STUDIES ON CONTINUOUS CLASSIFICATION IN PNEUMATIC SYSTEMS

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree of

MASTER OF ENGINEERING

in

CHEMICAL ENGINEERING

(Equipment & Plant Design)

By

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November 1978

C E R T I F I C A T E

It is Certified that thesis entitled " STUDIES ON CONTINUOUS CLASSIFICATION IN PNEUMATIC SYSTEMS" which is being submitted by Sri Madhav Kant, in partial fulfilment of the requirements for the award of the Degree of MASTER OF ENGINEERING in CHEMICAL ENGINEERING (Equipment and Plant Design) at the University of 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 thesis has not been submitted for the award of any other degree.

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SUMMARY

The thesis entitled " Studies on Continuous classification in Pneumatic Systems" is presented in six Chapters. In Chapter I, the introduction to the classification of materials is given.

In Chapter II, the review of earlier work relating to fluidization Characteristics minimum fluidizing velocity, bed expansion, terminal velocity in Pneumatic systems, is reported. The studies on continuous air classification for mixed sized particles and their analogy are also indicated.

In Chapter III, is presented the physical and flow properties of solids like particle diameter, particle density, static bed porosity, sphericity and solids angle of repose for material like spherical glass beads, bauxite and Calcite.

Chapter IV deals with the experimentation as continuous. Pneumatic classification in 70 mm I.D. perspex column having a vertical wooden beffle conical in shape. Aluminium grid plate having 10% opening is used as air distributor and to support the particles, spherical glass beads, crushed bauxite and calcite in

size range of 977 micron to 460 microns have been studied. The experimental procedure is also explained.

In Chapter V, the observed behaviour of bed is explained along with the correlations. The effect of air flow rate, solid feed rate, composition of feed, ratio of DC/DF, material density and Height of stabilizing zone on the loading ratio (R_1/r_2), ~~in view~~ inrichment factor and stipping factor have been shown in the form of dimensionless groups like (R_e/r), F_r, D_C/DF, H_1/H, and $(\rho_s - \rho_s)/\rho_g$

In Chapter VI are given the conclusions based on the present study and the scope for further work.

The Biblography is given at the end of Chapter VI III.

The data tables, sample calculation and computer programmes are given in appendices I, II and III respectively.

A C K N O W L E D G E M E N T

The author wishes to express his deep sense of gratitude and indebtedness to Dr. N.Gopal Krishna, Professor & Head, and Dr. N.J.Rao, Reader of the Department of Chemical Engineering, University of Roorkee, Roorkee for their valuable and expert guidance and inspiration throughout the preparation of this thesis.

Many thanks are extended to:

- Dr. S.K.Saraf, Professor, Department of Chemical Engg., University of Roorkee, Roorkee for his valuable suggestion during thesis seminars.
- Dr. V.Chandra, Reader, Department of Chemical Engg., University of Roorkee, Roorkee for his suggestion and help during the preparation of this thesis.
- Sri Surendra Kumar, Lecturer, Sri M.C.Bansal, Lecturer Department of Chemical Engineering, University of Roork Roorkee for their help in Computer work during the preparation of this thesis.
- Sri Ravi Kumar Anand, A colleague for his help during fabrication and experimentation.
- The staff of the Unit Operation and fabrication section for their help during experimentation.
- Finally to those behind the scene friends whose names do not appear in print have helped, supported and encouraged in the preparation of this thesis.

CONTENTS

LIST OF NOTATIONS

A	Cross Sectional Area Available for Fluidization cm^2.
DCMAX	Diameter of column Cm.
DEMIN	Equivalent Diameter of column at Minimum Cross Sectional area Cm.
DCEMR	Equivalent Diamter of column in Enrichment section cm.
DCSTR	Equivalent Diameter of column at Stripping Section cm.
D_{b_1}	Diameter of baffle (Minimum) cm.
Db_2	Diameter of baffle (Maximum) cm
DC	Diameter of coarse particle Cm.
DC	Diameter of c a rse particle Cm
DF	Diameter of fine particle (cm.
DPz	Ratio of DC/DF DP1 ~~avg.diameter of the~~
DP_1	Avg. diameter of particle in top product.
DP_2	Avg. diameter of particle in bottom product.
EF	Enrichment factor
Fr	Froude factor DPg/Uf^2
g	Acceleration due to gravity 980 gm/sec^2
Gf	Fluid mass velocity Kg/m^2s.
Gmf	Minimum fluidizing mass velocity $kg/m^2/sec$.
Hi	Height of stabilizing zone Cm
H	Height of top exist cm.
r	Solids loading ratio(Ws/Wg).
r1	Solids loading at ratio at top
r2	solids loading ratio at bottom

Re	Reynolds number DG_f/μ_f
u_f	linear velocity of fluid m/sec.
u_{mf}	Fluid velocity at on set of fluidization m/sec.
u_t	Terminal velocity of particle m/s.
WF	solids feedrate kg/s
WT	Top product rate kg/s
WB	Bottom product rate kg/s.
XF	Friction of fines in feed
XT	Friction of fines in top product
XB	friction of fines in bottom product

Greek Symbols

ϵ	Bed voidage
ϵ_{mf}	Bed voidage at on set of fluidization
ϵ_o	Static bed voidage
ϕ	Sphericity
θ	Angle of repose of solid degree
μ_f	Fluid viscosity g/cm.sec.
ρ_s	Solid density g/cm^3
ρ_g	gas density g/cm^3

Subscripts

1.	large size particles
2.	Small size particles

CHAPTER-I

INTRODUCTION

Separation of materials into two or more fractions depending upon their physical properties is called classification. The classification of materials on the basis of size, density etc. is frequency important as a means of preparing a product for sale or for a subsequent operation. It is also a widely used means of analysis, either to control or gauge the effectiveness of another operation or to determine the value of a product for some specific application. The classification of solid have important applications in the Chemical, mining, petrochemical, Pharmecitical, Metallurgical and either allied industries.

Classification equipment can be categorized based upon the physical properties of salid, and mechanism employed, like mechanical or non-mechanical, batch or continuous and Hydraulic classifier (wet) or Pneumatic classifier (dry) depending upon the fluid used. The major limitation of hydraulic classifier is the wet product. If dry product is required the material from the hydraulic classifier must pass through a drying equipment, many times inspite of this additional operation the final product may not have the desired characteristic due to possible agglomeration. Dry product can be directly obtained from a Pneumatic classifier as the medium is gas (usually air).

The pneumatic classification of material based on size and density has attached the attention of several workers, among these, investigations of zenz and weill (11), Lewis, Gilliland and Lang (14) Blyakher and Pavlov (15), Leva (7), Osberg and charleswort Yagi and Aochi (9), wen and Hashinger (12), Sanaris (8) Kunii (13), Thomas et al (10) and Gopal Krishna and Rao (20,21) may be mentioned as leading works.

In spite of large number of investigations, information available is not sufficient to design a continuous Pneumatic classifier or to predict the performance of this type of classifier. The aim of the present investigation is to study the effect of various parameters like air flow rate, solid feed rate, solid composition, ratio of diameter of coarse to fines, density of solids, and position of baffle on the product rate, enrichment factor, stripping factor and loading ratio (r_1/r_2) and to develop correlation to predict the performance if the unit.

In order to have fine sapaeration of two components or to increase the classification efficiency a vertical conical baffle made of wood has been introduced into a cylinderical column, which will provide different linear velocities of fluid at different heights of the column. The provision were made to shift the baffer verticallyin its position. The classification was used as continuous unit.

The seperation efficiency in each case has been calculated in terms of Enrichment factor and stripping factor, and attempt has been made to propose a correlation in terms of dimensionless numbers.

CHAPTER - II

A REVIEW OF EARLIER WORK

2.1 Separation of materials into two or more fractions depending upon their physical properties is called classification. The separation of materials on the basis of physical properties such as size, density etc. is frequently important as a means of preparing a product for sale or for a subsequent operation. It is also a widely used means of analysis, either to control or gauge the effectiveness of anoth operation , or to determine the value of a product for some specific application.

In the marketing of coal, the size of the particles is the basis of its classification for sale. Certain equipment such as stokers require definite limits of size for successful operation. In the case of sand and gravel for concrete, on the other hand, only a properly blended series of sizes will ensure the most dense packing, requiring the minimum of cement and securing the greatest strength and freedom from voids. It has frequently been observed that the rate of a chemical reaction between a solid and a fluid is roughly proportional to the surface involved. Since the surface areas may be computed from a knowledge of the sizes of the particles, a sizing operation is of particular value in controlling the rates of reactions involving solids. Since the setting of Portland cement must take place within a specified time, it has been necessary to specify certain size limits. The hiding power of a paint pigment is indicated by size since it depends upon the projected area of the particles.

So the classification of solids have important applications in the Chemical, Mining, Petrochemical Pharmecitical, Metallurgical and other allid industries.

2.2 Based on the Physical properties of solids and the mechanism used, such as ;

(i) Mechanical or Non Mechanical

(ii) Batch or Continuous

(iii) Fluid used - Dry or wet.

The classification equipments can be categorized as follows:

1. Depending upon size & colour only, of the solids.
2. Depending upon size, density, & sphericity of solids.
3. Depending upon other properties of solids.

2.2.1 Based on size & Colour only, of the solids:

This can be further divided into two categories, that is Non Mechanical and Mechanical. The Non Mechanical includes the Picking out of particles by hand on the basis of size or colour. It is applicable only when size difference is much higher. And mechanical type includes the Screening or Sieving.

Screening is accomplished by passing the material over a surface provided with openings of the desired size. The equipment may take the form of stationary or moving bars, punched metal plate, or woven wire mesh, Screening consists in separating a mixture of various sizes of particles into two or more portions, each of which is more uniform in size of particles than is the original mixture. Dry screening refers to the treatment of a material containing a natural amount of moixture or a material that has been dried before screening. Wet screening refers to an operation in which water is added to the material being treated for the purpose of washing the fine material through the screen. Screen may be operated in batch or continuous depending upon the equipment. Screen can not be used for very low particle size range.

2.2.2 Based on Size, Density and Sphericity:

Separation of particles in contact with a fluid, depend on differences in the behaviour of particles with regard to their terminal falling velocity or terminal velocity. This depends primarily on density and size of particles and to a lesser extent on shape besides fluid properties like density and viscosity. Thus in many cases it is possible to use this method to separate a mixture of two materials of different density or material of different sizes into close cut size fractions. Some mechanical operation or device may also be attached to it, for a quick or easy separation.

Equipment used for the classification on the above mechanism can be categorized as, Mechanical, equipment and Non Mechanical equipments.

Mechanical equipments are:-

(a) Centrifugal separators

(b) Drag classifier

(c) Rake Classifier

(d) Spiral Classifier

(e) Bowl Classifier

(f) Hydroseparator

(g) Others

Non mechanical equipments can further be divided into Hydraulic (wet) or Pneumatic (Dry) classifiers and these units work on the basis of difference in terminal velocities of particles.

Hydraulic classifiers can be further divided as:

(a) The Gravity Settling tank

(b) The Spitzkasten

(c) The Double Cone Classifier

(d) Hydraulic Jig

(e) Elutriator

(f) Others

In Hydraulic classifier a liquid is used for classification in most of the cases the liquid is water as it is cheapest and easily available. The major limitation of using liquid like water is wet product that is obtained besides the possible loss of solids disolved in the liquid. If dry product is required the material from the hydraulic classifiers must pass through a drying equipment, many times inspite of this additional operation the final product may not have the desired characteristic due to possible agglomeration.

Dry product can be directly obtained from a classifier if a gas is used as a medium. Usually air is used as a classification medium, as it is available every where in plenty, and can be compressed whenever needed. These classifiers known as Pneumatic classifiers and can be further divided into:

1. Elutriator
2. Conical Vessel
3. Modification over Elutriator

These will be discussed at a later stage.

2.2.3 Based on Other Properties:

(a) Magnetic Properties

(b) Electrical Properties

(c) Surface Properties.

In the magnetic separator, material is passed through the field of an electromagnet which causes the retention or retardation of the magnetic constituent. It is important that the material should be supplied as a thin sheet in order that all the particles are subjected to a field of the same intensity and so that the free movement of individual p articles is most impeded.

Electrostatic seperators in which differences in the electrical properties of the materials are exploited in order to effect a separation, are now sometimes used with small quantities of fine material. The solids are fed from a hopper on a rotating drum which is either charged or earthed, and an electrode bearing the opposite charge is situated at a small distance from the drum. The point at which the material leaves the drum is determined by the charge it acquires and by suitable arrangement of the collecting bins a charge classification can be obtained.

Separation of a mixture using flotation methods depends on differences in the surface. Properties of the material involved. If the mixture is suspended in an aerated liquid, the gas bubbles will tend to adhere preferentially to one of the constituents - the one which is more difficult to wet by the liquid and its effective density may be reduced to such an extent that it will rise to the surface. If a suitable frothing agent is added to the liquid, the particles will be hold in the surface by means of the forth. Until they can be discharged over a weir. Froth flotation is widely used in the metallurgical industries where, generally , the ore is difficult to wet and the residual earth is greadily wetted.

2.3 The working of classifier using air as seperating medium can be understood by knowing the various changes that take place, when a bed of solid is contacted by air. This comes under the broad area of gas-solic fluidization.

