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TITLE: NOZZLE ASSEMBLY FOR ARMY MASS DELOUSING OUTFIT
SBIR 89.I (A89-076)

SUBTITLE: Concept Development, Meter Design, Nozzle Design and Prototypes for the DM-9 Backpack Blower

PRINCIPAL INVESTIGATOR: John W. Burke

CONTRACTING ORGANIZATION: Cardinal Scientific, Inc.
124 Indian Court
Waldorf, Maryland 20601

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John W. Burke

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Cardinal Scientific, Inc.
124 Indian Court
Waldorf, Maryland 20601

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APPENDIX B
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U.S. DEPARTMENT OF DEFENSE

SMALL BUSINESS INNOVATION RESEARCH PROGRAM
PHASE 1 – FY 1989
PROJECT SUMMARY

Topic No. A89-076 Military Department/Agency ARMY

Name and Address of Proposing Small Business Firm

CARDINAL SCIENTIFIC, INC.
124 Indian Court
Waldorf, Maryland 20601

Name and Title of Principal Investigator

John W. Burke, Vice President

Proposal Title

Nozzle Assembly for Army Mass Delousing Outfit

Technical Abstract (Limit your abstract to 200 words with no classified or proprietary information/data.)

Studied a pediculicide meter and nozzle for use with the Kioritz DM-9 backpack sprayer as a mass human delousing system. The project was reduced to 3 interdependent design areas: metering method, meter actuation, nozzle design (site access). Five initial metering designs (sliding gate, vertical membrane, inclined membrane, rotary membrane, and piston plunger), located in the lower tank area, were tested. Testing of the units focused on consistency. Although the prototypes do not reflect recommended material and configuration necessary for rugged field testing, they were essential in advancing proof of concept. Two specific meter designs were advanced: (1) the inclined membrane design, which exhibited consistent powder metering and (2) the auger (not among the initial designs tested), which was positioned to the blower exhaust. The two systems performed comparably; system test results are specified. The auger is more complex. The inclined membrane can be incorporated into a foot pedal design. It is recommended that in Phase II, both designs should be concurrently optimized and field prototypes and performance criteria and protocols be developed.

Anticipated Benefits/Potential Commercial Applications of the Research or Development

An inexpensive, safe means of applying pediculicide is valuable to the Army, domestic and international relief organizations, and world health organizations. Public perception may require the precise metering of a variety of commercial insecticides, particularly malathion. An industrial process, requiring precise volumetric metering with little power, could readily employ the proposed system.

List a maximum of 8 Key Words that describe the Project.

Human mass delousing, powder, metering, blower, pediculicide, malathion

Nothing on this page is classified or proprietary information/data

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I Introduction

Inadequate personal sanitation, common to the living conditions of modern military conflict or social upheaval are ideal for the breeding, infestation and transmission of lice on the body and clothing. The bites of lice, their body fluids, or their feces can transmit the pathogenic microbes of epidemic typhus.

The sound practice of lice eradication among military and civilian populations minimizes the risk of the rapid spread of disease. An epidemic would threaten the soldier in the field and seriously impair military mobilization and deployment. Development of efficient systems for mobile and wholesale application of pediculicide maximizes resources while advancing the total capability for meeting a large scale, remote demand.

II Administrative Comments

The Army Medical Research Acquisition Activity has contracted with Cardinal Scientific Incorporated, to research a pediculicide meter and nozzle for use with the Kioritz DM-9 backpack sprayer as a mass human delousing system. Contract Number DAMD17-89-C-9131 was awarded under Phase I of the 1989 Small Business Innovative Research (SBIR) Program. The period of performance spanned 15 August 1989 through 15 February 1990.

The actual research effort was performed for the U.S. Army Biomedical Research and Development Laboratory. Official notification of the Contract Officer's Representative (Capt. Edgecomb) have been received and acknowledged.

The project kick-off meeting was held on August 16, 1989 at the U.S. Army Biomedical Research Lab, Fort Detrick, Maryland. On December 11, 1989 a program review and site visit was conducted by U.S. Army Biomedical Laboratory personnel at CSI. Topics covered were chronological research progression, prototype hardware review, metering demonstration and brief facility tour.

III Background

In the last fifty years, changes have evolved in methods and substance for mass human delousing. The World War II era military system, unique and cumbersome, has become insupportable. The units and replacement parts are no longer manufactured. An increased emphasis has been placed on mobile equipment while maintaining precise quantities of administered substance. Malathion dust is deposited in amounts of 2 to 4 grams/site, 17 sites/person (maximum 68 grams/person). The 17 sites are often beneath multiple layers of clothing. For the pediculicide to be effective, a dispersal nozzle must be placed in close proximity to the sight prior to application. Effective application disperses dust on the skin, hair and surrounding clothing where the lice gestate.

The system presently used by field units consists of a regulating manifold (30 psig) and six self-actuating dispersal guns. The manifold pressure must overcome the constrictions of quick disconnections, line friction, elbow loss, hopper actuation and particle dispersement through a nozzle. The manifold can be supplied by a Military Standard engine and Military Standard compressor, a truck air brake connection, or any air supply of sufficient flow (4 scfm) and pressure. Consequently, the unit's portability is limited by the availability of a compressed air source.

The guns have a local pediculicide reservoir mounted on the nozzle gun with a volumetric capacity of approximately 1 quart; which must be refilled accordingly. Just below the reservoir a volumetric metering drum relies on gravity feed to an oval hopper. A mechanical trigger actuates a partial revolution to disperse the powder under pressure. The gun is a cast, welded assembly with a narrow, flexible metal tube for applying the powder below clothing. The guns cannot be disassembled for maintenance or servicing. Inadequate sealing and fill problems have been reported. During development, the drum and casing tolerances were tightened; resulting in repeated binding.

IV Kioritz DM-9 Backpack Blower System

The military presently possesses portable backpack sprayers for liquid insecticide. The sprayers are designed for the unmetered application of liquid insecticide mist or powder insecticide dust to foliage. The sprayer weighs approximately 30 pounds, is extremely mobile, and is commercially produced. The sprayer is equipped with a 10 liter reservoir (substantially larger than the nozzle gun). A liquid chemical line runs from the bottom of the reservoir tank to the main nozzle exit. As flow is throttled through the reduced diameter of the blower nozzle and past the liquid line orifice, the resultant vacuum aspirates the liquid into the airstream as a fine mist. Insecticide flow is continuous and based upon an unmetered average rate from the orifice size in the lower reservoir tank.

For powder dispersement (dusting), the lower tank line is removed. A volume control valve is installed between the reservoir tank and the lower tank area. Powder is gravity fed through the volume control valve, directly into the blower casing. The volume of dust is unmetered; dependent on duration (kg/min) and control lever position ("INCREASE" or "DECREASE", see Figure 1).

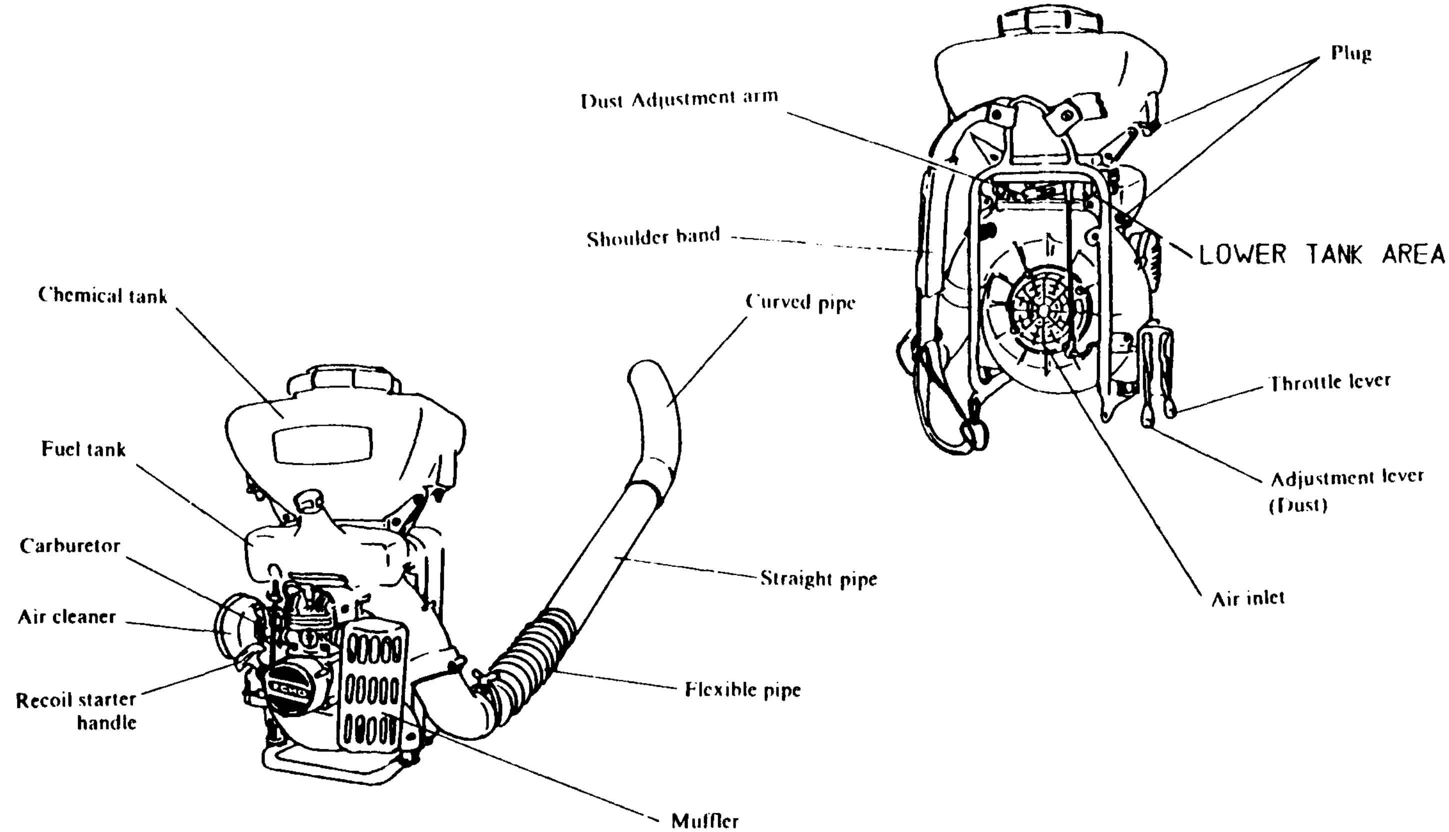

FIGURE 1 - KIORITZ DM-9 BACKPACK SPRAYER

COURTESY OF THE KIORITZ CORPORATION

Like most centrifugal blowers, air enters the DM-9 axially, is accelerated, and delivered tangentially through the casing at high flow rates and low pressure. Increase in air density is minimal as flow exits the casing, down a 2.5 inch diameter (unconstricted) flexible elbow, through a rigid plastic tube of equivalent diameter to atmosphere. The DM-9 blower is rated at a pressure of 12 inches of water at the maximum RPM of 7500, using a 58mm blow tube while producing 350 cubic feet per minute of discharge. These quantities equate to a high maximum air velocity (approximately 200 feet/sec). Figure 2 depicts a typical blower characteristic curve with approximate operating point for the DM-9.

