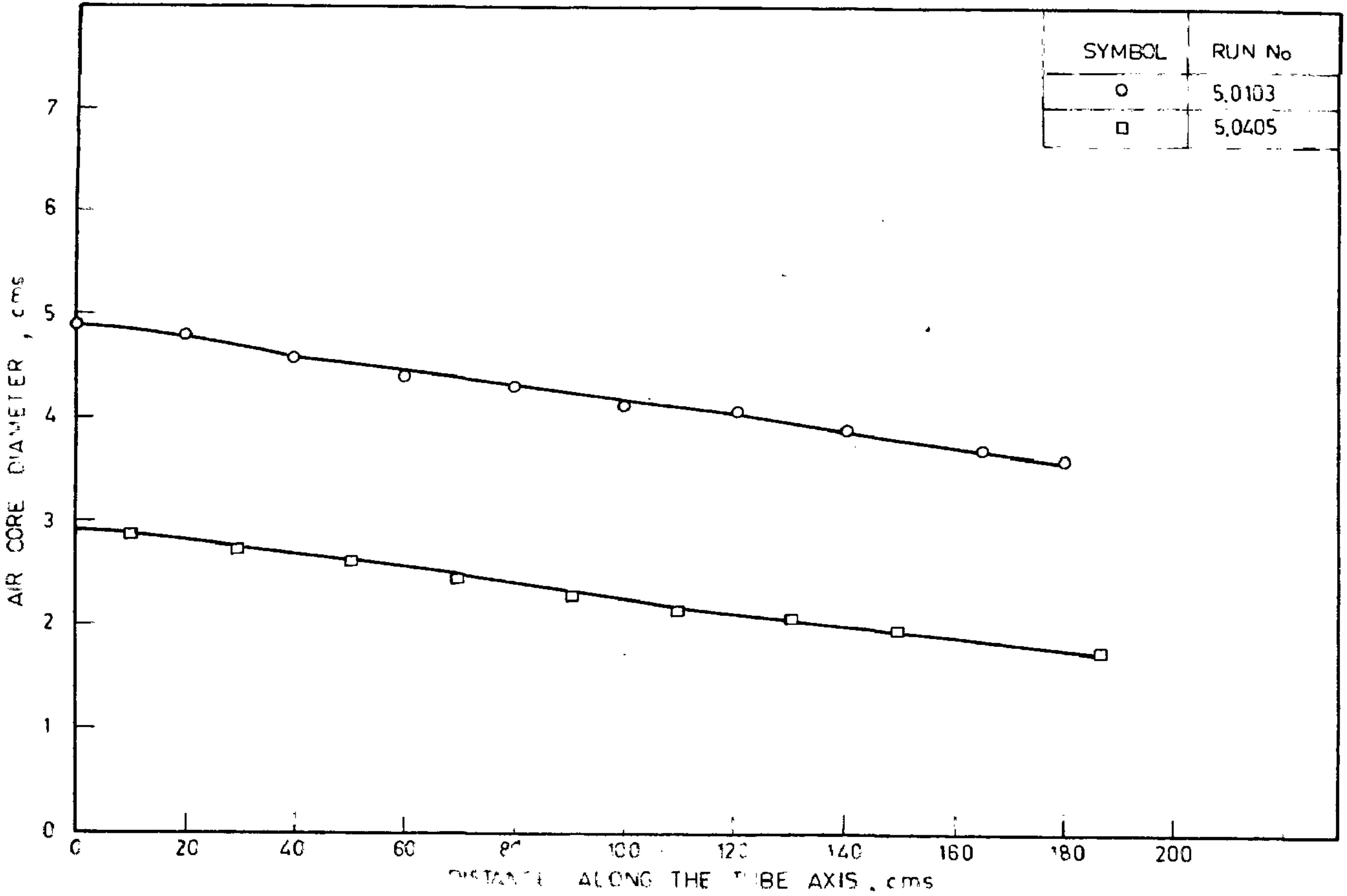


FIG. 5.08 VARIATION