Fluidization is a well known technique for contacting solids and fluids and finds wide application in petroleum, metallurgical, chemical and allid industries. The importance of this technique can be visualised from the following applications:-

1. Roasting of ores.
2. Production of carbon-disulphide and phthalic anhydride

3. Drying of granular solids and creats.

4. Coal gasification and coal carbonization.

5. Hydrocarbon synthesis

6. Fluidized bed crystallization

7. Classification and mixing of solids in fluidized beds.

Advantages of Fluidized beds:

Despite the serious draw-backs the compelling advantages of overall economy of the fluidized contacting system have been responsible for its successful use in many industrial operations. Understanding and deficiencies of fluidized contacting and efforts to overcome them can lead to successful operation of difficult systems.

Fluidization has many advantages like amenability of continuous controlled operations on large scale and high transfer rates. However, continuous fluidization systems have different residence time for solid particles yielding non-uniform product . Another limitation of fluidized system is the carry over of fines produced due to attrition of solids.

When a fluid is passed through a bed of fine particles at low fluid flow rates, the fluid merely percolates through the void spaces between the stationary particles leading to a ' FIXED BED ' (5,6). At increased flow rates, particles move apart and a few are seen to vibrate and move about in restricted zone giving " EXPANDED BED".

At still higher velocity a point is reached when the particles are all just suspended in the upward moving fluid. At this point, the pressure drop in any section of the bed equals the apparent weight of the solids in that section. The bed is considered to be just fluidized and is referred to as an " INCIPIENTLY FLUIDIZED BED" or a bed at " MINIMUM FLUIDIZATION".

In gas solid systems with the increase in flow rate of gas beyond minimum fluidization, large instabilities with bubbling and channelling of gas are observed. At higher flow rates agitation becomes more violent and movement of solids becomes more vigorous. Such a bed is called as "AGGREGATIVE FLUIDIZED BED", or a " BUBBLING FLUIDIZED BED". However, in liquid solid systems an increase in flow rate of the liquid above minimum fluidizing condition usually results in a smooth progressive expansion of the bed. Such a bed is referred to as " PARTICULATELY FLUIDIZED BED".

A " DENSE PHASE FLUIDIZED BED" is one where there is a clearly defined upper limit or surface to the bed. At sufficiently high fluid flow rates, when the terminal velocity of the solids is exceeded the upper surface of the bed disappears, entertainment becomes appreciable and the solids are carried out of the bed with the fluid stream. In this state we have a disperse, dilute or " LEAN PHASE FLUIDIZED BED" with pneumatic transport of solids.

"ENTRAINMENT" refers to the removal of solid from the bed by fluidizing gas. The section of the vessel between the surface of the dense phase and the exiting gas stream from the vessel is called the ' FREEBOARD'& its height is called the freeboard height. The purpose of the freeboard is to allow the solids to separate from the gas stream, and as its height is increased entrainment lessens. Eventually a freeboard height is reached above which entrainment becomes constant. This is called the transport disengaging height TDH.

The various investigations carried out on entrainment can be grouped as follows:

1. Entrainment at or above the TDH based on the saturation carrying capacity of the gas stream (11).
2. Entrainment below the TDH and the influence of the properties of the dense phase on this entrainment (11,14,15,18).

Table 2.1 summarizes representative investigations into the various aspects of entrainment.

TABLE 2.1

EXPERIMENTAL CONDITIONS FOR ENTRAINMENT FROM FLUIDIZED BEDS.

Investigator	Experiments	Internals used
Zenz & Weil (11)	Entrainment of FCC Crtalyst Steady state operation	None
Lewis, Gilliland and Lang (14)	Entrainment, one component steady state operation	Without and wit stimer or wire obstruction.
Blyakher & Parlov (15)	Entrainment, one component batch operation in carried vessels	Grids, above de bed, perforatec plates, or tube

2.4 SEPARATION OF MIXED SIZED SOLIDS

If the bed contains solid particles of various sizes (or densities), as velocity of gas increases mainly fine particles are first fluidized at a gas velocity U_{bf} (beginning of fluidization) and large particles later at the gas velocity U_{tf} (complete fluidization). Conversely as the gas velocity is reduced mainly large particles are first deposited from the bed, whilst the fine particles may still be fluidized. The processes in such a bed are represented by fluidization curves with typical reference points 1 and 2 (fig. 2.1) the abscissae of these points correspond to velocities U_{bf} and U_{tf} and they depend on the size distribution of the bed particles (or their densities).

In mixed particle system there will be a zone with beginning and completion of entrainment. This will be similar to minimum fluidization velocity for mixtures. Initiation of entrainment will correspond to a gas velocity U_{be} in the vicinity of the terminal Velocity of finer particle and the completion of entrainment will be at a velocity U_{te} in the vicinity of terminal Velocity of Coarse material. This represented in the Fig. 2.1 by point 3 & 4. The greater is the difference between terminal velocity the better will be the seperation. If the sizes of particles differ appreciably, elutriation occurs and the smaller particles are continuously removed from the system.

Elutriation refers to the separation or removal of the fines from a mixture and this may occur either below or above the TDH, while the entrainment refers to the removal of solids from the bed by fluidizing gas in both single component and multicomponent systems. More precisely, elutriation refers to the selective removal of fines by entrainment from a bed consisting of a mixture of particles sizes. The rate of elutriation of solids of some size from the misture is characterized by the net upward flux of this size of solid. In elutriation above the TDH both the size distribution and entrainment rate becomes constant and are given by the saturation carrying capacity of the gas stream under pneumatic transpert conditions. The study on elutriation can be classified as above and below the TDH.

Table 2.2 summarizes representative investigations into the various aspects of elutriation

TABLE 2.2

EXPERIMENTAL CONDITION FOR ELUTRIATION OF FINES FROM FLUIDIZED BEDS

Investigator	Experiment	Operation	Internals used.
Leva (7)	Two components	Batch	None
Osberg, Charles worth (8)	Two components	Batch	None
Yagi&Aochi(9)	Two &Multicomponents	Batch & steady state	None
Wen & Hashinger (12)	-do-	Batch	None
Sanari & Kunii(13)	Multi component	Steady state	None
Thomas et.al(10)	Two component	Batch	None
Gopal Krishna & Rao C. (20,21)	Two component	Batch & steady state	With baffl

2.5 <u>Fixed bed-fluidized bed - Entrainment</u> are analogus to solid-liquid-vapor phases of material. This anology was used by Kondukov and Sosna (25). The analogy between a fluidized bed and a liquid is caused thermodynamically by the relationship between the external effect and the corresponding conjugate potential and co-ordinate.

Considering the transition of a fixed bed to the fluidized state as analogous to melting a solid body, and entrainment (carry-over) of particles from the bed as analogous to transition of liquid to the vapour state, we may speak of three ' aggregate states' (Phases) of solid particles/ fluidizing agent system, ' solid', (fixed bed) ' liquid' (fluidized bed) and ' Vapour' (entrained material, dilute phase). Similar anology was also used by Gelperin et al (26) Petov(27).

The concentration of solid particles above the free surface of a fluidized bed increases with increase in the velocity of air in a similar way to the increase in vapour pressure of a liquid with temperature. The existence of the liquid is limited by the critical temperature, and similarly the upper limit of existence of a fluidized bed is close to the free falling velocity of single particles and it may further be proved by many other factors.

The existence of equilibrium between the dilute and dense phases of the fluidized bed made it possible to apply process of ' distillation' and rectification to separate mixture of particulate materials according to particle size.

The lean phase is treated analogous to the liquid vapour system by Leva (7), Zenz and Othmer (24), Gelperin & Eintein (28), Nakashio and Sakai(29), Gelperin et al (26) Wen and Hashinger (12), Donat (30) Friman et al (31) Gopal Krishna & Rao (20)(21).

2.6 FACTORS AFFECTING ELUTRIATION

Application of elutriation to a solids - separation problem requires an understanding of new elutriation rates are affected by system variables. Factors of importance may be apparatus born, involve the characteristics of solids and fluids or both.

Apparatus Effects:

Effects of apparatus construction appear complicated so far they have not been studied quantitatively enough to permit formulation of final correlations. The principal factors involved are:-

1. Fluid distribution and bed height.
2. Column diameter
3. Freeboard above the solids bed.

Effects of fluids & Solids

The effects of fluid and solids characteristics upon elutriation rates have been noted with more precision than the apparatus effects discussed above. Specifically investigat were influence of:-

1. Superficial gas rate through beds.
2. Particle size of fines components
3. Particle size of bed components

TABLE 2.3

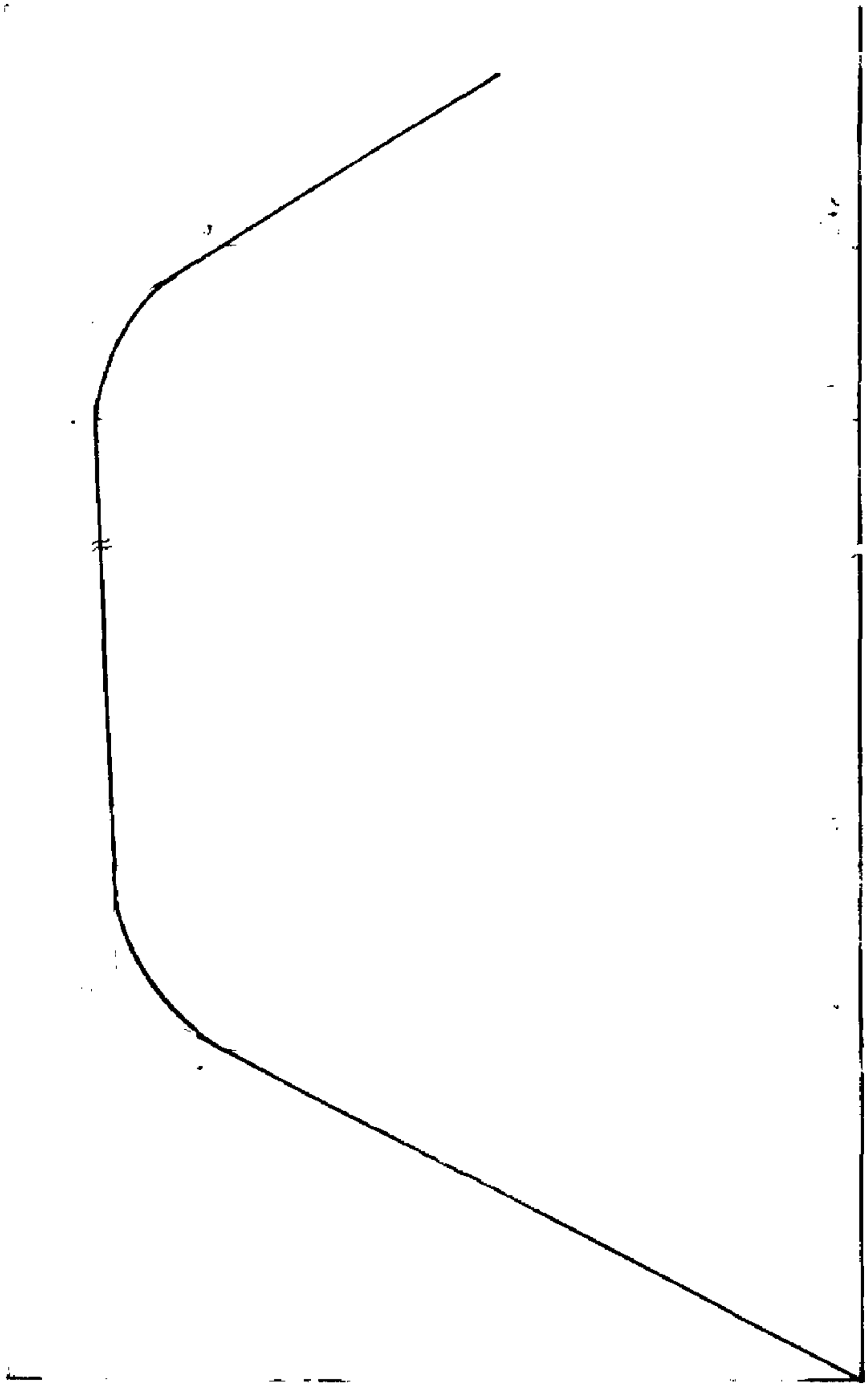
QUALITATIVE EFFECTS OF VARIABLES ON ELUTRIATION

Variable	Variation in elutriation rate
Fluid distribution	Should increase as fluid distribution improves.
Bed Height	Should decrease with increasing bed Height.
Column diameter	Effects so far observed are conflicting
Free board	Decreases as freeboard increases, becomes independent beyond Limiting value of free board .
Superficial gas rate	Increases sharply with gas rate.
Fines diameter	Incfeases rapidly with decreasing fines diameter.
Bed component diameter	Appears to increase as bed component size increases.
Solids density of fines component	Increases as for constant linear velocity, fines density decreases.
Particle shape of fines	Decreases as shape becomes more irregular
Particle shape of bed	Not yet investigated
Fluid Viscosity	Increases as for constant linear Velocity, Viscosity increases.

