DEPOSITION EVALUATION FOR AGRICULTURAL DUSTING RESEARCH

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This is to certify that the

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Major professor

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DEPOSITION EVALUATION FOR AGRICULTURAL DUSTING RESEARCH

By

Ross DeLine Brazee

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
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AN ABSTRACT

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Approved Walter M. Carleton

ROSS DELINE BRAZEE ABSTRACT

Many farmers are constantly faced with the challenge of how to more effectively and efficiently meet the infestations on crops. An important phase of this problem is proper application of chemical insecticides and fungicides to plants for their protection. Dusting and spraying of insecticides and fungicides on the plant surfaces have been the chief methods used up to the present time.

Dusting has the advantage over spraying in that it is an easier process to carry out. However, dusting has been found to be quite inefficient in the amount of dust actually deposited, due to large windage and drift losses. Thus, the overall aim of this study is to increase the efficiency of dust deposition through electrostatic charging of the dust particles.

Research involving improvement of dusting efficiency necessarily requires the availability of methods of dust deposition evaluation. Therefore, this investigation dealt with development of suitable methods of dust deposition evaluation for research applications.

Previous methods of dust deposit evaluation used at Michigan State College consisted of chemical analysis in field experiments and a light reflection method for use in the laboratory. A search for a more rapid means of evaluation suggested the use of a dyed dust for colorimetric estimation of dust deposits. Therefore further work was directed toward development of this method for field use. In field experiments, however, this procedure was found to be rather unsatisfactory due to the effect of foreign matter contamination.

More or less new methods were studied in an attempt to devise evaluation schemes. The possibility of using a vapor state fluorescence procedure was investigated, but under the conditions of experiment this approach failed. A copper titration method was also investigated as to its feasibility for field experimental use.

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INTRODUCTION

The research described here is concerned with the improvement of deposition of insecticidal and fungicidal dusts through electrostatic charging. Previous work on this subject at Michigan State College was carried on by Bowen (2) and Hebblethwaite (8).

At the present time, spraying finds more widespread use than dusting. Hebblethwaite states the reasons for this as follows:

1. Sprays give better coverage of the plant surfaces than do conventional dusting methods.
2. Spraying is more efficient than dusting; the amount of toxic agent required per acre being generally greater in the case of dusting. The reason for this is apparent when the amount of drift losses in dusting are observed.
3. Sprays are less susceptible to meteorological conditions both at the time of application and afterwards. The wind is less troublesome to spraying and when a spray deposit dries and adheres closely to the leaf surface it is less rapidly washed off by rain than is a similar quantity of dust.

Dusting has the advantage of being a simpler process to carry out. Less expensive machinery is required, and the need for transporting large quantities of water to the field is eliminated. It is believed that dusting would become more popular if its efficiency could be increased. In an article by Bowen (3), it is stated:

> In recent field tests dust recovery has been approximately 10 percent, with conventional field dusting, where dust recovery refers to the percentage of dust discharged by the duster that actually deposits on the plant. From this it is believed by the authors that under normal farm work the dust recovery seldom exceeds 15 to 20 percent, even on dense foliage.

The results summarized here make quite obvious the inefficiency of present dusting methods. Thus, the need for research designed to improve the efficiency of dusting is apparent. The ease with which dusting may be carried out justifies the study aimed at improving its efficiency. These factors caused the initiation of an electrostatic dusting project at Michigan State College.

Electrostatic methods of precipitation improvement, exclusively, have been studied at Michigan State College. By this method, an attempt is made to charge the dust particles, thereby increasing the attraction between the dust particles and the surface of deposition. A diagram of the electrostatic charging apparatus is shown schematically in Figure 1 . The electrostatic charging equipment may be mounted on a conventional fan-type duster, and its main components are charging nozzles and a source of high direct current potential. A fine wire is located in the charging nozzle, and is maintained at high direct current potential, while the charging nozzle walls are at ground potential. Because of the large voltage gradient, and due to the high curvature of the charging wire, corona discharge is produced, indicating air ionization within the nozzle. As

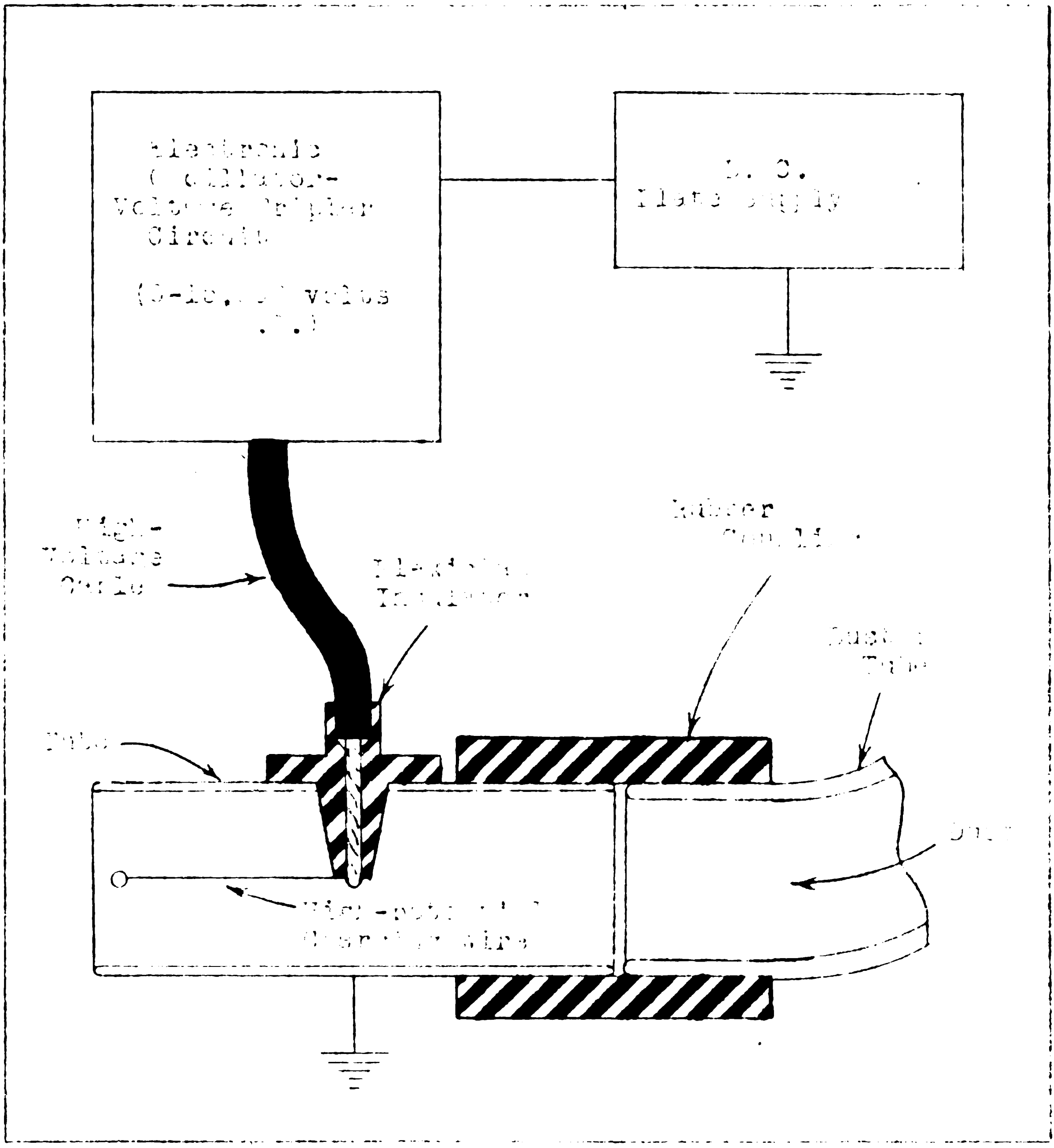


Figure **1.** The above illustration shows, schematically, the design of an electrostatic dust charging system undergoing tests at Michigan State College. Air ions formed in the high potential gradient of the nozzle become attached to the dust particles as they pass through the nozzle, resulting in a charge formation, or accumulation, on the dust.

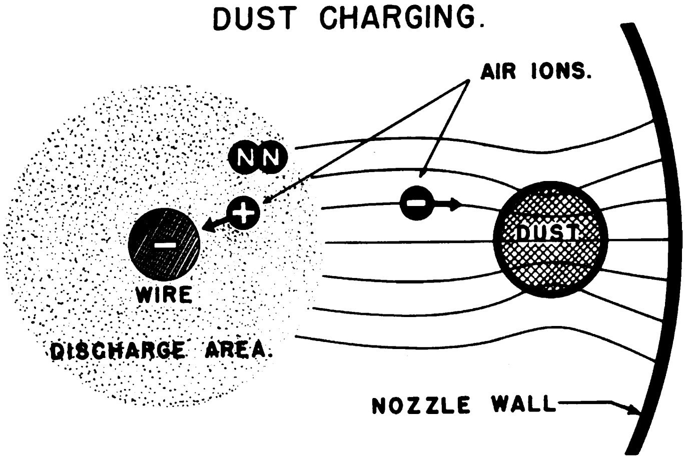


FIG. (4)

Figure 2. A schematic representation of the action of the ionizing type charging nozzle, designed at Michigan State College, is shown above. Both positive and negative air ions are produced in the corona discharge area, and the positive ions are, of course, attracted to the charging wire, which is negative in potential. The negative ions, under the influence of the high field potential gradient, tend to move to the grounded nozzle wall. As the negative ions move toward the nozzle wall, they are picked up by dust particles passing through the nozzle, which places a negative charge on the particles.

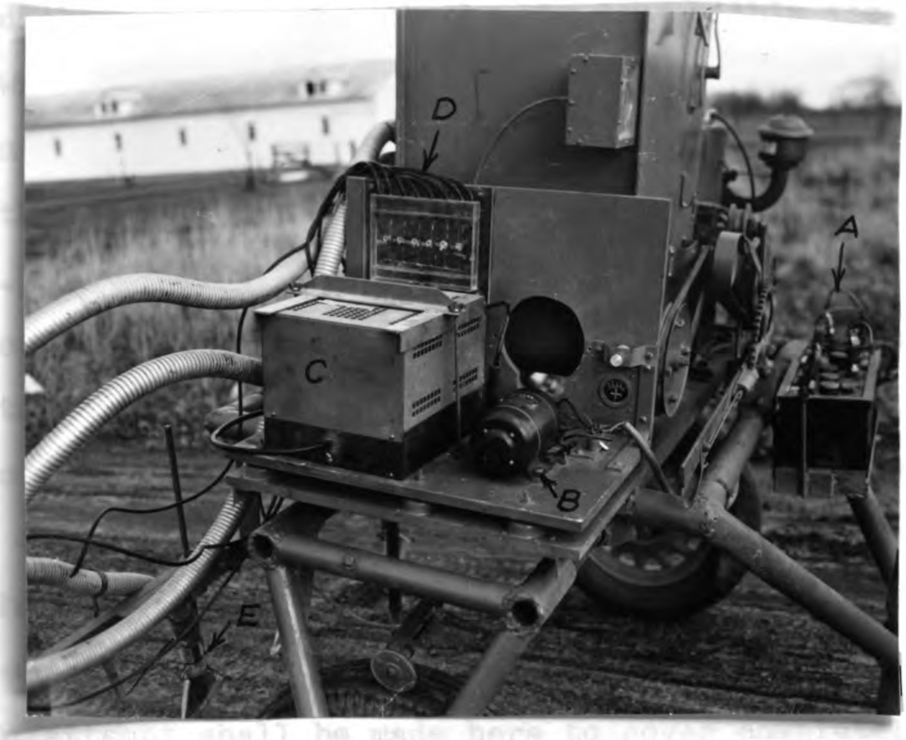


Figure 3. An experimental field duster equipped for electrostatic charging is shown above. Low voltage direct current supply from the storage batteries (A), is "converted" to a direct current supply of about 300 volts by the dynamotor (motor-generator) (B). This input is fed into the electronic oscillator voltage-tripler (C), which produces the required direct current charging potential of about 12,000 to 15,000 volts. The high voltage output is delivered to the charging nozzles (E) through high voltage cables (D).

dust passes through the nozzle, individual particles become charged through contact with the air ions within the nozzle, as shown in Figure 2. (The air ions would, of course tend to move in a direction perpendicular to the path of the dust under the influence of the strong electric field within the nozzle.) Then, as the charged dust particle nears the plant, electrostatic forces become effective as an aid to dust deposition. The complete set of charging equipment may be very easily incorporated into a field dusting machine, as shown in Figure 3. However, the fact must be emphasized that this is not an ultimate design, as future findings may very well necessitate changes.

No attempt shall be made here to cover completely the theory and experiments dealing with electrostatic dusting. For a more complete discussion of these methods, the reader is referred to the theses of Bowen and Hebblethwaite.

The work to be described here shall deal almost exclusively with dust recovery evaluation. The term dust recovery merely means the amount of dust retained on plant or other surfaces, with comparison to the amount of dust actually applied by the dusting machine. The need for dealing with dust recovery evaluation methods becomes obvious as quickly as one becomes engaged in dusting research. Techniques must certainly be devised for comparing dust deposition improvement devices with conventional designs.

Although effort in this direction seems rather divergent from the primary purpose, productive work can not proceed without it. Evaluation techniques must be kept abreast of the overall activity.

It must be understood that the dust recovery methods studied here are not in general biological. That is to say, no attempt is made to study the effect of dusts upon insects or plant diseases. Rather, the evaluation procedures described here are almost entirely quantitative, or qualitative, in nature. The present policy of being concerned with quantitative methods almost exclusively is based upon the fundamental aim of this project. The goal of the overall study is to increase knowledge of, and control over, dust deposition methods. Belief is retained at present that this work should not be concerned with biological factors of dusting. The biological studies should, no doubt, be carried out by specialists in the plant sciences. The preceding statements are not intended to imply that parallel biological experiments would not be desirable. In fact, efforts in this regard would be welcomed.

REVIEW OF LITERATURE

Quantitative estimation of dust deposition presents quite challenging problems in connection with pesticidal dusting research, since complicating factors are frequently encountered, particularly under field conditions. Deposits, themselves, are very elusive to quantitative estimation of the amount of dust present. However, a review of literature reveals some rather interesting methods of dust recovery at Michigan State College, as described by Hebblethwaite (8).

Chemical Evaluation of Dust Recovery: Lead Content Analysis and the Leaf Printing Technique

The lead content analysis, and the leaf printing technique, were used in connection with certain field tests described by Hebblethwaite. The lead content analysis was intended to supply information which would facilitate the determination of plant dust recovery as a percentage of the duster application rate. The leaf printing technique was utilized, in conjunction with the quantitative determinations, for study of dust deposit distribution on the leaf surfaces.

These evaluation methods were applied to field tests on navy beans, which had been drilled in 28-inch rows.

As previously stated, it was desired to express dust recovery as a percentage of duster output. The duster was calibrated, therefore, so that its application rate would be known for any given test.

Sampling. A representative one-foot length of row was selected and marked off. From this row length, a sample of nine leaves was taken. The leaves were so chosen that they represented, as nearly as possible, all leaves in the row length. That is to say, that some leaves were exterior, some leaves were interior, and others were intermediate between the two. The leaf samples were then carefully placed in bottles for transport to the laboratory. Undusted leaves or blanks were also taken for analytical use.

