Affectionately dedicated to
my beloved Dada, Aai
and Jyoti
with love and respect

Dayanand

PERFORMANCE EVALUATION OF CENTRIFUGAL FLOW MIST BLOWER FOR GRAPE VINEYARD

By

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B.TECH.(AGRIL.ENGG.)FIRST CLASS WITH DISTINCTION

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
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for the degree
of

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in

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DEPARTMENT OF FARM MACHINERY AND POWER
FACULTY OF AGRICULTURAL ENGINEERING
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CANDIDATE'S DECLARATION

I hereby declare that of the thesis entitled PERFORMANCE EVALUATION OF CENTRIFUGAL FLOW MIST BLOWER FOR GRAPE VINEYARD, or the part thereof has not been submitted by me or any other person to any other university or institute for a degree or diploma.

Place : Rahuri

Dated : 17/7/93

DAYANAND D. TEKALE

CERTIFICATE

This is to certify that the thesis entitled **PERFORMANCE EVALUATION OF CENTRIFUGAL FLOW MIST BLOWER FOR GRAPE VINEYARD".** submitted in partial fulfillment of the requirements for the degree of Master Of Technology in Agricultural Engineering (Farm Machinery and Power) of the Mahatma Phule Agricultural University, Rahuri, is a record of bonafide research work carried out by **SHRI TEKALE DAYANAND DEVIDASRAO** under our guidance and supervision. The subject of thesis has been approved by the student's Advsory Committee.

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(DAYANAND D. TEKALE)

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
bhp	Brake horse power
cc	Cubic centimeter
Fig.	Figure
hp	Horse Power
kmph	Kilometer per hour
l/ha	Liter per hectare
l/min	Liter per minute
ln	Natural logrithon
um	Micro meter
ucc	Micro cubic centimeter
No./sq.cm.	Numbers per square centimeter
rpm	Revolution per minute
rps	Revolution per second

ABSTRACT

PERFORMANCE EVALUATION OF CENTRIFUGAL FLOW MIST BLOWER FOR GRAPE VINEYARD

by

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Grape (*vitis vinifera L.*) is a worldwide popular fruit due to its taste and fruit of juicy nature. This grape crop is more susceptible to pests and diseases as such normally needs 20-25 applications of insecticides or pesticides in a year.

The conventional methods of spraying in grape vineyard are time consuming and labour intensive. Moreover, proper spray volume deposition and penetration are not obtained. To overcome these drawbacks, the present studies were undertaken to evaluate the performance of existing air carrier sprayers and to redesign a suitable one to meet the requirement. The laboratory studies revealed that blower of type 'A' is suitable for the grape vineyard. However its efficiency was found to be only 12.43 per cent leading to redesign it to give more efficiency. The field performance studies of type `A' blower indicated that proper spray deposition and penetration could be obtained at travel speed of 2 kmph and at the system pressure of 10.5 kg/cm^2.

(150 pages)

Introduction

CHAPTER 1

INTRODUCTION

Over the past 30 to 40 years Agricultural Engineering and Sciences have contributed lion's share for improvement in agricultural production throughout the world. The standard of living in most parts of the world, both 'developed' and 'developing' has risen largely as a result of more assured food supplies. In the developing country like India, food production is not sufficient to fulfil the requirements of its population. Most of the countries' food production is lost due to pests and diseases because they are predominant factors responsible for reduction in fruit and crop yields. Pests not only reduce the yield of fruits and crops but also lower the quality. Thus to use the pesticides and insecticides through improved plant protection techniques is the only solution to save the food production.

India occupies the pride of place in respect of the wide range of fruits grown. Horticulture covers about 6 per cent of the total cropped area. Perennial horticultural crops account for 4.4 million hectare area. The Grape (Vitis Vinifera L.) is one of the most important remunerative horticultural crops. Its per hectare income is probably the highest among all the horticultural crops.

According to Muchrikar (1989) India is the leading country producing grape in the world. The area under grape in India is about 24000, hectares with more than 5,00,000 tonnes of production. This involves marketing turnover of Rs. 300 crores in which Maharashtra state's share is almost one third. The other major grape growing state in India are Aandhra Pradesh, Tamilnadu, Karnataka, Haryana, Punjab, Uttar Pradesh and Rajasthan.

In Maharashtra, area under grapes is 8,800 hectares with more than 1,60,000 tonnes of production. Thus, Maharashtra occupies about 36 per cent of the total area under grape in India. The important grape growing districts in Maharashtra are Sangli, Nasik, Solapur, Pune, Ahmednagar, Osmanabad and Beed.

Spraying is one of the most important operations in plant and crop protection from the point of view of pests and diseases control. There are mainly two methods of spraying conventional and air carrier spraying method. In orchards and vines, it is difficult to spray the pesticide uniformly and efficiently throughout the tree by conventional method of spraying, specially in grape vines. It is difficult to use the conventional method of spraying due to its bushy leaves and method of planting. For grapes generally 20 to 25 sprayings per year are required to control the pests and diseases. Being time consuming labour intensive and nonuniform the conventional method of spraying is not suitable to control the pests and diseases on the grape vines. Air carrier sprayer provides good coverage consuming very less water, time and labour hence suitable for spraying the grape vines.

The sprayers which use air as a carrier for spraying chemicals are called as "Mist Blowers". It employs a blower to deliver an air blast of sufficient discharge and velocity. Spray fluid is introduced into this air blast in the form of fine droplets.

In air carrier spraying system centrifugal and axial flow blowers are used. The centrifugal flow blowers are suitable for small height plants where as axial flow blowers are suitable for large height plants which gives large air discharge with lower pressures and centrifugal blower gives lower air discharge with greater pressure which is suitable for orchards of small height like grape vines. For this centrifugal flow blower is selected for air carrier sprayer used for spraying grape vines.

The performance of an air carrier sprayer depends upon air flow rate and its velocity, liquid flow rate and its pressure, forward travel speed of sprayer as well as prevailing atmospheric conditions like wind velocity, humidity and temperature. No suitable centrifugal flow mist blower sprayers are available in market for grape crop.

In the light of above discussion there is an urgent need of the suitable spraying system for grape vines. With a view to design suitable air carrier sprayer system for spraying grape vines, the project is undertaken at ASPEE RESEARCH INSTITUTE, Bombay with the following objectives.

General Objective

To study the performance of an air assisted spraying system for grape vine.

Specific Objectives

1. To study the performance of the existing centrifugal flow mist blowers in the laboratory.
2. To evaluate performance of the same blower outside the laboratory in open air.
3. To measure the performance of an air assisted spraying system in the field.
4. Based on the above studies to redesign the blower suitable for grape crop.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

In order to fulfil the objectives set for present studies, it is necessary to know cultural practices and pest control methods for grape. In view of this, following sections are incorporated in this chapter.

1 Grape Crop,
2 Need to control pests,
3 Control of pests,
4 Technique and equipment used to pest control,
5 Air carrier sprayer,
6 Air sprayer jet theory,
7 Spray volume,
8 Orchard sprayers and
9 Operational technique for air carrier sprayer

2.1 Grape Crop (Vitis Vinifera L.)

The grape is one of the most important horticultural crops of the world. The world production of grape exceeds that of any other fruit crop. The grape fruit is utilised in many ways such as preparation of grape wine, raisins, juice canning and for table purposes. Bose (1986) quoted the following information regarding grape crop.

2.1.1 Climate

The grape requires long warm to hot dry summers and cool winters. Under humid summer conditions vines do not grow well.

2.1.2 Soil

Grapes can be grown on a variety of soils ranging from gravelly sand to clay loam and shallow to very deep. The best suited soils are sandy loam that are well drained and fairly fertile with good amount of organic matter. Heavy clay, wet and low lying soils should be avoided. The grape is moderately tolerant to salinity and alkalinity but excessive lime is harmful.

2.1.3 Varieties

There are about 10,000 varieties of grape in the world. Varieties are mainly seeded and seedless. In India seeded varieties are Anabe-shahi, Bangalore purple, Bhokri, Champa, Champion, Chema sahebi, Early muscat, Gold, Gulabi, Kali sahebi, Pandhari sahebi etc. Seedless varieties are Beauty seedless, Thompson seedless, Pusa seedless, Sharad seedless, Kishmish beli, Perlette, Cordinal etc.

2.1.4 Propagation

Main two methods of propagating grapevines are sexual and asexual. The sexual method is employed chiefly for evolving new varieties through hybridisation. In asexual method vines are multiplied by vegetative parts such as branches, buds, cans etc. Among these ,propagation by hard wood cutting, budding, grafting, layering and tissuculture is commonly done.

2.1.5 Spacing

There are different plant to plant and row to row spacings adopted for grape vines. Some preferred spacings are 3m x 3m, 2m x 2m, 3m x 2m.

2.1.6 Pests

There are different 50 pests found attacking grapevine and its fruit in different grape growing regions of the world. Insects constitute the major population of pest. However sometimes mites, nematodes, honeybees and birds also constitue the important pests.

2.1.7 Diseases

Grapes are susceptible to a number of diseases mostly caused by fungus. There is more spread of diseases under humid summer conditions. Disease like powdery mildew develops well in dry climate. Diseases which commonly occur in India are anthrachose, downy mildew, powdery mildew and dead arm.

2.2 Need to Control Pests

Matthews (1979) pointed out that pests were man's chief competitors on the earth. They fed on his crop and some of his possessions. They transmited diseases to him and his domesticated animals. Organisms that had become pests often included insects, fungi, bacteria, viruses, weeds, nematodes, rodents and birds. In agriculture alone the losses caused by pests were enormous. It was reported that on an average, about one third of the potential agricultural production in the world was annually lost to the pest.

Patel (1988) estimated that, percentage contribution of damage due to weeds, diseases, insects, rodents, birds, and others as 33, 26, 20, 6-8, 2-1, and 1-3 respectively.

2.3 Control of Pests

The control of pests or diseases can generally be achieved by natural control and control practices applied by man.

Matthews (1984) summarised and reported following methods to control the pests.

1. Physical control : Physical removal of barriers, traps and enviornmental manipulation.
2. Cultural control : Crop rotation, cropping system, crop spacing, trap crop, tillage etc.
3. Plant resistance : Immunity, resistance, tolerance etc.
4. Biological Control: Parasites, predators, viruses, bacteria, Fungi, protozoa, nematodes etc.
5. Genetic Control : Male sterile technique, hybrid sterility, chromosomal translocations etc.
6. Chemical Control : Pesticides, insect hormones, and pheromones etc.
7. Electrical Control: Electrical circuits for pest repeltion and irradication.
8. Integrated Control: Any combination of either of the above methodologies.

Chemical control of plant diseases and pests is the most popular technique because it gives quick results.

2.3.1 Chemical control

Chemical control is highly complex subject the application of chemicals to seed, soil and growing crops depends upon the epidemology of disease and the characteristics of the pesticide to be used.

It is applied for the pathogens on the aerial parts of plant which spread rapidly. Apart from choosing the correct pesticide, problems relating to placement and timing are particularly critical in chemical control of diseases.

2.4 Technique and Equipment used for Pest Control

It is observed that proper technique needs to be adopted for the dispersal of chemical and proper equipment is to be selected for applying the various types of chemicals with a view to achieve the required coverage.

Sastry (1985) listed the following spraying techiques with corresponding equipment used.

	Spraying Technique	Name of Equipment
1.	High volume spraying	Knapsack hand compression sprayer
2.	Low volume spraying	Knapsack motorised mist blower
3.	Ultra low volume spraying	Fog air mist-blower with restrictors.
4.	Fogging	Swing fog machines
5.	Elecrodyne Spraying	Electrodynamic sprayers.
6.	Herbicide spraying	Knapsack sprayer with flat fan nozzle.
7.	Dusting	Hand rotary or power duster
8.	Grannule application	Grannule spreader or grannule applicator
9.	Wet dusting	Sprayer cum duster

The effective application of pesticide requires high standards of performance of the equipment used. There are four essesntial factors in pesticide application that should be followed in order to obtain effective application. They are

1. Selection of suitable equipment
2. Selection of suitable pesticide
3. Correct timing of application
4. Proper training of personnel

Ultra low volume spraying technique using mist blower is a common practice for vineyards and commonly called as air carrier sprayer.

2.5 Air Carrier Sprayer.

As the name implies, an air carrier sprayer utilizes an air stream to carry the droplets, rather than depending upon energy from hydraulic pressure. The air stream must be sufficient to carry the spray liquid into the tree or plant canopy. The air velocity should be sufficient to impinge the spray droplet and able to perform effectively during light wind.

2.5.1 Classification of air carrier sprayers

Pesticide sprays are commonly classified on the basis of total volume of pesticide applied per unit of ground area. Spray volume categories also vary for different types of crop structures.

Matthews (1979) gives classification based on spray volume and droplet size as given in Table 2.1 and 2.2.

Table 2.1 classification of sprays according to volume used per unit area.

Spray classification	Volume applied, l/ha	
	Row and field crops	Tree crops
1. High Volume (HV)	> 600	> 1000
2. Medium Volume (MV)	200 - 600	500 - 1000
3. Low Volume (LV)	50 - 200	200 - 500
4. Very low volume (VLV)	5 - 20	50 - 200
5. Ultra low volume (ULV)	< 5	< 50

Table 2.2 Classification of spray based on droplet size

Spray Category	Volume median diameter of droplet (um)
1. Aerosol	< 50
2. Mist	51 - 100
3. Fine Spray	101 - 200
4. Medium Spray	201 - 400
5. Coarse Spray	> 400

Reten (1985) classified the sprayers based on air discharge rate and pressure applied to the pump for required velocity as given in Table 2.3.

Table 2.3 classification based on air discharge rate and pressure for required velocity.

Type of Machine	Air Discharge Rate (m^3/min)	Pressure at Pump (kg/cm^2)
1. Low Volume Low Pressure	425	7
2. Low Volume High pressure	425	7 - 42
3. Medium Volume Low Pressure	425 - 850	7
4. Medium Volume High Pressure	425 - 850	7 - 42
5. High Volume Low Pressure	> 850	7
6. High Volume High Pressure	> 850	7 - 42

2.5.2 Factors Affecting the Performance of Air Carrier Sprayer

The effectiveness of an airblast sprayer depends upon its ability to displace the air in all parts of the tree with spray-laden-air from the machine. The performance of an air carrier sprayer depends upon the travel speed, wind velocity and humidity of air etc.

Jogerson (1970) compared, two sprayers with same horse power but different discharge velocities and air flow rates. He advised to use the lowest air velocity needed at the outlet with the highest air flow.

Randall (1971) investigated the effects of air volume and pressure, ground speed and wind velocity on the uniformity of distribution of spray material. He suggested that a velocity of 44 km/hr of air blowing at the edge or canopy of apple tree was needed to reduce the projected leaf area to 40 per cent of its original area and allowed the spray to penetrate the canopy.

Reichard et al (1977) showed that air velocity developed by three orchard sprayers decreased as the tractor travel speed increased and velocity diminished rapidly with the increasing distance from the outlet. Air velocities increased at lesser rate for sprayer delivering higher discharge rate.

Osborne (1982) reported that as compared to forward curved centrifugal fan, the backward curved blade centrifugal fan gave more discharge with less head developed. He also stated that the number of blades should have been between 6-16 for backward curved and 30-60 for forward curved blade impeller. The outlet vane angle recommanded by him 10° to 50 ° for backward curved and 120° to 160° for forward curved impeller.

Brazee et al (1985) used a computer model to study the effect of a cross flowing wind on an air sprayer jet. The model could be used to predict the ambient wind velocities that were safe for operation of air carrier sprayers.

Samson (1987) studied the effect of number of blades, blade curvature, outlet blade angle of centrifugal blower on its performance. He found that the discharge increased with increasing blade angle from 120° to 140° and 140° to 160°. The blower discharge increased rapidly by changing number of blades from 20 to 24. Also forward curved blades were better than radial blades.

Murthy (1988) studied the effect of the distance between impeller tip to the cut-off point on the centrifugal blower performance. He tested various casings in the laboratory. He found that the blower performance deteriorated with the increase in impeller tip to cut off distance.

Unhale (1990) studied the rectangular outlet and annular outlet casing centrifugal blower for air carrier sprayer. Performance of both the blowers depended upon impeller speed, discharge, total pressure and power input increased with increase in speed. Both sprayed the whole tree, uniformly and efficiently covering front as well as back sides of leaves.

2.6 Air sprayer jet theories

Fox et al (1982) developed two equations for power in a sprayer air jet. The power in air jet from two Orchard sprayers was measured and compared with power calculated by these equations. In the main region of the sprayer, the measured power was 30 per cent less than ideal power. In the main region of the other sprayer jet, measured power was within 5 per cent of ideal power for most of the velocity profiles measured.

Brazee et al (1984) represented air sprayer jet by means of turbulent jet theory. They developed equations which gave air velocities at any point in the air sprayer jet as function of outlet configuration. The results obtained from these equations were later compared with those obtained by measuring the lateral and axial air velocity profiles, in the air jet produced by two orchard air carrier sprayers.

2.6.1. Droplet size distribution and spray deposition from air carrier sprayer.

The size of spray droplets produced by the air carrier sprayer influences the pest control. The effectiveness of the sprayer depends upon its ability to produce even distribution of droplet size and their impingement on the upper as well as lower side of the leaves.

Potts (1946) studied that in a particular air stream droplets of 60-80 µm diameter were carried 46m distance, while the larger droplets 200-400 µm travelled only 6-12m. This factor was particularly important when projecting spray vertically upwards into a crop canopy. Gravity affected the trajectory of the large droplets, increasing fall out which resulted in considerable wastage of pesticide on the ground as well as increasing the risk of operator contamination.

Anonymous (1961) studied and described a technique used for nozzle droplet studies. In that technique use of water soluble dye mixed with water which made droplets readily visible, when the sample was collected and allowed to dry when a round spot was formed on the collection plate where each droplet impacted.

Fleming (1962) studied two air streams of identical horse power but with 200um and 100um droplets. He observed the finer spray droplets were transported to a greater distance than coarse droplets. The coarse sprays were carried better in high velocity low volume air streams where as fine sprays were carried in equal amount by both streams.

Reichard et al (1977) studied the droplet size delivered by different atomizers on three types of sprayers. All atomizers produced a wide range of droplet sizes, but some delivered a much greater proportion of large droplets than others. Nearly all of the droplet sizes were distributed in either of two small size classes (7.5 - 22.5um and 22.5 - 37.5um).

Akesson and Yetes (1979) reported that as the air transported the spray droplets, those were not needed to be large in order to carry them through air. The diameter would be of the order of 400um to 600um VMD for hydraulic machines and down to 150um to 200um VMD for low liquid volume air carrier application.

Carpenter et al (1983) studied an air blast sprayer designed for row crops. He found that 70um to 100um is the upper limit for air transport particles. The spray deposition decreased logarithmically beyond the general region of the maximum deposits.

Salyani et al (1986) studied deposit efficiency of different droplet sizes for citrus sprayer with an objective to identify optimum droplet size deposition on citrus leaves. The results obtained indicated higher deposition for droplet size range around 400um.

Matthews (1992) stated that the term mist blower should be restricted to those sprayers which produced droplets in the range 50-100um. Air assisted sprayers were particularly useful when spraying large targets such as trees and had replaced the expensive and time consuming use of hand held lance in orchards.

2.7 Spray Volume

Spray volume is the amount of pesticide required for spraying the plant.

Turnstall et al (1961) recommended spray volumes based on height of cotton plant. They proposed that for plants less than 30cm in height, 56 l/ha of spray volume should be applied and for each subsequent increase in height of 30cm, the volumes were to be increased by 56 l/ha up to a maximum of 230 l/ha.

Matthews (1973) suggested that spray volume should be calculated based on the recommended droplets per unit leaf area and the effective droplet size.

Patel (1984) compared the hand compression sprayer with knapsack in the control of cotton pest complex. He developed equation for spray volume as a function of weeks after germination for cotton spraying.

$$Y = 24.310\,x - 40.30 \qquad \text{.......... 2.1}$$

where

Y = spray volume, l/ha

X = weeks after germination

Jose (1987) developed following equation for determining spray volume.

$$V = LAI \times DDt \times Fs \times Vvmd \times 100/pc \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 2.2$$

where

V = spray volume, l/ha

LAI = Leaf area index

DDt = Theoretical droplet density, No./sq.cm

Fs = Factor of safety

Vvmd = Volume of droplet of vmd size

pc = useful volume per cent

The present useful volume is the ratio of volume deposited on leaves to total volume multiplied by 100.

Sudhakar (1988) suggested two equations to determine the spray volume based on Jose's (1987) findings.

$$LAI = 1.51617 \times 10^{-4} x h^{1.96845} \ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

$$\ln (vs/2.5) = 1.431152709 + 0.131080763 \ln (LAI) \ldots\ldots\ldots\ldots\ldots 2.4$$

where

LAI = leaf area index

h = plant height, cm

vs = spray volume, cc

2.8 Orchard Sprayers.

Reichard et al (1982) developed experimental orchard sprayer for use with self propelled base unit. Pesticides were metered with variable displacement metering pump at the proper rate regardless of travel speed and were mixed with water in line to the nozzles. The operator could transfer pesticide from the shipping containers to compartment on the sprayer and flush the containers, compartment and also pumps by operating electrical switch of control panel provided on the sprayer.

Kashyap (1989) developed an orchard air carrier sprayer to spray mango orchard. He tested the blower of the sprayer to determine air discharge, outlet velocity, power consumption and efficiency. Later, they constructed two air carrier sprayers S1, S2 and tested them in the field. They found that the sprayer S1 was not suitable for spraying mango crop, while S2 gave good deposition when operated close to the tree. It was also found that the combination of rectangular and annular outlet blower performed better than the combination of the two annular outlets.

2.9 Operational Technique for Air Carrier Sprayers.

Anonymous (1983) reported the operational technique in cross wind and head and tail wind. When prevailing cross wind was so high that coverage on the up winds became problem. Up wind row should have been favoured in driving path. When the wind velocities were so high that the spray pattern was bent and coverage was not complete. It should have been spread at right angle to the wind. He also gave driving path when air carrier sprayer covering one row per pass from one side and air carrier sprayer covering two rows per pass.

Theoretical Considerations

CHAPTER III

THEORETICAL CONSIDERATIONS

This chapter explains the theoretical considerations involved in the process of designing the blower for air carrier sprayer, testing of blower in the laboratory and field testing of air carrier sprayer.

The first and second sections deals with the air carrier sprayers and centrifugal blower respectively. Design of centrifugal blower is dealt with in the third section and the laboratory testing of the blower is described in the fourth section. The terms used in the test are explained in the last section.

3.1 Air carrier sprayer

An air carrier sprayer is a sprayer which utilises air as a medium for carrying and breaking up the pesticide solution into a spray of fine mist and depositing it on the target.

An important part of the air carrier sprayer is the blower, which can truly be called as it's heart. There are mainly two types of blowers i.e. centrifugal and axial flow blower. The centrifugal blower gives lower discharge at greater pressure whereas axial flow blower gives large discharge at lower pressure.

The theoretical considerations for designing of centrifugal flow blower is explained below.

3.2 Centrifugal Blower.

A centrifugal blower is defined as a turbo machinery which increases the pressure energy of air or gas by centrifugal action. Whirling action is imparted to the fluid by means of the blades mounted on the disc known as an impeller. The centrifugal blower essentially consists of impeller mounted on the rotating shaft enclosed by a casing and a prime mover to supply power to rotating shaft. Parts of a commonly available blower are shown in Fig. 3.1.

Air or gas enters the impeller axially near the shaft and has energy both kinetic and potential, imparted to it by the varies in the form of velocity or pressure. As air leaves the impeller at a relatively high velocity, it is collected in a passage which may be a volute or a series of diffuser or simply a circular passages. This passage gradually decreases its velocity, as area increases towards outlet thus converting the kinetic energy into pressure at the outlet.

3.2.1. Inlet to blower

It is the opening through which the air enters the impeller. It is also called inlet cone. It is optional and if present it helps in properly guiding the incoming air.

3.2.2 Impeller

It is the rotating element that transfers energy to the fluid. It consist of the vanes or blades mounted on a disc. This impeller is mounted on the hub which in turn is keyed with the rotating shaft.

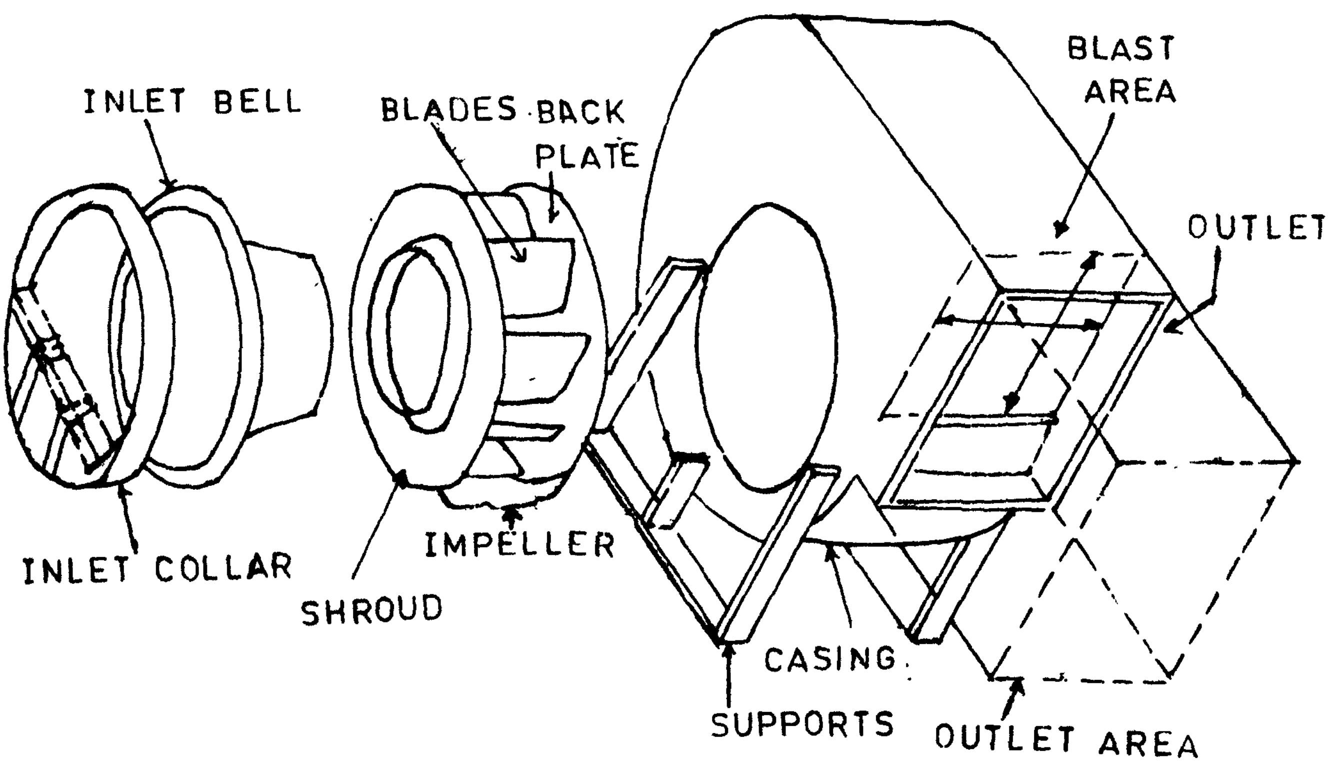

FIG. 3.1 PARTS OF CENTRIFUGAL BLOWER

The velocity of the particle relative to the ground is called absolute velocity and the velocity relative to the impeller is called relative velocity. These velocity triangles at impeller inlet and outlet of a centrifugal blower are shown in Fig. 3.2.

As shown in Fig. 3.2 the air approaches at radius r_1 with some absolute velocity V_1 and enters with relative velocity W_1, at an angle β_1, known as inlet angle. This air passes along the blade, leaving it with a relative velocity W_2, at the impeller outer radius r_2, where the angle made by the vane to the periphery is β_2, known as blade outlet angle. The absolute leaving velocity of the air V_2, will depend on W_2 and the impeller peripheral velocity $U_2 = W \times r_2$. The tangential components of absolute velocities V_1 and V_2 are Vu_1 and Vu_2. Whilst the radial component of absolute velocities are Vm_1 and Vm_2 respectively.

On the basis of outlet vane angles β_2 the impeller is classified into three types.

1. Forward curved blade $\beta_2 > 90°$
2. Radial blade $\beta_2 = 90°$
3. Backward curved blade $\beta_2 < 90°$

The velocity triangles for these three types of impellers are shown in Fig. 3.3.

