การออกแบบและศึกษาเครื่องป้อนลำเลียงวัสดุแบบไซโคลน

DESIGN AND STUDY OF CYCLONE CONVEYOR

โดย

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แผนกวิชาวิศวกรรมเครื่องกล

คณะวิศวกรรมศาสตร์

จุฬาลงกรณมหาวิทยาลัย

Design and Study of a Cyclone Conveyor

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Abstract

A cyclone occurs when the central area of air has lower pressure than the surroundings. The purpose of this research is to design a device called a cyclone conveyor which simulates the cyclonic motion of air. The vacuum created in such a device is used to convey materials. Twenty Cyclones with constant diameters of bottom-ends, inlet nozzles, suction pipes, and discharge pipes are built.

The study is divided into two parts. In the first part, the characteristic of Cyclones are investigated. For the tested Cyclones with some fixed parameters, it is found that the maximum vacuum occurs in the Cyclone at the constant Cyclone angle of 6° with different Cyclone heights and the vacuum in the Cyclone increases as the Cyclone height is decreasing.

In the second part, the Cyclones with given heights and Cyclone angles of 5 degrees are used to convey sand, cane-sugar, and tapioca. The rate of conveying increases as the Cyclone height decreases. The investigation reveals that the design system is feasible. The system, when comparing with the existing vacuum-pressure system, has greater operational flexibility and lower initial cost.

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*Thesis advisor

1 Introduction

The term "pneumatic conveyor" is commonly used to describe methods of transporting bulk materials by means of compressed air power, negative or positive. Three commercially available systems—material into airstream, air-mixing, and air into material systems—are recognizable. In the material into airstream type of system material enters a stream of air under either negative or positive pressure, or is induced into the stream of air by vacuum. A combination vacuum-pressure system which is one type of the systems based on this principle is shown in Fig. 1.[1]

The purpose of this research is to study and design a new type of pneumatic conveying system called "Cyclone conveyor". The Cyclone, simulating the cyclonic motion of air, creates vacuum which can be used to convey some kinds of material.

2 System Design

In the design of a cyclone[2], which is called, according to its function, Cyclone conveyor, it is desired that a boundary rotating air—cyclone—is divergent similarly to an inverted cone. Therefore, the design Cyclone is in the shape of an inverted cone with an apex cut at a desired bottom-end diameter to provide a space for an inlet nozzle, and suction pipe for the Cyclone. The Cyclone consists of an inlet nozzle, a suction pipe, and a discharge pipe (see Fig. 2). The principle of a pickup nozzle

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(1) Kraus M.N. Pneumatic Conveying of Bulk Materials. New York: The Ronald Press Company, © 1968.

design is shown in Fig. 3. The pickup nozzle is used to induce air and material into a negative-pressure system. In conveying of materials with large grain the nozzle in Fig. 3 a is favorable because there are a lot of voids, thus, there is no blockage at the entry of the pickup nozzle. The conveying of material with fine grains is studies in this experiment, therefore, the model of the pickup nozzle in Fig. 3 b is designed. The designed pickup nozzle is shown in Fig. 4.

The propose system of a Cyclone conveyor is shown in Fig. 5. In the operation of this system, an air compressor supplies compressed air through an inlet nozzle and into the Cyclone. The flow rate of the compressed air is comtrolled by a pressure regulator. The expansion of the compressed air in the Cyclone causes a cyclonic motion of air. The cyclonic motion of air produces a vacuum in the Cyclone, Air and material are then induced by the vacuum through a pickup nozzle and a suction line into the Cyclone. The remain power of the compressed air conveys air and material through the discharge pipe and discharge line to the Cyclone receiver.

The differences between the system of Cyclone conveyor and the combination vacuum-pressure system, Fig. 1, are: The Cyclone is used to produce vacuum for the vacuum system instead of the exhauster. The remaining power of the compressed air is used for conveying material into the pressure system instead of supplying by the blower. In addition, this system does not need the cyclone receiver of the vacuum system to separate material

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[2] The word "Cyclone" is capitalized when it is mentioned as the conveyor to distinguish it from the other meanings.

supplied to the pressure system. Thus the system of Cyclone conveyor contains less moving parts and machinery.

3 Experimental Investigation

Twenty Cyclones with variable Cyclone angle and height are built. The bottom-end diameter, the diameters of the inlet nozzle, the discharge pipe, and the suction pipe are kept constant at 75 mm, 4.9 mm, 26 mm, and 11.43 mm respectively in order to reduce the number of variables. The Cyclone angle are varied at 0,5,10,15, and 20 degrees with constant Cyclone heights. At each constant Cyclone angle the Cyclone heights are varied at 7.5,15,30, and 45 cm respectively.

The first stage of experimentation is to study the vacuum produced in the Cyclone. The schematic diagram for this test is shown in Fig. 6. The experimental results give Cyclone characteristics, when the Cyclone angles and Cyclone heights are varied , as shown in Fig.7 to 23. The maximum vacuum in Cyclones with different Cyclone heights occurs approximately at the Cyclone angle 6^{o}. Several of the tested Cyclones— with Cyclone angles of $5^{o}$and $10^{o}$and Cyclone heights 7.5 cm and 15 cm, create a minimum suction air greater than 55 per cent of compressed air supplied.

In the last stage a few Cyclones, which are likely to convey a greater amount of materials, are used to convey sand, cane-sugar, and tapioca. The schematic diagram for this test is shown in Fig.24. The results are shown in Fig.25 to 27. The smaller of the Cyclone heights, the greater rate of conveying of material will be obtained. It is seen that the characteristic curves are similar. Thus, the characteristics of Cyclones are not changed by different conveying materials.

4 Discussion and Conclusion

In designing a Cyclone, the Cyclone angle and height should be 5° and 17 cm respectively. But for a smaller Cyclone, Cyclone angle of 10° can be more efficient. It has been found out that the Cyclone conveyor used as a new variation of pneumatic conveyors is feasible. In comparision of the system of the Cyclone conveyor with the combination vacuum-pressure system, there are the following advantages. First of all it does not need a Cyclone separator including a rotary feeder to supply material for the pressure system. In addition, the Cyclone can be arranged conveniently. For a plant having an air compressor with sufficient capacity, a blower is not necessarily provided. Besides, a Cyclone can be easily made and is also portable. Therefore, the system of Cyclone conveyor has lower initial cost and greater operational flexibility. However, more study on this system should be preceeded as follows:

(1) In order to establish the design criteria of the optimum suction pipe, the pressure distribution of air at the bottom-end of the Cyclone with defferent diameters must be

studied.

(2) Study the inlet nozzle diameters with various sizes at a constant rate of flow of the compressed air supplied. The effect of changes in compressed air velocity on the vacuum produced in the Cyclone will be obtained.

(3) Study the effect of changes in discharge pressures on the vacuum produced in the Cyclone. The study will yield design criteria for the length of the suction line and the length of the discharge line.