Chemical Evaluation of Dust Recovery. The leaf samples taken were analyzed for lead content (a lead arsenate dust being used) by the experiment station chemist. As soon as the analysis results were available, the desired recovery percentages could be calculated.

Specific lead analysis results were available on the basis of a definite leaf area, and the duster application rate was expressed as the weight of dust applied per acre. Thus, knowledge of the leaf area per acre would facilitate computation of the dust recovery, in weight of dust per acre. The leaf area per acre was determined by measurement of leaf areas in one-foot row lengths, these data being transformed to expressions of leaf area in square inches per acre. Leaf areas for use in the dust recovery evaluation were obtained from the leaf prints made by the leaf printing technique. The details of this procedure will be described later.

The percentage of dust recovery was calculated as follows:

The lead content analysis results were put in terms of micrograms of lead per square inch of surface, and the area of leaf per acre was expressed in square inches. Knowing the weight of dust applied per acre and the percentage of lead in the dust, it was possible to compute the percentage recovery in the following manner:

Percentage Recovery =

$$\frac{\frac{\text{Wt. of lead}}{\text{Sq. in of leaf}} \times \text{Area of leaves, } \frac{\text{in.}^2}{\text{acre}} \times 100 \times 100\%}{(\text{Wt. of dust applied per acre})\ (\text{Percentage lead in dust})}$$

<u>The Leaf Printing Technique</u>. As previously mentioned, the leaf printing method was designed for the study of dust distribution on plant surfaces. Leaf printing facilitates comparison of macro-distributions produced by different dusting methods, and also provides a good conception of the micro-distributions. Hebblethwaite defines these terms as follows:

> Macro-distribution is the distribution between one leaf surface and another. For perfect macro-distribution each leaf surface would have on it the same quantity of toxic material, when expressed in terms of weight per unit area.

> Micro-distribution is the distribution upon one leaf surface and the position of each particle relative to the others. Perfect micro-distribution, however, is less easily defined. Certainly it should be even and regular, but when it comes to specifying how far from one another the particles may be spaced, the biologists who have worked on this subject are a little hesitant. One attempt at such a definition is to say that for disease prevention, perfect micro-distribution is accomplished when there is no space between dust particles large enough to contain a spore without that spore touching one of those particles. It is recognized that this does not give a complete picture of the requirements which should include consideration of such things as the volatility of the substance used. ....)

The method was originally obtained from Klingbeil (9) who in turn credits it to Hamilton (7). The method was simplified for use in the applications described by Hebblethwaite, who describes the following steps in the use of the leaf printing technique:

1. The plants were dusted with lead arsenate dust or a mixture containing this compound.

2. The sample leaves were placed between two sheets of sensitized paper. This paper was prepared by soaking good bond paper in 5% sodium hydroxide solution for one minute, then draining.

3. This sandwich of paper of leaves was squeezed between two foam rubber pads in a hydraulic press for one minute. In the field the required pressure was merely estimated, and a press consisting, essentially, of a hydraulic type automobile jack and two sheets of steel, was used.

4. The leaves were removed from the paper and the paper placed in a 5% solution of lime sulfur. The sheets were allowed to stand until the dark spots of lead sulfide (which denoted the location of dust particles) ceased to become darker.

5. All the yellow color was washed from the paper in clear water.

6. The sheets were dried.

The leaf prints obtained in this manner were easily studied. In the areas where dust occurred on the leaf, the prints showed dark areas against a white background. Also, since the leaves were pressed between two sheets of sensitized paper, prints were available for both the upper and lower leaf surfaces.

When the leaf prints were examined, the leaf outlines, themselves were clearly visible. This fact facilitated leaf area determination. Since the leaf outlines were plainly evident, it was possible to determine their areas by means of a planimeter.

Leaf samples for printing were taken simultaneously with those for lead content analysis. A sample of nine leaves, as nearly equal in size as possible to the others, was taken. These leaf samples were placed on the sensitized paper for printing as previously described.

Microscopic Examination

With regard to microscopic examination, Hebblethwaite makes the following statements:

> The microscope can provide both the qualitative and quantitative evaluation of dust deposits. But its use in particle size determination and in particle counts is very laborious when a large number of readings are to be taken. There have been some attempts to simplify this work and it may be that these will render the microscope much more useful for dust counts.

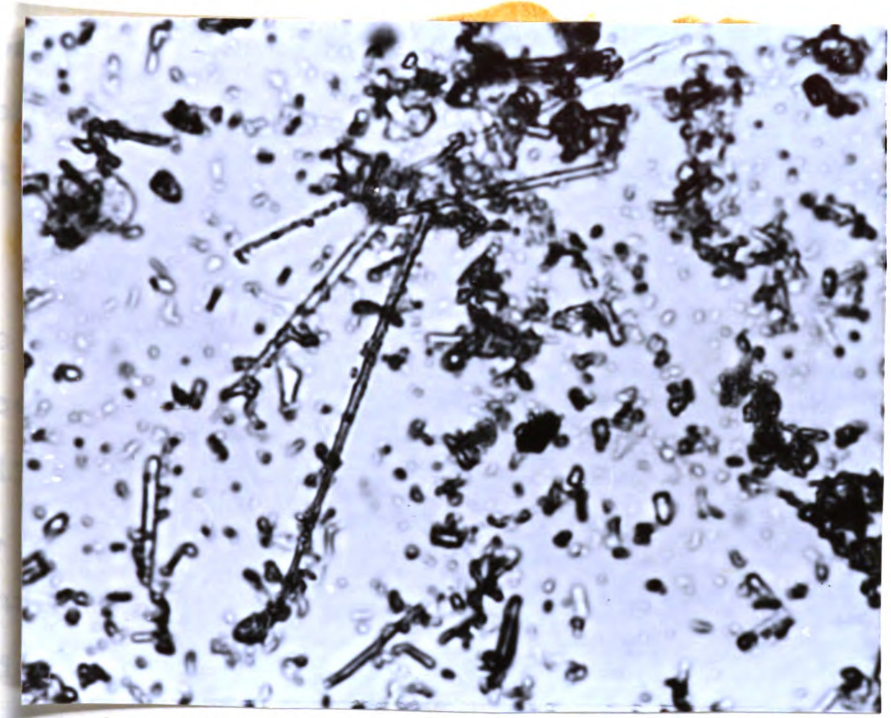


Figure 4. The above photomicrograph shows a dust deposit, and was taken by means of transmitted light. Difficulty was experienced, when using microscopic analysis, in distinguishing between individual particles and aggregates a darker background was found to make inspection simpler.

To distinguish between aggregates and individual particles is one of the most difficult tasks.

Figure 4, is a photomicrograph taken by means of transmitted light. The difficulty in measuring and counting particles becomes obvious.

Further experimental work mentioned by Hebblethwaite resulted in improvement of this method. It was found that

dark field illumination, or the use of a dark background, resulted in superior photomicrographs and greater ease of counting.

Apparently Hebblethwaite did not find any extensive experimental applications for this method, as it was seldom referred to in experimental results.

The Light Reflection Comparison Test

The light reflection comparison test for evaluation of dust recovery is a rather specialized method, and is intended primarily for use under carefully controlled laboratory conditions. It provides a rather rapid method of dust recovery determination. A light colored dust, such as a talc, is required for this method to be successful. Basically, the principle of this method is that when the light colored dust is deposited in increasing amounts, the reflection of light will be proportionally increased.

Special test surfaces were required for the light reflection comparison test. The test surfaces consisted of sheet metal discs, of three and one-half inches in diameter. (Metal discs were required for the reason that they were to be used in experiments with electrostatic dusting, where conducting surfaces were deemed necessary.) These discs were blackened by carbon coating with an acetylene torch, using a flame of almost pure acetylene. The carbon coating

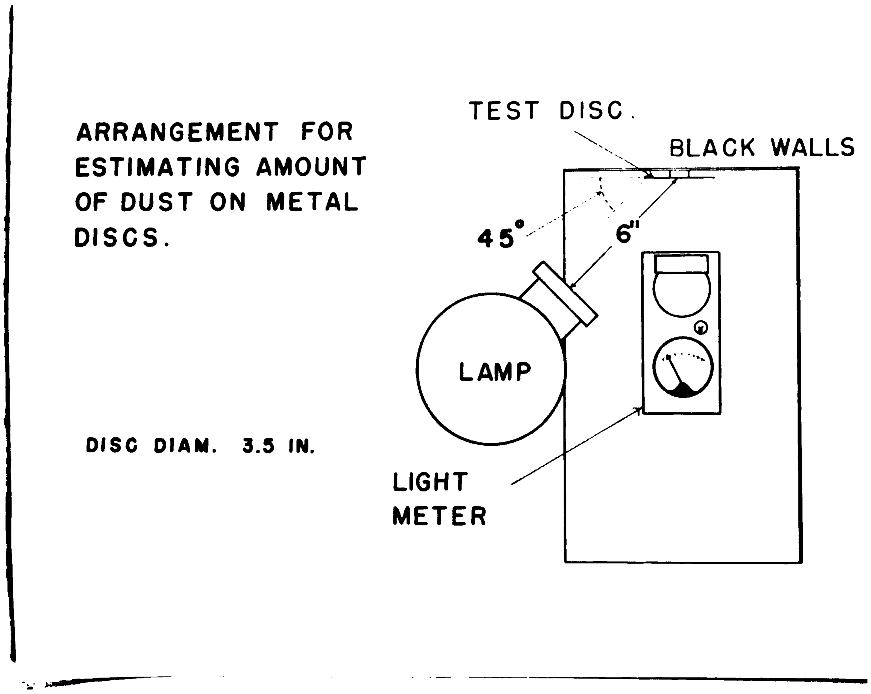


Figure 5. The light comparison test apparatus, designed by Hebblethwaite. The lamp used was a microscope illuminator.

provided a surface which was slightly rough, and of low light reflectivity. The roughness was desirable due to the fact that it more nearly approximated actual dusting surfaces. Several other methods of black coating the surfaces were tried, including black paints. Blackening with paints was found to be undesirable, however, since large variations in blank light reflectances were noted. (Blank reflectance refers to the reflectance of discs without dust deposits.) The carbon coated surfaces were found to be quite uniform in blank reflectance, with insignificant variation from disc to disc. This rendered possible one blank reflectance reading for perhaps an entire series of discs which were dusted experimentally.

The light reflection comparison test apparatus, designed by Hebblethwaite is shown schematically in Figure 5. The components were the test disc, a special black box, a microscope illuminator and a photoelectric light meter. A microscope illuminator, using a 100 watt bulb, was found to give the most sensitive as well as the most constant light beam. The amount of light reflected was measured by means of a photoelectric light meter.

A calibration curve for the light reflection comparison test is shown in Figure 6. Hebblethwaite describes the calibration of this test set-up as follows:

> Before it is possible to place confidence in a new method such as this, we compare it with some more basic method of measurement and thus light meter readings were compared with the actual weight of dust on discs. Zinc Oxide dust was used to dust a set of discs in such a way that they had a wide range of light meter values. These values were recorded and then the carbon film and the dust were washed with dilute sulfuric acid. The resulting suspension was carefully evaporated to dryness and then ashed. The ash consisted of anhydrous zinc sulfate which was weighed and the equivalent weight of zinc oxide determined by calculations. The curve which was obtained from this experiment indicates that a satisfactory relationship between the two variables does exist. There is some divergence from the curve, however, and for this reason three replications were always made to obtain a single net light meter index as quoted in the earlier tests.
>
> In using this test the extremely high and the extremely low readings were avoided whenever possible, because the sensitivity will obviously fall off in the low range and in the high range the readings will be inaccurate as soon as a significant number of particles become stacked one upon another.

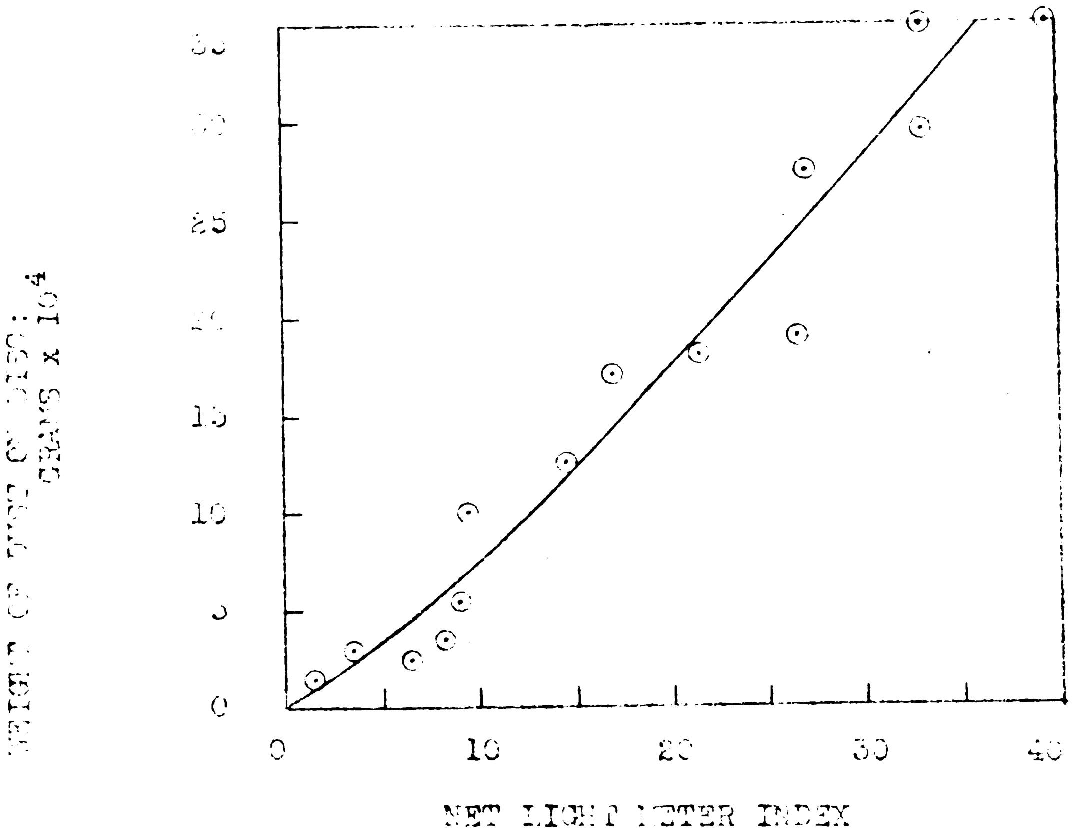


Figure 6. A calibration curve obtained by Hebblethwaite for the light reflection comparison test is shown above. Zinc oxide dust was utilized in the establishment of this curve.

Colorimetric Estimation

The colorimetric estimation method described by Hebblethwaite was a product of research for a more rapid method of dust deposit determination. Chemical analyses, although no doubt of good accuracy, consume a considerable amount of time. It is possible that long periods of time may elapse before changes in duster design, or precipitation methods, may be evaluated. Thus, the Michigan State College dusting workers suggested the possibility of preparing a colored dust. Provided that the coloring agent was soluble, it could be washed from the plant surfaces, and by examination of the color intensity, the amount of dust deposited could be estimated.

