Remarks by Dr. G. S. HARTLEY in opening a discussion on

IMPROVED APPLICATION IN RELATION TO BIOLOGICAL REQUIREMENTS

In the design of pesticide distribution equipment one should be concerned with:

(a) The possibility of putting the pesticide maximally where the biologist wants it and minimally where he does not want it.

(b) Optimum or adequate distribution in the sense of uniformity of spread within the target area.

(c) Minimal escape from the target area, such escape producing local drift damage, general pollution and wastage which vary in importance with the chemical and situation.

(d) Reasonable control of dosage.

I have attempted to list these in descending order of importance, while admitting that in some situations and with some pesticides (c) may be of overriding importance. There is, however, a common tendency to give the priority in reverse order, although one has no need for accurate control of an ill-defined rate of application to the wrong place. The great attention given to dosage has really as its main objective the simplification of the job of the accountant in farm and factory, but some of the papers reveal deviations from intended unifor ity so great that there is a real technical problem also.

I have no doubt that (a) is the most important question. It is also the one most difficult to answer, and this is the excuse for its receiving, at present, least attention, certainly as far as the equipment designer is concerned. He, like the formulator, has a difficult compromise course to steer among conflicting requirements and he naturally gives most attention to the requirements which can be put definitely: these are usually the physical requirements such as no-drift, no settlement in tanks, no blockage of filters or nozzles, no corrosion etc.

The biological requirements are more difficult to define and require more research. It is therefore a very satisfactory beginning that several contributions to this conference do concern simultaneous research, involving collaboration between stations, into what should be the biological demands on the machine designer. It is on these papers that I have been asked to initiate discussion and I shall not be concerned with the papers in which uniformity of distribution and means to measure it are judged by internal standards of perfection of the machine as a spreading tool.

The interesting paper by Courshee seems to me to come clearly in the first class although it is the only one with "uniformity" in the title. Courshee is looking at uniformity, not, in the example he treats in detail, as between one square cm and the next but on a very much larger scale. In spraying vast areas for residual attack on locusts, time may be all too short and the operation is very costly. To stripe the area rather than attempt to "colour wash" it uniformly saves both time and money. The insect is mobile and will soon run into trouble on the next stripe if it is missed by the last one. If one looks at this with engineering or planning perfection in mind, the question Courshee asks might be put "how badly can I do the job, in the interests of economy of time and money, and get an adequate result?". From the point of view of strategy against a very widely distributed pest it is important to know the answer to this question as the choice may well be between bringing 50% of the swarms to 99% extinction and bringing 90% to 90% extinction - a choice heavily in favour of "skimping".

Courshee's question is one which could with advantage be examined in many cases of pesticide application. The answers would be very different according to the behaviour of the pest, the type of economic loss it brings and the mode of action of the pesticide and particularly whether it has repellent or attractant action or is associated with another compound having such action. There are situations where a not fully uniform application has advantage in saving time or money but where the biological effect or selectivity of the chemical goes through an optimum as for instance when an insecticide can be so thinly spread and taken up into leaf surface constituents that its action is lost. Another extension of the question could be whether, in a vegetable row-crop for human consumption, it might be best to spray 1 row in every 10 with an attractant plus powerful residual toxicant, and 9 rows with a harmless repellent. It is an old gardener's dodge but should interest be renewed with the use of modern sophisticated machinery? For the pre-pack or deep-freeze market it is probably better to have a pre-located 90% of the crop 100% perfect rather than 100% of the crop with 1% of randomly spaced imperfections.

I would not go all the way with one of Courshee's parallels - he suggests that a bad distribution of fertiliser should be acceptable if all the doses are in the range of linear yield response. The catch is of course that the unevenness of ripening would be a serious difficulty in the way of harvesting the full increase of yield. I have no doubt Courshee would accept this qualification. I have no doubt also that whatever arguments of a similar kind could be put forward, there would be factors overlooked. I only wish here to emphasise the main general point of Courshee's argument, that the desirable, or optimal, degree of uniformity should be a subject of objective biological-mechanical-economic study.

Courshee's paper, as already mentioned, deals with deliberately non-uniform application on a large scale. In the last paper there is mention of distribution of pesticide in the soil in lines or vertical bands. Otherwise there is no concern in these papers with localised placement. A little more will be heard of this when we come later in this conference to granule application. There are of course operations which are more efficiently performed with granules, but very often a spot or line treatment could be just as easily performed with liquid. The tendency, verbally, to contrast granules and "spray" instead of granules and "liquid" serves to emphasise this misconception.

I think it is a matter of regret that this conference has not included any papers on localised application. The chemical industry has served agriculture very well. Of course, along the line, mistakes have been made. We hear a lot now about general pollution of the environment which is probably the least important of them. Encouragement of the development of resistance and failure to exploit to the full improvement of selectivity by placement have been much more serious. It is time we gave more attention to other advantages of chemical control than those associated with widespread distribtuion. There have been important advances, but this conference seems to have nothing to say about them.

Br. Crop Prot. Counc. Monogr. No. 2 (1970)

ECONOMIC ASPECTS OF APPLICATION INVOLVING SPECIALISED EQUIPMENT

K. P. Parish

Plant Protection Ltd., Fernhurst, Haslemere, Sussex

INTRODUCTION

Application of a pesticide can make or break the product. This is a provocative statement which will undoubtedly be challenged. The fact that this symposium has been convened highlights the important role application plays in ensuring the most efficient use and obtaining optimum results from pesticides.

The economic aspects of application by specialised equipment can be considered from several points of view - a) the pesticide manufacturer b) the machinery manufacturer c) the user, whether grower or contractor. There are also the alternatives of this equipment being sold, hired or supplied free of charge.

During the past 20 years and more particularly in the last decade there has been a rapid development of more sophisticated pesticides, many of which have necessitated specialised application equipment. Granular insecticides and herbicides requiring accurate dosage rates and placement, liquid herbicides which need to be applied as a directed spray with the minimum of drift in growing crops, liquid and powder seed dressings where small amounts of the product have to be applied uniformly to seed in bulk.

EQUIPMENT SPECIFICATION

Marrying the various and sometimes opposed requirements of pesticide, crop, target and operating conditions can present difficult application problems. It may be that a compromise is the only practical solution. Development of specialised application equipment requires a study of several factors.

1. The pesticide - its
    - formulation
    - mode of action
    - dose
    - toxicity - mammalian and crop
    - effect on equipment materials
2. The target
3. The crop

4. The operator

5. The operating conditions

Not all these points will need to be considered for every application, but it is essential to know why special equipment is necessary and what it has to achieve. The aim should be to produce a machine which has:

(a) efficiency in application and operation

(b) reliability

(c) simplicity

(d) economic price

ECONOMIC ASSESSMENT

What is an 'economic' price and on what basis is this assessed? If we look at a representative range of specialised equipment, take one or two examples and examine their contribution opposite their cost, we will at least get an indication of their economic value. First, however, let us consider the economic aspects facing the pesticide manufacturer, the machinery manufacturer and the user.

In developing a new pesticide the chemical manufacturer may be faced with the problem of introducing special application equipment to ensure efficient application and full commercial exploitation. The expenditure in man power and money can be considerable. What then decides a manufacturer to take this step and what factors need to be considered in arriving at a decision? Specialised equipment will only be developed if existing applicators are unsatisfactory.

It is then a question of assessing the market potential for the pesticide, estimating the short and long term realisation to the company and calculating the cost of developing specialised application equipment. In most cases this becomes a calculated risk as rarely are all the facts and figures available at this early stage of development. The total cost of developing a pesticide to the stage of marketing is considerable and a figure of £1 million has often been quoted. Even with a successful chemical it may take up to 10 years to recover these costs. It follows therefore that an essential part of this programme is the availability of efficient application equipment. Certain pesticide manufacturers have found it an advantage to set up their own agricultural engineering department so that a close liaison between the engineer and research chemist can be maintained. This enables application problems to be studied at an early stage of pesticide development and this investigation can influence the decision as to which formulation should be marketed. Prototype machines have to be developed and, after field testing, production of commercial machines is discussed with a machinery manufacturer.

The machinery manufacturer, usually with guidance from the pesticide company, has to carry out his own market assessment, estimate his development and production costs, calculate whether he can meet the target price and if so, decide whether the project is economically viable. He may test the market by small batch production and so lose the advantage of large scale production costs. There are alternatives. The pesticide manufacturer may decide to underwrite a production batch, purchase and hire the equipment to the grower or supply it free of charge.

The grower, I suggest, has an easier task in assessing the situation because he has most of the facts available to him. He knows the equipment and operating cost, the cost of producing the crop, including the price of the pesticide, and by comparing these costs with his estimated crop return he can arrive at an economic assessment. To evaluate the alternative crop protection measures he must set the expenditure of each against the benefits to be gained. These benefits are not always obvious and capable of expression in pounds shillings and pence.

EXAMPLES

Referring now to four examples of specialised equipment which cover very different application requirements and price levels.

(a) Granule Applicator

A pesticide manufacturer developed a granular systemic insecticide which needed to be placed in the root zone as entry into the plant was by root uptake. The crop was potatoes and a machinery manufacturer was asked to develop an applicator. This resulted in Horstine Farmery Limited producing a granule applicator at a retail price of approximately £40 for a 2 row machine which was attached to the potato planter. This had the advantage of low cost, effective equipment making use of the planting operation to apply the insecticide and so avoid the cost of a separate application. This was particularly important because the cost of the insecticide was higher than the main competitive products. The convenience of a dual planting/insecticide application in one operation was a factor readily appreciated by the grower and could be set against the premium charged for the insecticide.

I do not know the development expenditure and cannot, therefore, present an economic assessment other than in broad terms. The project enabled:

(a) The pesticide manufacturer to gain entry into the competitive insecticide market and a potential repeat business from users of the specialised application equipment.

(b) The machinery manufacturer to extend his range of equipment and increase sales.

(c) The grower to adopt a convenient and economic application technique.

This assessment is based on the assumption that the biological results are equal to or better than alternative insecticides and that no major disadvantage applied.

(b) Inter-row Sprayer

My own company introduced the bipyridyl herbicides and one of the many uses for these is weed control in row crops. This technique could only be practised if specialised application equipment was developed which directed the herbicide onto the weeds between the rows without the spray coming into contact with the crop. This meant, in effect, producing a drift-free nozzle and, as a result of extensive and intensive research the 'Vibrajet' nozzle was developed. The next stage was to produce prototype inter-row sprayers, field test them and then arrange for a manufacturer to take over final design and production.

