South Dakota State University

Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Electronic Theses and Dissertations

1968

Analysis of Two Granular Pesticide Applicators for Experimental Plots

Gerald Albert Stangl

Follow this and additional works at: https://openprairie.sdstate.edu/etd

Recommended Citation

Stangl, Gerald Albert, "Analysis of Two Granular Pesticide Applicators for Experimental Plots" (1968). *Electronic Theses and Dissertations*. 3498.
https://openprairie.sdstate.edu/etd/3498

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.

ANALYSIS OF TWO GRANULAR PESTICIDE APPLICATORS FOR EXPERIMENTAL PLOTS

BY

GERALD ALBERT STANGL

A thesis submitted
in partial fulfillment of the requirements for the
degree, Master of Science, Department of
Agricultural Engineering, South
Dakota State University

1968

SOUTH DAKOTA STATE UNIVERSITY LIBRARY

266123

ANALYSIS OF TWO GRANULAR PESTICIDE APPLICATORS FOR EXPERIMENTAL PLOTS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Agricultural Engineering Department Date

ACKNOWLEDGMENTS

The author expresses sincere appreciation to Doctor Paul Turnquist of the Agricultural Engineering Department, South Dakota State University, for his encouragement, suggestions and guidance throughout the conduction of this research project. Helpful suggestions were also obtained from members of the Agricultural Engineering Department and from Mr. Oriville Stangl, relative of the writer.

To the Entomology Department, South Dakota State University, and the National Science Foundation gratitude is expressed for supplying equipment and financial assistance.

Acknowledgment is given for technical assistance from Doctor W. Lee Tucker, Experiment Station Statistician, and from staff members of the Audio-Visual Center.

The author expresses appreciation to his wife, Linda Stangl, for encouragement and assistance in preparing this manuscript and to Mrs. Cheryl Anderson for typing the final copy of this thesis.

GAS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Pesticides are applied to agricultural crops to maximize returns on the investment by the farmer. Granular pesticides are replacing liquid sprays in many applications. Granules are composed of a sorptive, inert carrier material impregnated with a toxicant which is released when the granules contact water (2).[1]

Application of pesticides by granular carrier has numerous advantages over liquid application:

1. Ease of handling and of application as no mixing or addition of water is necessary in the field (20).
2. Less drift because of particle weight, and thus reduced operator exposure to toxic chemicals (2).
3. Less total weight applied (10 to 20% of liquid weight usually applied).
4. Better residual effects and retention of strength during a continued drought.
5. More effective for pre-emergence applications (19).
6. Increased reliability due to soil incorporation (13).
7. Less expensive application since no tanks, pumps, nozzles or related accessory equipment are needed (1).

Some disadvantages of granules are:

1. A uniform distribution requirement for proper protection at low application rates.

---

[1] Numbers in parentheses refer to appended references.

2. Higher chemical cost than sprays in most cases (15).
3. Soil moisture affects activation of chemical and its distribution.
4. Difficult calibration of applicator equipment.
5. Uniform application difficult because of:
    a. Low application rates.
    b. Variation in granule size, shape and density within and between pesticides.
    c. Field vibrations of the meter (20).

Physical properties of granular pesticides vary considerably according to Holzhei (19): mesh size from 8 to 100 (based on U. S. Standard Series sieve sizes of 8 to 100 holes per linear inch), bulk specific weight from 15 to 80 pounds/foot^3, angle of repose from 35 to 60^o, and formulations containing 1 to 30% toxicant by weight.

This introductory knowledge of granular pesticide characteristics is essential to appreciate the problem of uniform application of pesticides. Uniformity of application is of particular importance for experimental work such as that conducted by the Entomology Department at South Dakota State University. This department has been testing new granular corn rootworm pesticide formulations on experimental plots. These pesticides must be applied uniformily to show valid differences between types of pesticides and between rates of application. Experimental results determine relative merits of the new formulations, and lead to subsequent registration and commercial sale of the acceptable product.

Farmer-owned fields with known rootworm infestation are selected for use. Every pesticide treatment is applied to an experimental unit containing four 90-foot rows each with a 40-inch row spacing. A Noble Model 202 Granular Applicator,[2] see Figure I, pulled by a John Deere 110 garden tractor is used to apply the pesticide. The treatments are replicated four times over newly planted rows of corn. Forty or more treatments are applied to each four to five acre field. Field conditions encountered are of various types: conventional dryland methods, minimum tillage, and furrow irrigated. The treatments are applied within three days after the farmer has planted and fertilized the corn. Application rates of $\frac{1}{4}$, $\frac{1}{2}$, 3/4, 1, $1\frac{1}{2}$, 2, and 3 pounds/acre (total land area) for active pesticides, or toxicants, are desired. The pesticides tested usually range from 5 to 25% toxicant in composition. Therefore, 75 to 95% of the total weight applied consists of inert carrier material (6). Granules are distributed in a 4 to 7 inch band over the corn row and are incorporated in the upper $\frac{1}{2}$ inch of the soil. Application rates vary from 0.00207 gram/inch^2 to 0.01241 gram/inch^2 for the actual area covered with a 7-inch band width, or from 5 to 30 pounds/acre for the total land area. Applied pesticide weights vary from 62.64 to 375.84 grams per experimental unit. Depending upon granule density, this may represent volumes as large as one quart. Density is dependent mainly upon size and type of carrier material used. Carrier materials commonly used are: corn cob particles, expanded mica, and clay.

---

[2] Manufactured by Noble Manufacturing Company, Sac City, Iowa.

Knowledge of the metering uniformity of the applicator under field conditions is necessary. Although no definite guidelines have been established for the required metering uniformity to control rootworms, the Noble applicator appears to have a uniformity of questionable level for plot work, as found in previous studies (19, 22). Thus, it is desired to measure metering uniformity under simulated field conditions on the Noble unit. This would establish a criteria for development of an experimental cone metering device in an effort to obtain a more uniform meter than the Noble unit.

REVIEW OF LITERATURE

Applicator Requirements

Because granular pesticides are of variable size, shape and density an applicator is needed to meter a wide variety of particles. Accurate distribution is necessary for general use as well as for experimental work since the range in application rates from good control of insects to injury to crops is not great (2). Government regulation of residue tolerances also limits allowable distribution variability. In many cases the maximum allowable tolerance is an undetectable (zero) level. Low application rates deposit a small portion of granules for the actual band area covered (19). For example, a 2 pound/acre (total land area) application of 16/30 mesh granules, see page 16, results in a deposit of 52 particles/feet^2 or about one particle every 3 inches^2 over the total area (1). Thus, uniform distribution is necessary for adequate plant protection. Other applicator requirements include:

1. Application at a relatively constant rate whether metering large or small amounts of granules.
2. Variations in the tractor speed should not affect uniformity of metering appreciably on a per unit area basis.
3. Design should allow easy and thorough cleaning of the meter for use with different types of chemicals.
4. Meters for experimental plot work should be tractor mounted, power operated and easily transported.
5. Meter should be detachable so tractor can be used for other purposes (8).

6. Vacuum clean-out tube for thorough cleaning of the applicator between experimental plots (16).
7. Relationship between flow rate and ground speed proportional for a ground-driven device.
8. Meter causes a minimum of granular breakdown.
9. Granules with a wide variety of mesh sizes and angles of repose uniformly discharged.
10. Rates of discharge in the range of 0.071 to 1.070[3] grams/second based on the band area in each acre for a 7-inch band, a 40-inch row spacing and a tractor speed of 4 miles per hour (mph).

Note: The rates of discharge in number 10 are equivalent to a minimum application of 2 pounds/acre and a maximum of 30 pounds/acre for the total land area covered (19). The actual area covered is only 7/40 of the total area covered.

Applicator Variables

Variables to be considered in applicator design include: area and shape of metering orifice, length and speed of agitator, ground speed of applicator, roughness of the field or plot, design of bander, humidity (moisture content of granules), temperature, depth of material in hopper, and nature and size of granules (5, 15, 19). Granular variables include: depth of material in hopper, angle of repose, mesh size,

---

[3] A correction from 0.065 and 6.200 grams/second (19). For example, 2 lb/acre X 454 gm/lb X 1 acre/43,560 ft^2 X 4 mi/hr X 5280 ft/mi X 1 hr/3600 sec X 40 in X 7/40 X 1 ft/12 in = 0.071 gm/sec.

bulk specific weight, angle of hopper inclination from horizontal, shock vibrations and moisture content (19).

Types of Metering Devices

Numerous types of commercial granular applicators are available. Some principles of operation utilized are: a variable orifice with rotor-bar agitator resembling the grass seeder principle, a fixed orifice with screw conveyor auger, rubber roller with adjustable gate, rubber-flanged impeller between hopper and variable-sized orifice, and a variable opening between a hopper and an oscillating plate (4). Of these, the most commonly used principle is that of the grass seeder. A ground-driven shaft at the hopper bottom is keyed to one or more fluted cylinders. Each cylinder rotates over a variable orifice. Agitation of the granules by the cylinder prevents bridging of the granules above the orifice. The flow is set by varying the orifice opening through a sliding, slotted-plate, spiral cam linkage (19).

Problems of Applicators and Attempts to Solve Them

The major need is for adequate distribution by granular applicators on experimental plots. Other problems associated with applicators are continuity of flow and production of fines from pulverization of materials in hoppers (20). Several researchers have postulated improvements through the following metering principles: electrostatic charge or vacuum pick-up roller, double vibrating screen, double vertical flat belts, vibrating ramp, rotating spiral-grooved disk, vertical auger, increasing-pitch screw accelerator, horizontal disk centrifugal distributor, vertical centrifugal distributor (19), belt-tray meter (6), and cone-type meter (9, 10). The relative advantages of the latter two meters, indicated below, suggest that these meters merit consideration for use on experimental plots.

The belt-tray meter has the following advantages: it is easy to clean, belt movement and row length have positive correlation, variable particle size and density have little effect on metering rate, and the application rate may be changed without disturbing the belt speed. Its disadvantages are: the vibration and the belt slope may cause shifting of material on the belt; errors at the beginning and end of the plot are caused by: doubtful point of discharge from the belt, changes in driving speed, starting and stopping of the belt, and delayed fall of the granules; belt tension must prevent slippage; clearance between hopper and belt is critical; wind effects must be eliminated; and uniform placement of granules on belt is critical (6).

Advantages of the cone-type meter are: it is easy to clean, rotation of cone and row length have positive correlation (one revolution per row), variable particle size and density have little effect on metering rate, application rate is easily varied by placing additional material in the loader, slopes of 4 or 5% have little effect on distribution, a circular shield above hopper reduces wind effects, depth of granules on base plate does not influence accuracy, accuracy is more than twice that of the belt-type meter, and the loader automatically distributes granules uniformly around the base plate of the cone. Its disadvantages are: loading the device on a slope may cause uneven distribution of material on the base plate, distribution errors are caused by material falling out of the discharge funnel when loading the device and by sliding of material at the end of the revolution, starting and stopping at row ends causes distribution errors, and the applicator is affected by vibration (6, 9, 10).

Field Simulation of Vibration

When the above distribution devices are evaluated in the laboratory, field vibration conditions should be simulated in order to provide a more realistic test environment. Acceleration data can be utilized to characterize vibration and is more easily obtained than any other type of vibration data. Most metering devices use gravity flow at some stage of the metering process. Thus, anything which changes the apparent acceleration due to gravity, such as vertical acceleration of the unit, will affect discharge (23). An accelerometer can be used to measure vibration amplitudes and frequencies of the distributor when operated under field conditions. Then with the accelerometer and distributor mounted on a laboratory test stand, adjustments can be made to subject the unit to similar vibrations (15).

Romig (21), in testing shocks on fertilizer units attached to 2 and 4-row corn planters, used a ± 10g (g refers to the acceleration due to gravity) accelerometer with the recording system mounted on a tractor. The recording system consisted of an optical oscillograph, the accelerometer, a time signal generator, and a generator for the power source. The oscillograph used had good frequency response. Its high frequency response capability permitted accurate recording of vibration components as high as the 130 cycles per second (cps) encountered. This system was capable of detecting accelerations of 0.02g.

Tests were conducted on two fields: one of typical condition for New York state and the other of stoney condition. Variables included: implement adjustments, speed, load in fertilizer hoppers, type of suspension, and soil condition parameters such as stone content and size, soil strength, moisture content, and tillage practices (23). A randomized complete block design was used with four speeds (3, 4, 5 and 6 mph) as treatments and three hopper load conditions (0, 25 and 50 pounds of granules per hopper) as blocks (21).

Results of field tests showed a distinct periodicity of the acceleration trace with two well-defined frequencies. The amplitude and phase of these acceleration components changed constantly, but both frequencies appeared constant. The frequency components were: a high component of 127.5 cps and 41.2 cps for the 4-row and 2-row planters, respectively; and a low component of 3.8 to 7 cps for both units. The root-mean-square amplitude of both frequency components and peak amplitude values (positive and negative) varied with test conditions. Analysis of the data indicated that the frequencies were independent of speed and hopper load. Amplitude of the high frequency component responded to speed and load while that of the low frequency component had a significant response to speed alone. There was an indication that the low frequency component decreased in amplitude with increasing hopper load. Positive peaks of acceleration appeared to increase with speed and decrease with increasing load. Negative peaks were independent of speed while their reaction to loading was strongly influenced by implement design (21).