Mr. J. F. LesVeaux, of the Niagara Chemical Division of the Food Machinery Corporation, was contacted in regard to this matter. Members of this firm immediately set to work on this request and developed such a dust. The results were as follows as described in a project report abstract by Tidwell (12):

> The talc impregnated with a water soluble dye was produced for dusting experiments and a method of analysis was developed for determining the talc deposits on the leaves. The best dye for the impregnation was National Brilliant Scarlet 3R produced by the National Aniline Division of Allied Chemical and Dye Corporation. The analytical method is capable of detecting 0.5 milligrams of talc under field conditions and may be adapted for laboratory use to detect talc concentrations as low as 5 micrograms.

The colorimetric estimation method offers some interesting possibilities. Obviously the amount of dye impregnated dust could be estimated alone. However, there is also the possibility that the relative deposition of dust mixtures could be determined. That is to say, an active ingredient might be evaluated by chemical or other means, and the dyed talc might provide information as to the amount of inert carriers deposited. The actual experimental application of colorimetric estimation is as follows:

A dyed, or otherwise colored, dust is prepared. This dust may or may not contain active insecticidal or fungicidal ingredients.

A series of color standards is necessary in making the comparison test. The color standards are prepared by addition of specific quantities of dust to clear plant washing solution. (The plant washing solution will be described later.) The color standards are prepared by addition of specific quantities of dust to clear plant washing solution. (The plant washing solution will be described later.) The color standards are prepared in definite gradients, sufficient to cover all anticipated experimental concentrations.

A plant washing solution is then prepared. This solution is merely water plus a detergent. This type of washing solution is intended to provide thorough wetting of the plant surfaces, and therefore insure thorough dust removal.

Under actual experimental conditions, a definite size of dusted plant sample would be obtained. This would then be thoroughly washed using the plant washing solution. Comparison of the unknown washing with the color standards would then allow estimation of the amount of dust deposited on the plant.

This method was as yet untried in the field at the conclusion of Hebblethwaite's work. Therefore, a portion of the research described herein will involve further development and study of this technique.

STATEMENT OF PROBLEM

Dusting research requires careful attention to quantitative estimation of dust deposits. Therefore, the purpose of the work to be discussed here will be a study of quantitative, and not biological, methods of dust deposition determination. An attempt will be made to summarize previous methods, and to reach conclusions as to where they may be best applied. Further effort will be directed toward development of the colorimetric estimation method. Attention shall also be directed toward possible development of more or less entirely new evaluation techniques. An attempt will be made finally to bring the above results and conclusions into a meaningful entirety. This will be helpful in orienting dust recovery evaluation patterns.

A STUDY OF THE COLORIMETRIC EVALUATION METHOD

A. The Adaptation of Colorimetric Estimation to Utilization in Field

1. General

The object of the work subsequently described was to determine what measures might be necessary in adapting the laboratory evolved colorimetric method to field usage. The colorimetric method of crop dust deposit determination has been described in the review of literature.

The detailed objectives of this study were as follows:

1. The number of washings, to which a plant sample must be subjected to completely remove the deposited dust, must be determined.
2. The effect of foreign material in the plant washings, derived from the plants themselves, must be investigated.
3. The probable size of plant samples, and the method of plant sampling, must be decided upon.
4. Conclusions must be drawn from these findings which would allow the formulation of a practical, as well as reliable, field evaluation method.

Apparatus & Methods

Two different dyed-talc dusts were used: (1) The Niagara Chemical Company dyed-talc lead arsenate dust and (2) the Michigan State College dyed-talc dust.

The Niagara dust was especially prepared for this research by the Niagara Chemical Company, a division of the Food-Machinery and Chemical Corporation. Reference has been given to this fact previously. The dyed-talc diluent was merely impregnated with a water soluble red dye. Approximately 45 percent of this dust, by weight, was made up of lead arsenate active ingredient. This dust was intended for both quantitative evaluation and pest control purposes.

The Michigan State College dyed talc dust was made up of inert ingredients only. This dust was formulated by Henry D. Bowen (2)and the author, and was prepared as follows:

> The object of following process was to impregnate an inert, clay talc dust with a commercial, water soluble organic red dye.
>
> A dry mixture of five parts of dye and ninety-five parts of talc was prepared, and placed in a small concrete mixer. Mixing was then carried out, with periodic addition of water at such a rate that a slurry of free-flowing paste-like consistency was maintained. The slurry was mixed thoroughly to insure uniform distribution of the dye over the talc.

The mixed slurry was then removed from the mixer drum and spread evenly in large open pans, which were placed in an oven and completely dried, Upon completion of drying, the dust was removed from the pans and placed in suitable containers. Since the dried dust was somewhat caked, it was necessary to grind it to the desired fineness using a ball mill. Upon completion of the grinding operation the dust was ready for field use.

The Michigan State College dyed-talc dust was intended for use where pest control was not a prime objective. It was used for quantitative evaluation purposes only.

Alfalfa, young timothy, or navy bean plant samples were used in connection with these preliminary studies. The belief was held that these three types of plants would satisfactorily represent crops which might be encountered in field work. Small samples of these plants were taken to the laboratory for use. In order to simulate as nearly as possible field conditions, dust was applied to the plant samples by means of a small laboratory duster. This type of approach was necessary, certainly, in determining the suitability of the evaluation procedure.

A special washing solution was prepared for removal of deposited dust from the plants. The solution was made up of 0.2 percent by volume of Triton X-100, a detergent, in water.

The presence of the detergent would insure thorough wetting of dusted surfaces, with more efficient removal of dust deposits for quantitative evaluation.

Color comparisons, using color standards of known dust concentration, were of course necessary. The initial set-up for this purpose consisted of a specially constructed test tube rack with a fiber board back. The entire rack was painted with aluminum paint to increase the light reflectivity. Stoppered test tubes, containing the standard solutions of colored dust, were then placed in this rack. Plant washings of unknown concentration could then be analyzed, using this color comparator. This is to say, the solution of unkown concentration was visually compared with standards, thus making possible the bracketing and estimation of its concentration.

The previously stated experimental objectives were studied in the following manner:

> In determining the number of washings required for a given plant sample, single experimental plant samples were given three or four separate washings, each in a new solution. Any dust retained on the plant after a washing would certainly be indicated in the succeeding washing.
>
> Several methods of approach were utilized which would directly affect the amount of foreign material

introduced into the plant washing, as well as the efficiency of the washing process. The following methods were tried as to their suitability for plant washing procedures:

a. Method 1. The plant sample was placed in a screened funnel. The washing solution was poured through it, and the resultant plant washing was collected and allowed to stand until foreign matter suspensions had settled out.

b. Method 2. The plant sample was placed in a screened funnel, the washing solution was poured through it, and the resultant washing was collected and filtered in order to remove foreign matter.

c. Method 3. The plant sample was completely immersed in the washing solution and then removed from the resultant plant washing solution. The plant washing solution was then allowed to stand until foreign matter suspensions had settled out.

d. Method 4. The plant sample was completely immersed in the washing solution and then removed from the resultant plant washing solution. The plant washing solution then was filtered in order to remove foreign matter

In some cases the addition of a few drops of ammonium hydroxide solution was found to hasten coagulation and removal of fine dirt suspensions.

During the process of these experiments, it was realized that their results could not entirely dictate the ultimate method to be used. Certainly the field experimental set up itself would strongly influence the ultimate choice of the method. The size of sample, method of sampling and choice of method for evaluation would be partially dictated by the experimental conditions.

3. Results

As a consequence of the previous experiments, the following results were noted:

1. A single washing of a plant sample was found to give satisfactory removal of all significant quantities of dust deposit on the plants.
2. Methods one and two decreased the amount of foreign material in the plant washing. However, a greater quantity of washing solution was required to give complete dust removal from the plants.
3. Filtration of the plant washing solutions was found to consume an undue amount of time. Of course, a considerable length of time was also required in the methods where settling was allowed. However, the

filtered solutions as an end result gave no better color comparisons than those which had been allowed to settle. Thus, the settling methods were favored somewhat in this respect, since the necessity for carrying out a filtration was eliminated.

4. Apparently materials of plant origin entered the plant washings in either a dissolved or colloidal state. This factor was found to be quite significant. Color comparisons between the plant washing and the color standards were thus complicated. The presence of these plant substances produced an off-color in the plant sample washings. This would certainly make results very difficult to reproduce in certain cases.

4. Conclusions

At the completion of these tests, a method of field experiment had been decided upon, the details of this which are to be described later. Let it suffice to say that these experimental field trials were of such a scope that relatively large plant samples would be required, in order to assure good representation. Thus, the experimental conditions dictated rather large plant sample washings. Therefore, it seemed that Method Three for washing the plant samples would be most readily applicable.

The decision was made to adjust the color standards in order to compensate for the off-color of the plant washings. To accomplish this, undusted plants would be immersed in new washing solution in a manner similar to the actual washing procedure. Upon removal of the plants, this blank washing would be allowed to stand until foreign matter had settled out. Then, measured quantities of this blank solution would be placed in individual containers, and known amounts of colored dust would be added. In order to facilitate color comparison, it was considered desirable to prepare some sort of simple standard light source.

With these factors in mind, a tentative evaluation procedure was devised:

Step 1: A plant sample of about one-half pound in size would be carefully selected and cut, large shears being used in the cutting. For the experimental plots in question, an attempt would be made to correlate plant leaf area with plant weight, by statistical means.

Step 2: The plant sample thus obtained would be carefully removed to the container of clear washing solution, and its deposit would be removed by immersion washing.

Step 3: The amount of the plant sample would then be determined exactly by weighing.

Step 4: The plant washing would then be removed to a storage container and stoppered. This container would then be allowed to stand undisturbed over the period of time required for settling out of foreign matter.

Step 5: The plant washing could then be compared with the adjusted color standards, using the projected standard light source. Thus its concentration would be determined.

Actual application to field trials remained, before this evaluation method could be justified.

B. Initial Application of Colorimetric Estimation To Field Experiments as a Method of Evaluation of Dust Recovery

1. General

The experiment to be described was carried out during the summer of 1952. The primary goal was to obtain data whereby further comparisons of conventional and electrostatic dusting methods might be facilitated. The basis factors which were to be examined in this experiment, were as follows:

1. The depositions of conventional and electrostatic dusting were to be compared as a function of the rate of application of dust, or pounds of dust applied by the duster per acre.
2. Conventional and electrostatic dusting methods were to be compared in terms of dust deposition as a function of the fineness of dust.

Although perhaps subordinate in nature the colorimetric dust recovery evaluation method was to be tried and proven either satisfactory or unsatisfactory. Certainly information would be made available from this experiment which would show how the colorimetric estimation technique might be improved if necessary. If the method was a complete failure, its shortcomings would serve as guides in the development of a more satisfactory technique.

2. Apparatus and Methods

a. The Experimental Design. A randomized blocks setup was the design used in this experiment, the dusting being carried out on field beans planted in 28" row spacings. The field, or navy, beans involved were of such maturity that runners were being produced, flowering was taking place and some pods were beginning to form.

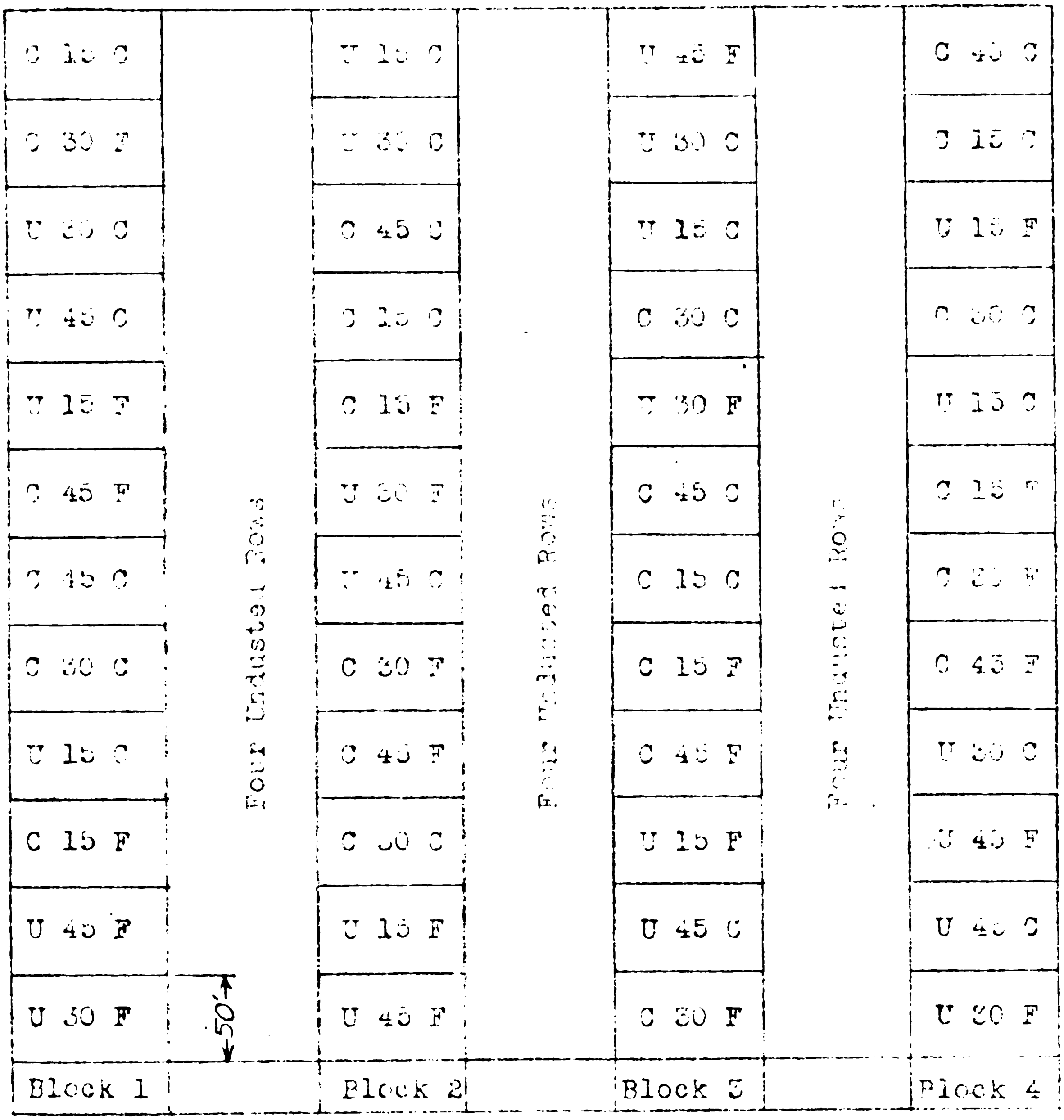
For the purpose of comparison of charging effects by the use of coarser and finer dusts, used was given two treatments. One-half of the plots were dusted with a dust which had been ground in a ball mill only.

The estimated particle size for this dust was approximately forty to fifty microns, on the average. (One micron is equal to 0.0001 centimeter.) The particle size in this range is usual for present dusts. The remaining half of the plots were dusted with a dust which had been micro-ground, or micronized. The average particle size for this dust was estimated at four to ten microns.

Three rates of application were used for each dust. The rates of application were fifteen, thirty and forty-five pounds per acre. Emphasis should be placed upon the fact that the rates of application represented the duster output only, and did not represent the amount actually deposited.