This resulted in E. Allman & Co. Limited marketing the 'Intaro' and Ransomes Sims and Jefferies Limited the 'Cleanrow' at a grower price of £375 for a 9-row machine with the option of varying the number of rows. The availability of commercial machines enabled the chemical inter-row weeding technique to be adopted. Like most new techniques which challenge existing farm practices, considerable effort is necessary to demonstrate the advantages and set out the economics of the operation. It is not possible to draw up a detailed balance sheet because of the widely different conditions from one season to another, and the difficulty of putting a value on some of the less obvious benefits. Chemical inter-row weeding competes with mechanical weed control and a comparison of costs shows chemical weeding to be at an initial disadvantage (Table 1).

Table 1

<u>Inter-row weed control costs</u>

Cost of equipment, 7 row, £		Cost per acre, £ Operating	Chemical
Inter-row sprayer	341	0.55	1.95
Steerage hoe	214	0.55	-

This only gives one side of the story - the expenditure and a closer study of the cost/benefit relationship gives a truer picture. In order to assess the economics of the alternative systems it is necessary to consider the benefits of each technique.

Steerage hoeing has the advantage of lower costs both of equipment and operation and in certain conditions the breaking of a soil surface crust. However, it suffers from the disadvantage of being more dependent on weather conditions and less effective in controlling grass weeds. In wet seasons it may not be possible to cultivate or alternatively results in transplanting weeds, not killing them. There is also the risk of damaging surface roots, producing another weed flush by soil disturbance and in dry areas causing moisture loss. The cost of a single chemical treatment is higher than one mechanical hoeing but several of the latter may not equal the weed control achieved with one or two herbicide applications. This in itself does not justify the chemical technique and it is the other more important advantages mentioned above which transform the economics in favour of chemical inter-row weeding. These advantages can be a yield increase, improved quality, lower production costs or improved soil structure. I have compared chemical weed control with steerage hoeing but in some crops hand hoeing is still practised. In these crops the economic advantages of chemical inter-row weeding are even more pronounced. I hope these few facts have shown the difficulty and the danger of an economic assessment, based on one set of conditions, being used as a standard for all situations.

The development expenditure by the pesticide manufacturer in this case has been considerable and has not yet been recovered, but the technique is being adopted in overseas countries as well as the U.K. and the potential market is large. The rate of acceptance has been slower than initially forecast and the introduction of new pesticides has reduced one of the major crop outlets. To balance this, new opportunities are being created and the advantages of the technique more widely appreciated. Additional equipment such as a cheaper non steerage inter-row sprayer and a hand-pushed single-row machine is now available and will expand the use of the herbicides.

An assessment of the position up to 31st December 1969 is as follows:

Total development cost	many £000
Sales of inter-row sprayers incorporating the 'Vibrajet'	764
Estimated gallonage of 'Bipyridyl' applied through inter-row sprayers	14,000

At the present rate of market development it is estimated that the break even point will be reached in 1972 - six years after the introduction of specialised equipment and ten years from commencement of development.

(c) Seed Treater

Just over ten years ago there was a serious disease problem in cotton which could be overcome by the application of fungicides to the seed. Government agencies in Africa were using slow batch-mixers of the drum type to apply these fungicides to the fuzzy cotton seed but a fully automatic continuous process for treating large quantitites of seed was required. No such application equipment was available and Plant Protection Limited decided to tackle this problem. A cotton seed treater was designed and developed, manufacture arranged and several machines installed. Although this involved considerable expenditure in developing this specialised application equipment it has resulted in a captive market for the Company's products for many years. The government agencies were able to treat large quantities of seed effectively and economically and the grower obtained crop protection at a very low cost. The project proved profitable for the pesticide manufacturer, the Government agencies and the growers.

The seed dressing situation in this country is changing. Mercury-based powder seed dressings were introduced just prior to 1930 and seed treaters such as the Strickland, BRH and Robinson were developed. These were designed for the application of powder formulations only and with the advent of liquid seed dressings new machines had to be developed. My own company decided it was necessary to provide a machine capable of applying both liquid and powder products although this meant a higher priced machine. The 'Plantector' seed treater was developed and marketed in 1960 and the premium for this liquid/powder application facility has been justified by the continued use of both powder and liquid products. This specialised application equipment and the supporting technical service has helped the company to maintain its high share of the seed dressing market during the last decade. This has been profitable to the pesticide manufacturer, the machinery manufacturer, the seed merchant and the grower. Seed dressings provide one of the cheapest methods of pesticide application and protection. It costs the grower of wheat and barley only an additional 3s 2d per acre to have seed dressed with a fungicide and insecticide.

The agricultural seed trade is, like other industries, moving towards fewer, bigger units and new seed dressing machines capable of a higher throughput and the application of new pesticide formulations may soon be required.

(d) Applicator for fungicides on cucumbers

Another example involving the use of specialised equipment illustrating how varied economic conditions can be. The cost of developing the applicator was £200 and it could be bought for £3.1. The costs and returns when it was used on outdoor melons in Spain and glasshouse cucumbers in England were as follows:

	£/ha
Melons	
Additional cost of pesticide compared with the standard treatment	23
Increase in crop value	60
Extra return	37

Cucumbers	
Increased return of untreated crop (£1 per plant)	6,250
Cost of treatment	125
Extra return	6,125

CONCLUSIONS

It is necessary to review the performance of specialised application equipment to meet the challenge of change. New pesticides, new formulations, new crop and market requirements will necessitate modification of existing equipment and development of new machines. There is a grower resistance to investing in specialised application equipment. In order to overcome this it must be clearly demonstrated that the technique involving pesticide and equipment offers sufficient advantages over alternative systems to justify the investment.

Br. Crop Prot. Counc. Monogr. No. 2 (1970)

LABORATORY METHODS FOR THE DIMENSIONAL ANALYSIS OF DROPLET POPULATIONS PRODUCED BY AGRICULTURAL SPRAYERS

P. Goffre and S. Musillami

C.N.E.E.M.A., Antony, France

(Translation from a French MS by W. J. T. Horton)

INTRODUCTION

Several methods have been put forward for making a dimensional analysis of the droplet populations obtained with agricultural sprays. Often the methods involve photographing the droplets during their passage or after collecting them on special targets. When account has been taken of the ratios of linear enlargement (or ratio of reproduction), the negatives display circles with diameters equal to or greater than those of the droplets; in the latter case the true dimensions are arrived at by using correction coefficients.

The method finally settled for was that of collecting the droplets on glass slides which had been treated with a water-repellent substance (silicone) and photographing them immediately afterwards. This method can in fact be applied to aqueous or oily sprays, which may or may not be carried in an airstream.

Some of the methods investigated at C.N.E.E.M.A. are dealt with briefly and, after that, a description is given of the method that is being used at present.

REVIEW OF SOME OF THE METHODS STUDIED AT C.N.E.E.M.A.

Segregation of droplets in a spray jet directed horizontally

In the case of nozzles where the spray jet is horizontal or inclined upwards, the distance travelled in still air by a droplet from nozzle to point of fall depends on droplet diameter; small diameter droplets, which are quickly slowed down by the air, fall near the nozzle while larger droplets travel a greater distance. This segregating on the basis of size is not, however, an absolute method because, on the one hand, some fine droplets can be carried along by coarse ones (this applies in particular to hollow cone type jets) and, on the other, the angles between the initial paths of the drops and the horizontal are not the same.

This characteristic can be used in the dimensional analysis of sprays from fan, anvil or swirl nozzles with a small spray angle, the nozzles being located at a suitable height (1.5 - 2.0 m) from the ground. The droplets are collected on transparent targets and photographed. The wetted area can be determined by counting and classifying by size or, taken as a whole, by densitometer measurement of light transmitted through the film.

In certain cases, if a colouring agent or a cation is added to the spray liquid, it is possible to determine by means of spectrophotometry the volume of all the droplets collected on targets located at different distances.

This method can be used to provide a rapid measurement of the SMD corresponding to the droplet population studied.

Direct measurement of droplets collected on high viscosity targets

The droplets are collected on a thin layer of colourless grease to which a colourless oil (e.g. glycerine) has been added. After spraying, a second layer of oil is required.

The analysis can then be effected by direct measurement of droplet dimensions with the aid of back illumination photography with linear enlargements which may be greater than 4 : 1.

This method is attractive in certain, very specific conditions (e.g. analysing spray patterns consisting of coarse droplets) but it involves a tedious preparation of targets, etc.

Droplets passing through a non-miscible liquid target

The speed of fall of the droplets is reduced by making them pass through a non-miscible liquid whose density and surface tension are lower than those of the droplets.

This target (petrol, fuel oil, etc. in the case of water) is contained in a glass basin with parallel sides, the height of the basin being varied with the degree of droplet segregation required. The droplets are photographed by transmitted light during their fall through the liquid. The diameters of the circles measured on the film are the actual diameters of the droplets. A very small fraction of the jet is uncovered by a slit corresponding to the depth of field.

This method can be used only for sprays which are not carried in an airstream and which consists of medium and large droplets, the fine and very fine ones remaining on the surface of the liquid.

With these three methods, as also with the one now in use, shutters with a linear or circular motion are employed. These devices are used to allow only a small quantity of the jet to pass and to protect the target just before and immediately after spraying.

Photographing droplets in flight

The droplets are photographed in flight in a dark room. Flashes of 1 - 10 µs duration are used with the spray located between flash and camera lens.

A slit device allows a tiny fraction of the jet to pass through, the different parts of the jet being exposed in turn by moving the sprayer.

The method is suitable for sprays not carried in an airstream. Drawbacks with this technique include the difficulties involved in counting and measuring the diameters of droplets whose outlines are not always clearly defined (e.g. droplets lying in planes parallel to the central plane and droplets moving one behind the other). As a consequence, the background of the film or plates is grey, the shade varying with the quantity of droplets within the area photographed. In addition, small and medium size droplets may be masked by larger ones.

METHOD AT PRESENT IN USE AT C.N.E.E.M.A.

Principle

The droplets are collected on glass treated with silicone and are photographed by back illumination. They appear on the film in the form of circles. When the ratios of linear enlargement (or ratio of reproduction) have been taken into account, the diameters of these circles correspond to the contact diameters (d_c) on the glass.