Typically, blowers of this type will exhibit maximum pressures of 60 inches of water (.2.2 psi). The blower supplies the static pressure which is exerted perpendicular to the tube walls. The blower must also deliver the velocity pressure; which is directly proportional to the square of the velocity. The total pressure of the blower is the sum of the static plus velocity pressures. There are frictional losses at the inner walls of the tube.

As the blower is back pressured due to flow constriction (pipe blockage), the engine will over speed (over revolution); causing unnecessary engine wear and abuse. The load characteristic curve (Ld) of figure 2 will shift upward beyond maximum blower pressure and toward zero flow capacity.

Assuming complete blockage, flow velocity becomes negligible; as does the corresponding velocity pressure. The static pressure becomes maximum or equal to total pressure. Since all discharge flow has been removed, blower intake ceases and pressure differential across the blower blades is removed. The blower free-wheels and the ungoverned engine over speeds. The engine has no permanent crankcase lubricant which would contribute to overheating as a result of repeated over speeding. Repeated overheating may result in permanent piston and/or bearing damage.

Bypass Branch to Reservoir Area

In the course of investigating the DM-9 airflow configurations, a bypass conduit was observed. Figure 3 shows the bypass flow branch to lower reservoir area. As air exits the DM-9 blower scroll, a portion of the air enters the conduit and is delivered up to the lower tank area; providing positive pressure for powder dispensing. The flow in this region assists the gravity fed granule and dusting dispersement for normal DM-9 operation.

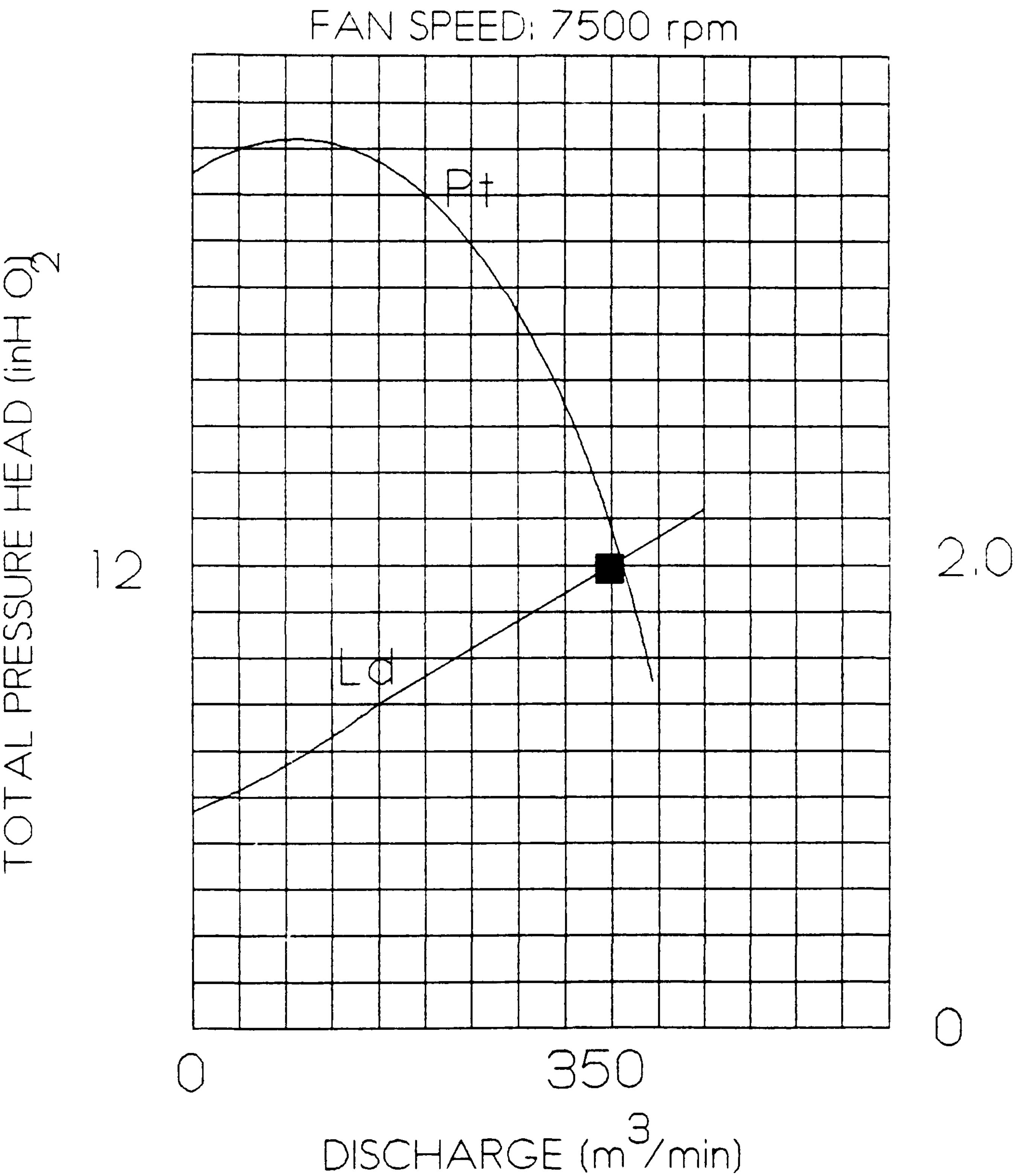

FIGURE 2 - DM-9 PERFORMANCE CURVES

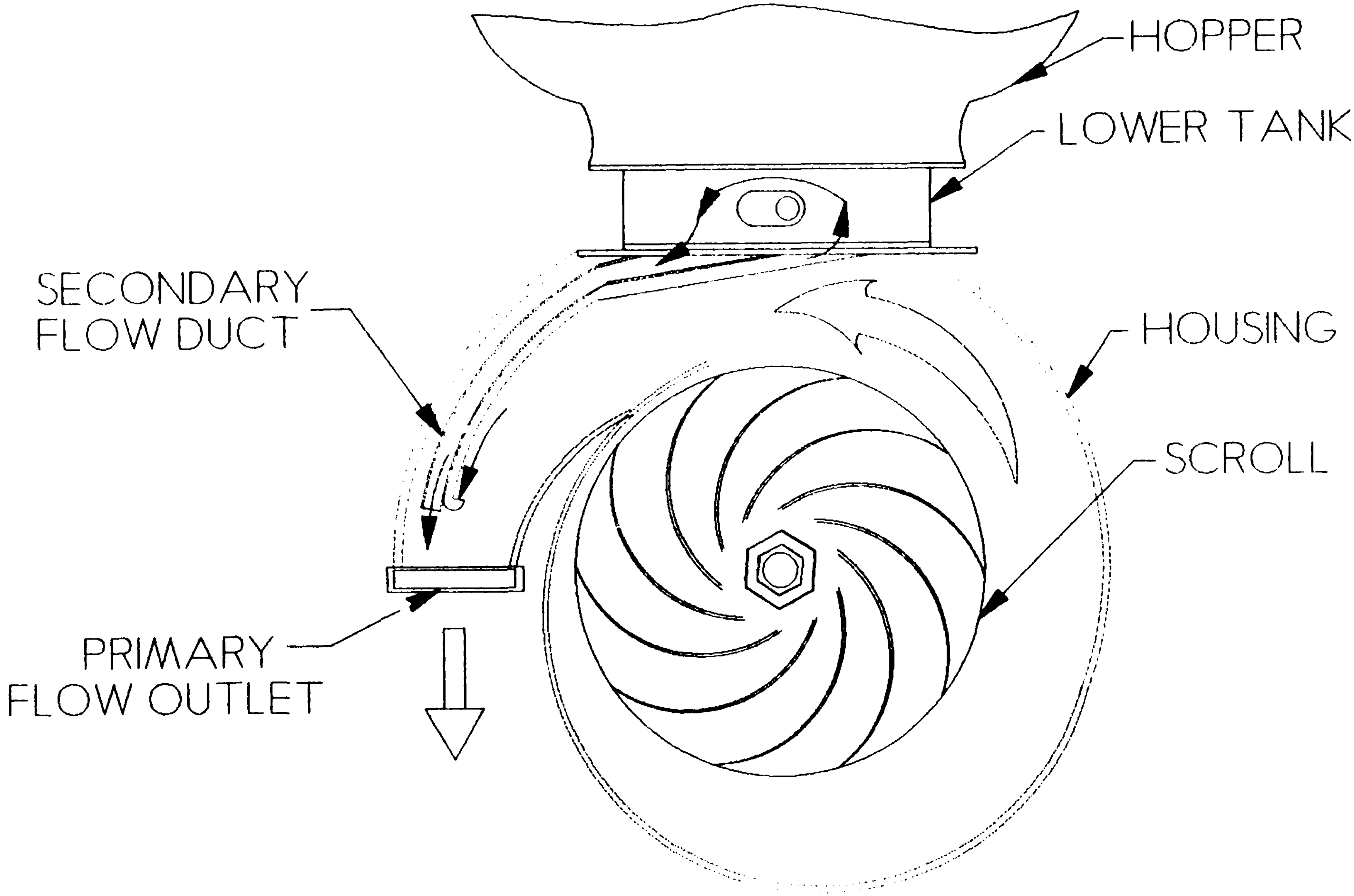

FIGURE 3 - DM-9 INTERNAL AIR FLOW PATTERNS

V Malathion Pediculicide Dust as a Bulk Solid

There are methods and relative factors to differentiate between free flowing and non-free flowing bulk materials. Non-free flowing material is characterized by internal forces in the particle bed, caused by cohesion, humidity or electro-static forces, which are prevalent over gravity forces. These internal forces are capable of randomly oriented planes after flow has begun (piping, arching, etc., see figure 4). The erratic flow must be handled in suitable hopper construction or with additional flow-aid devices.