With various treatments selected the block layout was established. The actual experimental layout is shown in Figure 7. A code for the various plots symbols was setup as follows:

1. The first letter refers to whether or not the dust application was charged or uncharged.
2. The two digit number following the first letter referred to the rate of application.
3. The last letter referred to the dust particle size. That is to say, whether the dust was micronized or unmicronized.



Block 1	Block 2	Block 3	Block 4
C 15 C	U 15 C	U 45 F	C 45 C
C 30 F	U 30 C	U 30 C	C 15 C
U 30 C	C 45 C	U 15 C	U 15 F
U 45 C	C 15 C	C 30 C	C 30 C
U 15 F	C 15 F	U 30 F	U 15 C
C 45 F	U 30 F	C 45 C	C 15 F
C 45 C	U 45 C	C 15 C	C 30 F
C 30 C	C 30 F	C 15 F	C 45 F
U 15 C	C 45 F	C 45 F	U 30 C
C 15 F	C 30 C	U 15 F	U 45 F
U 45 F	U 15 F	U 45 C	U 45 C
U 30 F	U 45 F	C 30 F	U 30 F

Figure 7. The plot arrangement for the first field experiment to which colorimetric estimation was applied appears above. The plots were four rows wide and fifty feet long. The plot code was such that the first letter (U or C) meant uncharged or charged; the integers (15, 30 or 45) referred to the dust application rate in pounds per acre; the last letter (C or F) denoted the relative dust particle size, whether coarse or fine.

In each case, the blocks were separated by four untreated rows. Each plot was four rows wide and fifty feet long. A photograph of the completed field setup is shown in Figure 10. The plot markers were placed in the undusted rows, and lettered with symbols corresponding their plots.

b. Composition of the Dust Used. The dust applied was designed for use with the colorimetric estimation technique, and was prepared by the method previously outlined. Of course, one-half of the amount applied was micronized. The inert ingredient of the dust was Eastern Magnesia Talc. The water soluble dye with which the talc was impregnated was commercial Luxol Scarlet. No active pesticidal ingredients were present with the dust.

c. The Experimental Duster. The field duster used was an eight outlet machine capable of dusting four rows at one time. This duster was an adaptation of a Niagara "Even-Flow", Model AA, machine. This duster was of course fitted with charging nozzles and the electronic power supply as shown in Figure 3, in the introduction. A speed indicator driven by the machine tire served to assure a fairly uniform ground travel rate.

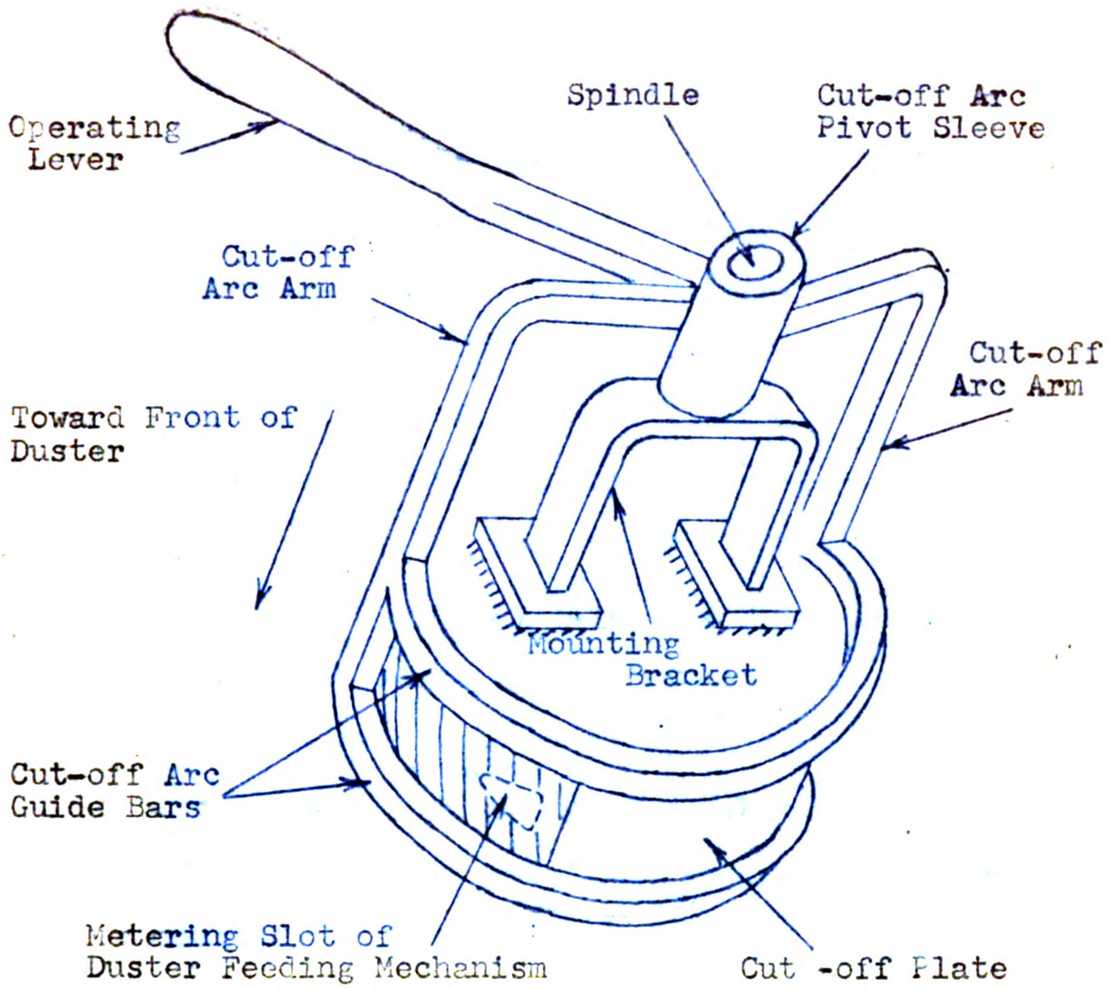


Figure 8. The duster feed cut-off used on the machine employed in this experiment is shown above. The mounting bracket was secured to the duster metering mechanism drum, which was of course stationary. The cut-off arc protruded slightly forward with respect to the mounting bracket, and was concentric with the lateral periphery of the metering drum. Since the curved cut-off plate was at close clearance with the lateral periphery of the metering drum, clockwise rotation of the cut-off arc (facing the front of the duster) would interrupt the flow of dust, whereas counter-clockwise rotation of the cut-off arc would permit the flow of dust. Stops limited the rotational travel of the cut-off arc.

d. The Experimental Duster Feed Cutoff. The scope and method of conduct of this experiment nessitated that it be carried out in as little time as possible. This was desirable in order to avoid wide variations in humidity and other weather conditions. For this reason, a duster feed cutoff shown in Figure 8, was devised in order that the dusting operation could be carried out as quickly as possible.

In order for satisfactory operation to result, it was necessary that the cutoff would stop the flow of dust almost instantaneously. Any lag in the dust flow cutoff would certainly introduce serious errors when travelling from plot to plot. Attachment of the feed cutoff directly to the duster metering mechanism as shown in Figure 9, was found to give quite satisfactory cutoff.

The design of the feed cutoff mechanism eliminated any stopping of the duster fan and metering mechanism, which allowed considerable saving in time. Two added advantages which were quite important were: (1) uniform ground travel speed of the duster could be maintained throughout a given plot and (2) the duster fan and metering mechanism were operating at full speed when the dust flow was initiated. These factors would tend

Figure 9. The above view shows the duster feed-cutoff mounted on the metering drum, at the rear of the duster hopper. An operator, standing on a platform on the rear of the machine could control the dust flow and charging apparatus as the duster passed from plot to plot.

to increase the probable reliability of results derived from this experiment.

e. Description of the Evaluation Method. One primary variation in the evaluation procedure as originally outlined was necessary. This was that the samples for colorimetric estimation would need to be larger than originally anticipated. Otherwise, the technique was

Figure 10. The experimental plots and the field duster are shown above. The blocks were separated by four untreated rows, and the plots were four rows wide and fifty feet long. The crop was navy beans, planted in twenty-eight inch row, spacings. The plot markers are visible along the length of the field.

essentially the same as outlined in the previous discussion. This measure was necessitated early in the experiment when it was found that selection of unbiased samples. This was remedied by marking off and cutting representative row lengths.

The evaluation procedure was fundamentally as follows:

The dusting operation for a given fineness of dust and rate of application was carried out. Sampling was then accomplished prior to the next dusting operation.

Figure 11. A representative row length was marked off in one of the center two rows of each plot. Sampling was accomplished by cutting the plants close to the ground, using large shears.

The evaluation procedure for a given plot, from sampling through plant washing, was completed before moving to the next plot.

The sampling was carried out as shown in Figure 11. The center two rows of the four rows dusted were used for sampling. This was for the reason that the center two rows were less subject to coverage variations. A row length was marked off sufficient to supply two pounds of dusted plant material, and the cutting was accomplished by means of large shears. The sample was then carefully removed to a scale pan for weighing, two pounds of plant

Figure 12. The washing procedure was carried out as illustrated above. Samples of a definite size were washed by immersion to remove the dust deposit, a measured quantity of washing solution being used. The red color of the washing is evident.

material being collected. The samples were then ready for washing.

A measured amount of the detergent water washing solution was then placed into the large washing beaker, and the washing of the dusted plant sample carried out as in Figure 12. The washing was accomplished in a definite manner so that any washing solution film clinging to the plants after washing, would be on a comparable

Figure 13. Plant washings were placed in sealed jars for transport to the laboratory. The samples were allowed to stand undisturbed for a sufficient length of time for any foreign suspensions to settle out.

basis. (That is to say, little variation from sample to sample should be introduced by this factor.) The plant washing was then transferred to its storage container for transport to the laboratory as shown in Figure 13.

Upon completion of the field experiments, the plant washing samples were removed to the laboratory. They were placed in storage for several days, in order to allow time for settling of dirt and foreign matter

Figure 14. The final evaluation of deposition was performed with the aid of a standard light source. The samples were visually compared with standard color solutions, thereby enabling estimation of sample concentrations.

suspension. In the meantime, adjusted color standards were prepared in the manner previously described.

Upon completion of the settling, the samples were quantitatively evaluated. This operation was carried out using the standard light source as shown in Figure 14. The plant washing sample and the various color standards were visually compared until a close match was obtained.

Thus, the concentration of the plant washing sample was estimated. If desired these results could then be related to the actual duster application as percentage of dust recovered. Of course, a correlation would need to be set up between plant weight and surface area, and data would be necessary as to the weight of plant material per acre.

No attempts were made in this experiment to determine distribution effects upon plant surfaces as produced by the various dusting procedures. The results of this experiment were entirely quantitative in nature.

3. Results.

Extremely erratic results were obtained from this experiment, and no consistent trends were noted. In a number of cases higher deposition was noted for the uncharged dust, than for charged dust. The results for the various plots have not been tabulated in this discussion. To do so would be meaningless, and aside from the main purpose.

Since no attempt was made to evaluate dust distribution on the plant surfaces, the quality of the various deposits was unknown. This is of course in reference to the possibility that charging may have been producing better distribution on the plant surfaces. Large clumps or agglomerates of dust were observed on the leaves on many of the uncharged dusted plots.

Thus, although charging may have been depositing less dust quantitatively, it may have been distributing the dust more efficiently.

With regard to the colorimetric evaluation method a slight off color in practically all the samples was noted. This effect was somewhat reduced by use of the standard light source, but nevertheless difficulty was experienced in concentration estimation by color matching.

A few of the plant washing samples were completely invalidated due to sharp color changes. The color change was from the typical reddish-orange to a clear light green. The exact cause of this is unknown, but it may have been due to oxidation or perhaps some photo-chemical action.

4. Conclusions.

Colorimetric estimation as applied to this experiment was found to be lacking. The complications introduced by direct contact with the plant surfaces with the washing solutions, were a source of much trouble. These factors seem to indicate that colorimetric estimation in its present form must be altered considerably in order to be successful. This could possibly mean complete abandonment of this technique for uses other than in the laboratory. In the laboratory the foreign matter problem should be less significant, particularly where artificial test surfaces are used.

Aside from the evaluation difficulties themselves, the results of the experiment were far from a complete loss. First of all the fact became apparent that more care must be given to charging current measurement. There is some possibility that the charging circuits may have been functioning improperly.

Secondly, in conjunction with this experiment a test found the dust being used was charging strongly positive by merely passing through the duster. The charging equipment was operated such that negative charges would be produced on the dust particles. Therefore, it is obvious that the efficiency of charging would be greatly reduced.

And finally, the problem of reverse ionization is another possible explanation for the erratic results of this experiment. Penney (10) describes reverse ionization as a characteristic of certain dusts possessing a high resistivity particularly at lower humidity. A brief explanation of the phenomenon of reverse ionization may serve to make more apparent its possible occurrence in this experiment:

> During charging a coating of dust readily tends to build up on the charging nozzle walls. Since a charging current is passing from the charging needle of the nozzle through the dust air space to the nozzle wall, a voltage drop is produced across the dust coating. If the dust is of sufficiently high resistivity, the voltage drop will become sufficient to cause internal breakdown of the dust.

This breakdown will be electrical in nature. It will be of such nature that counter ionization effects are produced, thus inhibiting the desired effects.

Penney states that the resistivity of dusts is almost entirely a function of relative humidity. The resistivity decreases as the humidity increases in general. The humidity during the course of this experiment, was approximately fourty-four percent.

Possibly a measurement of the dust resistivity under these conditions in a manner described by Penney would verify this conclusion.

Although the results immediately described and summarized may seem apart from a discussion of the evaluation, they could very well render considerable influence upon future evaluation developments. The results of this experiment although rather disappointing, may very well have furthered the development of electrostatic dusting which is the underlying aim of this project.

INVESTIGATION OF VAPOR STATE FLUORESCENCE AS A METHOD OF DUST RECOVERY EVALUATION

General

In early 1953, a search for analytical chemical methods which might be applied to dust recovery evaluation led to a reference where Radley and Grant (11) stated, regarding fluorescence **analysis:**

> If a substance is examined in the vapor state, the intensity of the fluorescence may be influenced by the vapor pressure or by the vapor density. An example of this is given by Niewodniczanski in a short paper on the results of his work with mercury vapor. The vapor at a temperature of 240° Centigrade was illuminated by ultra-violet light and it was found that when the intensity was altered, there was a corresponding change in the intensity of the fluorescence. The vapor state is, however, rarely used for ordinary analytical examinations.

Although Radley and Grant imply that the vapor state is seldom used for fluorescence analysis, the decision was made to conduct an experiment of such nature. If feasible, such a method of dust deposit determination, would offer a means of eliminating some of the problems ordinarily encountered. In reference to previous work, foreign matter in dust deposit analytical solutions presented a serious problem. Washing of dust deposits from plant surfaces will almost certainly remove such matter as soil accumulations, leaf waxes or possibly plant juices. Therefore, an evaluation method enabling removal of active ingredient by volatilization followed by quantitative analysis by vapor state fluorescence, should be less significantly affected by plant foreign matter. Furthermore, if the active ingredient itself did not exhibit fluorescence in the gaseous state, or would not volatilize, a vapor state fluorescent substance might be added as a tracer.