Holzhei (19) presented the following summary of Romig's findings:

1. Damping was negligible on the fertilizer hopper of the 4-row planter.
2. Natural frequencies of the planter and hopper together were near 5 cps and 125 cps for the low and high frequency components, respectively.
3. Maximum accelerations were 1g and 2g for high and low frequencies, respectively.
4. Peak amplitudes of 3 to 4g were obtained at higher speeds. However, a rigid planter frame could have caused accelerations in the order of 50 to 75g, according to Holzhei's analysis.

Surface undulations of a tilled field may be considered an ensemble of recorded time histories of a random process, thus subjecting an implement passing over the field to random vibration. Selecting a given wheel path causes one possible time history (ground wave) to excite the implement. Travel speed controls the exact frequency of excitation as wave lengths of the ground wave are fixed (21).

Periodic frequency components, if present, were expected to be a function of speed because of being a periodic component of the ground wave; however, this was not the case. Resonance in the planter chasis must have caused the two well-defined frequencies observed. These frequencies were so prominent that only resonant frequencies could be detected, and not others of the random vibration. The metering unit and suspension comprised a mass system of two or three degrees of freedom. Therefore it should have displayed two or three resonant frequencies which distort the vibration spectrum before it is observed at the metering unit.

Damping was mainly confined to hysteresis of the frame members and to friction of the suspension joints. The resulting low damping ratio allowed large resonant peaks and free vibration (or transients) to presist a long time.

Possible approaches to simulate vibration are:

1. A spring-mass system approximating the implement frame. An electronic exciter could serve as the random input generator.
2. If the vibration spectrum (i.e., acceleration) observed in the field consists of only a few frequencies as in this study, a periodic input can be used in place of the expensive electronic exciter.

In both cases a stationary test stand is advantageous because it is possible to correlate information collected with its time of occurrence (23).

Romig (21) attempted to simulate the result of the unknown, wide-band input (random vibration) into a mechanical filter composed of the tires, frame and linkage which had two narrow, widely separated pass bands (or low and high frequency responses). A simulator with high resonance and minimum damping was constructed of an adjustable spring mass system (the mechanical filter) with a cam impact exciter mechanism. Resonant frequencies were matched to those observed in the field by adjusting spring rates and adding ballast.

The vibration simulator was designed by Romig for vertical axis testing with a maximum vertical displacement of 2-inches through 36-inch lift arms and a cam exciter mechanism (21). The suspension allowed an inclination of up to 10° from the horizontal for the metering unit to simulate the effect of slope (23). Five springs in parallel provided a means of adjusting stiffness of the main system to produce the desired lower frequency. The high frequency component was controlled by stiffness of the subframe connecting the test item (fertilizer hopper) to the vibrator carriage (21). Extreme stiffness of the frame and suspension was emphasized to eliminate possible resonances in these components within the desired frequency range (23).

Adjustments to vary the form of test stand accelerations include: the cam lift, cam shaft speed, stiffness of the main suspension, stiffness of the subframe, and addition of ballast weight to the carriage and to the test unit. The simulator was tuned experimentally with the accelerometer monitoring the vibration output for comparison to actual data (21). From analysis of the field tests the required specifications for the test stand were: a maximum acceleration amplitude of 1g and 2g for the high and low frequency components, respectively; and frequencies of 3 to 8 cps for the low component and 40 to 150 cps for the high frequency component.

Monitoring the test stand output showed that the simulated high frequency component was higher than that observed in the field. It appeared to be a function of subframe design only (20). Thus the relative height of the low and high frequency peaks for the simulator differed from the desired spectrum. This was compensated for by using a nonuniform forcing function to raise the lower peak. Then most of the error was concentrated in frequency ranges with little energy present.

216153 SOUTH DAKOTA STATE UNIVERSITY LIBRARY

A second exciter mechanism was not added to simulate the observed occasional large accelerations under field conditions. These were probably caused by large stones.

From his analysis Romig formed the following conclusions:

1. Low damping of pneumatic tires and steel structures causes a field machine chasis to behave as a mechanical vibration filter with narrow, sharply peaked pass bands.
2. For light implements, as a corn planter, resonances occur in a region where the exciting spectrum (ground wave) is nearly uniform. Therefore vibration frequencies are independent of travel speed.
3. A mechanical filter with impact excitation will simulate the vibration environment of components mounted on a field machine if:
    a. The chasis of the simulator is lightly damped, thus producing a sharp peak or peaks in observed acceleration.
    b. The component (<u>i.e.,</u> fertilizer hopper) has no resonances in the low energy region of the spectrum where errors have been concentrated (21).

Several analyses of commercial and experimental granular pesticide applicators have been conducted under simulated "normal" field conditions. Hosokawa (14) utilized a parallel four-bar linkage as the vibration simulator. The linkage was lifted by a pair of constant-velocity-lift cams on a variable speed drive; then dropped onto a rubber stop. Stop height determined the amplitude of drop, maximum being $3\frac{1}{2}$ inches. The variable speed drive provided an impulse frequency upward from 20 cycles per minute (cpm). In actual tests the frequency of impacts varied from 20 to 80 cpm and the amplitude of drop from $\frac{1}{2}$ to 1 inch.

A test stand similar to Hosokawa's was used by Holzhei (19) and Price (22). The former tested a Noble Model No. A-22-A meter under shocks of 70 cpm for two orifice openings and an agitator speed of 10 revolutions per minute (rpm). The latter tested Noble and Gandy metering devices under shocks of 60 and 240 cpm with the hopper half-full and full, and agitator speeds of 15 and 20 rpm. The agitator drive consisted of a variable speed drive allowing an agitator speed range of 0 to 30 rpm.

Solutions to Vibration Problem

Holzhei (19) proposed two alternatives in designing to minimize shock effects on metering uniformity. They are:

1. Isolate the hopper completely from shocks and utilize gravity flow through an adjustable orifice regulated by a ground-driven linkage.
2. Allow the passage of shocks to the hopper, but subject the granules to an acceleration field large enough to reduce the overall effect of shocks on particle transport.

Solutions of the first alternative include: a shock isolator, a vibration absorber and critical damping. Holzhei chose the second alternative for further study because of no great breakthrough in vibration isolation design.

Applicator Tests

Appartus for evaluating applicator performance included the test stand described above. Tests were conducted with nontoxic, inert granular material such as clay and expanded mica. The material was designated as A, AA RVM or A, AA LVM. These letter designations indicated the method of processing the granules:

1. A - the inert part of the granule was unextruded (not formed by force).
2. AA - the inert material in the granule was extruded, and specially processed to improve porosity and enhance sorptive characteristics.
3. RVM - (regular volatile material), the granules have not been heated to drive off the combined water in the inert material and tend to disintegrate in water.
4. LVM - (low volatile material), super-hardened granules which resist disintegration in water (7).

Particle size should be determined by sieve analysis using the U. S. Standard Series sieves. For example, if the material size is 24/48, at least 90% of the granules, by weight, will pass through a U. S. Standard Series sieve No. 24, and at least 95% of the granules, by weight, will be retained on a U. S. Standard Series sieve No. 48. Size determination should be made after the inert material has been impregnated with toxicant as this may affect size range and amount of fine material in the finished product (18).

Moisture content of the granules is determined by the relative humidity of the atmosphere with which the granules are in equilibrium. Becker, et. al. (2, 3), based on results of tests with attapulgite (natural sorptive clay) granular carrier, stated that:

> If the granular carrier is treated with the toxicant and calibration of the metering device is completed with no change in the moisture content of the carrier, there will not be an appreciable error in the metering rate even if the moisture content changes after calibration.

Tests showed that error in application rate would be small if formulation and calibration are done when the carrier is in equilibrium with atmospheres where the relative humidity ranges between 30 and 75%. Gebhardt, et. al. (11), found that additional moisture in clay granules caused a slight increase in the effect of agitator speed on flow rate. The agitator speed had greater effect on flow at larger orifice settings.

Holzhei (19) utilized 15/30 mesh attapulgite carrier in equilibrium with the humidity of the room which varied from 25 to 80%. Thus, moisture content of the granules was affected very little, and did not enter in the tests as a variable since the same material was used throughout the investigation. Absolute weight values may have varied between tests because of moisture differences. However, this was not a problem as relative values (i.e., standard deviations and coefficients of variation) were used to compare applicator performance.

In order to determine applicator performance accurately the distribution pattern must be measured in terms of a fraction of a second or square inch of area covered (15). Hosokawa (14) developed an endless chain of 60 small collecting buckets to measure distribution uniformity along the row. The chain passed beneath the applicator, and a funnel directed the granules into the buckets. Increments of discharge were collected at 1/10 second intervals. The weight of each filled bucket was automatically recorded when it passed over a cantilever beam weight sensing element. One problem that remained was to measure the uniformity of distribution across the row by band distributors.

Price (15) developed equipment suitable for measuring distribution along and across the row for small increments of area. This equipment included the test stand described above, a variable-speed applicator drive and a conveyor collecting device to obtain samples of the granule distribution. The endless conveyor was an 18-inch wide flat belt with a 7-foot collecting surface. It passed under the meter discharge point at speeds ranging from 1 to 7 mph indicated on a surface speedometer mounted on the belt. Upper speeds were limited by the ability of a wooden brake to stop the belt before the collecting trays passed over the end of the roller (19). One-inch square plastic boxes 0.4 inch high were used to control the granule sample size. The boxes were adjusted to the same weight (± 0.0005 gm) by weighing them on a chemical balance and filing for adjustment. Fourteen boxes were placed side-by-side in a row across the belt and 15 rows were each placed ½ inch apart on the belt. These containers were held in place by stock aluminum channeling crimped and milled such that the boxes could slide into the channels and be held there as the belt made a complete revolution. The channels were fastened to the belt with elbow spring-clips on each end.

When analyzing banders for uniformity of distribution across the field row, the weight of the granules collected in each box was recorded. To analyze meter distribution uniformity along the field row the total weight collected in each aluminum channel or tray was recorded. Since each bander test involved 210 weighings, Price (15) developed an automatic weighing system. This reduced the required weighing time for each test from 3 or 4 hours to 15 or 20 minutes. The weighing system was required to single out each container and individually place it on a sensing element for the time necessary to weigh and record the weight. The system consisted of a small conveyor (driven by a variable speed drive) along which a row of collector containers was placed, a trip mechanism to separate the containers, a cantilever beam sensing element to measure the weight of each container, and a recording system. The weighing system had an accuracy of ± 0.005 grams, but heat dissipation from the strain gages on the sensing beam was a problem because of the high voltage input required for this sensitivity. Price (22) stated that the sensing element should be accurate to ± 0.0001 gram for tests involving application rates of under 20 pounds/acre.

Holzhei (19) in a later study used the same conveyor as Price at speeds ranging from 0.715 to 4.28 mph (63 to 378 feet/minute). He weighed each sample collected on a Mettler balance[4] rather than on the weighing system described above. No reason was given for not utilizing the already existing system.

In analyzing flow from commercial metering devices (John Deere[5] Model No. BB11176B and Noble[6] Model No. A-22-A) Holzhei used 25 collector trays on the conveyor belt. The Noble agitator had 6 flutes whereas the John Deere had 10. An attempt was made to measure cyclic flow

---

[4] Manufactured by Mettler Instrument Corporation, Princeton, New Jersey.

[5] John Deere Planter Works, Moline, Illinois.

[6] Noble Manufacturing Company, Sac City, Iowa.

caused by the flutes passing over the meter orifice. The conveyor speed was adjusted to obtain a resolution of measurement of 3 agitator flutes per test. This gave about 8 readings (trays) for each flute passing over the orifice as 25 trays were in each test. "Typical" agitator shaft speeds of 10 and 20 rpm were used. These corresponded to conveyor speeds of 71.5 and 144 feet/minute for the Noble unit. Resolution of measurement should be held constant for similar applicator types to reduce the effect of this factor on deviations in sample weights collected. This is particularly critical where metering is not of a continuous action, i.e., commercial applicators.

Other apparatus has been used by researchers in distribution analysis. Becker and Costel (2) recorded weights of metered samples continuously with time by a strain gage weight transducer. However, Hosokawa (14) stated that because of considerable differential between the inertia of flowing and collected material, this method could not show the inherent fluctuations in granular flow.

Test Results

Tests by the researchers mentioned above indicated much needed improvement in commercial metering devices and banders. Holzhei (19) summarized the findings of Hosokawa for the fluted-cylinder type meter: maximum discharge was twice that of minimum discharge at medium orifice settings. Under shock, maximum values were 4½ times minimum values. He also summarized the findings of Price: fluctuations were higher for larger orifice settings with a typical difference of 3 times down the row and up to 7 times across the row between maximum and minimum values.