OF AIR CORE DIAMETER ALONG THE TUBE AXIS

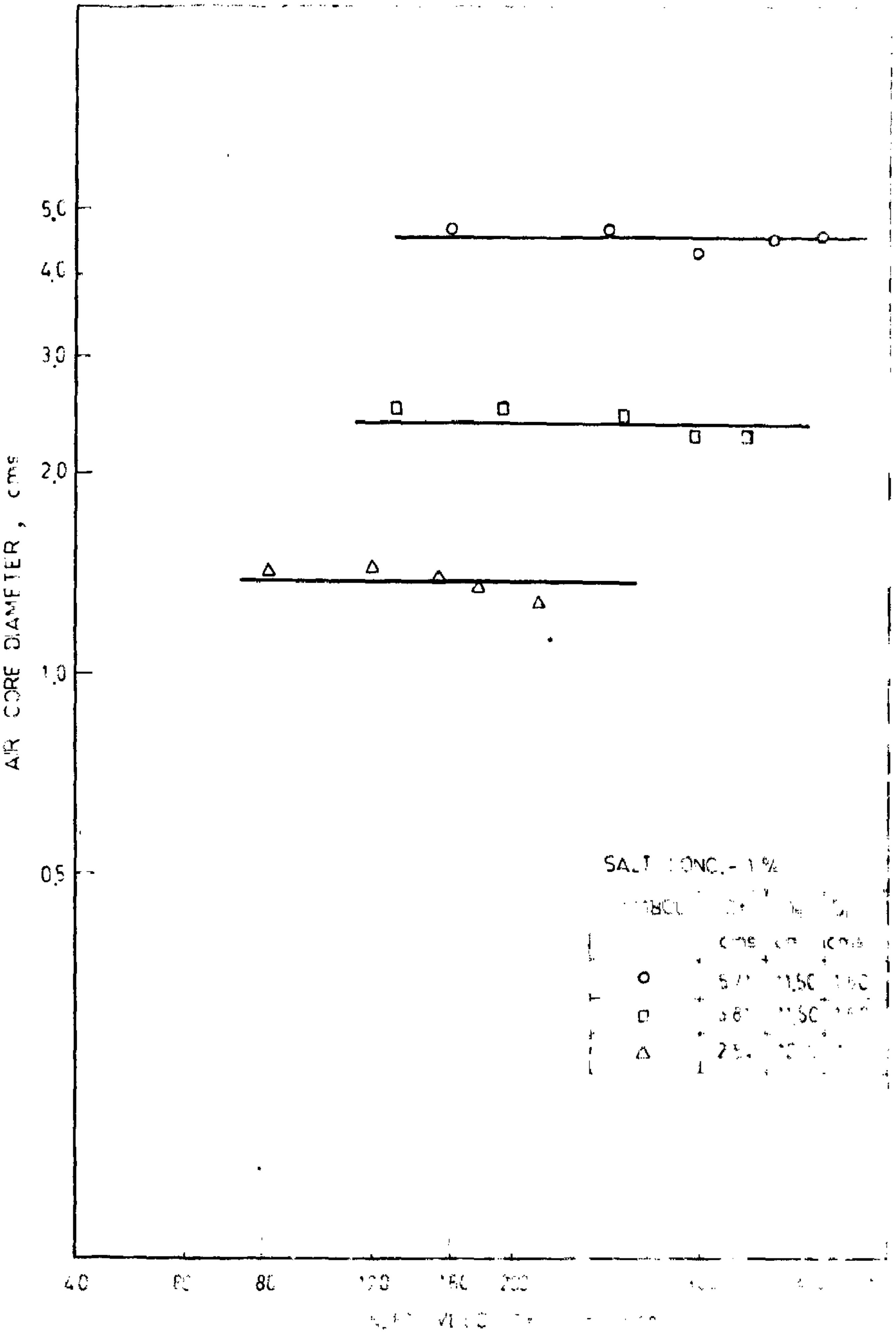