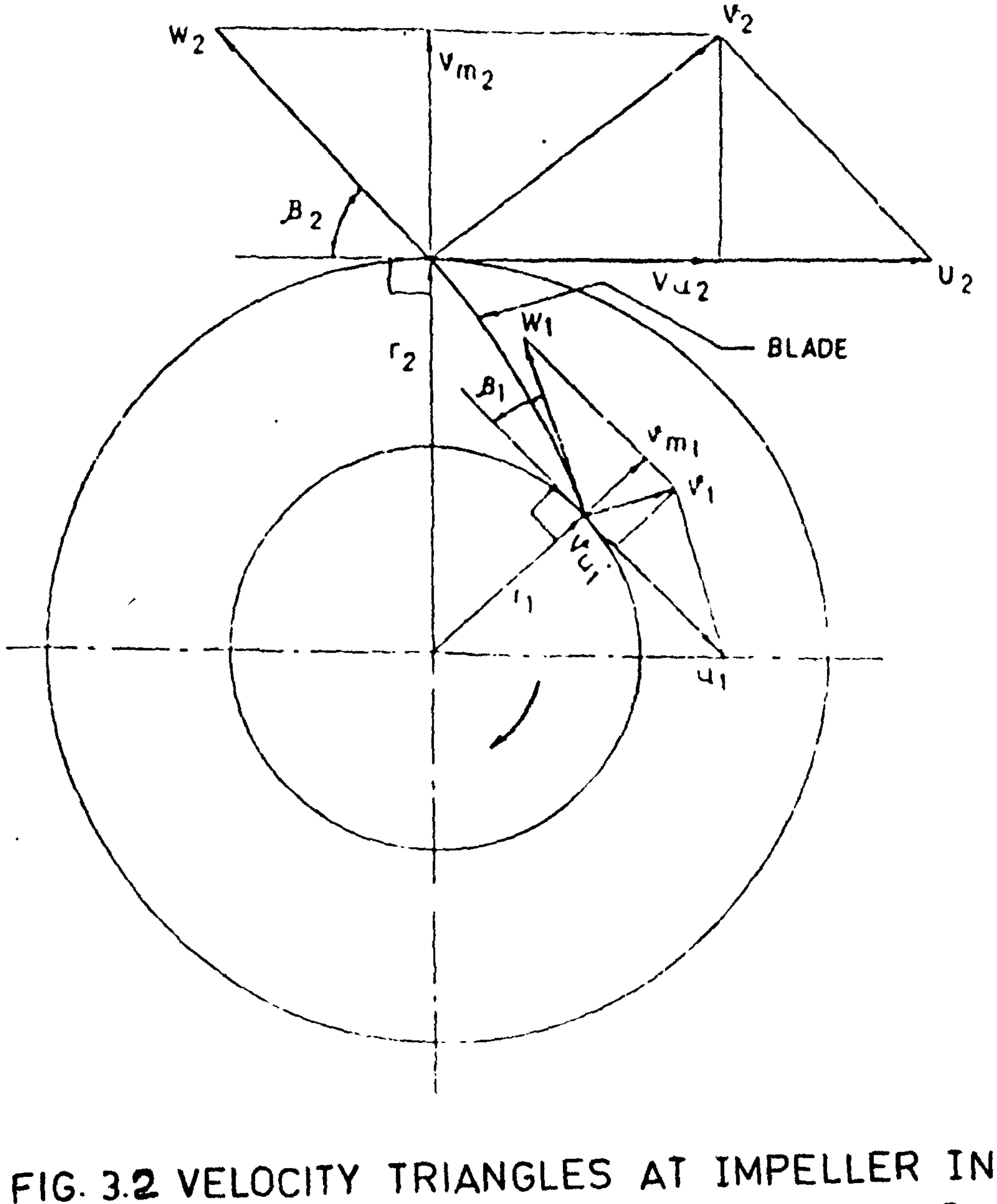

FIG. 3.2 VELOCITY TRIANGLES AT IMPELLER INLET AND OUTLET OF A CENTRIFUGAL BLOWER

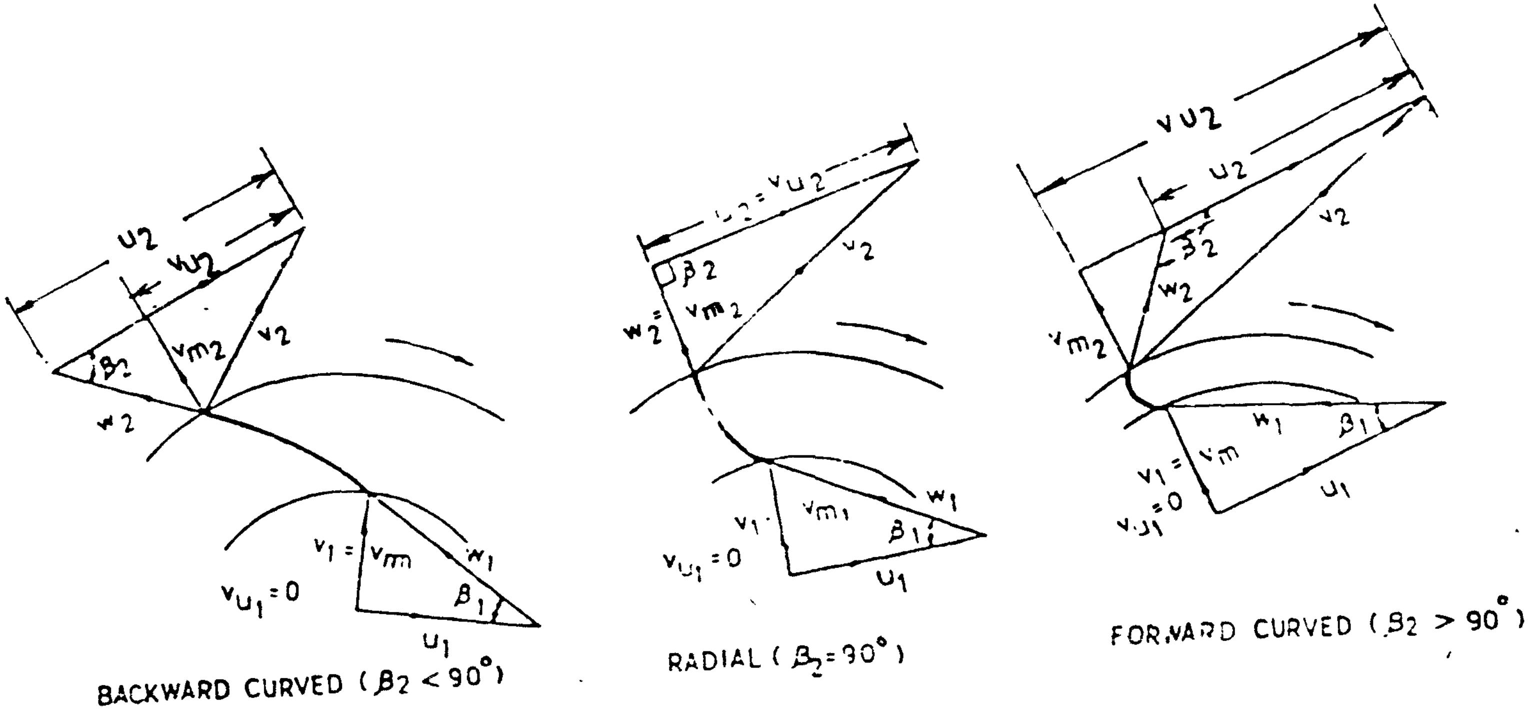

FIG. 3.3 VELOCITY TRIANGLES FOR THREE FORMS OF CENTRIFUGAL IMPELLER BLADES

3.2.3 Casing

The casing is a stationary element. It receives air from the impeller at higher velocity and provides proper path to the air towards the outlet. It converts kinetic energy into pressure energy.

Generally, the casings are of two types.

1. Volute casing
2. Diffuser casing

A third type of casing which is used in the design of the multiple outlet blower is a circular casing. The spiral shaped casing having no guide vanes is known as volute.

The diffuser consists of a number of diverging passages formed by guide vanes surrounding the impeller. This decreases the velocity and converts the kinetic energy into pressure. The circular casing ensures equal discharge from the different outlets which are equally spaced apart.

Loss of energy takes place during movement of air through a casing depending on the friction between air and casing surface. Shape and size of the casing will also affect loss of kinetic energy of air.

3.3 Design parameters of the centrifugal blower.

The suggested design of the centrifugal blower is based on the theory suggested by Osborne (1982) and pandey (1986). In this design the various parameters and coefficients are assumed based on the values available for the commercial designs as reported by as osborne and Pandey. And are stated whenever used.

3.3.1 Inlet diameter of impeller

Inlet diameter of impeller(d_1) is calculated from the consideration that the total flow has taken place through it axially at the velocity V_0.

Thus inlet diameter of impeller is given by the equation.

$$d_1 = \left[\frac{(4 \times Q)}{\pi \times V_0} + d^2_{hb} \right]^{1/2} \qquad \text{----- 3.1}$$

Where d_{hb} = The hub diameter. It is considered when the impeller is supported on both of its ends, otherwise it is considered as zero.

Q = discharge of air, m^3/sec

V_0 = Velocity of the air at blower inlet, m/sec.

3.3.2 Outlet peripheral velocity

The outlet peripheral velocity (U_2) is calculated by equation

$$u_2 = \frac{\pi \times d_2 \times N}{60} \qquad \text{------ 3.2}$$

where d_2 = outlet diameter of impeller, m

N = speed of impeller, rpm

3.3.3 Inlet peripheral velocity

The inlet peripheral velocity (U_1) is calculated by equation

$$U_1 = \frac{\pi x d_1 \ X \ N}{60} \qquad ------ \ 3.3$$

where d_1 = Inlet diameter of impeller, m

N = speed of impeller, rpm

3.3.4 Output static pressure

The output static pressure(Ps) is calculated by following equation.

$$Ps = U_2^2 \quad (X-Y) \qquad ------ \ 3.4$$

where Ps = static pressure, N/m^2

$$X = n \ x \left[1- \frac{\pi \sin \beta_2}{z} + \frac{K_2}{\tan (\pi - \beta_2)} \right]$$

$$Y = 1/2 \ \rho k_1^2$$

where

n = efficiency of blower is assumed generally in the range of 70 to 80 per cent

ρ = the density of air generally taken as 1.2, kg/m^3

β_2 = Outlet blade angle which is depend upon the choice of type of blower to be designed. It is generally ranging between 10 - 15° for backward curved blade impeller and 120 - 160° for forward curved impeller.

K_2 = It is the ratio of outlet radial velocity (Vm_2) to outlet peripheral velocity (U_2), generally it is taken as 0.2.

Z = Number of blades in the impeller. It is generally taken as 6 -16 for backward curved blade impeller and 30-60 for forward curved blade impeller.

K_1 = It is the ratio of blower outlet velocity (v_3) to the outlet peripheral velocity (U_2), generally it is taken as 0.3.

3.3.5 Radial component of air velocity at impeller outlet

Radial component of air velocity at impeller outlet (Vm_2) is calculated from equation

$$Vm_2 = K_2 \times U_2 \qquad \text{---- } 3.5$$

3.3.6 Radial component of air velocity at impeller inlet

The radial component of air velocity at impeller inlet (Vm_1) is calculated by considering the radial entry of air so

$$Vm_1 = Vm_2 \qquad \text{---- } 3.6$$

3.3.7 Velocity of air at impeller outlet m/sec.

Velocity of air at impleller outlet(V_2)is given by equation

$$V_2 = K_1 \times U_2 \qquad \text{------ } 3.7$$

3.3.8 Velocity of air at impeller inlet m/sec.

Velocity of air at impeller inlet(V_1) is taken as

$V_1 = Vm_1$, when there are no guide vanes provided.

3.3.9 Velocity of air at blower inlet m/sec.

The velocity of air at blower inlet (V_0) is given by equation

$$V_o = k_4 \times Vm_1 \qquad \text{---- } 3.8$$

where k_4 = ratio of inlet velocity (Vo) to radial velocity. It is generally taken as 2.0.

3.3.10 Diameter of the shaft

Diameter of the shaft (ds) is calculated by equation

$$ds = 1.94 \times \left[\frac{T}{t} \right]^{1/3} \qquad \text{-------3.9}$$

where

T = Torque on the impeller, Nm

t = allowable torsional strength of the material,

The torque (T) on the impeller can be calculated from

$$T = \frac{Pi}{2\pi N} \qquad \text{----- 3.10}$$

Where Pi = Input power to impeller, W

The power input to the impeller can be calculated by using following equation

$$Pi = Q \times (Ps + 1/2 \; k_1^2 \times U_2^2)$$

3.3.11 Inlet blade angle, (β_1)

The inlet blade angle(β_1) is given by using the velocity ratio.

$$\tan \beta_1 = \frac{V_1}{U_1} \qquad \text{------3.11}$$

since $V_1 = Vm_1$ at inlet

$$\tan \beta_1 = Vm_1 / U_1$$

3.3.12 Number of blades

The number of blades(z) assumed may again be checked by using the Pfleider's equation

$$Z = 6.5 \frac{(d_2 + d_1)}{(d_2 - d_1)} \times \sin \beta \qquad \text{---- } 3.12$$

where $\beta = (\beta_1 + \beta_2)/2$

3.3.13 Width of blades

It is calculated by assuming that the flow enters in the impeller radially through an area $\pi\ d_1\ b_1$

so $Q = (\pi\ d_1\ b_1\ Vm_1)$ ---- 3.13

$b_1 = (Q / \pi\ d_1\ Vm_1)$.

Since $Vm_2 = Vm_1$,

the width of blade at impeller outlet is

$b_2 = b_1\ d_1 / d_2$

3.3.14 Design of Impeller blades

The object of design of blade is to provide the minimum flow separation. Most sheet metal blades join inlet angle β_1, to outlet angle β_2 as smoothly as possible with either a curve or a straight line. Generally for curved blades a circular arc is used.

The impeller inlet flow angle (β_1) is always less than 90° whereas the outlet flow angle (β_2) can be less than, equal to or greater than 90°. The impeller blades are of two types curved and straight . The curved blades can be used for any value of β_2.

3.3.15 Design of casing

The casing of centrifugal blower serves two functions, first it collects the air from the periphery of the impeller and discharges it in the desired direction. Secondly, it converts the high kinetic energy developed into the pressure head. i.e. static head.

There are mainly two types of casings volute and diffuser type. Volute type casing are commonly used for blowers developing low heads whereas diffuser type casing are used for developing high heads.

3.3.16 Inlet and outlet area of casing

(a) Width of casing is

$$Wc = k_5 . b_2 \quad ---- \quad 3.14$$

Where K_5 = Ratio of width of casing (wc) to impeller blade (b_2)

(b) Area of casing outlet

$$Aco = Q/ V_3 \quad ---- \quad 3.15$$

(c) Height of casing outlet of rectangular shape is

$$hco = Aco/wc \quad ---- \quad 3.16$$

(d) Area of casing inlet

$$Aci = Aco/k_6 \quad ---- \quad 3\ 17$$

where K_6 = Ratio of casing outlet area (Aco) to inlet area (Aci)

(e) Diameter of casing inlet

$$dci = (4\ Aci/\pi)^{1/2} \quad ---- \quad 3.18$$

The AMCA standard recommended that casing outer area of forward curved impellers to be between 0.828 d_2^2 and

0.833 d_2.

3.4 Laboratory Testing of Blowers

The theoretical considerations for determining test parameters during the laboratory testing of blowers are explained in this section.

3.4.1 Definitions of terms used in laboratory testing of blowers

3.4.1.1 Dry bulb Temperature

Dry bulb temperature is the air temperature measured by a dry bulb thermometers.

3.4.1.2 Static pressure

Static pressure is that portion of the air pressure which exists by virtue of the degree of compression only.

3.4.1.3 Velocity/Dynamic pressure

Velocity pressure is that portion of air pressure which exists by virtue of the rate of motion only.

3.4.1.4 Total pressure

Total pressure is the sum of static pressure and velocity pressure.

3.4.1.5 Pressure loss

It is the change in total pressure due to friction and turbulence.

3.4.1.6 Blower flow rate

It is the volumetric flow rate of blower outlet

3.4.1.7 Blower power output

It is proportional to the product of blower total pressure and blower flow rate.

3.4.1.8 *Flow coefficient*

It is the volume of air per revolution per second with an impeller of one meter diameter.

3.4.1.9 Pressure coefficient

It is defined as the pressure developed per revolution per second with an impeller of unit diameter.

3.4.1.10 Power coefficient

It is said to be the power developed per revolution per second with an impeller of unit diameter.

3.4.2 Measúrement of incompressible flow parameters.

The theory involved in the measurement of incompressible flow parameters is presented in this section.

3.4.2.1 Determination of mean velocity at test section

The air velocity is affected by the dynamic pressure (dp). The dynamic pressure is a pressure head measured when both the ends of the manometer are connected to the pitot tube

$$dp = (vm)^2/2g$$

The mass of air handled by the blower is affected by the climatological factors such as ambient air temperature surrounding the blower, relative humidity etc. To determine the density of the air at the time of experimentation, it has to be compared with the density of the air at the standard condition. The air density at standard condition is 1.225 kg/m^3 at a temperature of 15°C and 760 mm of mercury head.

Thus, the dry density of the air at t°C is given by the equation as

$$\rho_d = \frac{1.225 \times 288}{273 + t} \qquad \text{------ 3.19}$$

Since, the density is also affected by humidity, the density of humid air is given as

$$\rho_a = \rho_d \frac{(Pab - 0.378 \times P'v \times RH)}{Pab} \qquad \text{--- 3.20}$$

where Pab = absolute pressure of atmospheric air

= 101325 N/m^2

P′v = Saturated vapor pressure which can be obtained from Fig. 3.4

So considering above parameters, density of air is given by

$$\rho_a = \frac{1.225 \times 288}{273 + t} \times \frac{Pab - 0.378 \times P'v \times RH}{Pab}$$

--- 3.21

The dynamic pressure observed as manometric water level difference when compared with air velocity. The equation can be written as

$$\rho_w \times g \times hm = \rho_a \times vm^2/2 \qquad \text{------3.22}$$

Where w = density of water kg/m^3

g = acceleration due to gravity, 9.81 m/sec^2

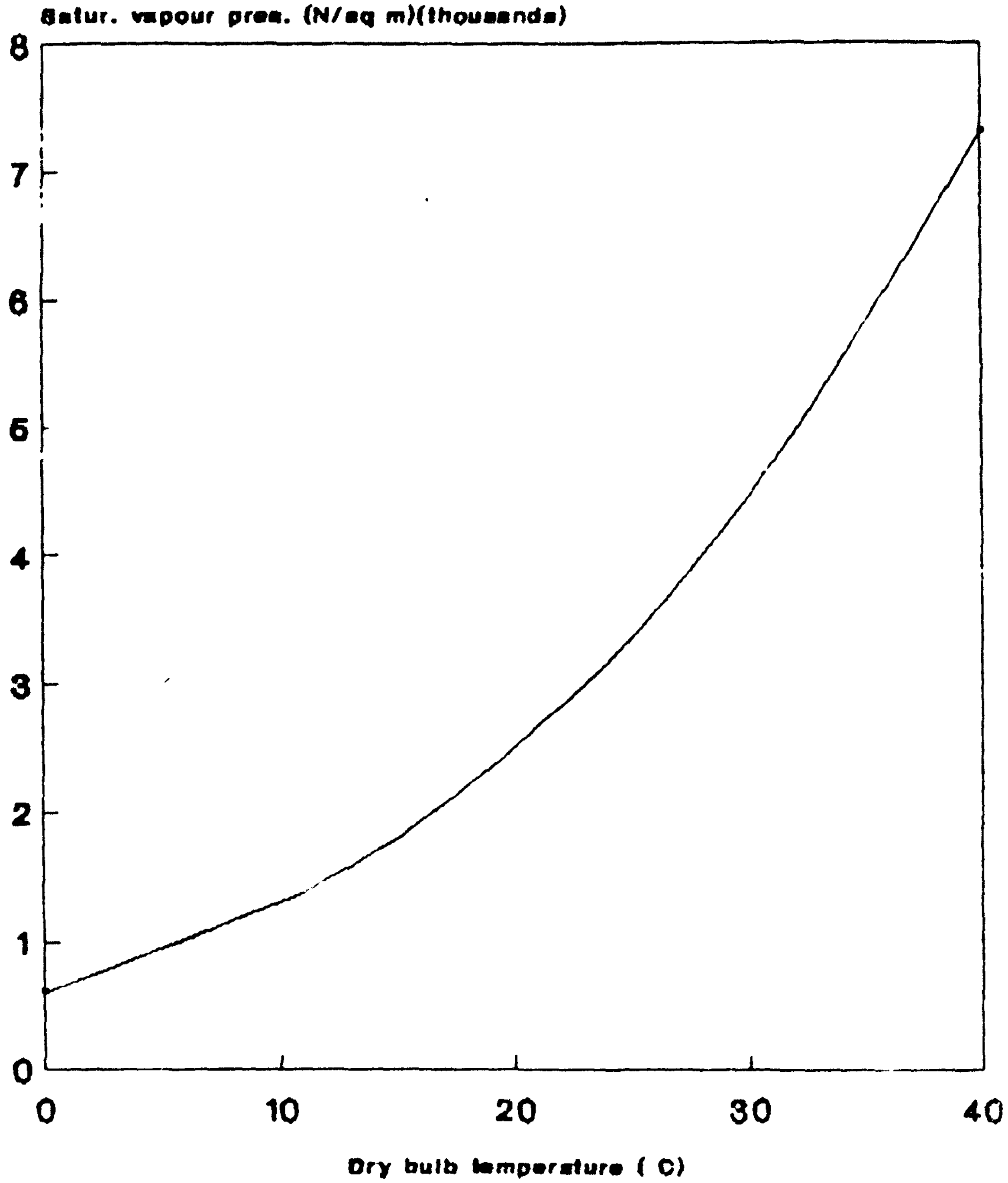

FIG. 3.4 RELATIONSHIP BETWEEN DRY BULB TEMPERATURE AND SATURATED VAPOUR PRESSURE

Vm = mean velocity, m/sec

hm = mean dynamic head, meter of water column.

So the equation for mean velocity as

$$V^2m = (2 \times g \times \rho w \times hm)/ 2 \quad --- \quad 3.23$$

$$\text{i.e. } Vm = k \times (hm)^{1/2}$$

where,

$$K = \left[\frac{(2 \times 9.81 \times 1000)}{1.225 \times 228} \times \frac{(273 + t)(Pab)}{(Pab - 0.378 \times P'v \times RH)} \right]^{1/2}$$

The mean dynamic head, hm is obtained from the pitot static tube measurements by tangential and log linear method discussed below.

3.4.2.2 Tangential and log linear method

According to this method, at test section each radial plane is divided into n zones and four points are taken for observations in a zone. considered amounting to 4n observations. Taking v_1, v_2,----v_n as the velocities obtained at different traversing points, the mean value is given as

$$Vm = \frac{k\sqrt{h_1} + k\sqrt{h_2} + ----- + k\sqrt{h_{20}}}{4n} \quad --- \quad 3.24$$

or

$$k\sqrt{hm} = \frac{\sum E k\sqrt{h}}{4n}$$

or

$$\sqrt{hm} = \frac{\sum E\sqrt{h}}{4n}$$

where, hm = mean dynamic head ,m of water column

h_1 to h_{20} = head at test section m, of water column

n = number of observation

3.4.2.3 Determination of air discharge rate

Knowing the values of mean velocity 'Vm' m/sec and cross sectional area 'A' in m^2 at the test section, the discharge rate can be given as

$$Q = A \times Vm = A\ k\sqrt{hm} \qquad ---- \quad 3.25$$

where hm = mean dynamic head, m of water column.

3.4.3 Determination of dynamic, static and total pressure at test section.

One meter of water column amounts to a pressure of 9810 N/m^2 the dynamic and static heads at test section are converted into respective pressure as

Dynamic pressure (Pv) = dynamic head x 9810, N/m^2

Static pressure (Ps) = static head x 9810, N/m^2

Total pressure (Pt) = Pv + Ps, N/m^2

3.4.4 Determination of various parameters at blower exit

In order to calculate the blower output parameters, the parameters obtained at test section can not be used because of various losses in the wind tunnel. So it is necessary to compute these parameters at the blower exit. The theory followed in calculating the same is discussed in this section.

3.4.4.1 Pressure head loss in the wind tunnel

The pressure is reduced from the blower exit to the test section in the wind tunnel. This pressure loss is mainly due to the flow straightner in the wind tunnel and due to the friction in the wind tunnel. It can be given as

$$P = f \left| \frac{L_1}{D_h} + \frac{L_2}{D_h} \right| \times P'v \qquad \text{---- } 3.26$$

where f = friction factor

L = length between blower outlet and test section, m.

D = equivalent hydraulic diameter of blower outlet, m.

The term L /D in the above equation can be computed by the equation.

$$\left[\frac{L}{D} \right] = \frac{15.04}{[1 - 26.65 \times Y/D + (Y/D)^2]^{1.85}} \qquad \text{--- } 3.27$$

Where Y = thickness of flow straightner, mm

D = diameter of test section, m

(generally Y/D = 0.005) and

Pv = dynamic pressure at test at section N/m^2

The friction factor is given by equation

$$f = \frac{0.14}{Re^{0.17}} \qquad \text{---- } 3.28$$

The Reynold's number is given by equation

$$Re = \frac{\rho a \times V \times Dn}{u} \qquad \text{---- } 3.29$$

Where, v = Velocity of air, m/s

a = density of air kg/m^3 and

u = viscosity of air, kg/m^2

which is generally taken as $1.85 \times (10)^{-5}$

3.4.4.2 Determination of dynamic pressure at blower exit

The dynamic pressure at blower exit (Pve)is given by

$$Pve = Pv \times \left[\frac{At}{Ac} \times \frac{\rho t}{\rho e} \right]^2 \qquad ----- \quad 3.30$$

where At = cross sectional area of test section, cm^2

t = air density at test section, kg/m^3

Ac = cross sectional area of blower exit, cm^2

e = air density at blower exit, kg/m^3

Generally t and e are considered equal

$$Pve = Pv \times \left[\frac{At}{Ac} \right]^2 \qquad ---- \quad 3.31$$

3.4.4.3 Determination of total pressure at blower exit

The total pressure at blower exit (Pte) will be more than that at the test section because of friction loss, so the total pressure at the blower exit is given by

$$Pte = Pt + Pl \qquad --- \quad 3.32$$

3.4.4.4 Determination of static pressure at blower exit

The static pressure at the blower exit (Pse) will be the difference between the total and dynamic pressure at the exit.

Therefore, static pressure at blower exit is given by equation

$$Pse = Pte - Pve \qquad \text{------ } 3.33$$

3.4.4.5 Determination of air velocity at blower exit

The blower velocity at exit (Ve) can be determined by using the equation of continuity.

Therefore

$$At \times Vt = Ae \times Ve \qquad \text{------ } 3.34$$

$$Dt^2 \times Vt = De^2 \times Ve \qquad \text{------ } 3.35$$

so,

$$Ve = \left[\frac{Dt}{De}\right]^2 \times Vt \qquad \text{------ } 3.36$$

where Dt = diameter at test section, cm

De = diameter at blower exit, cm

Ve = velocity at blower exit, m^2/sec

3.4.5 Calculation of Power consumption

The power consumed by motor and blower is explained in this section.

3.4.5.1 Input power to the motor

The power consumed is computed by using the voltage and current drawn by the electric motor.

Input power to the motor is calculated by equation as

$$P = 3 \times E \times I \times \cos\varnothing \qquad \text{----------- } 3.37$$

where P = power input to the motor, W

E = input voltage to the motor, V

I = input current to the motor, A

cosØ = power factor

Power factor of motor depends upon the current consumed by motor. Power factor of three phase motor at various load can be found out by using current, load and power factor relationship graph. If watt meter is used then it directly gives the input power consumed by motor. Relationship between power factor, load current and efficiency is shown in Fig. 3.5

3.4.5.2 Output power of the motor

The output of the motor varies according to the efficiency of the motor which depends on the input load.

$$Po = p \times nm \qquad \text{--------3.38}$$

where nm = motor efficiency, per cent

value of nm may be assumed 80 per cent

3.4.5.3 Input power to the blower

Input power (P) is the output power of motor minus the transmission loss (k) due to the V-belt drive. It can be expressed as

$$P1 = P0\ (1-k) \qquad \text{----- 3.39}$$

where k = transmission loss

Generally value of k is taken as 0.02

3.4.5.4 Output power of the blower

The output power of the blower (Pob) is calculated from the discharge and the total pressure at the blower exit, so it is given by the equation.

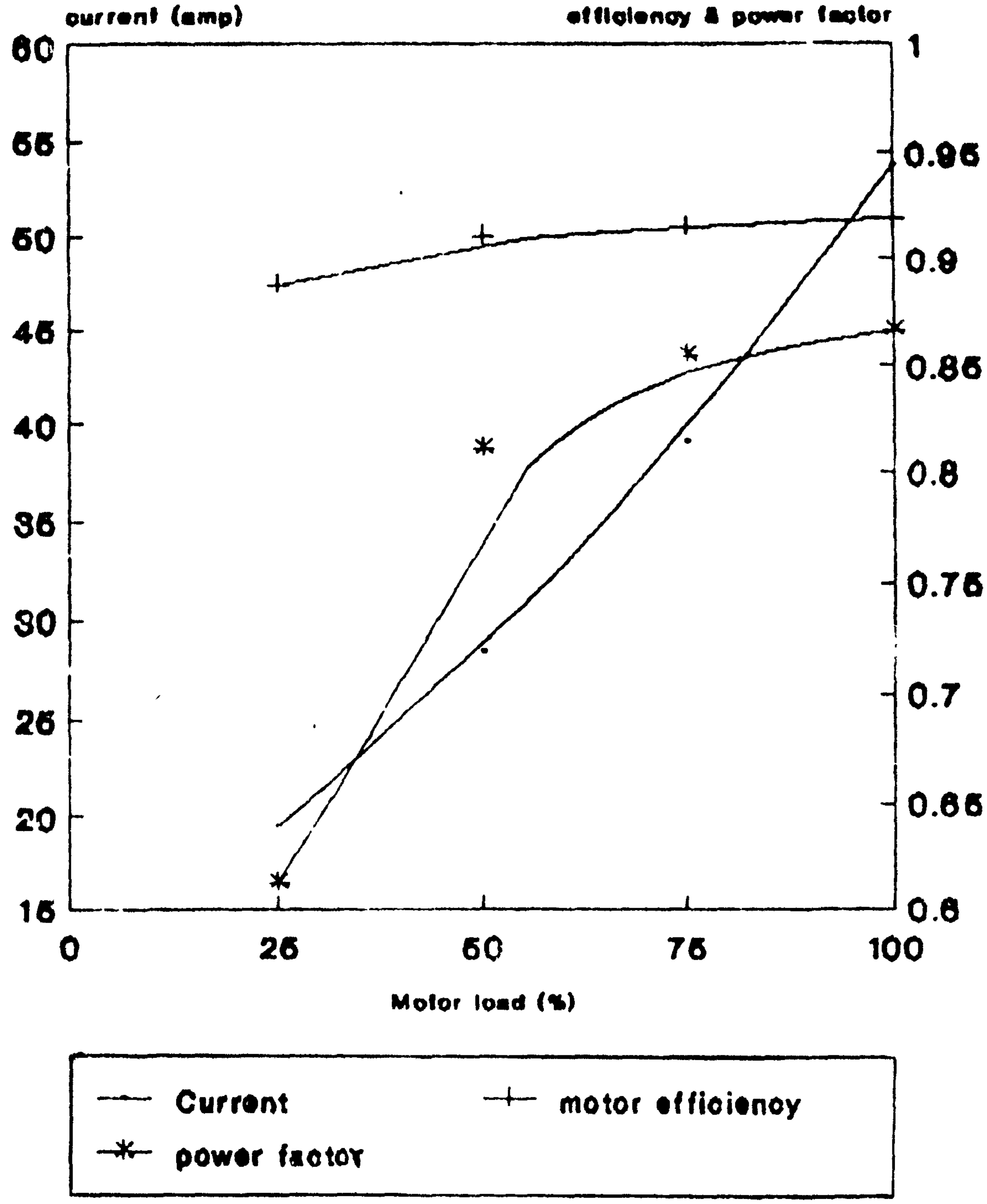

FIG. 3·5 RELATIONSHIP BETWEEN MOTOR LOAD AND CURRENT

$Pob = Q \times Pte$

where Q = discharge rate, m^3/s

3.4.5.5 Efficiency of blower

The blower efficiency (nb) can be calculated by using the power input and output equations of the blower. It is given by the equation

$$nb = \frac{\text{output power of the blower}}{\text{input power to the blower}} \times 100$$

$$nb = \frac{Pob}{Pib} \times 100 \qquad \text{----- } 3.40$$

3.5 Terminology Used for Performance Evaluation of Air Carrier Sprayer

3.5.1 Volume median diameter

Volume median diameter (VMD) is a sample of droplets of a spray is divided into two equal parts by volume so that one half of the volume contains droplets smaller than a droplet whose diameter is the VMD and the other half of the volume contains larger droplets.

3.5.2 Number median diameter

Number median diameter (NMD) is the average diameter of droplets without any reference to volume. The diameter corresponding to the size which divides the droplet into two parts by number only is known as NMD.

3.5.3 Spread factor

It is the ratio of the diameter of actual droplet to the diameter of the droplet spread on any object is called as spread factor.

3.5.4 Uniformity coefficient

The ratio of VMD/NMD is known as uniformity co-efficient. It indicates the range of droplets. The more uniform the size the ratio is nearer to unity.

3.5.5 Droplet density

The number of droplets per unit area of leaf surface is called droplet density.

3.5.6 Spray Deposition index

An ideal spraying would result in deposition of 25 droplets of 100 u size per square centimeter leaf area. The actual volume of spray deposit per unit area is given by formula.

$$Va = \pi/6 \times d^3 \times n \qquad \text{----- } 3.41$$

where d = diameter of droplet, m

n = number of droplets/ sq.cm. area

Va = Actual volume of deposit, cc

The volume of spray deposited in ideal spraying can be computed by formula .

$$Vo = \pi/6 \times (100)^3 \times 25 \qquad \text{--- } 3.42$$

$$= 0.130899 \times 10^{-4} \text{ cc}$$

$$= 13.0899 \text{ ucc}$$

$$\text{Deposition index (D.I.)} = \frac{Va}{Vo}$$

If the deposition index is less than one, then there is under spraying. If deposition index is equal to one then spraying is satisfactory and if deposition index is more than one then there is good spraying.

In this chapter the various design parameters of the blower have been discussed and these theoretical design parameters are used to design a new centrifugal blower for the grape vines.

Chapter Opener Page

Materials and Methods

CHAPTER IV

MATERIALS AND METHODS

This chapter deals with materials used for laboratory testing of blower and field testing of air carrier sprayer. Methods for laboratory testing of blower and field testing of air carrier sprayer are elaborated in later sections.

4.1 Constructional Details of Tractor Mounted Air Carrier Centrifugal Sprayer.

The performance of a tractor mounted air carrier centrifugal sprayer was evaluated in the laboratory as well as in the grape field.

The sprayer consists of following components :

1. Centrifugal blower,
2. Frame for mounting blower,
3. Hydraulic pump,
4. Distributor,
5. Hoses,
6. Nozzles,
7. Pesticide tank,
8. Strainers and
9. Power transmission unit.

The overall view of tractor mounted air carrier sprayer is shown in Fig. 4.1

4.2 Details of Existing Centrifugal Blower

FIG. 4.1 TRACTOR MOUNTED AIR CARRIER SPRAYER

Three centrifugal blowers namely Pagrut's (P), Unhale's (U) and Aspee's (A), were tested in laboratory to study the comparative performance of blowers. Aspee's (A) centrifugal flow mist blower was tested in grape field to study the performance in the field. Based on the performance information new centrifugal flow mist blower for grape vines is to be designed.