In gravity flow tests through an orifice with no agitator Holzhei (19) found no appreciable difference in metering uniformity between granule types. Two granule sizes, 15/30 and 20/35 mesh, of attapulgite carrier were used.

Metering uniformity graphs (weight collected per tray versus tray number) were plotted for various orifice settings on the Noble and John Deere meters. Attapulgus 15/30 mesh granules were used throughout the tests. As the orifice was opened up, the fluctuation effect of the fluted agitator increased and uniformity of distribution was impaired. No significant difference in flow uniformity between agitator speeds was found for the two "typical" speeds (10 and 20 rpm) tested. The average coefficient of variation of the collected sample weights under both high and low flow rates (#80 and #15 settings, respectively) was 55.0% without shocks for the Noble device. With shocks this increased to 65.0%.

An experimental spiral-disk applicator was designed by Holzhei (19). Particle weightlessness occurred when the applicator was subjected to vertical shocks. Therefore Holzhei attempted to solve this problem through particle acceleration. To reduce the effect of vertical shock accelerations on particles entering free fall an outside vertical force was required at the meter discharge outlet. This force must be of sufficient magnitude to retain uniformity of flow under all field conditions. An air blast was selected to supply this force. The air conducted the granules through an air chamber and into the 36 plastic tubes which composed the 13-inch hose-type bander. This metering device had a coefficient of variation of 24.0% without shocks, 36.5% with shocks, and 22.5% with shocks and air for distribution. At low flow rates the spiral uniformity was inferior to that of the Noble unit. Two distinct limitations of the spiral disk were indicated: it was difficult to clean and the upper limit of flow rate was lower than desired. An auger-feed applicator was also developed by Holzhei. However, this device had a distribution much inferior to that of commercial units and the device was discarded.

Price (22) indicated the following results of Noble applicator tests:

1. That very little effect, if any, can be attributed to field shocks.
2. Variation along the row was primarily caused by the flutes on the agitator.
3. Considerably more fluctuation was noticed across the row than along the row.
4. Depth of material in hopper has no significant effect on distribution.
5. The two carriers tested showed no significant difference.
6. The higher the application rate the greater the fluctuation across the row.

THESIS OBJECTIVES

An improved metering device for plot application of granular pesticide is needed. Therefore, this study is undertaken with the following objectives:

1. Develop a granular metering device for uniform field application of pesticide. Emphasis should be on:
    a. Minimizing calibration problems.
    b. Minimizing the effect of vibration on metering uniformity.
2. Compare the developed metering device with the presently used Noble Model 202 experimental plot unit under approximated field vibration conditions.

This study is limited to analysis of the Noble unit and modifications of an experimental cone meter[7] under field simulated conditions.

---

[7] Manufactured by Craftsman Machine Company, Winnipeg, Canada.

SIMULATION OF FIELD VIBRATION

A previous study by this investigator (24) measured field vibration on the cone and Noble meters for typical southeastern South Dakota corn field conditions (this being a plowed and disked field). Acceleration data was used to characterize this vibration. Two essentially periodic frequency components, a low and a high frequency component (LFC and HFC), were observed for the accelerations. The low frequency component was related to field conditions while the high frequency component was associated with the tractor engine vibration. Mean frequencies and mean or maximum mean peak amplitudes of acceleration were selected as the vibration characteristics to be simulated. These values are shown in Table 1.

Mean frequencies (LFC and HFC), mean HFC amplitude and maximum mean peak LFC amplitude of acceleration were considered to characterize the vibration. Mean frequencies and mean HFC amplitude were selected because observed frequencies and HFC amplitudes varied little with speed (24). The maximum mean peak LFC amplitude was used because it was an indication of the most severe conditions experienced under typical field conditions. Therefore, simulated vibration would subject the metering devices to vibration more severe than would be expected in the field. Thus, assuming vibration is detrimental to metering uniformity as is indicated in the Review of Literature, a meter performing satisfactorily under the simulated conditions should do so under typical field conditions.

Besides vibration data, tractor speed and Noble agitator speed were measured in the field tests. The tractor was operated at 3.1 mph when applying pesticide. Therefore, field measurements were made for: 2.6, 3.1 and 3.7 mph. Agitator rotation corresponding to these speeds were: 19, 23 and 27 rpm, respectively. As the cone meter makes one revolution per 90-foot field row, this meter rotates at 2.5, 3.0 and 3.5 rpm, respectively. The 3.7 mph speed was not simulated in the laboratory because it was too high for practical use on the field plots (24). Field vibration characteristics did not vary appreciably with speed. Hence, the criteria for laboratory simulation was based on a combination of the field data for 2.6 and 3.1 mph, see Table 1.

Table 1. Characteristics of Field Vibration on Two Meters

Characteristic*	Noble meter	Cone meter
Max. LFC mean positive** peak amplitude, g	0.30	0.23
Max. LFC mean negative peak amplitude, g	0.21	0.08
Mean of LFC mean frequencies, cps	5.94	5.46
Mean of HFC mean peak amplitudes, g	0.26	0.34
Mean of HFC mean frequencies, cps	180.40	120.60

*Measurements are from two speeds of the John Deere 110 garden tractor--about 2.6 and 3.1 mph at full throttle.

**Positive acceleration amplitudes are downward accelerations (<u>i.e.</u>, directed as the acceleration due to gravity). Negative amplitudes are oppositely directed.

Vibration Simulation Equipment

Since two acceleration frequency components were observed in field vibration data, the need for two exciting mediums for simulation of this vibration was apparent. Study of several previously used systems, such as the spring-mass system and the four-bar parallel linkage with cam exciter described in the Review of Literature, indicated that their performance was unsatisfactory, especially for two excitation frequencies. These systems were also of complex design.

In order to obtain an adjustable simulation device with simplicity of design, it was decided to utilize a tractor treadmill to simulate the low frequency component of vibration; the tractor engine was used to produce the high frequency component. The simulator consisted of a table support for the tractor and a rotating drum for supporting the Noble applicator drive wheel, see Figures I and II. For cone meter tests the rear tractor wheels were placed on the drum, see Figures III and IX. The drum was tuned to simulate LFC vibration through a variable speed drive and a series of sheetmetal strips bolted axially to the drum. The strips are analogous to lobes on a cam (the drum). Tractor engine speed was adjusted to produce the HFC vibration.

Test equipment and instrumentation used for vibration simulation included the following:

± 10g strain gage accelerometer, Type 4-202-0012, Consolidated Electrodynamics Corporation.

10-foot shielded five-wire lead cable.

2-channel Offner Type RS Dynograph Direct Writing Recorder with Type 709 Timer.

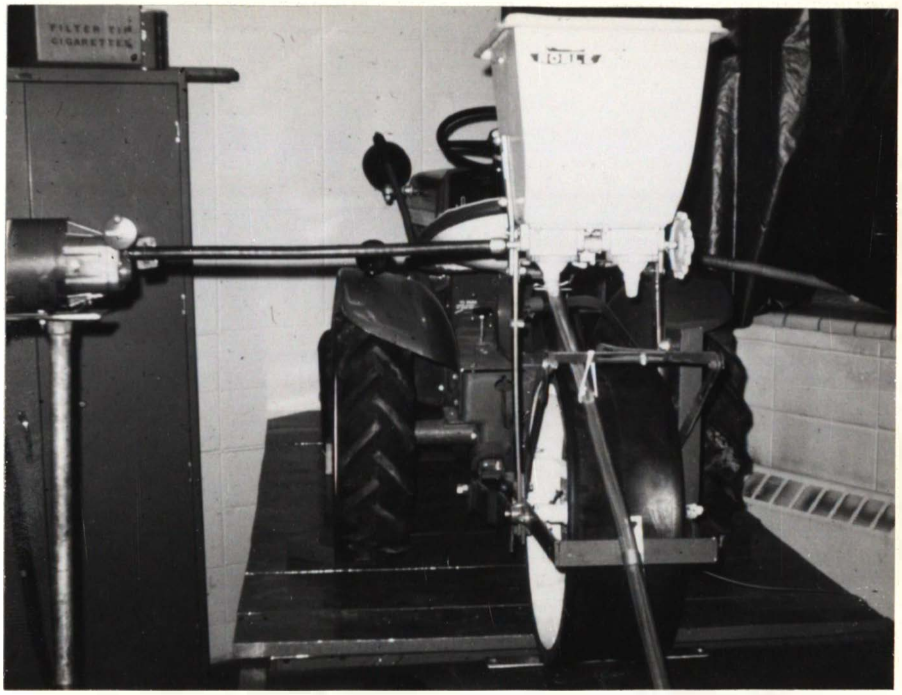

Figure I. Noble Meter on Test Stand

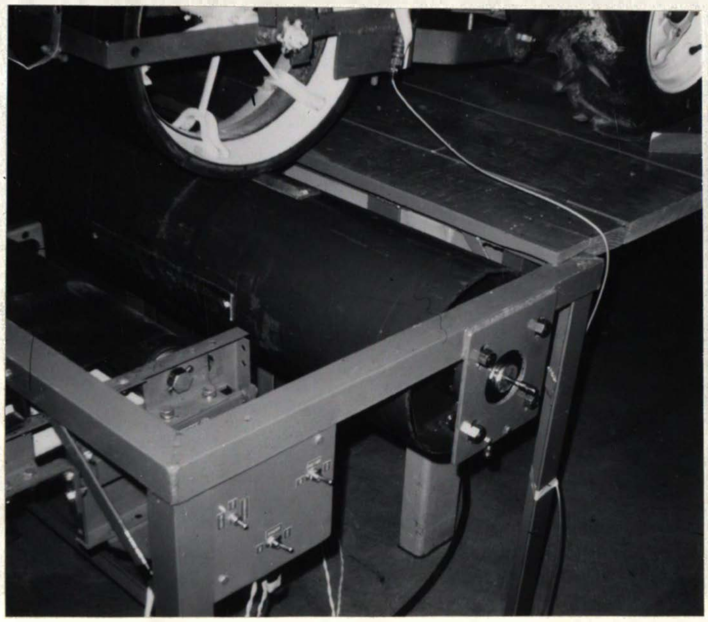

Figure II. Impulse Drum and Control Panel (Lower Left)

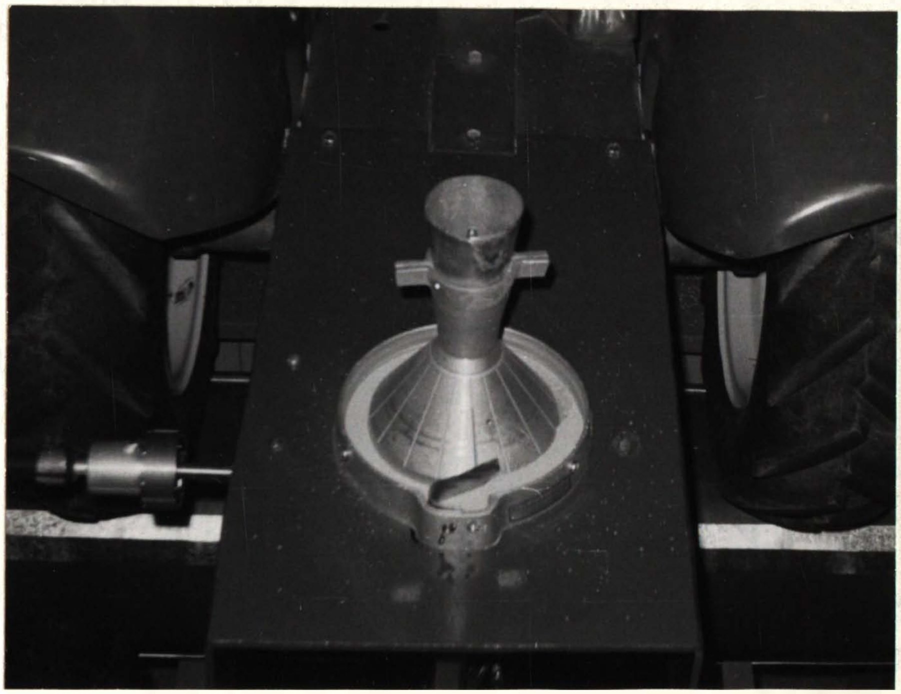

Figure III. Unmodified Cone Meter on Test Stand

Chronotac, Type SG-6, Standard Electric Time Company.

Stop watch.

1/8 horsepower variable speed drive, manually switched, speed range: 0 to 400 rpm.

½ horsepower variable speed drive, manually switched, speed range: 500 to 5,000 rpm.

18:1 gear reducer.

Table for tractor.

Impulse drum, 12x44-inch conveyor pulley.

The accelerometer and Offner recorder with timer were used to measure acceleration versus time on each meter in the field (24). The recorder has a 20% reduction in amplitude response for frequencies above 100 cps. Thus, the acceleration amplitudes in Table 1 for the high frequency component should not be considered as absolute values. However, the same measurement system and calibration procedure were used in monitoring the simulated vibration and in measuring the field vibration. Therefore, comparisons between the two forms of vibration were valid.