Examination in conjunction with photography of the droplets (camera lens and light beam opposite each other and on an axis parallel to the glass slide) shows the cross-sections of the droplets as arcs bounded by chords equal in length to diameters d_c. In other words, the drops collected on the glass slide treated with silicone are segments of a sphere. The ratio of height (h) of segment to contact diameter (d_c) varies directly with the surface tension of the spray liquids.

The values for d_c are therefore always greater than the actual diameters (d_r) of the droplets as they are still passing through the air. This is why the spread factor (E) on glass coated with silicone has to be determined for each spray liquid. This factor is the ratio $d_c : d_r$. As d_c and h are known, d_r is obtained from the expression for the volume of the segment of a sphere.

In cases where spread is appreciable, e.g. certain oily spray liquids, the diameters (d_r) of the droplets, regarded as thin lenses, are calculated in accordance with measurements for diameter d_c and the focal distance ascertained with a specially equipped microscope as described by May (1945).

Target preparations

Microscope slides which have been carefully checked for thickness and for surface quality are used. Cleaning of slides is effected at the outset.

Cleaning is essential after each exposure to oil or emulsion sprays.

Pure or diluted liquid silicone is applied to the target so as to form a thin, uniform coating on it.

Slides prepared in this manner can be wiped and re-used several times (3 to 4 times at least) when the spray liquid is water.

Photographic equipment

This consists of:

A 24 x 36 mm camera with a reflex view-finder; the lens is fitted with extension tubes (linear magnification greater than 5 : 1); the unit is mounted on a platform carried on two vertical columns and its height is adjustable.

A microscope stage mounted horizontally and designed for vertical displacement on a micrometric scale and having a circular orifice for passage of light beam.

A micrometric grid photographed at the beginning of the tests.

Prior to commencing tests, this equipment, which is protected inside a portable dark room, is set up near the area where the spray droplets are to be collected.

Application

When a jet of liquid is sprayed by pressure, i.e. without air blast, the droplets are collected (40 - 120 samples according to section of jet) at a distance from the nozzle (0.6 - 2.0 m) such that shattering of the droplets is avoided while the same exposure time is maintained for all the slides. This time, which is fixed beforehand, corresponds to a droplet density (on silicone treated glass) which is adequate and avoids running the risk of droplet coalescence.

In the case of sprays carried in an airstream, the slides are exposed to the spray in a section of the jet where the air speed does not exceed 5 m/sec. This section is formed by a nylon thread grid (100 mm mesh) in a vertical frame. The corresponding distance is often greater than the distance would be from foliage to be treated. To ensure that the sample represents the whole of the spray, the drops which fall prior to reaching the vertical frame are sampled with the aid of a horizontal grid.

Prior to starting a test the period of exposure to the spray is determined in the zone of maximum droplet density. The number of samples required to constitute a spray test will vary according to the section of the jet and may exceed a hundred.

Possible risks of evaporation are eliminated by (a) setting up the photographic equipment close to the sampling area; (b) raising the humidity of the laboratory beforehand to near saturation point; (c) ensuring that test preparations are complete, e.g. the importance attached to the use of slides of the same thickness; and (d) exposing the slides one after the other and photographing each slide immediately.

Use of film

The film is developed. With the aid of a continuous control enlarger, droplets on the film are counted and classified according to 10 and 20 μ size groups. The total linear enlargement is X100, which means that the whole film can be read in 3 runs at least. Once a run has begun, it must be completed even if the droplets counted considerably exceed in number the minimum required to provide a representative sample for the spray material. The number of droplets counted must be greater than 3,000.

The following calculations are then made:

Sauter mean diameter, SMD, $d^{v/s} = \frac{\Sigma nd^3}{\Sigma nd^2}$

coefficient of homogeneity, $H = \frac{(\Sigma nd^2)^2}{\Sigma nd \times \Sigma nd^3}$

mean volume diameter, $d^v = \sqrt[3]{\frac{\Sigma nd^3}{\Sigma n}}$

The accumulated percentages for number, surface area and volume of the populations counted are plotted on a graph for each size group.

Finally, the results are corrected by applying the spread factor for the particular spray material.

Reference

MAY, K. R. (1945) The cascade Impactor. An instrument for sampling coarse aerosols. J. Sci. Instr. 22 (10) 187 - 195.

Br. Crop Prot. Counc. Monogr. No. 2 (1970)

A RAPID TECHNIQUE FOR ASSESSING THE EFFICIENCY OF HIGH VOLUME (RUN-OFF) SPRAY APPLICATION

D. R. Johnstone

Tropical Pesticides Research Unit, Porton, Salisbury, Wilts

INTRODUCTION

In contrast to the ever increasing trend towards very low volume spraying for control of insect pests in agriculture, the practice of applying high volume total-wetting sprays is still adhered to in horticulture for a number of sound reasons.

(i) If well carried out, this form of spraying should give maximum possible protection through very complete spray cover.

(ii) Although toxic insecticides may be effectively used in this way, emulsifiable non-phytotoxic oils of negligible mammalian toxicity, can be used. When these are spread over the foliage as thin liquid films they trap and suffocate small insects but are inocuous to spray operators and also to a number of desirable parasites, predators and other beneficial insects.

(iii) It has yet to be conclusively demonstrated that control of relatively static insect pests such as hard and soft scales, can be satisfactorily achieved by sprays applied at less than high volume rates.

Thus circumstances arise in the appraisal of horticultural sprayers when techniques are needed to make rapid assessment of the efficiency of spray penetration and cover at high volume application.

Various techniques have been used by a number of workers for this purpose, e.g. Hebblethwaite and Richardson (1961) and Bullock et al (1968). Dyes may be added to the spray liquid and the residue may be subsequently washed off the surface of sampled leaves and determined colorimetrically (Wallis and Lee, 1964). Fluorescent tracers have been used, both quantitatively, in a parallel manner to dyes, obtaining instrumental readings by use of a fluorimeter (Sharp, 1960), also qualitatively, by examination of the sprayed residue under ultra-violet light and scoring for degree of cover against selected arbitrary standards (Bullock, op. cit. Staniland 1959). It may sometimes be possible to determine the values of the standards by fluorimetry or by chemical means, thereby rendering the classification semi-quantitative (Courshee and Ireson, 1961).

An alternative means of visual qualitative assessment has been devised which may be rendered semi-quantitative in suitable circumstances. This utilises a dyed water-sensitive paper* which produces permanent bright red stains on wetting with aqueous spray.

---

* Water sensitive paper IR 135 - obtained through Hoffman (g.b.) Ltd., 11 Elmwood Court, Pershore Road, Birmingham 5.

Figure 1

The relationship between cover rating and wetted area of paper strips

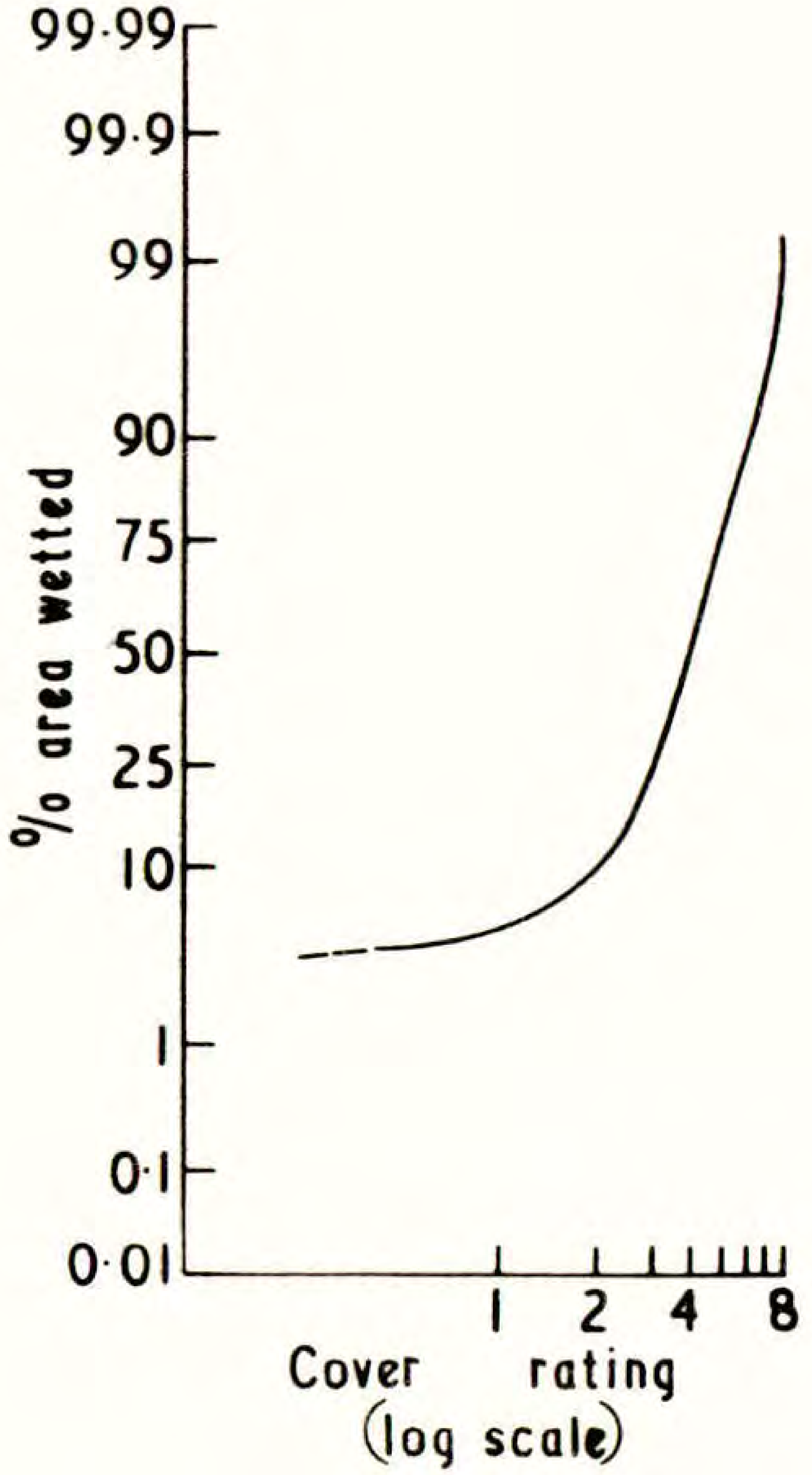
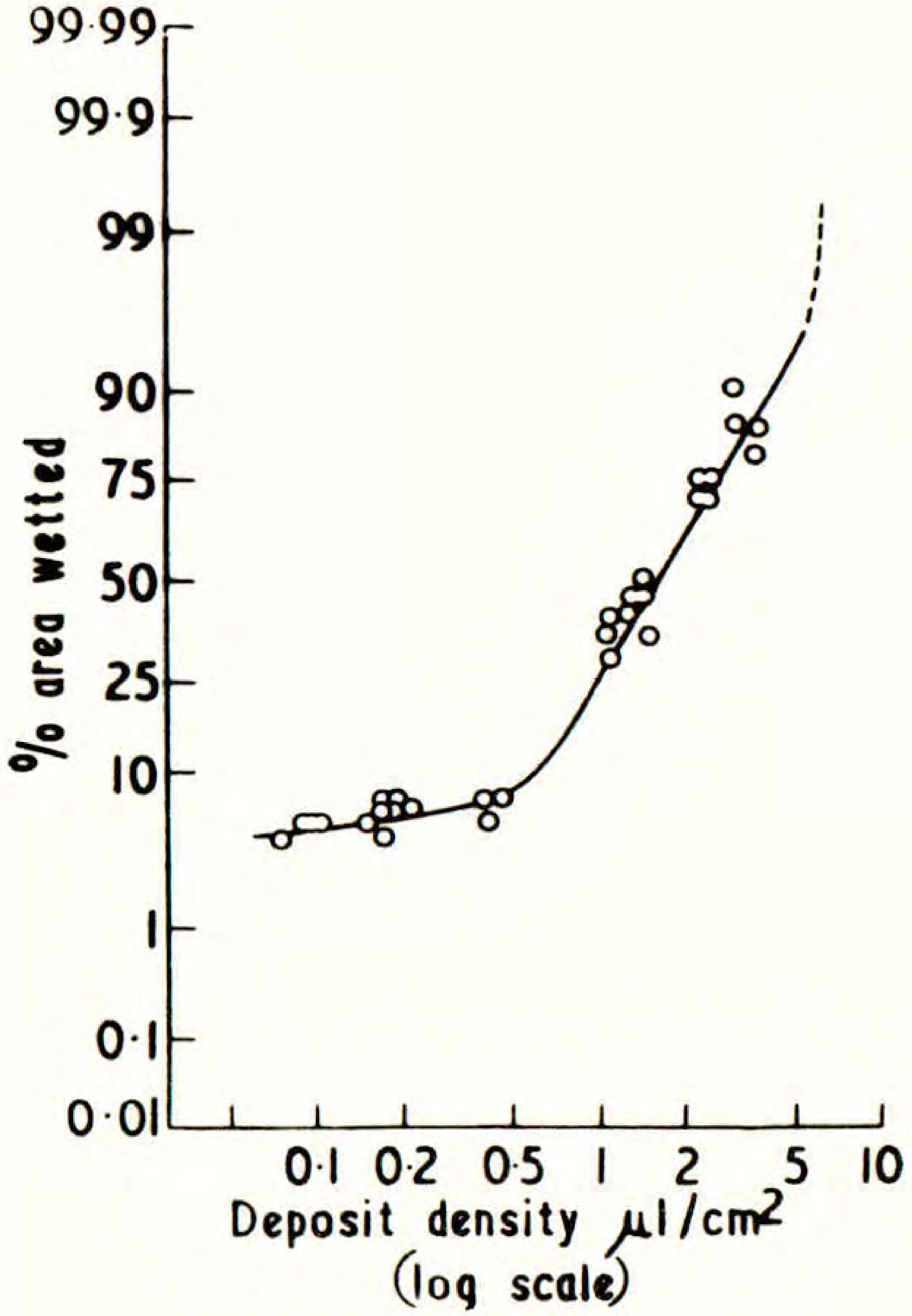