Constructional details of above three blowers are given in Table 4.1 and schematic views of impellers of the three blowers are given in Fig. 4.2 through 4.4. Also schematic views of casings of above three blowers are given in Fig 4.5 through 4.7.

4.3 Laboratory Testing of the Blowers

The main purpose of the laboratory testing of the blowers was to evaluate their performance at different speeds. From these tests, the optimum speeds of operation of the blowers were determined.

4.3.1 Experimental design for laboratory Testing

4.3.1.1 Independent variables

1. No of blowers : 3
2. Speeds of rotation : 5
3. Test section points : 20
4. Measurements of atmospheric variables
   a. Temperature,
   b. Humidity.

TABLE 4.1 SPECIFICATIONS OF BLOWER 'P', 'U' AND 'A'

Sr. No.	Details	'P'	'U'	'A'
1.	**Impeller :-**			
	1. Impeller type	double sided	double sided	double sided
	2. Outer diameter, mm	500 mm	419.1	406.4
	3. Inlet diameter, mm	400	355.6	336.5
	4. Impeller width, mm	200	230	244.4
2.	**Blades :-**			
	1. Number of blades	108	72	48
	2. Blade type	forward curved	forward curved	forward curved
	3. Inlet blade angle	12.5°	25°	20°
	4. Outlet blade angle	160°	155°	157°
3.	**Casing :-**			
	1. Type	Circular	Volute	Volute
	2. Number of outlets	8	2	2
	3. Inlet diameter, mm	162	390	430
	4. Outlet diameter, mm	162	965 x 65	760 x 90
	5. Width, mm	-	152	140

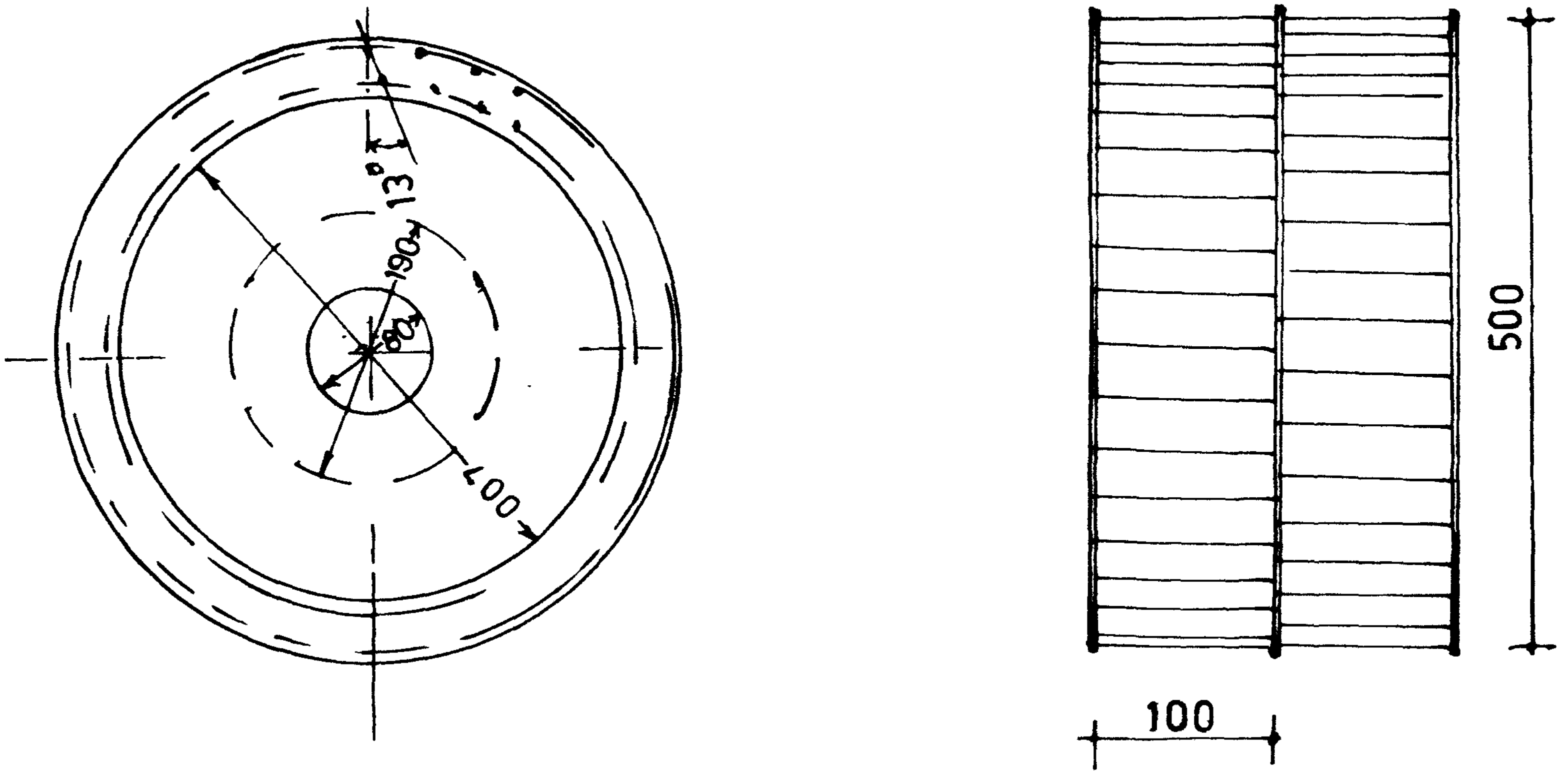

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FIG. 4.2 SCHEMATIC VIEW OF IMPELLER OF BLOWER 'P'

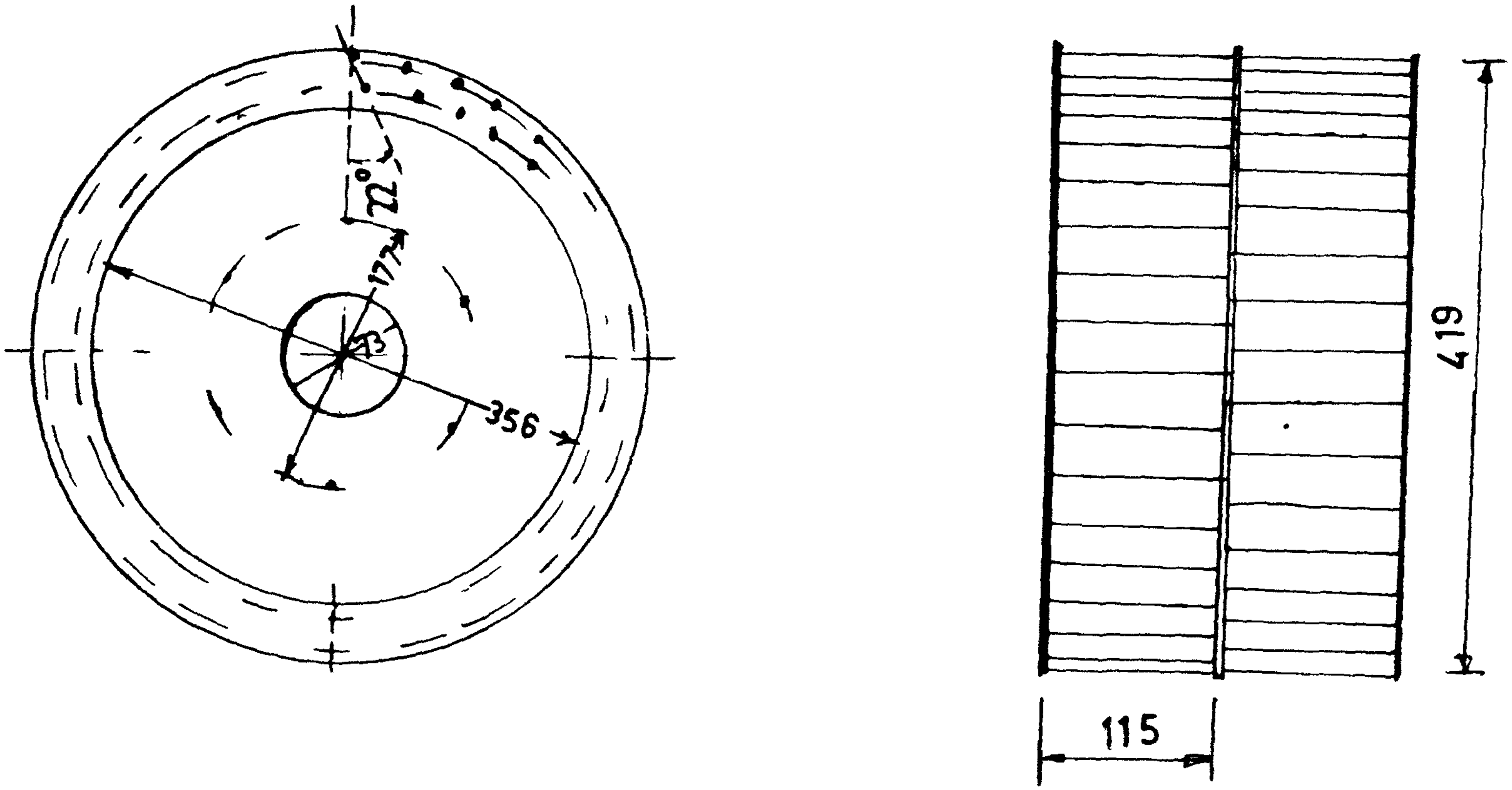


FIG 4.3 SCHEMATIC VIEW OF IMPELLER OF BLOWER 'U'

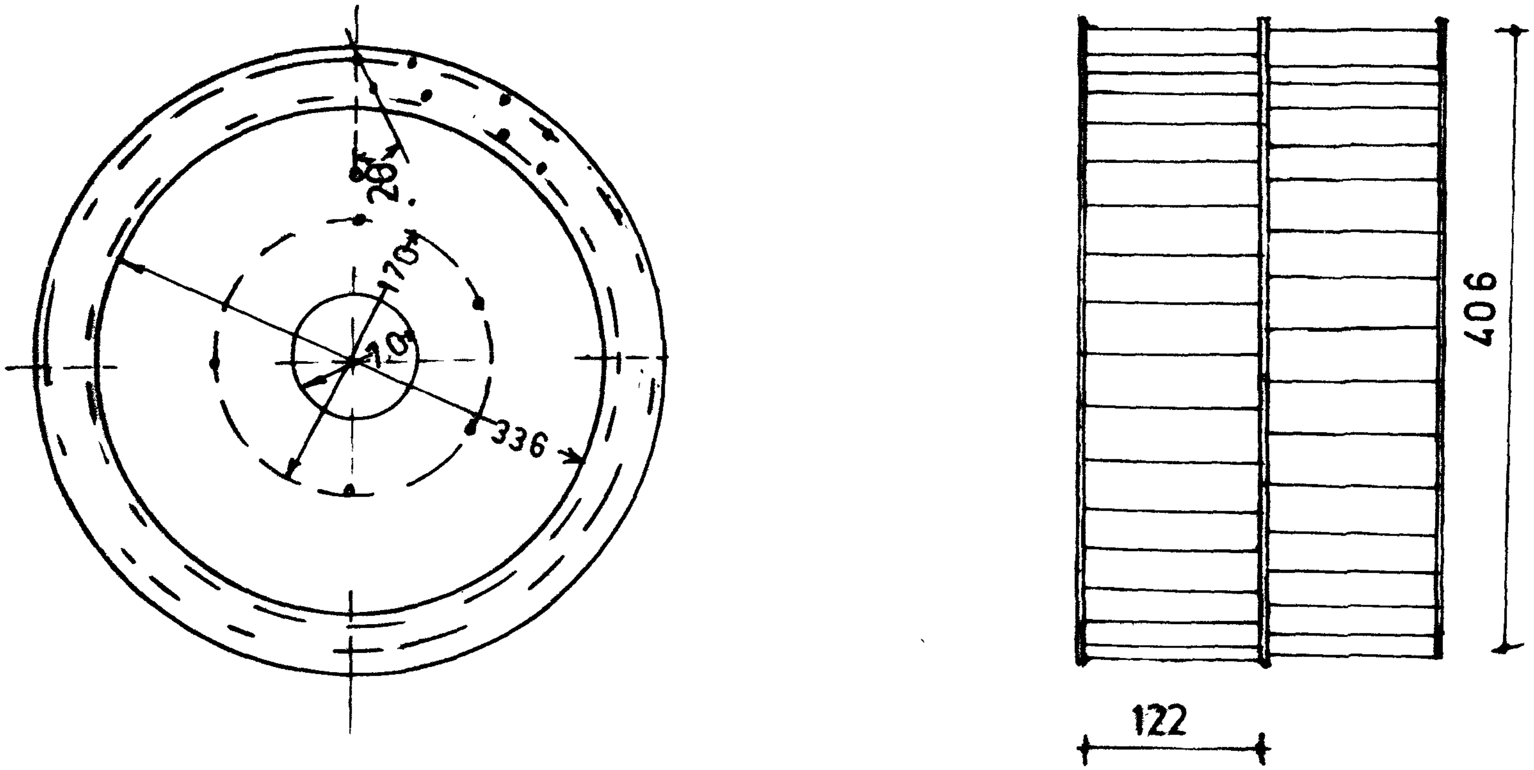


FIG-4-4 SCHEMATIC VIEW OF IMPELLER OF BLOWER 'A'

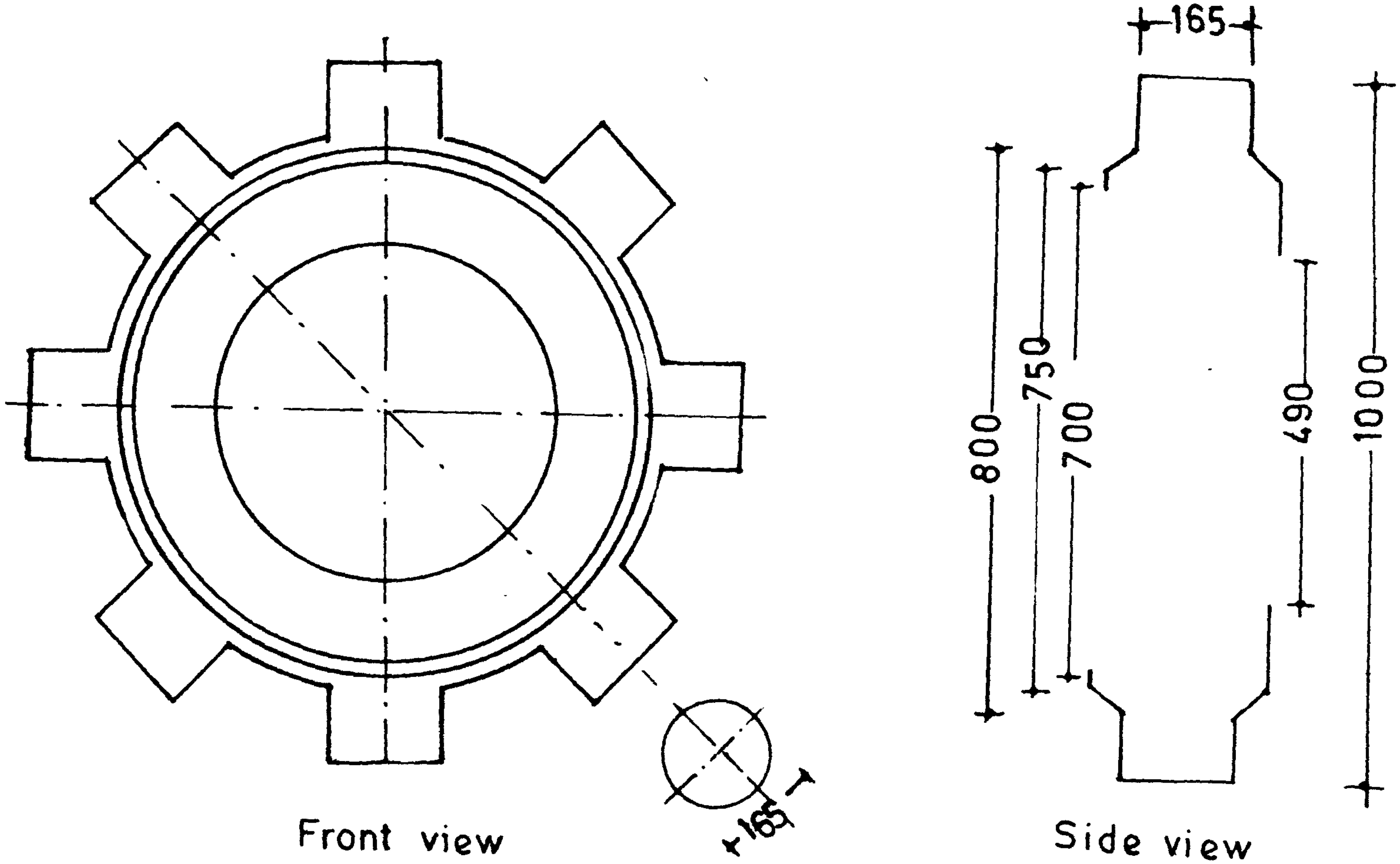


FIG. 4.5 SCHEMATIC VIEW OF CASING OF BLOWER 'P'

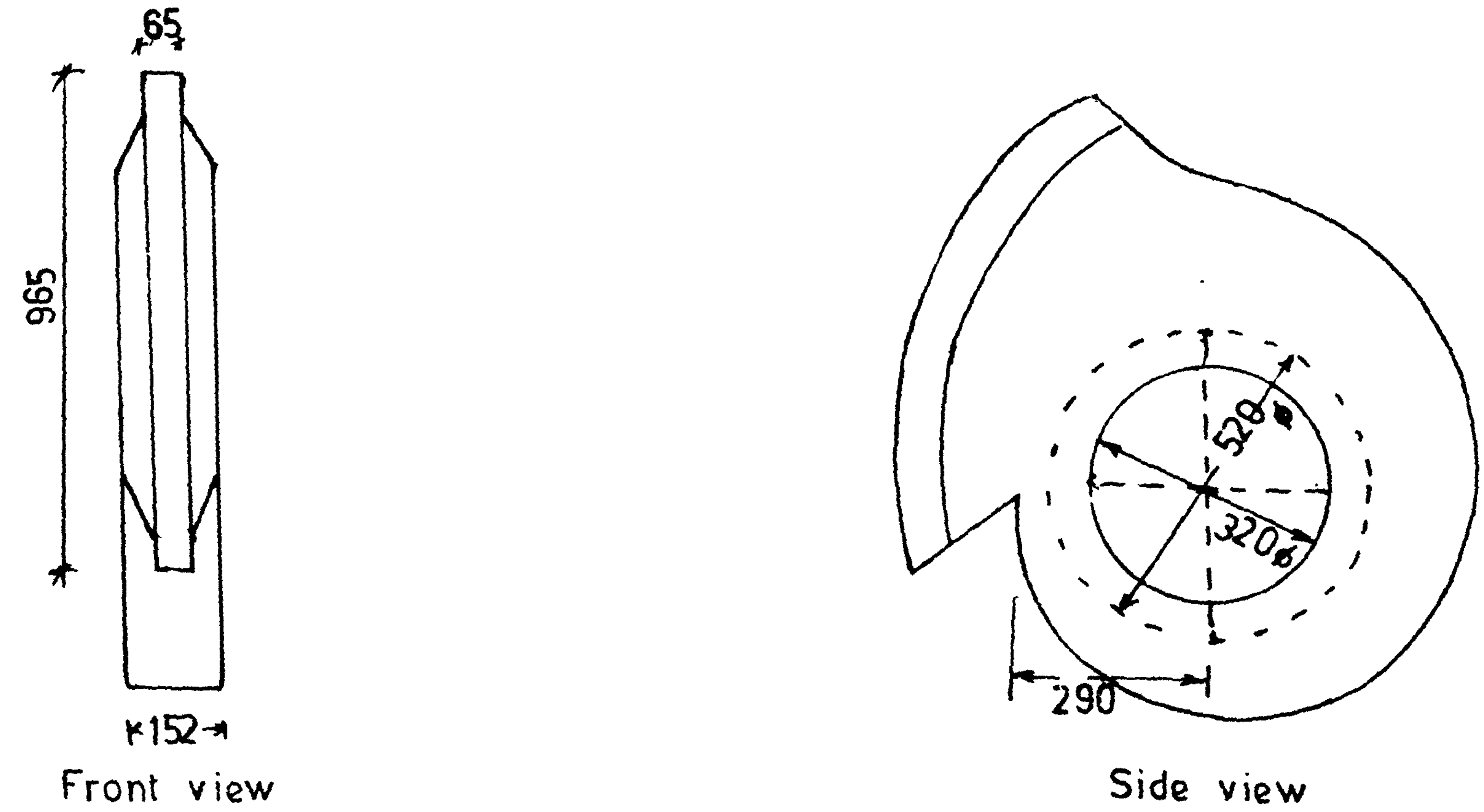


FIG. 4.6 SCHEMATIC VIEW OF CASING OF BLOWER 'U'

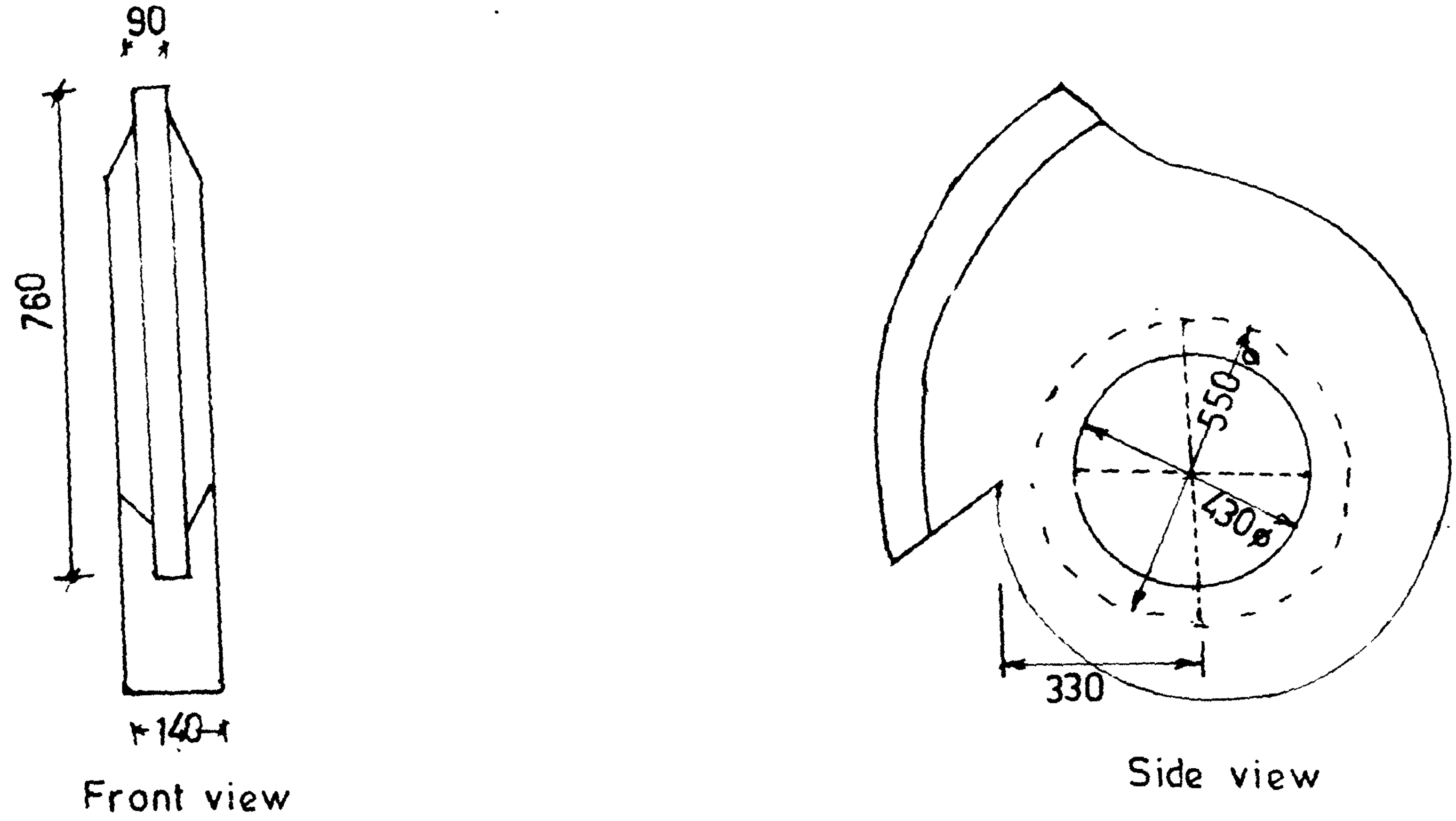


FIG. 4.7 SCHEMATIC VIEW OF CASING OF BLOWER 'A'

4.3.1.2 Dependent variables

1. Static Pressure,
2. Dynamic Pressure,
3. Air Velocity,
4. Air Discharge,
5. Blower efficiencies,
6. Power input and
7. Power output.

4.3.2 Details of laboratory set-up for testing

The laboratory test set-up consists of the following accessories, equipments and instruments for conducting laboratory tests of the blower

1. Blower assembly,
2. Frame to support the blower,
3. Wind tunnel assembly,
4. Prime mover,
5. Transmission assembly,
6. Pressure measuring instruments,
7. Power measuring instruments,
8. Speed measuring instruments and
9. Temperature measuring instruments.

4.3.2.1 Blower assembly

This consists of the centrifugal flow impeller, casing and bearing block.

4.3.2.2. Frame to support blower assembly

The frame was fabricated by joining the two m.s. angles of size 50 x 50 x 5 mm and bolted to heavy m.s. plate to resist the vibration while in operation. The m.s. plate has number of holes. The blower was fitted to these m.s. plates by nuts and bolts.

4.3.2.3 Wind tunnel assembly

The wind tunnel assembly was constructed according to AMCA (1985) specifications. It consists of transition section, flow straightner and the tunnel. The details of wind tunnel assembly for different blowers are given in Table 4.2 and the schematic view is as shown in Fig 4.8.

4.3.2.4 Prime mover

The blower was driven by different induction motors by means of chain and sprockets. The details of motors used are given in Table 4.3.

4.3.2.5 Power transmission assembly

Power was transmitted from the motor shaft to the impeller shaft of the blower by means of chain, sprockets and belt-pulley arrangement for obtaining different speeds. Schematic views of chain and sprocket, belt and pulley arrangement are as shown in Fig. 4.9 and 4.10.

4.3.2.6 Pressure measuring instruments

The static, dynamic and total pressure of the air that has been blown by the blower were determined by standard pitot tube in conjuction with U tube manometer as shown in Fig. 4.11.

TABLE 4.2 DETAILS OF WIND TUNNEL USED FOR BLOWER 'P','U' AND 'A'.

Sr. No.	Details of wind tunnel	Blower 'P'	Blower 'U'	Blower 'A'
1.	Diameter of wind tunnel,mm	165	265	265
2.	Length of wind tunnel,mm	1830	2650	2650
3.	Slope of transition section %	-	7	7
4.	Length of transition Section, mm	-	2550	2550
5.	Distance of test section from the end of transition section,mm	-	2420	2420
6.	Total length between outlet and test section,mm	1805	4970	4970
7.	Distance between flow straightner and test section,mm	1030	1500	1500
8.	Width of flow straightner,mm	75	130	130
9.	Thickness of fins of flow straightner,mm	7.5	13	13
10.	Spacing of fins of flow straightner, mm	20	20	20

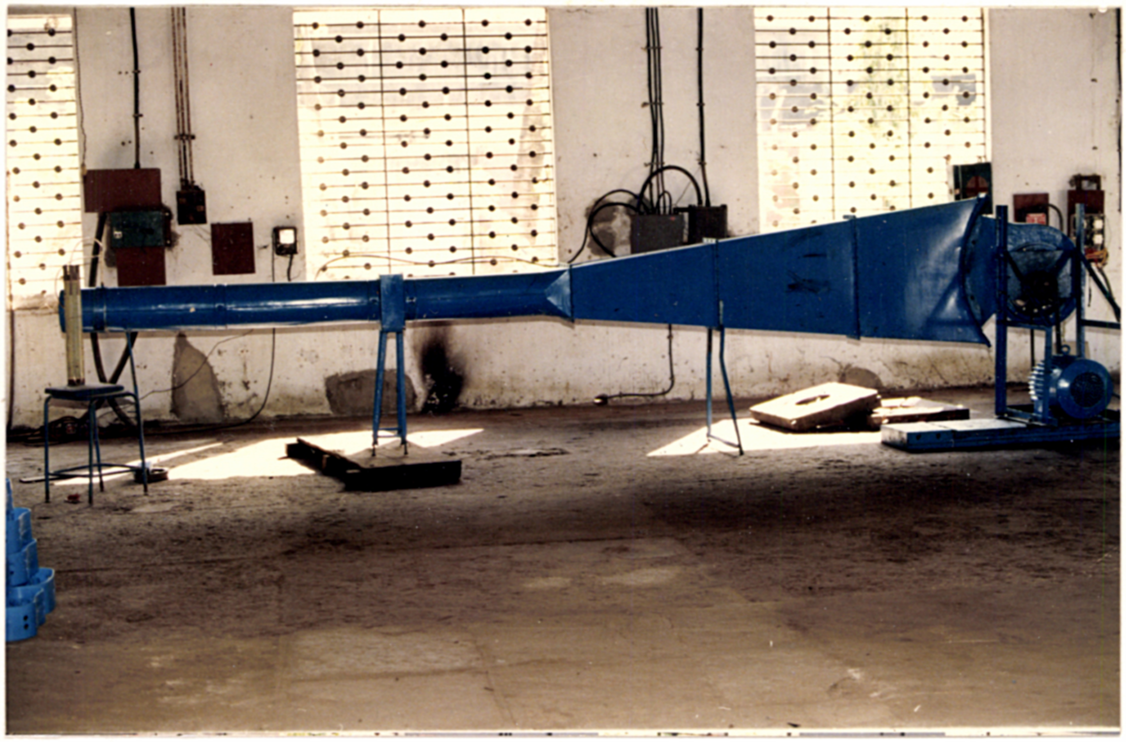


FIG. 4.8 SCHEMATIC VIEW OF WIND TUNNEL ASSEMBLY

FIG. 4.9 SCHEMATIC VIEW OF CHAIN AND SPROCKET ARRANGEMENT

TABLE 4.3 DETAILS OF PRIME MOVER USED FOR BLOWER 'P','U' AND 'A'.

Sr. No.	Details of electric motor	'P'	'U'	'A'
1.	Type	Squirrel cage Induction motor	Squirrel cage Induction motor	Squirrel cage Induction motor
2.	Rated speed, rpm	1465	1465	1470
3.	Rated voltage, 'V'	414	414	400
4.	Phase / cycle	3/50	3/50	3/50
5.	Rated current, A	52.8	52.8	22
6.	Type of starter	Star-delta type	Star-delta type	Star-delta type
7.	Efficiency, %	90.9	90.9	77.5
8.	Rated hp	40	40	15

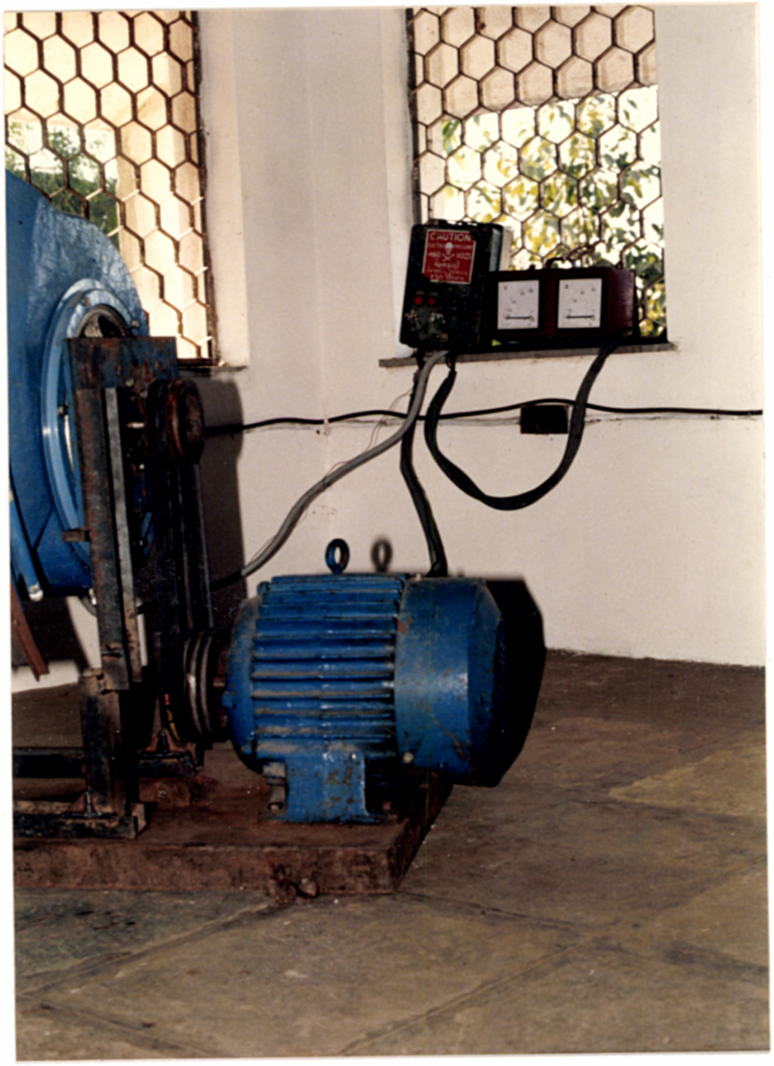


FIG. 4.10 SCHEMATIC VIEW OF BELT AND PULLEY ARRANGEMENT

FIG. 4.11 SCHEMATIC VIEW OF PITOT TUBE CONNECTED WITH MANOMETER

and pitot static tube with spherical head as shown in Fig. 4.12.