(4) Design a Cyclone conveyor system on a large scale to compare its performances with other pneumatic conveying systems.

(5) The system of the Cyclone conveyor has a less dense stream of material in the discharge line than in the suction line. The rate of flow of air in the discharge line is greater than in the suction line by the amount of compressed air supplied. The discharge part of the system may be modified to convey a denser stream of material. Thus, a discharge line equipped with a material feeder should be studied.

(6) On the theoretical side, relationships between the vacuum produced in the Cyclone and its independent variables should be analysed.

(7) Since the Cyclone with 7.5 cm Cyclone height give results differing from the results of Cyclones with greater heights, an experimental study of Cyclones with very small heights should be investigated.

(8) Study the effect of changes in compressed air supplied at a constant pressure on the vacuum produced in the Cyclone. The results of the study may give information on the type of the blower suitable for the system.

(9) Study the Cyclone generating from the other curves revolves about the cone axis.

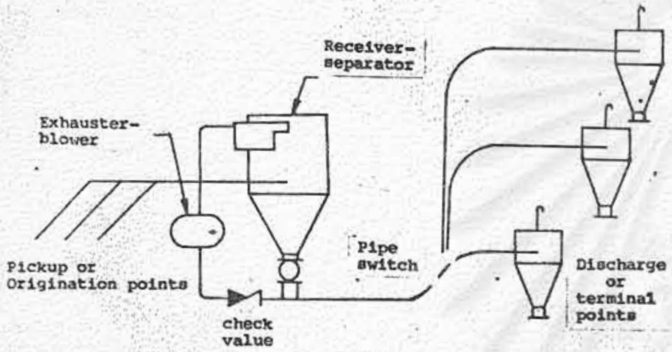

Fig. 1 COMBINATION VACUUM-PRESSURE SYSTEM USING

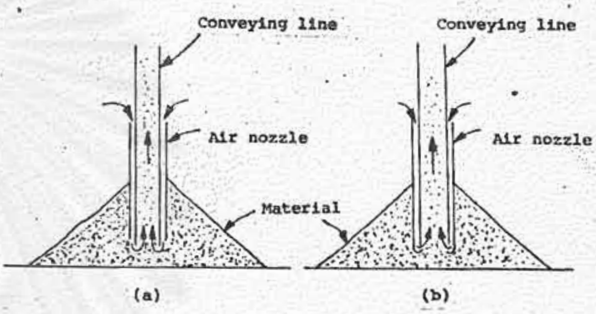

Fig. 3 PICKUP NOZZLE DESIGN

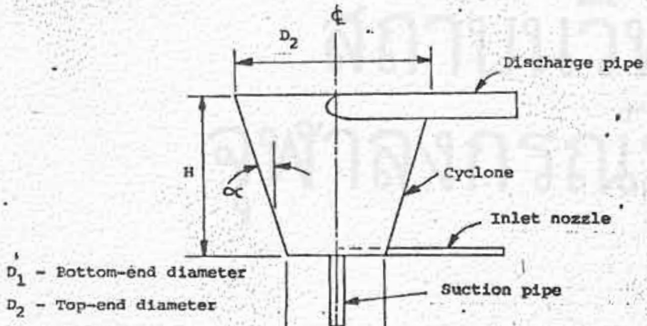

Fig. 2 A CYCLONE

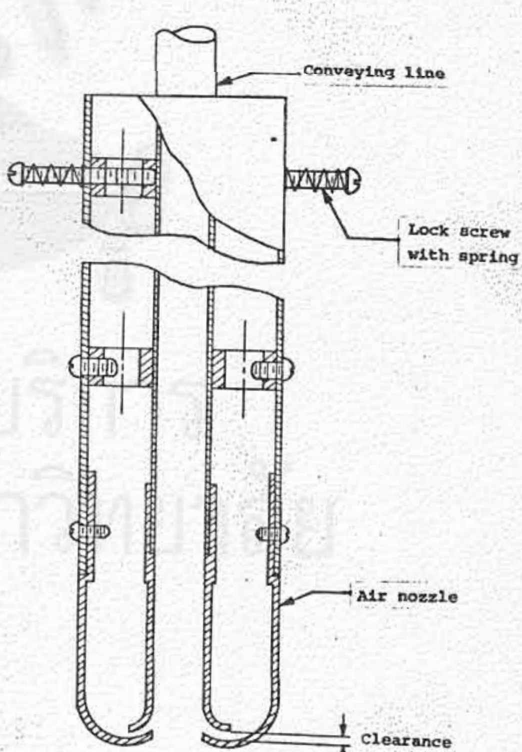

Fig. 4 SECTION VIEW OF PICKUP NOZZLE

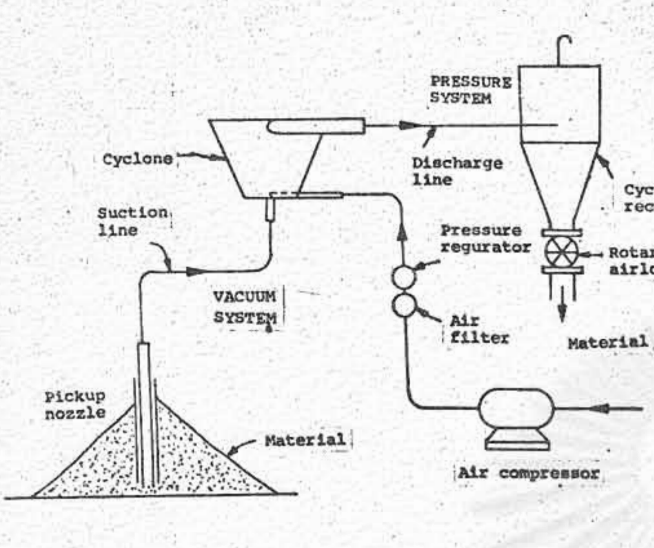

Fig. 5 SYSTEM OF A CYCLONE CONVEYOR

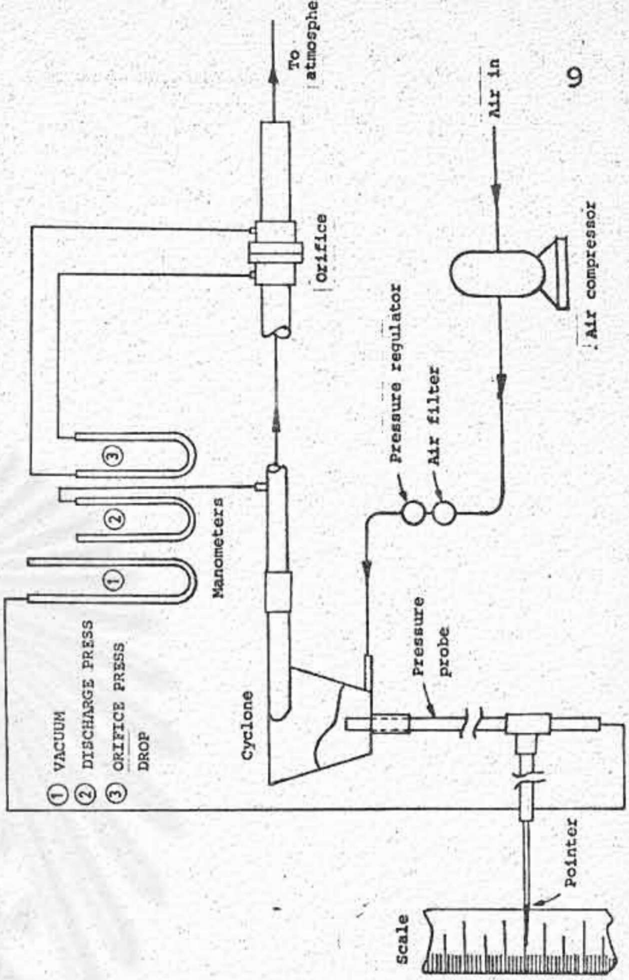

Fig. 6 SCHEMATIC DIAGRAM OF MEASUREMENT OF VACUUM IN CYCLONE

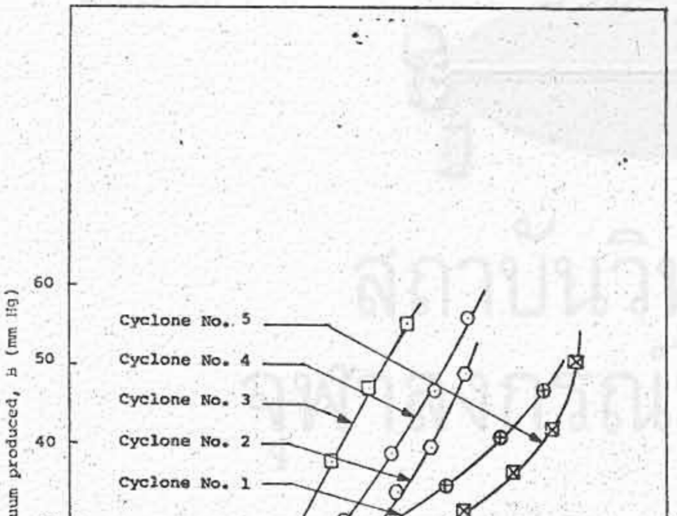

Fig. 7 VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLES AND CYCLONE HEIGHT, H = 7.5 cm