2.7 PROPOSED WORK

After review of earlier work it is concluded that solid seperation is possible by using air-solid fluidization in lean beds, analogous to distillation. Better separation can be attain by creating a rectification zone in which air velocity should decrease as we go up the column. The height of rectification column should be sufficient enough, so that the coarser particles whose terminal velocity is higher than the gas velocity, may fall back to the bed. This height may also be called as the height of stabilizing zone as it stabilize the separation of materials. So to develop such rectification column, a special type of wooden baffle conical in shape and provided with holes in the upper portion to adjust it in different positions (different height of stabilizing zone) is used in a cylinderical vessel as shown in fig. 4.2

The aim of the present investigation is to study the effect of various parameters like air flow rate, solid feed rate, solid composition, ratio of diameters of fines to coarse in feed, density of solids and position of baffle on the product rate, enrichment factor, stripping factor and overall effectiveness of the classifier.



3.2 DENSITY ρ_s

The density of the solids is determined by the usual liquid displacement. To ensure that the wettability of the solids by a liquid does not effect the results, the densities were determined by water, Kerosene and Carbon Tetrachloride . The densities are shown in the Table 3.1

3.3 POROSITY ϵ_s

The porosity or void fraction of a solid material of a definite size is determined by knowing the volume of the bed and the volume of the solids. The ratio, void volume to the volume of the bed gives the porosity of the bed. The porosity data is shown in Table 3.1. To ensure that the wall effect does not influence the porosity values, cylinder of similar dimension as used in the present experiment was employed.

3.4 SPHERICITY ϕ_s

The sphericity of crushed materials was determined by pressure drop measurements. For a given material, the pressure drop is determined in fixed bed zone using air as the medium. In the test carried out the gas velocity was kept in laminar zone by limiting the particle Reynold's number value to less than 10. With voidage pressure drop and other fluid and solid properties known, the sphericity was calculated using Ergun's (37) fixed bed pressure drop equation. The sphericity values are shown in Table 3.1

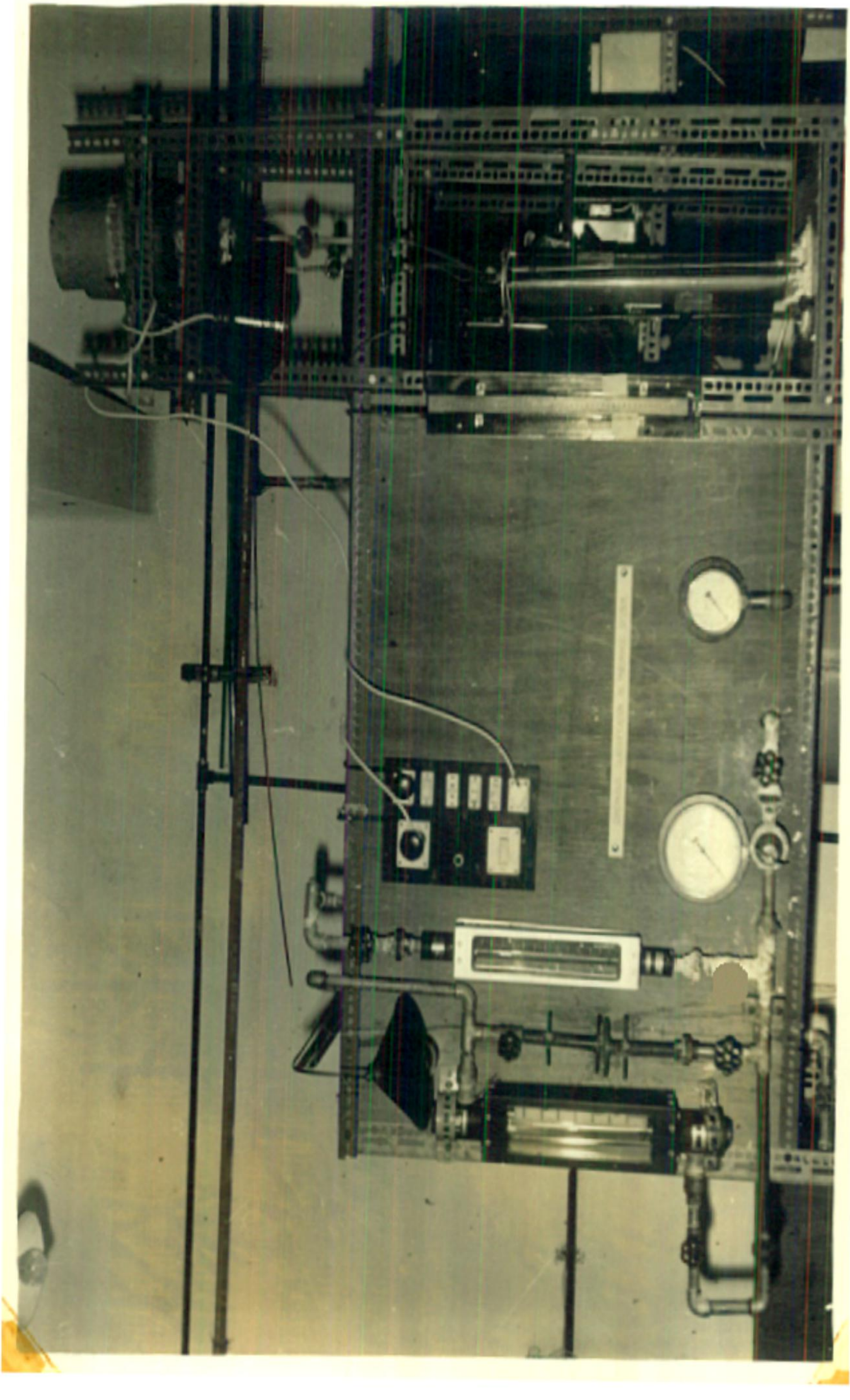
3.5 ANGLE OF REPOSE θ

For free flowing solids discharged from a vertical or horizontal opening the angle formed by the free surface of the material along with the horizontal is termed as the ' angle of repose'. The angle of repose of various materials was determined by measuring the dimensions of the Pile (cone) of solids formed below a hollow vertical cylinder. The values of obtained and other Physical properties are shown in Table 3.1

TABLE 3.1

PHYSICAL PROPERTIES OF SOLIDS

Sl. No.	Material	Density ρ_s gm/cc	Particle size Microns DP	Static Bed Porosity ϵ_s	Sphericity ϕ_s	Angle repose θ Degree
1.	Bauscite	2.3	977	0.530	0.880	39.00
2.			650	0.518	0.860	38.00
3.			460	0.490	0.854	37.50
4.	Glass Beads	2.5	977	0.400	1.000	26.60
5.			650	0.390	1.000	26.00
6.			460	0.382	1.000	26.00
7.	Calcite	2.75	977	0.520	0.590	29.80
8.			650	0.482	0.625	29.00
9.			460	0.446	0.626	28.80



CHAPTER - IV

EXPERIMENTAL INVESTIGATION

4.1 EXPERIMENTAL SET UP :

The experimental classification unit is shown in the schematic diagram (Fig. 4.1). The details of the baffle, and outlet connections are shown in fig. 4.2. The column (K) essentially consisted of a perspex tube 70 mm I.D. and 622 mm length placed between two special flanges (F 1, F2). One conical internal baffle (B) made of wood, was inserted vertically concentric to the column in a hole provided in the upper flange and is held in position by holding pin (HP) in the holes (H) on the baffle. The baffle is held in position without wobbing during classification by means of guiding pins (GP 1) fixed on the baffle. A grid plate made of 3 mm thick aluminium sheet having 1.5 mm holes drilled on a square pitch of 4 mm was fitted in the special flange (F2) The area of the openings in the grid was 10% of the empty column cross section. The grid plate, covered with a 200 mesh brass wire screen, was used as air distributor and to support the solids. Air drawn from the compressor (C) through surge tank (S) after filtration and regulated through pressure regulator (PC) was introduced into the column at the bottom through a calming section (AD) which was filled with porcelain raschig ring to provide uniform air distribution through the bed.

composition were fed to the classifier, through the gravity feed hoppers (GF 1, GF 2) at a steady rate controlled by stop cocks T1, T3. The gravity feeders were calibrated earlier, by determining the weights of the material discharged at air flow rates. The bottom product rate was controlled with the help of stop cock provided, while the top product rate is at the full opening, a steady state bed height of 70 mm, was attain. Steady state conditions were assumed when: (1) Bed height (2) Pressure drop across the bed & (3) Solid inlet and outlet rates remained constant. Then the run was taken, the duration of the run was maintained for 5 minutes after which the solid feed was stopped and the air flow cut off. During the run, bed height was checked constantly with the help of manometer to ensure constant bed height in the classifier.

The top and bottom product receivers were removed and the products weighed. The percentage of fines in top and bottom products was determined by sieve analysis.

To see if the duration of the run has any effect on the percentage of fines or the rates of the products obtained the classifier was operated for 4 to 10 minutes.

Frequently observations were checked for reproducibilit by repeating the runs.

The air classifier was used for studies on continuous air classification of feed under different operating conditions

Data were taken for different materials which included crushed bauxite and calcite & glass beads, density, ranging from 2.3 to 2.75 gm/cm^3.

The data obtained are the solid feed rate, air flow rate%of fines in feed, diameter of coarse and fines, position of baffle, rate of the top and bottom product and the percentage of fines in each product. Sample tables of experimental data are given in Appendix I, and detailed data are presented as graphs in Chapter - V.

4.3 RANGE OF EXPERIMENTAL VARIABLES.

TABLE - 4.1

Sl. No.	Variable	Units	Range
1.	Materials		Bauscite, Glass beads and calcite.
2.	Solid density ρ_s	gm/cm^3	2.30 - 2.75
3.	Air flow rate G_f	$gm/cm^2/min$	340.986 - 877.898
4.	Particle size D_p	Um	460 - 977
5.	Solid feed rate W_f	gm/min	95.00 - 360.00
6.	Feed composition X_F	% fines	31.78 - 82.82
7.	Ratio of diameter of coarse to fines DC/DF		1.413 - 2.124
8.	Height of stabilizing zone Hl	mm	168 - 308.

- [illegible] - Air filter
- [illegible] Surge tank
- [illegible] Pressure gauge
- [illegible] Baffle
- [illegible] Column
- [illegible]
- [illegible] Pressure control valve
- [illegible]
- [illegible]
- [illegible]
- [illegible] - Bottom outlet
- [illegible] Vibratory feeder
- [illegible]
- [illegible]
- R1,2 Rotameters
- F1,2 Flanges
- [illegible]
- [illegible]
- [illegible]
- [illegible]
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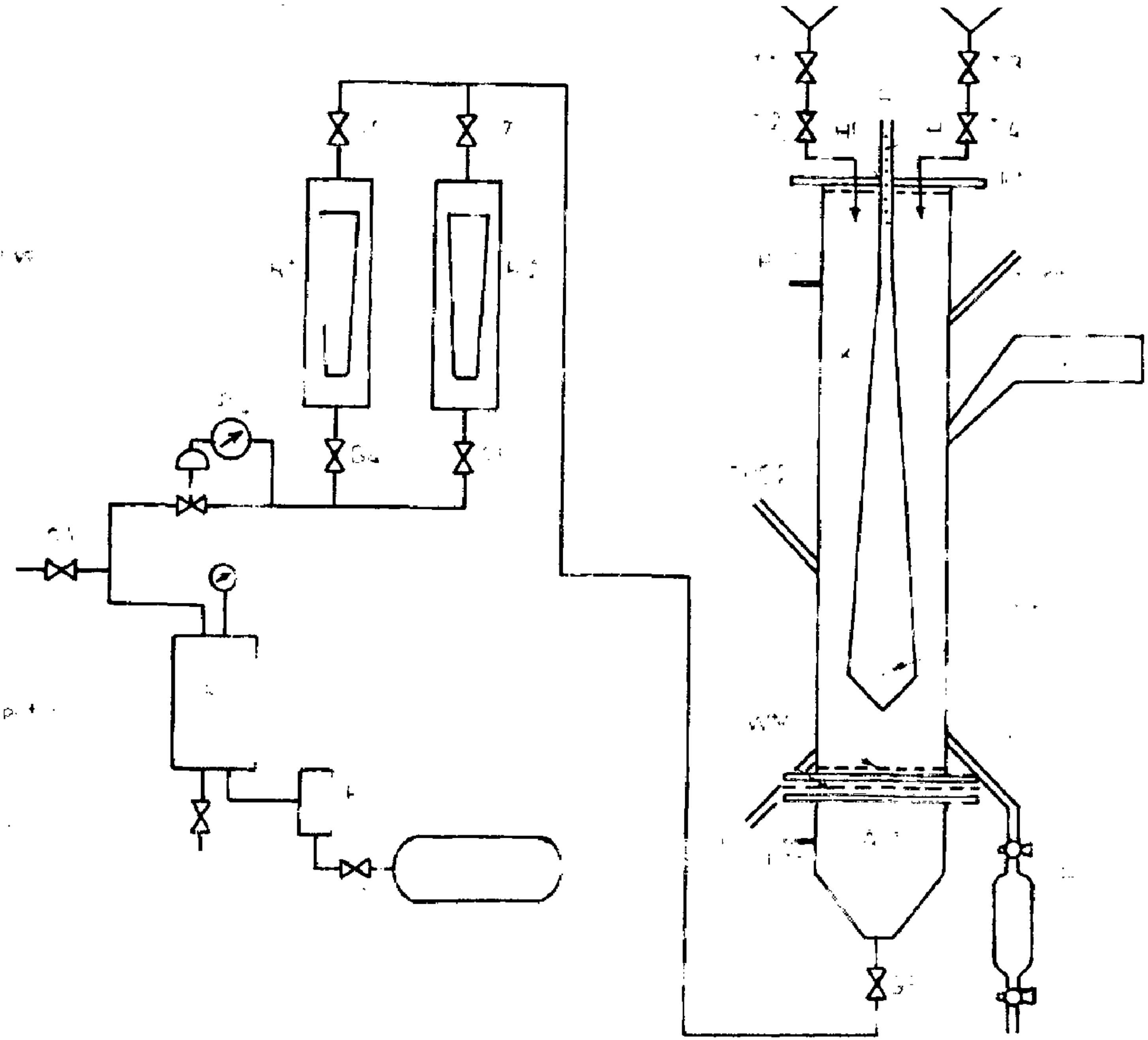

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CHAPTER V

RESULTS AND DISCUSSION

The air classifier was used for studies on continuous air classification of mixed size feed, under different opertin conditions. The solids feed rates ranged from 95 gm/ mim. to 360 gm/min. and air flow rates varied from 340.986 gm/ Cm^2 min. to 877.898 gm/Cm^2-mim. At constant solids feed rate and air flow rate, classification was carried out at different compositions of the feed ranging from 31.78 percent of fines to 82.82 percent of fines. The ratio of the diameter of coarse to the fine was varied from 1.413 to 2.124. The height of the stabilizing zone was varied from 168 mm to 308 mm by changing the position of the baffle.