The common problems associated with flow of the powder from the reservoir to the volumetric hopper and from the hopper to the airstream include: arching or bridging, rat-holing, erratic or non-uniform fill, or no flow. These problems depend on the pediculicide flow properties and result from one or a combination of conditions, such as (1) inadequate agitation, (2) improper hopper orifice shape and size (active bottom), or (3) back pressure.

Classification of bulk solids range from coarse to fine to powdered. Powder exhibits a free flow function of less than 2, which characterizes a very cohesive and non-free flowing substance; a powder factor of 95-100%, relatively low flowability range of 5 to 25 and a floodability range of 0 to 20.

Using a precise volume and triple beam balance scale, the talc was measured at 0.602 g/cm^3 and the malathion at 0.604 g/cm^3. The 2 and 4 gram volumes are equivalent to 3.3 cc (.201 in^3) and 6.6 cc (.402 in^3), respectively. Malathion Premium Grade 1% dust consists of 1% Malathion and 99% inert ingredients with the appearance and consistency of talc. The same density calculation was performed on fragrance talc. No perceptible change in density was measured. Talc was used throughout the meter testing as a malathion dust substitute. Since the powder did not exhibit dramatic changes in aeration or density, consistent volumetric metering is feasible.

VI Commercial Methods

There a three basic commercial techniques for the metering of fine powder: rotary vacuum fill, auger systems, and net weight loss agitation.

Rotary vacuum fill is most common in production packaging such as baby powder. A cylindrical head with radial cavities indexes under a large hopper. Agitation moves the powder above the cavity. Vacuum suction, through a porous plug at the bottom of the cavity, sucks the powder charge. The cylinder revolves, sealing the previous cavity and indexing a new one. As the cylinder continues to revolve, the filled cavity indexes opposite from the hopper,

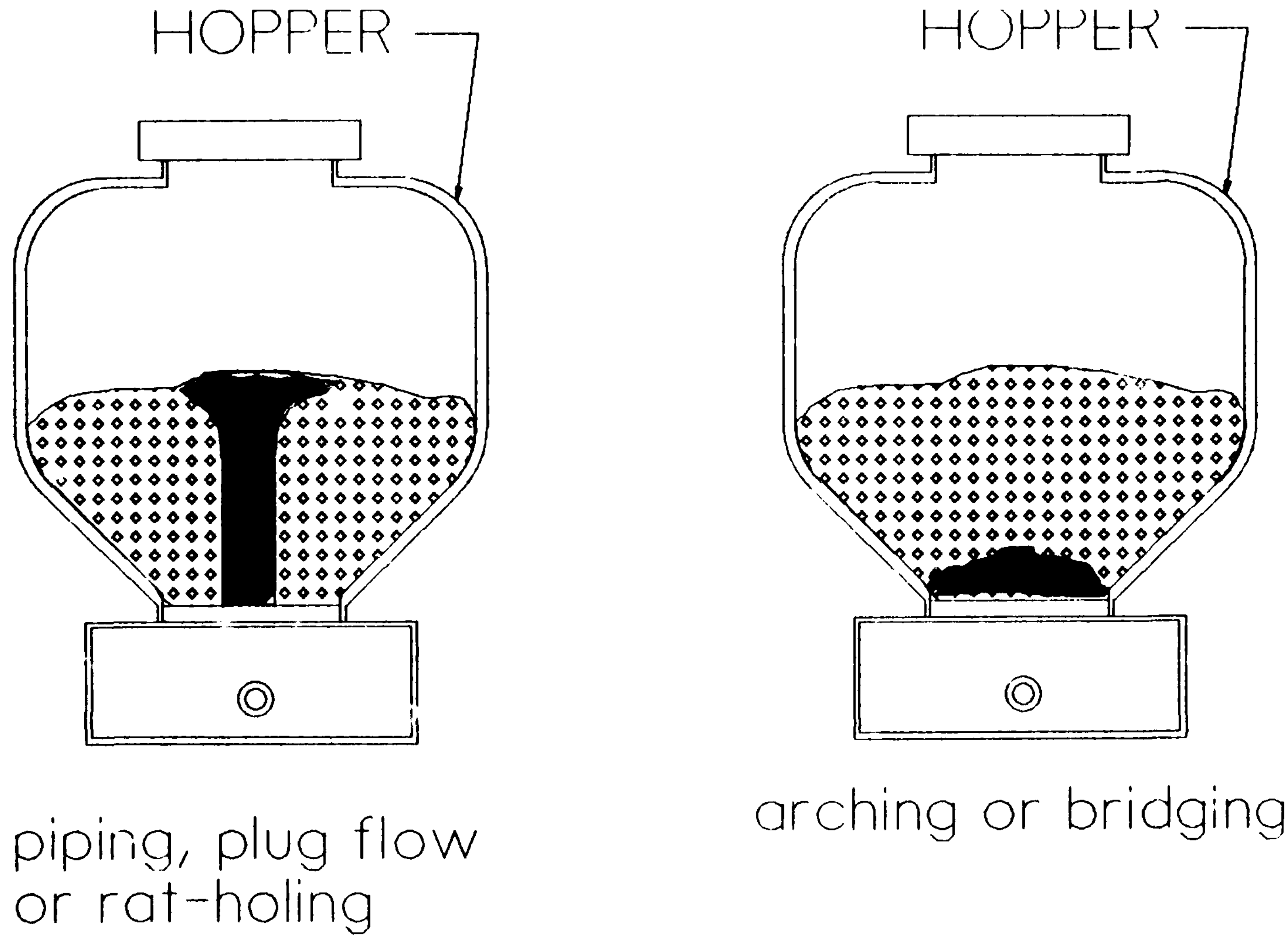

FIGURE 4 - BREADBOARD MASS DELOUSING SYSTEM

over the desired discharge sight (typically an empty bottle or carton). Pressure through the same porous plug discharges the powder. The Army's present nozzle/gun system is similar to rotary vacuum fill systems. They both require pressure sources and rotate cylinder or drum chambers. The army systems, however, do not have additional agitation, vacuum fill, a vented reservoir, or comparable seals.

Auger systems, the most reliable, simply rotate counter to the spiral, forcing the powder down a column. Non-free flowing (self-feeding) designs taper out to gather material. Auger systems are designed to provide a specific flow rate based on size and RPM. Augers are common in industrial food processing and other bulk solid applications; requiring proper alignment, power sources (i.e. an 110 VAC motor), and power transmission. Difficulties associated with a DM-9 batch metering (2 to 4 grams of malathion dust) system include a portable power source and adequate sealing between applications.

Net weight loss agitation systems are used for precise scientific measurement. Vibrating agitation slowly moves the material from a hopper down a horizontal tube to the orifice. The entire assembly is mounted on a scientific scale. A microprocessor controls the agitation based on the net weight loss of the system. As the total system weight loss approaches the metered amount, the agitation is slowly tapered off to avoid any access material. This type of system is impractical for portable and rapid mass delousing.

VII Concept Development and Approach

The Army evaluated DM-9 unit as superior in performance to any other commercial sprayer for the portable, remote application of insecticide. The logical approach of diversifying the unit's function will consolidate resources, reduce support requirements, and meet the development needs for alternative delousing systems.

The application of a DM-9 backpack sprayer as a mass delousing system was to meet the following criteria: (1) dispense 2 to 4 grams of powder per actuation; (2) maintain unconstricted flow during continuous operation; (3) access the 17 sites/person for effective placement; and (4) remain portable and self-contained.

In order to achieve adaptation, several system limitations must be overcome. Available energy sources on the unit include limited air pressure, limited air vacuum (orifice capillary action at blower casing intake, blower nozzle, engine intake manifold or crankcase), shaft power take-off, heat and electricity. Considering metering actuation concepts, the 39.7cc engine's maximum shaft power (2.· PS at 8000 rpm) is adequately sized for the unaltered blower system load of 2 (PS). The engine power and high speed correspond to limited engine torque (approximately 20 in-lbs); therefore power take-off is not practical. The blower pressures and vacuums are inadequate for a feasibly sized pneumatic diaphragm. Using a precision Dwyer vacuum gage, the manifold vacuum was measured at the intake and exhaust of the blower (straight throat). The magnitudes were typically a few inches of water; considerably less than the vacuum necessary to actuate a choke diaphragm. Manufacturing data illustrates a maximum crankcase pressure of 50 psi. Employing a portion of this pressure (or vacuum) was considered. The design would require proper orifice sizing, a check flap or valve and pressure accumulator. The use of manifold crankcase pressure, however, would degrade the overall engine performance and consequently blower performance. Actuation exploiting mechanical advantage was the most feasible alternative.

A dispersal gun, similar to the existing metering system, requires substantial pressure for actuation. The concept of a nozzle gun was rejected due to secondary reservoir requirements and cumbersome application or site access. Ideally, a meter would dispense more pediculicide dust than air. For the DM-9 application the inverse is true. The blower can be considered a constant-head--constant capacity (volumetric) machine. The blower will develop the same head at a given capacity regardless of the fluid and a pressure proportional to the density. Excessive constriction will cause excessive back pressure. Due to the low pressure characteristics, the meter design was to exhibit one of the two following characteristics: impart the powder charge into the airflow and in the direction of flow to conserve energy or introduce the powder as a thin membrane perpendicular to the air flow, maximizing velocity pressure load on the powder while minimizing head. The metering was to be fast-acting to ensure tight aerosol clouding.

The chamber orientations to the larger powder reservoir were to be rectangular or oval to facilitate gravity fill. The system was to employ the existing DM-9 reservoir to maintain continuity with minimum system impact; thus reducing the cumbersome operation of a nozzle mounted reservoir.

The project was reduced to three inter-dependent design areas:

- Metering method
- Meter actuation
- Nozzle design (site access)

VIII Meter Designs and Locations

As shown in figure 3, there are two internal air flow branches from the blower scroll to upstream of the exhaust elbow. The primary flow passes through the housing and exits the unit. A secondary flow channel diverts air upward to the lower tank area of the unit. The secondary branch serves several functions, namely, to disrupt the reservoir contents during dry, gravity feed and to propel the substance toward the primary blower exhaust. At the secondary branch reentry into the primary flow, negative pressure serves to assist the rapid dispersement of the unmetered substance. As intended by the original designers, the location takes full advantage of engine vibration/agitation and reservoir height during backpack operation. When the unit is operated from the ground, a full reservoir could destabilize the unit (or make it top heavy).