Apparatus & Methods

Sovacide, a commercial fogging oil, was selected for study. Sovacide is intended for insecticidal fogging use, where the oil serves as an insecticide carrier. A fog generating machine, into which the oil-pesticide mixture is fed at a controlled rate, transforms the liquid material into a dense fog cloud, by means of heat. The fog stream is directed toward the vegetation to be treated, which it more or less completely surrounds, thus depositing pesticidal material. Such a mixture for pesticidal treatment is referred to as a heat generated aerosol. This oil is characterized by reasonably high volatility, and exhibits strong fluorescence when in the liquid state, or in solution. Because of these properties, Sovacide could possibly be expected to serve as an indicator of the feasibility of a vapor state fluorescence technique.

The apparatus used is shown in Figure 15. An oil sample bottle was connected to the vacuum pump through rubber suction tubing and a stopcock. A fluorescence detection chamber (an Erlenmeyer flask) was connected to the oil sample bottle by means of tubing and a second stopcock. A filtered ultra-violet lamp was provided for the actual detection of vapor state fluorescence. During conduct of the experiment, the Erlenmeyer flask and the ultra-violet lamp were enclosed in a dark box, so that the presence of any fluorescence could be more readily noted.

The experimental procedure was as follows:

A blank, or empty bottle was put in the place of the oil sample bottle, and both stopcocks were opened. The entire system was then evacuated. Upon completion of the evacuation the stopcock leading to the fluorescence detection flask was closed. Air was then readmitted to the remainder of the system, and the blank bottle was replaced by the oil sample bottle containing Sovacide. This part of the system was then re-evacuated and the stop clock between the vacuum pump and the oil sample bottle closed. (Violent boiling of the oil was usually noted during the evacuation.) The oil sample bottle was gently heated, and the stop cock to the fluorescence detection flask was opened. (Vigorous boiling of the oil was again noted as the vapor rushed into the evacuated space, indicating strong volatilization.) The fluorescence detection flask was then examined by ultra-violet radiation to determine the presence of fluorescence, if existent.

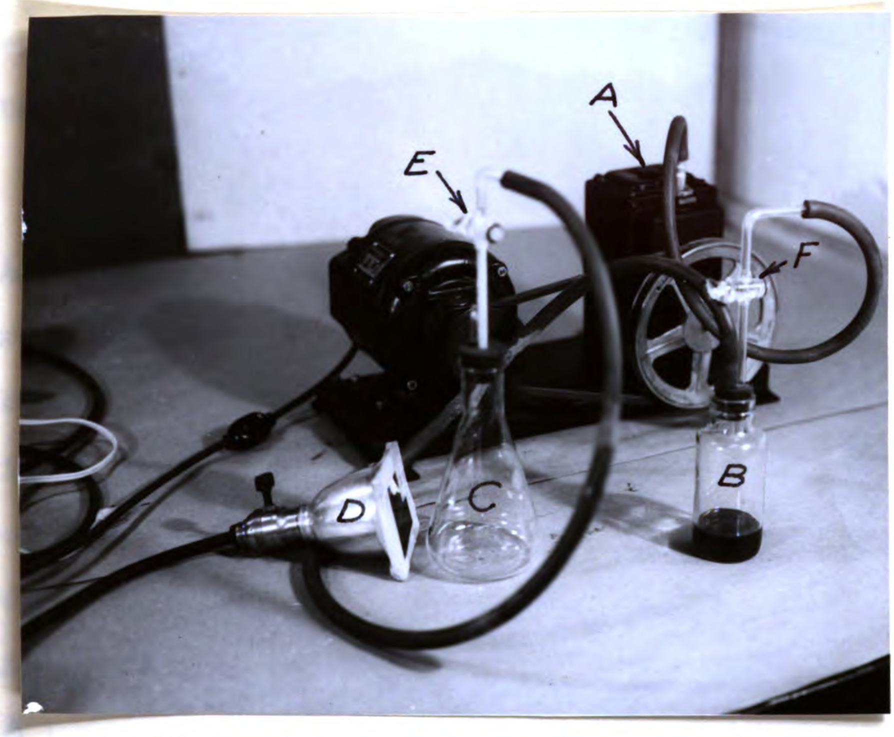


Figure 15. The vapor state fluorescence detection apparatus is shown above. The vacuum pump (A) was connected to the oil sample bottle (B) through suction tubing and the stopcock (F). The oil sample bottle was connected to the fluorescence detection flask (C) through suction tubing and the stopcock (E). The filtered lamp (D) was used as a source of ultra-violet radiation.

Results

Under the conditions of this experiment, no vapor state fluorescence was noted. No substances other than Sovacide were tried.

Conclusions

Admittedly the apparatus used in this experiment was rather crude, but fluorescence of a measurable intensity should have been detected. However, doubt is strong that the results of this experiment should be allowed to completely rule out the possibility of this method. At the time, work in this regard was shelved in favor of more immediately promising techniques.

A possible source of error in this experiment might have been condensation of the oil vapor at some point within the system. The small quantity of oil involved in the vapor state prevented evaluation of this factor, but if such condensation actually did occur, it is probable that for this reason the method would be unsuitable for experimental use. As a check, the vapor phase above the liquid oil in the oil sample bottle was examined for fluorescence, with none being detected. Another conceivable source of error in this experiment could have been excessive absorption of the ultra-violet rays by the glass containers. A check examination of a liquid oil sample in a glass container resulted in strong fluorescence.

The conclusion was, therefore, that under the given experimental conditions, vapor state fluorescence evaluation was impossible. This must not imply that more extensive investigations might not prove successful, and any future work in this area might be directed at the following points:

1. There might be some possibility that test containers which would assure absolutely free transmission of ultra-violet radiation could be used successfully.
2. Higher vapor pressures and vapor densities should certainly increase the chance of vapor state fluoresence detection.
3. There is a wide range of fluorescence substances which might be tried. Perhaps certain others could be more successfully applied to this purpose than the oil used.
4. If such a method succeeded, a photoelectric or similar method of fluorescence intensity measurement should be used in actual quantitative measurements.
5. Instead of attempting to detect fluorescence in the vapor state, the volatilized ingredient might be condensed and trapped by a suitable solvent. Fluorescence in solutions is often quite easily measurable, even when of low intensity.

A PRELIMINARY INVESTIGATION OF A VOLUMETRIC METHOD OF DUST DEPOSIT EVALUATION

General

As outlined in previous studies, plant foreign matter continually presents a problem in dust deposit evaluation. This problem is of important significance in analyses which depend upon color shades or intensity. Thus the idea presented itself that a method might be devised wherein determinations depended upon a color change only. If the color change was sufficiently sharp, perhaps this familiar problem could be eliminated.

A volumetric, or titration, procedure naturally lends itself to such an application, since the determination of many titration end points depends upon a color change. Therefore, a search was undertaken to find a suitable compound which could be analyzed by means of a titration. Thus, it might be possible to establish a satisfactory method of dust deposit evaluation.

Dr. Erwin J. Benne, of the Michigan State College Department of Agricultural Chemistry, was consulted in regard to this matter. Dr. Benne indicated that copper and certain copper compounds could be quantitatively analyzed quite easily by titrimetric means. Upon further study of the problem, the decision was made that a Bordeaux mixture might be formulated as a dusting material suitable for this method of analysis. (A Bordeaux mixture is a combination of hydrated copper sulfate and a calcium compound such as calcium hydroxide.) Upon application of this dusting material to plants, during experiments, it might be washed off for analysis purposes. Using the titration method, the solution would be analyzed for copper and hence the dust coverage might be evaluated.

A few immediate and important questions remained to be answered by preliminary investigation. The effect of foreign matter upon the titration reactions would need to be determined. Also, if the procedure was quite inconvenient, and required excessive time to carry out, it would probably be unsuitable.

Theoretical Background of the Thiosulfate Volumetric Method of Copper Determination

The titration method chosen for investigation was the thiosulfate volumetric procedure as outlined in the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (1). A brief discussion of theoretical background of this titration will now be presented.

Standardization of the Thiosulfate Titration Reagent. The compound sodium thiosulfate is used as the titration reagent in this procedure. Thus, before any actual quantitative determinations may be carried out, the sodium thiosulfate reagent solution must be standardized against a known amount of copper.

First of all, a sodium thiosulfate solution of the desired concentration is prepared. An accurately weighed quantity of pure electrolytic copper is dissolved in a definite volume of nitric acid solution. The reaction for this process may be written as follows:

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO$$

During this process, nitrous acid may be formed by virtue of the following reactions:

$$2NO + O_2 = N_2O_4$$

$$2H_2O + 2NO + N_2O_4 = 4HNO_2$$

The nitrous acid is expelled as completely as possible by boiling the solution, and any remaining trace is removed by the addition of an excess of strong bromine water, the action being as follows:

$$HNO_2 + H_2O + Br_2 = HNO_3 + 2HBr$$

Excess bromine in the solution is then driven off by boiling, and the solution is neutralized by the addition of a small quantity of sodium hydroxide. Upon neutralization of the solution, a precipitate of copper hydroxide is formed. The precipitate is dissolved, and the solution made slightly acid, by the addition of a small quantity of acetic acid.

The solution is now in readiness for standardization of the sodium thiosulfate reagent solution. A solution of potassium iodide is prepared and added in a definite quantity to the copper solution. This solution is titrated with the sodium thiosulfate reagent, the reaction being essentially as follows:

$$2Cu(NO_3)_2 + 4KI = 2CuI + 4KNO_3 + I_2$$

$$I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$$

It is interesting to note that copper does not react directly with the sodium thiosulfate. Actually, the procedure consists of the titration of free iodine with sodium thiosulfate, and it is therefore possible to use starch as an indicator of the endpoint. While free iodine is present the starch will cause the solution to be a deep blue in color. When the endpoint is reached, the blue color rapidly disappears.

During the standardization procedure a known amount of copper will have been titrated and a measured quantity of sodium thiosulfate solution added in attaining the endpoint. Therefore, it is possible to calibrate the sodium thiosulfate reagent by means of the following expression:

$$\text{Thiosulfate Reagent Calibration} = \frac{(\text{Wt. of copper present, gms.})}{(\text{Vol. of sodium thiosulfate solution used, ml.})}$$

When analyzing for an unknown quantity of copper, the amount present may be calculated from the results of the titration by the use of the following expression:

Amount of copper in unknown, gms. =

= (Reagent Calibration) x
(Vol. of thiosulfate solution added, ml.)

<u>Titration for Unknown Amounts of Copper</u>. The analysis for **unknown** amounts of copper in a Bordeaux mixture fungicide is somewhat simpler than the standardization. Essentially, the titration procedure is the same, but preparation of the sample is more easily carried out.

First of all, the sample of Bordeaux mixture is dissolved in a dilute solution of nitric acid. A small amount of ammonium hydroxide is then added, followed by acidification with a limited quantity of acetic acid. Potassium iodide is added to the solution and the titration is carried out with standardized sodium thiosulfate solution, the reactions being as follows:

$$2CuSO_4 + 4KI = 2CuI + 2\ K_2SO_4 + I_2$$

$$I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$$

With the results of the titration available, the calculation of the amount of copper present is carried out as shown previously.

Apparatus and Methods

With a standard method of copper titration available, it was possible to speculate on its adaptation as a field method of dust coverage evaluation. Upon consulation with Dr. Benne, a tentative field method was decided upon:

1. A Bordeaux mixture fungicide consisting of hydrated copper sulfate and calcium hydroxide would be prepared for dusting purposes and applied to the plants.
2. Plant samples would be taken in a specified manner and rinsed of their dust deposits in a solution of approximately 2½ percent acetic acid. The presence of the acetic acid would help prevent precipitation of copper hydroxide and its possible loss.
3. The samples would be removed to the laboratory and analyzed for copper by the titration method. An attempt would be made to simplify the titration procedure by elimination of nitric acid addition and neutralization with the ammonium hydroxide.

Obviously, with a known amount of copper in the fungicide applied, it would be possible to evaluate the dust deposition.

A number of factors would need to be investigated before such a method of analysis could be justified. These would include such problems as the effect of foreign matter upon the titration, the reliability of results at minute concentrations of copper, the presence of absence of calcium hydroxide in the Bordeaux mixture, and the possibility that the plants might adsorb some copper during the washing process. A preliminary experiment was therefore conducted with the intention of studying these important considerations.

The method of experimental conduct was as follows:

1. Three 100-ml. samples of varying copper concentration were prepared, without the addition of calcium hydroxide. The copper used in formulating the solutions was supplied in the form of electrolytic copper, dissolved in nitric acid solution in the manner previously indicated. These dilutions also contained 2½ percent of acetic acid, with distilled water added to make the total volume 100 ml.
2. Three more samples of a corresponding copper concentration range were prepared in a similar manner. The only variation was that calcium hydroxide was added to these dilutions. For this purpose, a typical Bordeaux mixture was assumed in deciding upon the quantity of calcium hydroxide to be added. Frear (4) and (5) indicated that such a mixture might be approximately 50 percent of hydrated copper sulfate and 50 percent calcium hydroxide. Using this basis for the solution formulation, a weight relationship between electrolytic copper and calcium hydroxide was established for simulation of a Bordeaux mixture.

3. Each 100-ml. sample was placed in large beaker and subjected to plant contact, by immersion. The plants used were young, green field beans. The plants were immersed in the various solutions, with agitation, for a definite period of time, after which they were removed. No special care was exercised in preventing the introduction of foreign material into the sample dilutions. Of course, different plants were used for each individual treatment.
4. Three 20-ml. aliquots were taken from each sample and analyzed for copper by the titration method. With three separate dilutions, two treatments of each dilution treatments referring to the presence or absence of calcium hydroxide and with three titration replications of each sample, the results of 18 separate analyses were available.
5. Since the original amount of copper in each aliquot was known, percentages of error for the analysis results could be tabulated. Using these error percentages as a basis, an analysis of variance was performed to determine the influences of the variables of copper concentrations, titration replications, and the presence or absence of calcium. The results of this analysis of variance should indicate the validity of the copper titration method, plus the influence of the previously mentioned variables.

TABLE I

(A) Calcium Hydroxide Absent:

Replication	Original Copper Concentration (gm/ml.)	Percentage Error in Analysis Results
1	0.001521	4.54
2	"	4.54
3	"	3.91
1	0.003042	2.29
2	"	1.96
3	"	2.29
1	0.006084	2.22
2	"	2.30
3	"	2.30

(B) Calcium Hydroxide Present:

Replication	Original Copper Concentration (gm/ml.)	Percentage Error in Analysis Results
1	0.001521	0.66
2	"	1.94
3	"	2.27
1	0.003042	1.30
2	"	1.79
3	"	1.46
1	0.006084	2.30
2	"	2.38
3	"	2.22

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Dilutions (D)	2	3.90	1.95
Replications (R)	2	0.23	0.115
Treatments (T)	1	5.59	5.59
Interaction (RxT)	2	0.52	0.260
Interaction (DxR)	4	0.20	0.050
Interaction (DxT)	2	6.04	3.02
Second-order Interaction (DxRxT)	4	0.98	0.245
Total	17	17.46	

Note: Treatments refer to the presence or absence of calcium Hydroxide.

F tests of significance:

(Assuming that random variation only is measured by the mean square for second-order interaction. In the calculations shown below, interation refers to the mean square for second-order interaction.)

1.) $F_{2,4} = \frac{\text{Dilutions}}{\text{Interaction}} = 7.96^{*}$ (Significant at the 5% level.)