Data were taken for different materials, which included glass beads and crushed particles of bauscite and calcite of densities ranging from 2.3 to 2.75 gm/Cm^3. The experimenta data are plotted, Fig. 5.1 to 5.10.

Fig. 5.1. is a plot showing the variation of solid feed rate with air flow rate for glass beeds of size 977 and 460 microns. This plot is for an initial feed compsition of 55 percentage of fines when no air flow is present. The graph shows that with the increase in air flow rate, the total solids feed rate and the individual component feed rates from the gravity feeder decreases. The decrease of solid feed rate is observed to be 20 gm/ mim in the case of particle size 460 microns as compared to 5 mg/mim for the

particle size of 977 micrones. When the air flow rate increases from 340.986 gm/mim Cm^2 to 877.897 gm/mim Cm^2. This would mean change in feed composition of 56.62 of fines to 60.14 of fines with the total air flow rate range. In the present analysis under the condition of changing feed rate of solids and feed composition of solids with air flow rate, the average values of composition of feed and feed rate of solid have been taken at all air flow rate.

Fig. 5.2 is a plot of percentage of fines in top and bottom product vs air flow rate from the classifier without baffle for air glass beeds system of mixed particle size of known composition. It is observed that with increase in air flow rate, the percentage of fines in the top and bottom product decreases. It may be noticed that percentage of fines in the top product at any air flow rate is more than the corresponding value of in the feed while the percentage of fines in the bottom at any flow rate is lower than corresponding feed value. Fig. 5.3 shows variation of percentage of fines in top and bottom product with air flow rate for classifier with baffle. The trained of variation of percentage fines is similar to the observed in beds with out baffle, that with increase in air flow rate the percentage of fines in top and bottom product decreases.

This decrease of percentage of fine in top and bottom product with increase in air flow rate is in agreement with the earlier observation of Gopala Krishna and Rao (20)

Fig. 5.4 is a plot of percentage of fines in top and bottom products vs air flow rate with and without baffle for air-glass beeds system of fixed composition. It is observed that with increase in air flow rate, the percentage of fines in the top product and bottom product decreases in both case (with and without baffle). It can be seen that at any ~~fk~~ air flow rate, the percentage of fines in top product are more when baffle is used compared to the corresponding value for bed without baffle. The trained was similar for the bottom product composion, this indicates that classifier with baffle is more effective than classifier without baffle.

Fig. 5.5 is a plot of percentage of fines in the top product and bottom product Vs air flow rate for the feed of different compositions, the system being air glass beads. It is observed that, the percentage of fines in the top and bottom product increases with increase in percentage of fines in the feed.

Fig. 5.6 shows the variation of the ratio of top product to bottom product rate with air flow rate for different feed compositions. The ratio (r_1/r_2) increases with increase in air flow rate for a given feed composition, it can be further seen that at a given air flow rate the (r_1/r_2) increases with increase in percentage fines in the feed.

Fig. 5.7 (A) shows the variation of percentage fine in top product (XT) with air flow rate, with DC/DF as a perameter. For a given DC/DF percentage fines in top product decrease with air flow rate as observed earlier. At any air flow rate the percentage of fines in top product increase with increase in DC/DF ratio.

The ratio of top product rate of bottom product rate (WT/WB) is plotted as a function of air flow rate in fig.5.7 (B) for different values of DC/DF, it is observed that the ratio increases with increase in DC/DF value at a given air flow rate.

Fig. 5.8 (A) is a plot of ratio of top or bottom product rates Vs air flow rate for various particle densities This reveals, that, with the increase in particle density, the ratio of top product to the bottom product increases.

From fig.5.8 (B) showing the variation of percentage of fines in top product with air flow rate for different particl densities, it will be observed that the percentage of fines in the top product increases with increase in particle density at constant air flow rate.

Fig. 5.9 (A) and (B) are the plot of ratio of top product to the bottom product rate Vs solid feed rate and Vs solid feed rate, percentage of fines in the top product for the system air-glass beeds at constant air flow rates, and feed composition. It is observed that, at constant air flow rate, the ratio of the top product to the bottom product rates and also the percentage of fines in the top product decreased with increase in solids feed rate.

Fig. 5.10 (A) and (B) are the plots of ratio of top product to bottom product Vs height of stabilizing sone and percentage of fines in the top product Vs height of stabilizing zone for air glass beeds system at constant air flow rate. It is observed that at a constant air flow rate and solid feed rate as the height of the stabilizing zone increased, the ratio of the top product to the bottom product increased while there was a decrease in the percentage of fines in the top product.

The above observed behaviour can be well understood with the theory of fluidization. In any bed at gas velocities higher then minimum fluidizing condition gas will flow essentially in two phases, the bubble phase and emulsion phase. The bubble phase will be surrounded by a cloud of sloids and will be followed by a wake of material behind it as the bubble rises and reaches to the surface of the bed the bubble will burst projecting agglomerates of solids into the space above the bed. In this space the gas velocity will be lower then the bubble raise velocity and the solids which are essentially in lean phase will be present in three forms, namely (1) finely dispersed upmoving solid phase (2) agglomerates which are down moving, (3) agglomerates which are upmoving. There is a continuous interchange among these phases, and some short of balance is maintained. When two solid size are used in the feed and when the gas velocity is greater then the terminal velocity of the finer solid, the upmoving dispersed phase is likely to be fine material. At any gas flow rate depending upon the amount of bubbling the top product rate will be controlled by the gas velocities, increasing air flow rate, the bubbling becomes more pronounced the bursting at surface will become more violent and larger quantities of solids, both fines and coarse will be thrown in the space above, this will result a larger product rate at top and more quantity of coarse getting out of top outlet; resulting in decrease in fines composition at top.

An decrease in the diameter of fine particle keeping coarse particle size constant, will result in a faster rate of removal of fines from the bed, this will result an increase in top product rate as well as increasing percentag fine in the top product, when compared with the performance under inentical condition when the fines size is large (DC/DF is lower).

At any given air flow rate the U/Ut values will be hig for a lighter particle than for a dense particle when particle size is constant. Thus it will be observed that the top product rates will be lower for denser particles then for lighter particle under identical condition, for the same percentage of fine in top product will be more with higher density solid material then compared to lower density material.

The intorudction of a baffle in the dispersed phase essentially helps in stabilizing the material in the lean phase and reduceases the value of TDH as a result,, when the baffle did not interfere with dense phase it is expected that percentage fines in top product will increase in bed with baffle when comared with a bed without baffle. When the baffle is lowered and it penetrates the dense bed the dense bed characteristics are changed as the effective area available for gas flow is reduced, thus reduced, thus results in more severe bubbling and large quantity of solid is been pushed in the space above the bed as a result it is expected that the top product rate will increase at the expense of decrease in the percentage of fines in the top product.

Thus it is expected that the baffle location always be sharp that of should help in reaching the more homogenity in the space above the bed causes due to bubbling and smoothen the characteristic of the bed rather then making the bed more violent by increasing the bubbling due to the baffle penetration into the bed.

To evaluate the performance of classifier, correlation, have been developed. This made possible by knowing the effect of various characteristics of classifier, which include flow properties of solids and air, geometry of bed and baffle and air flow rate, solid feed rate, feed composition, top and bottom product composition and rates. Then these parameters were grouped to give dimensionless groups namely

$$R_e = \frac{D.v.\rho}{\mu}$$

$$F_r = \frac{D_p\, g}{U_g^2} \text{ and } \frac{H_1}{N}, \frac{Dl}{DF}, \frac{\rho_s - \rho_g}{\rho_g},$$

$$r, r_1, r_2, \left(\frac{r_1}{r_2}\right), \text{ EF and SF}$$

The expected correlationare of the form as shown below -

$$\left(\frac{r_1}{r_2}\right) = K_1 \left[\left(\frac{R_e}{r}\right)^a (F_r)^b \left(\frac{DC}{DF}\right)^c \left(\frac{Hi}{H}\right)^d \left(\frac{\rho_s - \rho_g}{\rho_g}\right) \right]^f$$

$$EF = K_2 \left[(r_1)^{a'} (F_{r1})^{b'} \left(\frac{DC}{DF}\right)^{b'} \left(\frac{Hi}{H}\right)^{d'} \left(\frac{\rho_s - \rho_g}{\rho_s}\right)^{e'} \right]^{f'}$$

$$\text{and } SF = K_3 \left[(r_2)^{a''} (F_{r2})^{b''} \left(\frac{DC}{DF}\right)^{c''} \left(\frac{Hi}{H}\right)^{d''} \left(\frac{\rho_s - \rho_g}{\rho_s}\right)^{e''} \right]^{f'}$$

The various terms used in the calculation of the dimensio less groups are defined here and sample calculation is given in Appendix II. The calculation were made with the help of computer. The computer programme for one set of calculatio is given in Appendix III, other programme are based on the same steps. The final correlations were also tried with help of computer programme given in Appendix III.

Solids Loading ratio: The ratio of gms. of solids per gm. of air is termed, the solids loading ratio 'r', r_1' and 'r_2' represent the solids loading ratios in the enrichment and stripping sections of the classifier respectively. This $r = r_1 + r_2$ and r_1/r_2 becomes the ratio of the top product to the bottom product.

Enrichment factor

$$EF = \frac{\text{Percentage fines in top product}}{\text{Percentage fines in feed}} - \frac{\text{Percentage coarse in top pro}}{\text{Percentage coarse in}}$$

Stripping factor

$$SF = \frac{\text{Percentage coarse in bottom product}}{\text{Percentage coarse in feed}} - \frac{\text{Percentage fines in bott product}}{\text{Percentage fines in feed}}$$

To develop correlation of the expected type the graphs are plotted Fig.514-31 the slopes of these graphs are given in table No. 5.1