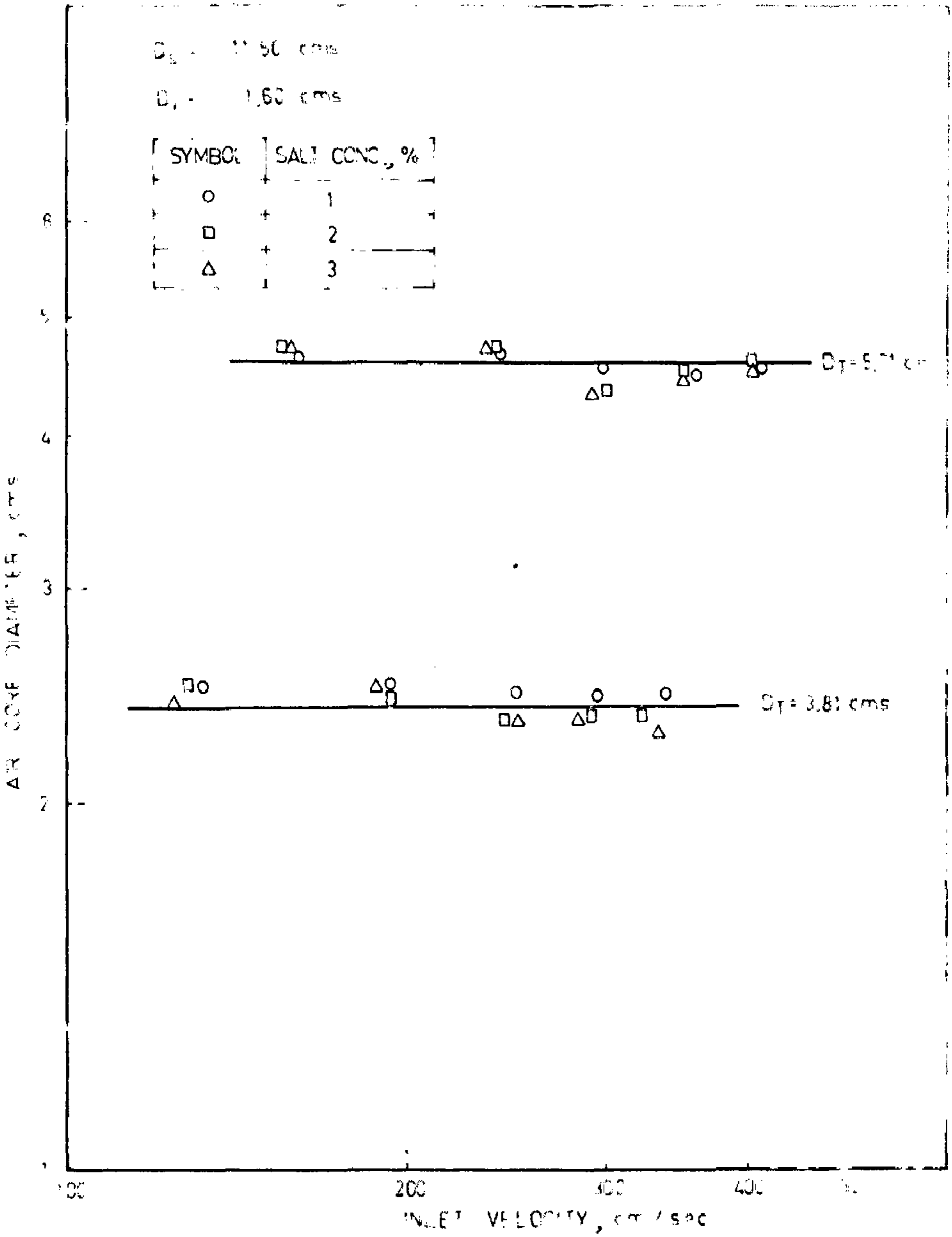