2.) $F_{2,4} = \frac{\text{Replications}}{\text{Interaction}} = 0.469$ (Not significant)

3.) $F_{1,4} = \frac{\text{Treatments}}{\text{Interaction}} = 22.8^{**}$ (Significant at the 1% level.)

4.) $F_{2,4} = \frac{\text{RxT}}{\text{Interaction}} = 1.06$ (Not significant)

5.) $F_{4,4} = \frac{\text{DxR}}{\text{Interaction}} = 0.204$ (Not significant)

6.) $F_{2,4} = \frac{\text{DxT}}{\text{Interaction}} = 12.3^{*}$ (Significant at the 5% level.)

Results

The results of this experiment are shown in Table I and the Analysis of Variance.

Examination of the titration results and the Analysis of Variance indicates significant influence resulting from the presence or absence of calcium hydroxide. In practically all cases the analysis results seemed more reliable when calcium hydroxide was present, particularly in the low concentration range. Some effect is exerted upon the analysis accuracy by the copper concentrations and the interaction of dilutions and treatments. Very little variation was noted with regard to replications.

Summary and Conclusions

The results of this preliminary experiment seem to indicate that the copper titration method can be satisfactorily applied to dust coverage evaluation. The presence of plant foreign matter in the titration solution seemed to introduce very little error. Note is made of the fact that in no case was the percentage error greater than 5 percent. This degree of accuracy would be acceptable in dusting field experiments.

The analysis of variance indicated significant effects due to the presence or absence of calcium hydroxide. Apparently greater accuracy in the analysis results is obtained if calcium hydroxide is present. This is probably due to the need of initial neutralization of the titration solution. Thus, it appears that a Bordeaux mixture may successfully be used.

Some influence was indicated for dilutions by the analysis of variance. This is scarcely unexpected. With the low copper concentrations which would probably be encountered in dusting experiments, a less concentrated sodium thiosulfate reagent solution might increase the attainable accuracy.

There seemed to be significant influence due to the interaction of dilutions and treatments. This is possibly due to the fact that the accuracy of the analysis results was considerably greater in the low concentration range when calcium hydroxide was present.

Strangely enough, all analysis results indicated greater amounts of copper than were originally present. This definitely indicates a possible source of error for this experiment, which could have been introduced by the thiosulfate standardization. Reference sources indicate that if all bromine is not removed before standardization of the thiosulfate solution, titration results will be high. Also, some of the free iodine may have been lost by volatilization. However, it should be reiterated that the error limits indicated by the results are not so excessive that the method could not be suitably applied to dusting field experiments.

The copper titration was found to be quite readily carried out. In fact it may very well yield results more quickly that the colorimetric estimation method. Furthermore, its reliability is definitely less subject to question than the colorimetric estimation method. The copper titration method could conceivably be used in the development and accurate calibration of an even more rapid method. The method is even more reassuring in the sense that continual checks on standardization may be made, thus increasing its dependability.

Further study of the copper titration method must be directed toward the following factors:

1. The amount of dust retained on the plants following a single washing should be evaluated as a check upon the method.
2. The dusting characteristics of a Bordeaux mixture should be given consideration.
3. This experiment itself might be repeated in order to check the validity of its results.
4. Possibly some method of weighing dust deposits could be devised as a further check upon the suitability of the copper titration method.

SUMMARY AND CONCLUSIONS

Research directed toward improvement of dust deposition through electrostatic charging has great implications. Although many complications have been encountered, certain successful trials still warrant investigation in this area. As previously indicated, deposition evaluation methods are of extreme importance to the conduct of such research. A beginning has been established to a series of deposition evaluation methods, but a considerable amount of effort remains. Thus the writer feels, at this time, that it would be desirable to attempt to classify and summarize the methods which were herein reviewed and investigated. Admittedly this classification and discussion of limitations may be somewhat arbitrary in nature. Therefore, any summary should be regarded as suggestive only in helping to establish deposition evaluation schemes for application to specific studies.

Lead Content Analysis and the Leaf Printing Technique

The lead content analysis and the leaf printing technique should be most applicable to field or laboratory experiments on actual vegetation. Although these analysis methods may be somewhat difficult to carry out, when properly executed their accuracy may scarcely be questioned.

The leaf printing technique should be considered quite valuable in experiments where it is desired to evaluate dust distribution on plant surfaces. The method is quite desirable from this standpoint.

Limitations on the accuracy of the results obtained from the lead content analysis and the leaf printing technique of course depend upon the care given in their conduct. When properly carried out they should be inherently accurate.

Light Reflection Comparison Test

The light reflection comparison test should be applicable mainly to laboratory tests. Fairly well controlled laboratory conditions, and uniform deposition surfaces are necessary. It should function merely as a good indicator of the merit of various deposition improvement methods, particularly during the process of evolution of a design.

One important limitation upon its accuracy would be the care with which the special deposition surfaces are prepared. Another important factor would be the actual care with which measurements are conducted, including regulation of the uniformity and intensity of the source of illumination. The light meter used should be of good sensitivity.

Microscopic Examination

Microscopic examination has seen rather limited use up to the present time. However, it seems that this could be applied to any sort of laboratory or field evaluation. Possibly it could best be applied in conjunction with one or more associated evaluation methods. The microscope should be readily applicable to evaluation of the quality and distribution of dust deposits.

At this writing it seems that insufficient attention has been rendered the potentialities of microscopic examination. It could prove to be a valuable aid to particle sizing of deposits, providing that the difficulty in distinguishing between individual particles and agglomerates can be minimized.

Colorimetric Estimation

At the present time it seems as though colorimetric estimation might be more readily applied to laboratory experiments than to field investigations. It is certainly less sensitive to small differences in dust coverage than certain other methods. It is a convenient method for applications where it is not subject to contamination with foreign materials.

The chief limitations upon the accuracy of the colorimetric estimation method are the possibility of foreign discolorations and the sensitivity of the method used to detect differences in color intensity due to solution concentrations.

The Volumetric Copper Determination

Although incompletely developed at this writing, the volumetric copper determination method shows great promise as a method of evaluation. If a Bordeaux mixture dust can be used successfully, this technique could be quite readily applied to either laboratory or field experiments. In view of its potential sensitivity, its accompanying convenience recommends it for application.

At this time the most significant limitations of its reliability may be expected to be the care with which reagents are prepared, the attention given to the proper standardization of the titration reagent, plus the experience of the worker in conducting the titration.

Further development of any or all of these evaluation methods may well be instrumental in evolving completely new and more advanced methods of dust coverage evaluation. Merely working with any one of these methods may very well bring to mind new schemes of evaluation previously overlooked. In a sense these evaluation methods may be regarded as "stepping stones".

It is scarcely possible that any one of these evaluation methods will become universal, as each will have its own peculiar limitations. Therefore it seems that an individual evaluation plan may be required for each new dusting experiment.

APPENDIX A

THE PROBLEM OF REVERSE-IONIZATION AND ITS RELATIONSHIP TO DUST RESISTIVITY: THE MEASUREMENT OF DUST RESISTIVITY

General

The reader will recall earlier reference to the phenomenon of reverse-ionization as a partial cause of the erratic results of the 1952 field experiment. The negative results for electrostatic charging, from that experiment, were concluded as due to positive frictional charging of the dust while attempting to charge it negatively; the possibility of excessively low charging currents; and of course reverse-ionization. The reader will also remember that the field duster used was equipped with tubular charging nozzles and that the Michigan State College dyed-talc dust was applied to the plots.

The basis for the conclusion that reverse-ionization was encountered in that experiment was an article by G. W. Penney (10), published in 1951. Penney's writings discussed reverse-ionization as it occurs in smoke precipitators. However, in order to adapt this available information to the electrostatic dusting problem, it was necessary to carry out the studies which will be subsequently described. Since Penney stated that dust electrical resistivity is an important factor in reverse-ionization occurrence, measurements related to this factor would need to be carried out in the course of this investigation.

Theory of Reverse-Ionization

Some attention must be given to the theoretical background of the factor of reverse-ionization. This treatment will necessarily be brief, and for a more thorough discussion the reader is referred to a Ph. D. thesis by Bowen, at present in preparation.

As previously mentioned, Penney was interested in the phenomenon of reverse-ionization as applied to electrostatic smoke precipitators. However, the basic similarity of smoke precipitator designs and the tubular charging nozzles for pesticidal dust should justify the application of this information.

During the charging process, dust particles passing through the tube gain charge by virtue of the presence of air ions in the electric field between the axial charging wire and the walls of the tube. In the course of this process, a light coating of charged dust particles usually becomes deposited on the tube walls. Now the passage of gas ions from the charging wire to the tube walls actually constitutes a current. Wigh a dust coating present on the tube walls, a voltage drop must occur across this dust coating by virtue of the current. If the dust possesses a high resistivity, and if the dust coating is thick enough, the voltage drop will be sufficient to cause internal electrical breakdown of the dust. When the internal electrical breakdown takes place, ions opposite in sign to those desired for charging will appear at the surface of the dust coating. (That is, the unwanted ions will appear at the dust coating surface nearest the charging wire. For example, if the charging wire is at high negative potential negative air ions will move across the space toward the tube walls, which will tend to produce negative dust particle charging. In this instance, if reverse-ionization should occur, positive ions would be liberated at the surface of the dust coating.) Of course this obviously reduces the efficiency of dust particle charging, or perhaps even prevents it entirely.

Penney indicates that the breakdown voltage of the dust and its resistivity are two of the most important factors in reverse-ionization. He states that the following conditions are quite essential to the appearance of reverse-ionization:

> In estimating the conditions at which reverse-ionization will occur, the resistivity of the dust and the electrical breakdown voltage are primary factors. The uniformity of the dust deposit is also important. The resistivity of collected dust may vary from a fraction of an ohm-centimeter to 10^{13} ohm-centimeter or even higher. The breakdown voltage

> varies through a much smaller range. General experience seems to indicate that reverse-ionization is probable if the resistivity of the dust is greater than 10^{11} ohm-centimeters and is improbable if the resistivity of the dust is less than 5×10^{9} ohm-centimeters.

Penney makes clear that resistivity of dust is, in general, variable. Slight variations in dust resistivity may be caused by the voltage gradient across the dust. Apparently, as the voltage gradient is increased, the resistivity tends to decrease somewhat. However, the most significant variation in dust resistivity is brought about by atmospheric relative humidity changes. Atmospheric relative humidity changes would of course alter the moisture content of the dust.) The resistivity of dust tends to decrease as the relative humidity, or moisture content, increases. Personal communication with Mr. Penney reveals that very little influence upon dust resistivity is effected by temperature changes.

The laboratory apparatus which Penney used for dust resistivity measurements is pictured in Figure A-1. The dust used for his measurements was fly-ash, taken from a smoke precipitator. The ash to be tested was placed in a cup which served as a high potential electrode. The ground potential electrode placed on the surface of the dust was of such weight that the pressure on the dust per square centimeter was about 4.75 grams. Humidity control within the measuring chamber was accomplished by manipulation of the heater and fan draft.

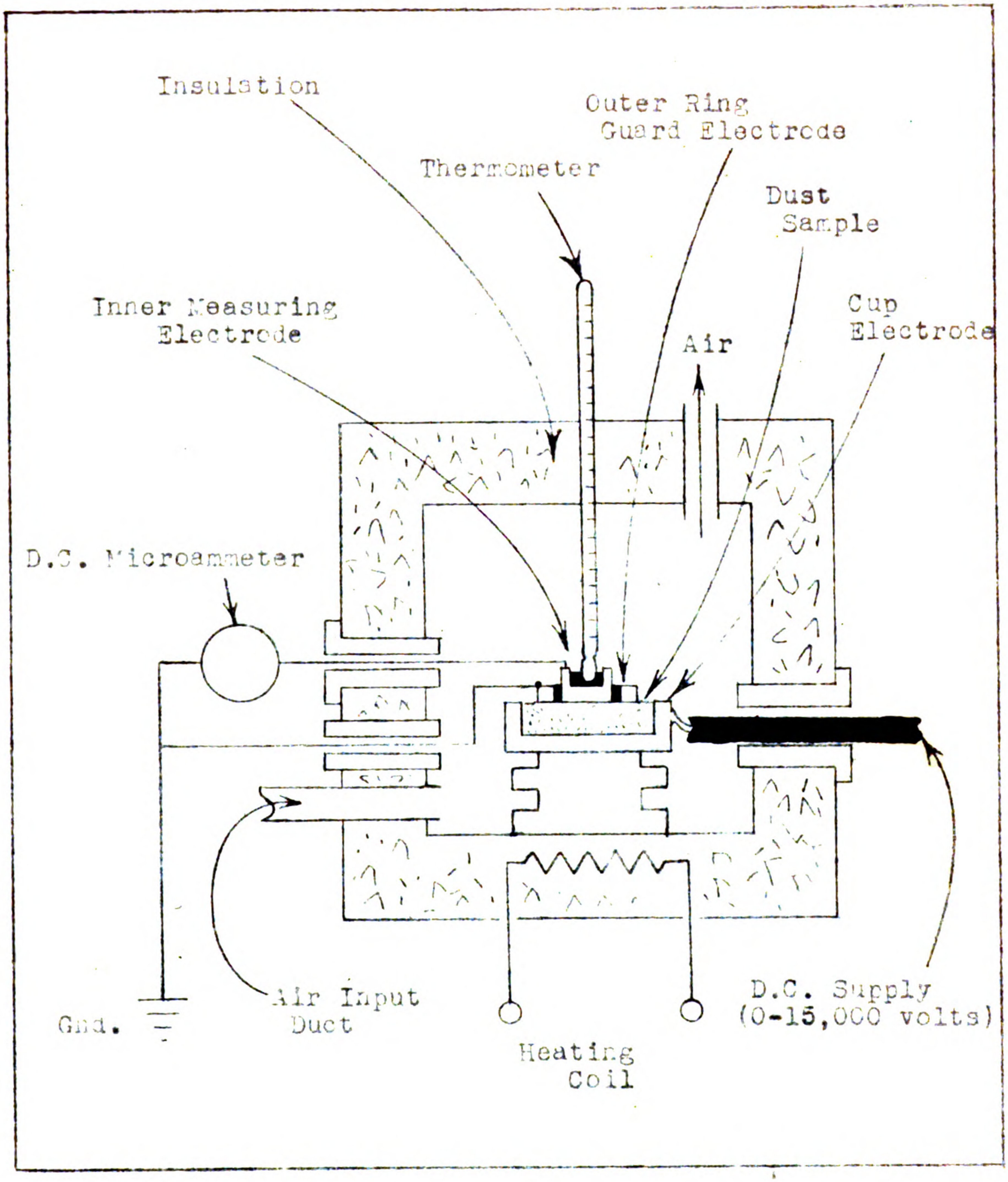


Figure A-1 A schematic view of the laboratory apparatus used by G.W. Penney for dust resistivity measurements. Humidity within the chamber was controlled by means of regulation of the fan and electrical heater.

A source of high direct current potential was connected to the measuring electrodes for current passage.

Apparatus and Methods.

A resistometer similar to Penney's was constructed by Michigan State College dusting workers for use in dust resistivity investigations. This design followed Penney's very closely for the reason that comparison of results was desired. A schematic diagram of the Michigan State College resistometer is shown in Figure A - 2. The actual laboratory set up of the resistometer and its associated instruments may be seen in Figure A - 3. Attention shall now be given to the various components of this resistometer setup and their functions.