In order to exploit the large reservoir and bypass branch and engine vibration, five initial designs were located in the lower tank area. The designs were incorporated into the Kioritz lower tank casing for rapid change-out and minimal system impact. One design, the vertical membrane, attempted to use the mechanical linkage of the control lever for actuation. The designs are described in detail below.

Sliding Gate

The metering device employed two synchronized sliding gates to progressively fill a hopper, isolate the hopper from the powder reservoir, and then release the volume into the blower airstream (see figure 5). This was proposed by offsetting the mating orifices of the fixed plates. The chamber orifices have rectangular dimensions to facilitate powder flow from the hopper. When the top slide is completely exposed to the reservoir contents, the lower slide is closed to the air flow and vice versa. In the fill position, the chamber is exposed to the reservoir. When operated, the top slide seals off the reservoir and the lower slide exposes the chamber to the backside flow from the opening in the slide's thinner portion. To exploit the lower tank air flow, ducts direct the air toward the backside opening. The powder would gravitate out of the chamber, assisted by the air flow, becoming suspended in a propelled cloud.

Concerns for this design included the lack of adequate sealing to prevent unwanted blow by of unmetered powder. During the rapid stroke, there are positions at which the reservoir gate and the air flow gate are both exposed. Due to the sliding action of the plates, conventional sealing methods were unlikely. The metering unit components were fabricated with the anticipation that static pressure would act on the closed gate surface, isolating the chamber.

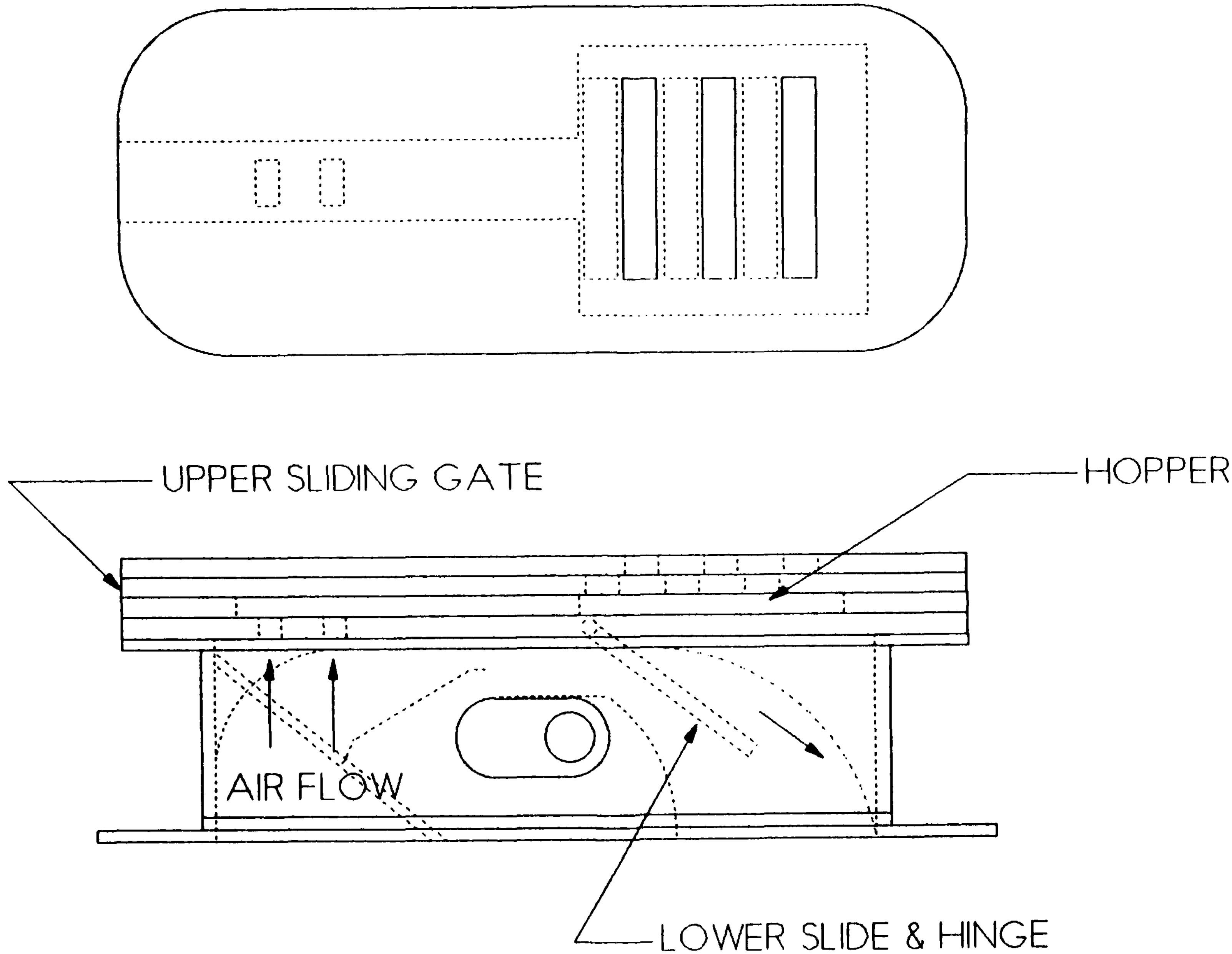

FIGURE 5 - SLIDING GATE METERING DEVICE
(SECONDARY FLOW LOCATION).

Vertical Membrane

The vertical membrane device introduces a thin, relatively large diameter cross section of powder directly into the lower tank air flow (see figure 6). The meter is composed of a plate with a slot or groove chamber. In the fill position the plate is immersed in the powder; relying on gravity and engine vibration to completely fill the volumetrically sized chamber. The filled chamber represents a vertical membrane of powder which slides linearly into a fabricated air duct. The chamber is translated by manipulating the existing granule control valve linkage on the sprayer. Actuation entails lowering the plate and membrane through the isolation plate which scrapes off excess powder as the chamber passes. Further into the stroke, the metered volume is isolated from the reservoir and the air flow. The metered charge is then introduced into the flow duct; permitting the air stream to flow through the chamber only. The charge is suspended and dispensed.

Suspect areas with this design include the adequate sealing of the sliding plate through the isolation plate. Due to the thin rectangular geometry, o-ring seals were not incorporated. The chamber possessed the desirable oval shape; however, the vertical orientation could cause inconsistent fill.

Inclined Membrane

Similar in design to the vertical membrane, the inclined membrane reclines the chamber providing a lower angle of incidence. The inclined chamber presents a rectangular profile to the reservoir for better filling characteristics (see figure 7). Fill is accomplished from one side of the chamber and the actuation stroke is longer than the vertical membrane. The charge is translated by means of a rotating pinion gear which translates the meshing rack on the sliding plate. The inclined design facilitates the incorporation of a teflon insert in the isolation plate to minimize binding. As the hopper is deployed into the airstream, its leading edge serves to duct the air through the hopper; affecting powder aerosoling. Concerns for the inclined design were similar to the vertical design with the exception of better fill characteristics and the addition of a lengthened stroke.

Rotary Membrane

The next design employed a rotary chamber. This design considers back pressure and direct airstream introduction. The charge is gravity fed into a circular orifice. The chamber fills and the rotary cylinder or drum is rotated, sealing off the reservoir (see figure 8).

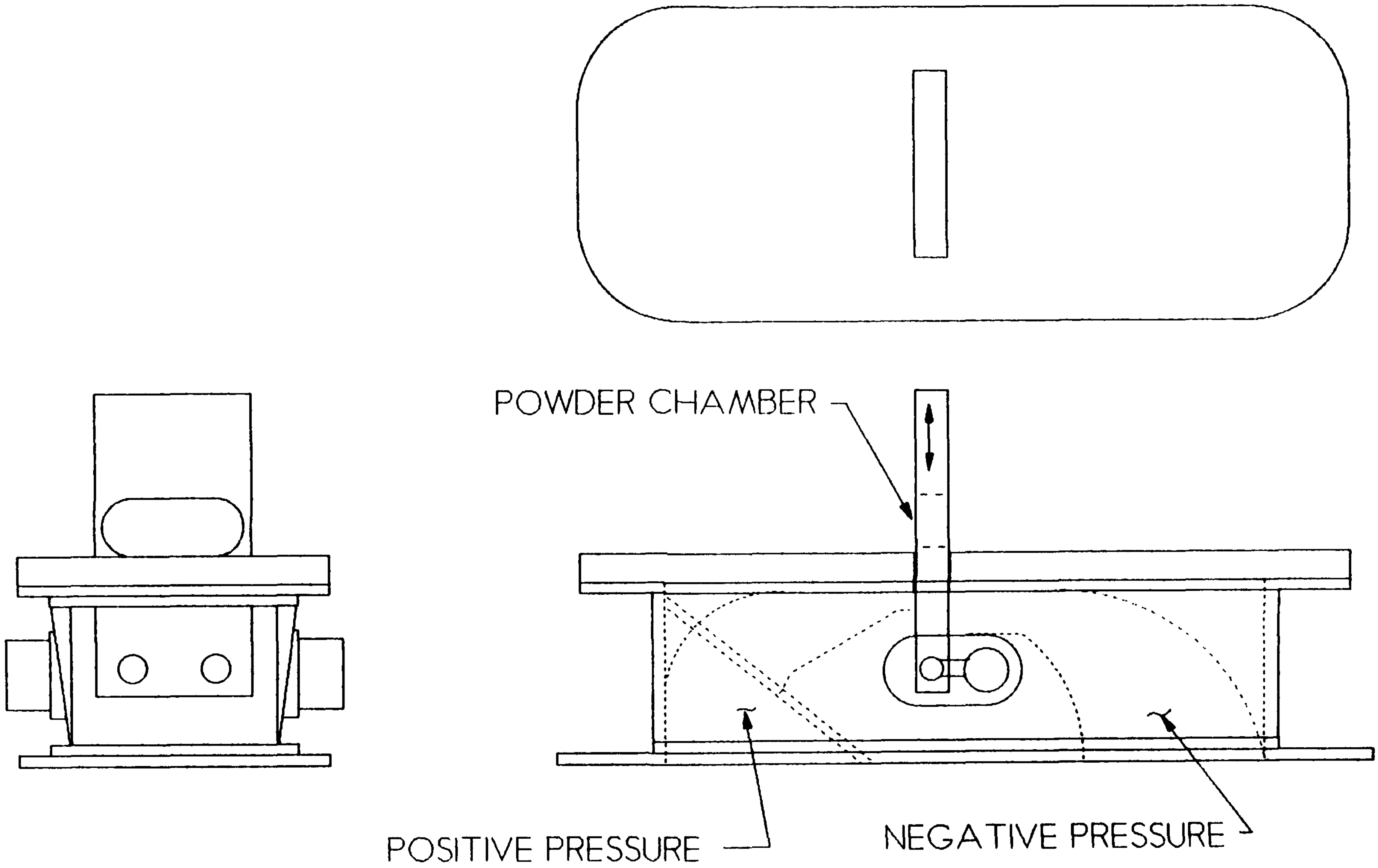

FIGURE 6 - VERTICAL MEMBRANE METERING DEVICE
(SECONDARY FLOW LOCATION).