FIG. 5.09 EFFECT OF TUBE DIAMETER ON AIRCORE DIAMETER



G. 5.10 EFFECT OF SALT CONCENTRATION ON AIRCORE DIAMETER

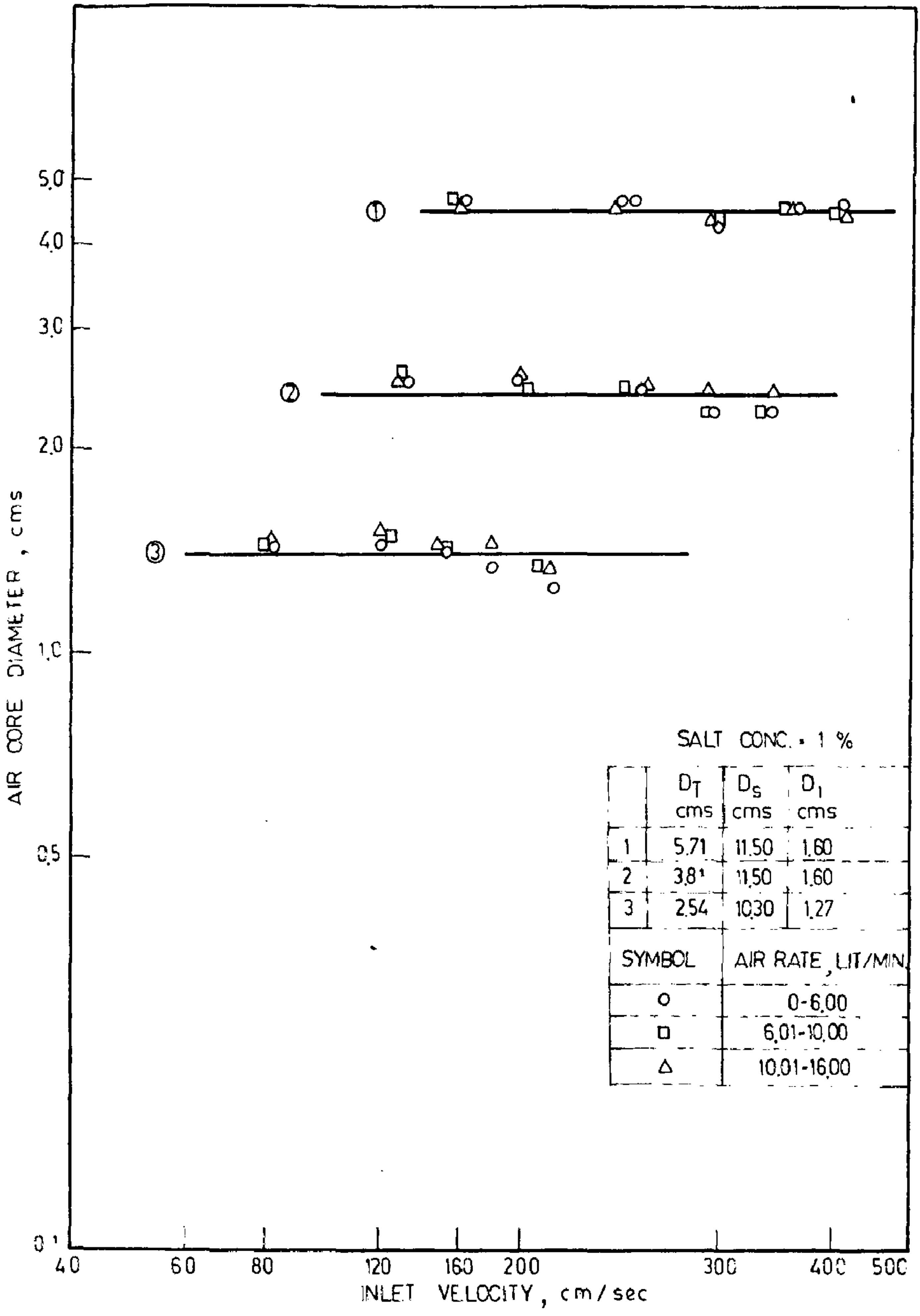


FIG 5.11 EFFECT OF AIR RATE ON AIRCORE DIAMETER

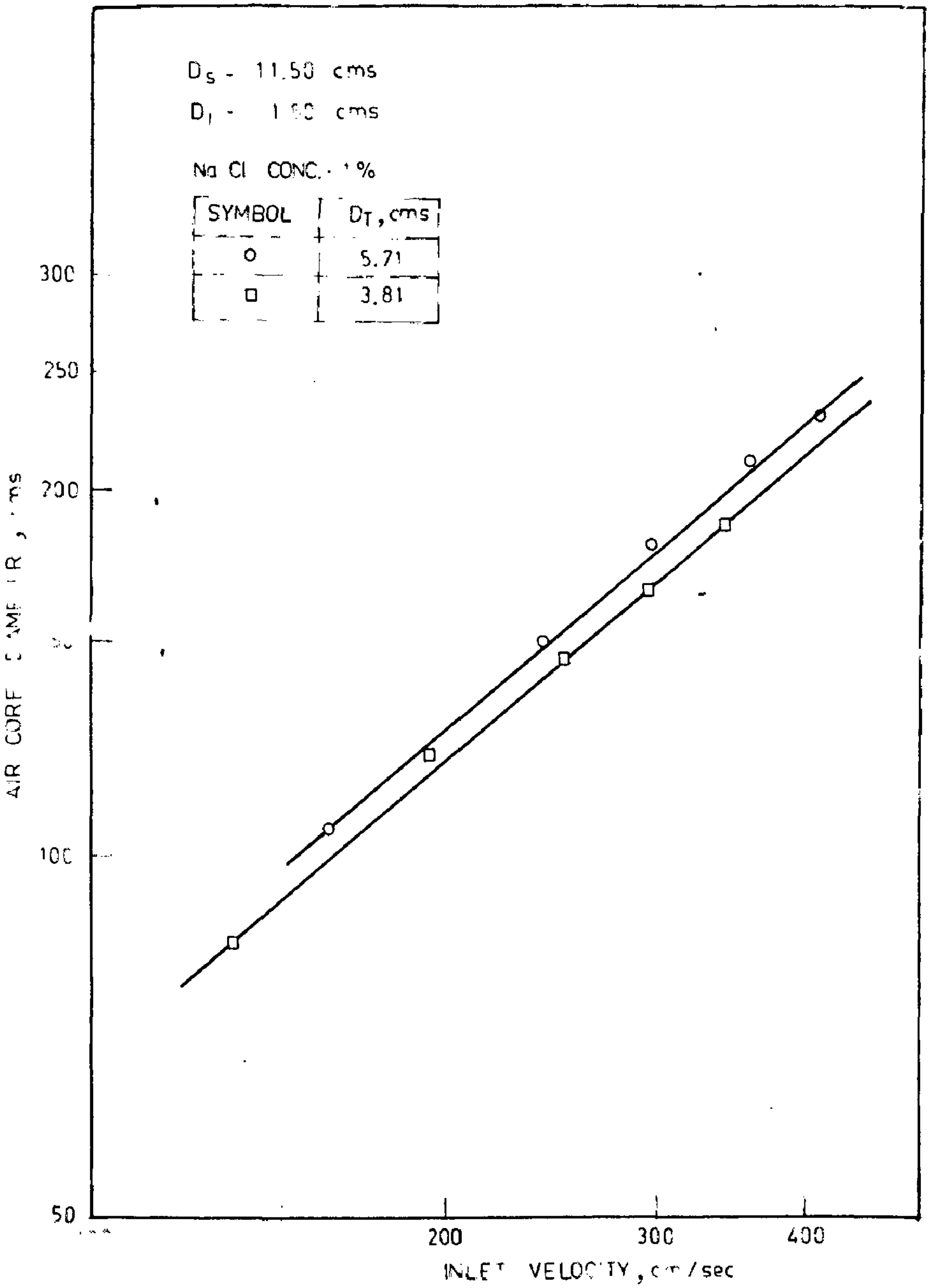


FIG.5.12 EFFECT OF TUBE DIAMETER ON AIRCORE LENGTH

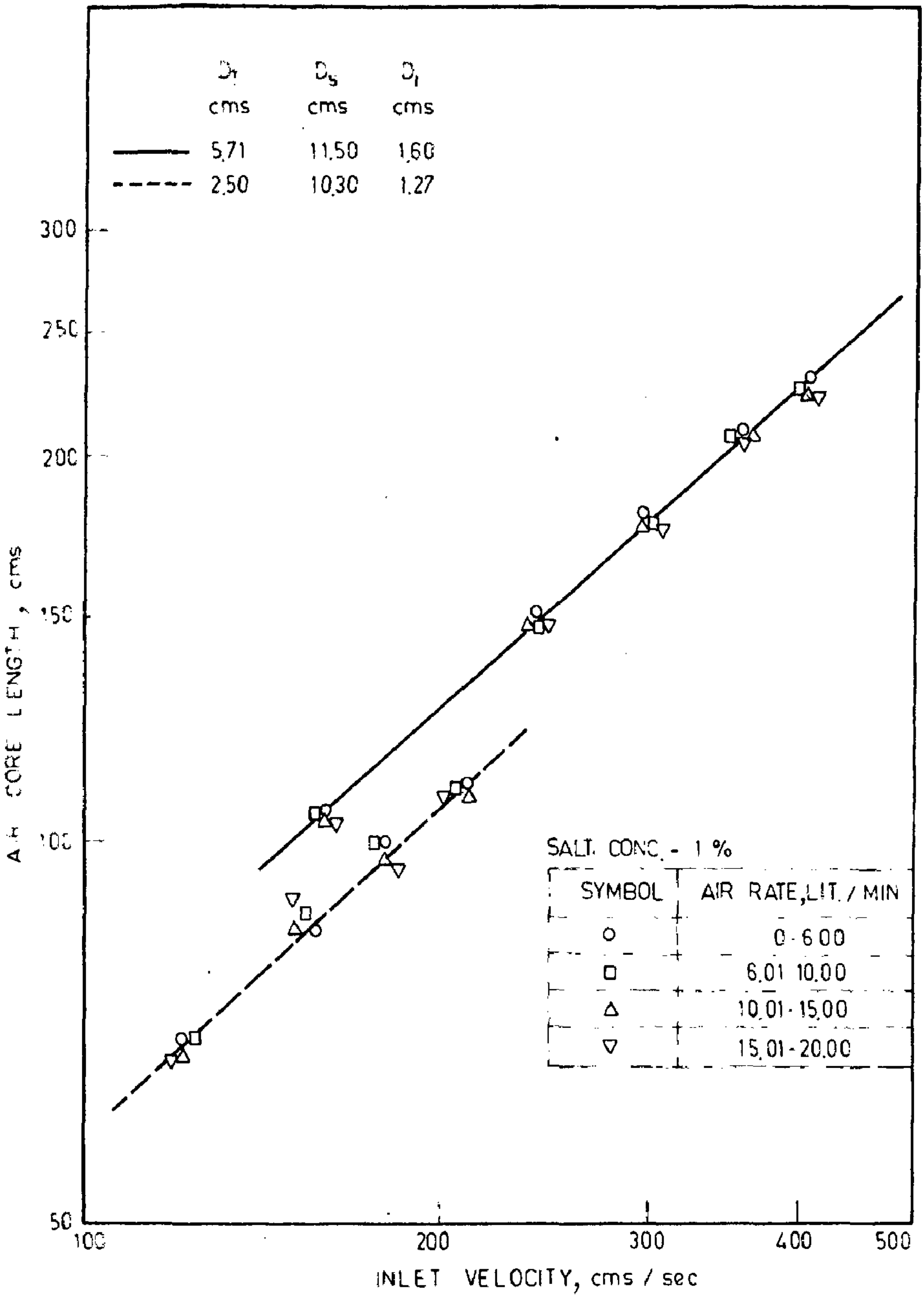


FIG 5.13 EFFECT OF AIR RATE ON AIRCORE LENGTH

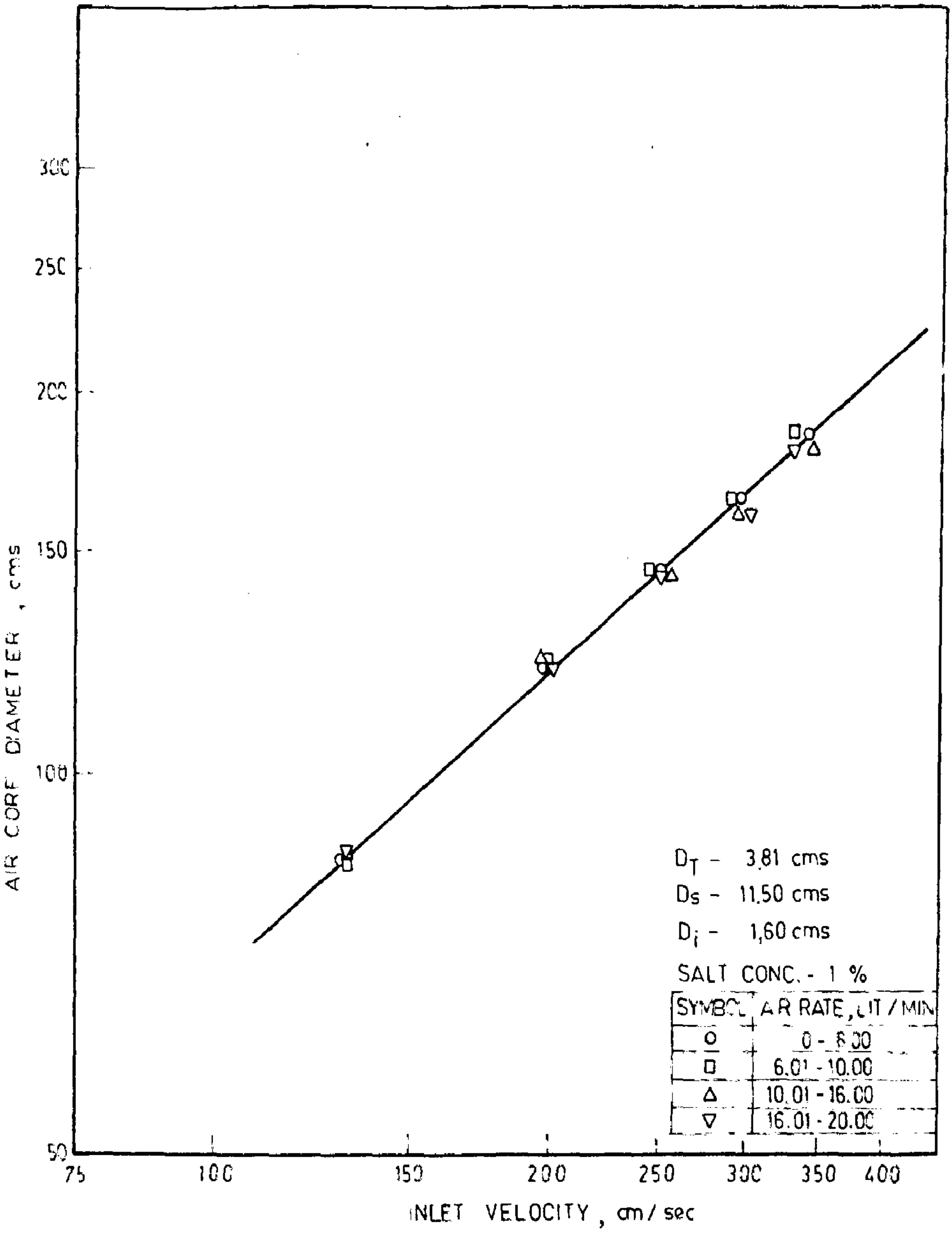


FIG. 5.14 EFFECT OF AIR RATE ON AIR CORE LENGTH

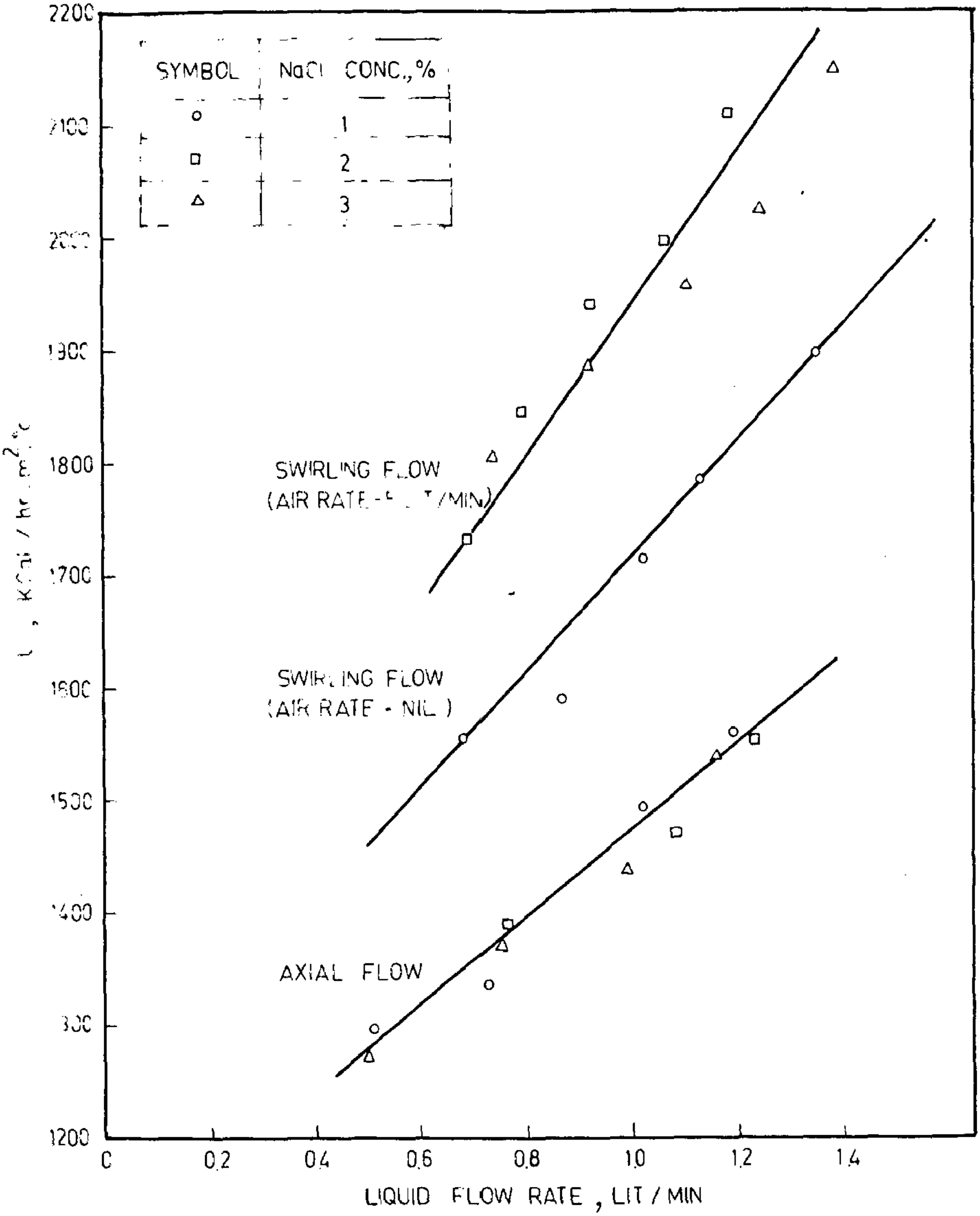


FIG. 5.015 COMPARISON OF OVERALL HEAT TRANSFER COEFFICIENTS FOR SWIRLING AND AXIAL FLOW

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.01 CONCLUSIONS

From the present investigation the following was concluded.