Figure 2

The relationship between wetted area and deposit density on Hoffman water-sensitive paper, from a laboratory calibration



METHOD

The manner of use may be described with brief reference to trials work carried out by Johnstone (1970) in citrus groves (grapefruit) in Cyprus during 1969. Water-sensitive paper strips were prepared measuring 25 by 150 mm and these were folded in half longitudinally, sensitive surface facing outwards. In the field these were fastened to leaves on several trees (functioning as replicates) in a systematic fashion, at upper and lower levels, in both along and across the row sites, within the interior of the tree canopy. Each target was applied over the leaf, to sandwich both upper and lower faces, and then stapled in position through the leaf, at the loose edge, with a pocket stapler. Following spray treatments the targets were recovered by detaching at the staple, opening out at the fold, and were then clipped to a retaining card in ordered sequence by means of the stapler. Rapid visual comparison between treatments is immediately possible, but preferably the final test is to obtain an index of cover and this may be accomplished by visually scoring the degree of cover (i.e. % wetted area) against a standard wetting chart, such as that reproduced by Conibear and Furmidge (1964). This provides nine classes, numbered 0-8 (0 = zero deposit) and the relation between the proportion of the area wetted and cover rating scores is shown in Fig. 1. Laboratory calibration relating % wetted area to deposit density is shown in Fig. 2. (Comparison of Fig. 1 and 2 indicates that the non-linear scoring classification adopted produced a relation with % wetted area which corresponds well with the analogous deposit density/wetting relation. Each relation appears to be a combination of two component log-normal functions with a transition at about the 10% level of wetted area marking the onset of accumulation by coalescence or overlap of spray droplets. Both relations are essentially log-normal from between 10-25% wetted area up to saturation or run-off.) In this way cover may be expressed in numerical form and comparison can than be made between the several factors, e.g. treatments, sampling height, position, upper and lower sides of leaf, etc., which may be included in the assessment, by conventional analysis of variance, coupled with the multiple range test of Duncan (1955).

The results may be analysed in an alternative way if the spread of spray liquid on the paper targets can be related to that which would have taken place on the surface of the leaf. This may be ascertained by comparative calibration in the laboratory or from the field data (Fig. 3 and 4) from just one of a series of experiments, by using a fluorescent tracer or dye as previously mentioned. If then, one can, for 'a priori' reasons, justify an arbitrary degree of cover (say, for instance $> 75\%$) of the leaf as being synonymous with adequate control, one may relate this to the corresponding score on the water-sensitive paper targets and make a comparison on the basis of the number of 'protected' and 'underprotected' surfaces thus identified, establishing significant differences by a χ^2 test. This method of analysis appears to lead to more sensitive discrimination between efficiency of treatments than conventional analysis of variance and is illustrated by the following example.

EXAMPLE

Three treatments comparing the same high volume application rate were made by an air-blast sprayer with detailed modifications, as follows:

A Double-sided, fixed outlet

B Single-sided, fixed outlet (greater volume of air)

C Double-sided, oscillating outlet

Figure 3

A comparison of cover rating on grapefruit leaf samples and on Hoffman water-sensitive paper targets placed adjacent to the leaves in a field operation

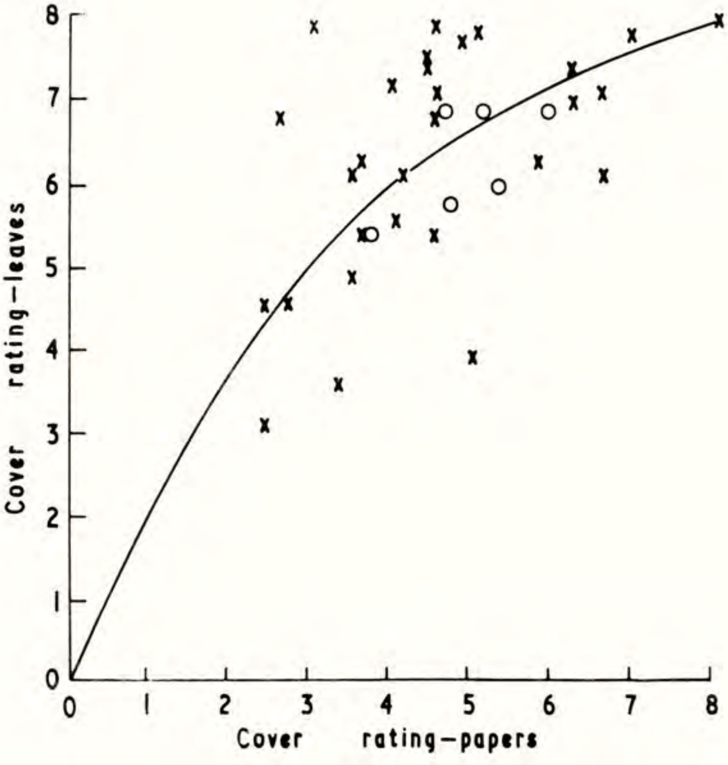
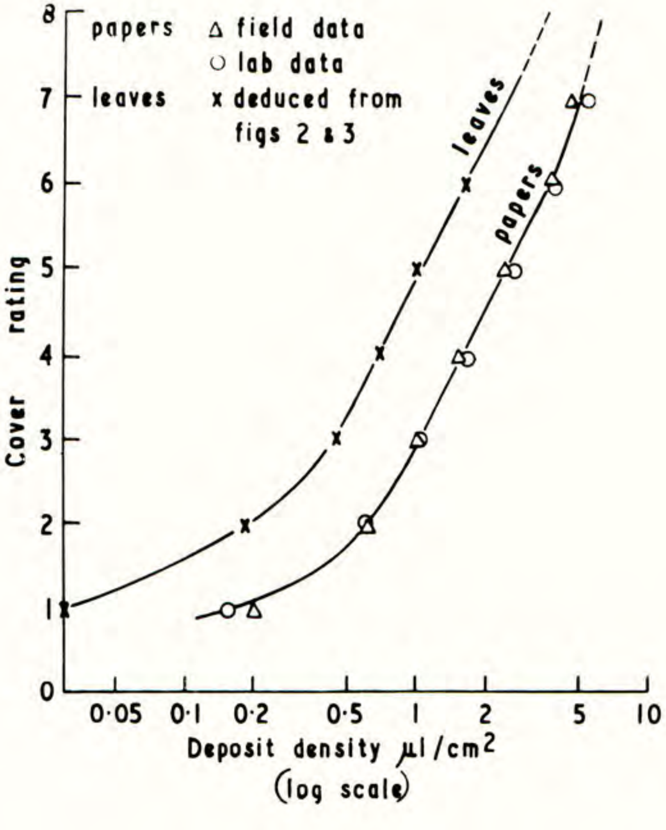


Figure 4

The relationship between cover rating and deposit density on paper and on leaves



Papers registering the apparent spray cover on top and bottom surfaces of leaves at eight sites (from 'along' and 'across' the row positions) were recovered from four trees/treatment and scored in the manner previously described. By use of the fluorescent tracer Saturn Yellow, Johnstome showed that 50% wetted area on the leaves (score 4) corresponded closely to 10% wetting of the papers (score 2) and since we are looking for differences between 'along' and 'across' the row penetration, the data for each treatment have been transformed as the number of surfaces 'underprotected' and 'protected' in these two positions, by taking 75% wetted leaf area as an arbitrary criterion for 'protection' i.e. score of 4 or less (leaves) and 2 or less (papers) constitutes 'underprotection'.