The pitot tube was inserted into the tunnel through the holes drilled on tunnel surface. Velocity and static pressure were measured at various traverse points. (Fig. 4.13). Then average of the readings was considered for calculating these pressures.

4.3.2.7 Power measuring instrument

For measuring the power consumption by the blower, a voltmeter and ammeter were used . Voltmeter and ammeter were connected to the line supplying power in parallel and series respectively after the starter as shown in Fig 4.14

Specification of ammeter :-

Range : 0 - 100 ampere

Least count : 2 ampere

Specifications of voltmeter :-

Range : 0 - 500 volt

Least count : 10 volt

4.3.2.8 Speed measuring instrument

Tachometer was used to measure the speed of the impeller shaft in revolutions per minute.

Ranges available : 30-150, 100-500, 300-1500, 1000-5000. 10000-50000 rpm.

4.3.2.9 Temperature measuring instruments

A dry bulb temperature was measured by dry bulb thermometer.

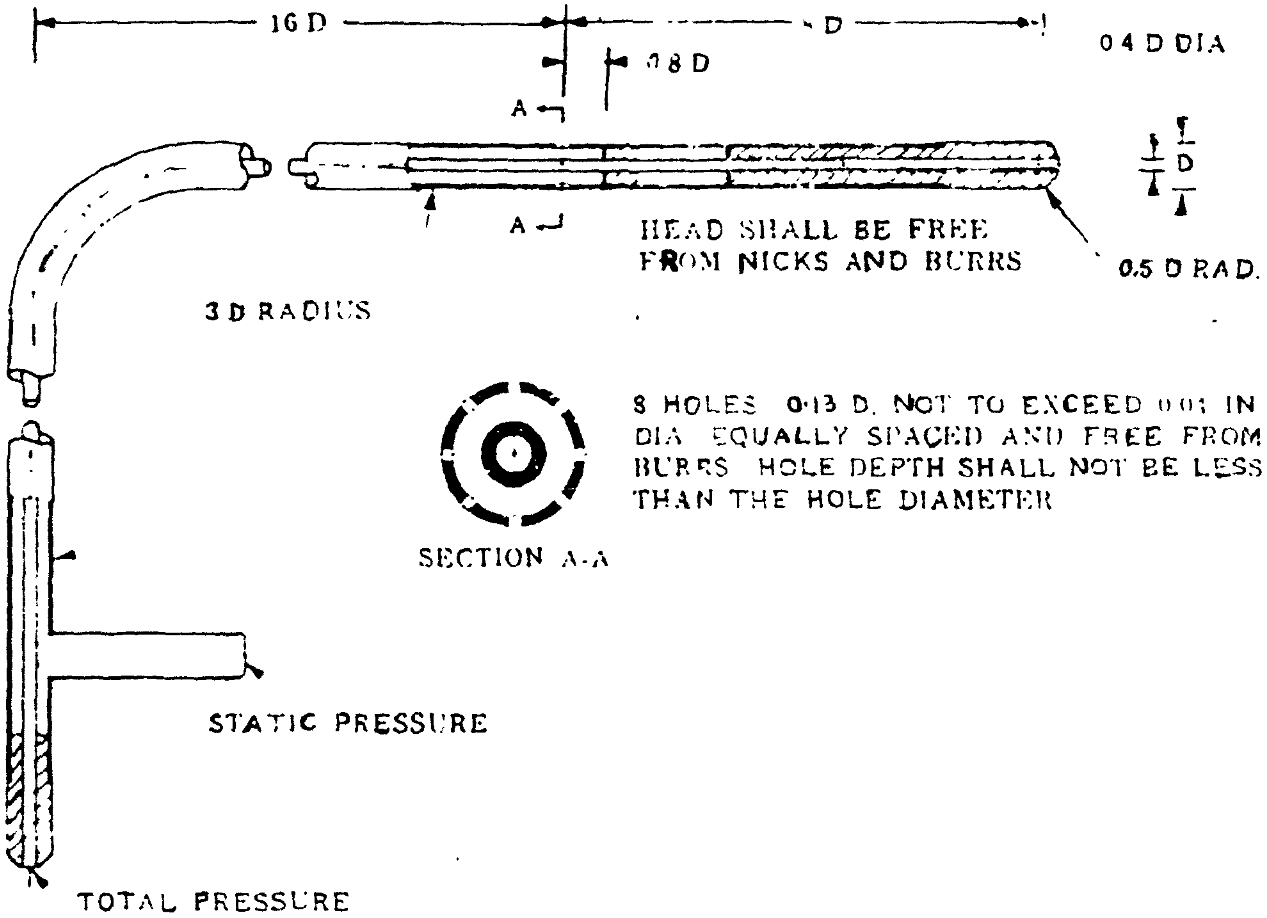


FIG. 4.12 PITOT STATIC TUBE WITH SPHERICAL HEAD

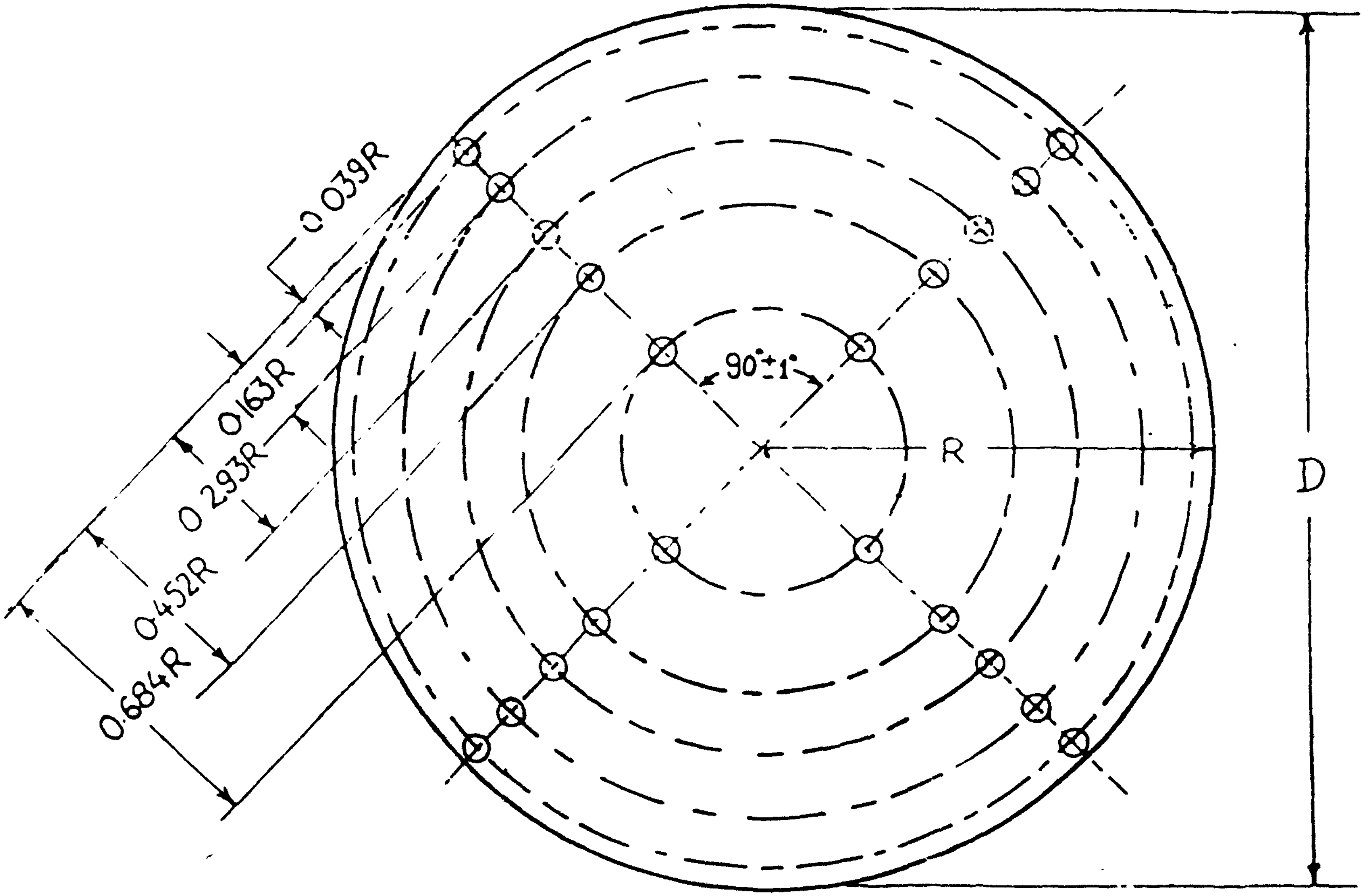


FIG. 4.13 TRAVERSE POINTS IN WIND TUNNEL

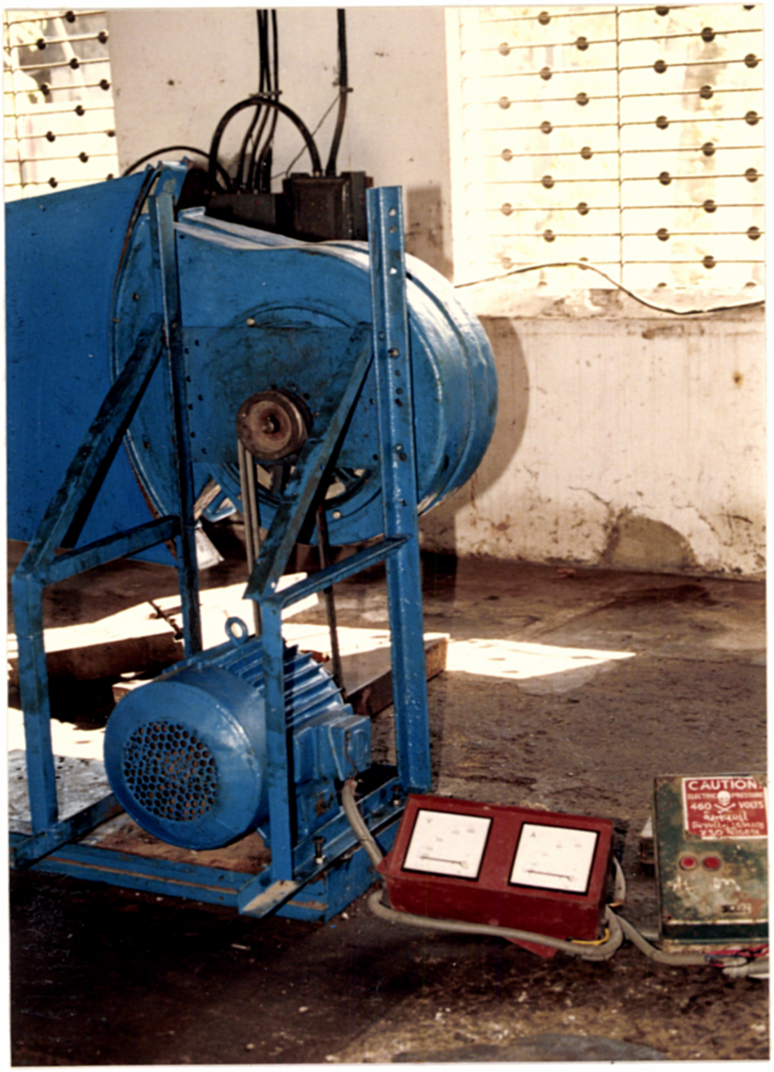


FIG. 4.14 SCHEMATIC VIEW OF VOLTMETER AND AMMETER CONNECTION ARRANGEMENT

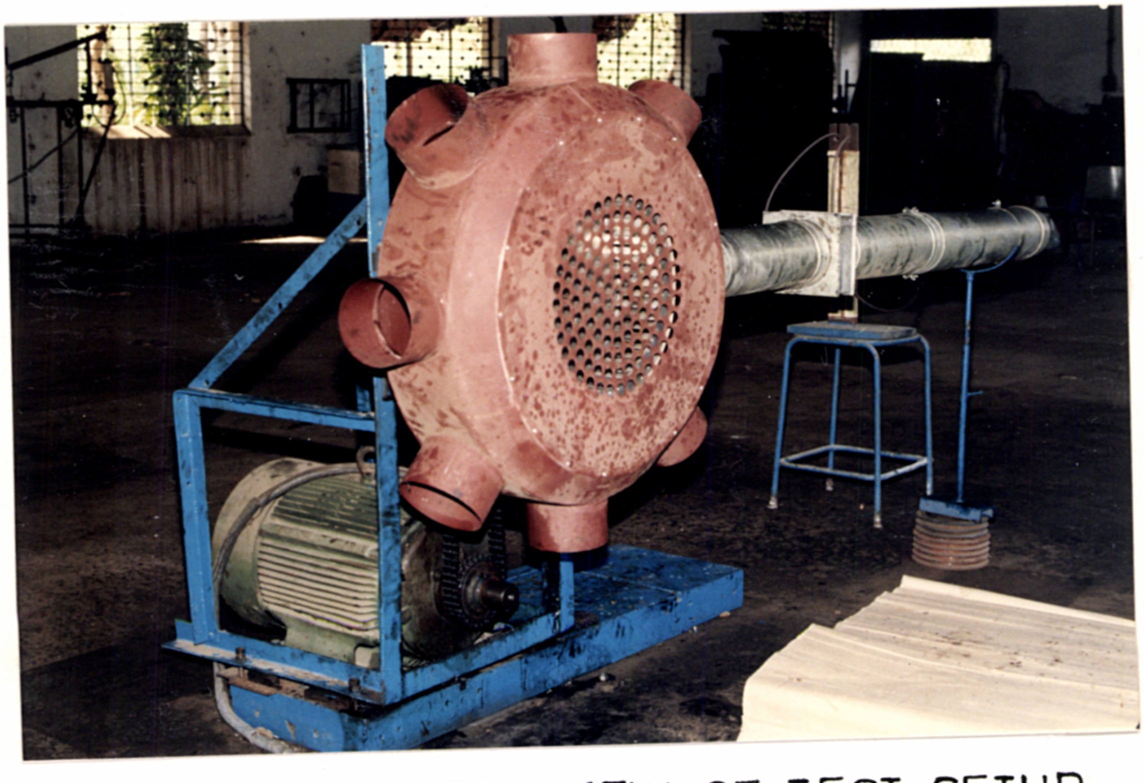


FIG. 4.15 SCHEMATIC VIEW OF TEST SETUP OF BLOWER P

Range : 0 - 100°C

Least count : 1°C

4.3.2.10 Humidity measuring instrument

Humidity in the air was measured by Hygrometer.

Range : 0 to 100 per cent

Least count : 1 per cent

4.3.3 Laboratory test procedure

The wind tunnel was fixed to the blower. It was operated at the desired speed of rotation. The various observations taken at the time of experiment included dry bulb temperature, relative humidity, static and dynamic head, current and the voltage. The test setup is shown in Figs 4.15 through 4.17 for different blowers.

4.3.3.1 Determination of static, dynamic and total pressure at test section

When the two limbs of the manometer are connected to the pitot tube, the difference in water column in the two limbs gives the dynamic head. When the static end of the pitot tube is connected to one end of the manometer and the other limb is kept open to the atmosphere, the difference in the water level of U tube limbs gives the static head. These heads converted in terms of pressure unit by using the property that one cm rise in water column corresponds to the 98.1 N/cm^2 of pressure.

Thus static pressure (Ps) = static head x 98.1

Dynamic pressure (Pd) = dynamic head x 98.1

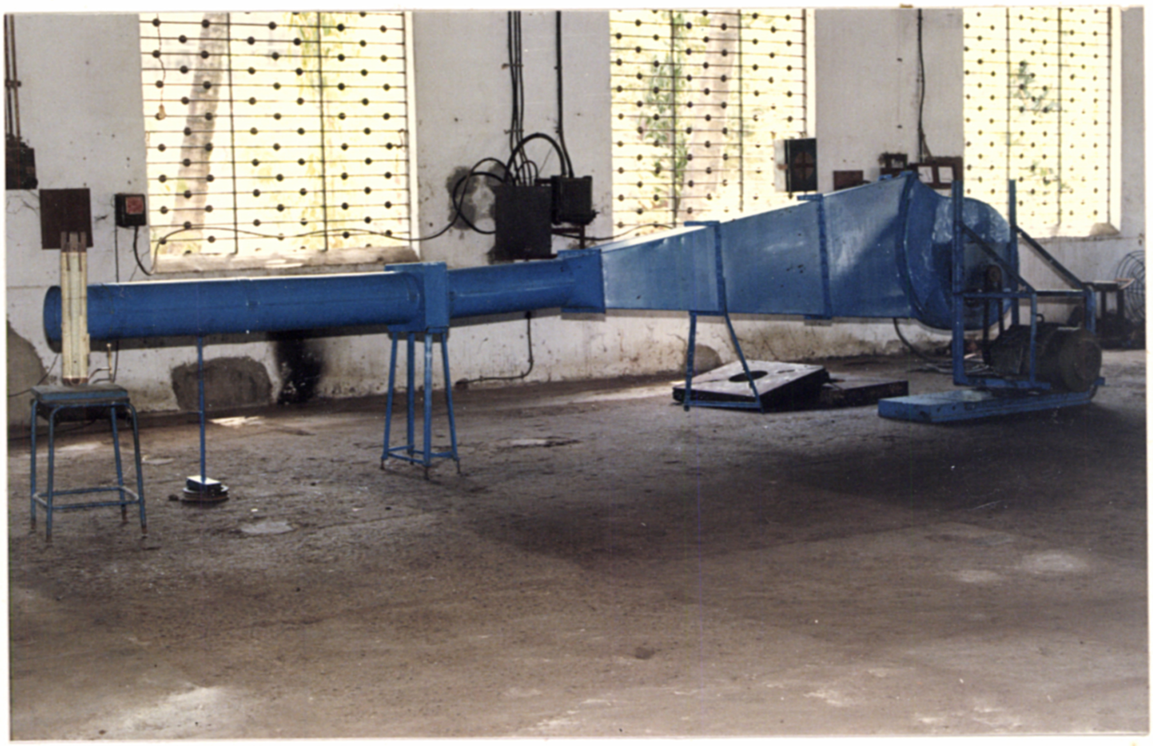


FIG. 4.16 SCHEMATIC VIEW OF TEST SETUP OF BLOWER U

FIG. 4.17 SCHEMATIC VIEW OF TEST SETUP OF BLOWER A

Then the total pressure was computed by adding theses two pressures.

Based on theory suggested in chapter III, a computer programme was developed to compute the various laboratory performance parameters. The programme is given in Appendix - A

4.4 Outside Laboratory Test of Air Carrier Sprayer in Open Air.

The outside laboratory test of the air carrier sprayer in open air was done for the calibration of sprayer before testing it in the field.

For outside laboratory testing tractor mounted Aspee's centrifugal flow mist blower was used. Steps in calibration were as follows.

1. The Aspee's centrifugal mist blower was first mounted on the tractor.
2. Bicycle wheel was attached to the left side of the tractor to measure the travel speed.
3. Selected Nozzles were fixed in the blower outlet casing where nozzles were fitted on m.s.pipe. Then hose was connected to the m.s.pipe.
4. The chemical store tank was filled completely by water. The suck back valve on control panel was positioned such that the liquid was injected back into the chemical tank. Then tractor was operated.
5. Subsequently Pto shaft was engaged and blower speed was adjusted at 1800 rpm. The pressure in the pump was

maintained by adjusting the pressure control valve for testing at three different pressures of 3.5, 7.00, 10.5 kg/cm^2. Tractor travel speed was maintained at three different speeds i.e. 2, 4, 6 kmph. For this speed flow device was used.

6. Then the discharge through individual nozzle was measured for a minute.
7. The discharge was checked for its correctness at above given pressures.

4.5 Field Experiment

The methodology followed in planning, conducting and analyzing the field results is discussed in this section.

4.5.1 Experimental design of field testing

4.5.1.1 Statistical design of field trials

Field trials were carried out for the evaluation of volume deposition for tractor mounted air carrier sprayer system. Split plot design with nine treatments each with three replications were made to conduct the field trials.

4.5.1.2 Independent variables

1.	Number of sprayers	:	1(Tractor mounted Aspee's centrifugal flow mist blower).
2.	Blower speed	:	1700 rpm
3.	Tractor speed	:	2 kmph, 4 kmph, 6 kmph
4.	System pressure	:	3.5, 7, 10.5 kg/cm2
5.	Flow rate	:	750 ml/min per nozzle

4.5.1.3 Dependent variables

1. Spray Volume deposition
2. Droplets size distribution

4.5.1.4 Biological observation

1. Height of plant : 2.15 m.
2. Spread of vine branches on either side of stem : 3 m
3. Average number of leaves per plant : 150
4. Row to row spacing : 3 m
5. Plant to Plant spacing : 1.5 m
6. Variety of grape : Sharad seedless

4.5.2 Specification of tractor used in field testing

1. Model : MISTUBISHI shakti M.T. - 180D
2. Horse power : 18.5
3. Engine: 3 cylinder water cooled
4. Clutch type : single disc dry clutch
5. Travelling speed : 1 to 14.5 kmph
6. P.T.O. speeds : 623, 819, 1506 rpm
7. Weight of tractor : 640 kg
8. Hydraulic lifting capacity : 500 kg
9. Height of tractor : 1.5 m
10. Width of tractor : 1.0 m
11. Gears : 6

4.6 Method of Selection of Various Parameters in the Field Experiment

4.6.1 Selection of tractor

Power constraint of tractor is important factor while designing a blower for orchard air carrier sprayer. Total power to tractor mounted orchard air carrier sprayer is given by

$$P = P_1 + P_2 + P_3 + P_4 \quad \text{.......} \quad 4.1$$

where, P_1 = Input power to blower, hp

P_2 = Input power to pump, hp

P_3 = Power required to overcome soil resistance while running tractor at a specific speed, hp

P_4 = Transmission losses in transmitting power from Pto to blower and pump, hp

From laboratory testing results the blower requires

P_1 = 5 hp

P_2 = pump requires 3.0, hp

P_3 = F.R.S.,

where

$F = (W_1 + W_2) \times 9.8$

W_1 = weight of tractor, kg

W_2 = weight of air carrier sprayer filled with mixture of pesticide and water, kg

R = coefficient of soil resistance

S = speed of tractor, m/s

In this case

W_1 = 640 kg (wt. of Mistubishi tractor)

W_2 = 300 kg (wt. of Aspee's mist blower with water)

R = 0.2

S = 0.8 m/sec

$F = (640 + 300) \times 9.8$

$= 9212\ kg/m^2$

$P_3 = 9212 \times 0.2 \times 0.8$

$= 1473.92$

$= 1.47$ hp

say 1.5 hp

power required to overcome soil resistance = 1.5 hp

power transmission loss = 1.5 hp

Total power required for tractor mounted air carrier sprayer operating at 3 kmph

$P = 5 + 3.0 + 1.5 + 1.5$

$= 11.0$ hp

A 18.5 hp tractor, gives 16 bhp and 13.5 hp at pto. Therefore available power is around 13.5 hp. But power required is around 11 hp which is within the power limit of 18.5 hp tractor. Therefore 18.5 hp tractor in good condition can be used to operate this sprayer.

4.6.2 Pump

Pump is used to discharge spray liquid from tank to air stream produced by blower. Details of pump is given below.

Type - Horizontal Triplex pump

Maximum discharge = 40 l/min at 950 rpm

Maximum pressure = 28 kg/cm^2

Input power = 3 hp

This pump was fitted on the frame, below the liquid storing tank. Power was transmitted to pump from propeller shaft with the help of belt and pulley arrangement.

4.6.3 Control system

It is used to regulate the liquid discharge. It was fitted in the front side of frame as shown in Fig. 4.18. It consists of backsuck valves. Backsuck controls the flow of liquid moving towards nozzles. Pressure regulator valve was fitted on the pump to regulate the system pressure.

4.6.4 Application rate

The flow rate depends upon the application rate and speed of travel. There is no fixed method to determine the application rate for air carrier system. Often, the dilute application rate for control of particular pest is supplied by the pesticide manufacturers for the hydraulic sprayer. It is an air carrier sprayer system to use the sprays of various concentrations such as 2 x, 4 x ,5 x, 10 x, 40 x etc. The digit indicates the number of time by which the dilute application rate is reduced. The dilute application rate suggested by manufacturers for the grape crop is about 1500 l/ha. So we assumed that the rate of application 5 x, i.e. 300 l/ha. The swath width for air carrier was 3 m and operating speed was 3 kmph.

$$\text{Discharge rate} = (\text{Application rate, l/ha} \times \text{speed kmph} \times \text{swath width `m'}) / 600$$

$$= \frac{300 \times 3 \times 3}{600}$$

$$= 4.5 \text{ l/min}$$

This is total discharge required for six nozzles. Thus the discharge required was approximately 750 ml/min per nozzle.

FIG. 4.18 CONTROL SYSTEM ON SPRAYER

FIG. 4.19 ARRANGEMENT OF NOZZLES IN CASING OUTLET

4.6.5. Selection and arrangement of nozzle

Nozzles are required to atomize liquid and to spray it into air stream produced by blower. So proper nozzle selection is essential for the better performance of the air carrier system. Total six nozzles are required, three on each side of the outlet. Selection of nozzle is done on the basis of discharge requirement. So six BCN type spraying angle 90° discharge nozzles, having 750 ml/min discharge rate were taken. Arrangement of nozzles on sprayer is shown in Fig. 4.19.

4.6.6 System pressure

It is also one of the important parameters in air carrier spraying. For a lower flow rate it is necessary to operate the system at lower pressure. But low discharge at higher pressure will damage the nozzles at faster rate. Three pressures 3.5, 7.0 and 10.5 kg/cm^2, were selected for this study.

4.8.7 Travel speed

The travel speed of the air carrier sprayer is also the most important parameter in air carrier spraying. Too low a speed, results in over spraying, leading to loss of time, fuel and spray material, while in too high speed, plants are not filled with chemical laden air. Considering above points, travel speeds selected for this study were 2 kmph, 4 kmph and 6 kmph.

4.7 Design of field experiment

An experiment was planned in selecting split plot design having nine treatments involving three travel speeds and three pressure levels with three replication in each row of each treatment. So total 9 rows were selected for different treatments. Planning of experiment is shown in Fig. 4.20.

4.8 Method of Assessing the Spray Deposition

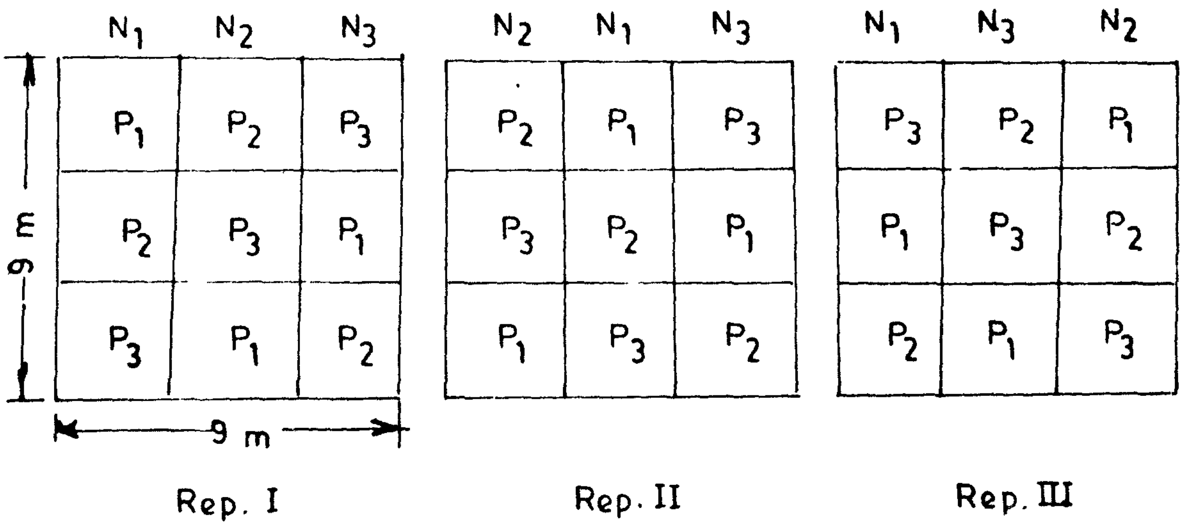
Droplets deposited on the leaves are difficult to analyse as they are absorbed by leaves and no marks are left on the leaves, if sprayed with pesticide. Glossy paper retains shape and size of droplet if sprayed with coloured water. So, white colour glossy paper was preferred to ensure easy detection in the plant and also for definitive determination of droplet deposition on the card surface. The methyl violet colour dye was used as tracer at the rate of 5 gm/l of water. The papers were stitched to the leaf by using the staple pins. The papers were located on upper and lower surface of the leaf as shown in Fig. 4.21.

Nine locations were selected for glossy paper in each replication as shown in Fig. 4.22. The cards were marked to identify the test treatments, replication number, row number, orientation of the leaf to which it was attached.

4.9 Experimental Trials

The field experiment was conducted at Pimpalgaon (Baswant), Dist Nasik on March 25-26, 1993.