1. Swirling flow can be obtained by injecting the liquid through two diametrically opposite tangential inlets. In ordinary tangential entry swirl flows the direction of flow of liquid at the axis of the tube is found to be in a direction opposite to that of bulk flow. However, by inducing air at the axis of the tube the flow reversal can be eliminated and a stable flow with uniform air core is easily obtained.

2. Apart from tube diameter, tube length and liquid flow rate the pressure drop in swirling flows depends upon the swirl chamber diameter, tangential inlet diameter, density and viscosity of the liquid.

3. Empirical equation (5.01) for calculating ~~pressures~~ drop in swirling flow with out flow reversal was found to be valid for water as well as dilute salt solutions.

4. As in the case of water the air core diameter depends only upon tube size, tangential inlet diameter and

swirl chamber size for dilute salt solutions also; Liquid flow rate and viscosity of liquid do not seem to affect the air core diameter.

5. Air core length increases with increasing liquid inlet velocity, tube diameter and tangential inlet diameter.

6.. The air rate does not seem to have any significant effect on pressure drop, air core diameter and air core length. However, the stratification of air core at the down stream was observed at higher air rates.

7. Overall heat transfer rates were found to increase significantly in swirling flow. In a double pipe heat exchanger the overall heat transfer coefficients for swirling flow increase by 16 per cent for without induced air and 32 per cent with induced air over the ordinary axial flow.