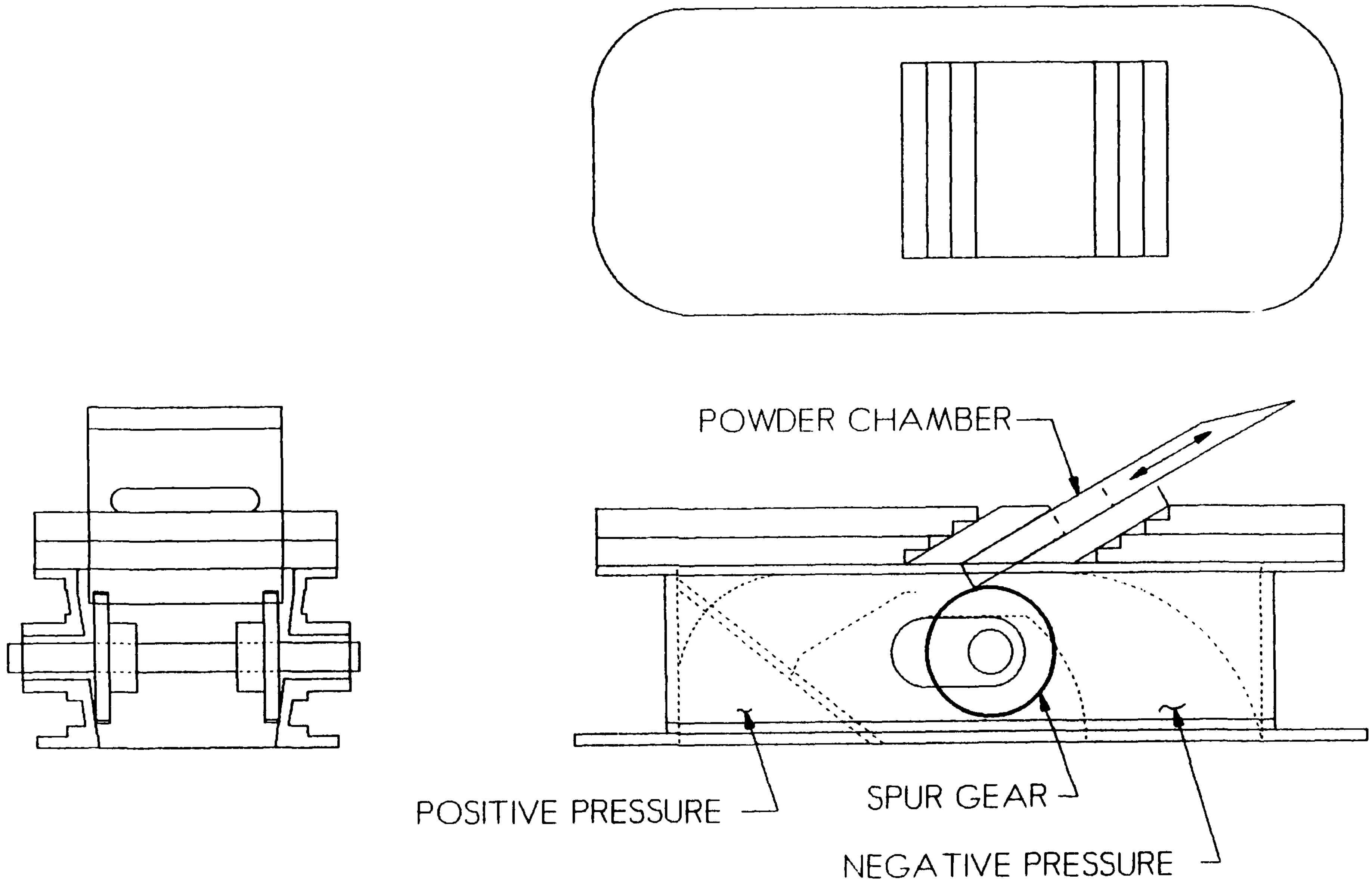

FIGURE 7 - ANGLED MEMBRANE METERING DEVICE (SECONDARY FLOW LOCATION).

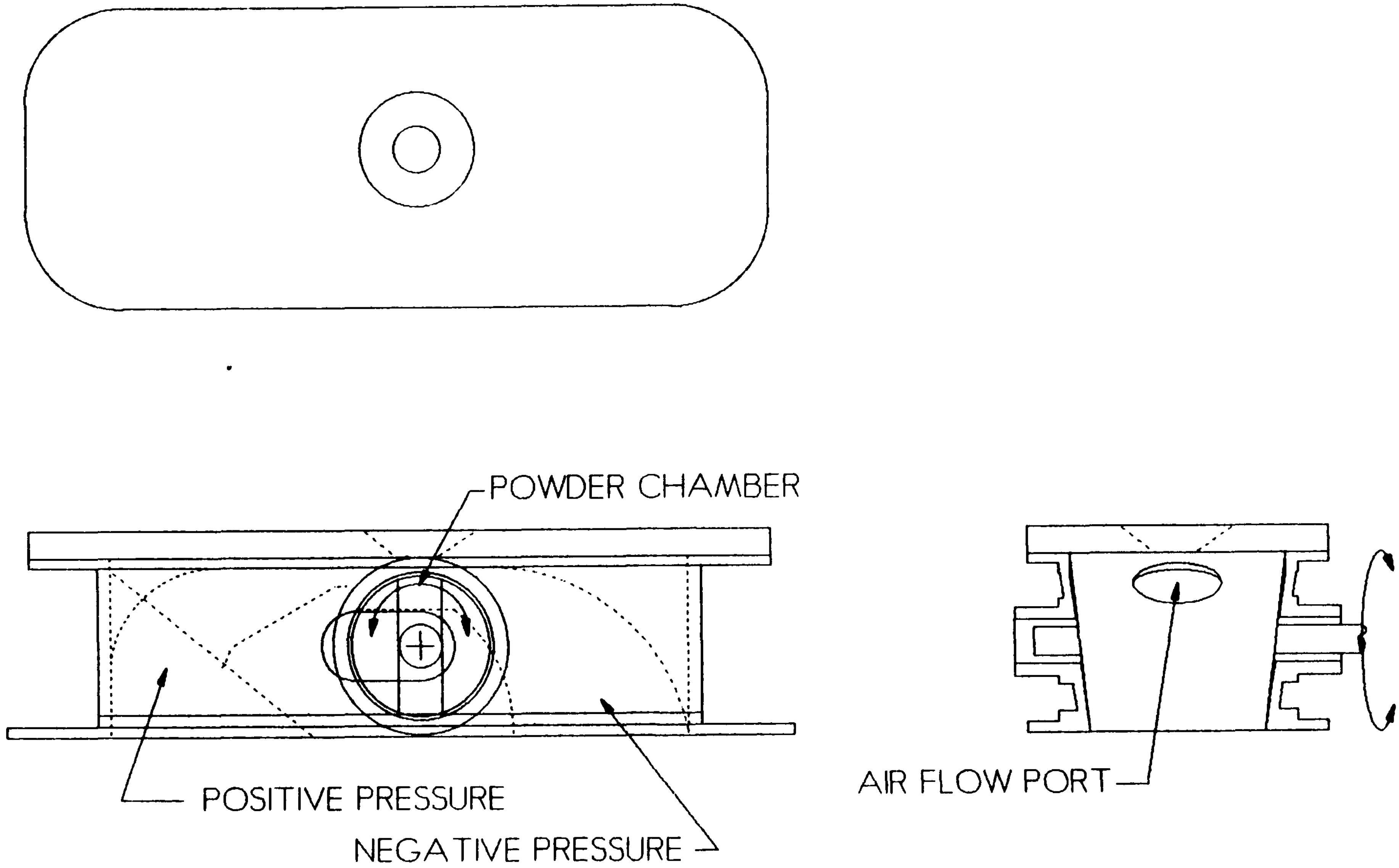

FIGURE 8 - ROTARY CHAMBER METERING DEVICE
(SECONDARY FLOW LOCATION).

After a 45° rotation, the chamber orients itself in the ducted air flow of the lower tank area. The rotary membrane incorporates o-ring seals to prevent air leakage into the reservoir and to limit powder binding of the drum. The circular cross-section of the rotary chamber may cause the powder to compress against itself, causing bridging during fill. Unlike commercial units, the rotary membrane does not have the benefit of vented or vacuum assisted fill.

Piston Plunger

The piston plunger design employs a retractable, spring loaded piston (see figure 9). The piston rod is guided by an upper support plate. On the rod, between the upper support plate and the piston body, is a compression spring. The chamber consists of the grooved cavity between two forks in the piston body. The two forks are guided by a circular hole in the isolation plate. On the air flow side of the isolation plate are two torsion spring loaded trap doors for sealing the reservoir. At the top of the stroke, the meter is in the fill position; the spring is fully compressed and the reservoir is sealed. Powder would fill the vertical groove through gravity and engine vibration. To meter the unit, the rod is released. The compressed spring rapidly moves the piston down through the isolation plate, each fork forcing its mating trap door open. The piston reaches full stroke when the stop bottoms out against the top of the upper support plate. Thus, the powder is imparted into the air stream and in the same general direction.

Concerns for the piston plunger design included the question of adequate sealing by the trap door covers; and whether the vertical orientation of the groove would consistently fill.

Fabrication

Six lower tank assemblies (the molded plastic component that ducts the bypass air flow below the reservoir) and eight lower tank metal casings were acquired from Kioritz and altered to accommodate the individual ducting requirements of each design. The meter chambers were not fabricated with the appropriate powder volume. Consequently, the chamber volumes did not reflect precise 2 gram charges. Testing of the units focused on consistency. Eventual chamber size and stroke can undergo modification for precise volumes.