Resistometer Chamber. The resistometer chamber construction is shown schematically in Figure A - 2. The chamber consisted of two galvanized sheet metal boxes, one larger than the other. The smaller box was placed inside the larger and the intervening space was packed with insulation. Carefully fitted openings through the insulation between the boxes were provided for insertion of electrical cables and the fan duct. A cover plate of galvanized sheet metal was supplied for the box. An exhaust air opening was provided in the cover as well as fittings for insertion of thermometers and electrical wires. The cover was also fitted with an insulation pad, which was easily removable.

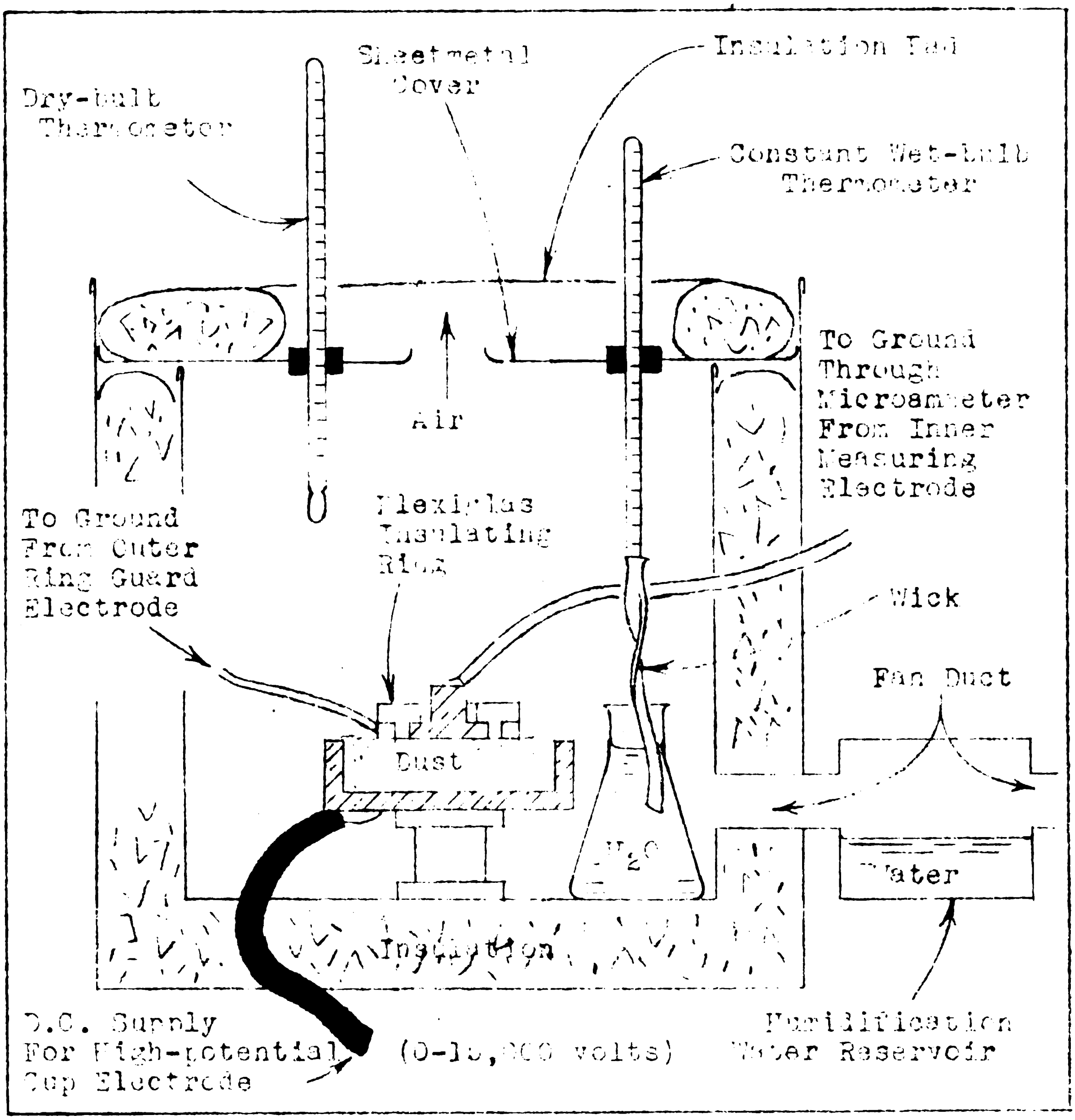


Figure A-2 The above view is a schematic representation of the Michigan State College "resistometer" used in the dust resistivity studies. It was purposely built quite similarly to Penney's so that a comparison of results could be made. The relative humidity of the chamber "atmosphere" was controlled by adjustment of the fan heating coil temperature, fan operation, and external heating of the water reservoir.

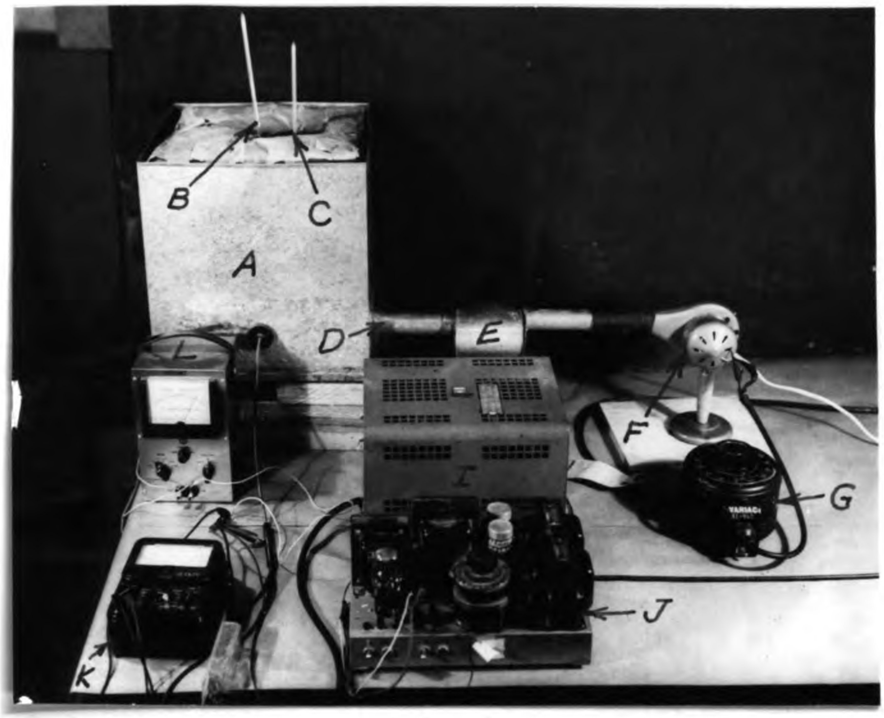


Figure A-3. The above view shows the laboratory set-up for dust resistivity measurment. The resistometer chamber (A) air circulation was supplied by the fan (F) through the fan duct (D). Humidity control was aided by the fan duct water reservoir (E) and the fan heating coils, which were energized through the autotransformer (G). Measuring current was supplied through the tripler circuit (I) from the plate supply (J). Resistance measurements were made with the voltmeter (K) and the microammeter (L). A dry-bulb thermometer (B) and a wet-bulb thermometer (C) made possible humidity measurement.

Figure A-4. The above illustration shows the interior of the resistometer chamber. The high-voltage in put cable (A) leads to the electrode cup containing the dust sample (B), and the wires (C) lead from the ground electrode on the dust surface. The flask (D) contained water for the constant wet-bulb thermometer.

The Dust Electrodes. The dust, or measuring, electrodes are shown schematically in Figure A - 2 and in actual dust sample contact in Figure A - 4. Their construction was almost identical to that of Penney's. The cup electrode, maintained at high direct current potential, was necessarily mounted on a heavy insulating pedestal. The cup was designed to contain a dust sample of one centimeter in depth, and the ground potential electrode rested on the upper dust surface. This electrode actually consisted of two separate electrodes, both of which were connected to the ground terminal of the power supply. The inner electrode was disc-shaped, while the outer electrode was ring-shaped and concentric with the inner electrode. The two electrodes were maintained in this relationship by means of an intermediate ring made of insulating plexiglas, which prevented electrical contact between the two parts of the electrode. The purpose of the outer electrode was to minimize edge effects, so that the area of current passage would be very nearly that of the inner electrode area. The area of the inner electrode was five square centimeters, and the weight of the entire electrode was carefully adjusted so that pressure upon the dust sample would be comparable with that of Penney's apparatus. Brass was used in the construction of all metallic parts of the electrodes.

The Measurement Circuit. The measurement circuit used for resistivity determinations is shown in Figure A - 5. A voltmeter was connected in parallel with the dust sample from the high voltage input cable to ground. A direct current microammeter was placed in the line from the inner ground electrode to the ground terminal of the power supply. In this

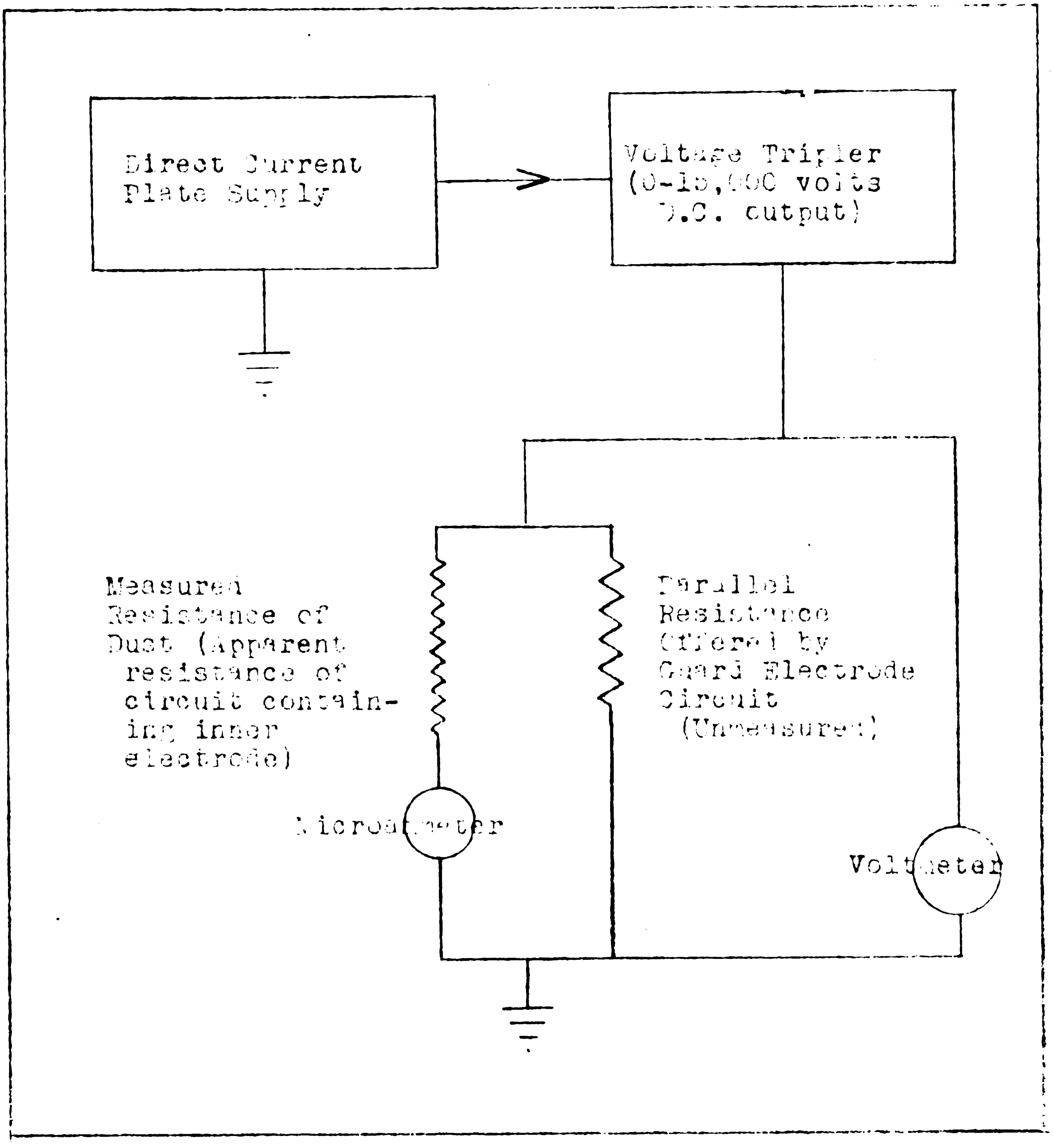


Figure A-5 The electrical circuit used in conjunction with the Michigan State College resistometer for dust resistivity measurements is illustrated schematically above. In these investigations, all readings were taken at a direct current potential of 5000 volts.

manner, current passing through the inner electrode only was measured.

The Electrical Source. The variable direct current potential supply was taken from a voltage tripler circuit normally used for charging operations. The tripler was capable of delivering up to about 15 kilovolts, and its plate supply was drawn from a rectifier operating on 110 volt alternating current mains. The rectifier was equipped with an autotransformer so that voltage variations would be possible if desired.

Humidity Control. The air draft through the resistometer chamber was maintained by a small fan. The fan had heating coils built into its output duct in order to aid humidity control. The heating coils were energized through an autotransformer whereby the intensity of heating could be varied. The air duct leading from the fan into the resistometer chamber contained a water reservoir as shown in Figures A - 2 and A - 3. The water reservoir was easily accessible to external heating so that the vapor pressure of the water could be altered as desired for humidity control. Manipulation of the various components of the humidity control system made possible wide variation of the relative humidity within the resistometer chamber.

Humidity Measurement. Humidity measurement was accomplished by means of dry-bulb and wet-bulb thermometers placed in the cover of the resistometer chamber. A constant wet-bulb thermometer was constructed as shown in Figure A - 2. The use of the dry-bulb and the wet-bulb temperature readings in conjunction with a psychrometric chart made possible a check of the relative humidity at any time.

Conduct of Experimental Measurements. To perform a resistivity measurement, the humidity control equipment was adjusted to produce the desired relative humidity. After a fairly steady relative humidity was attained, the dust sample in the resistometer chamber was allowed to reach equilibrium. Current readings were taken periodically at a given voltage until they became constant. At this time, current and corresponding voltage readings could be taken for the given experimental relative humidity, and the dust resistivity could be calculated by use of the following formula:

$$P = \frac{AV}{IL}$$

where,
P = dust resistivity, ohm-cm.
A = area of inner ground electrode, cm.^{2}
L = length of current path through the dust, cm.
V = applied voltage, volts.
I = measured current, amperes.

Dusts Investigated. In these studies, the Niagara dyed-talc lead arsenate dust and the Michigan State College dyed-talc dust were examined. No attempt was made to study the resistivity of these dusts under conditions of varying voltage, since Penney indicated that this factor was not especially important.