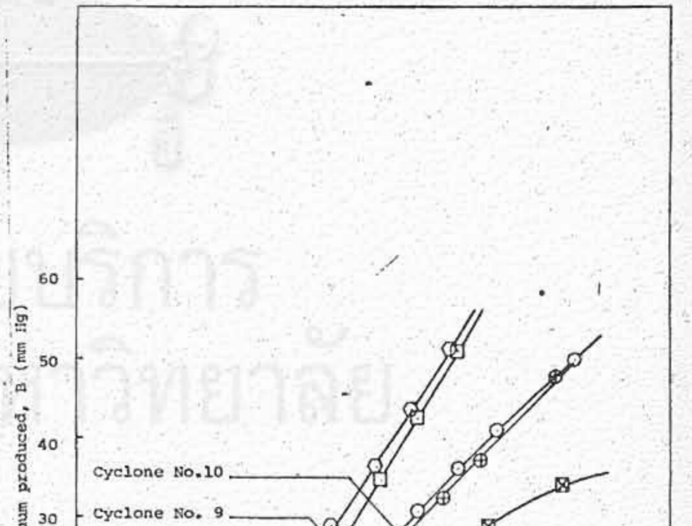

Fig. 8 VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, H = 15 cm

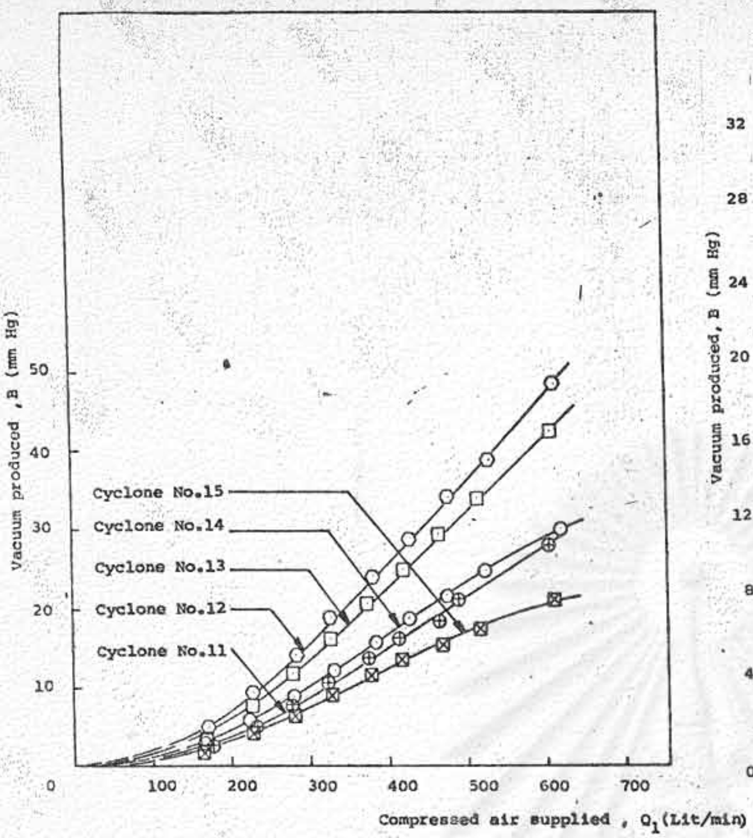

Fig. 9 VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT H = 30 cm

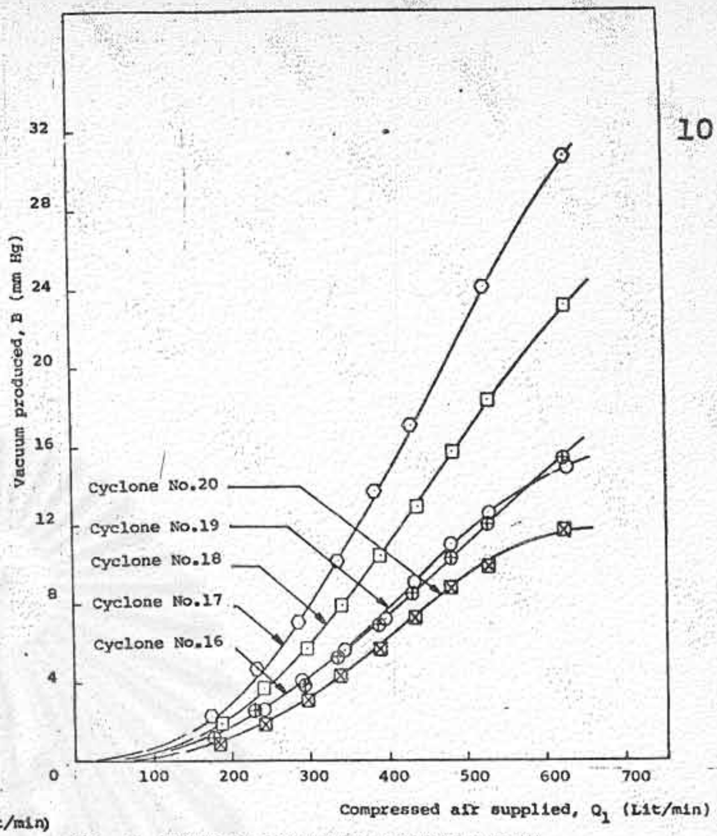

Fig. 10 VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, H = 45 cm

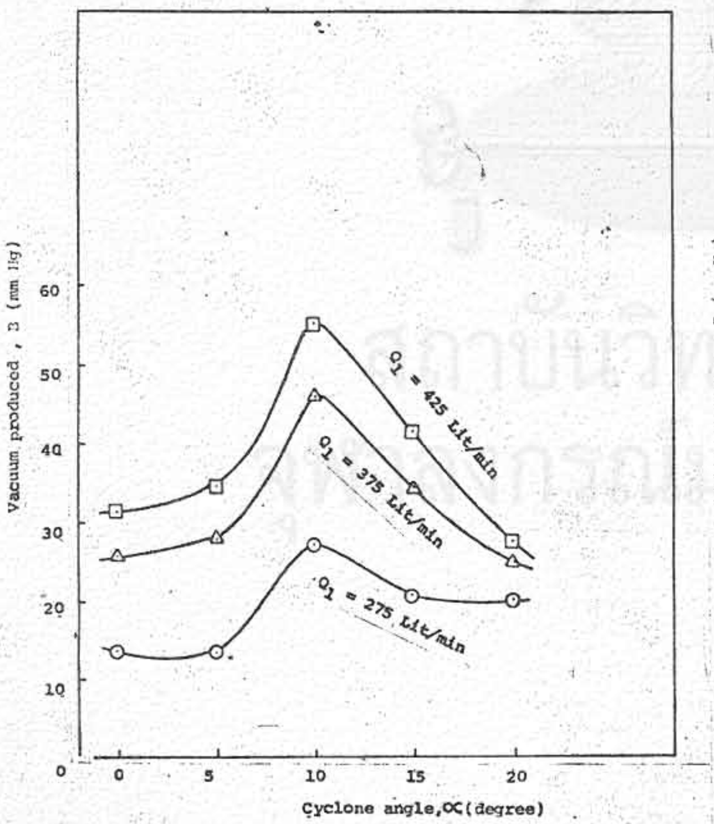