The prototype fabrication was a time consuming portion of the research process, due to coincidental design modifications resulting from visual testing. The materials used (brass, aluminum, teflon and acrylic) were well suited for the function and visual verification of the concept prototypes. The prototypes do not reflect recommended material and configurations necessary for rugged field testing.

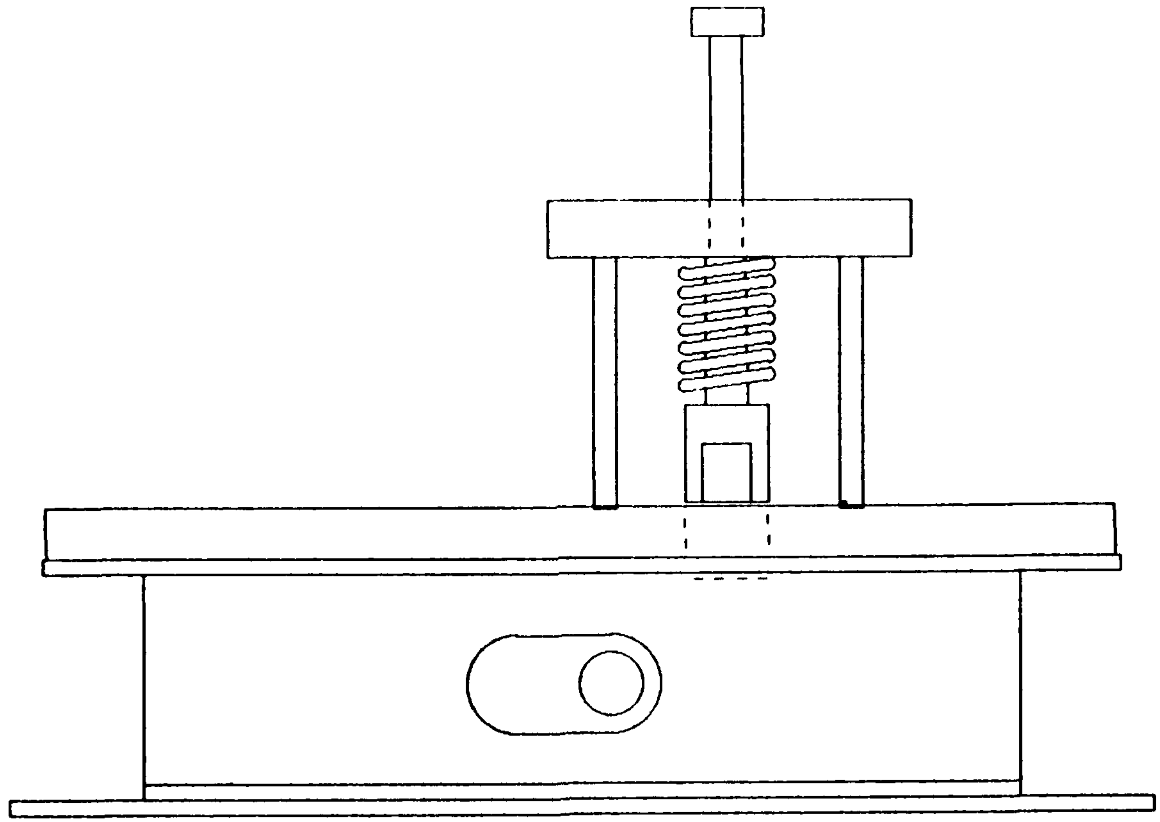

FIGURE 9 - PISTON PLUNGER DESIGN

IX Initial Meter Testing

Briefly, the initial test procedure consisted of the following. Each meter was installed on the blower system with an open blower exhaust. The meters were individually actuated by hand for visual inspection of the size and duration of the aerosol cloud. The initial meter designs were tested using a polypropylene bag filter. The filter had a 3" opening which was clamped and sealed to the blower exhaust. To reduce pressure head, the filter bag flared to a 6" diameter for a length of 18". The filter had a 99% efficiency for 1 micron particle sizes. Using a precision triple beam balance, the filter was weighed before and after the meter actuation. The difference in gross weight verified the metered amount. For each design, manual actuation was used to reduce test variables.

The bag demonstrated a back pressure of 10 in. of water at the meter location (lower tank area). Even though some primary flow was still maintained, the bag filter caused minimal flow in the lower tank bypass. After numerous attempts, the 99% bag filter and a less accurate (more porous) bag filter continually resulted in back pressure head and engine over speed. The filter back pressure is a function of its internal surface area. The filters were undersized for the application; however, they represented a fair approximation of the load the blower would encounter while dispensing pediculicide under several layers of clothing. The meters worked sporadically and with in consistent amounts.

The bag filter was removed and a less accurate filter was used. A more porous, foam filter was placed over the blower exhaust. Prior to each meter test, the filter was weighed on a metric triple beam balance. The blower reservoir was filled with approximately 1 Kg of talc. The filter was held in position with the engine running at an initial speed of approximately 7500 rpm (maximum blower pressure of .19 in. of water). Engine speed was verified with an optical tachometer. The engine ran for a interval of 1 minute; at which time the filter was removed and weighed again. The net weight determined the amount of dust which trickled into the airstream (blow-by) as a result of gravity, vibration or pressure differential.

The filter was then cleaned with a vacuum, weighed and reinstalled. The meter was manually actuated. The engine was cut and the filter was removed and weighed. The test was repeated five times for each meter design. For results see table 1.

Table 1: Initial Meter Actuation

Meter	Engine RPM
a. Sliding Gate Valve	7520
Hopper volume =.233 in^3 . Hopper capacity of 2.295 g.	
Visual test indicated long cloud length with leakage around the valve stems and through the gates.	
One minute blow-by test accumulated 13 grams of trickle talc, indicating substantial leakage. The slides gradually became more difficult to actuate.	7900
Actuation	
1. 7.2 grams net weight with slight binding	7900
2. 8.8 grams net weight with noticeable binding	8100
3. 3.9 grams net weight with shortened stroke	8500
4. Jammed due to powder build-up	
Inspection	
Powder accumulated in the valve air passage preventing self cleaning. Further accumulation in the void of both slide strokes prevented actuation.	
b. Plunging Hopper	
Hopper volume =.159 in^3 . capacity of 1.569 g.	
Visual test indicated little noticeable metering, no aerosol clouding.	
One minute blow-by resulted in 1 gram of talc leakage.	7850
No actuation test conducted.	
c. Inclined Membrane	
Hopper volume= 1.328 in^3 . capacity of 1.311 g.	
Visual test slight leakage with good clouding during actuation.	7500
One minute blow-by resulted in 0.9 grams of leakage.	8050
Actuation	
1. 0.8 grams net weight	
2. 1.0 grams net weight	
3. 1.0 grams net weight	
4. 1.0 grams net weight	
5. 1.1 grams net weight, no noticeable binding	
Inspection	
The hopper was blow clean of talc with no noticeable build-up.	

Table 1 (cont.)

d. Vertical Membrane

Hopper volume = 1.343 in^3 . capacity of 1.323 g.

Visual test indicated slight leakage with good clouding. 7900

One minute blow-by resulted in 1.0g of leakage or trickle. 7900

Actuation

1. 0.6g net weight 8050
2. 0.7g net weight
3. 0.6g net weight
4. 0.6g net weight
5. 0.7g net weight no noticeable binding

Inspection

Slight build-up of talc around vertical slide.

e. Rotary Valve

Hopper volume = 1.31 in^3 . capacity of 1.29 g

Visual test indicated no visible leakage, with a short aerosol cloud. 7550

One minute blow-by test showed 0 net weight or no trickle leakage. 7900

Actuation

1. 0.6g net weight
2. 0.6g net weight
3. 0.4g net weight
4. 0.6g net weight
5. 0.6g net weight, no noticeable binding

Inspection

Some powder accumulation around the drum with negligible binding effect.

Initial Testing Results

Blow-by or meter leakage was apparent for the sliding gate valve. After only a few actuations, the slides of the valve loaded with powder, preventing the actuation stroke. The sliding gate valve was designed with small access holes at the end of each slide, which were ineffective. The multi-layered plates served to trap reservoir and chamber powder.

The plunger design was unable to accumulate a powder charge in the chamber. The orientation and shape of the plunger compacted the powder, allowing an empty cylinder to form with repeated actuation. The membrane and rotary designs performed well with no noticeable binding. The inclined membrane performed best with consistent metering volumes.

As a result of device testing, two specific meter designs were advanced. First, the inclined membrane design; so named because it introduces a large, thin cross-section (membrane) of powder perpendicular to the flow of air. During testing the design exhibited consistent powder metering. Design trade-offs for the membrane design included hopper orientation to insure complete fill, stroke length and force of stroke.

Second, the auger was not among the initial designs tested. The auger is one of the most widely accepted, highly reliable commercial methods of handling bulk solids. The auger requires an independent power source and precise indexing for volumetric metering. Advantages include significantly reduced dependency on gravity feed to the hopper.

The back pressure significantly reduced the air flow through the bypass, thus degrading meter performance at the location. The theoretical benefits of the lower tank area were negated by the impractical performance at that location. Consequently, for system testing the meters were repositioned to the blower exhaust; so the aerosol would take place in the primary airflow. In the absence of complete flow blockage, some primary flow will remain.

X Nozzle and Bypass Design

In order to effectively disperse the pediculicide, a nozzle can be held in close proximity to a target area. The areas must be accessed through and under several layers of clothing. The nozzle must be flexible and rugged. The DM-9 has the additional requirement of unconstricted flow. The design must maintain an adequate exit cross section yet be a practical geometry for site access.

During additional flow tests, an orifice area of 2 in^2 resulted in inappreciable over speed at the rated blower/engine of 7500. Consequently, the nozzle design replicates this cross-section. The conduit becomes elliptical with an elongated orifice. The design concept is a good compromise between maintaining flow dimensions and site accessibility. The material is a durable, rigid ABS with an adequate degree of flexibility to assist in site access, yet maintain flow dimensions (see figure 10). At the orifice, the system discharges the aerosol into the atmosphere; converting the total head of the air into kinetic energy. By incorporating smooth, well tapered reductions in cross-section, the nozzle minimizes head loss (friction) due to turbulence or subsequent air recirculation. The test nozzle was acquired from a commercial source with slight modifications.

