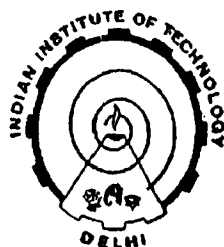


STUDIES IN PNEUMATIC CONVEYING IN HORIZONTAL PIPES

By
P. V. RAMACHANDRA IYER

THESIS SUBMITTED TO THE
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

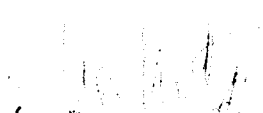


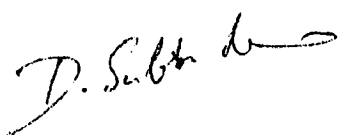
Department of Chemical Engineering
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
September, 1983

CERTIFICATE

This is to certify that the thesis entitled 'STUDIES IN PNEUMATIC CONVEYING IN HORIZONTAL PIPES' being submitted by Mr. P.V. Ramachandra Iyer to Indian Institute of Technology, Delhi, for the award of Doctor of Philosophy in Chemical Engineering, is a record of bonafide research work carried out by him. Mr. P.V. Ramachandra Iyer has worked under our guidance and supervision and has fulfilled the requirements for the submission of thesis, which to our knowledge has reached the requisite standard.

The results contained in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.


(M.S. Murthy)
Professor
Department of Chemical Engg.
Indian Institute of Science
Bangalore-560012


(D. Subba Rao)
Associate Professor
Dept. of Chemical Engg.,
Indian Institute of Tech.
New Delhi-110016

ACKNOWLEDGEMENTS

The author wishes to express his deep gratitude to Prof. D. Subba Rao and Prof. M.S. Murthy, his supervisors, for the advice, help and constant encouragement that they have given during the entire course of this work.

He would also like to thank Prof. P.N. Sahgal, Head of the Department and all his other faculty colleagues in the Department for their help which enabled him to complete this work on a part time basis. Particularly, the unstinted help rendered by Prof. M.K. Sarkar, Dr. T. Rajeswara Rao and Dr. K.K. Baweja, during the final stages of this work, is very gratefully acknowledged.

Thanks are also due to all the laboratory and workshop staff of the Department for their assistance. Special mention should be made of Mr. Same Singh and Mr. R.D. Tiwari for the help rendered by them in installing the experimental set-up.

And finally, he would like to extend his warm appreciation to Mr. K.K. Pathak and Mr. V.P. Gulati for their assistance in the preparation of this thesis.

P.V. Ramachandra Iyer

(P.V. Ramachandra Iyer)

ABSTRACT

For the design of pneumatic conveying systems for bulk transportation of solids, information is required on the saltation velocity and the pressure drop accompanying the conveying. Although a large volume of literature has appeared in the field, no single unified approach has evolved for predicting them in horizontal pneumatic conveying systems. Prediction of pressure drop will require a knowledge of particle velocity which, in turn, has been correlated by many earlier workers in terms of the excess pressure drop due to presence of solids. Moreover, particle-wall and particle-particle interaction factors, included in some of the correlations, cannot be measured accurately.

In the present study, horizontal pneumatic transport of solids, at low solids to gas ratios, is analysed in terms of the mechanisms of particle suspension and its transport and the factors responsible for energy losses during the conveying. At saltation, the upward forces due to velocity fluctuations accompanying turbulence is assumed to counterbalance the gravitational forces acting on the particles. At higher gas velocities, the already suspended particle is pushed forward by the drag exerted by the gas on it. The particle velocity can, therefore, be related to the size and shape of the particle, gas velocity and the physical properties of the gas. The excess pressure drop due to solids is analysed in terms of the drag on the

particles, particle concentration and the energy required to suspend the particles.

Correlations are proposed for predicting (a) saltation velocities of large-sized single and multiparticles, (b) particle velocity and (c) pressure drop, on the lines indicated above. All the correlations are in terms of properly identified dimensionless groups, involving easily measurable parameters. Prediction of particle velocity by the proposed correlation does not require a knowledge of the excess pressure drop.

Single particle saltation velocities of a variety of large-sized particles were measured using a horizontal glass pipe. Particle velocity and pressure drop measurements were made by pneumatic conveying of particles of different size, density and sphericity in a horizontal copper pipe.

The proposed correlations are found to agree well with the data of the present investigation as well as with those of several earlier investigators, covering a very wide range of variables.

CONTENTS

		<u>Page</u>
	CERTIFICATE ..	i
	ACKNOWLEDGEMENTS ..	ii
	ABSTRACT ..	iii
	CONTENTS ..	v
	LIST OF TABLES ..	viii
	LIST OF FIGURES ..	x
	NOMENCLATURE ..	xiii
CHAPTER 1	INTRODUCTION ..	1-5
CHAPTER 2	LITERATURE SURVEY ..	6-54
2.1	Saltation Velocity in Horizontal Pneumatic Conveying ..	6
2.2	Measurement of Particle Velocity ..	16
2.3	Particle Velocity in Horizontal Pneumatic Conveying ..	18
2.4	Pressure Drop in Horizontal Pneumatic Conveying ..	34
2.5	Acceleration Length and Electro- static Effect ..	49
2.6	Conclusions and Scope of Present Work ..	50
CHAPTER 3	EXPERIMENTAL ..	55-73
3.1	Single Particle Saltation Velocity Measurements ..	55
3.2	Particle Velocity and Pressure Drop Measurements ..	61

CONTENTS (Contd.)

		<u>Page</u>
CHAPTER 4	SALTATION VELOCITY ..	74-90
4.1	Introduction and Scope of the Work ..	74
4.2	Main Features of the Thomas Model ..	75
4.3	Development of the Present Correlations for Large Particles ..	78
4.4	Comparison of the Correlation for Single Particle Saltation Velocity With Experimental Data ..	84
4.5	Conclusions ..	90
CHAPTER 5	PARTICLE VELOCITY ..	91-122
5.1	Introduction and Scope of the Work ..	91
5.2	Analysis of the Experimental Data ..	92
5.3	Development of the Correlation ..	100
5.4	Comparison of the Particle Velocity Correlation with the Data of Present Work ..	103
5.5	Comparison of the Particle Velocity Correlation With the Data of Earlier Workers ..	109
5.6	Discussion and Features of the Particle Velocity Correlation ..	119
5.7	Conclusions ..	121
CHAPTER 6	PRESSURE DROP ..	123-140
6.1	Introduction and Scope of the Work ..	123
6.2	Development of the Correlation for the Excess Pressure Drop ...	124

CONTENTS (Contd.)

	<u>Page</u>
6.3 Discussion of the Proposed Correlations for Pressure Drop ..	137
6.4 Conclusions ..	139
CHAPTER 7 SUMMARY AND CONCLUSIONS ..	141-144
REFERENCES ..	145-156
APPENDICES ..	157-179
Appendix A : Single Particle Saltation Velocity Data ..	157
Appendix B : Particle Velocity and Pressure Drop Data ..	158
Appendix C : Pressure Drop for Flow of Air Alone ..	168
Appendix D : Saltation Velocity Data on Multiparticle Systems ..	169
Appendix E : Sample Calculations ..	174
ABOUT THE AUTHOR ..	180