Fig. 11 MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT , H = 7.5 cm

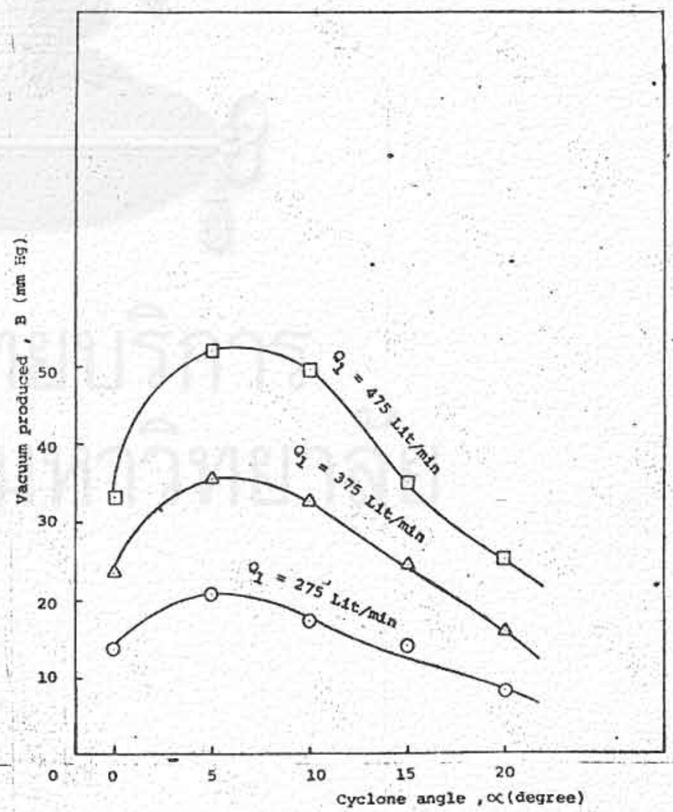

Fig. 12 MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT , H = 15 cm

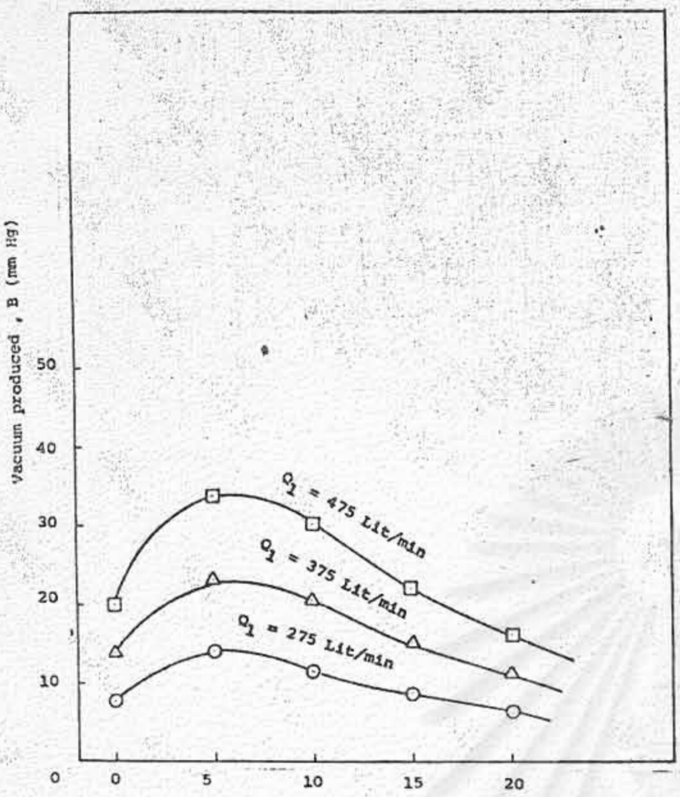

Fig. 13 MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT , H = 30 cm

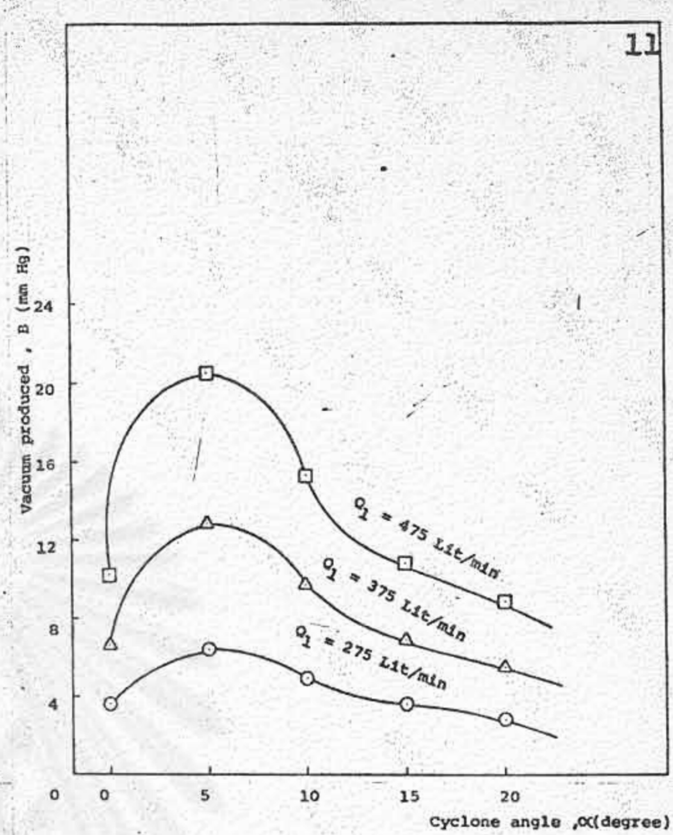

Fig. 14 MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT , H = 45 cm