While attempting to insert the nozzle, the system could become subject to back pressure before metering is commenced. In addition, the uninterrupted, high velocity air throttling from the nozzle could cause difficulties when accessing, for example, the arm sleeve at the cuff. Continuous flow would be diverted away from the subject during site access. One concept which could delay or avoid this cycle is a bypass or blow off of the continuous air flow upstream of the nozzle (see figure 11). The sites would be accessed with little air flow through the nozzle. The bypass vane would be synchronized with the metering trigger. Momentarily subjecting the blower to the higher pressure heads during pediculicide application; then returning to a bypass condition. The next site would then be accessed; and the metering process would be repeated.

A bypass valve was fabricated; which was valved in one branch. The single branch valve provided full flow in one channel or partial flow in both. Ideally, the valve would provide slight flow in one branch and almost full flow to the other, regardless of valve position.

XI System Configuration

The breadboard system consists of the blower with reservoir removed and the lower tank area capped to prevent pressure loss; a meter and reservoir mounted conduit; flexible tubing and nozzle Full integration of a synchronized foot pedal actuation was not be achieved (see figures 12 and 13).

Auger Design

A stainless steel non-free flowing or self- feeding auger was acquired from a vendor (see figure 14). The auger was sized to deliver 4 grams per revolution. The addition of a drip flight to reduce powder trickle, reduces the flow by approximately half.