Results from the paper targets and also directly from leaves by assessment of fluorescent tracer deposit under ultra-violet illumination are shown together in Table 1.

Table 1

The number of paper and leaf surfaces protected and underprotected

		Papers			Leaves		
Treatment		A	B	C	A	B	C
Underprotected	Across	3	3	1	5	1	2
	Along	14	10	3	11	11	2
Protected	Across	29	29	31	27	31	30
	Along	18	22	29	21	21	30

(64 surfaces/treatment)

The data may be re-expressed as % number of surface protected, see Table 2.

Table 2

Percentage by number of surfaces protected

		Papers			Leaves		
Treatment		A	B	C	A	B	C
	Across	90.7	90.7	97.0	84.5	97.0	93.8
	Along	56.3	68.8	90.7	65.6	65.6	93.8

The data for both papers and leaves each constitute a 2 x 3 table and a χ^2 test confirms that treatment C gives significantly better protection to leaves sampled in the 'along' the row position.

Acknowledgements

Helpful discussion and advice regarding the statistical treatment of results were obtained from Mr. S. Peto, M.R.E., Porton and the laboratory wetting calibrations were performed by Miss K. A. Huntington.

References

BULLOCK, R. C., BROOKS, R. F. and WHITNEY, J. D. (1968) A method of evaluating pesticide application equipment for Florida citrus. J. econ. ent., 61 (6), 1511

CONIBEAR, D. I. and FURMIDGE, C. G. L. (1964) Physio-chemical studies on agricultural sprays. VII - The visual assessment of spray coverage, J. Sci. Fd. agric., 3, 144

COURSHEE, R. J. and IRESON, M. J. (1961) Experiments on the subjective assessment of spray deposits. J. agric. Engng Res., 6 (3), 175

DUNCAN, D. B. (1955) Multiple range and multiple F tests. Biometrics, 11, 1

HEBBLETHWAITE, P. and RICHARDSON, P. (1961) Procedures for sprayer testing. J. Proc. Inst. agric. Engrs, 17 (2) 51

JOHNSTONE, D. R. (1970) High volume application of insecticide sprays in Cyprus citrus. Research report, PANS, 16 (1), 146 - 161

SHARP, R. B. (1960) An experimental fluorescent tracer solution. J. agric. Engng Res., 5 (3), 340

STANILAND, L. N. (1959) Fluorescent tracer techniques for the study of spray and dust deposits. J. agric. Engng Res., 4 (2), 110

WALLIS, J. A. N. and LEE, C. W. (1964) Tractor-powered sprays for Arabica Coffee. J. agric. Engng Res., 9 (2), 132

Br. Crop Prot. Counc. Monogr. No. 2 (1970)

SPRAY FORMATION FROM VIBRATING JETS

J. R. Lake

N.I.A.E., Wrest Park, Silsoe, Bedford

INTRODUCTION

In experiments on spray application it is often desirable to use sprays with narrow drop size spectra. Such sprays are normally produced by means of spinning discs, but these are limited in terms of throughput for any given drop size. Throughput can only be increased by the use of multiple discs but then air movement generated by the discs causes problems. In contrast, the throughput from vibrating jets can be simply increased many times by the provision of several holes. This system is used commercially (Douglas, 1968) in the 'Vibrajet' to produce sprays mainly of relatively large drops with the object of controlling drift.

This paper is concerned with investigations carried out to assess the suitability of using a modified 'Vibrajet' nozzle to produce a range of sprays with narrow drop size spectra for use in research on spray placement.

EXPERIMENTAL

Apparatus

The 'Vibrajet' consists of an oscillator unit which provides a 25° oscillation of a shaft at a frequency of 58 Hz. Liquid passes through the shaft and into a co-axial cylinder formed by a 22 mm outside diameter plastic tube with a wall thickness of 1.5 mm. Filaments of liquid are formed from simple holes in the walls of the tube. The standard plastic sleeves were considered unsuitable for experimental purposes due to difficulties in producing accurate holes with sharp edges in the material. A number of brass blank sleeves were obtained which were then drilled using a high speed precision drill and the holes inspected under a microscope before use. The weight of the brass sleeves resulted in an increased load on the 'Vibrajet' motor, so that the sleeves were oscillated at 50 Hz instead of the normal 58 Hz.

The spray solution - deionised water plus dyes where stated - was contained in a modified polythene-lined fire extinguisher. Pressure was obtained from an air line supply, and a regulator on the output side maintained a supply of liquid to the nozzle at a constant pressure.

Procedure

The investigations were confined to an examination of the aqueous sprays produced from a range of single holes at different pressures and heights:

Hole diameter, mm	Pressure, kN/m^2 (lb/in^2)		Height, mm
1. 0.18	1. 7	(1)	1. 305
2. 0.25	2. 14	(2)	2. 457
3. 0.34	3. 28	(4)	3. 610
4. 0.46	4. 56	(8)	
5. 0.61			
6. 0.74			

Distribution in the direction of oscillation was determined by collecting between 0.5 and 1.0 l. of spray on a patternator divided into troughs 25.4 mm wide. At the same time the flow rate of liquid to the nozzle was recorded. Additional information on short term variations in deposit was obtained by arranging for a length of chromatography paper 50 mm wide to be drawn through the spray at a constant speed of 76 mm/s. The paper was then cut into 25.4 mm strips and the quantity of spray absorbed determined by extraction of fluoresceine LTS dye which had been previously added to the spray solution. This was carried out for two hole sizes only at a nozzle height of 610 mm and a pressure of 14 kN/m^2.

Drops were photographed in flight using 35 mm Micro Neg Pan* film and two x xenon filled discharge tubes in conjunction with a twin flash unit‡. The 'Vibrajet' was arranged so that the drops were between the camera and the tubes, the latter being positioned behind an opal glass screen to provide even illimination. The use of a suitable time interval between the discharge of the two lamps enabled both drop velocity and diameter to be determined from the one negative. Contrast was improved by the addition of 0.2% by weight of Nigrosine G140 dye to the spray solution. Photographs covered the centre 305 mm of the spray swath only.

RESULTS AND DISCUSSION

Spray distribution and flow rate

Patternator results are shown in Fig. 1 to 5 and flow rates in Table 1.

Table 1

Flow rate, ml/min, for different pressures and hole diameters

Pressure, kN/m^2	Hole diameter, mm				
	0.25	0.34	0.46	0.61	0.74
7	7	13	23	50	63
14	10	17	36	73	97
28	16	29	63	113	148
56	24	43	93	177	208

---

* Ilford Ltd.

‡ Ernest Turner Electrical Instruments Ltd.