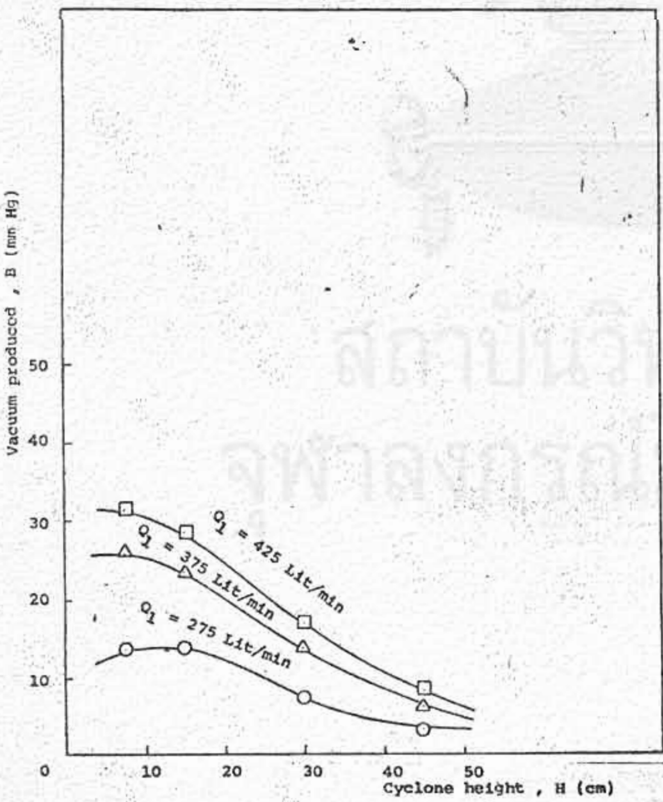

Fig. 15 VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE , $\alpha = 0^{\circ}$

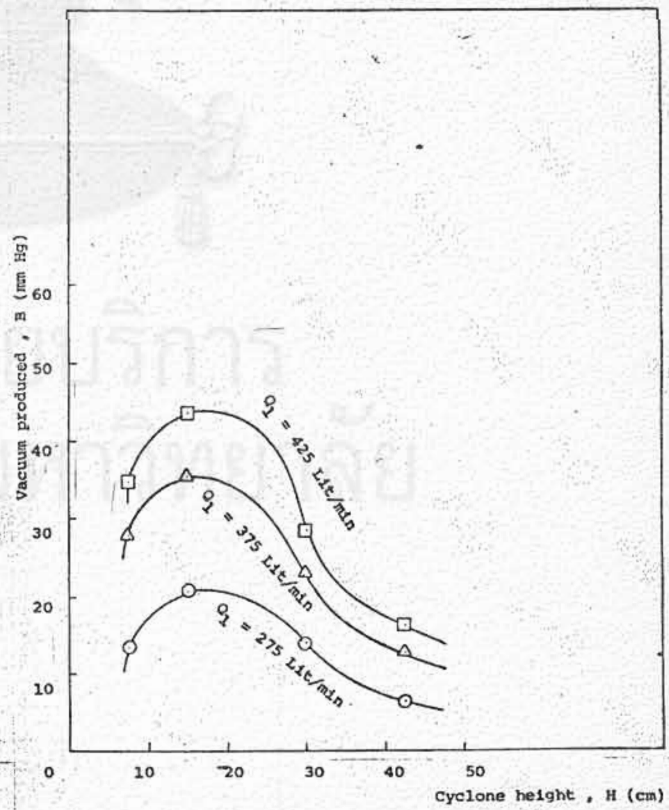

Fig. 16 : VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE, $\alpha = 5^{\circ}$

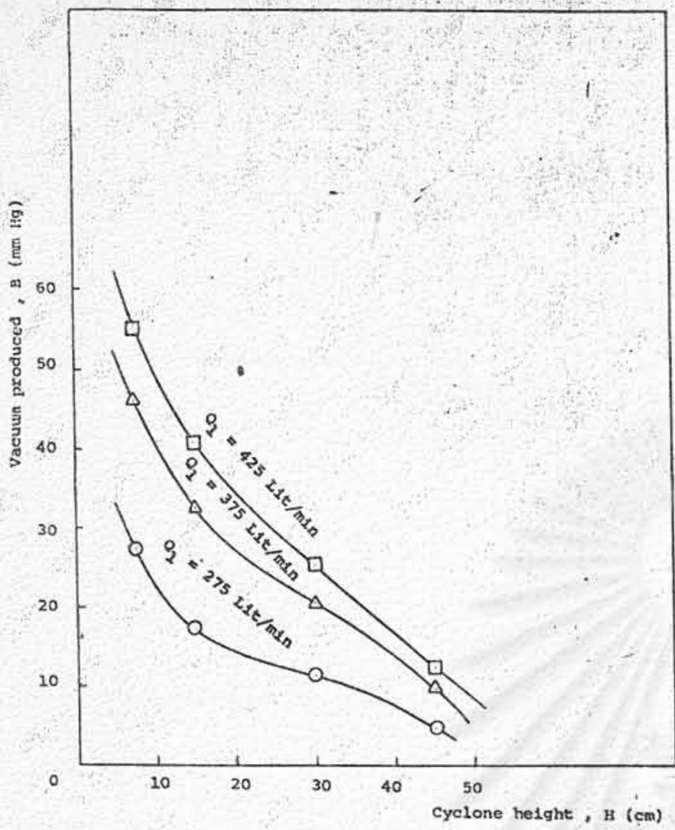

Fig 17 VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE , $\alpha = 10^\circ$