Engine speed was measured with the Chronotac and drum speed with the stop watch. The 1/8 hp variable speed unit drove the meter, and the ½ hp unit and gear reducer drove the impulse drum. The test equipment and instrumentation system is shown in Figures I and IV.

Simulation Objectives

The objective of this portion of the study was to approximate the field vibration values in Table 1 in order to later determine metering uniformity under simulated field conditions for speeds of 2.6 and 3.1 mph.

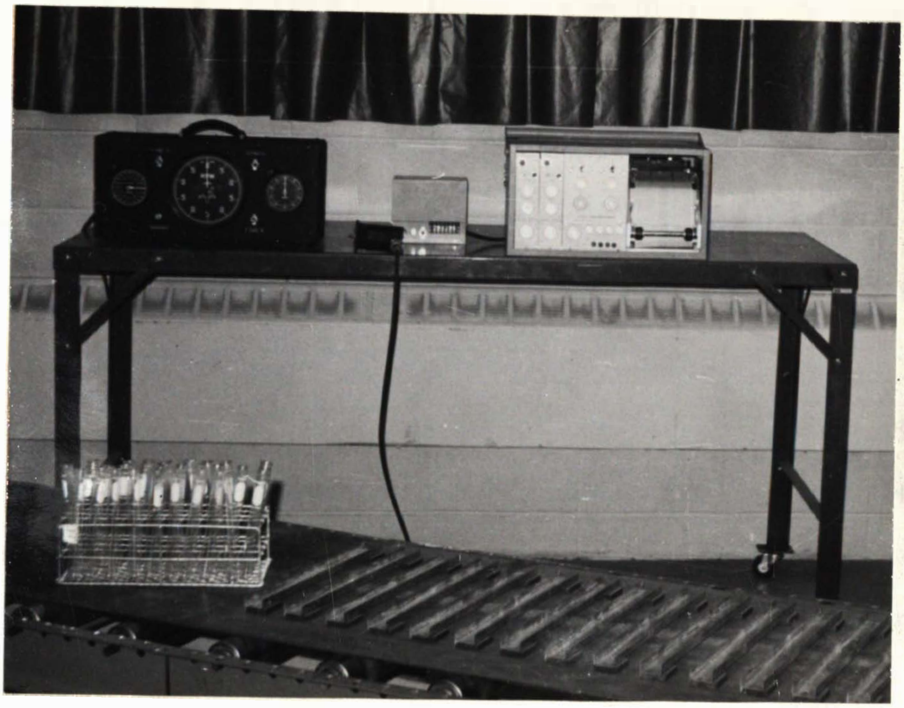

Figure IV. Instruments Employed, Left to Right: Chronotac, Timer and Offner Recorder, Conveyor Collector Trays and Test Tubes in Foreground

Simulation Procedure

A trial and error procedure was used to find the combination of impulse drum speed, lobe size and tractor engine speed which created vibration best simulating the field values. As a starting point calculations were made with the assumption of harmonic motion (17). Four equally spaced lobes (sheetmetal strips) were to be placed on the drum. If each lobe simulated a cycle of the low frequency component, a drum speed of 82 to 92 rpm would be required. However, the final speed needed was about half of this, probably because of unknown properties of the tractor and meter systems. Assuming harmonic motion with the cone meter, for example, yielded the following value for the displacement amplitude:

$$x=A\sin(wt)$$

$$\dot{x}=wA\cos(wt)$$

$$\ddot{x}=-w^2A\sin(wt)$$

$$\ddot{x}_{max}=w^2A=A(2\pi f)^2$$

$$A=\frac{\ddot{x}_{max}}{4\pi^2f^2}$$

where:
x=displacement, inches;
A=maximum displacement, inches;
$w=2\pi f$=frequency, radians/second;
f=frequency, cps;
t=time, seconds;
$\dot{x}$=velocity, inches/second;
$\ddot{x}$=acceleration, inches/second^2;
$\ddot{x}_{max}$=maximum acceleration, inches/second^2.

For the cone meter $f=5.46$ cps and $\ddot{x}_{max}=0.23g(386in/sec/g)$.

$$A=\frac{0.23g(386in/sec^2/g)}{4\pi^2(5.46cps)^2}$$

$$A=0.075 \text{ inch.}$$

This calculated amplitude was comparable to the final trial and error lobe height for vibration simulation which was 0.092 inch. However, the calculated amplitude of 0.080 inch for the Noble meter was much less than the actual 0.140 inch lobes used.

The trial and error procedure for simulating the field vibrations of both meters was as follows:

1. Select lobes of a given height and width. (Values tried varied from 1 to 6 inches in width and up to eight layers of 24 gage sheetmetal.)
2. Calibrate Offner recorder and accelerometer as in the field vibration tests: With the accelerometer upright on a stationary, level surface zero the recorder pen. Then invert the accelerometer 180°, and set the pen deflection to the desired level (40 millimeters) with the recorder gain adjustment. Inversion of the accelerometer results in a 2g output. Thus, the recorder was calibrated for 0.05g/mm of pen deflection (24).
3. Record acceleration traces with only the impulse drum running. Vary the drum speed to obtain a frequency near the LFC frequency to be simulated. Changing the lobe width may also affect frequency.
4. If the simulated peak positive amplitude of the low frequency component (as determined by spot checks on the trace) is different from the desired value, increase or decrease lobe height to respectively increase or decrease the peak amplitude.
5. When simulation of the low frequency component is approaching the desired values, start the tractor engine to superimpose the high frequency component upon the low component. Record acceleration traces at various engine speeds until the

desired HFC frequency and amplitude is obtained.

6. Check the overall simulation of both vibration components and make minor changes in the test stand if necessary.

Such factors as added weight and change of tire pressure were found to have negligible effect on the simulated components. Higher engine speeds increased peak HFC amplitudes, but the HFC frequency changed little unless large changes in engine speed were made.

Simulation Results

Simulation of field vibration for the cone meter proved to be relatively easy. Although the desired values in Table 1 were not exactly attained, the simulated vibration closely approached field values. The simulated vibration characteristics are shown in Table 2.

For the Noble meter no means was found to reduce the LFC frequency below 7.00 cps. A rubber tire was added to the press wheel when the unit was placed on the test stand to reduce the shock effect of the impulse drum. The tire and several other factors studied did not appear to be the cause of this problem. It was concluded that the desired values and the actual test stand values did not differ enough to be of major concern.

Table 2. Characteristics of Simulated Vibration on Two Meters

Characteristic*	Noble meter	Cone meter
LFC positive peak amplitude, g	0.25	0.25
LFC negative peak amplitude, g	0.20	0.20
LFC frequency, cps	7.00	5.40
HFC peak amplitude, g	0.30	0.30
HFC frequency, cps	178.57	119.05

*See below for method of analysis.

The simulated vibration values were determined by analyzing a "typical" cycle block (5 cycles of vibration for the low frequency component and 20 cycles for the high frequency component). This procedure was justified by the periodicity of the simulated vibration. Within the LFC cycle block a line was sketched through the acceleration trace following the general trend of the low frequency component and through the middle of the high frequency component. The LFC peak positive and negative amplitudes were measured from the zero acceleration line to the sketched line. The LFC frequency was determined from the recorder chart speed (125 millimeters/second), the chart length of the block and the number of cycles per block. The HFC frequency was determined in the same manner. The peak HFC amplitude within the HFC cycle block was recorded. Analysis of field vibration data consisted of a similar procedure (24).

The test stand input values needed to obtain the simulated vibration are indicated in Table 3. The same vibrational values were used, on a given meter, for both speeds tested (2.6 and 3.1 mph) in the meter tests which followed. A comparison of field and simulated vibration traces is shown in Figure V for a field speed of 3.1 mph.

Table 3. Test Stand Settings for Vibration Simulation

Input	Noble meter	Cone meter
Tractor engine speed, rpm	3266	3710
Impulse drum speed, rpm	38	44
Lobe height, inches (4 on drum)	0.140 6 layers of 2-inch-wide sheetmetal, 24 gage	0.092 4 layers of 2-inch-wide sheetmetal, 24 gage

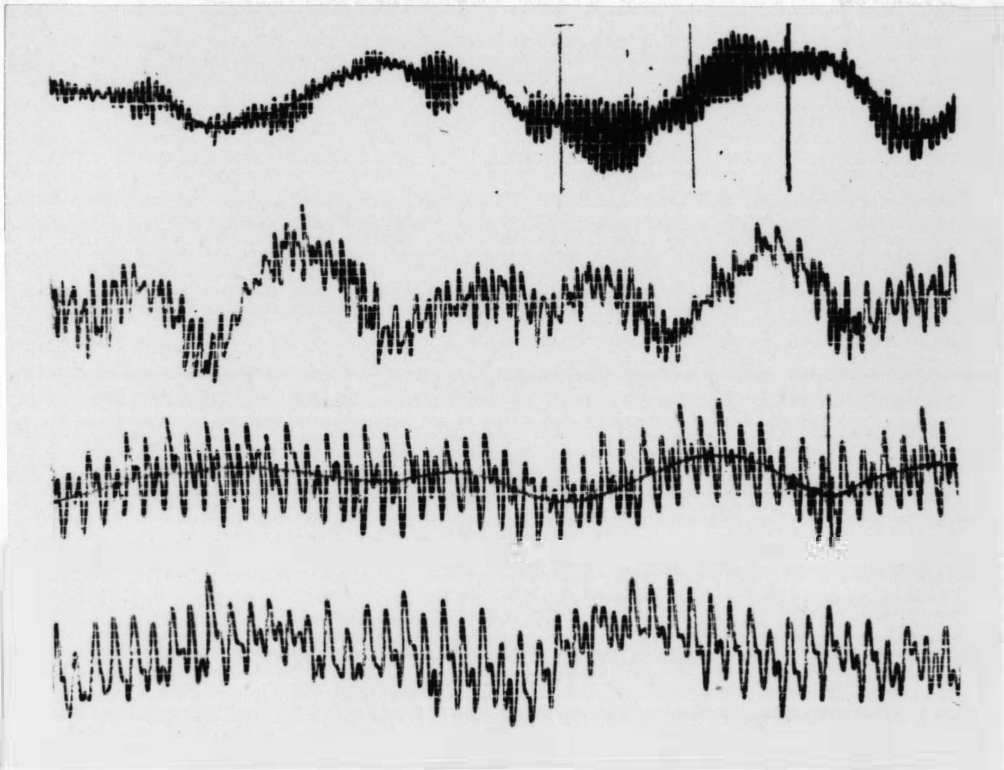

Figure V. Comparison of Field and Simulated Vibration on Noble and Cone Meters, Top to Bottom: Noble Field Vibration, Noble Simulated Vibration, Cone Field Vibration and Cone Simulated Vibration

METER TEST EQUIPMENT AND PROCEDURE

After the field vibration simulation was completed for the Noble and cone meters, it was possible to analyze the distribution of granules from these units under approximated field conditions. Metering tests were the means utilized for establishment of a criteria for evaluating modifications of the cone meters. The meters tested are described below.

Description of Metering Devices

The Noble Model 202 meter is a commercial unit utilizing the grass seeder principle. A fluted, rubber agitator rotates above a variable, slotted orifice. The agitator has six flutes. The orifice has setting numbers ranging from 0 to 50, the latter giving the highest application rate. The applicator is seen in Figure I, and a schematic diagram of the meter mechanism is shown in Figure VI.

The cone meter was selected over the belt-type meter as a possible replacement for the Noble unit because of the relative merits of these two meters as listed in the Review of Literature. The cone meter is designed for single-row application while the Noble unit may be used on several rows without refilling the hopper with pesticide. The dismantled, unmodified unit is shown in Figure VII; the assembled unit in Figure III. The amount of granules to be metered onto one field row are placed in the loader. When the loader is raised, the cone distributes the granules onto its base plate. Rotation of the cone and base plate causes the granules to be discharged by the deflector. The meter makes one revolution per row, and must be refilled after each row.