Fig. I. Distribution from a 0·25 mm Diameter Hole

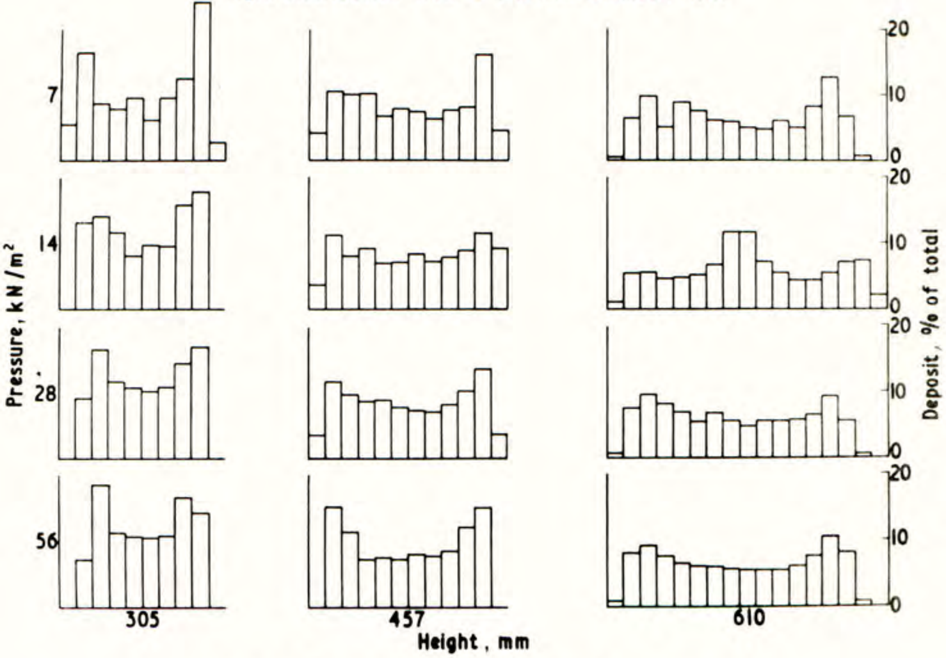


Fig. 2. Distribution from a 0·34mm Diameter Hole

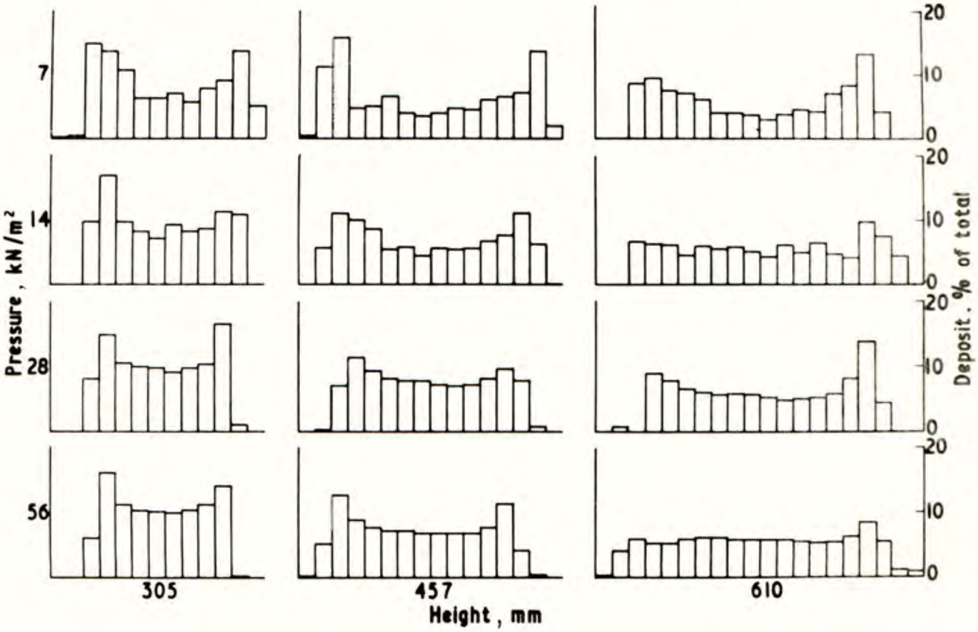


Fig. 3. Distribution from a 0·46 mm Diameter Hole

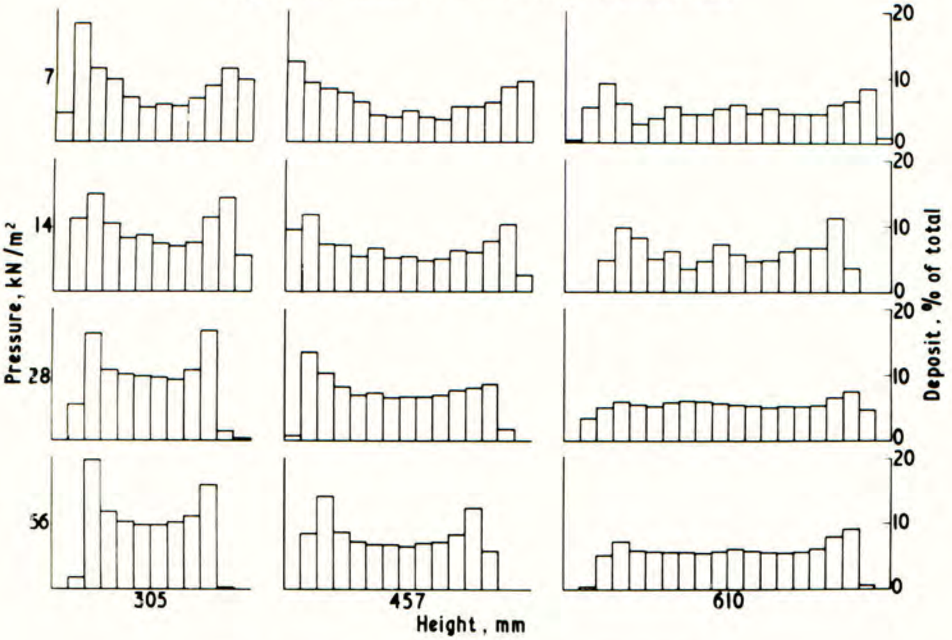


Fig. 4. Distribution from a 0·61mm Diameter Hole

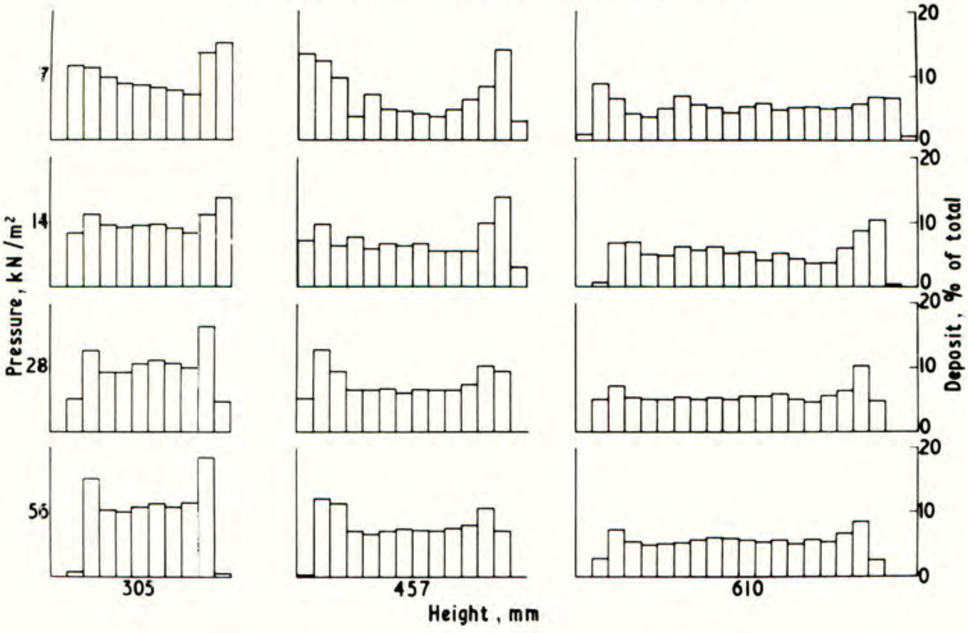


Fig. 5. Distribution from a 0·74 mm Diameter Hole

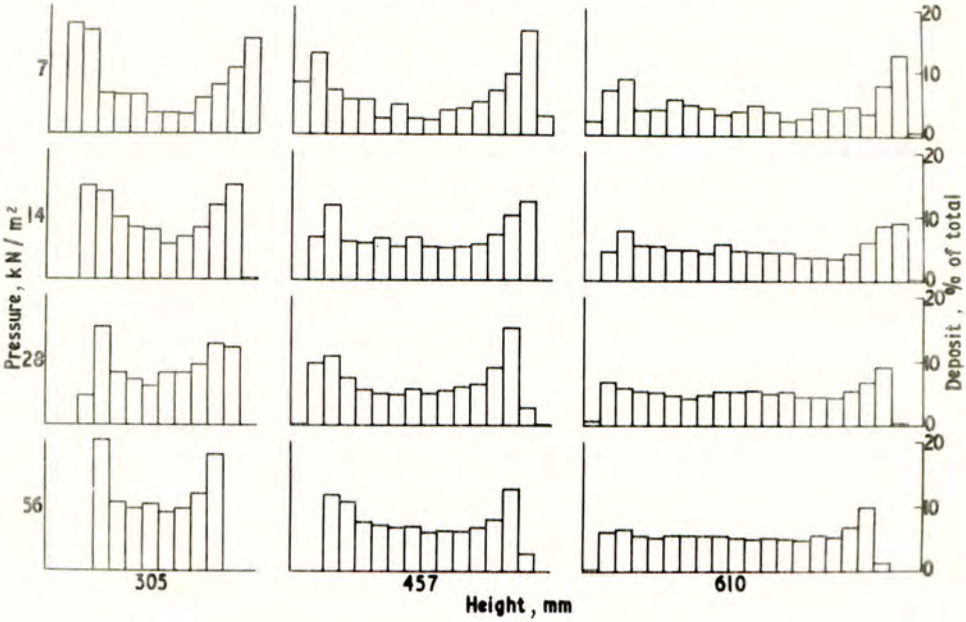
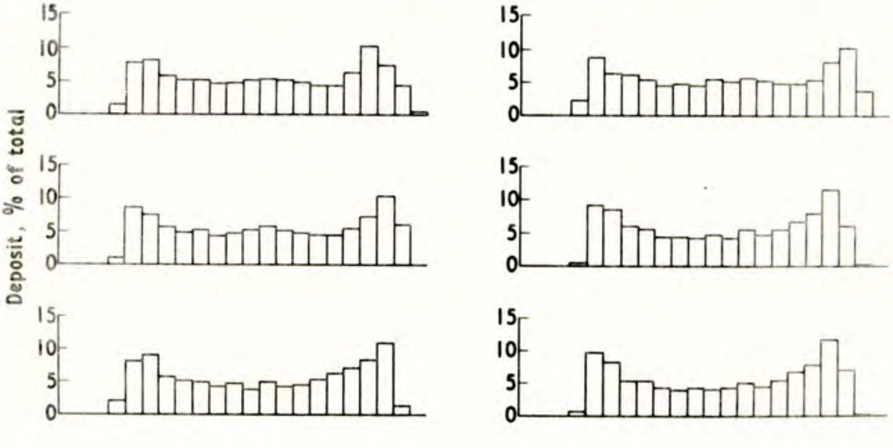


Fig. 6. Replicates of the Distribution from a 0·61 mm Diameter Hole
Height 610 mm Pressure 14 kN^2



No results were obtained for the smallest hole size due to difficulties in maintaining a stable filament of liquid. This was probably due to irregularities in the shape of the hole. As an indication of the repeatability of the results several patterns were replicated under identical conditions. An example is shown in Fig. 6 where coefficients of variation ranged from 26.0% to 31.5%.

Under nearly all conditions an increase in deposit occurred near the edges of the spray. This is probably due to the approximately harmonic motion of the liquid filament resulting in an uneven distribution of drops across the width of the spray. However, the initial velocity of the drops is dependent on the pressure of the liquid so that the motion has less effect on the trajectories of the drops as the pressure increases.

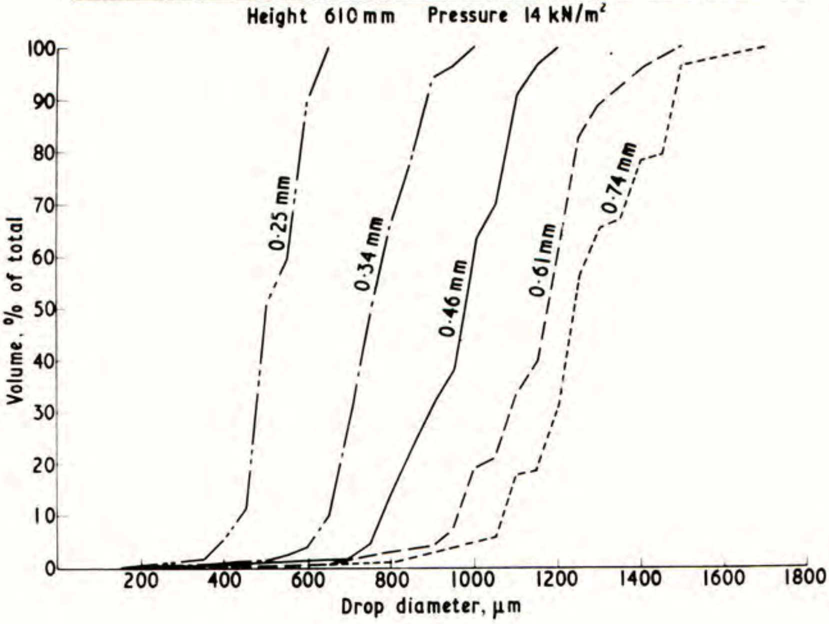
Extract from the paper strips gave coefficients of variation at a given point in the pattern of 9.08% for the 0.46 mm diameter hole and 8.21% for the 0.61 mm diameter hole. Maximum deviations from the mean deposits were 23% and 16% respectively.