There were nine treatments with three replications and glossy papers were attached as stated above. Speed flow device as shown in Fig. 4.23 was used to maintain proper tractor speed. The arrangement as shown in Fig. 4.24 gave tractor speed in terms of revolution of wheel attached to the side of tractor, was



No. of treatments	-	9
No. of replication	-	3
System pressure (kg/cm^2)	-	P_1 3.5 P_2 - 7.0 P_3 -10.5
Travel speed (KMPH)		N_1 - 2 N_2 - 4 N_3 - 6

FIG. 4.20 LAYOUT OF EXPERIMENTAL PLOT
(SPLIT PLOT DESIGN)

FIG. 4.21 ATTACHMENT OF GLOSSY PAPER
ON PAPER

FIG. 4.23 SCHEMATIC VIEW OF SPEED FLOW
DEVICE

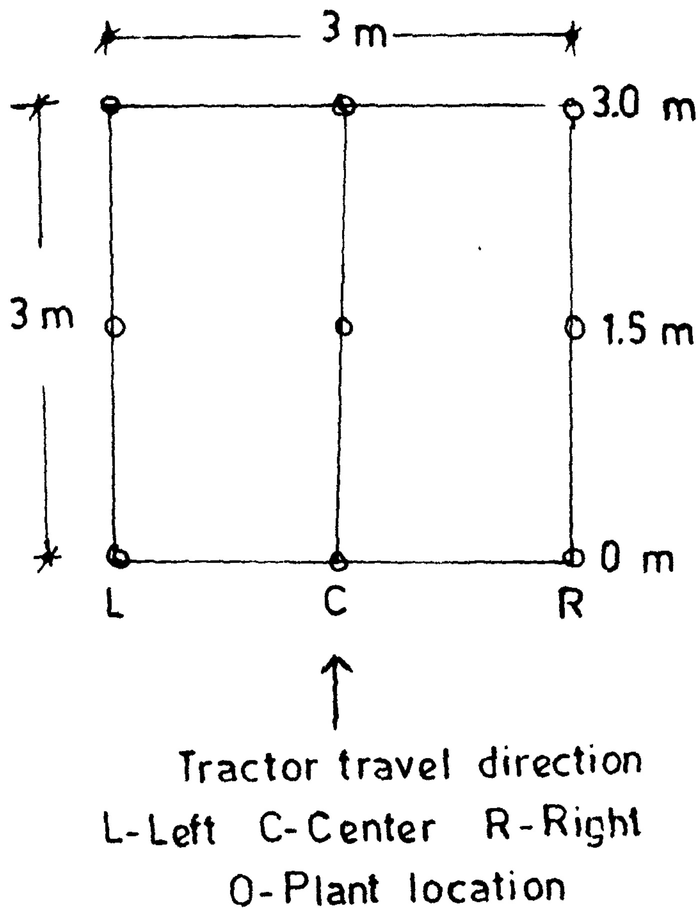


FIG. 4.22 ARRANGEMENT OF GLOSSY PAPERS ON THE ROOF OF GRAPE VINEYARD

FIG. 4.24 BICYCLE WHEEL ATTACHMENT TO THE TRACTOR

FIG. 4.25 SCHEMATIC VIEW OF ACTUAL SPRAYING IN GRAPE VIEN YARD

then converted to travel speed in kmph. Approximately, 7 rpm meant 2 kmph. This device also gave liquid flow rate in l/min. Mechanical pressure gauge was used to measure the pressure. Thermometer, hygrometer and wind meter were used for measuring the temperature, relative humidity and wind speed respectively in the field. Schematic view of actual spraying in grape vineyard is as shown in Fig. 4.25.

Prior to applying treatments, driver was given intensive training to maintain proper tractor speed and liquid pressure. Then after adding dye to the water, the tractor mounted sprayer was operated in the field. When the dye solution was sufficiently dry, the glossy papers were removed from the leaves. Then, the papers were kept according to the treatment number and replication to avoid further sorting. The papers were taken to the laboratory for the droplet spectrum analysis for the performance evaluation of the sprayer.

4.10 Determination of Droplet Size

The analysis of glossy papers was done in laboratory using the microscope and the particle size analyzer as described in Appendix B and schematic view of parcticle size analyzer and microscope are shown in Fig. 4.26.

The preliminary results gave the size of droplets and number of droplets in the particle size range was counted. Then using the diameter of the droplet and number of droplets in the particular size range the volume of liquid applied was calculated. For this, computer program was used to calculate the

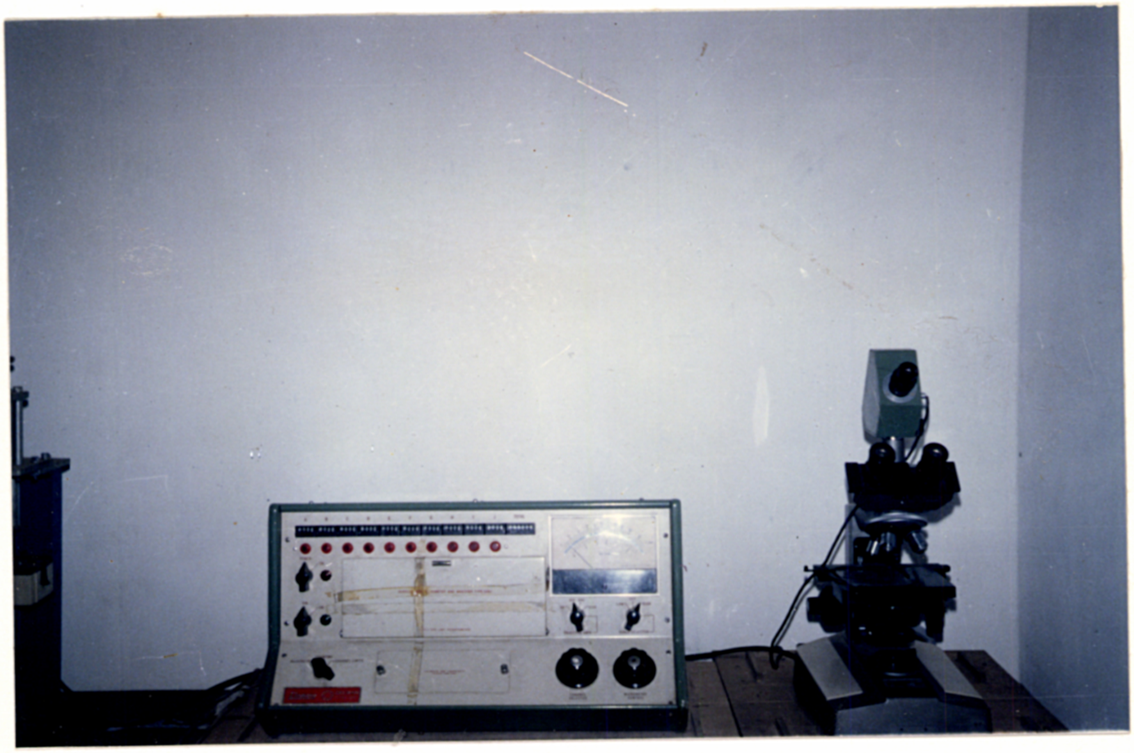


FIG. 4.26 SCHEMATIC VIEW OF PARTICLE SIZE ANALYZER AND MICROSCOPE

parameters such as a spray volume deposition, volume median diameter, number median diameter, uniformity coefficient and droplet density. The computer programme is given in Appendix C. The droplet size distribution analysis is given in Appendix D.

Results and Discussion

CHAPTER V

RESULTS AND DISCUSSION

In this chapter results obtained from the laboratory testing of three centrifugal blowers and the field testing of one tractor mounted air carrier sprayer are discussed.

5.1 Laboratory Performance of the Blowers

Three centrifugal blowers namely \`P′, \`U′ and \`A′ were tested separately in the laboratory at different speeds such as Blower \`P′ from 2050 to 2450, blower \`U′ from 2000 to 2400 and blower \`A′ from 1600 to 2000 rpm. The results obtained are discussed in the following sub section.

5.1.1 Laboratory performance of blower \`P′

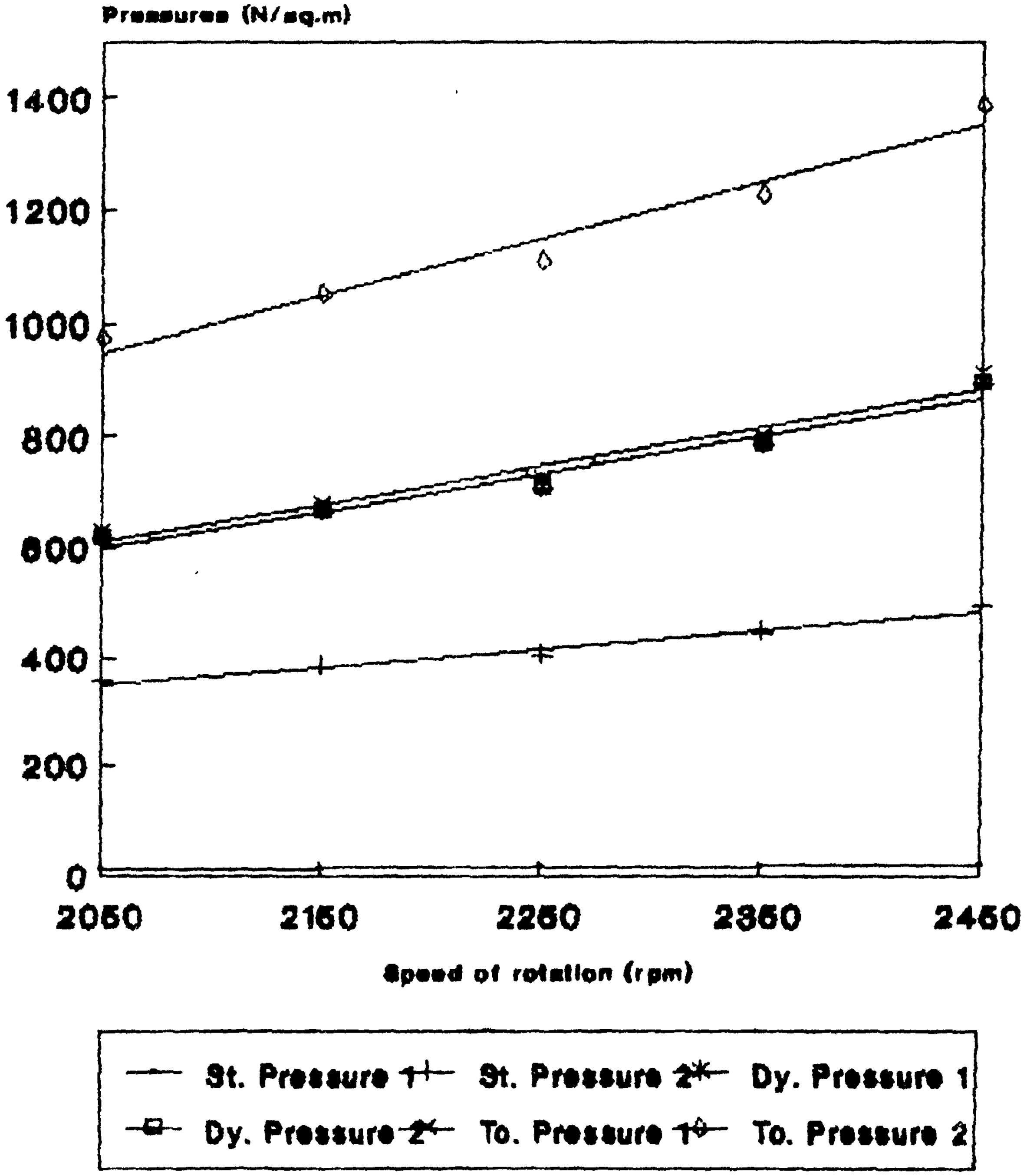
The blower \`P′ was tested at speeds ranging from 2050 to 2450 rpm at 100 rpm interval. The various observations taken at the time of testing and the various computed values of performance parameters are presented in Table 5.1. The performance curves are presented here from Fig.5.1 through Fig.5.3 and discussed below.

5.1.1.1 Pressure output of the blower

The relationships between the speed of rotation and various pressures are shown in Fig. 5.1. From the graphs, it was observed that as the speed of rotation increased the pressure output also increased. The data indicated that total pressure

TABLE 5.1 PERFORMANCE DETAILS OF BLOWER 'P'

Sr. No.	Performance details	Speeds, rpm				
		2050	2150	2250	2350	2450
(a)	**Observations**					
1.	Mean dynamic head, cm of water column	6.30	6.82	7.23	7.99	9.10
2.	Mean static head, cm of water column	0.112	0.125	0.143	0.158	0.194
3.	Input current, amp	40.0	41.5	42.0	46.5	51.5
4.	Input voltage, volt	400.0	395.0	385.0	395.0	384.5
5.	Average air temperature, °C	32.0	31.0	29.0	33.0	26.0
6.	Relative humidity, per cent	34	33	41	31	37
7.	Power factor, Ø	0.860	0.870	0.875	0.90	0.920
(b)	**Computed values at test section**					
1.	Mean static pressure, N/m^2	10.99	12.26	14.03	15.50	19.03
2.	Mean dynamic pressure, N/m^2	618.03	669.04	709.26	783.82	892.71
3.	Total pressure, N/m^2	629.02	681.31	723.29	799.39	911.74
4.	Air velocity, m/s	32.69	33.96	34.85	36.87	38.90
5.	Air discharge, m^3/sec	5.59	5.81	5.96	6.30	6.65
(c)	**Computed values at blower exit**					
1.	Mean static pressure, N/m^2	354.62	390.90	401.06	443.58	493.27
2.	Mean dynamic pressure, N/m^2	618.03	669.04	709.26	783.82	892.71
3.	Total pressure, N/m^2	972.65	1049.94	1110.32	1227.40	1385.98
4.	Air velocity, m/s	32.69	33.96	34.85	36.87	38.90
(d)	**Motor**					
1.	Input power, kw	23.83	24.70	24.51	28.63	31.56
2.	Output power, kw	21.45	22.23	22.05	25.77	28.41
(e)	**Blower**					
1.	Input power, kw	21.02	21.79	21.61	25.25	27.83
2.	Output power, kw	5.44	6.10	6.62	7.74	9.22
3.	Blower efficiency, per cent	25.36	27.98	30.64	30.50	33.11



1 -Test section 2 - Blower exit

FIG. 5.1 EFFECT OF ROTATIONAL SPEED ON PRESSURE FOR BLOWER 'P' output at blower test section varied from 629.03 N/m^2 at 2050 rpm to 911.74 N/m^2 at 2450 rpm and total pressure output at blower exit from 972.65 N/m^2 at 1750 rpm to 1385.976 N/m^2 at 2450 rpm. This shows that the total pressure at blower exit was more than the total pressure at the test section because of various losses in the wind tunnel.

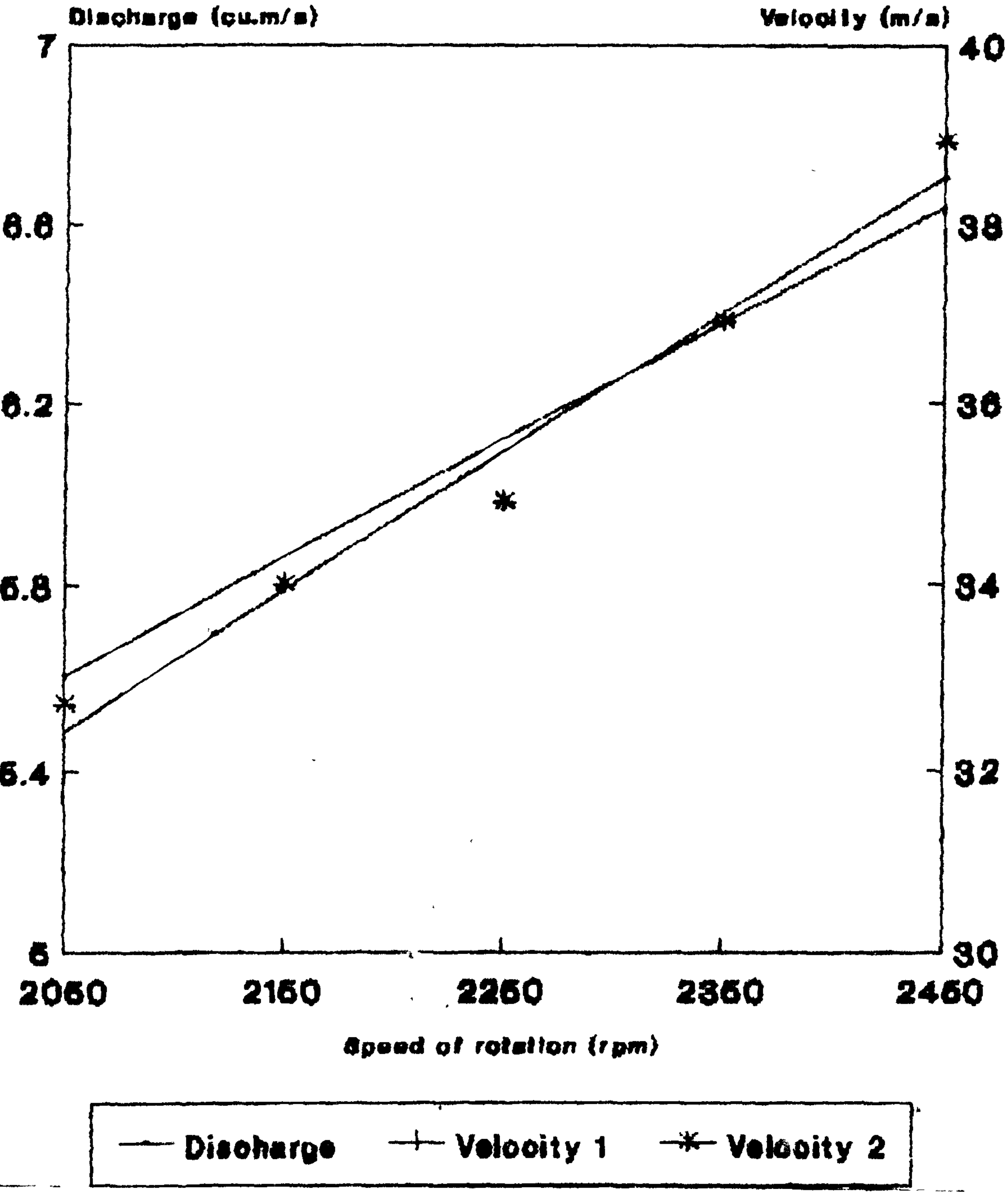
5.1.1.2 Velocity and discharge of the blower

The relationship between velocity and discharge with rotational speed is shown in Fig.5.2. The data indicated that the velocity and air discharge varied from 32.69 m/sec and 5.59 m^3/sec at 2050 rpm to 38.90 m/sec and 6.65 m^3/sec at 2450 rpm respectively. It indicated that as the speed of rotation of the impeller increased the velocity and discharge also increased. The increase in the velocity of air may be due to its increase in peripheral velocity of the impeller. The air velocity and discharge were same at test section and blower exit because of the same cross sectional area at test section and blower exit.

5.1.1.3. Power requirment of the blower

The relationship between the speed of rotation and power requirment is shown in Fig. 5.3. The data revealed that the power input to the blower varied from 21.02 kw at 2050 rpm to 27.83 kw at 2450 rpm. If the different power losses are considered, this blower can be operated by tractor of 45 hp and above.

The static pressure at all speeds at test section and blower exit was less compared to dynamic pressure because air was



1- Test section 2- Blower exit

FIG. 5.2 EFFECT OF ROTATIONAL SPEED ON DISCHARGE AND VELOCITY FOR BLOWER 'P'

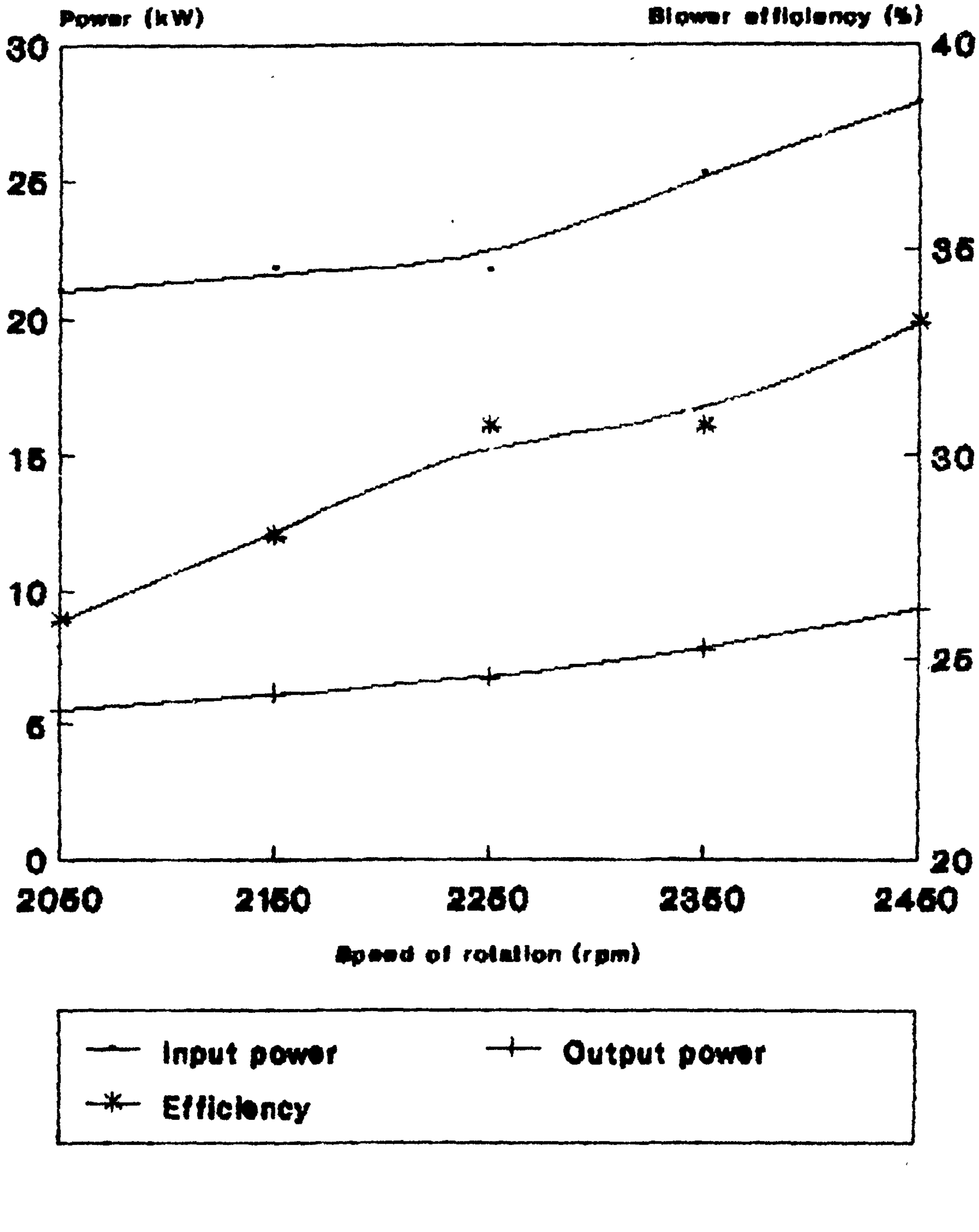


FIG. 5.3 EFFECT OF ROTATIONAL SPEED ON POWER AND EFFICIENCY FOR BLOWER 'P'

at low pressure and had high velocity.

The dynamic pressure was found to increase with increase in speed linearly. This is because of increase in the outlet peripheral velocity which is the function of impeller speed. The dynamic pressure at test section and blower exit was same due to the same cross sectional area of outlet and wind tunnel.

5.1.1.4 Efficiency of the blower

The relationship between the speed of rotation and efficiency of the blower is shown in Fig.5.3. The efficiency was calculated from the power input and power output values of the blower. The data indicated that the efficiency of blower varied from 25.87 per cent at 2050 rpm to 33.12 per cent at 2450 rpm. It showed that the efficiency of blower increased as speed increased. Higher efficiency of the blower observed at 2450 rpm. So, 2450 rpm was the best operating speed of the blower in the field operation. At this speed velocity, discharge of air and the efficiency of the blower were found to be 38.90 m/sec 6.65 m^3/sec and 33.12 per cent respectively.

5.1.2 Laboratory performance of blower `U'

The blower `U' was tested at speeds ranging from 2000 to 2400 rpm at 100 rpm interval. The various computed values of performance parameters are presented in Table 5.2. To study the relationship of various parameters,the graphs were drawn and are shown in Figs 5.4 through 5.6.

TABLE 5.2 PERFORMANCE DETAILS OF BLOWER'U'

Sr. No.	Performance details	Speeds, rpm				
		2000	2100	2200	2300	2400
(a)	**Observations**					
1.	Mean dynamic head, cm of water column	6.912	7.825	8.402	8.927	10.101
2.	Mean static head, cm of water column	0.772	0.792	0.832	0.842	0.745
3.	Input current, amp	38.5	45.5	52.3	59.25	66.00
4.	Input voltage, volt	395	395	340	376.25	380.00
5.	Average air temperature, °C	28.5	30.0	29.0	28.75	30.5
6.	Relative humidity, per cent	49.5	60.5	50.5	47.33	68.25
7.	Power factor, Ø	0.842	0.865	0.885	0.895	0.91
(b)	**Computed values at test section**					
1.	Mean dynamic pressure, N/m^2	678.07	774.99	824.04	873.09	990.81
2.	Mean static pressure, N/m^2	75.73	77.49	82.41	83.39	73.58
3.	Total pressure, N/m^2	753.80	852.48	906.45	956.48	1064.39
4.	Air velocity, m/s	34.04	36.49	37.57	38.65	41.29
5.	Air discharge, m3/sec	3.62	3.88	3.99	4.11	4.39
(c)	**Computed values at blower exit**					
1.	Mean dynamic pressure, N/m^2	523.91	598.79	636.69	674.59	765.54
2.	Mean static pressure, N/m^2	667.34	749.79	793.27	833.44	920.72
3.	Total pressure, N/m^2	1191.25	1348.60	906.45	956.48	1064.39
4.	Air velocity, m/sec	29.93	32.08	33.02	33.97	36.29
(d)	**Motor**					
1.	Input power, kw	22.18	26.93	31.27	34.54	39.29
2.	Output power, kw	19.97	24.24	28.14	31.08	35.58
(e)	**Blower**					
1.	Input power, kw	19.57	23.749	27.58	30.46	34.87
2.	Output power, kw	4.31	5.23	5.70	6.19	7.38
3.	Blower efficiency, per cent	22.00	21.98	20.67	20.30	21.19

5.1.2.1 Pressure output of the blower

The relationships between the speed of rotation and various pressures are shown in Fig. 5.4. From the graph and data indicated that static pressure at test section was less than at blower exit, whereas dynamic pressure at blower test section was more than that at blower exit. It indicates that static pressure increases with increase in area.

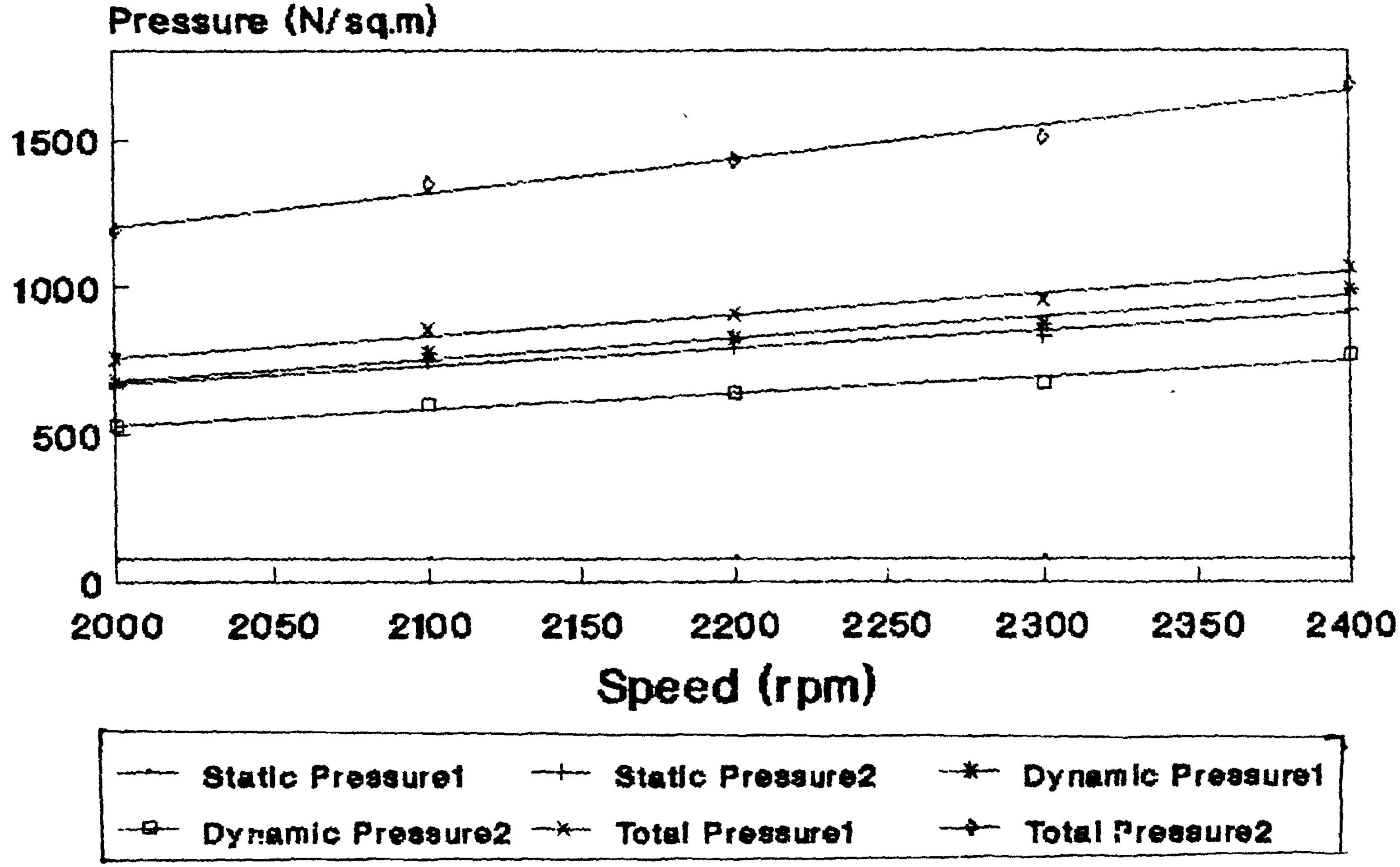
Total pressure at test section was less than that at blower exit section. It was due to frictional losses from blower exit to test section i.e. in wind tunnel. The graph showed that static, dynamic and total pressure at test section as well as blower exit section increased linearly with increase in rotational speed.

5.1.2.2 Velocity and discharge of the blower

The relationships between velocity and discharge with rotational speed are shown in Fig. 5.5. The data indicated that the air velocity and discharge increased as speed of rotation increased linearly. The graph also showed that air velocity at test section was more than that at blower exit because of difference in cross sectional area at test section and blower exit. But discharge was same irrespective of cross sectional area.

5.1.2.3 Power requirement of the blower

The relationship between the speed of rotation and power requirement is shown in Fig.5.6. The data showed that the power input to the blower varies from 19.57 kw at 2000 rpm to



1 Test section . 2 - Blower exit

FIG. 5.4 EFFECT OF ROTATIONAL SPEED ON PRESSURE FOR BLOWER 'U'

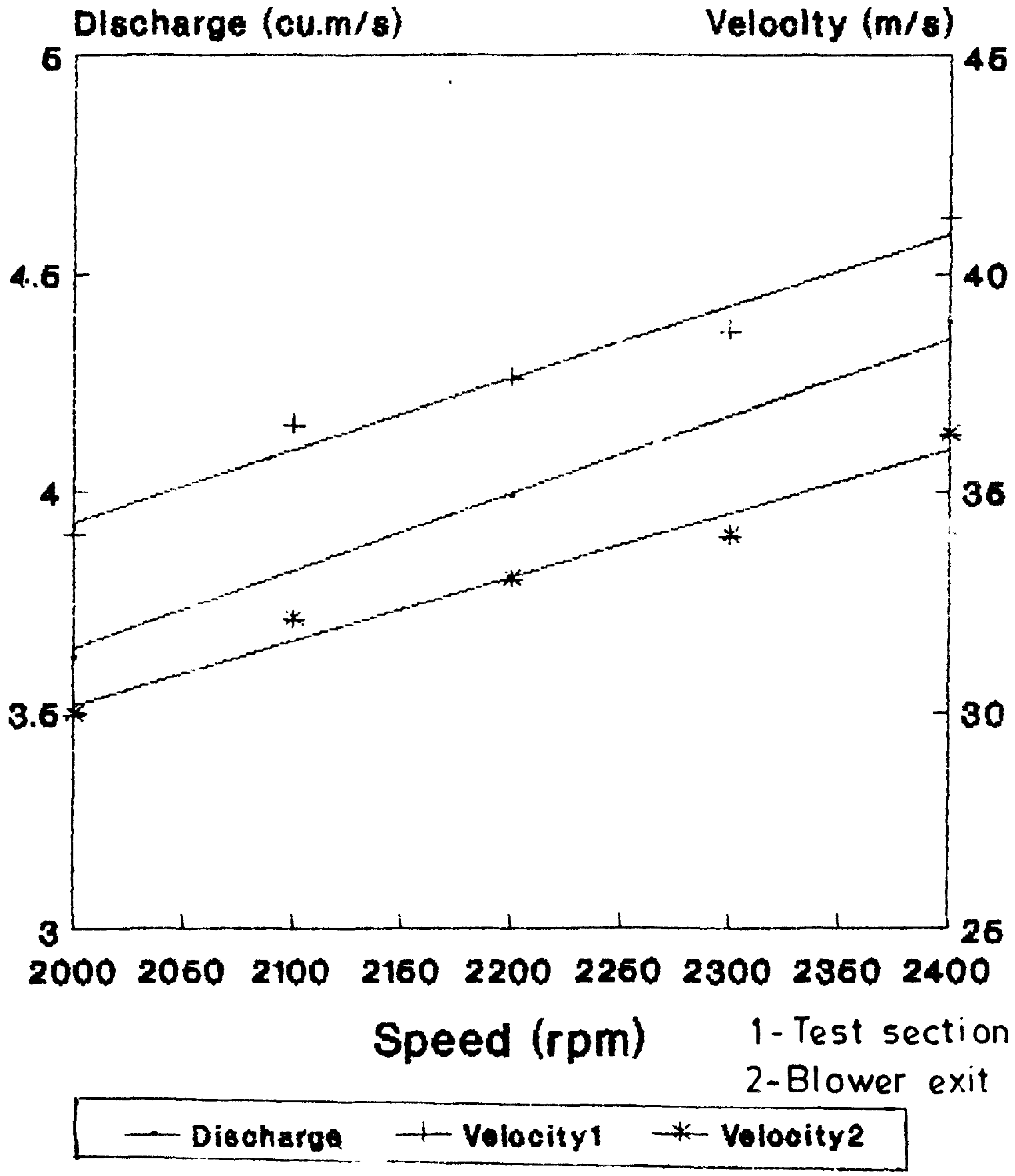


FIG. 5.5 EFFECT OF ROTATIONAL SPEED ON DISCHARGE AND VELOCITY FOR BLOWER 'U'

34.87 kw at 2400 rpm. If the power losses were considered, this blower was operated by above 50 HP tractor. It was found from data that blower output and input power increased linearly with increase in rotational speed.