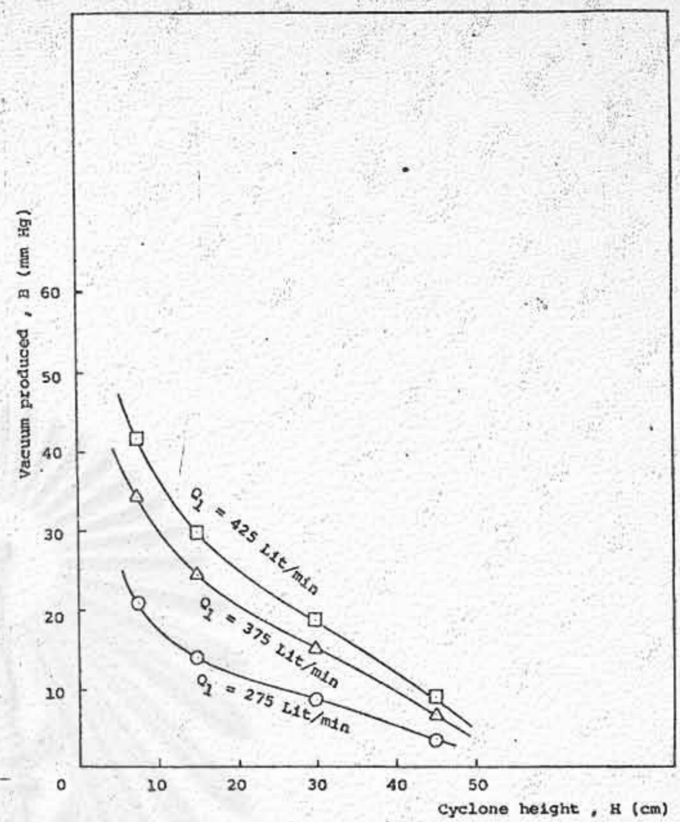

Fig. 18. VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE , $\alpha = 15^\circ$

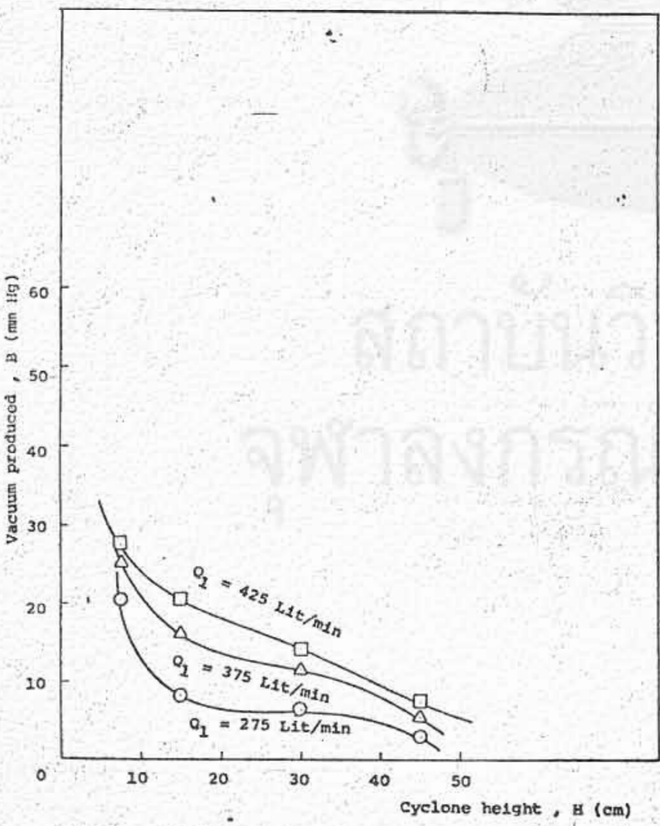

Fig. 19 VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE $\alpha = 20^\circ$