Drop size and velocity

Drop size was found to be dependent on hole diameter (Fig. 7). At a pressure of 14 kN/m^2 and a height of 610 mm the drop MMD ranged from approximately 500 um with the 0.25 mm diameter hole to 1250 um with the 0.74 mm diameter hole. The range of drop size was also found to increase with hole diameter. An increase in pressure from 14 to 56 kN/m^2 had no effect on the drop size distribution from the 0.25 mm diameter hole, but with the 0.74 mm diameter hole the MMD decreased from 1230 to 1160 um due to an increase in the numbers of small drops. A photographic examination of the break up of the liquid filament showed that this was due to irregular drop formation resulting in the formation of satelite drops.

Figure 7

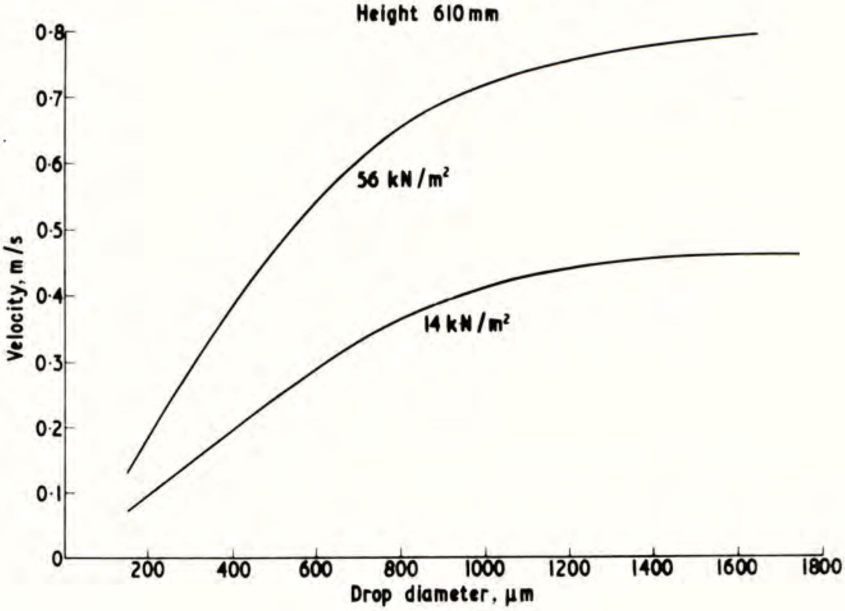
Volume of spray in drops of given size for various hole diameters



Drop velocity at any given distance from the nozzle was found to be dependent on the pressure of the liquid and the size of the drop, and independent of hole diameter. The results from all five hole diameters were used to produce the curves given in Fig. 8. At a pressure of 14 kN/m^2 drops above approximately 900 μm diameter were travelling at less than their terminal velocities (as given by Yeo, 1957) 610 mm below the nozzle.

Figure 8

Relationship between drop diameter and velocity at 610 mm below the nozzle



CONCLUSIONS

Vibrating jets produce sprays with narrower drop size spectra than can be obtained from nozzles forming sprays by the disintegration of sheets of liquid. Although with water it is impracticable to produce drops much below 400 μm in diameter, vibrating jets can be a means of extending the range of sprays produced by spinning discs. However, if the full width of the spray is used, difficulties may arise due to uneven distribution as a result of high deposits at the edges of the spray.

Acknowledgement

P. C. Shephard assisted with the experimental work and carried out most of the drop size and velocity measurements.

References

DOUGLAS, G. (1968) A comparison of the 'Vibrajet' nozzle and a fan jet for overall application of bipyridyl herbicides. Weed Res., 8, 14 - 27

YEO, D. (1957) The free fall of droplets in the atmosphere. Colonial Pesticides Research Unit, Arusha, Tanganiyka, Miscellaneous Report No. 174

Br. Crop Prot. Counc. Monogr. No. 2 (1970)

A DEVICE FOR SAMPLING DROPLETS MOVING IN HIGH VELOCITY AIRSTREAMS

C. W. Lee, R. F. Hill and J. S. Coles

Tropical Pesticides Research Unit, Porton, Salisbury, Wilts

INTRODUCTION

The development and construction of an apparatus designed to collect a representative sample of droplets from a concentrated cloud of spray moving in a high velocity airstream is described. This requirement arose on the commencement of a programme on work at the Tropical Pesticides Research Unit to assess the physical properties under laboratory conditions, of aircraft spray equipment. The equipment was set up in an open jet wind tunnel so that a simulation of flight conditions was partially achieved.

BASIC REQUIREMENTS

In evaluating the performance of spraying equipment it is desirable to collect spray droplets in some form so that the individual particles can be examined and sized microscopically. Assessment of sprays dispersed in high velocity air present two major problems: (a) the isolation of a small representative fraction from a dense continuous spray cloud, and (b) the collection of this sample by impaction in some media or matrix under controlled conditions which limit spread and shatter of droplets.

Some initial experiments were made with an apparatus (Nash et al, 1967) which incorporated a rotary shutter mechanism designed to momentarily expose eleven slides to the droplet cloud. This proved to be unsatisfactory for sampling airstreams containing dense clouds of spray droplets because contamination of the slides occurred from accumulation of spray on the shroud cover. It was observed on activating the shroud that an appreciable proportion of the spray was blown off the shroud and deposited on the targets.

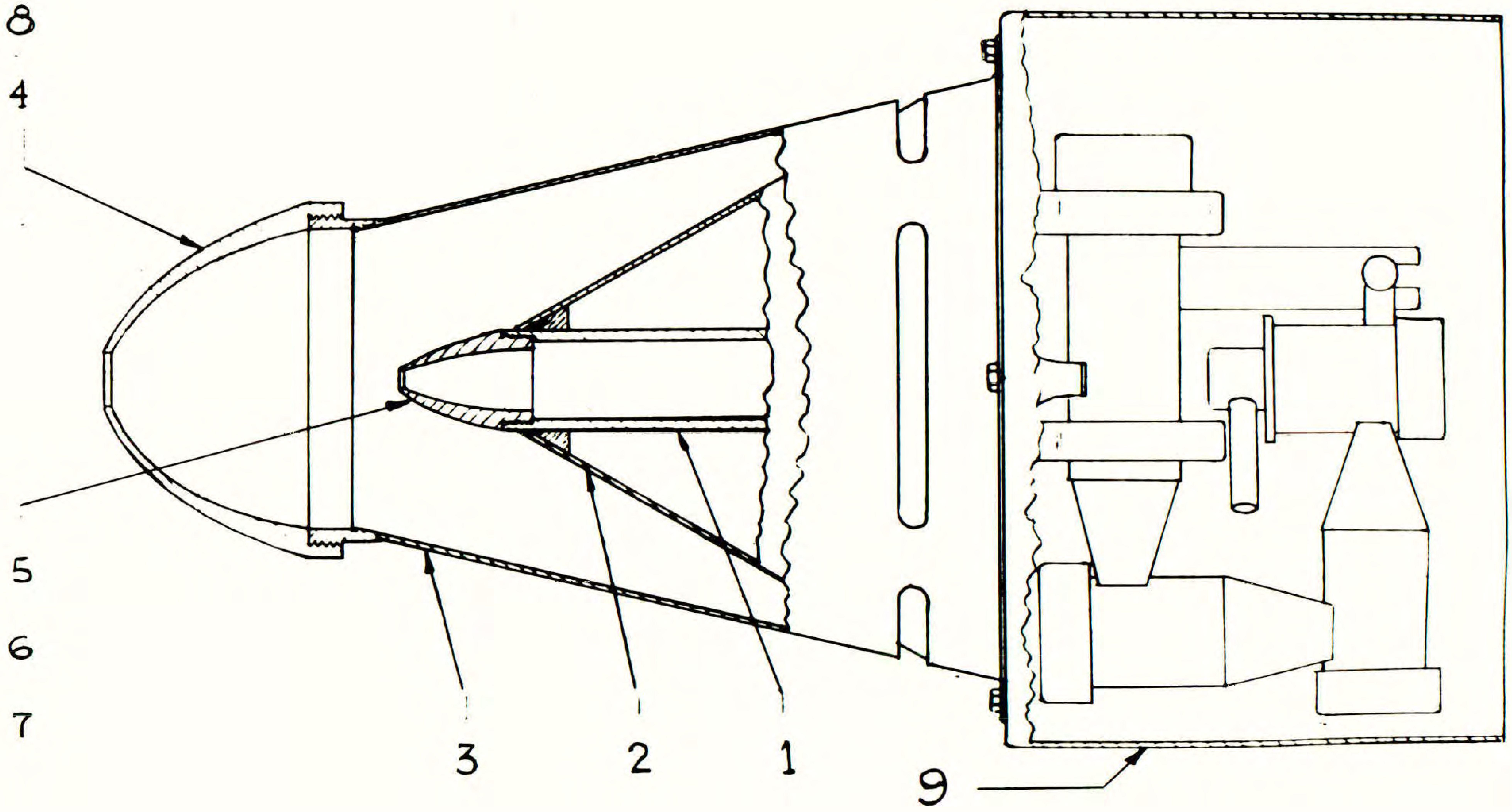
An alternative means of sampling droplets in a moving spray cloud was therefore studied in a wind tunnel. The wind tunnel consisted of a 42 in (1.07 m) diameter fan driven by a V8 petrol engine, capacity 3622cc developing 85 brake horse power (63.4 kW) at 3000rev/min. Downstream of the fan, the air is ducted through a cone, 28 in (711 mm) in length reducing to 28 in (711 mm) internal diameter followed by a parallel section 7 in (178 mm) in length in which a honeycomb of 4 in (102 mm) squares is located to smooth out variations in the airflow approaching the outlet. The wind tunnel is trailer mounted for mobility.

Air velocity measurements were determined in a combination of tubes and funnels placed in the airstream. The most promising combination consisted of two concentric tubes which reduced the air velocity in the inner tube to a value equivalent to one tenth of that in the mainstream. On the basis of these initial measurements a device was constructed.