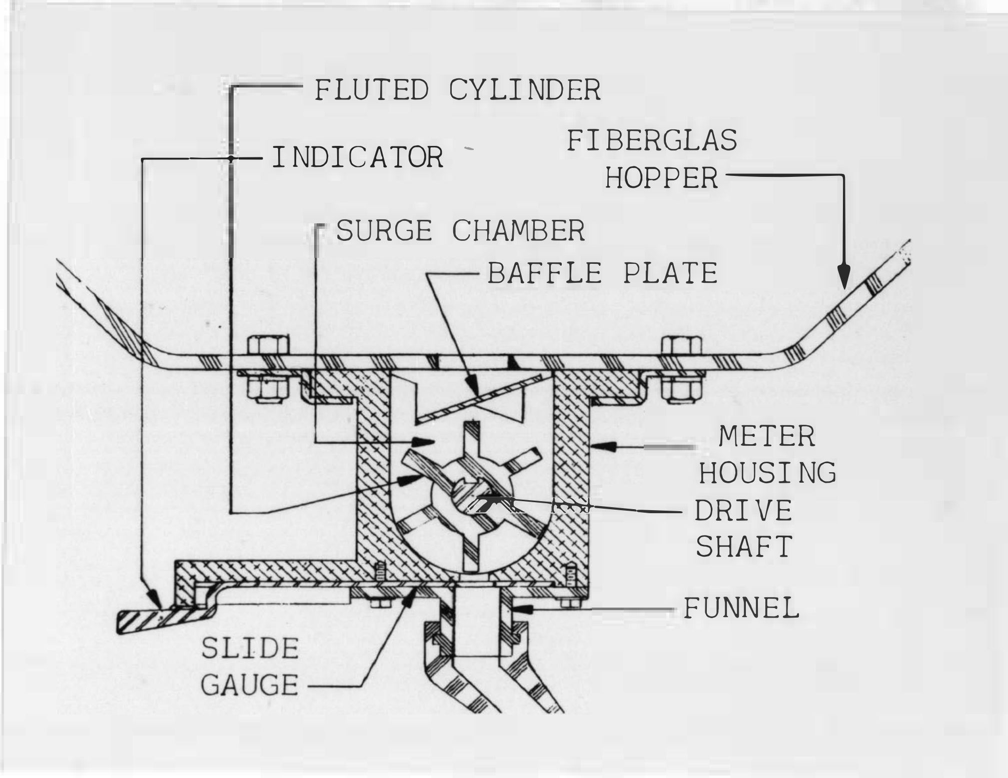

Figure VI. Noble Meter Schematic Diagram

Figure VII. Cone Meter, Left to Right and Bottom to Top:
Delivery Tube, Drive Gear, Bushing, Loader,
Discharge Funnel, Cone Base, Bushing,
6-inch Scale, Deflector, Cone
with Base Plate and
Windshield

Modifications of the Cone Meter

After initial metering tests had been completed on the unmodified cone meter, several modifications were made in an attempt to improve the distribution of the unit. These modifications are shown in Figure VIII. Not pictured is the third modification. The meter modifications are described in detail below.

For the first modification a new deflector and a back plate were added to the cone meter. The back plate was needed to prevent the granules from sliding to the rear on the base plate while the unit was rotating. Prior to loading the meter the cone base had to be positioned to permit about one revolution of the base before the back plate reached the deflector and a stop. The stop and a slip clutch in the meter drive prevented the cone base from rotating the back plate against the deflector. A build-up of granules at the back plate during meter operation showed that this was not a completely effective addition. The deflector was similar to the one on the unmodified meter; however, it was larger to accommodate the high flow rates. A flaired portion at the top of the deflector was in contact with the cone, and prevented granules from falling behind the deflector when the meter was loaded. The base was positioned such that the back plate was behind the deflector when loading the meter with granules.

The second modification of the cone meter utilized a different deflector than the first modification. This deflector was designed to reduce the size of the meter discharge orifice. The orifice size was about one-third of that for the first modification. The back plate was also used on this unit. The deflector change was an attempt to reduce

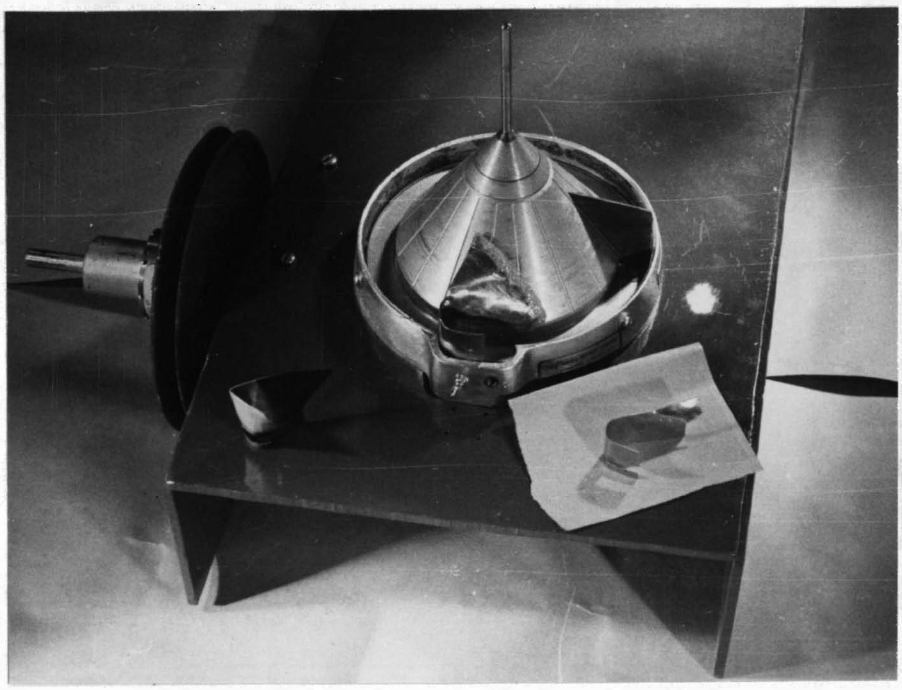

Figure VIII. Modifications of the Cone Meter, Left to Right:
Deflector from Second and Third Modifications,
Deflector from First Modification (on
Meter), Deflector from Unmodified
Unit and Back Plate (on Meter)
used for all Three
Modifications

the effect of low frequency vibration on meter performance.

The third modification was similar to the second modification except that a circular extension was added to the cone base. This extension prevented granule overflow from the meter at high flow rates. The extension and deflector were Teflon[8] coated to reduce the frictional force and the build-up of granules at the back plate.

Meter Test Equipment

Meter tests have been conducted by several researchers (2, 14, 19, 22). Of the various types of equipment employed by them, the conveyor collecting device was selected for use in this study because of its simplicity of design and adaptability for other purposes. A flat belt conveyor was used to collect samples of the meter discharge. It was driven at applicator field speeds by a variable speed drive. The drive unit was adjusted to give the desired belt speed with the aid of the Chronotac. A 6-foot section of the belt was divided into 30 sampling intervals. In each interval a 1-inch wide sheetmetal tray ½ inch high and 12 inches long was used to collect granule samples for distribution analysis. Permanent magnets epoxied to the belt held the collector trays in place. The 30 trays were equally spaced on the belt to obtain a sample for every 2.4 inches of the belt in the 6-foot sampling interval. The sampling interval was selected as 6 feet because it represents a fractional portion of the 90-foot field row and because

---

[8] Manufactured by E. I. Du Pont De Nemours and Company, Inc., Wilmington, Delaware.

this was the maximum length allowable in order to stop the belt before the trays were emptied over the end of the conveyor after collecting samples of the meter discharge. A solenoid-actuated brake on the drive unit was used to stop the belt. With the 6-foot sampling interval on the belt and belt speeds of 2.6 and 3.1 mph the times required for the collector trays to pass under the meter discharge tube were 1.57 and 1.32 seconds, respectively. This gave 1/15 revolution of the cone meter per test and about three agitator flutes passing over the orifice in each Noble meter test as Holzhei (19) had used.

A control panel, see Figure II, mounted on the impulse drum support allowed individual control of the meter drive, impulse drum drive, conveyor drive and conveyor brake. The conveyor drive and brake were manually switched for the Noble meter tests. For the cone meter tests these were automatically controlled by a micro switch and cam actuator attached to the rotating cone drive shaft. This insured that the same portion of the cone revolution would be sampled in each test provided that the conveyor was always started from the same position for each test at a given belt and meter speed. The starting positions of the belt for the two speeds used were determined by trial and error. The back plate addition to the cone meter prevented the meter from making more than one revolution. Therefore, a slip clutch was added to the meter drive train. After each test the cone base had to be returned to its starting position.

The equipment necessary to measure granule distribution from the meters included:

15-foot conveyor, with 18-inch wide flat belt.

30 sheetmetal collector trays, $\frac{1}{2}$x1x12 inches, each attached to the belt with two permanent magnets.

3/4 horsepower variable speed drive, with solenoid-actuated brake, speed range: 0 to 350 rpm.

Manual switch, single pole double throw (Noble meter only).

Micro switch, single pole double throw (cone meter only).

Slip clutch, 3 to 30 inch-pounds (cone meter only).

The test apparatus is shown in Figures IV and IX.

Meter Test Procedure

The meter tests were conducted with a nontoxic, inert, attapulgite clay carrier material in equilibrium with room temperature and humidity. Florex[9] 16/30 mesh AA-RVM granules were used in all tests since this type and size of carrier material is one of the most commonly used for pesticide formulations. A sieve analysis was conducted on a 100 gram sample of the granules with a Soil Test[10] Model CL-392-B shaker and U. S. Standard Series sieves. The shaker was run for 2 minutes. Tabulated results of the sieve analysis are included in Appendix A along with physical properties of the granules.

Rates of granule application used for the tests were representative of the low, median and high rates applied in the field. Since the cone meter is designed for application on one 90-foot row while the

---

[9] Manufactured by the Floridin Company, New York, New York.

[10] Manufactured by Soil Test, Inc., Chicago, Illinois.

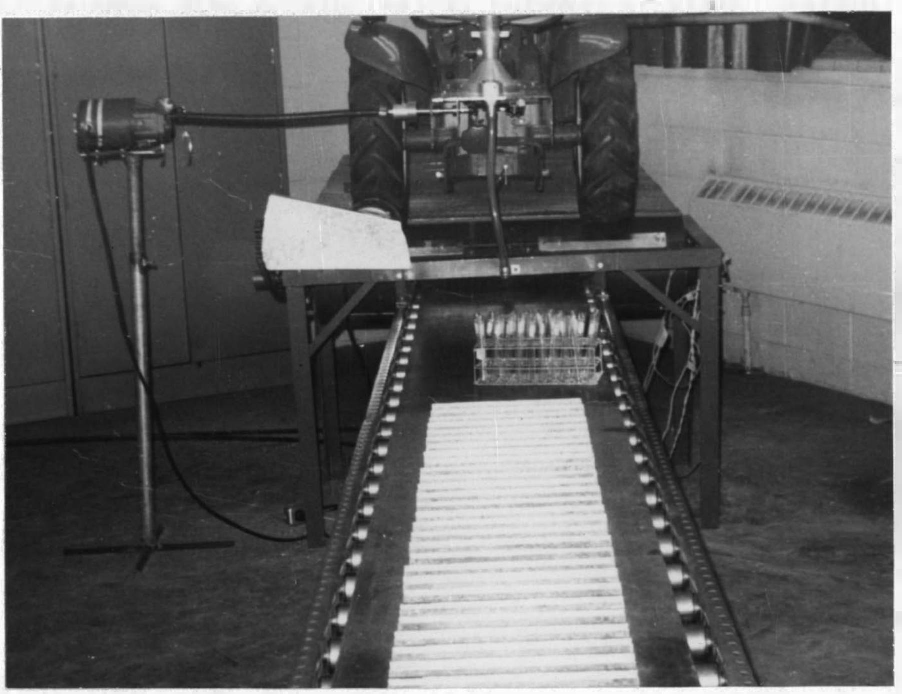

Figure IX. Meter Test Apparatus, Bottom to Top: Conveyor with Collector Trays, Test Tubes, Vibration Simulation Stand and Tractor with Cone Meter

Noble unit is used on four rows for one filling of the hopper, the amount of granules used in the cone meter was one-fourth of that used in the Noble meter at the same flow rate. Each meter was tested at two speeds for each of the three flow rates. These test values are summarized in Tables 4 and 5.

The Noble agitator and cone speeds were determined from field test data and are given on page 25. In order to determine the orifice settings of the Noble meter that were necessary for the desired application rates, a calibration test was conducted. The granular discharge was collected and weighed for various orifice settings until the appropriate settings were found to deliver granules at the three rates for both agitator speeds. This procedure was not required for the cone meter because the meter made one revolution per row; therefore, the application rate was governed by the amount of granules initially placed on the cone base plate.

Since the effect of slope was not studied, the meters were tested under level conditions in all cases.

Table 4. Summary of Noble Meter Tests

Meter facts	Tractor field speed* 2.6 mph	Tractor field speed* 3.1 mph
Agitator speed, rpm	19	23
Orifice setting number for low flow rate of 64grams/4rows	11	12
Orifice setting number for median flow rate of 220grams/4rows	32	34
Orifice setting number for high flow rate of 376grams/4rows	39	43

*Tractor field speed was the speed at which the conveyor belt was run in these tests.

Table 5. Summary of Cone Meter Tests

Meter facts	Tractor field speed 2.6 mph	Tractor field speed 3.1 mph
Cone and base plate speed, rpm	2.5	3.0
Granules* added to meter for:		
Low flow rate, grams/row	16	16
Median flow rate, grams/row	55	55
High flow rate, grams/row	94	94

*Granule amounts used in all tests were weighed to the nearest 0.01 gram.

The procedure for the Noble and cone meter tests was as follows:

1. Select test to be conducted.
2. Tune test stand for simulation of field vibration by setting engine speed, impulse drum speed and lobe size to previously determined values.
3. Adjust conveyor belt speed and Noble agitator or cone speed

to the values for the desired test. For the cone meter tests place the conveyor belt in the appropriate starting position.