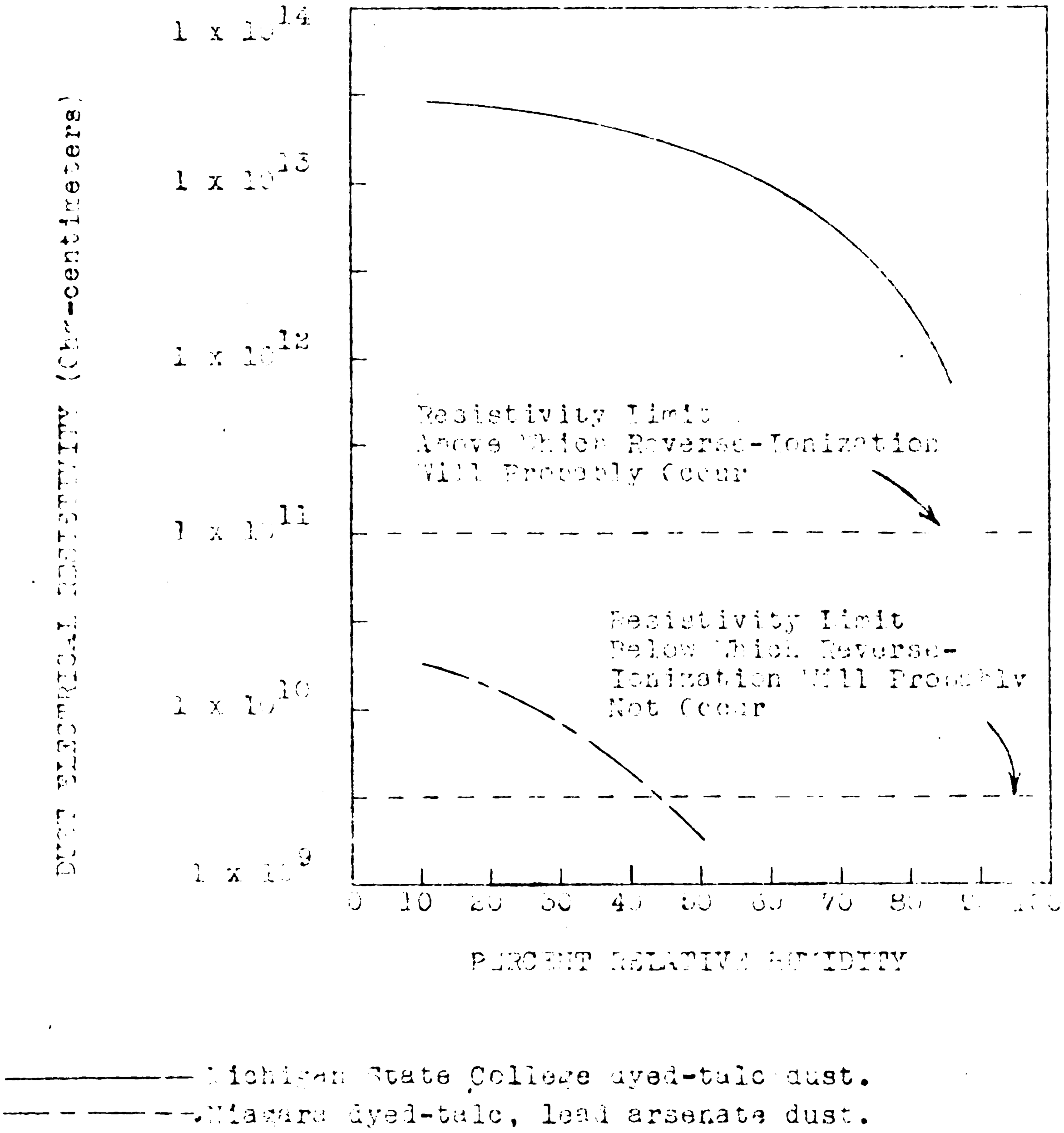


Figure **A-6** The variation of electrical resistivity with respect to relative humidity for the Niagara dyed-talc lead arsenate dust, and the Michigan State College dyed-talc dust. The curve obtained for the Niagara dust (the lower curve) is somewhat questionable as to its reliability, due to rather erratic behavior of the dust while reaching equilibrium at the various humidities. However, this dust is believed to exhibit little reverse-ionization in actual use, as the curve indicates.

Results

The variation of resistivity with relative humidity, or moisture content more directly, for the two dusts studied is shown graphically in Figure A - 6. The resistivity of both dusts was noted as decreasing at a more rapid rate at higher relative humidities.

In conjunction with this experiment observation was made of a charging nozzle at operating potential in a darkened room. The nozzle possessed a tube-wall coating of Michigan State College dyed-talc dust. The purpose of this observation was to determine if any visible glow was present at the surface of the dust coating under conditions of reverse-ionization. (Penney pointed out that this glow could possibly be seen when reverse-ionization was occurring.) Under the conditions previously enumerated, corona discharge could be seen on the dust surface.

Summary and Conclusions

The results of this investigation seem to fully substantiate the conclusion that reverse-ionization was one of the factors responsible for the erratic results of the 1952 summer field experiment. The relative humidity observed during the conduct of that experiment was in the neighborhood of forty-four percent, and the resistivity of the Michigan State College dyed-talc dust at that humidity is far above the resistivity limit given by Penney at which reverse-ionization is sure to occur.

Although the results of the experiment wherein this dust was applied were rather disappointing, this special evaluation dust certainly brought to attention more factors to be considered in electrostatic dusting research. The problem of reverse-ionization may seem somewhat aside from the area of deposition evaluation. However, the measurement of resistivity and the use of the resistometer in reality provides a means of accounting for erratic deposition results. Therefore, this technique might be viewed as a somewhat specialized form of evaluation method, although rather indirect in nature.

APPENDIX B

PROPOSED FUTURE WORK:

THE MICHIGAN STATE COLLEGE LABORATORY DUSTER

With electrostatic crop dusting research in its present status, a number of factors have, apparently, presented themselves as complications. Electrostatic dust precipitation has rendered very significant deposition improvements under certain conditions, while in other cases it has failed completely. The 1952 dyed-talc dust field experiment, wherein reverse - ionization effects were first noted, serves as an example. Obviously, a considerable amount of fundamental work needs to be carried out in order to isolate and examine such phenomena.

Near the end of 1953, Michigan State College dusting workers realized the need for a somewhat more elaborate dusting machine test set-up, where such problems might be more readily studied. Factors which might be investigated, employing such a laboratory machine, were enumerated as:

1. Dust metering devices must be investigated due to the dependence of successful duster operation upon them. Uniformity of dust flow and application rate depend upon the suitability of the metering mechanism.
2. Comparisons should be made of various methods of supplying electrical energy for charging.

3. Charging mechanisms, such as nozzles, must be studied under varying conditions to determine performance effects.
4. A study must be made of the effects of machine construction and framing, particularly in the proximity of the charging elements, upon deposition efficiency.
5. Research should be conducted with the purpose of finding the significance of fan speeds and nozzle air-dust stream velocities upon the deposition efficiency.
6. Further research directed at development of deposition evaluation methods will be continually required. This work would be greatly facilitated by the availability of a laboratory test set-up.
7. Relative humidity has been found to render considerable influence in connection with most of the previous factors. Its definite relationships should be more thoroughly investigated.

With a laboratory dusting apparatus available, year round "simulated field experiments" would be possible. That is to say, tests employing actual plants might be made at any time, without the limitation of summer experimentation only. (Greenhouse grown plants would be used.) Also, the need for readying a considerable amount of equipment for the field would be eliminated in some instances.

Proposed Laboratory Duster Design

A schematic view of the proposed laboratory duster design intended to fulfill the previously outlined purposes is shown in Figure A-7. Two closed chambers are to be provided, with one serving as the dusting "tunnel", and the other housing the duster fan and metering mechanism. Full provision is to be made for humidity control in both chambers. At this time, individual attention will be given to the various components and features of the laboratory duster.

Humidity Control. Humidification of the intake air will be accomplished in the intake system, which is shown in Figure A-7. A sheet metal "Tee" will be located at the entrance end of the intake duct. One branch of the "Tee" will open to the outer atmosphere, and the other branch will open into the laboratory air. Dampers will be placed in these Tee branches to enable proper mixing of inside and outside air supplies, which will aid in obtaining the desired humidity and temperature levels for a given experiment. The laboratory air inlet will also allow the application of heating or cooling coils when necessary to proper "air-conditioning" of the testing chambers. The primary humidity control would be accomplished by means of the introduction of steam into the air stream. The steam is to be introduced at the beginning of

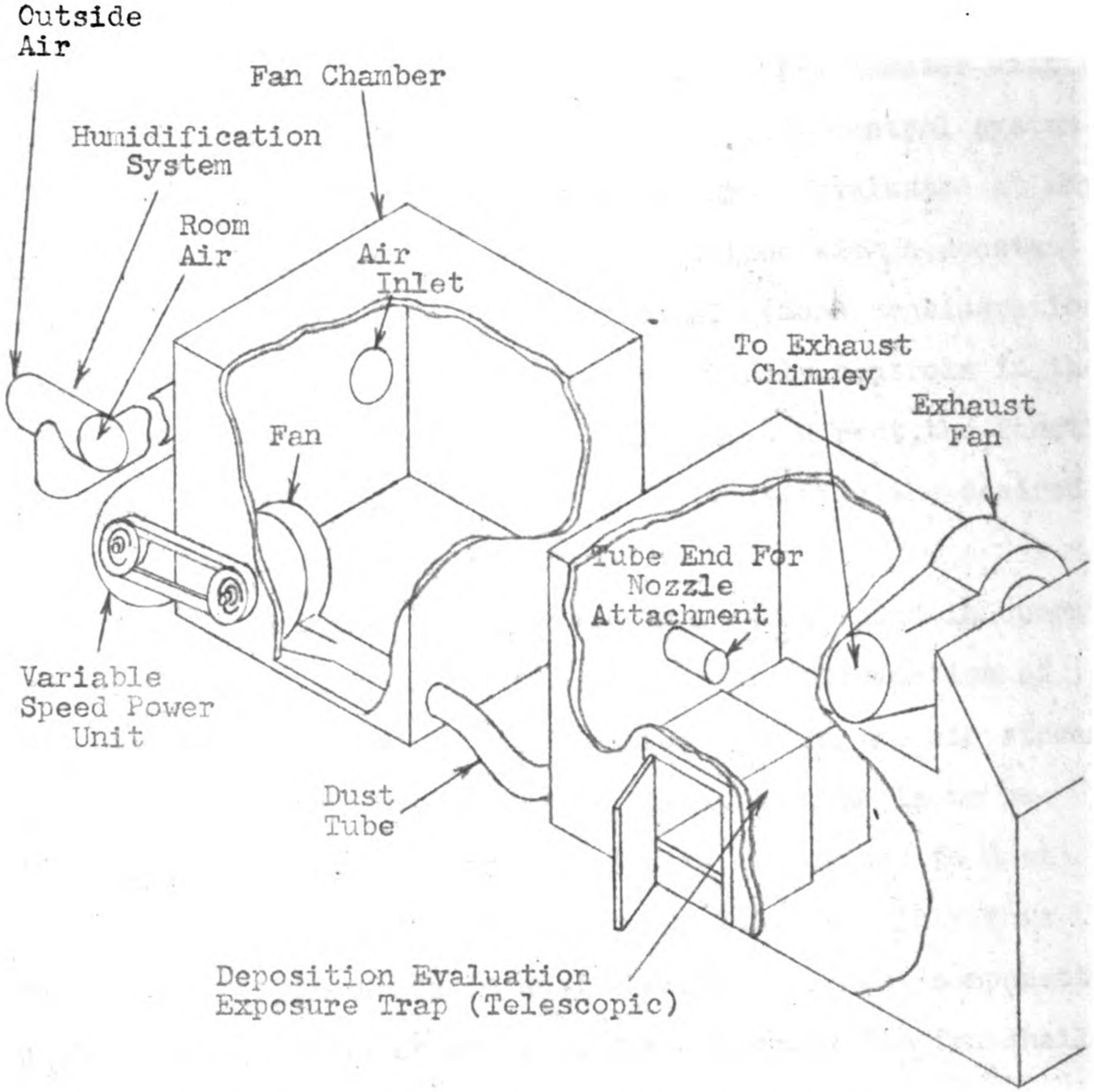


Figure A-7 · The Proposed Michigan State College Laboratory Duster the main air duct and will be at low pressure. A sufficient length of main air duct will be provided, so that reasonably thorough air-water vapor mixing can be accomplished before reaching the duster fan chamber. The air-intake flow is intended to be maintained by the duster fan operation.

The Fan Chamber. The humidity of the fan chamber will be dependent upon the adjustment of the humidity control system. In order that its humidity conditions may be evaluated at any time, a dry-bulb thermometer, in conjunction with a constant wet-bulb thermometer, is to be employed. (Some consideration is being given to locating automatic humidity controls in the fan chamber. Such automatic controls would direct the functioning of the humidification system, thus obtaining the desired experimental atmospheric conditions).

A variable-speed centrifugal fan is to be used in operation of the duster. Provision will be made for introduction of dust either ahead of, or following the fan, in the air stream. (The reason for this allowance is that some time is to be devoted to study of performance effects as related to dust introduction before, or following, the fan. Possibly this factor may influence static dust charging and dust component partitioning during passage from the duster.) The fan shall be driven by a variable-speed power unit, located outside the fan chamber and coupled to the **fan** by means of a V-belt drive, as shown in Figure A-7. Fan rotational speeds of up to four-thousand revolutions per minute will be attainable if desired.

The air-dust stream from the fan is to be conducted to the dusting chamber through ordinary types of duster tubing. Of course, before initiating an actual dusting experiment, time would need to be allowed for the dust moisture content to reach equilibrium at the test atmospheric relative humidity.

The Dusting Tunnel. The dusting tunnel, or chamber will be the point of actual experimental set-up. The humidity of the atmosphere of this chamber will be again dependent upon the humidification system, its air supply being provided by the duster fan.

Dust precipitation targets, such as plants or artificial deposition surfaces will be placed in the dusting tunnel during the conduct of an experiment. Also, sufficient space will be provided to allow assembling of charging mechanisms for trials.

Another feature of the dusting tunnel which was felt desirable is the evaluation exposure trap, shown in Figure A-7. The function of this device is to allow the dust-air stream to reach the operational state before target exposure. This will insure more comparable test replications. Plants or other deposition surfaces will then be exposed for the desired length of time. The trap merely consists of a telescopic chamber, which may be opened or closed from outside the dusting tunnel, as may be noted from Figure A-7.

The Laboratory Duster Exhaust System. In order to keep the dust cloud within the dusting tunnel at relatively constant density, it will be necessary to provide an exhaust system. The exhaust system draft will be provided by a second centrifugal fan, with its throughput controlled by a variable intake opening. The fan will deliver the air-dust exhaust to a chimney through which it may be discarded.

Summary

The fundamental aim of constructing a laboratory machine such as the one described is to furnish a suitable means of simulating field experiments at almost any time. Thus, the limitation of summer field experiments is removed, with the utilization of greenhouse plants.

The laboratory duster will be so designed that humidity conditions may be varied; fan speeds and resultant dust-air stream velocities may be readily adjusted.

Areas of study inherent with electrostatic crop dusting research may be more easily examined with such equipment in constant readiness. Dust-air stream characteristics, dust metering devices charging methods and power supplies and deposition evaluation methods may be examined by the use of this set up. Atmospheric effects upon these factors may be evaluated.

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