.1

The final correlation so obtained for $(\frac{r_1}{r_2})$, EF, and SF are;

$$-\left(\frac{r_1}{r_2}\right) = K_1 \left[\left(\frac{R_e}{r}\right)^{1.5282} (F_r)^{-1.2985} \left(\frac{DC}{DF}\right)^{2.3558} \left(\frac{Hi}{H}\right)^{2.355} \left(\frac{\rho_s - \rho_g}{\rho_s}\right)^{-1.1028}\right]^{a}$$

$$-EF = K_2 \left[(r_1)^{-.2493} (F_{r1})^{0.3153} \left(\frac{DC}{DF}\right)^{4.7046} \left(\frac{H_1}{H}\right)^{.7962} \left(\frac{\rho_s - \rho_g}{\rho_s}\right)^{2.6529}\right]^{b}$$

$$-SF = K_3 \left[(r_2)^{-.7265} (F_{r2})^{-2.1445} \left(\frac{DC}{DF}\right)^{-2.1445} \left(\frac{Hi}{H}\right)^{-1.0649} \left(\frac{\rho_s - \rho_g)}{\rho_g}\right)^{-0.6847}\right]^{c}$$

where $K_1 = 4.7785 \times 10^{-12}$

$K_2 = 8.8247 \times 10^{-8}$

$K_3 = 1.2998 \times 10^{-13}$

$a = +0.6008$

$b = +0.6249$

$c = +0.7812$

TABLE 5.1

Fig. No	Variables	Slope
5.14	$(\frac{r_1}{r_2})$ Vs $(\frac{R_e}{r})$	= + 1.5282
5.15	$(\frac{r_1}{r_2})$ Vs (F_r)	= - 1.2985
5.16	$(\frac{r_1}{r_2})$ Vs $(\frac{DC}{DF})$	= + 2.3558
5.17	$(\frac{r_1}{r_2})$ Vs $(\frac{Hi}{H})$	= + 2.3558
5.18	$(\frac{r_1}{r_2})$ Vs $(\frac{\rho_s - \rho_g}{\rho_g})$	= - 1.10285
5.19	EF Vs (r_1)	= -.2493
5.20	EF Vs (F_{r1})	= + 0.3153
521	EF Vs $(\frac{DC}{DF})$	= + 4.7046
5.22	EF Vs $(\frac{Hi}{H})$	= -0.2962
5.23	EF Vs $(\frac{\rho_s - \rho_g}{\rho_g})$	= + 2.0503
5.24	SF Vs (r_2)	= -0.7265
5.25	SF Vs (F_{r2})	=- 2.1445
5.26	SF Vs $(\frac{DC}{DF})$	= - 2.1445
5.27	SF Vs $(\frac{Hi}{H})$	= - 1.0649
5.28	SF Vs $(\frac{\rho_s - \rho_g}{\rho_s})$	= - 0.6847
5.29	$\frac{r_1}{r_2}$ Vs B	= + .6008
5.30	EF Vs B'	+ .6248
5.31	SF Vs B''	= + .7812

are

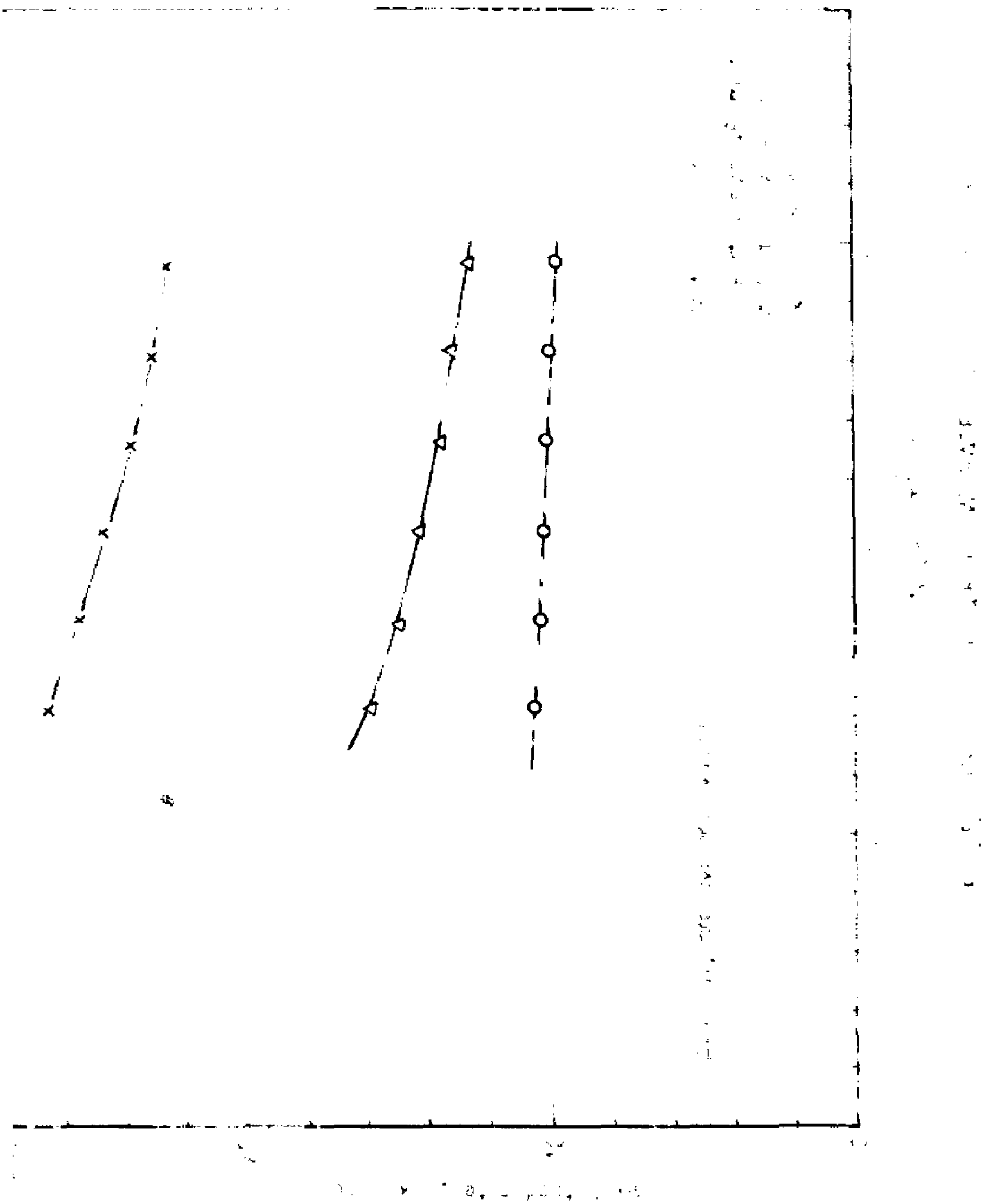
$$= \left(\frac{R_e}{r}\right)^{1.5282} (F_r)^{-1.2985} \left(\frac{DC}{DF}\right)^{2.3558} \left(\frac{Hi}{H}\right)^{2.3558} \left(\frac{\rho_s - \rho_g}{\rho_g}\right)^{-1.10}$$

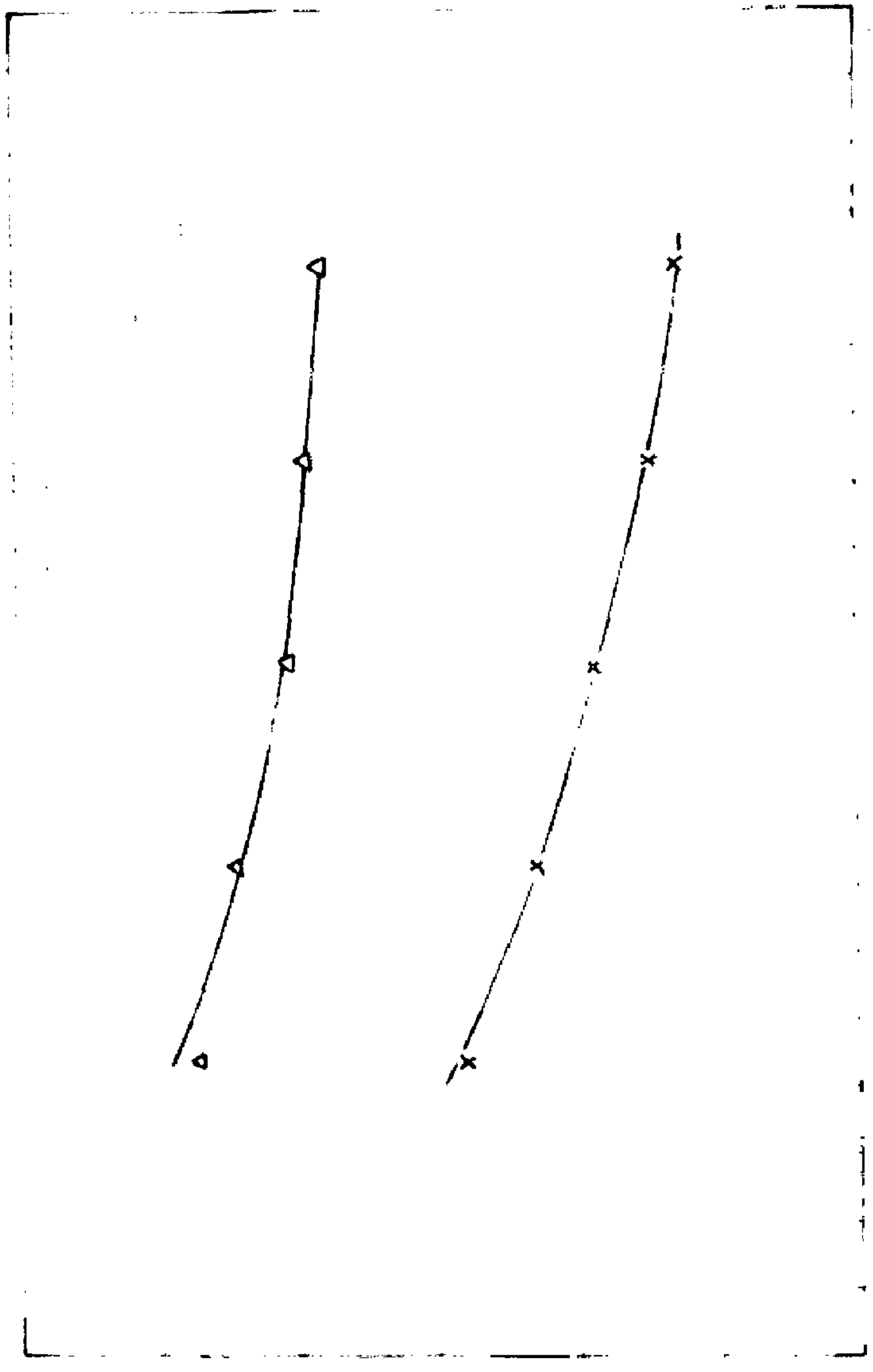
$$(r_1)^{-.2493} (F_{r1})^{0.5153} \left(\frac{DC}{DF}\right)^{4.7046} \left(\frac{Hi}{H}\right)^{-.2962} \left(\frac{\rho_s - \rho_g}{\rho_g}\right)^{2.050}$$

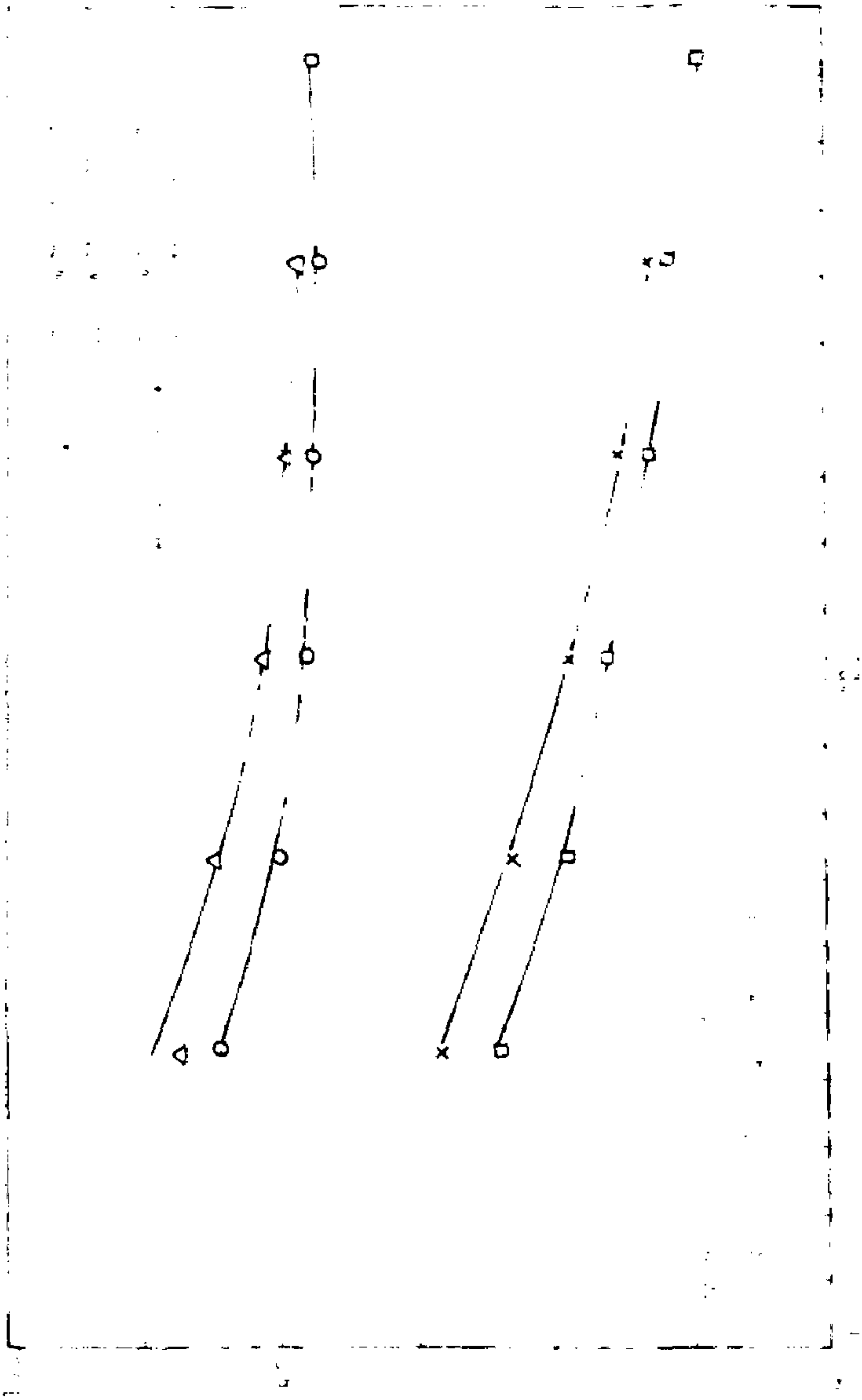
$$= (r_2)^{-.7265} (Fr_2)^{-2.1445} \left(\frac{DC}{DF}\right)^{-2.1445} \left(\frac{Hi}{H}\right)^{-1.0649} \left(\frac{\rho_s - \rho_g}{\rho_g}\right)^{-0.6}$$