6.02 RECOMMENDATIONS

1. Solutions of various salts and other compounds of higher-concentration must be studied to compute more precisely the effect of viscosity and density variation.

2. Slurries of large concentration variation must be used to study the affect of centrifugal force imparted by swirling motion on the particles of different density in the slurries.

3. Comprehensive heat and mass transfer studies ~~be~~ must be carried out using concentrated solutions and slurries to simulate industrial heat and mass transfer equipments.

APPENDIX

SAMPLE CALCULATION FOR CALCULATING OVERALL HEAT TRANSFER COEFFICIENTS

Outside diameter of the tube = 3.18 cms

Inside diameter of the tube = 2.84 cms.

Length of tube = 114.5 cms

Heat transfer area $= 3.14 \times 3.18 \times 114.50 \times 10^{-2}$

$= 11.43\ m^2$

Run No.5.1601

Inlet temperature of the liquid $= 40^{\circ}C$

Outlet temperature of the liquid $= 45^{\circ}C$

Temperature of steam $= 111.37\ ^{\circ}C$

Liquid flow rate = 0.68 lit./sec

Mass flow rate of liquid $= 0.68 \times 1.004$ kg/sec

$\doteq 0.68$ kg/sec.

Rise in temperature of the liquid $= 5^{\circ}C$

$$\text{LMTD} = \frac{(111.37 - 40) - (111.37 - 45)}{\ln \dfrac{(111.37 - 40)}{(111.37 - 45)}} = 68.84$$

Overall heat transfer coefficient (U)

$$= \frac{0.68 \times 1.0 \times 3600 \times 5}{11.43 \times 10^{-2} \times 68.84}$$

$= 1555.58$ Kcal/ $m^2\ ^{\circ}C$. hr.

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