4. Weigh out the amount of 16/30 mesh Florex granules to be placed in the meter. Adjust orifice setting on Noble meter to obtain desired flow rate.
5. Start the tractor engine.
6. Pour the preweighed granules into the Noble hopper or cone loader. Lift loader to distribute granules on the cone base plate.
7. Start meter and impulse drum drives simultaneously. This simulates starting a field row.
8. Pass conveyor collector trays under the meter delivery tube at the desired speed.
9. Stop the conveyor drive and apply the brake.
10. Stop meter and impulse drum drives and the tractor engine.
11. Transfer the granular content of each tray into a separate test tube using a uniform procedure for all tests.
12. Record the weight of granules in each test tube to the nearest 1/10,000 gram on a Mettler[11/] balance.
13. Clean the meter with an air blast, and prepare for another metering uniformity test.

[11/] Manufactured by Mettler Instrument Corporation, Princeton, New Jersey.

The granules were transferred to test tubes for weighing. The use of six sets of test tubes permitted six tests to be conducted before weighing the collected samples.

DATA ANALYSIS AND PRESENTATION

The weights of granules collected in preliminary meter tests for the Noble unit were used to calculate meter flow rates for comparison with the actual average flow rates (from calibration tests) used in the tests. The calculated flow rates were less than the actual flow rates used. The differences between these values caused by granules bouncing out of the trays during the tests. Thus, such factors as conveyor belt speed, collector tray design and meter flow rate would affect the flow rate as calculated from the amount of granules collected in the trays. Specially designed collector trays would be necessary to overcome this problem; however, this solution was considered impractical. This problem was resolved by limiting comparisons between meter test data to that data from tests which were conducted at the same flow rate and conveyor belt speed. Thus, the only valid data comparisons were between meters tested under identical conditions. However, this would be sufficient to establish a criteria for analyzing the granule distribution from the cone meter and its modifications relative to the distribution from the Noble unit.

Graphical presentation of the meter test data is included in Appendix B for the Noble and unmodified cone meters, see Figures XII through XV. Weight of granules collected is plotted versus tray number; tray number one being the first tray to pass under the delivery tube.

Statistical Design

In order to compare the distribution uniformity of the two meters some measure of the variability in the collected samples of granule discharge was needed. The variance, s^2, of the weights of the samples was selected as this indication of variability. The coefficient of variation ($\frac{s}{\bar{x}} \times 100$, where s= sample standard deviation, and $\bar{x}$= sample mean) of the collected weights as used by Holzhei (19) was not valid in this study because the variability of the weights, and not the effect of the mean, was of interest.

A two-tailed F test[12] was the criteria used to statistically compare the variances of the distribution from the two meters (or their uniformity) operated under like conditions (25). The probability levels of 0.05 and 0.01 for indication of significant differences in uniformity were selected prior to running the tests. The variances and F values from comparison of the metering uniformity of the unmodified cone meter to that of the Noble meter are shown in Table 6. Comparisons for the first, second and third modifications of the cone meter are seen in Table 7.

---

[12] $F = \frac{\text{Larger } s^2}{\text{Smaller } s^2}$, where both the numerator and denominator variances have 29 degrees of freedom. Two-tailed F=2 x one-tailed F.

Data Analysis

Table 6. Comparison of Metering Uniformity of Noble Meter and Unmodified Cone Meter

Test conditions		Variance, s^2			
Speed, mph	Flow rate, grams/row	Noble meter	Unmodified cone meter	F	Smaller variance
2.6	16	0.00002272	0.00001418	1.60	Cone
	55	0.00025000	0.00014861	1.68	Cone
	94	0.00021716	0.00114960	5.29**	Noble
3.1	16	0.00002136	0.00001122	1.90	Cone
	55	0.00021363	0.00035260	1.65	Noble
	94	0.00015880	0.00100629	6.34**	Noble

**Significantly different at the 0.01 level, $F_{.01}(29,29)=2.68$.

Table 7. Comparison of Metering Uniformity of Noble and Modified Cone Meter

	Test conditions				
Cone modification	Speed, mph	Flow rate, grams/row	Variance, s^2	F	Smaller variance
First	2.6	16	0.00002064	1.10	Cone
		55	0.00031017	1.24	Noble
		94	0.00078017	3.59**	Noble
	3.1	16	0.00002028	1.05	Cone
		55	0.00050764	2.38*	Noble
		94	0.00044040	2.77**	Noble
Second	2.6	16	0.00003551	1.56	Noble
		55	0.00042005	1.68	Noble
		94	0.00184832	8.51**	Noble
	3.1	16	0.00001753	1.22	Cone
		55	0.00047605	2.23*	Noble
		94	0.00156334	9.84**	Noble
Third	2.6	16	0.00003601	1.58	Noble
		55	0.00045780	1.83	Noble
		94	0.00102668	4.73**	Noble
	3.1	16	0.00005473	2.56*	Noble
		55	0.00014970	1.43	Cone
		94	0.00116031	7.31**	Noble

*Significantly different at the 0.05 level, $F_{.05}(29,29)=2.10$.
**Significantly different at the 0.01 level.

Inspection of Tables 6 and 7 shows that the cone meter did not have statistically superior uniformity compared to the Noble meter under any of the test conditions; whereas, the Noble unit uniformity was significantly better than that of the cone meter at the high flow rate in all cases. After analyzing the first modification of the cone meter for metering uniformity, a slight improvement in uniformity was noted at the high flow rate. However, the Noble uniformity was still significantly better. Hence, it was decided at this point to investigate possible causes of the variability in the cone meter discharge at the high flow rate.

Vibration appeared to be the main cause of the variability of the cone meter. Therefore, a test was devised to determine the effect of the components of vibration upon metering uniformity. Both the Noble meter and the first modification of the cone meter were subjected to this test following a procedure similar to that described on page 48. Instead of testing the meters under simulated vibration, they were tested under no vibration, engine (HFC) vibration only, and impulse drum (LFC) vibration only. The vibration component tests were considered as separate experiments for the two meters. The metering uniformity of each meter was determined for each test condition listed above at the high flow rate only. Variance of the collected weights was again used as the criteria for uniformity. The condition of no vibration was used as a control for comparison with the uniformity at other components of vibration. A one-tailed F test (25) was used in these tests to statistically determine the significant vibration factors affecting metering uniformity. The statistical analysis is shown in Tables 8 and 9. The uniformity data from previous tests under simulated vibration were included for comparison purposes. Metering uniformity graphs of the component tests are seen in Figures X and XI.

Table 8. Analysis of Vibration Effects on First Modification of Cone Meter at High Flow Rate

Test conditions			
Speed, mph	Vibration component	Variance, s^2	F***
2.6	No vibration	0.00003970	----
	Engine only	0.00006578	1.66
	Drum only	0.00049717	12.52**
	Engine and drum	0.00078017	19.65**
3.1	No vibration	0.00008641	----
	Engine only	0.00007226	0.84
	Drum only	0.00048127	5.57**
	Engine and drum	0.00044040	5.10**

**Significantly different at 0.01 level, $F_{.01}(29,29)=2.42$.

***$F(29,29)=\frac{\text{Component } s^2}{\text{Control } s^2}$.

Table 9. Analysis of Vibration Effects on Noble Meter at High Flow Rate

Test conditions			
Speed, mph	Vibration component	Variance, s^2	F
2.6	No vibration	0.00030137	----
	Engine only	0.00036588	1.21
	Drum only	0.00045658	1.52
	Engine and drum	0.00021716	0.72
3.1	No vibration	0.00007123	----
	Engine only	0.00010247	1.44
	Drum only	0.00009719	1.36
	Engine and drum	0.00015880	2.23*

*Significantly different at the 0.05 level, $F_{.05}(29,29)=1.86$.

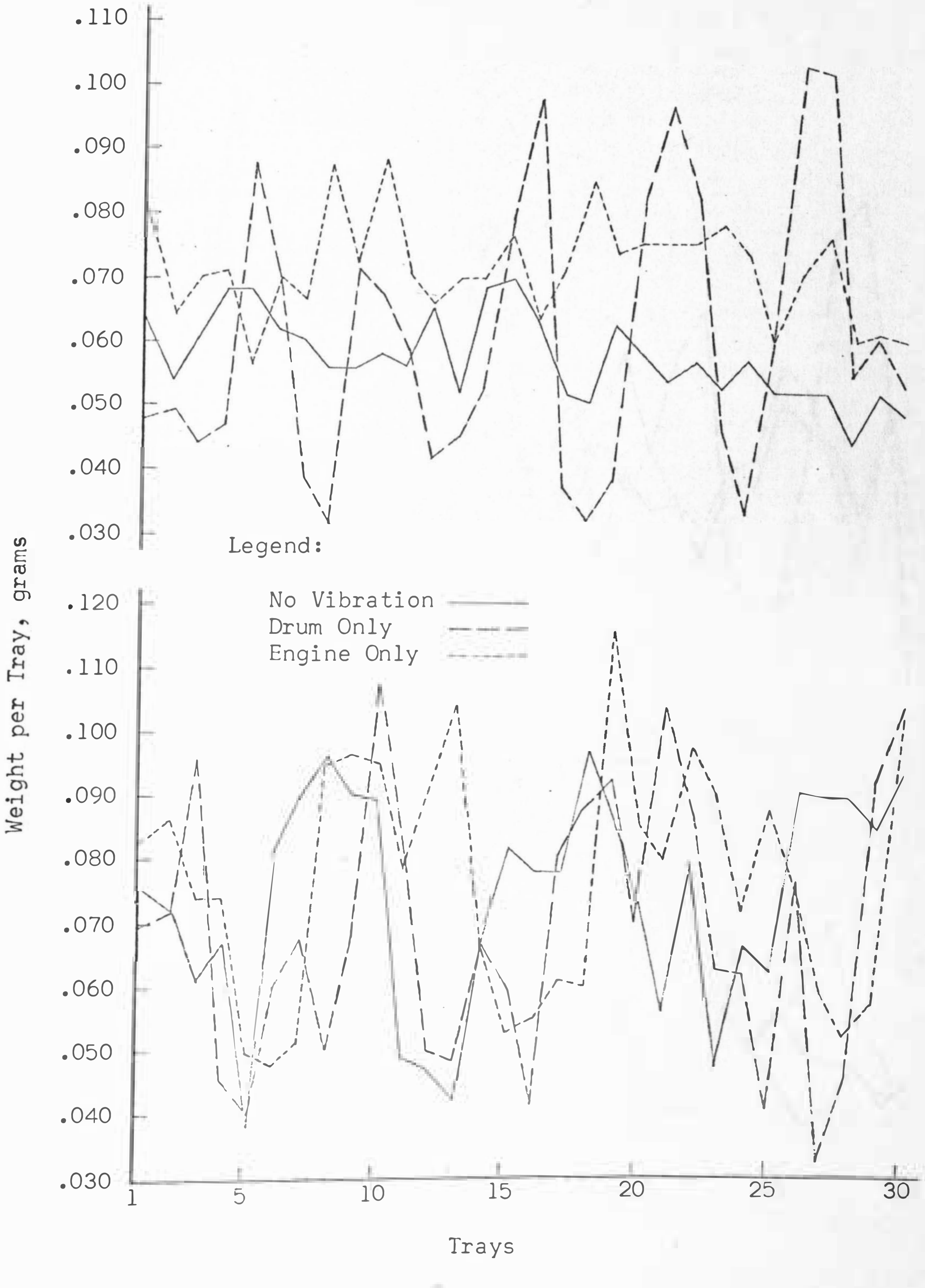

Figure X. Vibration Component Tests of Noble (Bottom) and Cone (Top) Meters: High Flow Rate, 2.6 mph