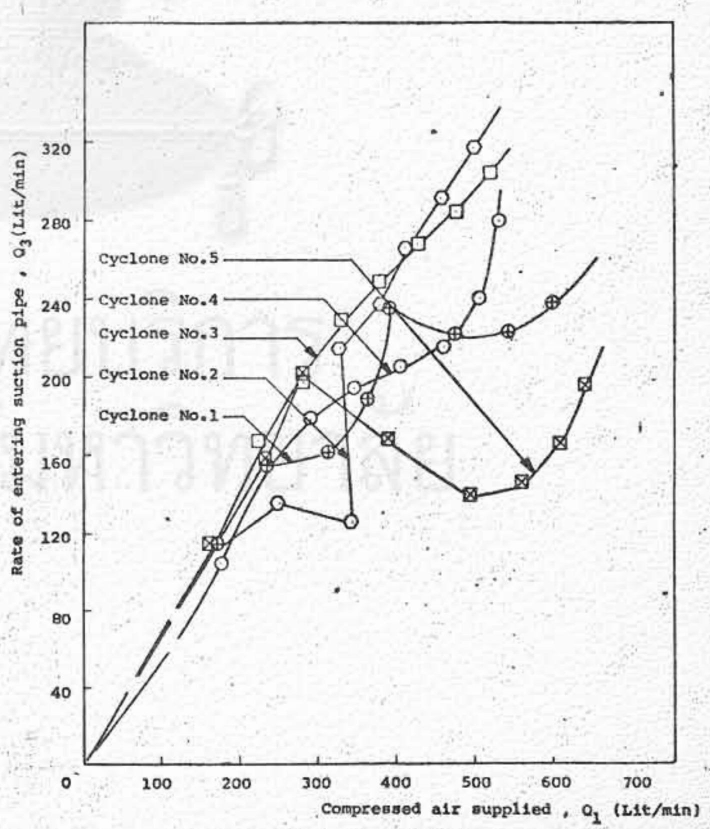

Fig. 20 RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT , H = 7.5 cm

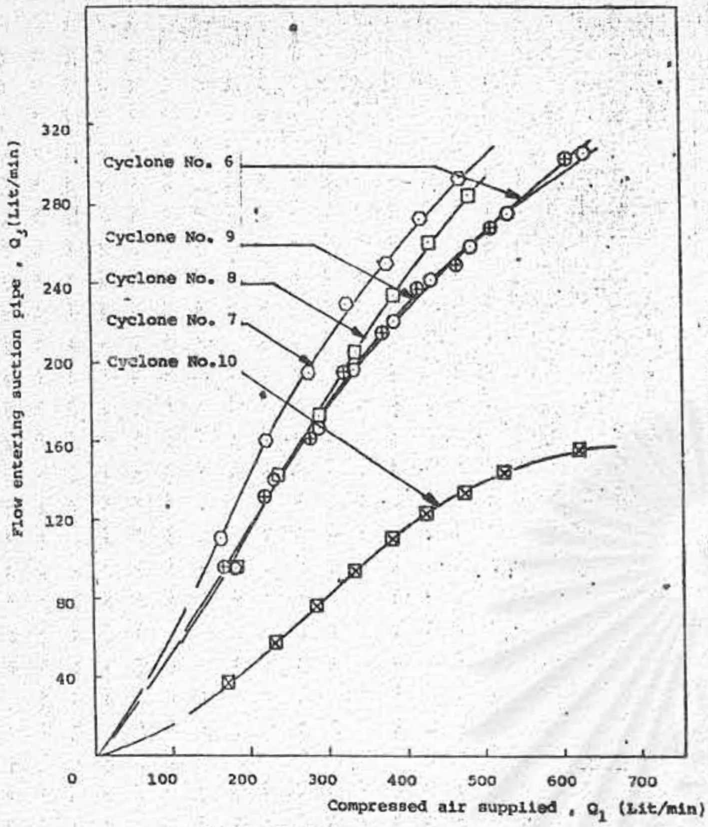

Fig. 21 RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, H = 15 cm

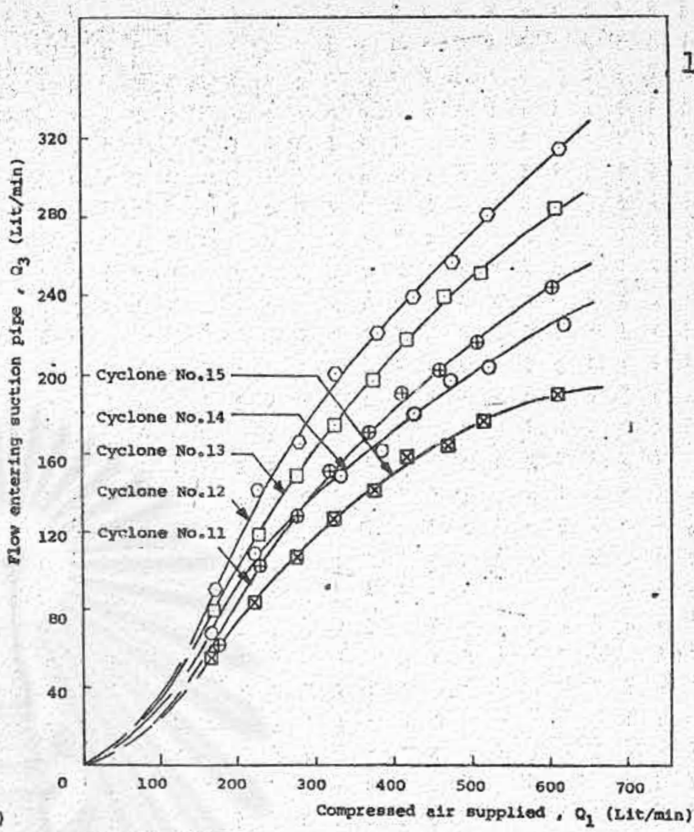

Fig. 22 RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLE AND HEIGHT, H = 30 cm