5.1.2.4 Efficiency of the blower

The relationship between rotational speed and efficiency of blower is shown in Fig.5.6. Data showed that maximum blower efficiency was found at 2000 rpm as 22 per cent after which it decreased. Hence the blower should be run at a speed of 2000 rpm. Therefore this blower was operated in the field at 2000 rpm. where air velocity, air discharge and efficiency of the blower were found to be 29.93 m/sec, 3.62 m^3/sec and 22 per cent respectively. The power requirement was 19.57 kw. At this speed, blower was operated by 35 hp tractor.

5.1.3 Laboratory performance of blower 'A'

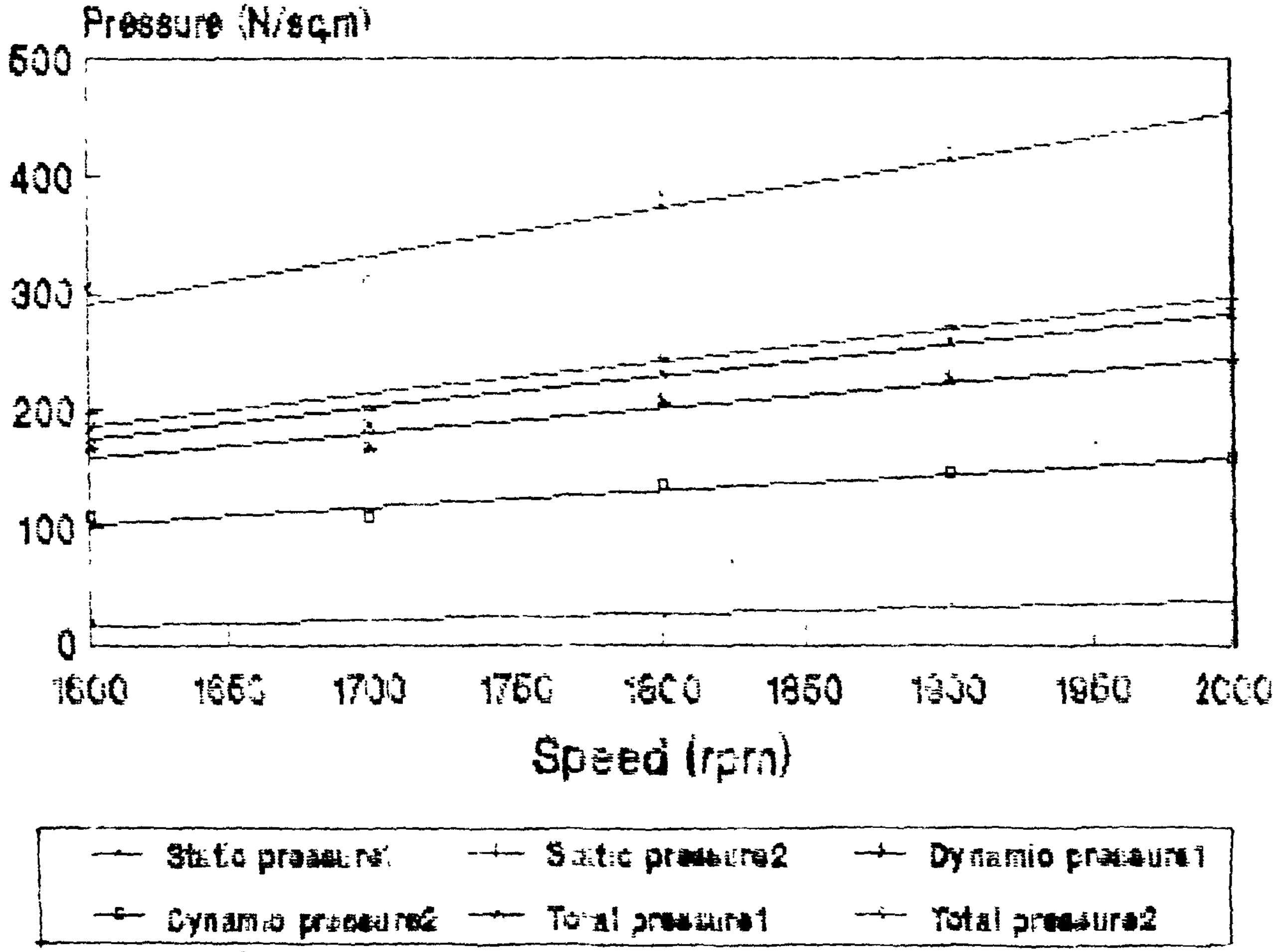
The blower'A' was tested at speeds ranging from 1600 to 2000 rpm, at 100 rpm interval. The various observations taken at the time of testing and various computed values of performance parameter are presented in Table 5.3.

5.1.3.1. Pressure output of the blower

The relationship between the speed of rotation and various pressure is shown in Fig. 5.7. The graph and data indicated that static pressure at test section was less than that at blower exit. Whereas dynamic pressure at blower test section was more than that at blower exit. And total pressure at test section was less than the total pressure at blower exit.

TABLE 5.3 PERFORMANCE DETAILS OF BLOWER 'A'

Sr. No.	Performance details	Speeds, rpm				
		1600	1700	1800	1900	2000
(a)	**Observations**					
1.	Mean dynamic head, cm of water column	1.605	1.665	2.0766	2.213	2.422
2.	Mean static head, cm of water column	0.175	0.203	0.252	0.325	0.369
3.	Input current, amp	14.0	15.0	19.25	20.40	21.40
4.	Input voltage, volt	395	400	395	400	400
5.	Average air temperature, °C	28	28	28	29	29
6.	Relative humidity, per cent	34.5	35.0	33.5	36.5	36.0
7.	Power factor, φ	0.5134	0.550	0.705	0.748	0.784
(b)	**Computed values at test section**					
1.	Mean dynamic pressure, N/m^2	166.77	166.77	206.01	225.63	245.25
2.	Mean static pressure, N/m^2	17.17	20.60	24.53	32.38	36.29
3.	Total pressure, N/m^2	183.94	187.38	230.54	258.00	281.55
4.	Air velocity, m/s	16.87	16.87	18.75	19.66	20.49
5.	Air discharge, m^3/sec	1.80	1.80	1.99	2.09	2.17
(c)	**Computed values at blower exit**					
1.	Mean dynamic pressure, N/m^2	108.34	108.34	133.84	146.58	159.33
2.	Mean static pressure, N/m^2	196.67	200.09	243.60	271.45	294.94
3.	Total pressure, N/m^2	305.00	308.44	377.43	418.03	454.26
4.	Air velocity, m/sec	13.60	13.60	15.12	15.85	16.51
(d)	**Motor**					
1.	Input power, kw	4.99	5.72	9.35	10.58	11.62
2.	Output power, kw	4.48	5.15	8.42	9.52	10.46
(e)	**Blower**					
1.	Input power, kw	4.39	5.04	8.25	9.33	10.25
2.	Output power, kw	0.55	0.56	0.76	0.88	0.98
3.	Blower efficiency, per cent	12.43	10.96	9.11	9.35	9.64



1 - Test section 2 - Blower exit

FIG. 5.7 EFFECT OF ROTATIONAL SPEED ON PRESSURE FOR BLOWER 'A'

This shows that the performance trend of blower `A´ and blower `U´ are similar.

5.1.3.2 Velocity and discharge of the blower

The relationship between velocity and discharge with rotational speed is shown in Fig. 5.8. The graph and data showed the trend of linearly increasing velocity and discharge with increasing speed.

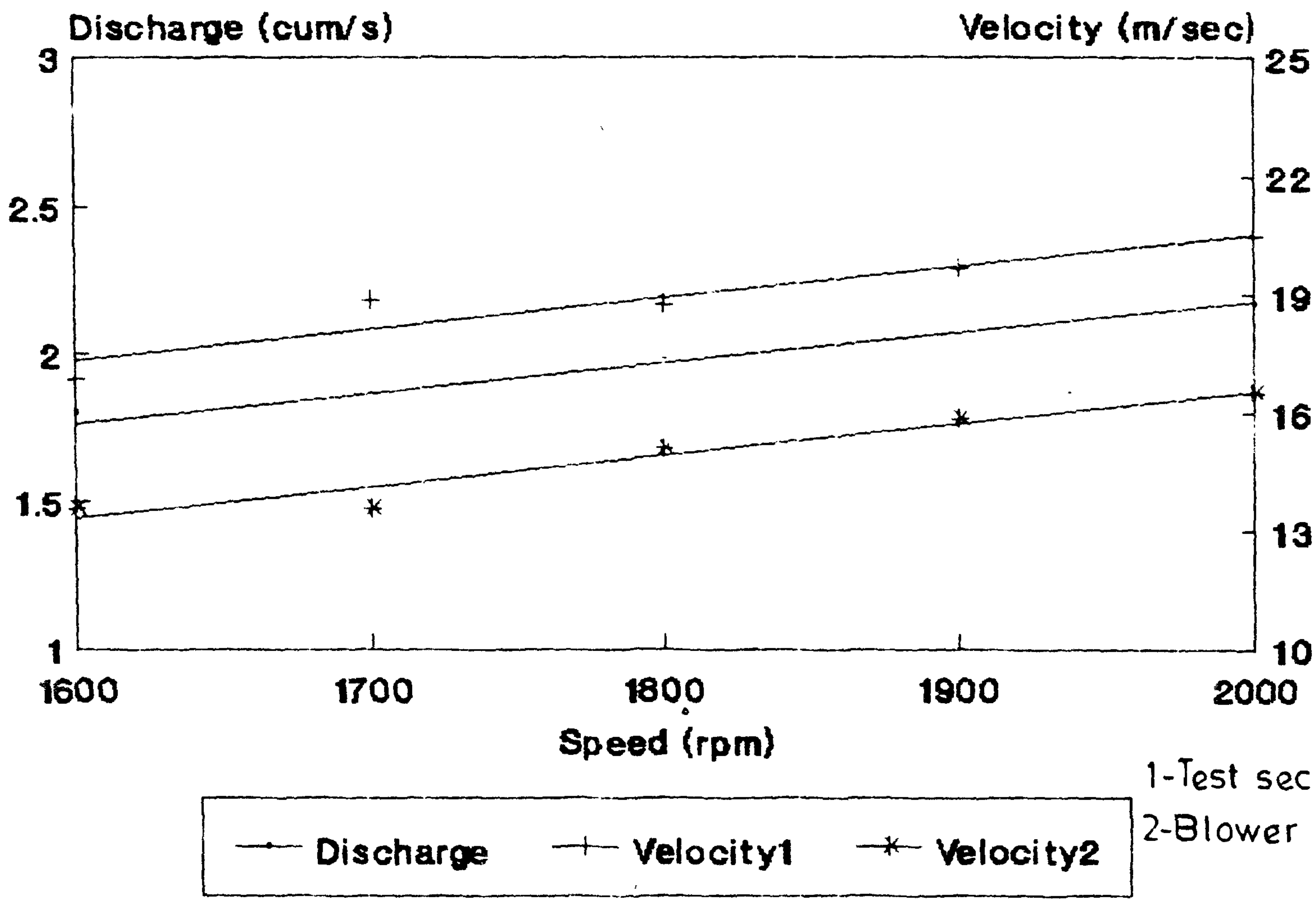
5.1.3.3 Power requirement of the blower

The relationship between the speed of rotation and power requirement is shown in Fig. 5.9. The data showed that power input to the blower varies from 4.39 kw at 1600 rpm to 10.25 kw at 2000 rpm. So if the power losses were considered, this blower was operated by above 18 hp tractor. Also, relationship shows power output and input to blower increases linearly with increase in rotational speed.

5.1.3.4 Efficiency of the blower

The relationship between the speed of rotation and efficiency of blower is shown in Fig. 5.9. Data showed that maximum blower efficiency was found at 1600 rpm i.e 12.43 per cent. After this the efficiency decreased.

So this blower was operated in the field at 1600 rpm, where air velocity, air discharge and efficiency of the blower were found to be 13.60 m/sec, 1.80 m^3/sec and 12.43 per cent and input power was 4.39 kw. So at this speed blower `A´ was operated by 18 hp tractor.



1-Test section
2-Blower exit

FIG. 5.8 EFFECT OF ROTATIONAL SPEED ON DISCHARGE AND VELOCITY FOR BLOWER 'A'

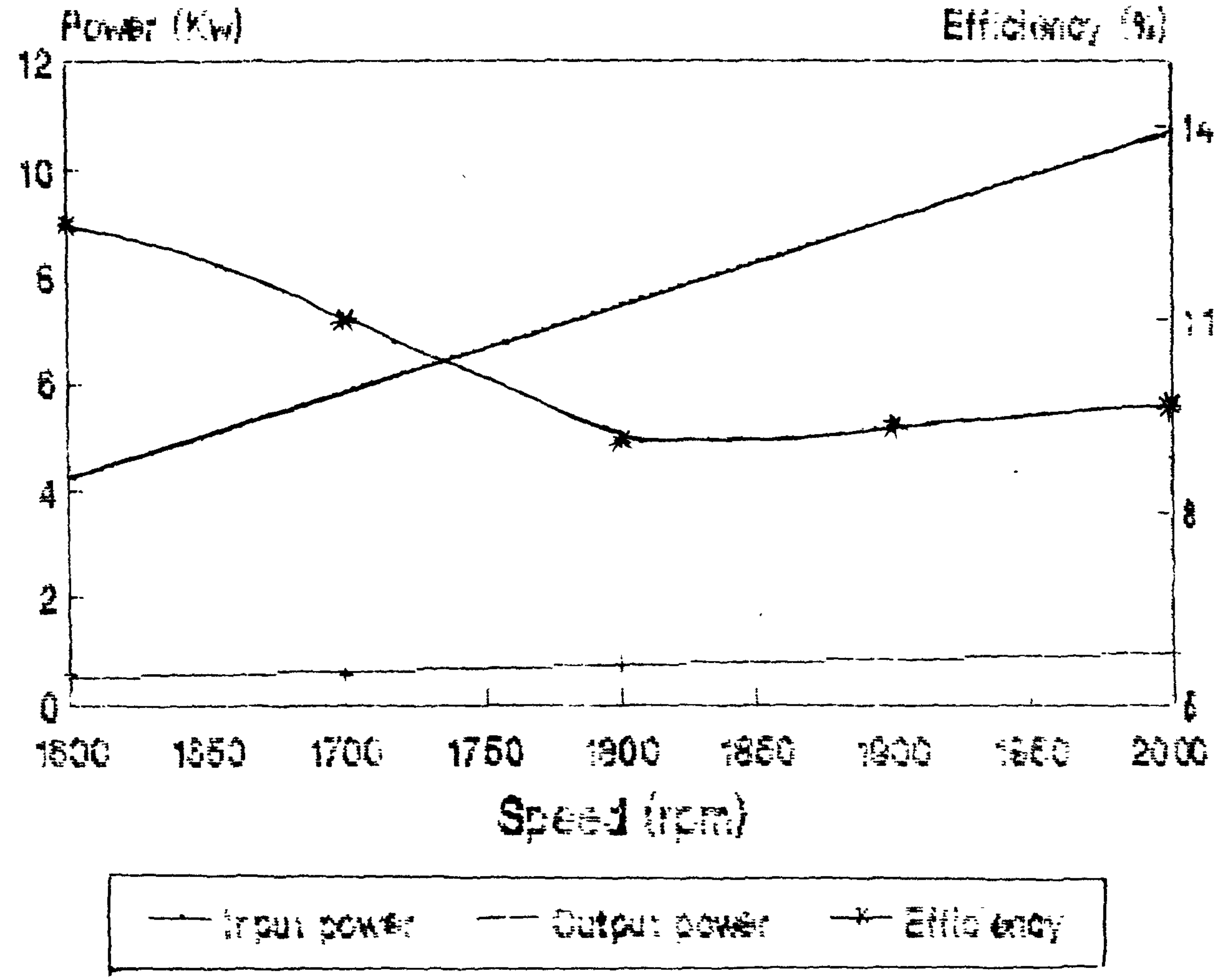


FIG. 5.9 EFFECT OF ROTATIONAL SPEED ON POWER AND EFFICIENCY FOR BLOWER 'A'

5.2 Performance Comparison of Blowers `P´, `U´ and `A´

The performance comparison of blowers `P´,`U´and `A´ was done on the basis of power requirement, air discharge, air velocity and efficiency.

The blower `P´ gave more velocity, discharge of air and efficiency at 2450 rpm speed of impeller. The corresponding values were 38.90 m/sec, 6.65 m^3/sec and 33.12 per cent respectively. Whereas power required to run the blower was 28 kw which required above 45 hp tractor to operate it in the field. This blower is designed for cotton crop by the manufacturer.

The blower `U´ gave more velocity, discharge of air and efficiency at 2000 rpm of impeller. Corresponding values are 29.93 m/sec, 3.62 m^3/sec and 22 per cent respectively. Whereas power required to run the blower was 19.57 kw which required 35 hp size tractor to operate it in the field. This blower is recommended by the manufacturer for orchard crop.

The blower `A´ gave more velocity, discharge of air and efficiency at the impeller speed of 1600 rpm. corresponding values were 13.6 m/sec, 1.8 m^3/sec and 12.43 per cent whereas power required to run the blower was 4.39 kw for which 18 hp tractor can be used to operate it in the field. This blower is suitable for spraying grape crop, where limitation of size is a governing factor.

This blower is therefore tested in grape crop field and performance is as follows.

5.3 Field Performance of Blower `A'

Air carrier sprayer equipped with centrifugal blower `A' was tested in the grape field at various system pressures and travel speeds as mentioned in chapter IV.

5.3.1 Meteorological observations

The various meteorological observations include dry bulb temperature, relative humidity and wind velocity at the test site. The average dry bulb temperature was found to be 32°C The wind was blowing intermittently from left to the right side direction of the sprayer unit with average velocity of 1.45 kmph. The relative humidity was 50 per cent.

5.3.2 Comparison of results between treatments

The data obtained were volume deposits, number median diameter, droplet density, volume median diameter, uniformity coefficient and deposition index were used to compare the effects of speed and pressure on the performance of the sprayer unit. The results obtained are presented in Appendix D.

The treatment effects were compared on the basis of mean spray volume deposits. Spray deposition was measured in terms of droplet density on front and back sides of the leaf. The average volume of spray deposition on left, centre and right are given in Table 5.4.

The Analysis of Variance was used to study the significant effect of each treatment. The ANOVA of left side, centre and right side of the sprayer are given in Tables 5.5 through 5.7.

Table 5.4 Average (three replications) spray volume(ucc) deposition on grape vines.

Tratement	Position of spraying		
	Left	Center	right
N1P1	438	570	507
N1P2	528	598	543
N1P3	570	610	580
N2P1	136	335	157
N2P2	161	371	170
N2P3	260	426	190
N3P1	67	157	126
N3P2	83	196	161
N3P3	118	218	208

The 'F' values in the Table 5.5 indicate that the volume deposits on left side of sprayer at speed 2 kmph, 4 kmph and 6 kmph are significant at 1 per cent level whereas the effect of pressure levels i.e. 3.5, 7, 10.5 kg/cm^2 on the volume deposits are also significant at 1 per cent level.

The 'F' values in the Table 5.6 implies that the volume deposits at the central location of sprayer at speeds of i.e. 2, 4, 6 kmph were significant at 1 per cent level. However the effect of pressure levels i.e. 3.5, 7, 10.5 kg/cm^2 on volume deposits was found to be insignificant because of maximum spray deposition occur on centre of the sprayer.

The 'F' values in the Table 5.7 indicated that the volume deposits on right side of sprayer at speed level i.e. 2, 4, 6 kmph were significant at 1 per cent level.But the effect of pressure levels on volume deposits were insignificant.

The volume of spray deposition on left,centre and right sides of sprayer was as shown in Fig. 5.10, through 5.12.

Fig. 5.10 indicates the volume of spray deposition on left side of sprayer on grapevines. In this case maximum spray deposition (570ucc) was found at system pressure at 10.5 kg/cm^2 with travel speed of 2kmph and minimum spray deposition at (67ucc) was found at system pressure at 3.5 kg/cm^2 with travel speed of 6 kmph. The graph trend and data showed that there was increase in volume deposition with increased system pressure. But it decreased with the increase in travel speed.

TABLE 5.5 Analysis of variance of spray volume deposition on left side of sprayer.

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed F	Tabular 'F' 5%	Tabular 'F' 1%
1. Replication (r-1)	3-1 =2	2938.1	1469.05			
2. Speed level (A) (a-1)	3-1 =2	884307.2	44213.60	177.6 xx	6.94	18.0
3. Error (a) (r-1)(a-1)	(3-1)(3-1)=4	9988.12	2497.10			
4. Pressure level(B) (b-1)	3-1 =2	46878.30	24439.20	13.35 xx	3.88	6.93
5. A x B (a-1)(b-1)	(3-1)(3-1)=4	12181.93	3045.50	1.73 ns	3.26	5.41
6. Error (b) a(a-1)(b-1)	3(3-1)(3-1)=12	21060.41	1755.1			
7. Total rab-1	3x3x3-1 = 26	977354.10				

Cv(a)=19.08%　　Cv(b)=16%

xx - significant at 1 % level of significance

ns - not significant

TABLE 5.6 Analysis of variance of spray volume deposition on center side of sprayer.

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed 'F'	Tabular 'F' 5%	Tabular 'F' 1%
1. Replication	2	12636.72	6318.36			
2. Speed level (A)	2	742159.1	371079.59	62.62 xx	6.94	18.0
3. Error (a)	4	23701.27	5925			
4. Pressure level(B) (b-1)	2	15958.27	7979.13	1.47 ns	3.88	6.93
5. A x B	4	1489.06	372.26	0.068 ns	3.26	5.41
6. Error (b)	12	64775.11	5397.95			
7. Total	26	860726.00				

Cv(a) = 20.33 % Cv(b) = 19.40%

xx - significant at 1 % level of significance

ns - not significant

TABLE 5.7 Analysis of variance of spray volume deposition on right side of sprayer.

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed 'F'	Tabular 'F' 5%	Tabular 'F' 1%
1. Replication	2	16106.92	8053.46			
2. Speed level (A)	2	727136.26	363568.13	146.35 xx	6.94	18.0
3. Error (a)	4	9936.65	2484.21			
4. Pressure level(B) (b-1)	2	4330.92	2165.46	1.16 ns	3.88	6.93
5. A x B	4	58962.85	14740.7	7.92 xx	3.26	5.41
6. Error (b)	12	22335.19	1861.1			
7. Total	26	838809.90				

Cv(a) = 15.82 % Cv(b) = 13.70%

xx - significant at 1 % level of significance

ns - not significant

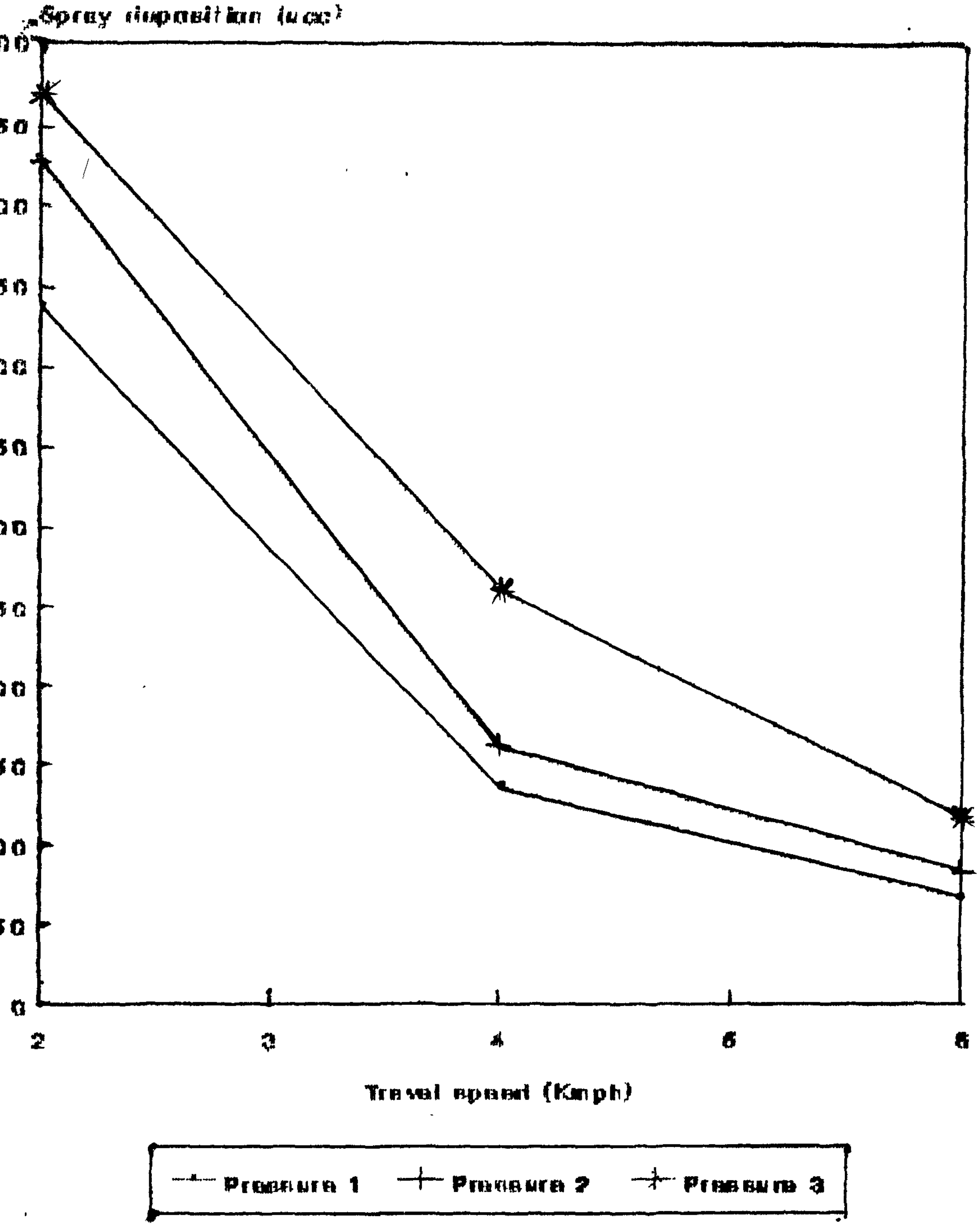


FIG. 5.10 SPRAY DEPOSITION ON GRAPEVINES ON LEFT SIDE OF SPRAYER

Fig. 5.11 showed the volume of spray deposition on centre side of sprayer on grapevines. The data indicated that maximum spray deposition (610ucc) was found at system pressure at 10.5 kg/cm^2 with travel speed of 2 kmph. And minimum spray deposition (157ucc) was found at 3.5 kg/cm^2 system pressure and 6 kmph travel speed respectively. In this case volume of spray deposition increased with increased system pressure and decreased with increase in travel speed of sprayer.

Fig. 5.12 showed the volume of spray deposition on grape crop on the right side of sprayer. The data indicated that maximum spray deposition (580ucc) was found at 10.5 Kg/cm^2 system pressure with 2 kmph travel speed and minimum spray deposition (126ucc) found at 3.5 kg/cm^2 system pressure with travel speed 6 Kmph.

Thus, the volume of spray deposition increased as system pressure increased but it linearly decreased with increased travel speed of sprayer.