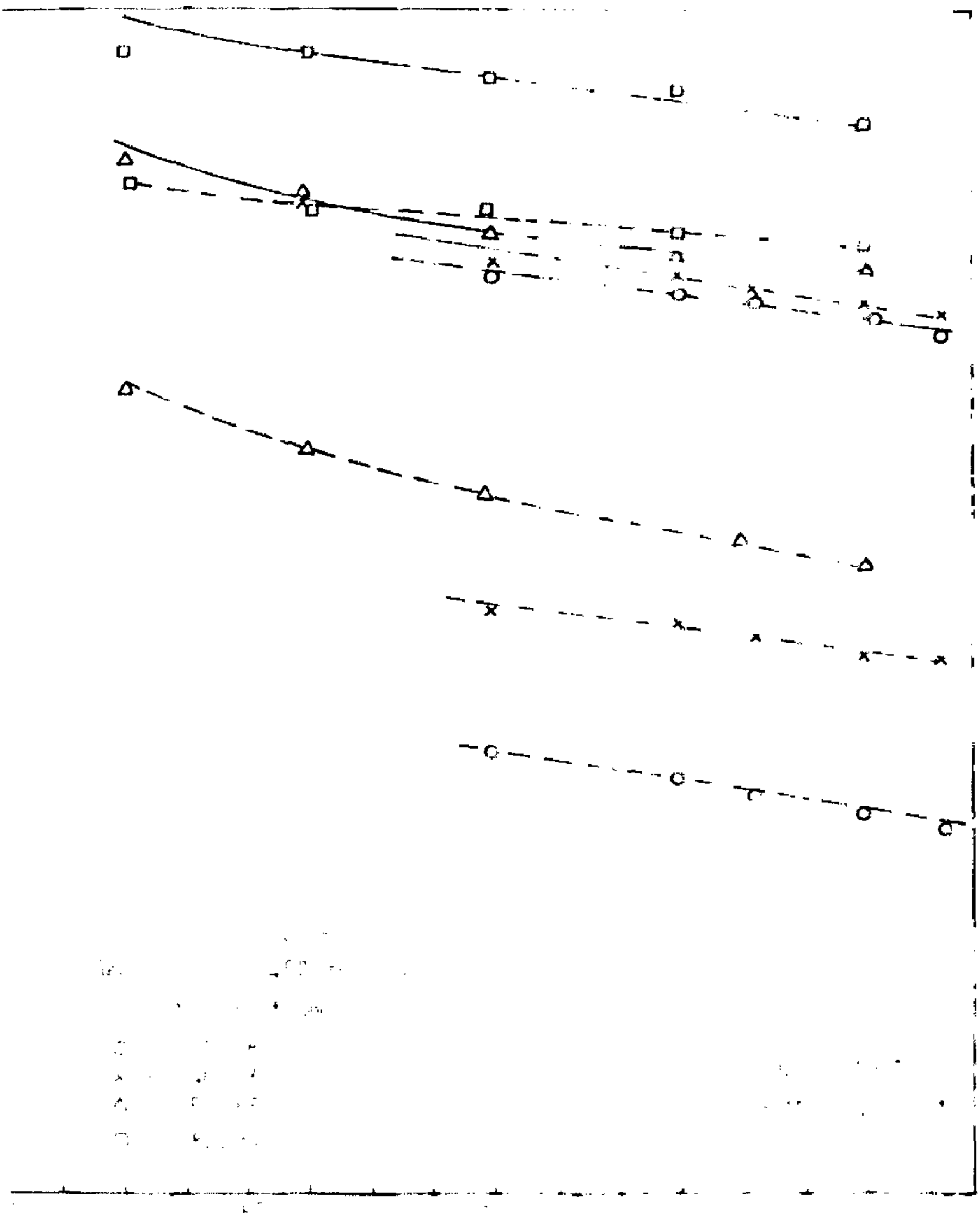
Intercept of the curve Fig. 5.29 to 5.31 are 4.7785×10^{-12}

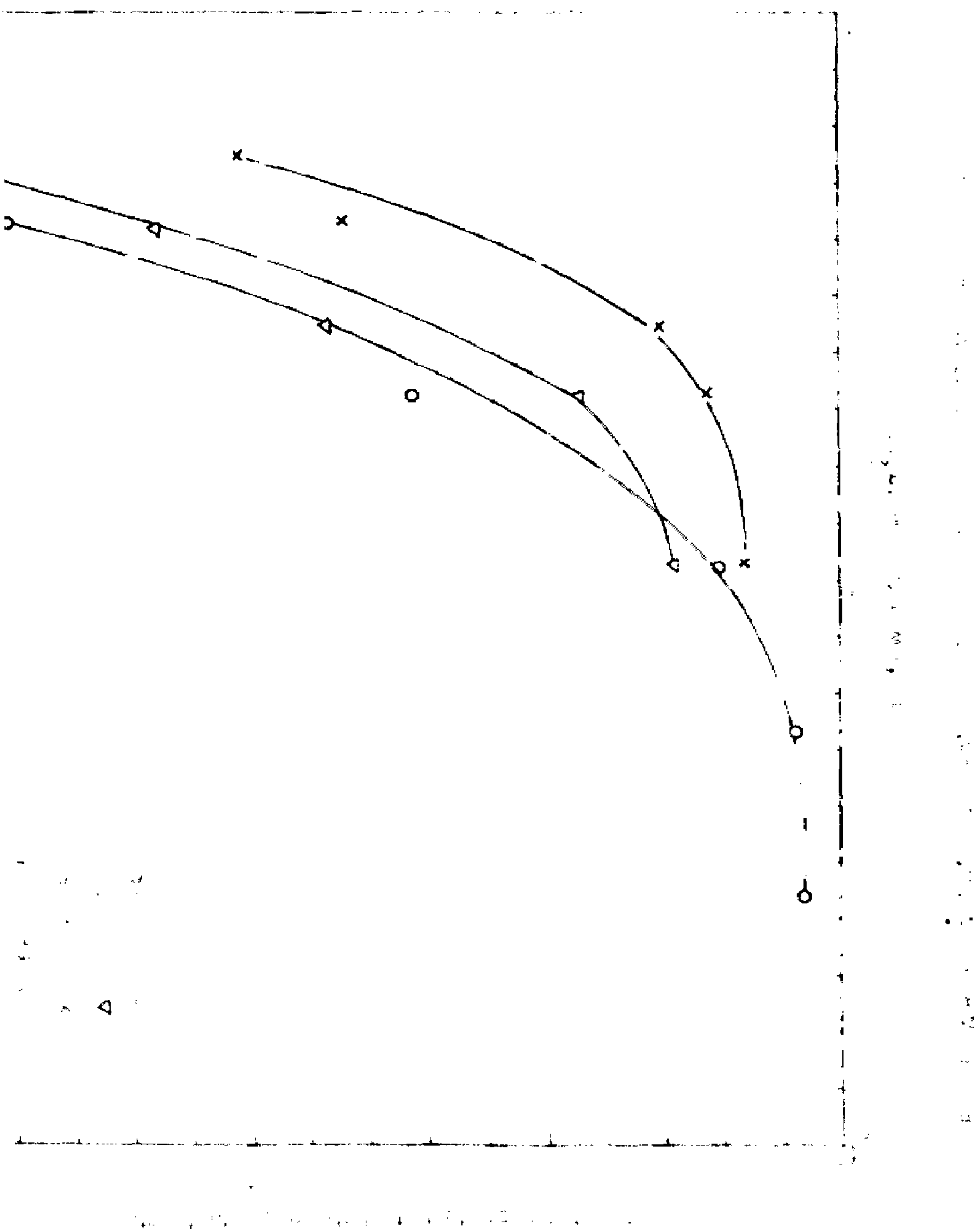
7×10^{-8} and 1.2998×10^{-13} respectively.