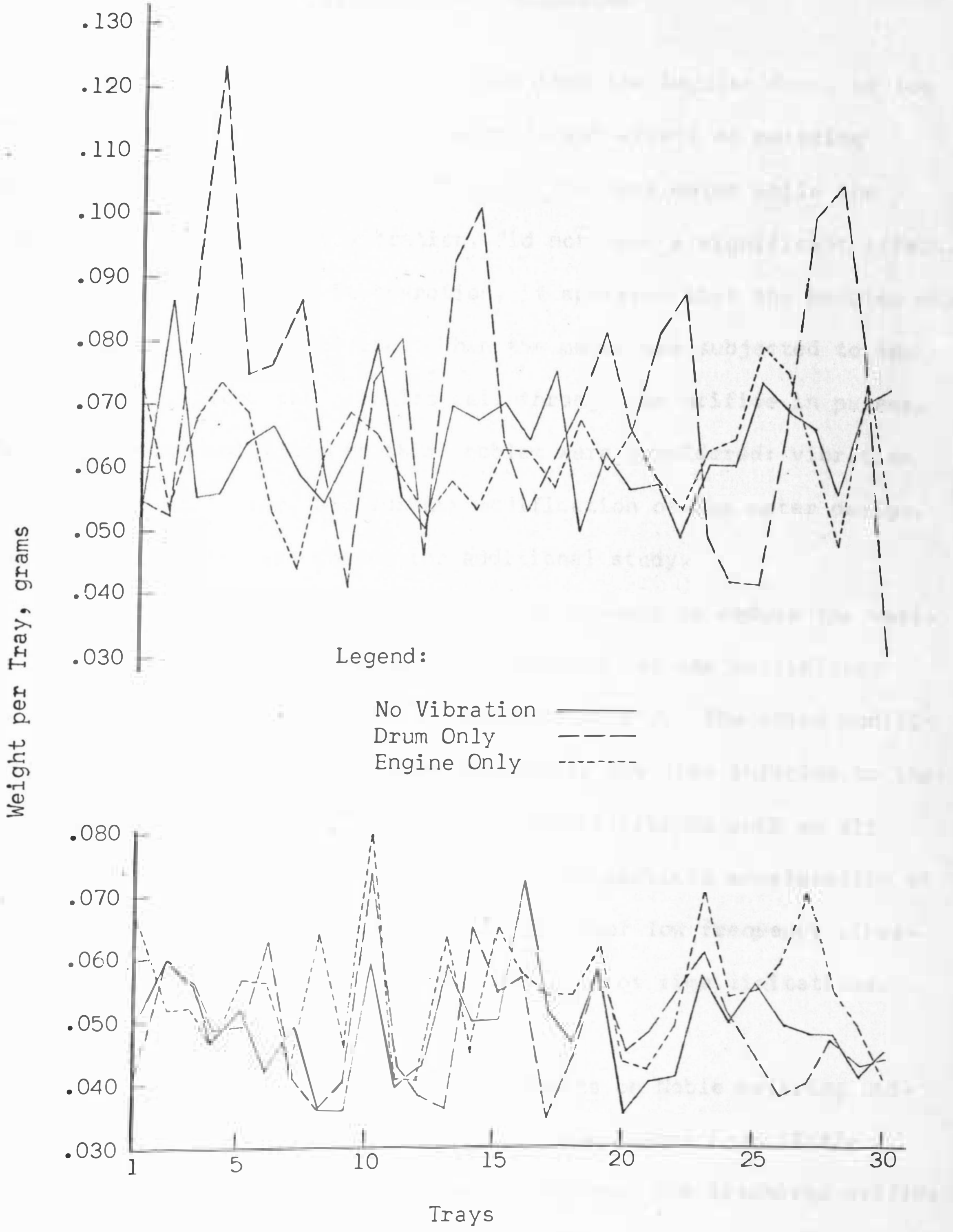

Figure XI. Vibration Component Tests of Noble (Bottom) and Cone (Top) Meters: High Flow Rate, 3.1 mph

RESULTS AND CONCLUSIONS

Examination of Table 8 indicates that the impulse drum, or low frequency vibration, had a highly significant effect on metering uniformity for the first modification of the cone meter while the engine, or high frequency vibration, did not have a significant effect. From observing the meter in operation, it appeared that the problem was at the meter discharge orifice. When the meter was subjected to low frequency vibration, the granules fell through the orifice in pulses. Two alternative solutions to this problem were considered: vibration isolation of the meter, and further modification of the meter design. The latter solution was chosen for additional study.

The second cone modification was an attempt to reduce the variability caused by the low frequency vibration, but the variability increased for this modification as seen in Table 7. The third modification, identical to the second in principle, was also inferior to the first modification. Possibly some other modifications such as air transport of the granules or another means of particle acceleration at the discharge orifice would reduce the effect of low frequency vibration on metering uniformity. However, because of time limitations, further study was not conducted.

Analysis of vibration component effects on Noble metering uniformity, Table 9, indicates that vibration components have little effect on uniformity. The agitator rotating over the discharge orifice does, however, have a cyclic effect on the flow rate as seen in Figures X and XI for the curves from the tests with no vibration. About three peaks in the flow rate may be seen on both curves. This can be attributed to the three agitator flutes which pass over the orifice during a test. Under vibration conditions this agitator effect, or some other meter characteristic, reduces the effect of vibration on metering uniformity compared to that of the cone meter.

Based on the findings of this study, it can be concluded that the Noble Model 202 meter had a metering uniformity significantly better than the cone meter at higher flow rates. Modification of the cone meter did little to alleviate the effect of low frequency vibration which was the major cause of the metering variability. Although use of the cone meter would reduce calibration time, the overall superiority of metering uniformity for the Noble meter precludes replacement of this unit by the cone meter at this time.

SUMMARY

An experimental cone-type meter was selected for further development as a plot applicator of granular pesticides. The cone meter was chosen over other types of meters because it had ease of calibration and other stated advantages as outlined in the Review of Literature. The metering uniformity of this meter, with and without modification, was statistically inferior to the presently used Noble Model 202 applicator under simulated field conditions, especially at high application rates. The high metering variability of the cone meter was attributed to the effect of low frequency vibration. Modifications attempted on the cone meter were not solutions to this problem. Thus, until some means is found to reduce the effect of low frequency vibration on the metering uniformity of the cone meter, this unit should not replace the Noble meter for application of granular pesticides.

LITERATURE CITED

1. "Agricultural Products for Granular Formulations." Technical Information Bulletin No. 153. Minerals and Chemicals Division of Minerals and Chemicals Philipp Corporation, Menlo Park, New Jersey. January 1966.

2. Becker, C. F. and Costel, G. L. "The Effect of Relative Humidity on the Application of Pesticides to Agricultural Crops." Humidity and Moisture, Vol. 2, Chapt. 28, pp. 226-230. 1963.

3. Becker, C. F., Costel, G. L., Hood, G. and Alley, H. P. "Equipment for Metering, Distributing and Mixing Granular Herbicides into Bands." Transactions of the ASAE, Vol. 3, No. 2, pp. 108-110. 1960.

4. Becker, C. F. and Costel, G. L. "Metering and Distributing Granular Carriers for Pesticides." Paper No. 62-609. American Society of Agricultural Engineers. December 1962.

5. Bowers, W. "Calibrating and Adjusting Granular Row Applicators." Circular No. 839. University of Illinois, College of Agriculture Extension Service, Urbana, Illinois. October 1961.

6. "The Design of an Insecticide Applicator for Plot Use." Unpublished Class Project. Agricultural Engineering 452, Agricultural Engineering Department, South Dakota State University, Brookings, South Dakota. Spring Semester 1966.

7. "Florex Granular Mineral Absorbent Basic Data." The Floridin Company, New York, New York.

8. Dudley, R. F. and Ridgway, R. L. "Applicator for Precision Placement of Chemicals in Soil." Publication No. 42-123. Agricultural Research Service, United States Department of Agriculture. October 1966.

9. Futral, J. G., Head, Agricultural Engineering Department, University of Georgia, Experiment, Georgia. Personal Correspondence. April 18, 1966.

10. Futral, J. G., Reid, J. T. and Butler, J. L. "Precision Metering Device for Fertilizers and Other Materials Used in Field Plot Work." Mimeograph Series N. S. 34. University of Georgia Agricultural Experiment Stations, Athens, Georgia. March 1957.

11. Gebhardt, M. R., Day, L. C. and Read, K. "Metering Characteristics of Granular Herbicides." Paper No. 67-637. American Society of Agricultural Engineers. December 1967.

12. Gunkel, W. W. "Applicators Designed for Pesticide Research." Farm Research, Vol. 28, No. 1, pp. 2-3. 1962.

13. Gunkel, W. W. and Holzhei, D. E. "Design and Development of New Granular Applicators." Paper No. 66-112. American Society of Agricultural Engineers. June 1966.

14. Gunkel, W. W. and Hosokawa, A. "Laboratory Device for Measuring Performance of Granular Pesticide Applicators." Transactions of the ASAE, Vol. 7, No. 1, pp. 1-5. 1964.

15. Gunkel, W. W. and Price, D. R. "Measuring Distribution Patterns of Granular Applicators." Transactions of the ASAE, Vol. 8, No. 3, pp. 423-425. 1965.

16. Harmond, J. E., Rampton, H. H. and Yoder, E. E. "Precision Planter and Fertilizer Applicator for Use on Experimental Plots." Miscellaneous Publication No. 962. Agricultural Research Service, United States Department of Agriculture. March 1965.

17. Harris, C. M. and Crede, C. E. <u>Shock and Vibration Handbook.</u> Vol. 1. McGraw-Hill Book Company, Inc., New York. 1961.

18. Hedden, O. K., Wilson, J. D. and Sleesman, J. P. "Equipment for Applying Soil Pesticides." Agricultural Handbook No. 297. Agricultural Research Service, United States Department of Agriculture. January 1966.

19. Holzhei, D. E. "The Design and Development of a New Granular Pesticide Applicator." Unpublished M. S. Thesis. Cornell University, Ithaca, New York. June 1965.

20. Lovely, W. G. and Mahlstede, J. P. "Application of Granular Herbicides to Ornamental Plant Materials in Nurseries." Publication No. 42-96. Agricultural Research Service, United States Department of Agriculture. May 1966.

21. Millier, W. F. and Romig, B. E. "Determination and Simulation of Field Machine Vibrations." Paper No. 66-603. American Society of Agricultural Engineers. December 1966.

22. Price, D. R. "The Development of Laboratory Apparatus for Determining the Distribution Pattern of Granular Applicators." Unpublished M. S. Thesis. Cornell University, Ithaca, New York. January 1963.

23. Romig, B. E. "The Development of Apparatus Suitable for the Laboratory Testing of Granular Fertilizer Metering Equipment." Unpublished M. S. Thesis. Cornell University, Ithaca, New York. September 1964.

24. Stangl, G. A. "Measuring Field Vibration on Two Plot Applicators of Granular Pesticide." Unpublished Special Problem. Agricultural Engineering 750, Agricultural Engineering Department, South Dakota State University, Brookings, South Dakota. February 1968.

25. Steel, R. G. D. and Torrie, J. H. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc., New York. 1960.

APPENDIX A

Table 10. Physical Properties of Florex RVM Granular Carrier Material (7)

Property	Value
Color	Light gray
Combined moisture, %	9--12
Surface area, meters^2/gram	125-135
Angle of repose, degrees	30--33
Specific gravity	2.5
Packed bulk density, pounds/foot^3	36--38

Table 11. Sieve Analysis of Florex 16/30 Granules

U. S. Standard sieve number	Cumulative percent retained	Percent finer by weight
16	0.1	99.9
20	35.5	64.5
30	83.8	16.2
40	96.8	3.2
50	98.0	2.0
80	98.7	1.3
100	98.8	1.2

APPENDIX B

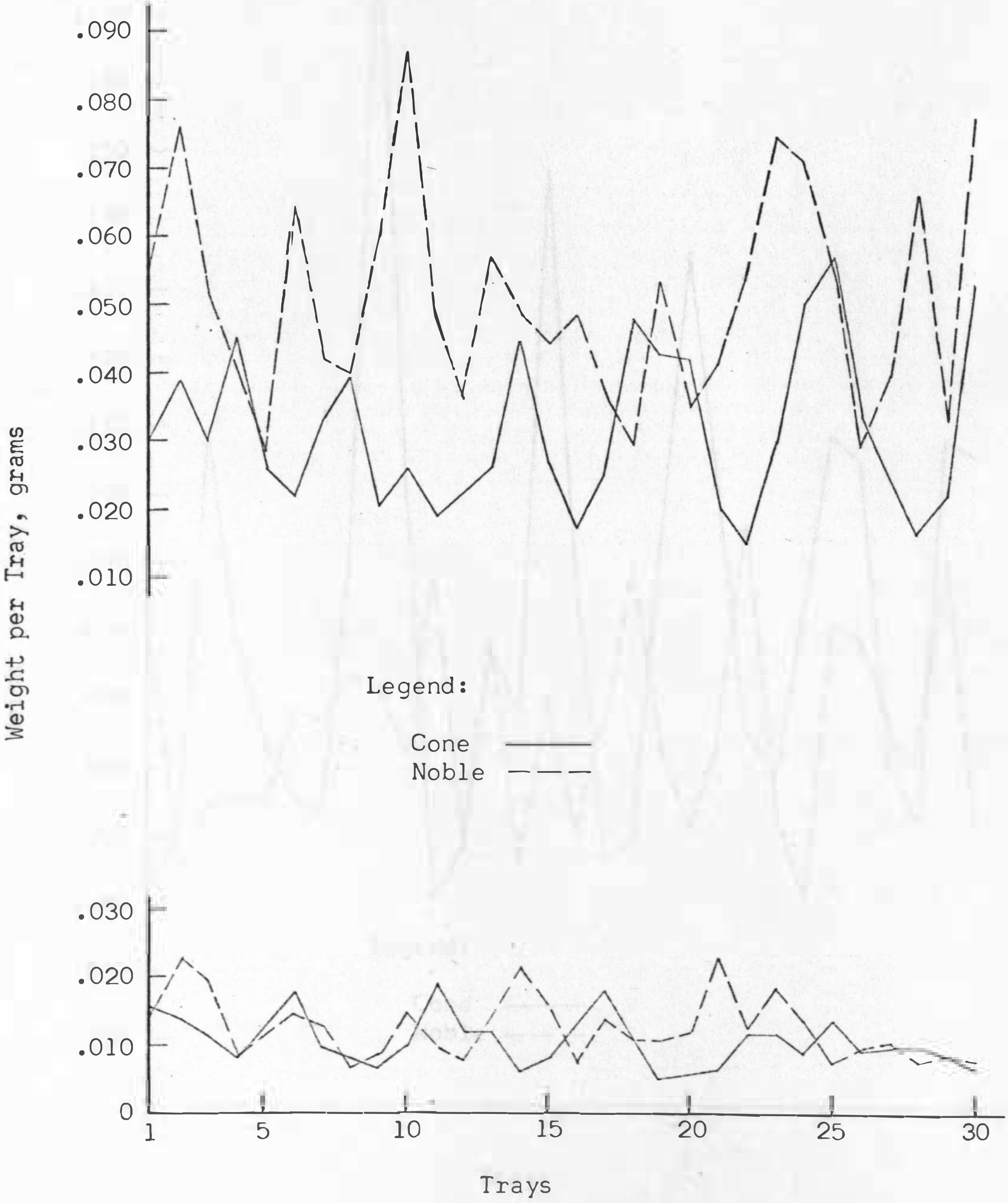

Figure XII. Metering Uniformity of Unmodified Cone and Noble Meters: Low and Median Flow Rates, 2.6 mph