The Fig. 5.13 shows that volume of spray deposition was more on center side than at left and right side of spraying. This is due to wind velocity disturbances while spraying. In the center side of sprayer more spray material was deposited due to overlapping spray of the nozzles. In right side also more deposition occurred compared to that on left side because of wind disturbances. However, it was still lesser compared to deposition at central location. It is therefore concluded that as travel speed increases spray volume deposition decreases. The spray

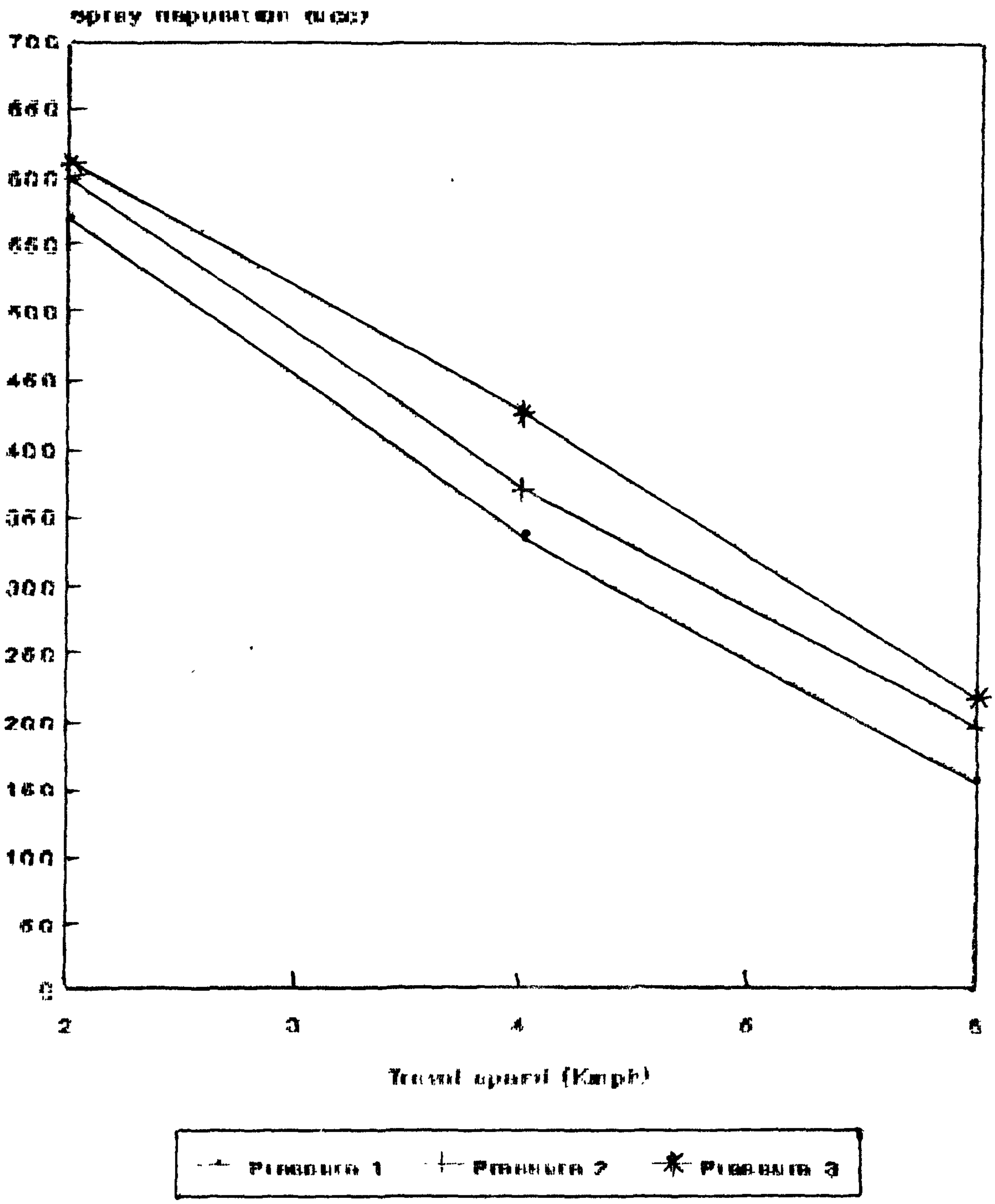


FIG. 5.11 SPRAY DEPOSITION ON GRAPEVINES ON CENTRE OF SPRAYER

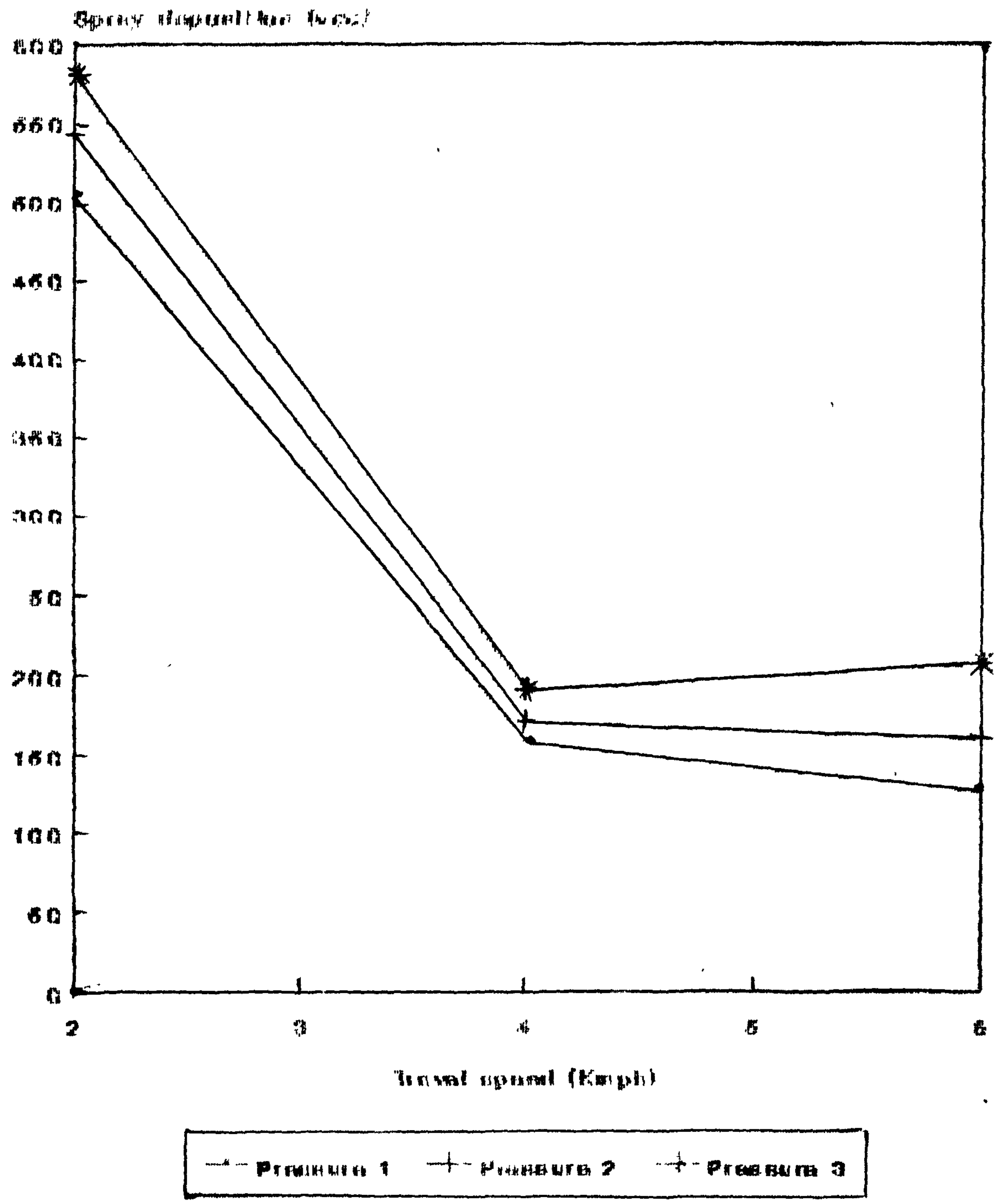


FIG. 5.12 SPRAY DEPOSITION ON GRAPEVINE ON RIGHT SIDE OF SPRAYER

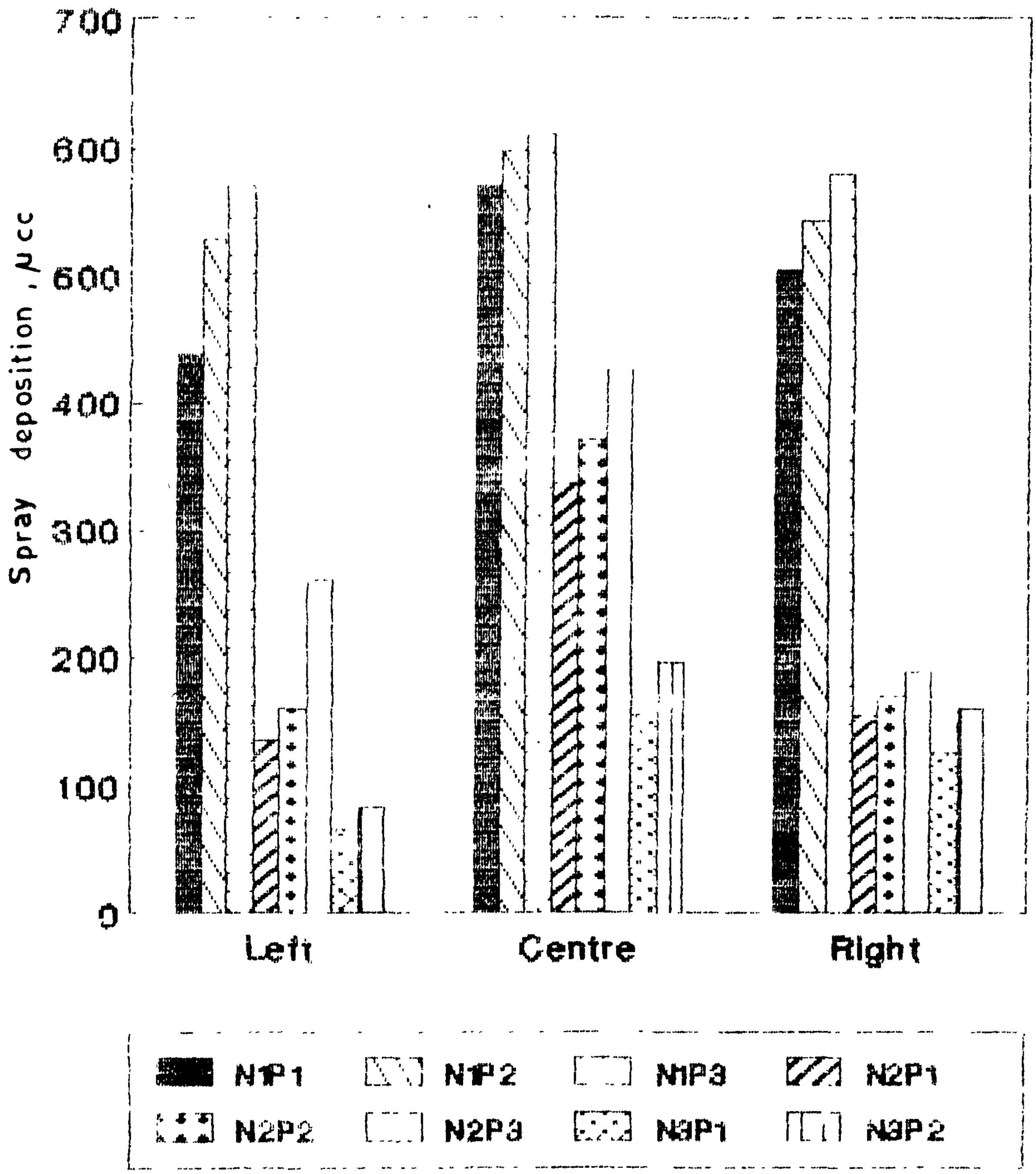


FIG. 5.13 SPRAY DEPOSITION ON GRAPEVINES

deposition at a particular location also depends upon the time spent for spraying at that location. As speed increases, time spent for spraying a particular location decreases. As travel speed increases, air resistance also increases. Which diverts the spray, affecting spray deposition. In fact, speed should not be too low or too high. Too low a speed may cause over spraying and too high a speed causes under spraying.

The effect of speed level was found to be highly significant at all spraying sides. Therefore considering the effect of travel speed on spray deposition, air carrier sprayer should be run at proper speed.

From the test of least significant difference, it was found that this sprayer should be run at 2 kmph travel speed with 10.5 kg/cm^2 system pressure for obtaining the best results of spraying in the field.

Along with the spray volume deposits the droplet density was also measured.The data indicated that as the pressure increased the number of droplets also increased. The droplet density was found to be more than 50 No/sq.cm at all system pressures. Which was as shown in Table 5.8.

Due to obstruction of dense foliage, the air velocity was greatly reduced. In such situation the small droplets can be handled easily than the large ones. So smaller droplets will have greater penetrating ability compared to that of large droplets. Therfore spray pattern should contain large number of smaller

Table 5.8 Average (three replications) number of droplets per square centimeter.

Tratement	Position of spraying		
	Left	Center	right
N1P1	64	81	65
N1P2	92	80	70
N1P3	59	55	60
N2P1	57	59	64
N2P2	88	75	54
N2P3	56	60	67
N3P1	54	64	57
N3P2	57	45	54
N3P3	80	89	75

droplets for dense foliage crop like grape. This needs higher pressure of operation for the spraying system. Therefore the system pressure of 10.5 kg/cm^2 is found suitable for grape crop.

The average volume median diameter and number median diameter on left side, at center and on right side of spraying was shown in Table 5.9.

The volume median diameter(VMD) on left side of sprayer ranges from 321.2 to 334.3um, on center side 318.5 to 335um and on right side of sprayer ranges from 322.3 to 334.3um. The number median diameter (NMD) on left side of sprayer ranges from 62 to 202um, on center side of sprayer 68 to 190um and on right side ranges from 73 to 190um. Which was as shown in Table 5.10. The uniformity coefficient and deposition index above unity for all treatments showed effective spraying.

Table 5.9 Average (three replications) volume median diameter(um) observed on left, center and right side of sprayer

Treatment	Position of spraying		
	Left	Center	right
N1P1	330	327	328
N1P2	326	326	328.5
N1P3	326.5	324.5	322.5
N2P1	321.1	325.3	335.5
N2P2	328.8	318.5	334.33
N2P3	328.3	329.3	322.3
N3P1	334.3	335.5	325.0
N3P2	332.5	322.2	325.8
N3P3	334	331.8	328.6

Table 5.10 Average (three replications)number median diameter (um) observed on left, center and right side of sprayer.

Treatment	Position of spraying		
	Left	Center	right
N1P1	198	147	145
N1P2	202	178	190
N1P3	147	190	177
N2P1	76	119	68
N2P2	73	141	76
N2P3	81	126	97
N3P1	62	68	119
N3P2	72	97	73
N3P3	82	120	76

Summary and Conclusions

CHAPTER VI

SUMMARY AND CONCLUSIONS

The grape (*Vitis Vinifera L.*) is one of the most important remunerative horticultural crops. India is the leading country producing grape in the world. The area under grape in India is about 24,000 hectares with more than 5,00,000 tonnes of production. In Maharashtra, the area occupied by grape crop is about 36 per cent of the total area under grape in India.

Thus, there is a need to have an effective technique to control the pests and diseases of grapevines. Due to drawbacks of hydraulic spraying, the air carrier spraying is becoming popular. An air carrier sprayer utilizes an air stream to carry the spray fluid introduced into air stream in the form of fine droplets to the target. Past studies on the air carrier sprayers indicate that a very little work has been done on grape crop. The present work was, therefore, undertaken to study the performance of the air carrier spraying system in the grape crop with the following objectives.

General Objective

To study the performance of air assisted spraying system for grapevines.

Specific Objectives

1. To study the performance of the existing centrifugal flow mist blowers in the laboratory.
2. To evaluate performance of the same blower outside the laboratory in open air.

3. To measure the performance of an air assisted spraying system in the field.
4. Based on the above studies, to redesign a blower suitable for grape crop.

6.1 Conclusions

6.1.1 Laboratory performance of existing centrifugal blowers

Three centrifugal blowers namely `P´,`U´ and `A´ were tested separately in the laboratory at different speeds, such as blower `P´ from 2050 to 2450 rpm, blower `U´ from 2000 to 2400 rpm, blower `A´ from 1600 to 2000 rpm at 100 rpm interval respectively. From the data collected following conclusions are drawn.

1. It indicates that static pressure and dynamic pressure increases linearly with increase in the rotational speed.
2. The maximum blower efficiency was observed in blower P´ 33.11 per cent compared to blower `U´ 12 per cent and `A´ 12.43 per cent.
3. The blowers `P´, `U´, and `A´ were operated best in the field at 2450, 2000 and 1600 rpm speed of impeller and needed 28.83 kw, 19.57 kw and 4.39 kw respectively.
4. The maximum air discharge was observed in blower `P´ (6.65 $m^3$/sec) as compared to the discharge of blower `U´ (3.62 m^3/sec) and blower` A´ (1.8 m^3 /sec).

5. The blower 'P', 'U' and 'A' needed tractors of size 45 hp, 35 hp and 18 hp respectively.

6. The maximum air velocity was observed in blower 'P' (38.90 m/sec) as compared to blower 'U' (29.93 m/sec) and blower 'A' (16.51 m/sec).

6.1.2 Field performance of centrifugal blower 'A'

Centrifugal blower 'A' was tested in the grape crop to study the effect of travel speed and pressure on the performance of blower. There were overall nine treatments which included three system pressure P_1 = 3.5 kg/cm^2, P_2 = 7 kg/cm^2 and P_3 = 10.5 kg/cm^2 and three travel speeds N_1 = 2 kmph. N_2 = 4 kmph, N_3 = 6kmph. Experimental layout of split plot design was selected for experimentation. The results are given below.

1. The field test of blower indicates that the travel speeds have significant effect on the spray volume deposition on left, centre and right side of spraying.

2. The best results of spraying were obtained when sprayer 'A' was operated at travel speed of 2 kmph and at system pressure of 10.5 kg/cm^2.

3. The spray volume deposition was obtained more (610ucc) on backside surface than the front side of leaf.

4. When system pressure increases from 3.5 kg/cm^2 to 10.5 kg/cm^2 the volume of spray deposition increases whereas when travel speed increases from 2 kmph to 6 kmph the volume of spray deposition decreases.

Blower `A' should therefore be operated at rotational speed of 1600 rpm at system pressure of 10.5 kg/cm^2 with tractor forward speed of 2 kmph in the field.

Suggestions for Future Work

CHAPTER VII

SUGGESTIONS FOR FUTURE WORK

A new design of centrifugal blower was done on the basis of laboratory and field performance results of existing blower `A´ as the blower had very low efficiency i.e. 12.43 per cent and less air discharge i.e. 1.8 m^3/sec. which is not sufficient to grape vines.

In view of above findings, the blower was redesigned based on the theory of Osborne (1982) and Pandey (1986). Some assumptions were made to design a new blower suitable for grape vineyard to give increased efficiency and better spraying deposition as well as good penetration. The details of the new design are given in the Appendix `E´.

It´is necessary to develop a centrifugal blower based on the new design and to evaluate its performance in laboratory as well as in the field.

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Appendices

APPENDIX A

```
10 CLS
20 PRINT "PROGRAM FOR BLOWER EFFICIENCY"
30 PRINT "DEVISED BY D.D.TEKALE, M.TECH STUDENT, MPKV RAHURI
40 PRINT "FOR CONTINUATION OF PROGRAM, PRESS KEY [F5]
50 END
60 CLS
70  PRINT "LIMITATION : THIS PROGRAM IS USED TO COMPUTE  THE  AIR
           VELOCITY,   DISCHARGE   AND   BLOWER   EFFICIENCY   OF
           AXIAL  OR  CENTRIFUGAL BLOWER USING T WIND  TUNNEL  OF
           FOLLOWING DIMENSIONS"
80 PRINT "DIMENSIONS OF WIND TUNNEL"
90 PRINT "LENGTH OF TUNNEL = 5 M"
100 PRINT : OUTLET DIA = 26 CM"
110 PRINT "FOR CONTINUATION OF PROGRAM PRESS KEY [F5]
120 END
130 CLS
140  PRINT "FILL IN THE REQUISITE DATA AFTER (? SIGN)  AND  PRESS
           ENTER KEY"
150 PRINT
160 INPUT "HP OF MOTOR";HP
170 PRINT
180 INPUT "POWER FACTOR (PF)AT GIVEN LOAD";PF
190 PRINT
200 INPUT "BLOWER RPM (N)";N
210 PRINT
220 INPUT "INPUT CURRENT (I)";I
230 PRINT
240 INPUT "INPUT VOLTAGE (V)";V
250 PRINT
260 INPUT "AV. TEMPERATURE (T)IN DEGREE C.";T
270 PRINT
280 INPUT "AV. HUMIDITY (E1) IN %";E1
290 PRINT
300 INPUT "AV. STATIC HEAD (HS) IN CM"; HS
310 PRINT
320 INPUT "AV.DYNAMIC HEAD (HD), IN CM";HD
330 CLS
340 PRINT
350 PRINT "CALCULATIONS BEGINS :"
360 PRINT
370 PRINT "BLOWER RPM = "N
380 PRINT
390 REM MEAN STATIC PRESSURE AT TEST SECTION (PS)
400 REM 1 CM OF WATER COLUMN = 98.1 N/SQ.M
410 PS = HS * 98.1
420 PRINT "MEAN STATIC PRESSSURE AT TEST SECTION (PS) = "PS "N/M2
430 PRINT
440 REM MEAN DYNAMIC HEAD AT TEST SECTION (PD)
450 PD = HD * 98.1
460 PRINT "MEAN DYNAMIC HEAD AT TEST SECTION (PD) = "PD "N/M2"
470 PRINT
480 REM TOTAL PRESSUE AT TEST SECTION (PT)
```

```
490 PT = PS + PD
500 PRINT "TOTAL PRESSUE AT TEST SECTION (PT) = "PT"N/M2"
510 PRINT
520 REM PAB = ABS ATMOSPHERIC PRESSURE = 101320 N/M2
530 PAB = 101.32*10^3
540 REM PVS = SATURATED VAPOUR PRESSURE = 41000 N/M2
550 PVS = 41! * 10^3
560 REM ED = DRY AIR DENSITY, KG/M3
570 REM DENSITY AT STP = 1.225 KG/M3
580 ED = 1.225/(273 + T)
590 EA = ED * (PAB - .378 * PVS * RH/100)/PAB
600 PRINT "HUMID AIR DENSITY = "EA "KG/M3"
610 REM K = VELOCITY CONSTANT
620 PRINT
640 PRINT "VELOCITY CONSTANT = "K
650 PRINT
660 REM VELOCITY AT TEST SECTION
670 VT = K* (HD/100)^.5
680 PRINT "AIR VELOCITY AT TEST SECTION = "VT " m/s"
690 PRINT
700 REM DISCHARGE AT TEST SECTION (Q)
710 REM A = CROSS SECTIONAL AREA OF TUNNEL OUTLET
720 REM D = DIA. OF TUNNEL OUTLET
730 D = .26
740 A = 3.14/4* D^2
750 Q = A * VT
760 PRINT " AIR DISCHARGE AT TEST SECTION = "Q*2 " "M3/S"
770 PRINT
780 REM REYNOLD NUMBER
790 REM U =DYNAMIC VISCOSITY OF AIR, n.S/M2
800 U = (11 + .18 * (1.8* T + 32)) * 1.49 * 10^-6
810 RE = EA * VT * D/U
820 PRINT "REYNOLD NUMBER = "RE  " (DIMENSIONLESS)"
830 REM FRICTION FACTOR (F)
840 F = .14 / (RE)^.17
850 PRINT
860 PRINT "FRICTION FACTOR = "F  " (DIMENTIONLESS)"
870 PRINT
880 PRINT "FOR CONTINUATION OF PROGRAM, PRESS KEY [F5]
890 END
900 CLS
910 REM PRESSURE LOSS BETWEEN BLOWER EXIT AND TEST SECTION (PL)
920 REM DH = EQUIVALENT HYDRAULIC DIA OF BLOWER OUTLET, M
930 DH = .26
940 REM L1 = LENGTH BETWEEN BLOWER EXIT AND TEST SECTION
950 L1 = 5
960 REM L2 = EQUIVALENT LENGTH OF STRAIGHTENER
970 REM Y/D RATIO = 0.005
980 J = .005
990 L2 = 15.04 * DH /((1 - 26.55 * J) + 184.6 * J^2)^1.83
1000 PL = F * PD * ((L1 + L2)/DH)
1010 PRINT "PRESSURE LOSS BETWEEN BLOWER EXIT AND TEST SECTION
            = "PL
```

APPENDIX A CONTINUED...

```
1020 PRINT
1030 REM TOTAL PRESSURE AT BLOWER EXIT (PTE)
1040 PTE = PL + PT
1050 PRINT "TOTAL PRESSURE AT BLOWER EXIT = "PTE
1060 PRINT
1070 REM DYANAMIC PRESSURE AT BLOWER EXIT
1080 REM AT = AREA OF BLOWER AT TEST SECTION
1090 REM AE = AREA OF BLOWER EXIT
1100 REM RATIO AT/AE = AR = 0.716 (COMPUTED)
1110 AR = .716
1120 PDE = PD * (AR)^2
1130 PRINT " DYNAMIC PRESSURE AT BLOWER EXIT = "PDE  "N/M2"
1140 PRINT
1150 REM STATIC PRESSURE AT BLOWER EXIT
1160 PSE = PTE - PDE
1170 PRINT "STATIC PRESSURE AT BLOWER EXIT  =   "PSE  "N/M2"
1180 PRINT
1190 REM VELOCITY AT BLOWER EXIT
1200 VE = AR * VT
1210 PRINT "VELOCITY AT BLOWER EXIT = "VE   "M/S"
1220 PRINT
1230 REM INPUT POWER TO MOTOR (PI)
1240 PI = 3^ .5 * V * I * PF * .001
1250 PRINT "INPUT POWER TO MOTOR  =  "PI  "KW"
1260 PRINT
1270 REM MOTOR OUTPUT
1280 REM EM = MOTOR EFFICIENCY
1290 EM = .9
1300 PO = EM * PI
1310 PRINT " MOTOR OUTPUT   = "PO "KW"
1320 PRINT
1330 REM BLOWER INPUT POWER (PIB)
1340 REM ET = TRANSMISSION EFFICIENCY
1350 ET = .98
1360 PIB = ET * PO
1370 PRINT "BLOWER INPUT POWER  = " PIB  "KW"
1380 PRINT
1390 REM HALF THE POWER WAS MEASURED
1390 REM HALF THE POWER WAS MEASURED
1400 REM BLOWER OUTPUT POWER (POB)
1410 POB = 2 * Q * PTGE *.001
1420 PRINT " BLOWER OUTPUT POWER  =  'POB " KW"
1430 PRINT
1440 REM EB = BLOWER EFFICIENCY
1450 EB = POB/PIB * 100
1460 PRINT "BLOWER EFFICIENCY  = "EB "%"
1470 END
```

APPENDIX - B

B-1 MICROSCOPE

The microscope of olympus series BH system was used for the study of droplets collected on the glossy paper. It had a build in light source. It had four objective lenses (4x, 10x, 40x, 100x). The selection depends upon the range of particle size range needed. The head unit with the eye-piece received signals from the particle size micrometer and the analyzer.

B- 2 PARTICLE SIZE MICROMETER AND ANALYZER

The 526 particle size micrometer and analyzer used was a product of flaming instruments Ltd. Michigan. It had a vibrator unit which created double image in the head unit of the microscope. The shearing of the two images indicates the size range of the corresponding droplet. The analyzer had ten channels representing the droplet size range of 25 to 50 um size each. If the total size is 0 to 500 um, it would be classified with a counter classified into 10 classes, thus at the end one can get the total number of droplets in the particular range.

APPENDIX C

```
10 CLS
15 PRINT "DEVELOPED BY D.D.TEKALE,MPKV,RAHURI"
20 PRINT "PROGRAM TO STUDY PARTICLE SIZE ANALYSIS"
30 PRINT
40 PRINT "THIS PROGRAM CALCULATES THE MEAN MEDIAN DIAMETER AND"
50 PRINT "AND VOLUME MEAN DIAMETER"
60 PRINT
70 PRINT "FOR CONTINUATION OF THE PROGRAM PRESS KETY [F5]"
80 PRINT
90 END
100 CLS
110 REM  D - IS ACTUAL DROPLET DIAMETER IN MICRONS (um)
120 REM  N - IS NUMBER OF DROPLETS IN THE  GIVEN  DROPLET  SIZE RANGE
130 REM  S - IS CUMULATIVE SUM OF NUMBER OF DROPLETS
140 REM  C - IS CUMULATIVE PERCENTAGE OF NUMBER OF DROPLETS
150 REM  V - IS VOLUME OF DROPLET IN CC
160 REM  A - IS CUMULATIVE SUM OF THE VOLUME OF DROPLETS CC
170 REM  B - IS CUMULATIVE PERCENTAGE OF VOLUME OF DROPLETS
180 REM  Z - IS AVERAGE SIZE OF THE DROPLET IN um
190 REM  NMD IS NUMBER MEAN DIAMETER IN um
200 REM  VMD IS VOLUME MEAN DIAMETER IN um
210 DIR R(11),N(11),S(11),C(11),D(11),V(11),B(11),Z(11),T$(1),U$(5)
220 FOR I = 1 TO 11
230 INPUT N(I)
240 NEXT I
250 PRINT"-------------------------------------------------------"
260 PRINT "DROP SIZE        AVERG.   ACTUAL      NO.OF    VOL.OF "
270 PRINT "  RANGE          SIZE    DIAMETER  DROPLETS DROPLET"
280 PRINT "   um             um        um                 cc
290 FOR I = 1 TO 10
300 READ R(I)
310 NEXT I
320 DATA 50,100,150,200,250,300,350,400,450,500
330 FOR I = 1 TO 11
340 READ Z(I)
350 NEXT I
360 DATA 25,75,125,175,225,275,325,375,425,475,525
370 FOR I = 1 TO 11
380 READ D (I)
390 NEXT I
400 DATA 16.8,50.6,84.4,118.2,152.1,185.8,219.5
410 DATA 253.3,287.1,320.9,354.7
420 FOR I = 1 TO 11
430 S (0)=0
440 LET S(I) = S(I-1) + N(I)
450 NEXT I
460 FOR I = 1 TO 11
470 C(I) = 100 * S(I)/S(11)
480 IF C(I) < 50 THEN 580
490 IF C(I) = 50 THEN 510
500 IF C(I) > 50 THEN 520
510 LET NMD = D(I) : GOTO 600
520 LET X2 = D(I)
```

APPENDIX C CONTINUED.....

```
530 LET X1 = D(I-1)
540 LET F1 = C(I)
550 LET F2 = C(I-1)
560 LET NMD = X1 + (((50-F1)/(F2-F1))*(X2-X1))
570 GOTO 590
580 NEXT I
590 PRINT"-------------------------------------------------------"
600 FOR I = 1 TO 11
610 V(0)=0
620 V(I) = N(I) * (3.14/ 6) * (d(I) * 10^-4 )^3
630 LET A(I) = A(I-1) + V(I)
640 PRINT R(I-1)+1"TO"R(I),TAB(17);Z(I);TAB(29);D(I);TAB(47);N(I);
    TAB(55);V(I)
650 NEXT I
660 FOR I = 1 TO 11
670 B(I) = 100 * A(I)/A(11)
680 IF B(I) < 50 THEN 770
690 IF B(I) = 50 THEN 710
700 IF B(I) > THEN 720
710 LET VMD = D(I)
720 LET Y2 = D(I)
730 LET Y1 = D(I-1)
740 LETG2 = B(I)
750 LET G1 = B(I-1)
760 LET VMD = Y1 + (((50-G1)/(G2-G1))*(Y2-Y1))
770 NEXT I
780 LET UC = VMD/NMD
790 PRINT"-------------------------------------------------------"
800 PRINT TAB(47);S(11);TAB(55);A(11)
810 PRINT"-------------------------------------------------------"
820 PRINT "NUMBER MEDIAN DIAMETER = " NMD
830 PRINT "VOLUME MEDIAN DIAMETER = " VMD
840 PRINT "UNIFORMITY CO-EFFICIENT= " UC
850 PRINT "DROPLET DENSITY        = " S(11)
860 PRINT"-------------------------------------------------------"
870 END
```

APPENDIX - D

D-1 Droplet size distribution analysis

System pressure :3.5 kg/cm^2 Ambient Temperature :32°C
Travel speed :2.0 kmph Relative Humidity :55 per cent
Air discharge :1.8 m^3/s Wind Velocity :1.5 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left 0.0 F	Left 0.0 B	Left 1.5 F	Left 1.5 B	Left 3.0 F	Left 3.0 B	Center 0.0 F	Center 0.0 B	Center 1.5 F	Center 1.5 B	Center 3.0 F	Center 3.0 B	Right 0.0 F	Right 0.0 B	Right 1.5 F	Right 1.5 B	Right 3.0 F	Right 3.0 B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	2	2	2	0	2	1	7	12	13	12	14	18	8	17	9	11	16	13
101-150	125	84.4	6	5	5	6	9	5	17	16	14	17	15	18	10	19	11	12	20	13
151-200	175	118.2	8	7	6	8	9	4	7	11	9	13	11	15	9	15	13	10	14	9
201-250	225	152.1	10	6	10	6	9	5	8	10	10	8	8	11	8	13	7	6	11	6
251-300	275	185.8	7	4	5	3	7	5	9	8	7	8	7	5	2	8	5	5	8	3
301-350	325	219.5	5	4	8	4	7	6	7	9	8	6	9	3	4	6	6	8	9	4
351-400	375	253.3	8	6	10	2	9	4	7	6	10	6	8	2	4	5	6	9	8	4
401-450	425	287.1	10	3	7	4	7	5	8	5	8	4	8	1	3	7	7	9	10	4
451-500	475	320.9	6	2	10	2	6	5	10	6	9	5	7	3	2	5	6	5	12	3
>500	525	354.7	10	2	10	3	11	1	13	9	11	8	15	4	6	9	9	8	15	3
Number median dia. um			199	182	252	124	210	217	158	128	169	146	171	109	148	149	121	169	184	99
Volume median dia. um			327	333	329	330	326	336	326	327	328	327	323	328	323	327	327	329	327	332
Uniformity Coefficient			1.7	1.8	1.3	2.6	1.6	1.5	2.1	2.5	1.9	2.3	1.8	3.0	2.2	2.1	2.7	1.9	1.8	3.3
Droplet density,no/sq.cm.			72	41	73	38	76	41	93	92	99	87	102	80	56	104	79	83	123	62
Volume of droplets,ucc			610	230	670	230	620	270	730	540	690	470	740	250	300	530	530	550	860	260
Deposition index			46.6	17.5	17.6	47.4	20.6	55.8	41.3	52.7	35.9	56.5	19.1	22.9	40.5	40.5	41.0	42	65	19

Position of Spraying: Left / Center / Right; Distance 'm': 0.0, 1.5, 3.0

F= front of leaf B = back of leaf

Appendix - D cont..