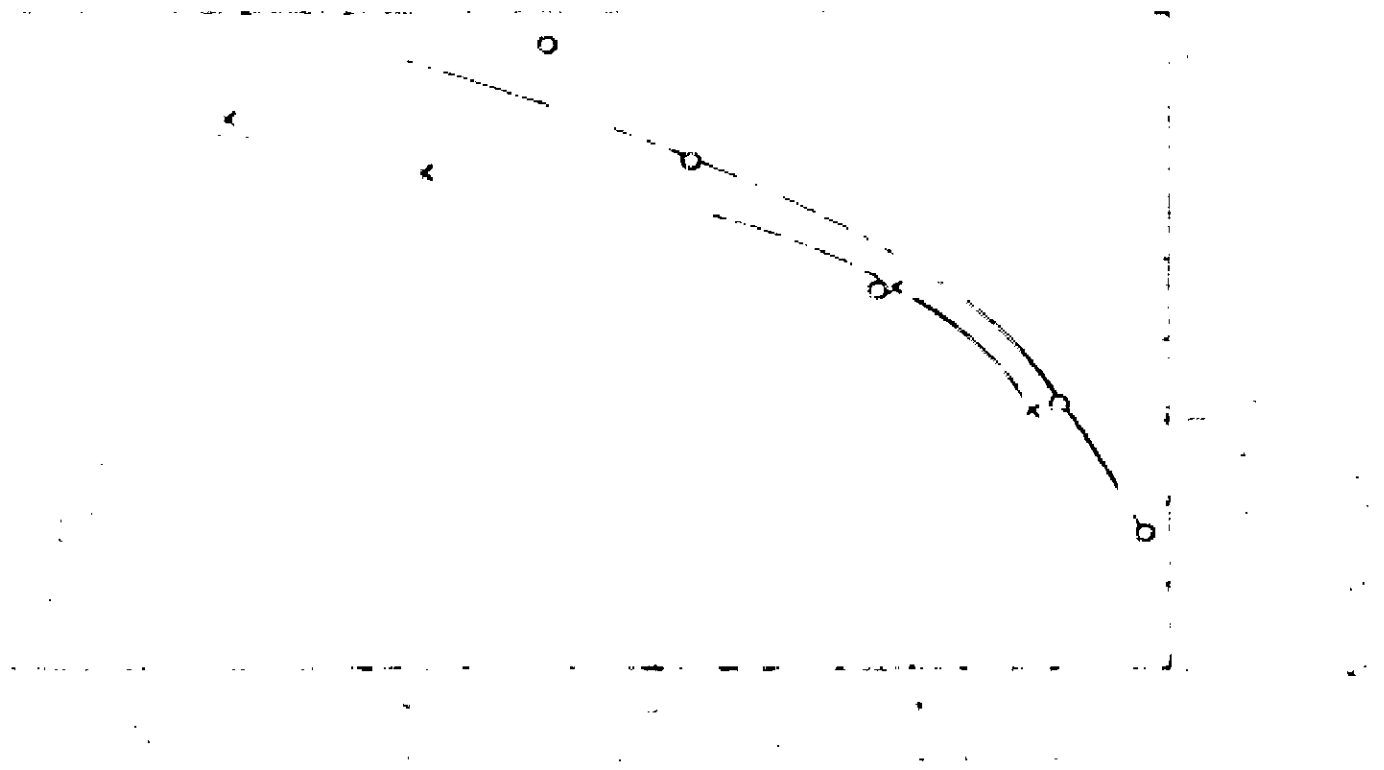


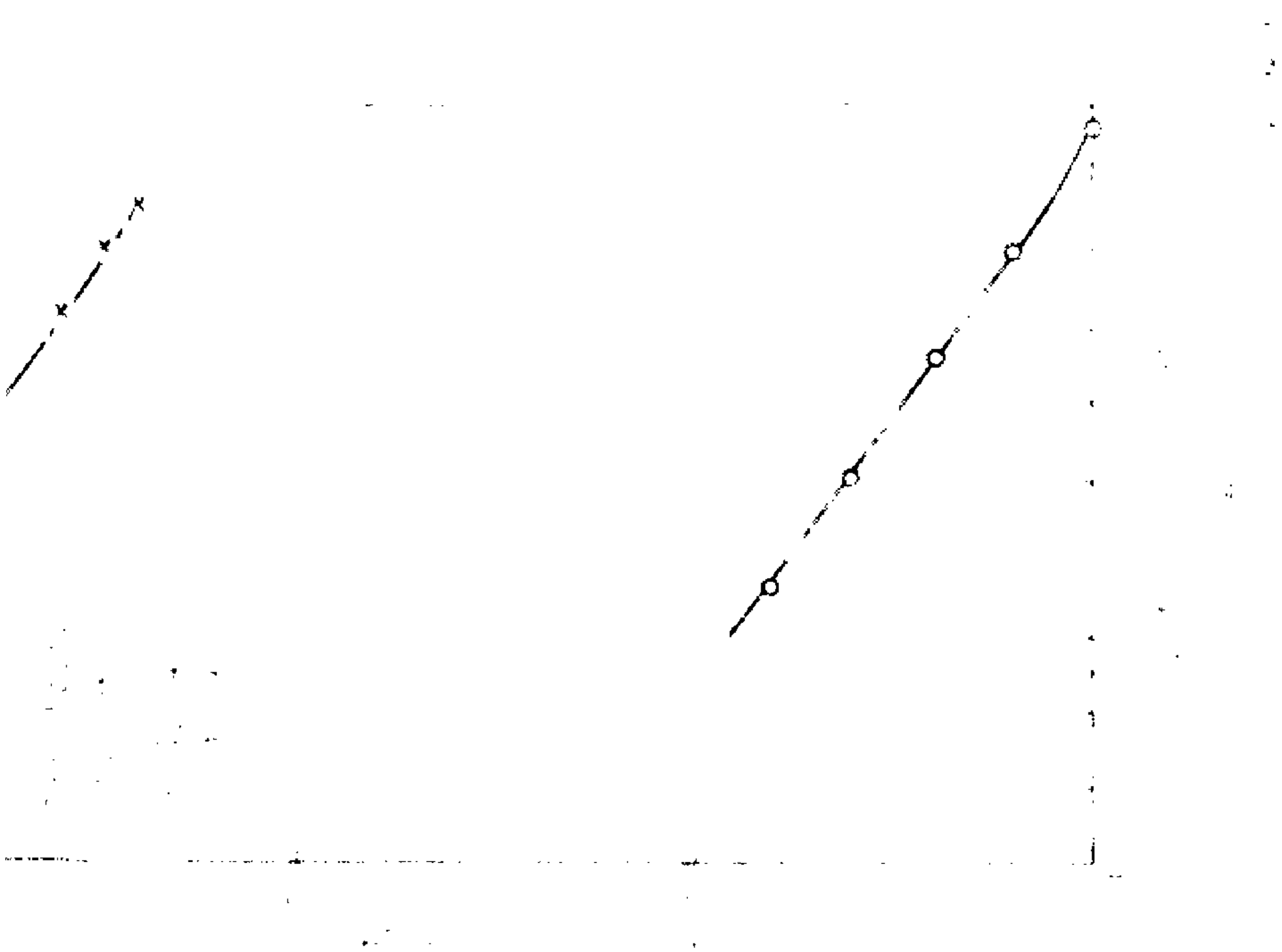


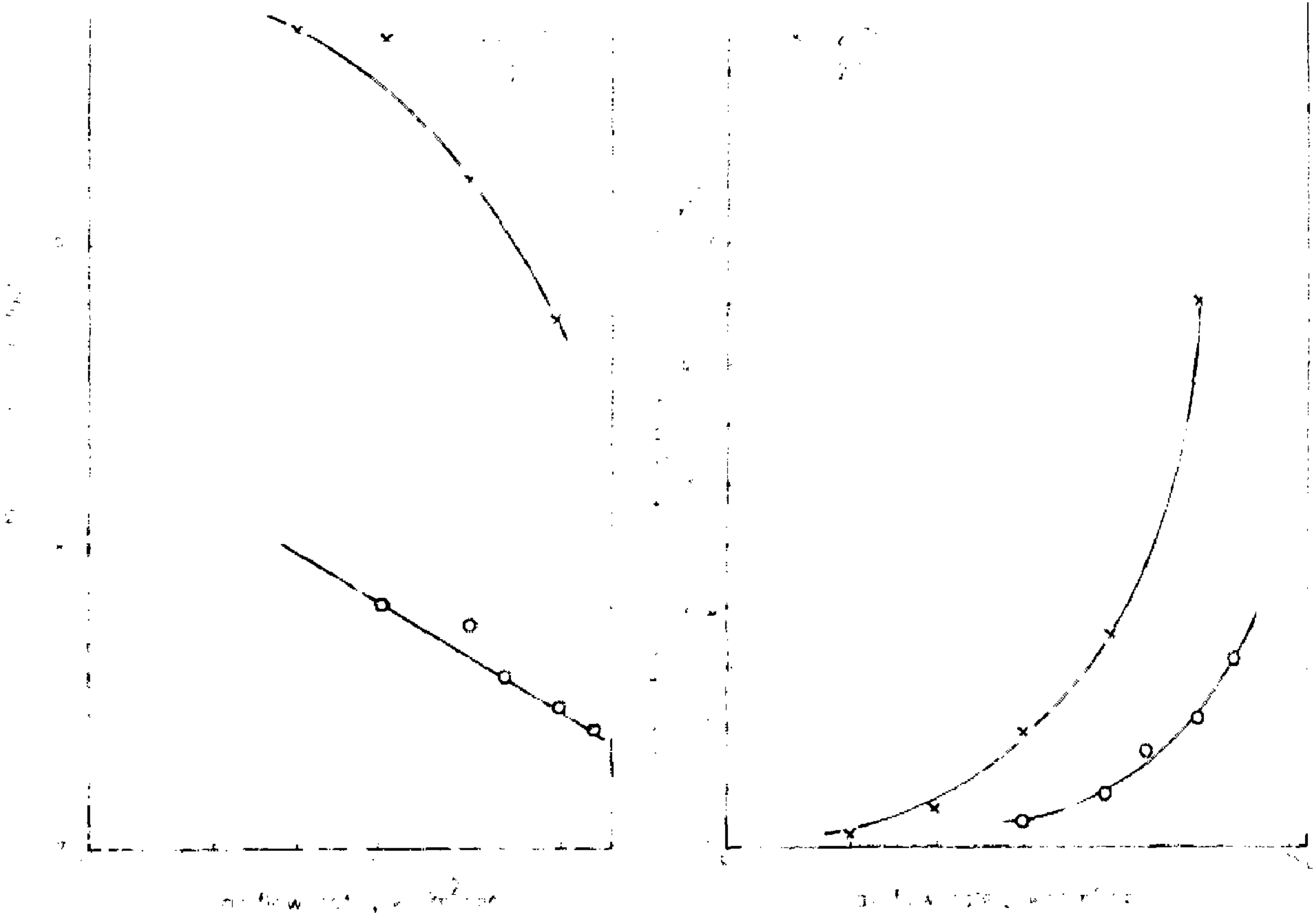












CHAPTER-VI

CONCLUSIONS AND RECOMMENDATIONS

The studies on continuous pneumetric classifier showed that the efficiency of this new classifier is better in comparision to elutriator. The major property of this unit is that it does not have any movible part and can be convently used for classifying the solid materials. The following conclusion can be drawn based on studies conducted.

(1) With introduction of baffle, percentage of fines in top product and also the ratio of top. product to the bottom product increased.

(2) at constant solids feed rate and air flow rate, as the percentage of fines in the feed increased, the ratio of the top product to the bottom product and also the percentage of the fines in the top product increased.

(3) With the increase in the ratio of the diameter of coarse to the fines the ratio of top product to the bottom product as well as the percentage of fines in the top product increased.

(4) at constant solid feed rate and air flow rate as the density of the material increased the ratio of top product to the bottom product as well as the percentage of fines in the top product increased.

(5) at constant air flow rate, as the solids feed rate increased, the ratio of the top product to the bottom product and also the percentage of fines in the top product decreased,

(6) at a constant air flow rate and solid feed rate, as the height of the stabilizing zone increased, the ratio of the top product to the bottom product increased while there was a decrease in the percentage of fines in the top product.

The values of (r_1/r_2), EF and SE can be predicted from the proposed correlation No.1,2 and 3. FURTHER experimental investigations are necessary in order to predict the performance of Pneumatic classifier, specifically to preduct over all efficiency and design of the classifier. The collection of large number of data. Using better technique of control in experimentation, various quantities like solid feed rate, Solid composition, Air flow rate, diameter of particles, position and Geometry of beffle will result a more generalized correlations. These studies can be made broadly in the following areas:

(1) Changing the location of feed point

(2) Use of different beffle geometry.

(3) Use of materials of various densities.

(4) Use of reflux of top material.

(5) Use of materials of various DC/DF

(i) Keeping DC constant

(ii) Keeping DF constant

(6) Changing Height of top exit.

(7) Use of different gases (effect of density) of gas).

and (8) Use of various diameters columns.

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APPENDIX - I

DATA TABLES

TABLE NO. 1

EXPERIMENTAL DATA

System : Air Glass beads (without baffle)

Column Dia : 70 mm

Solid feed size: Coarse = 977 micron

Fine = 460 micron

Ratio of diameter coarse to fines = 2.124

Solid feed rate = 145.76 gms/min

Percentage of fines = 58.15

RunNo.	Air flow rate gm/cm^2/min	Top Product		Bottom product	
		Rate gm/min	% of fines	Rate gm/min	% fi
1.	877.897	74.40	77.15	61.00	49.18
2.	788.412	54.70	77.15	82.71	51.64
3.	698.927	35.80	77.65	104.80	53.05
4.	609.442	24.65	78.09	123.20	56.17
5.	519.956	13.16	80.01	140.50	57.22
6.	430.471	4.60	84.78	154.40	58.04

Similarly other tables for different materials, solid feed rates, composition of feed and ratio of diameter of coars to fines with baffle at a position to give height of stabilizi zone 248mm were prepared, and are presented in Table No.. 2 to7

TABLE NO. 2

EXPERIMENTAL DATA

Column Dia (D) = 70 m.

Height of (HI) Stabilization zone = 24.8 mm.

Solid feed size (DP1) Coarse : 977 microns

(DP2) Fine : 460 microns

Ratio of diameter of coarse to fine ($\frac{Dc}{Df}$) = 2.124

Solid feed rate (WF) = 167.07 gm/min

Percentage of fines in feed (PF) = 57.86

Run No.	Air flow rate	Top Product Rate	Top Product % fines	Bottom Product Rate	Bottom Product % Fines
12	788.412	22.00	78.18	155.00	53.03
13	663.133	11.60	79.31	158.80	54.97
14	609.442	1.40	80.89	166.40	55.00
15	519.956	1.30	84.61	170.60	56.00
16	430.471	1.15	86.96	173.40	57.05

TABLE NO. 3

System : Air Glass Beads (with baffle)

Feed size DP_1 = mesh 977 micron

DP_2 = 460 micron

Feed rate WF = 120.08 g/min

PF = 49.13

Run No.	Air flow rate	Top Product		Bottom Product	
		Rate	% of fines	Rate	% of fines
17	824.206	14.60	73.97	93.00	44.95
18	788.812	12.00	74.83	102.60	45.22
19	734.721	9.10	75.82	104.80	46.99
20	698.927	5.00	77.40	112.80	48.09
21	609.442	3.35	78.21	120.20	49.10

TABLE NO. 4

System : Air glass Beads (With baffle)

Size DP_1 = 977 micron

DP_2 = 460 micron

Rate WF = 95.03

PF = 37.78

Run No.	Air Flow rate	Top Product		Bottom Product	
		Rate	% of fines	Rate	% of fines
22	824.206	8.40	72.50	82.40	31.31
23	788.412	7.00	74.28	82.80	32.37
24	734.721	2.80	75.00	91.40	33.70
25	698.927	2.10	76.19	93.00	35.27
26	609.442	2.60	77.50	100.20	37.55

TABLE NO. 5

System : Air Glass Beads (with Baffle) 4th hole

size DP_1 = - 16 + 18

DP_2 = - 22 + 25

DP_1 / DP_2 =

Rate WF = 137.83

PF = 58.10

Run No.	Air flow rate	Top Product		Bottom Product	
		Rate	% fines	Rate	% fines
27	877.897	12.90	50.00	132.80	50.90
28	788.412	10.00	52.00	134.20	52.10
29	698.927	6.20	54.03	137.20	52.75
30	609.442	2.60	56.15	139.00	53.24
31	519.956	1.45	57.93	143.00	54.62

Table No. 6

System : Air Glass Bead (with baffle)

Size DP1 = 650 micron

DP2 = 460 micron

Rate WF = 281.39

PF = 84.12

Run No.	Air flow rate	TOP PRODUCT		BOTTOM PRODUCT	
		RATE	% fines	RATE	% fines
37	824.706	60.00	85.50	250.00	78.77
38	698.927	14.20	88.52	267.00	81.25
39	663.133	7.30	90.41	274.60	82.68
40	609.442	5.90	91.19	281.20	83.00
41	519.956	4.00	93.5	283.60	83.36

TABLE NO. 7

System : Air Lime Stone (with baffle)

Size DP1 = 977 microns

DP2 = 460 microns

Rate WF = 121.70

PF = 40.88

Run No.	Air flow rate	TOP PRODUCT		BOTTOM PRODUCT	
		Rate	% fines	Rate	% fines
42	824.706	35.33	87.74	77.18	34.79
43	698.927	17.16	92.25	95.16	35.20
44	609.442	11.49	97.13	114.16	37.35
45	519.956	5.99	97.33	136.50	39.56
46	430.471	2.20	98.22	141.65	40.27

TABLE NO. 8

EXPERIMENTAL DATA

System : Air Glass beads (with baffle)

Column dia. 70 mm.

Height of stabilizing zone : 248 mm

Solid feed size: Coarse : 977 microns

Fines : 460 microns

Ratio of diameters of coarse to fine : 2.124

Percentage of fines in feed : 44.19

Air flow rate = 788.412 $gm/cm^2/min$.

Run No.	Solid feed rate gm/min	Top Product		Bottom Product	
		Rate gm/min	% fines	Rate gm/min	% fines
51	358.07	11.60	75.86	343.60	39.11
52	301.69	12.00	77.05	292.80	40.09
53	250.83	13.20	78.57	241.60	40.98
54	187.40	14.40	80.55	165.20	42.35
55	146.87	16.00	82.50	130.80	44.19

One more similar table was there at different air flow rate. equal to 116.488 $Kg/M^2/S$.