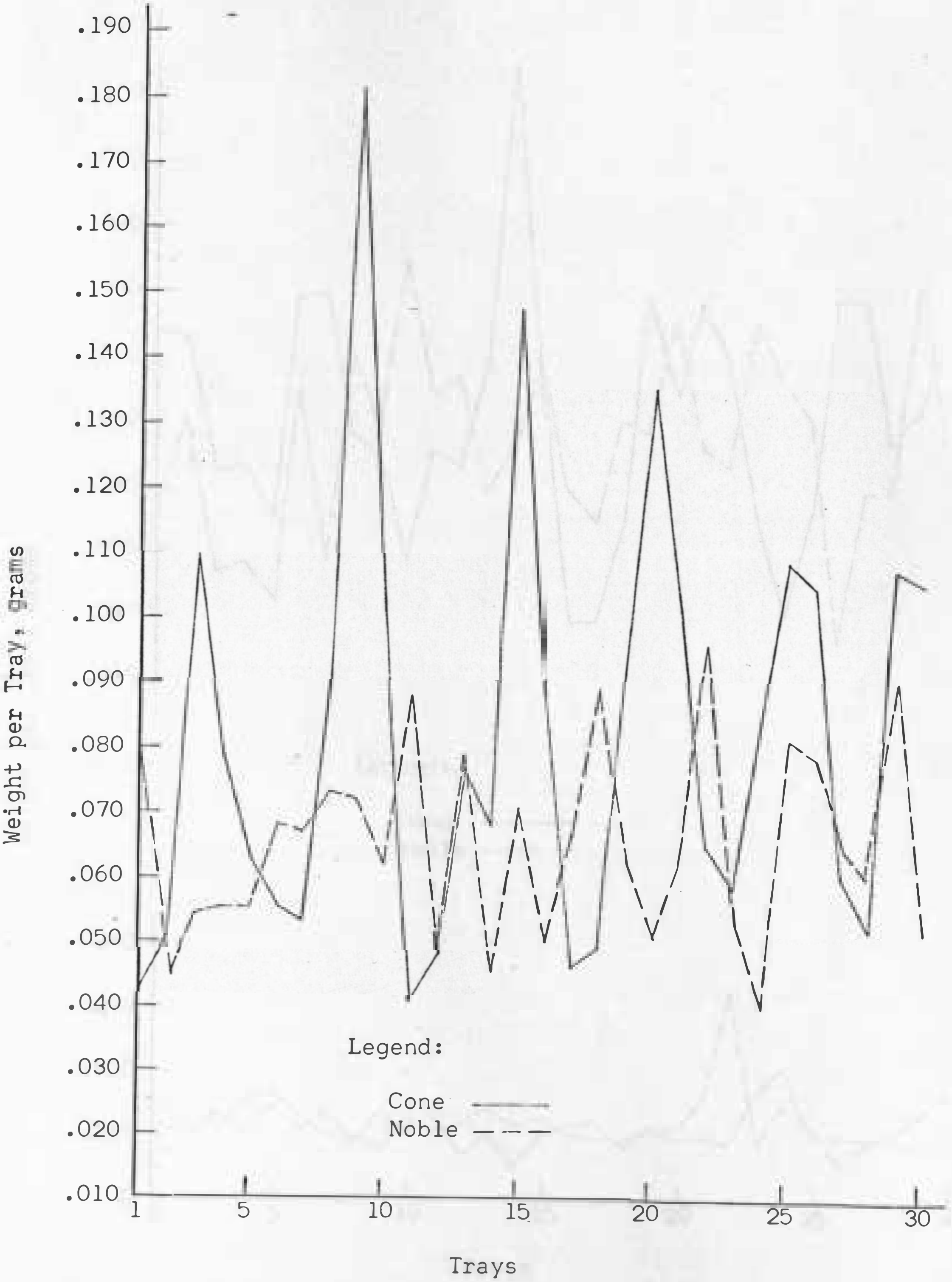

Figure XIII. Metering Uniformity of Unmodified Cone and Noble Meters: High Flow Rate, 2.6 mph

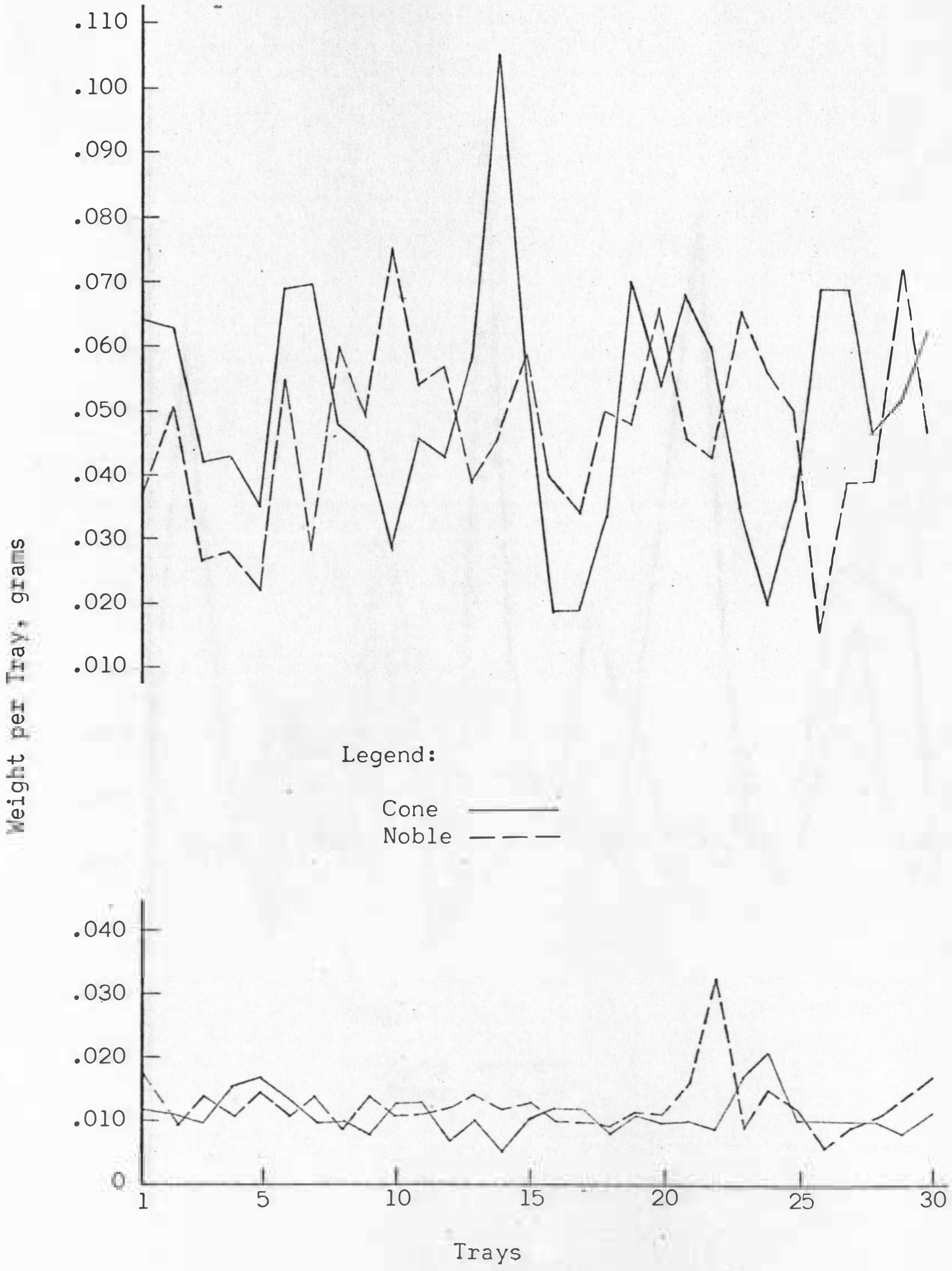

Figure XIV. Metering Uniformity of Unmodified Cone and Noble Meters: Low and Median Flow Rates, 3.1 mph

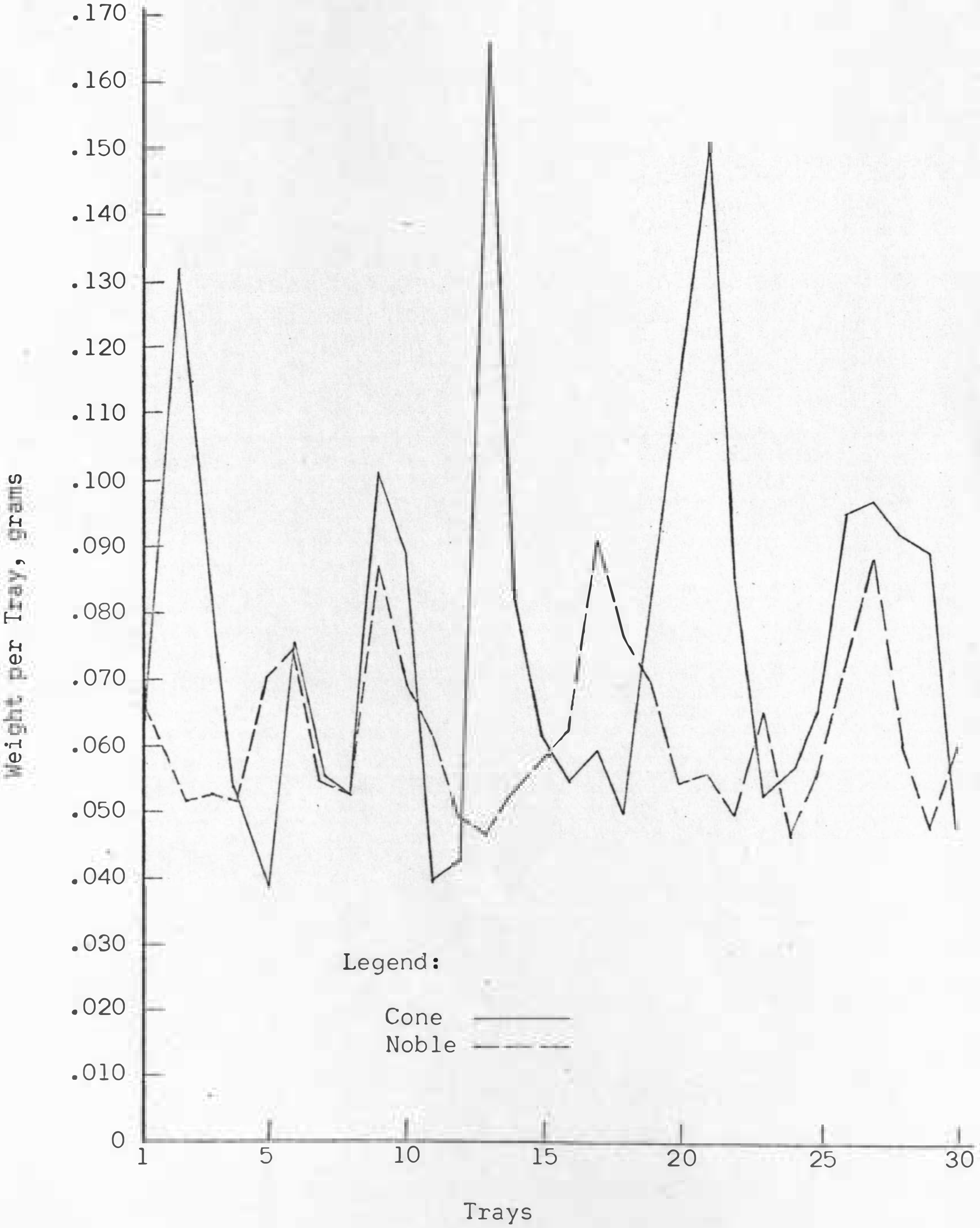

Figure XV. Metering Uniformity of Unmodified Cone and Noble Meters: High Flow Rate, 3.1 mph