Figure 1

A section of the sampling device, showing it mounted on a Cascade Impactor

(Numbers denote parts referred to in the text)



DESCRIPTION OF DEVICE

The device is illustrated in Fig. 1 and consists of a 1 in (25.4 mm) outside diameter brass tube (part No. 1) tapered at the rear end to mate with the entry port of a cascade impactor. (May, 1945). At the front it is threaded to receive a choice of nose cones (part Nos. 5, 6 and 7). The tube is mounted co-axially inside a metal cone (part No. 3) which forms the outer casing of the device. The small end of the outer cone is screwed to receive one or two nose cap fittings (part Nos. 4 and 8). The inner brass tube is centrally located by a cone (part No. 2) which is attached to the rear of the outer cone and adjacent to a series of vents. A cascade impactor is attached to the end of the inner brass tube and protected by a metal box (part No. 9) which has one side and the rear hinged to facilitate changing the impactors during the course of the experiments.

CONCLUSIONS

Preliminary tests have been carried out with the apparatus mounted on a steel frame at a point where the air velocity was 60 mile/h (27 m/s). Exposure of targets in the cascade impactor for 15-30 s, 2 m downstream of a rotary atomiser sprayer emitting 1-2 gal/min (76-152 ml/s) gave discrete droplet distributions at the 1st, 2nd and 3rd stages in the cascade impactor. It is planned to fully calibrate the instrument over a range of air velocities and liquid outputs. A 3-way manually operated air valve in the suction line to the cascade impactor is needed in the unit to allow more precise sampling of spray droplets. The possibility of using the device to sample droplets from transient airstreams might be worthy of study.

References

MAY, K. R. (1945) The Cascade Impactor. An instrument for sampling coarse aerosols. J. Sci. Instr. 22, (10), 187 - 195

NASH, J. H., LEITER, G. G. and GRIMM, F. (1967) A sampling device for liquid droplets. The Review of Scientific Instruments. 38, (1), 73 - 77

Br. Crop Prot. Counc. Monogr. No. 2 (1970)

DROP SIZE ANALYSING METHODS

J. Zaske

Institut für Landtechnik, Technische Universität, Berlin

INTRODUCTION

The droplet sizes produced by certain nozzle types considerably change the effectiveness of spraying and the accompanying risks. Therefore it is necessary to analyse the spray. But most of the methods of analysing droplets are difficult and take a long time while automatic droplet size analysers such as the flying-spot particle analyser used by the United States Department of Agriculture, or the Quantimet Analysing Computer* are not yet available to most of the agricultural institutes. To reduce the time required for counting, sizing and classifying an automatic scanning system has been developed, consisting of a scanner and a tape punch or a tape recorder. The data registered on the tape can be fed into a computer. The computer counts and measures the droplet images according to a logic programme and calculates the droplet size spectra. The results are then given in the form of tables and graphs.

SAMPLING METHODS

The droplets can either be photographed in flight or collected on a sampling surface. To avoid some disadvantages of these methods, the droplets of water-based sprays have been sampled in silicone oil (Wacker AK 1000). This has the following properties:

1. transparent;
2. a density similar to the spray fluid (0.97) which keeps the droplets suspended and in spherical shape;
3. low surface-tension (20 dynes/cm or µN/mm) which avoids shattering of the droplets when they hit the liquid surface;
4. low viscosity (10 St) sufficient to avoid shattering, but high enough to reduce the sinking velocity.

To sample the droplets of oil based sprays, water thickened by Vistic** is used. Wollschwartz dye is used to get a good contrast.

The sprayer boom or the nozzle positioned at the recommended height is moved at a known speed across several glass dishes containing the sampling liquid. Subsequently the droplets suspended in the sampling liquid are photographed or microphotographed. Conventionally the drop size spectrum is determined from an enlarged transparent photograph by a semi-automatic analyser, e.g. Zeiss TGZ, Fig. 1.

---

* Metals Research Ltd., Royston, Cambridge, England.

** Hercules Powder Co. Ltd.

Figure 1

Zeiss semi-automatic drop size analyser

Figure 2

A new scanning system showing the scanner, left, and recording and monitoring units

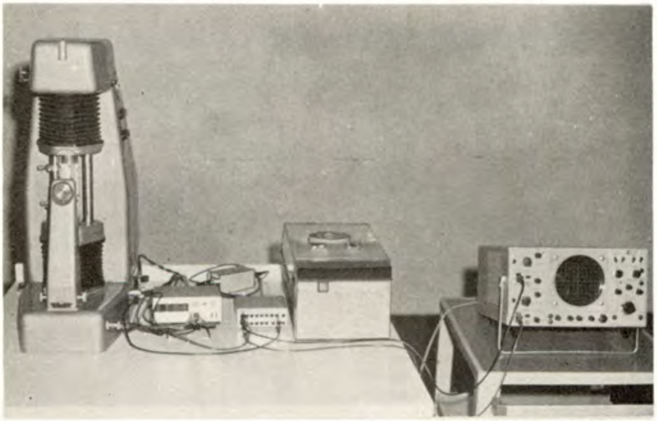
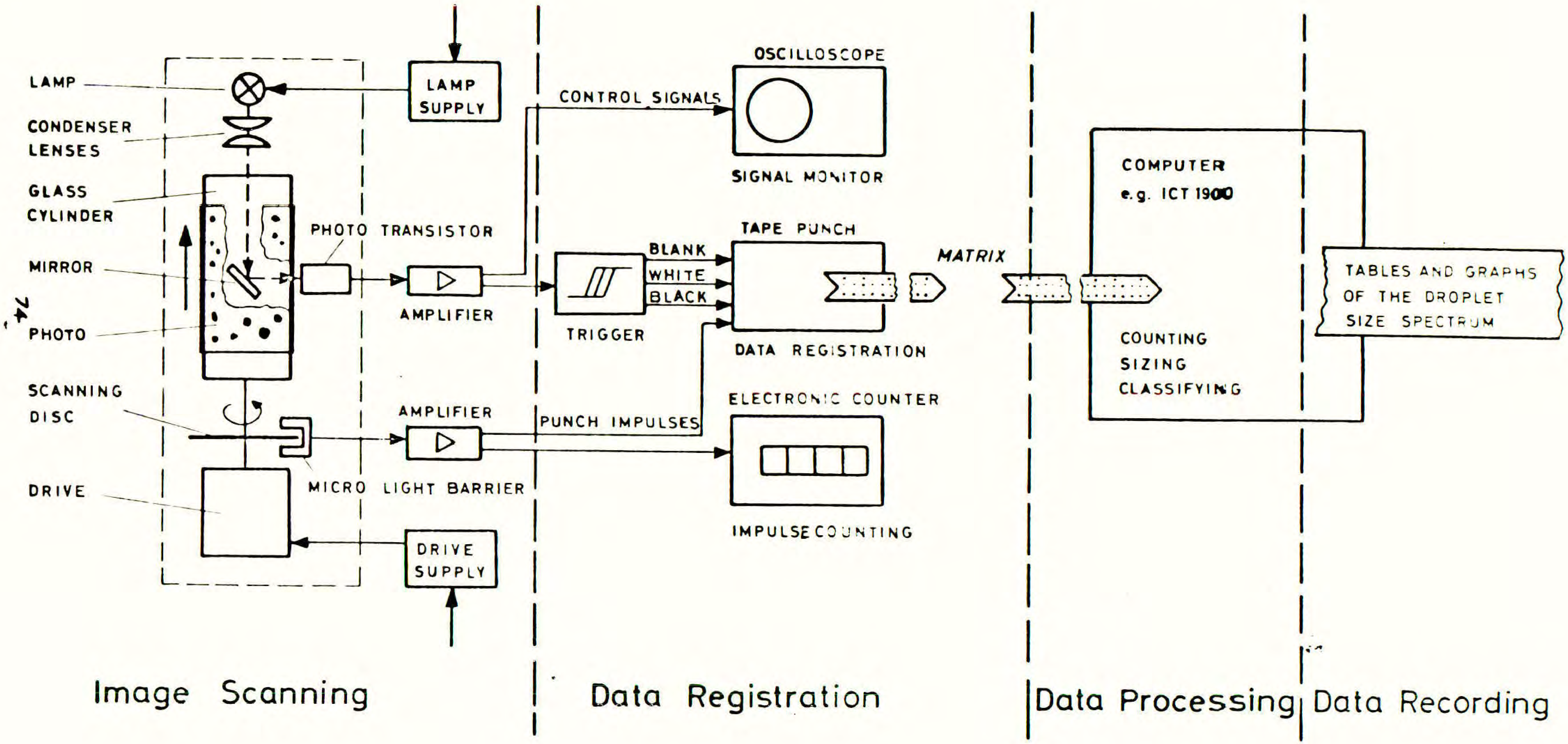


Figure 3

Block diagram of the scanning system and data recording and processing units



NEW SCANNING SYSTEMS

In a new scanning system, (Fig. 2 and 3) the photograph, 150 x 140 mm, is attached to the glass cylinder of the scanner-unit, which has a diameter of 50 mm. As it rotates this cylinder is moved vertically by a worm gear drive. A bright lightspot is projected on the photograph by an optical system located inside the cylinder. The image-modulated light signal is detected by a photo-transistor which converts the optical image to a three-level (black, white and blank) electrical signal. Differences in the transparency of the photographs require preliminary setting of the light-intensity. The scanning sequence is induced by a disc scanner giving a certain number of impulses per revolution, e.g. 500. Each single scan line is registered by a tape punch or tape recorder.

By feeding the data into a computer of the type commonly used at research stations, e.g. ICT 1900, the matrix or image is stored by the computer. A logic p programme ensures that the droplets are counted only once and measured at maximum diameter only. After the droplet images are classified the computer calculates the real droplet diameters by the given enlargement factor and determines the droplet size spectrum. The results are presented by the computer either in the form of tables giving the numbers and volumes of drops in each size range, separately or cumulatively, or as graphs showing the cumulative data.

An alternative scanning system consists of an X-Y recorder with an incremental chart advance. Instead of the pen system a photo-transistor is attached, moving in the Y-direction. A neon tube positioned behind an opal glass screen provides even i illumination of the transparent photograph. The data pick-up in the Y-direction is triggered by an electronic clock. After one Y-scan line is registered by a tape punch or tape recorder the photograph is advanced one step in the X-direction while the photo-transistor is reset and the next line can be scanned. After the entire area of the photograph has been scanned and the images registered, measuring, counting and computing is carried out by a computer as described above.