Table No. 9

56	362.69	8.75	78.86	354.20	39.64
57	298.27	9.15	78.91	292.00	41.06
58	248.31	9.95	80.30	240.00	42.21
59	191.59	11.12	81.74	181.00	43.55
60	147.22	12.50	83.20	134.25	44.96

TABLE NO. 10

EXPERIMENTAL DATA

System : Air glass beads (with baffle)

Column dia: 70 mm.

Solid size : Coarse = 977 micron

fines = 460 micron

Ratio of diameters of coarse to fines = 2.124

% fines in feed = 56.34

Solid feed rate = 127.26 gm/min

Air flow rate = 698.927 gm/cm^2/min.

Run No.	Height of Stabilizing zone mm.	Top Product		Bottom Product	
		Rate gm /min.	% fines	Rate gm/min	% fines
61	30.8	15.20	81.50	113.30	53.80
62	28.8	9.40	82.98	119.20	54.19
63	26.8	7.85	83.10	120.50	54.50
64	24.8	6.00	83.33	122.00	54.79
65	22.8	5.00	84.25	123.50	55.20
66	20.8	4.50	84.44	125.00	55.40
67	18.8	4.00	86.35	125.45	85.98
68	16.8	3.40	88.23	126.20	56.26

One more similar table is there fordifferent material and other conditions., Table No. 11

TABLE NO. 11

EXPERIMENTAL DATA

System : Air Lime stone (With Baffle)

Column Dia : 70 mm

Feed size : Coarse = 977 microns
Fines = 466 microns

Ratio of diameters of coarse to fines = 2.124

% fines in feed = 43.48

Solid feed rate = 121.92 g/min

Min. flow rate = 101.574 kg/m^2/sec.

Run No.	Height of stabilizing zone mm	Top Product		Bottom Product	
		Rate gm/m	% fines	Rate g/m	% fines
69	28.8	13.25	96.98	112.20	33.39
70	24.8	11.49	97.13	114.16	37.35
71	20.8	6.50	97.38	120.25	42.59
72	16.8	5.17	97.68	122.00	43.91

APPENDIX - II

SAMPLE CALCULATION

Sample calculations for Run No. 20, Table No. 3 are given below:

Data Given:

(1) Constant in Table :-

Density of Gas ρ_g = 1.294×10^{-3} gm/cm^3

Viscosity of gas μ_g = 1.83×10^{-4} gm/cm.sec.

Height of stabilizing zone H_2 = 24.8 cm.

Height of exit (Top) H = 41.5 cm.

Density of solid ρ_s = 2.50 g /cm^3

Friction of fines in feed XF = 0.4838

Diameter of column De Max. = 7.0 cm.

Diameter of column at Min Cross-section De Min = 6.3245 cm.

Average diameter of column in Enrichment section
De ENR = 6.6217 cm.

Average diameter of column in stripping section
De STR = 6.8809 cm.

M_A Air flow rate = 698.927 gm / cm^2/min, Solid feed rate
WF = 128.28 g/min.

(2) Variables in Table:

Diameter of coarse particle De = 9.77×10^{-2} cm.

Diameter of fine particle DF = 4.60×10^{-2} cm.

Top Product rate WT = 5.0 g/min

Bottom product rate WB = 112.80 g/min

Friction of fines in Top Product XT = 0.7740

Friction of fines in bottom product XB = .4809

CALCULATIONS

(i) Constant quantities in Calculation:

1. Solid loading ratio ' r' =

$$r = \frac{\text{solid feed rate in g/min}}{\text{Air flow rate in g/min}} = 4.7691 \times 10^{-3}$$

2. Reynold's Number Rep.

$$Rep = \frac{D\ V\ \rho_g}{\mu_g} = 4.4558 \times 10^{+5}$$

D - at maximum cross section of column

3. $\underline{Rep} = 9.3431 \times 10^{+7}$

4. Froude Group Fr.

$$Fr = \frac{D_p\ g}{U_g^2} = 5.9759 \times 10^{-1}$$

D_p : Average diameter of particles in feed based on mass friction

Ug : Linear velocity of air at minimum annular area.

5. Stabilization Factor HF

$$HF = \frac{Hi}{H} = 5.9759 \times 10^{-1}$$

6. $\dfrac{\rho_s\ \ \rho_g}{\rho_g} = 1930.9938$

(ii) Variable quantities in calculation

7. $r_1 = 1.8588 \times 10^{-4}$

8. $r_2 = 4.1938 \times 10^{-3}$

9. $\dfrac{r_1}{r_2} = 4.4326 \times 10^{-2}$

10. $Fr_1 = \frac{DP_1\, g}{Ug_1^2} = 5.9184 \times 10^{-7}$

DP_1 : Average diameter of particles in top product based on mass friction

Ug_1 : Average linear velocity in enrichment section.

11. $Fr_2 = \frac{DP_2\, g}{Ug_2^2} = 8.2238 \times 10^{-7}$

DP_2 : Average diameter of particles in bottom product

Ug_2 : Average linear velocity in stripping section

12. $\frac{De}{Df} = 2.1239$

13. Enrichment faction $EF = \frac{(XT - XF)}{XF(1-XF)} = 1.16202$

14. Stripping factor $SF = \frac{(XF - XB)}{XF\,(1-XF)} = 1.1612 \times 10^{-2}$

15. Effectiveness :

$$EFMS = \left(\frac{XT}{XF}\right)\left(\frac{XF - XB}{XT - XB}\right)\left[1 - \frac{(1-XT(XF-XB))}{(1-XF)(XT-XB)}\right]$$

$$= + 0.01576$$

```
:  MADHAV KANT*M.E. THESIS* CONTINUOUS CLASSIFICATION IN PNUMATIC
    SYSTEM * EFFECT OF R AND REN
   DIMENSION R(10),R1(10),R2(10),RT1B2(10),REN(10),REBR(10),FR(10)
   DIMENSION FR1(10),FR2(10),EF(10),SF(10),EFNS(10),IJ(10)
   READ 5, N
 5 FORMAT (I5)
   DO 100 ISET=1,N
   READ 10, RG,DC,DF,VISG
.0 FORMAT (4E15.5)
   READ 11, RS,H4,H,XF,G,DCMAX,DCMIN,DCENR,DCSTR
.1 FORMAT (9F8.4)
   DCM2=DCMAX**2
   YGM=(3.1416/4.0)*DCM2
   A50=VISG*60.0
   A51=DC*(1.0-XF)+DF*XF
   A52=(DCMAX*DCMAX)/(60.0*RG)
   A53=A52/(DCMIN*DCMIN)
   A54=A53*A53
   A55=A52/(DCENR**2)
   A56=A55*A55
   A57=A52/(DCSTR*DCSTR)
   A58=A57*A57
   A1=(RS-RG)/RG
   A2=H4/H
   A3=DC/DF
   PUNCH 12, ISET
 2 FORMAT(/20X,12HSET NUMBER =,I3/)
   PUNCH 13,A1,A2,A3
 3 FORMAT(10X,11H(RS-RG)/RG=,F10.4,5X,5HH4/H=,F7.4,5X,6HDC/DF=,F7.4/)
   PUNCH 14
 4 FORMAT(72H************************************************************
  1****************/)
   READ6,M
 6 FORMAT (I5)
   DO 50 J=1,M
   READ15, IRN,WF,AMA,WT,WB,XT,XB
 5 FORMAT (I5,6F12.5)
   AMAGM=AMA*YGM
   A10=1.0/AMAGM
   R(J)=WF*A10
   R1(J)=WT*A10
   R2(J)=WB*A10
   RT1B2(J)=WT/WB
   REN(J)=(DCMAX*AMA)/A50
   REBR(J)=REN(J)/R(J)
   FR(J)=(A51*G)/(AMA*AMA*A54)
   DAPMT=DC*(1.0-XT)+DF*XT
   FR1(J)=(DAPMT*G)/(A56*AMA*AMA)
   DAPMB=DC*(1.0-XB)+DF*XB
   FR2(J)=(DAPMB*G)/(A58*AMA*AMA)
   EF(J)=(XT-XF)/(XF*(1.0-XF))
   SF(J)=(XF-XB)/(XF*(1.0-XF))
   REC=(XT*(XF-XB))/(XF*(XT-XB))
```

```
      REJ=1.0-((1.0-XT)*(XF-XB))/((1.0-XF)*(XT-XB))
      EFNS(J)=REC*REJ
      IJ(J)=IRN
   50 CONTINUE
      PUNCH 51
   51 FORMAT(2X,2HSN,2X,6HRUN NO,6X,1HR,11X,2HR1,11X,2HR2,10X,5HR1/R2,
     1 8X,6HREY NO)
      PUNCH 60
   60 FORMAT (72H*************************************************************
     1*****************//)
      DO 53 J=1,M
      PUNCH52,J,IJ(J),R(J),R1(J),R2(J),RT182(J),REN(J)
   52 FORMAT(2X,I2,2X,I6,2X,5E13.5)
   53 CONTINUE
      PUNCH 61
   61 FORMAT (72H*************************************************************
     1*****************//)
      PUNCH 63
   63 FORMAT(2X,2HSN,2X,6HRUN NO,3X,4HRE/R,8X,2HFR,8X,3HFR1,7X,3HFR2,
     1 11X,2HEF,6X,2HSF,4X,4HEFNS)
      PUNCH 75
   75 FORMAT (72H*************************************************************
     1*****************//)
      DO 70 J=1,M
      PUNCH 72,J,IJ(J),REBR(J),FR(J),FR1(J),FR2(J),EF(J),SF(J),EFNS(J)
   72 FORMAT(X,I2,X,I6,X,4E11.4,2F7.4,E11.4)
   70 CONTINUE
      PUNCH 80
   80 FORMAT (72H*************************************************************
     1*****************//)
   )0 CONTINUE
      STOP
      END
```

```
      MAIN PROGRAM FOR LEAST SQUARE  CURVE FITTING
      PROGRAM WAS EXECUTED AT THE COMPUTER CENTRE AT SERC ROORKEE
      DIMENSIONA(15,15),X(15,100),XB(15),CO(15),Y(100),ER(100)
    2 READ1,N,M,IM
    1 FORMAT(3I5)
*
      N IS NO. OF VARIABLES  M IS NO. OF DATA POINTS
      IM =1 INDICATES RELATIONSHIP OF TYPE Y=A*(X**B)*(Z**C)
      IM=2 RELATION IS Y=A+B*X+C*Z
      READING OF DATA POINTS

    3 FORMAT(6E12.5)
      DO5 J=1,M
      READ3,(X(I,J),I=1,N)
    5 CONTINUE
      IF  IM=1 GO TO 10 , IF IM=2 GO TO 20
      IF(IM-1)10,10,20
   10 DO15 I=1,N
      DO 15 J=1,M
   15 X(I,J)=LOGF(X(I,J))
   20 AM=M
      DO 50I=1,N
      SUM=0.0
      DO 40 J=1,M
      SUM=SUM+X(I,J)
   40 CONTINUE
      XB(I)=SUM/AM
   50 CONTINUE
      PUNCH 55
   55 FORMAT( 5X, 11HMEAN VALUES//)
      PUNCH 3,(XB(I),I=1,N)
      DC 60 I=1,N
      DC 60 J=I,M
   60 X(I,J)=X(I,J)-XB(I)
      N1=N-1
      DO 65 I=1,N1
      DO 65 K=I,N
      A(I,K) =0.0
      DO 65 J=1,M
      A(I,K) =A(I,K)+X(I,J)*X(K,J)
   65 CONTINUE
      DO 70 I=2,N1
      I1=I-1
      DO 70 J=1,I1
   70 A(I,J) =A(J,I)
      PUNCH 71
   71 FORMAT( 5X, 24HCOEFFICIENT OF EQUATIONS//)
      DO 80 I=1,N1
      PUNCH 3,(A(I,J),J=1,N)
   80 CONTINUE
      CALL SIMEQ(A,N1,CO)
      COI1 =XB(N)
      DO 82 K=1,N1
      COI1 =COI1-CO(K)*XB(K)
   82 CONTINUE
      IF(IM-1)83,83,84
```

```
3 I=IT
  J=IT
4 U(I,J)=A(I,J)
  IF(IT-1)7,7,5
5 M1=IT-1
  DO6K=1,M1
6 U(I,J)=U(I,J)-U(I,K)*U(K,J)
7 IF(JT-1)8,8,10
8 I=I+1
  IF(I-N)4,4,9
9 JT=2
  GO TO 1
0 U(I,J)=U(I,J)/U(I,T)
  J=J+1
  IF(J-M)4,4,20
0 CONTINUE
  DO30 I=1,N
  DO30 J=1,M
  IF(I-J)25,27,27
5 U1(I,J)=U(I,J)
  GO TO 30
7 U1(I,J)=0.0
0 CONTINUE
  DO 35J=1,N
5 X(J)=0.0
  N1=N
0 I=N1
  X(I)=U1(I,M)
     DO45 J=1,N
5 X(I)=X(I)-U1(I,J)*X(J)
  N1=N1-1
  IF(N1-1)47,40,40
7 RETURN
  END
```