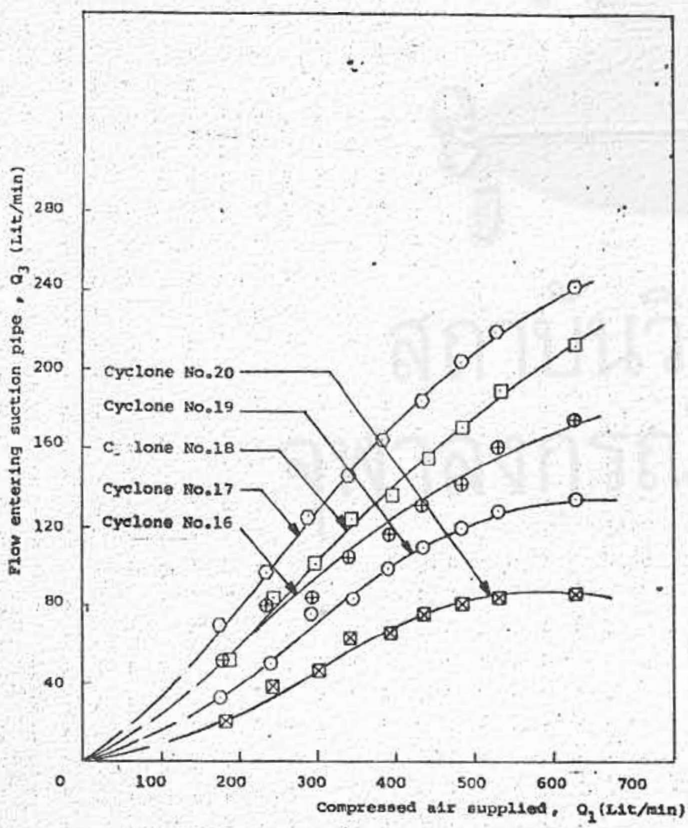

Fig. 23 RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT , H = 45 cm

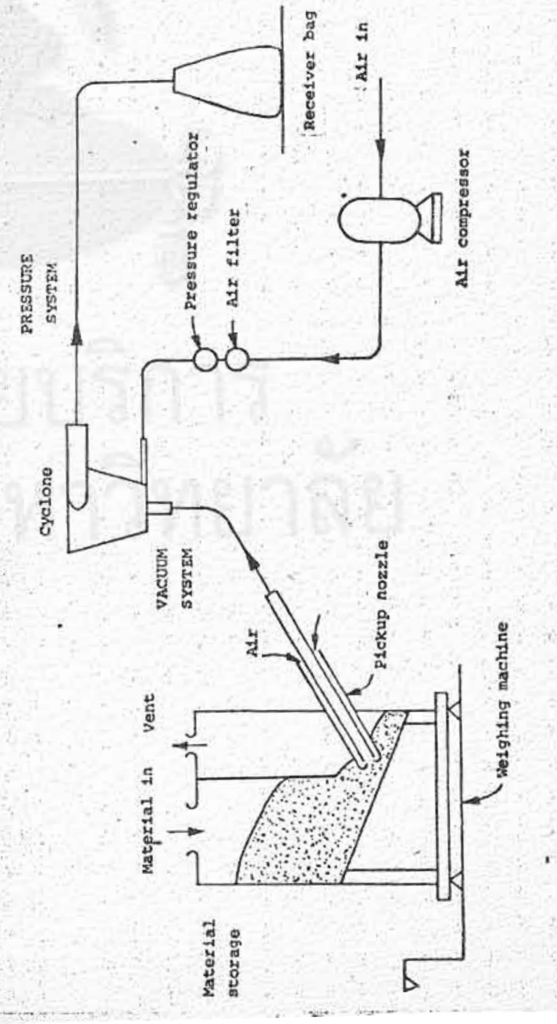

Fig. 24 SCHEMATIC DIAGRAM OF CONVEYING OF MATERIAL TEST

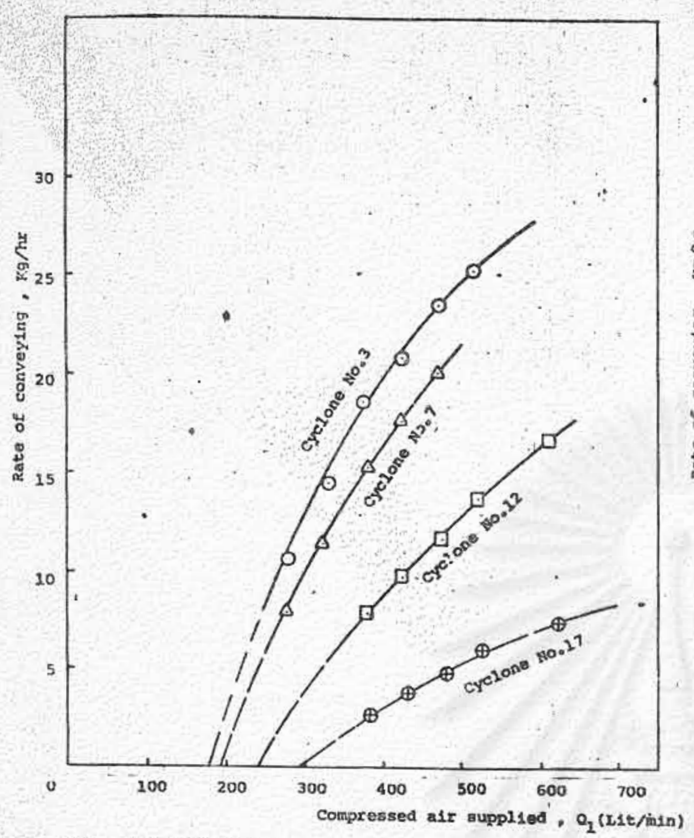

Fig. 25 CONVEYING CAPACITY OF CYCLONES

(FOR CONVEYING OF SAND)

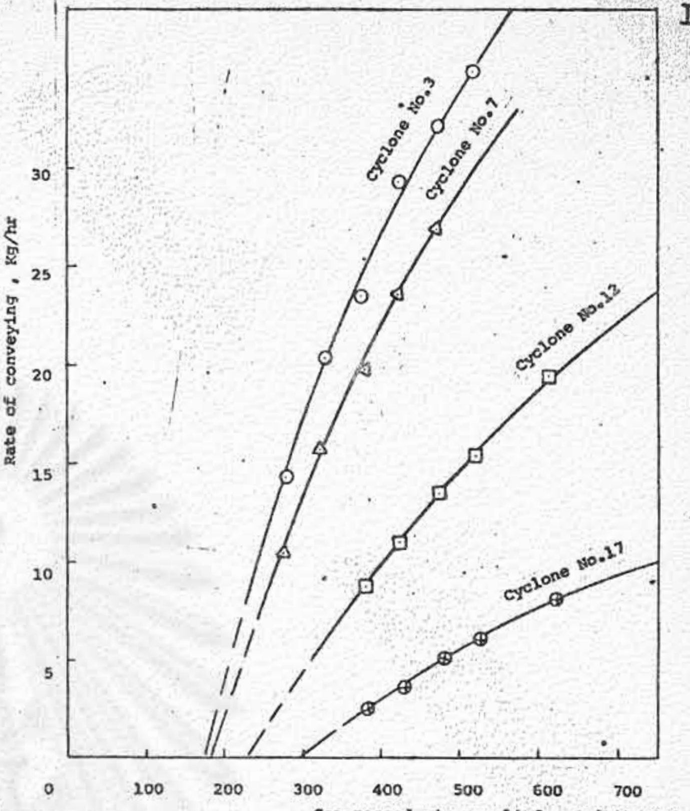

Fig. 27 CONVEYING CAPACITY OF CYCLONE

(FOR CONVEYING OF TAPIOCA)

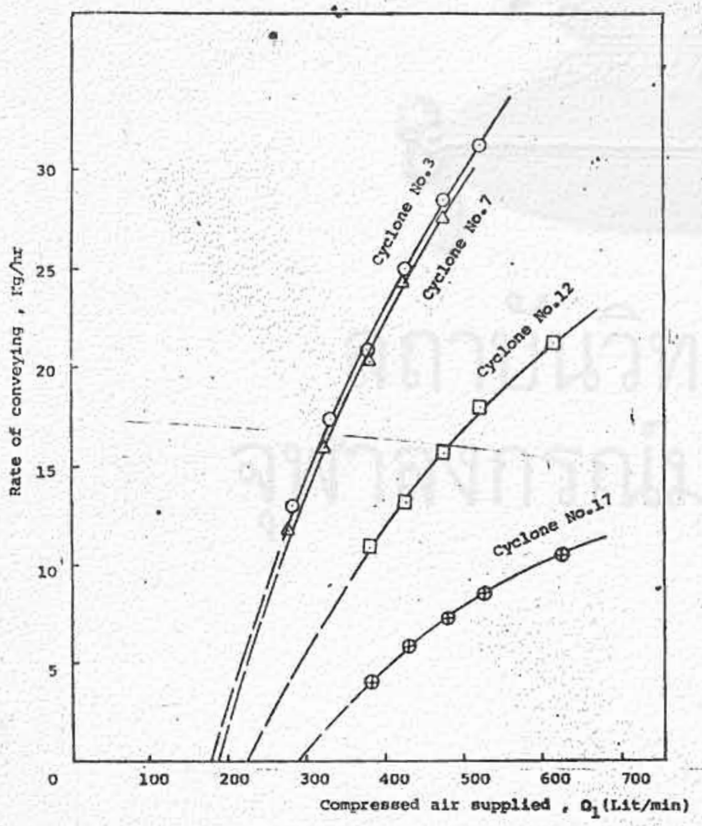

Fig. 26 CONVEYING CAPACITY OF CYCLONE

(FOR CONVEYING OF CANE-SUGAR)

Appendix

DIMENSIONS OF CYCLONES

Cyclone no.	H (mm)	D_1 (mm)	D_2 (mm)	α (Degree)
1	75	75	75.0	0
2	75	75	88.0	5
3	75	75	102.0	10
4	75	75	115.0	15
5	75	75	130.0	20
6	150	75	75.0	0
7	150	75	101.2	5
8	150	75	128.0	10
9	150	75	155.4	15
10	150	75	184.2	20
11	300	75	75.0	0
12	300	75	127.5	5
13	300	75	181.0	10
14	300	75	236.0	15
15	300	75	293.0	20
16	450	75	75.0	0
17	450	75	154.0	5
18	450	75	234.0	10
19	450	75	316.0	15
20	450	75	401.0	20