D-2 Droplet size distribution analysis

System pressure : 7 kg/cm^2 Ambient Temperature : 32°C
Travel speed : 2.0 kmph   Relative Humidity : 55 per cent
Air discharge : 1.8 m^3/s   Wind Velocity : 1.5 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left 0.0 F	Left 0.0 B	Left 1.5 F	Left 1.5 B	Left 3.0 F	Left 3.0 B	Center 0.0 F	Center 0.0 B	Center 1.5 F	Center 1.5 B	Center 3.0 F	Center 3.0 B	Right 0.0 F	Right 0.0 B	Right 1.5 F	Right 1.5 B	Right 3.0 F	Right 3.0 B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	4	2	3	3	7	4	12	2	8	4	6	1	3	3	3	2	2	3
101-150	125	84.4	5	6	8	2	11	7	17	12	14	9	8	3	6	7	8	4	6	10
151-200	175	118.2	4	8	8	5	13	16	15	11	10	7	9	7	8	9	9	6	7	8
201-250	225	152.1	6	4	9	2	12	4	10	8	9	9	10	9	7	9	6	6	5	11
251-300	275	185.8	4	7	7	2	5	3	12	4	9	6	9	4	3	5	7	2	4	5
301-350	325	219.5	5	6	5	2	12	6	11	5	11	4	7	8	2	5	4	6	9	5
351-400	375	253.3	8	5	7	3	8	4	7	5	6	9	10	5	7	4	5	8	12	5
401-450	425	287.1	4	3	9	8	8	1	10	8	4	7	8	3	10	4	7	11	16	5
451-500	475	320.9	9	6	5	8	11	1	5	3	8	9	9	3	8	4	3	9	9	6
>500	525	354.7	11	7	17	7	11	4	14	7	17	6	13	7	10	5	5	12	13	6
Number median dia. um			249	186	193	279	217	89	179	121	160	186	207	215	239	120	174	224	229	152
Volume median dia. um			325	327	318	328	329	326	325	327	319	332	326	325	327	329	330	327	328	330
Uniformity Coefficient			1.4	1.8	1.7	1.2	1.6	3.6	1.8	2.7	2.0	1.8	1.6	1.5	1.4	2.8	1.9	1.5	1.4	2.2
Droplet density, no/sq.cm.			60	54	78	42	98	50	113	65	96	70	89	50	64	55	57	66	83	64
Volume of droplets, ucc			590	420	740	450	740	230	740	430	760	530	750	380	590	340	370	690	840	430
Deposition index			45.1	37.0	56.5	34.4	56.5	17.6	56.6	32.9	58.1	40.1	57.3	29.0	45.1	25.9	28.3	52.7	64.1	32.8

F= front of leaf   B = back of leaf

Appendix - D cont..

D-3 Droplet size distribution analysis

System pressure :10.5 kg/cm^2 Ambient Temperature :33°C

Travel speed :2.0 kmph Relative Humidity :50 per cent

Air discharge :1.8 m^3/s Wind Velocity :1.5 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Position of Spraying: Left, Distance 'm' 0.0 F	Left 0.0 B	Left 1.5 F	Left 1.5 B	Left 3.0 F	Left 3.0 B	Center, Distance 'm' 0.0 F	Center 0.0 B	Center 1.5 F	Center 1.5 B	Center 3.0 F	Center 3.0 B	Right, Distance 'm' 0.0 F	Right 0.0 B	Right 1.5 F	Right 1.5 B	Right 3.0 F	Right 3.0 B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	7	12	13	12	14	18	4	15	4	11	4	11	5	1	3	2	1	2
101-150	125	84.4	17	16	14	17	15	18	8	16	12	10	5	11	19	10	5	5	13	2
151-200	175	118.2	7	11	9	13	11	15	8	15	8	10	6	12	12	15	9	5	8	6
201-250	225	152.1	8	10	10	8	8	11	5	12	6	8	7	10	8	5	10	9	5	7
251-300	275	185.8	9	8	7	8	7	5	4	11	5	5	3	5	7	6	10	3	4	6
301-350	325	219.5	7	9	8	6	9	3	6	8	6	6	5	5	8	5	9	2	9	7
351-400	375	253.3	7	6	10	6	8	2	8	6	5	5	8	7	7	3	5	1	11	6
401-450	425	287.1	8	5	8	4	8	1	6	5	6	8	8	5	8	4	11	1	9	5
451-500	475	320.9	10	6	9	5	7	3	7	7	8	7	10	5	9	4	10	1	10	3
>500	525	354.7	13	9	11	8	15	4	17	10	12	10	12	8	16	8	16	5	16	7
Number median dia. um			158	128	169	146	171	109	247	134	214	179	236	134	160	122	193	133	244	207
Volume median dia. um			326	327	328	327	323	328	317	327	324	326	326	327	323	323	324	314	324	327
Uniformity Coefficient			2.1	2.5	1.9	1.3	2.4	1.5	2.1	2.5	1.9	2.3	1.4	2.4	2.1	2.7	1.7	2.4	1.4	1.6
Droplet density,no/sq.cm.			93	92	99	87	102	80	73	105	72	80	68	79	99	61	88	34	86	51
Volume of droplets,ucc			730	540	690	690	740	250	730	590	610	580	680	470	790	410	840	200	840	410
Deposition index			55.8	41.3	52.7	35.9	56.5	19.1	55.7	45.0	46.6	44.3	51.9	35.9	60.3	31.3	64.2	15.3	64.1	31.3

F= front of leaf B = back of leaf

Appendix - D cont..

D-4 Droplet size distribution analysis

System pressure : 3.5 kg/cm^2 Ambient Temperature : 34°C
Travel speed : 4.0 kmph Relative Humidity : 48 per cent
Air discharge : 1.8 m^3/s Wind Velocity : 1.4 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left, 0.0 F	Left, 0.0 B	Left, 1.5 F	Left, 1.5 B	Left, 3.0 F	Left, 3.0 B	Center, 0.0 F	Center, 0.0 B	Center, 1.5 F	Center, 1.5 B	Center, 3.0 F	Center, 3.0 B	Right, 0.0 F	Right, 0.0 B	Right, 1.5 F	Right, 1.5 B	Right, 3.0 F	Right, 3.0 B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	17	17	22	11	14	10	9	11	7	10	19	5	25	14	25	10	20	8
101-150	125	84.4	17	13	25	9	14	6	10	12	7	10	22	4	18	12	17	10	25	9
151-200	175	118.2	12	12	20	6	10	6	6	8	9	8	16	7	11	9	11	8	17	7
201-250	225	152.1	8	7	17	5	7	4	4	3	6	2	9	1	10	5	9	6	11	0
251-300	275	185.8	3	4	9	1	2	1	1	0	2	0	3	0	3	0	5	1	6	0
301-350	325	219.5	1	3	6	0	2	0	3	0	0	0	1	2	5	0	2	0	2	0
351-400	375	253.3	0	1	3	0	1	0	3	4	3	0	1	8	1	0	2	0	3	0
401-450	425	287.1	0	1	3	0	0	1	2	11	4	3	2	11	4	0	6	0	5	0
451-500	475	320.9	1	1	1	0	0	0	2	5	7	2	0	8	5	0	4	0	5	0
>500	525	354.7	3	2	5	2	2	1	5	7	7	3	3	11	3	0	1	0	5	0
Number median dia. um			57	117	104	62	55	59	98	89	135	53	55	282	52	68	53	59	105	69
Volume median dia. um			320	330	328	301	323	325	322	328	326	324	326	326	332	339	336	338	330	338
Uniformity Coefficient			5.6	2.8	3.2	4.8	5.8	5.5	3.3	3.7	2.4	6.0	5.9	1.2	6.4	5.0	6.4	5.7	3.2	4.8
Droplet density, no/sq.cm.			62	61	111	34	52	29	45	60	52	38	76	57	85	40	82	35	93	24
Volume of droplets, ucc			140	140	320	68	99	54	240	440	390	160	160	620	290	22	240	25	360	9
Deposition index			10.7	10.7	2.4	5.2	7.6	4.1	18.3	33.6	29.8	12.22	12.2	35.9	10.2	1.7	18.3	31.9	27.5	0.68

F= front of leaf B = back of leaf

Appendix - D cont..

D-5 Droplet size distribution analysis

System pressure : 7.0 kg/cm^2 — Ambient Temperature : 34°C
Travel speed : 4.0 kmph — Relative Humidity : 48 per cent
Air discharge : 1.8 m^3/s — Wind Velocity : 1.4 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left 0.0 F	Left 0.0 B	Left 1.5 F	Left 1.5 B	Left 3.0 F	Left 3.0 B	Center 0.0 F	Center 0.0 B	Center 1.5 F	Center 1.5 B	Center 3.0 F	Center 3.0 B	Right 0.0 F	Right 0.0 B	Right 1.5 F	Right 1.5 B	Right 3.0 F	Right 3.0 B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	14	8	13	17	19	20	8	8	7	8	8	8	22	16	23	13	25	10
101-150	125	84.4	11	8	12	13	17	17	9	9	7	10	8	8	21	11	22	10	20	9
151-200	175	118.2	11	5	7	12	14	12	8	8	9	8	6	7	15	15	9	5	15	8
201-250	225	152.1	8	4	3	8	5	6	4	7	11	8	7	9	10	5	10	9	12	5
251-300	275	185.8	5	1	6	2	7	2	4	5	5	9	10	4	8	6	10	3	8	2
301-350	325	219.5	4	1	1	0	3	0	0	1	3	8	10	1	7	5	9	2	7	0
351-400	375	253.3	4	0	2	0	2	0	0	2	3	4	5	0	2	3	5	1	4	0
401-450	425	287.1	2	0	1	1	2	0	3	0	5	0	3	0	2	4	11	1	3	0
451-500	475	320.9	3	0	1	2	4	1	8	3	3	3	3	5	4	4	10	1	9	0
>500	525	354.7	8	0	3	2	2	1	14	7	10	7	5	7	5	8	16	5	6	0
Number median dia. um			87	61	520	55	125	66	152	118	126	125	174	147	106	50	75	59	97	58
Volume median dia. um			320	338	324	328	333	330	311	313	318	323	329	317	326	338	338	338	331	338
Uniformity Coefficient			3.6	5.5	6.3	6.0	2.9	5.0	2.0	2.6	2.5	2.6	1.9	2.2	3.1	5.6	4.4	5.7	3.4	5.8
Droplet density,no/sq.cm.			70	27	49	57	75	59	58	50	63	65	65	49	97	48	51	41	109	34
Volume of droplets,ucc			370	24	160	130	230	76	530	270	430	350	360	360	290	360	39	58	480	26
Deposition index			28.2	1.8	12.2	9.9	17.6	5.8	40.5	20.6	32.8	26.7	27.5	22.1	27.5	2.9	4.5	4.4	36.7	1.9

F= front of leaf B = back of leaf

Appendix - D cont..

D-6 Droplet size distribution analysis

System pressure : 10.5 kg/cm^2 | Ambient Temperature : 34°C
Travel speed : 4.0 kmph | Relative Humidity : 48 per cent
Air discharge : 1.8 m^3/s | Wind Velocity : 1.5 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left 0.0 F	Left 0.0 B	Left 1.5 F	Left 1.5 B	Left 3.0 F	Left 3.0 B	Center 0.0 F	Center 0.0 B	Center 1.5 F	Center 1.5 B	Center 3.0 F	Center 3.0 B	Right 0.0 F	Right 0.0 B	Right 1.5 F	Right 1.5 B	Right 3.0 F	Right 3.0 B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	27	26	21	12	27	22	14	11	16	22	10	16	14	11	16	8	16	7
101-150	125	84.4	20	25	19	11	23	18	14	9	15	18	12	12	16	10	14	9	14	9
151-200	175	118.2	14	18	16	8	19	13	12	7	14	15	6	8	11	6	10	9	12	8
201-250	225	152.1	9	11	14	6	15	13	8	6	6	10	4	7	8	3	7	9	8	4
251-300	275	185.8	4	3	8	3	10	7	4	6	5	7	3	6	5	3	6	9	5	1
301-350	325	219.5	2	2	5	1	3	1	2	7	10	4	4	2	3	1	4	4	1	0
351-400	375	253.3	4	3	4	1	4	2	8	1	8	2	2	3	1	0	2	2	1	0
401-450	425	287.1	2	3	5	2	2	1	9	5	6	3	10	2	0	0	0	2	0	2
451-500	475	320.9	2	1	3	2	3	1	9	4	8	2	10	3	3	0	3	4	0	2
>500	525	354.7	4	6	6	2	6	1	9	4	13	3	14	6	5	1	5	4	2	6
Number median dia. um			58	54	96	114	108	52	133	135	121	111	198	58	109	63	106	147	52	104
Volume median dia. um			328	322	328	330	327	335	329	331	324	331	323	338	322	325	324	329	325	309
Uniformity Coefficient			5.8	6.0	3.4	2.8	3.0	6.5	2.5	2.4	2.6	2.9	1.6	5.8	2.9	5.2	3.0	2.2	6.3	2.9
Droplet density, no/sq.cm.			88	98	101	48	112	79	89	60	101	86	75	34	66	35	67	55	59	39
Volume of droplets, ucc			250	280	390	150	350	140	600	310	680	250	690	26	240	53	250	27	110	220
Deposition index			19.1	21.4	29.8	11.5	26.7	10.7	45.8	23.7	51.9	19.1	52.7	1.98	18.3	4.1	19.1	2.1	8.4	16.8

F= front of leaf B = back of leaf

Appendix - D cont..

D-7 Droplet size distribution analysis

System pressure : 3.5 kg/cm^2 | Ambient Temperature : 31°C
Travel speed : 6.0 kmph | Relative Humidity : 52 per cent
Air discharge : 1.8 m^3/s | Wind Velocity : 1.5 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Position of Spraying																	
			Left						Center						Right					
			Distance 'm'						Distance 'm'						Distance 'm'					
			0.0		1.5		3.0		0.0		1.5		3.0		0.0		1.5		3.0	
			F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	16	8	22	13	13	22	25	14	25	10	20	8	9	11	7	10	19	5
101-150	125	84.4	24	14	21	12	10	20	18	12	17	10	20	9	10	12	7	10	22	4
151-200	175	118.2	19	8	17	8	8	15	11	9	11	8	16	7	6	8	9	8	16	7
201-250	225	152.1	10	4	9	4	4	7	10	5	9	6	11	0	4	3	6	2	9	1
251-300	275	185.8	2	0	6	1	2	1	3	0	5	1	6	0	1	0	2	0	3	0
301-350	325	219.5	3	0	1	0	1	0	5	0	2	0	2	0	3	0	0	0	1	2
351-400	375	253.3	1	0	0	0	0	0	1	0	2	0	3	0	3	4	3	0	1	8
401-450	425	287.1	1	0	0	0	0	0	4	0	6	0	5	0	2	11	4	3	2	11
451-500	475	320.9	2	0	1	0	1	0	5	0	4	0	5	0	2	5	7	2	0	8
>500	525	354.7	1	0	0	0	1	1	3	0	1	0	5	0	5	7	7	3	3	11
Number median dia. um			518	63	58	68	61	66	52	68	53	60	105	69	98	89	135	54	55	283
Volume median dia. um			326	338	338	338	330	327	333	338	336	338	330	338	322	328	326	324	324	326
Uniformity Coefficient			2.1	5.3	5.8	5.0	5.4	4.9	6.4	5.0	6.4	5.7	3.2	4.8	3.3	3.7	2.4	6.0	5.9	1.2
Droplet density,no/sq.cm.			93	34	77	38	40	66	85	40	82	35	93	24	45	60	52	38	76	57
Volume of droplets,ucc			730	19	82	22	71	6	290	22	240	25	360	9	240	440	390	160	160	620
Deposition index			55.8	1.4	6.3	1.7	5.4	0.4	22.1	1.7	18.3	1.9	27.5	0.7	18.3	33.6	29.8	12.2	12.2	47.3

F= front of leaf B = back of leaf

Appendix - D cont..

D-8 Droplet size distribution analysis

System pressure	:7.0 kg/cm²	Ambient Temperature	:31°C
Travel speed	:6.0 kmph	Relative Humidity	:53 per cent
Air discharge	:1.8 m³/s	Wind Velocity	:1.4 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left 0.0 F	Left 0.0 B	Left 1.5 F	Left 1.5 B	Left 3.0 F	Left 3.0 B	Center 0.0 F	Center 0.0 B	Center 1.5 F	Center 1.5 B	Center 3.0 F	Center 3.0 B	Right 0.0 F	Right 0.0 B	Right 1.5 F	Right 1.5 B	Right 3.0 F	Right 3.0 B
			Position of Spraying: Distance 'm'																	
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	11	7	9	4	6	7	14	11	16	8	16	7	14	8	13	17	19	20
101-150	125	84.4	11	5	9	6	6	7	16	10	14	9	14	9	11	8	12	13	17	17
151-200	175	118.2	7	5	10	3	4	5	11	6	10	9	12	8	11	5	7	12	14	12
201-250	225	152.1	3	5	3	1	3	4	8	3	7	9	8	4	8	4	3	8	5	6
251-300	275	185.8	1	0	2	0	0	0	5	3	6	4	5	1	5	1	6	2	7	2
301-350	325	219.5	0	0	0	0	1	0	3	1	4	4	1	0	4	1	1	0	3	0
351-400	375	253.3	0	0	0	1	4	0	1	0	2	2	1	0	4	0	2	0	2	0
401-450	425	287.1	1	0	0	0	4	0	0	0	0	2	0	2	2	0	1	1	2	0
451-500	475	320.9	2	1	1	1	3	1	3	0	3	4	0	2	3	0	1	2	4	1
>500	525	354.7	2	0	0	1	3	0	5	1	5	4	2	6	8	0	1	2	2	1
Number median dia. um			60	54	54	59	141	60	109	62	107	147	52	103	89	61	52	55	115	66
Volume median dia. um			326	338	337	326	330	338	322	325	324	329	325	308	320	338	324	328	333	330
Uniformity Coefficient			5.4	6.3	6.2	5.5	2.3	5.6	2.9	5.2	3.0	2.2	6.3	2.9	3.6	5.5	6.3	6.0	2.9	5.0
Droplet density,no/sq.cm.			38	23	34	17	34	24	66	35	67	55	59	39	70	27	49	57	75	59
Volume of droplets,ucc			120	32	41	56	220	32	240	53	250	270	110	220	370	24	160	130	230	76
Deposition index			9.2	2.4	3.1	4.3	16.8	2.4	18.3	4.1	19.1	20.1	8.4	16.8	28.3	1.8	12.2	9.9	17.6	5.8

F= front of leaf B = back of leaf

Appendix - D cont..

D-9 Droplet size distribution analysis

System pressure : 10.5 kg/cm^2 Ambient Temperature : 31°C

Travel speed : 6.0 kmph Relative Humidity : 50 per cent

Air discharge : 1.8 m^3/s Wind Velocity : 1.5 kmph

Number of droplets per square centimeter on grape leaf (Average of three replications)

Size Range um	Average Size um	Actual Size um	Left						Center						Right					
			Distance 'm'						Distance 'm'						Distance 'm'					
			0.0		1.5		3.0		0.0		1.5		3.0		0.0		1.5		3.0	
			F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B
0-50	25	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51-100	75	50.6	20	12	22	10	24	10	7	10	17	8	11	5	13	15	18	8	17	7
101-150	125	84.4	18	8	19	10	19	8	8	12	14	6	9	6	11	11	14	6	13	6
151-200	175	118.2	16	6	17	6	19	7	6	7	12	5	8	5	12	12	12	7	10	4
201-250	225	152.1	10	2	13	2	11	2	3	4	7	2	9	2	10	7	8	5	7	4
251-300	275	185.8	6	1	5	0	8	0	0	1	2	1	8	1	4	2	5	0	5	0
301-350	325	219.5	1	0	4	0	1	0	0	1	0	3	5	0	1	0	4	0	6	7
351-400	375	253.3	0	0	0	0	0	0	3	0	0	4	1	6	1	0	2	0	3	6
401-450	425	287.1	2	0	2	0	2	0	4	2	1	5	5	9	3	0	5	0	5	5
451-500	475	320.9	1	1	3	0	4	0	2	4	1	5	1	7	4	1	4	0	5	3
>500	525	354.7	1	0	2	0	6	0	4	0	1	4	1	6	5	2	8	0	8	7
Number median dia. um			52	72	113	71	111	69	99	55	59	169	114	228	96	54	96	56	86	65
Volume median dia. um			334	338	333	338	324	337	325	338	332	331	335	330	326	323	323	338	325	337
Uniformity Coefficient			6.4	4.7	2.9	4.8	2.9	4.8	3.3	6.2	5.6	1.9	2.9	1.4	3.4	6.0	3.4	6.0	3.7	5.2
Droplet density,no/sq.cm.			75	30	87	28	94	27	37	41	55	43	42	47	64	50	80	26	79	21
Volume of droplets,ucc			130	33	210	13	310	13	220	120	88	310	130	440	280	98	400	17	440	13
Deposition index			9.9	2.5	16.0	1.0	23.7	1.0	16.8	9.2	6.7	23.7	9.9	33.6	21.4	7.5	30.6	1.2	33.6	1.0

F= front of leaf B = back of leaf

APPENDIX - E

DESIGN OF NEW CENTRIFUGAL BLOWER

Following assumptions were made to design a new blower suitable for grape vine yard based on the theory of Osborne (1982) and Pandey (1986).

I INPUT DATA

1.	Blower discharge (Q), m^3 /sec	= 2.5
2.	Blower speed (N), rev/sec	= 30
3.	Impeller output blade angle (B_2)	= 155°
4.	Number of blades in impeller(z)	= 52
5.	$K_1 = v_3 / u_2$	= 0.5
6.	$K_2 = vm_2 / u_2$	= 0.3
7.	$k_4 = vo/vm_1$	= 2
8.	Ratio of width of casing (Wc) to impeller blade (b_2) k_5	= 1.5
9.	Ratio of casing outlet area (Aco) to inlet area (Aci) k_6	= 1
10.	Coefficient for pressure loss due to entry and turning of flow, k_7	= 0.8
11.	Coefficient for pressure loss due to flow separation, k_8	= 0.25
12.	Coefficient for pressure loss in casing, kg	= 0.4
13.	Discharge coefficient for leakage through inlet and casing, (CD)	= 0.6

II OUTPUT RESULTS

1.	Outlet static pressure (Ps), KPa	= 2.232
2.	Blower input power, w	= 8441.26
3.	Total outlet pressure (PT), KPa	= 2.947

4. Blower inlet velocity (V_o), m/sec = 27.55

5. BLower outlet velocity (v_3), m/sec = 5.63

6. Impeller outlet velocity (u_2), m/sec = 41.35

7. Impeller radial velocity (Vm_2), m/sec = 12.40

8. Flow coefficient, (Ø) coefficient = 0.4

9. Pressure coefficient (SI) = 3.29

10. Torque on impeller (T), N-M = 44.78

11. Efficiency of blower, per cent = 38.86

III DESIGN DETAILS OF IMPELLER

1. Material of construction of impeller =mild steel

2. Outer diameter of impeller (d_2), m = 0.436

3. Inner diameter of impeller (d_1), m = 0.356

4. Minimum thickness of impller back plate, mm = 4

5. Minimum diameter of impeller shaft, mm = 20

6. Impeller shaft supported on only one side

7. Distance of impeller from bearing impeller, m = 0.40

IV DESIGN DETAILS OF IMPELLER BLADES

1. Type of impeller blade =forward curved

2. Outer radius of impeller (r_2), m = 0.22

3. Inner radius of impeller (r_1), m = 0.18

4. Impeller blade inlet angle (β_1), = 22.2°

5. Impeller blade outlet angle (β_2) = 155°

6. Width of blade at impeller inlet (b_1), m= 0.18

7. Width of blade at impeller outlet (b_2), m = 0.15

8. Angular pitch of blades on impeller, = 6.92°

V DESIGN DETAILS OF BLOWER CASING

1.	Outer radius of impeller (r_2),m	= 0.22
2.	Width of casing 'm'	= 0.22
3.	Height of casing outlet, m	= 0.730
4.	Diameter of casing inlet (Dci), m	= 0.36
5.	Minimum thickness of casing, mm	= 2.5
6.	Material of construction of casing	= mild steel
7.	Width of casing outlet, m	= 0.09

VI THE DETAILED DRAWINGS OF THE DESIGNED NEW CENTRIFUGAL BLOWER IS GIVEN IN FIG. EE-1 AND EE-2

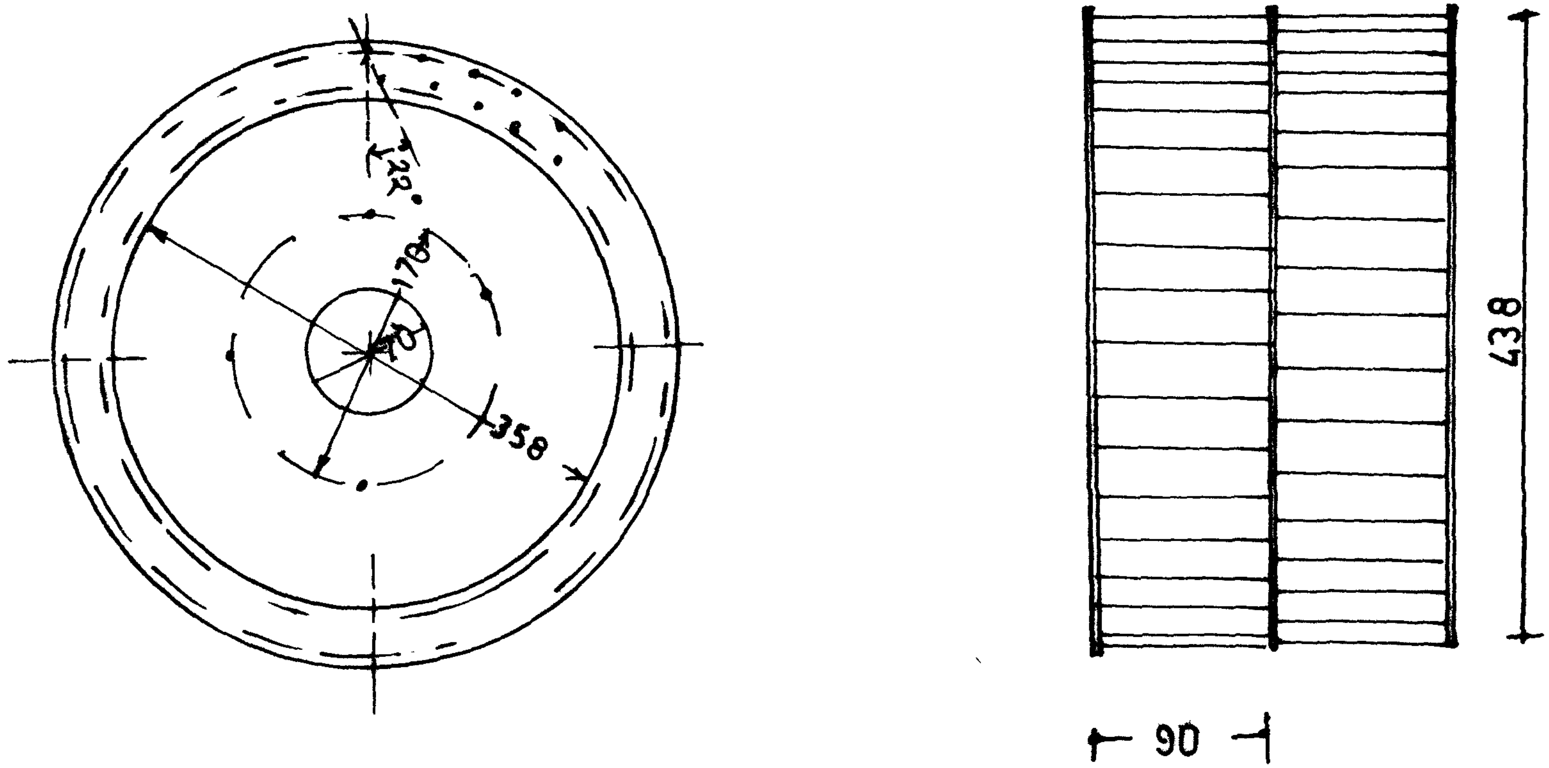

FIG. EE 1 SCHEMATIC VIEW OF IMPELLER OF NEW DESIGNED BLOWER

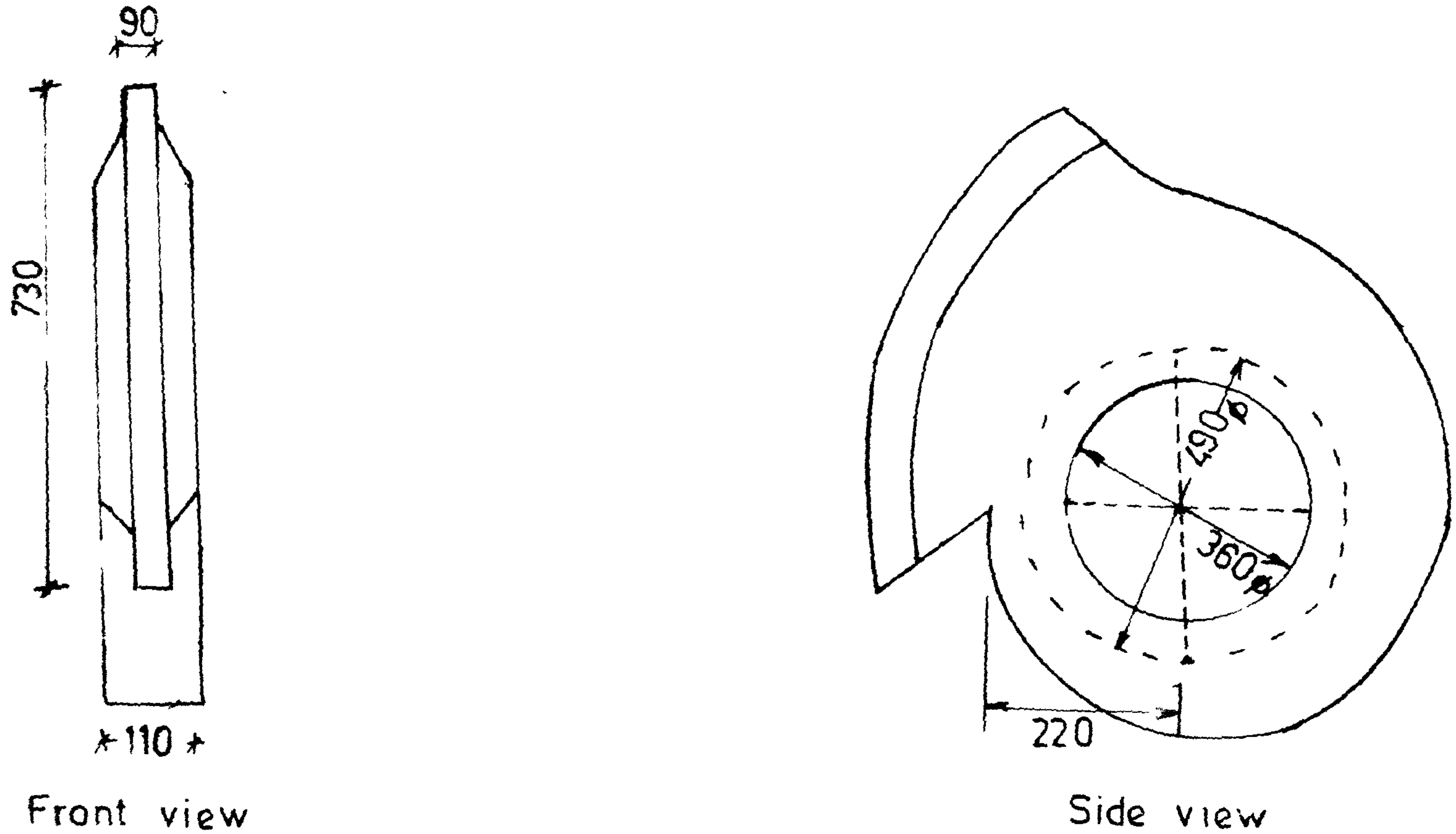

FIG. EE-2 SCHEMATIC VIEW OF NEW DESIGNED CASING

Vita

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of

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in

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