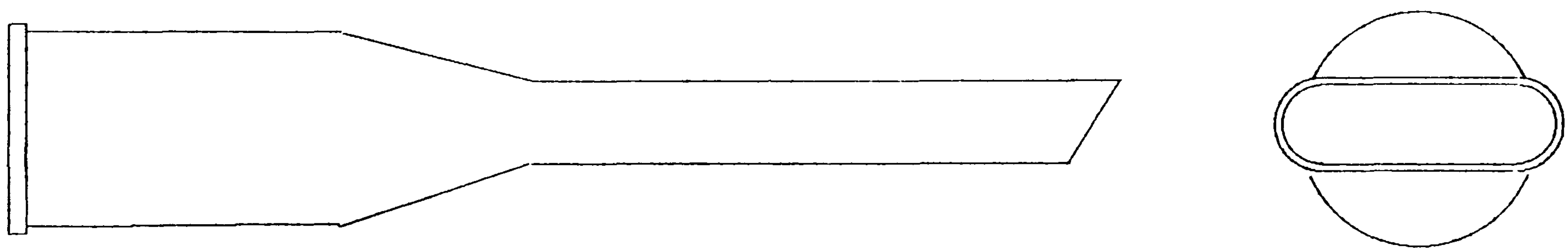

FIGURE 10 - COMMERCIAL NOZZLE CONFIGURATION

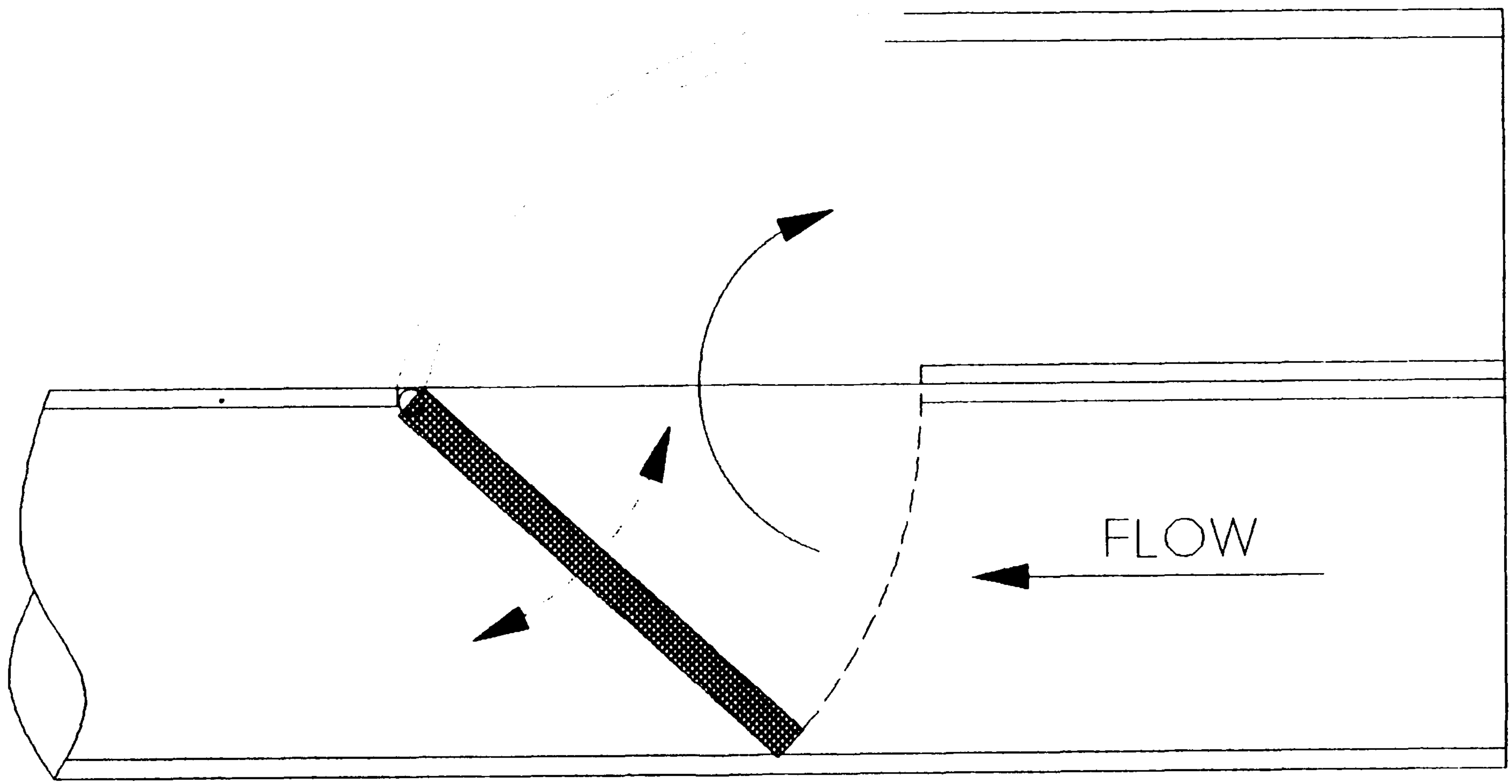

FIGURE 11 - FLOW BYPASS VALVE

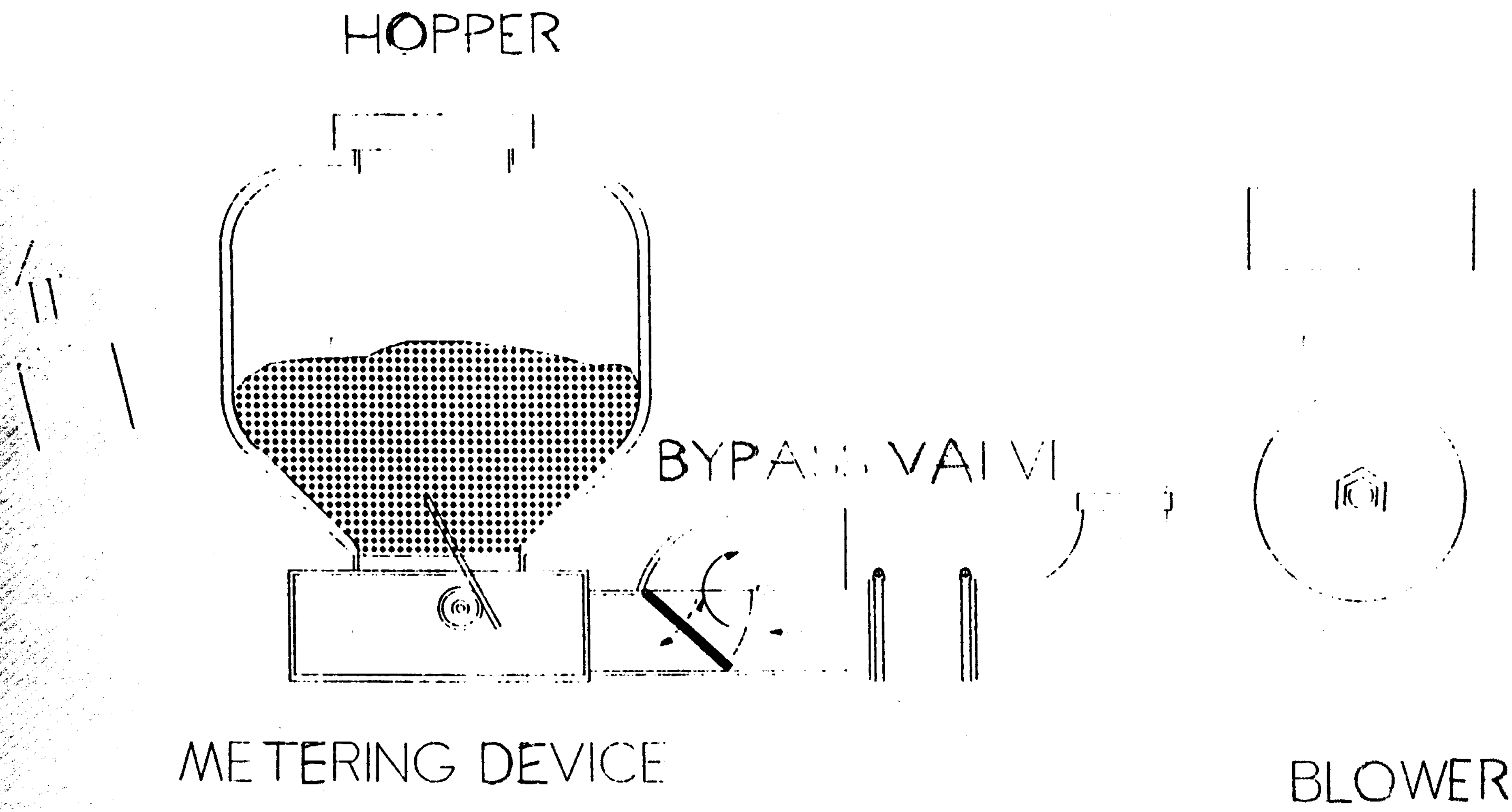

FIGURE - PRIMARY FLOW MEMBRANE METERING DEVICE CONFIGURATION

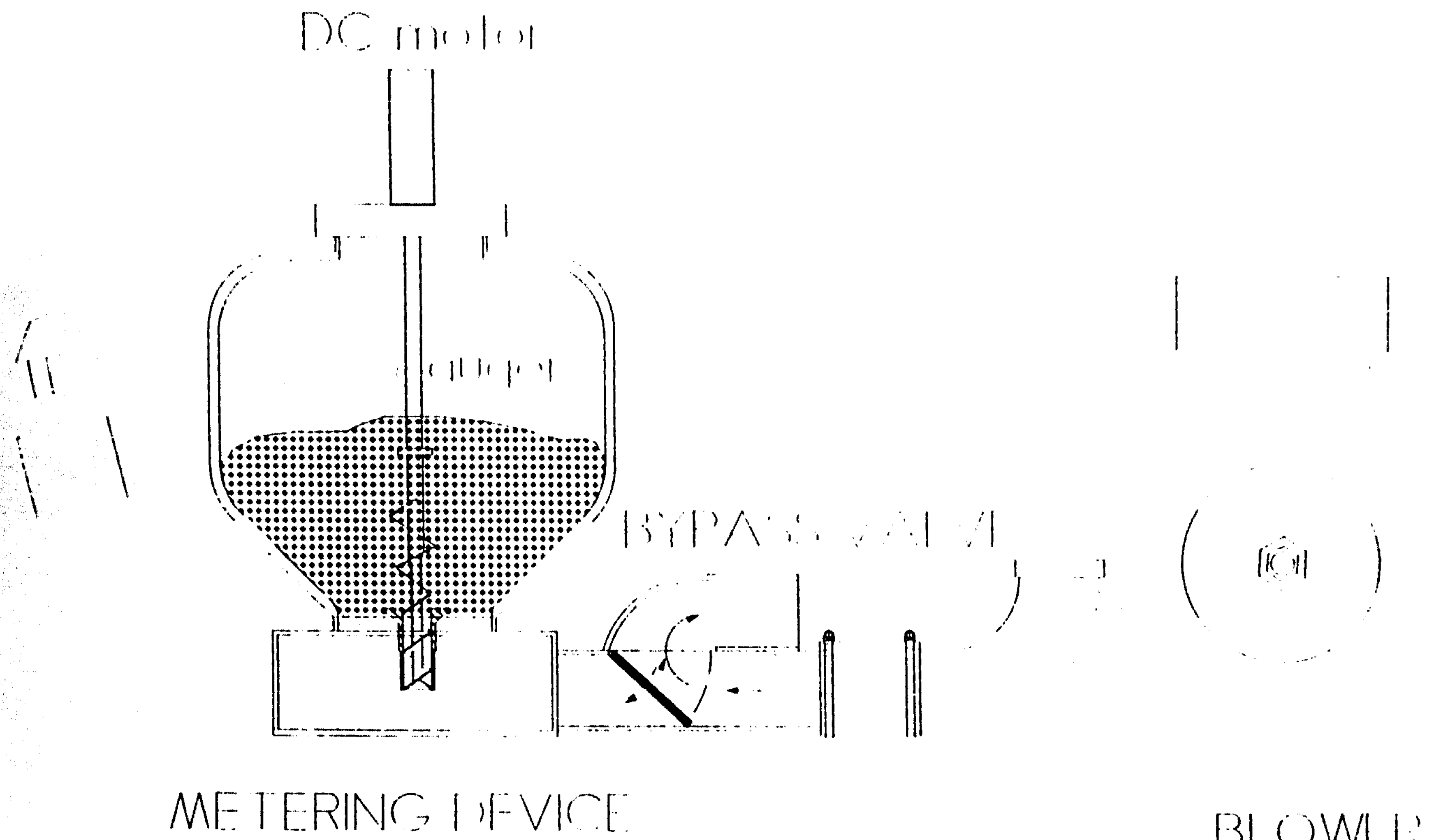

FIGURE - PRIMARY FLOW METERING AUGER CONFIGURATION

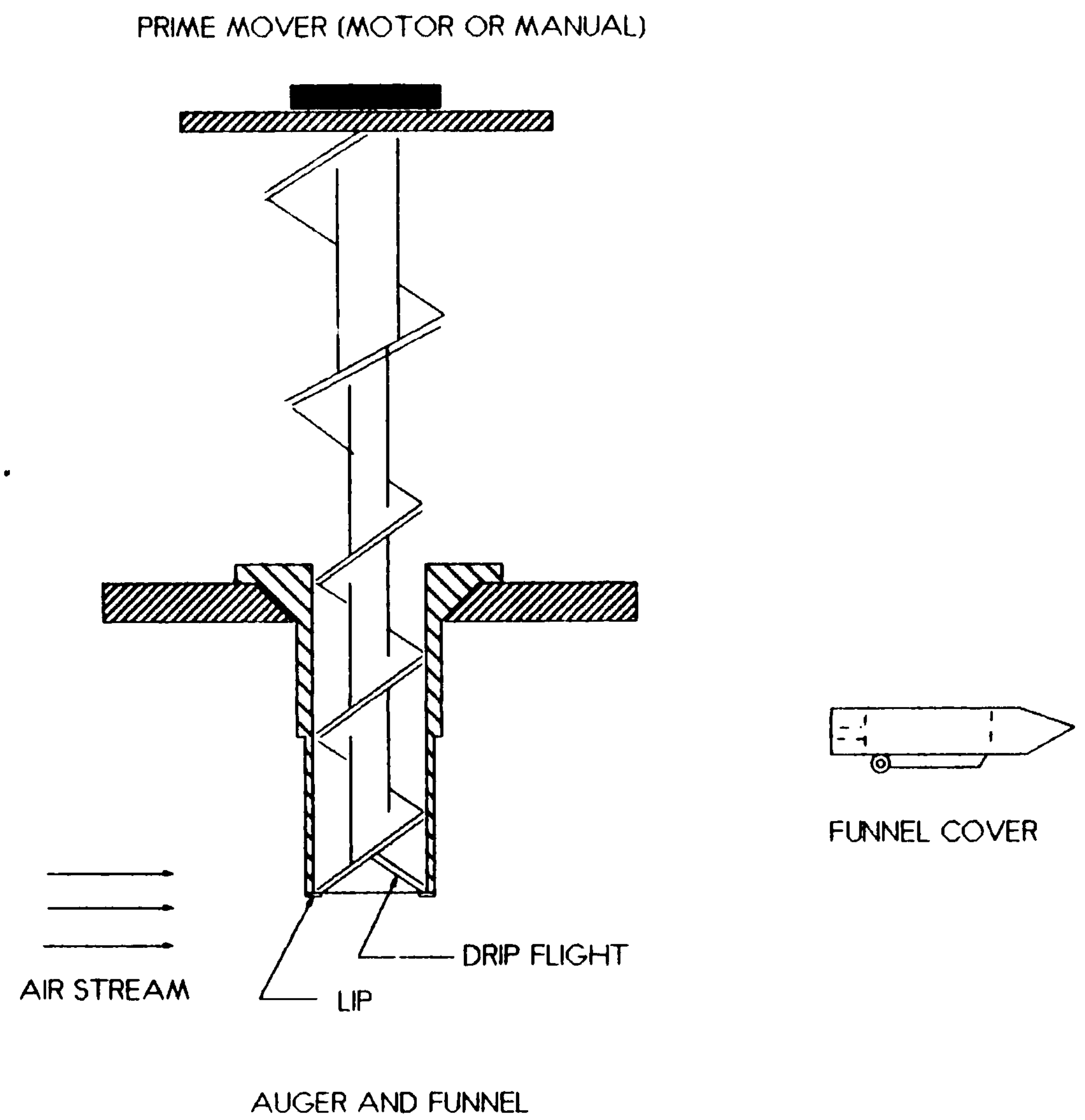

FIGURE 14 - AUGER AND FUNNEL DETAIL

The auger inserts into a stainless steel funnel. The funnel is lipped to prevent powder flow down clearance between auger and funnel. The auger is supported and guided by an upper plate. From the upper plate the auger is driven from a direct shaft by a commercial cordless screwdriver. The driver is equipped with a rechargeable battery, dc motor and satellite gear reduction for an unloaded RPM of approximately 120. On the shaft, a cam was mounted. The cam is circular with a indentation on the circumference. A roller switch rides on the cam; opening the circuit when it encounters the indentation. A shunt pushbutton switch initially closes the circuit. The button is released and the shaft continues to revolve since the roller switch is now closed. The auger makes one revolution, encounters the cam indentation and stops.

The major concern with the auger system is trickling of ummetered powder out the open end of the funnel. Under normal conditions, the auger's self-feeding action sufficiently compacts the powder. In the presence of vibration and air flow, however, the funnel requires additional flow stops. Similar to the piston plunger, the funnel exhaust was equipped with a torsion spring loaded cover. The auger action forces open the cover, the metered charge is blown clean, and the cover returns to a closed position.

Modified Inclined Membrane Design

The inclined membrane was slightly modified for incorporation at the new location. The chamber was enlarged for an approximate 4 gram capacity. The slide and surrounding insert were constructed of teflon to reduce binding. The rack and pinion actuation were positioned to provide stops for the fill and dispensing strokes. The meter was completely sealed with RTV silicon sealant.

Flexible Tubing

Flow through the flexible tubing would span from the metering device on the ground to the 17 body sites. The tubing should present a large cross-section flow to minimize friction loss and back pressure, yet remain maneuverable to access the body with the necessary length and bends.

An inflatable concept considered was a DuPont MYLAR tube of thin wall and large diameter. The MYLAR would easily inflate under the nominal static pressure of the blower, allowing the suspended powder to travel its length in a uniform cloud. The tube would slightly deflate once the bypass valve is opened, then reinflate during the next actuation. The conduit could be rolled and stored as a small volume. Unfortunately, MYLAR cannot be effectively sealed without an additional resin coating. The availability of this particular type of MYLAR, in the conduit dimensions, is limited.

Several alternative inflatable materials were considered for the metering system tubing. The most practical and available substitute was a thin walled vinyl tube. The tubing inflated to a diameter of approximately 4 inches. The flexible tube was subject to twisting during normal handling. When left unattended the tube and nozzle tends to whip from the high velocity nozzle exhaust. Solutions for these problems include a swivelled collar connection on the nozzle and a heavier nozzle, respectively.

Small particles naturally tend to accumulate electrical charge. The particles are being rapidly moved down a non-conductive conduit. The dry air quality can also contribute to electrical charging. The prevention method described for Kioritz dusting operations should be sufficient for smaller volume pediculicide metering.

System and Actuation

The two metering devices, mechanical actuation, flexible tube and nozzle were integrated into a functional breadboard prototype. The prototypes were evaluated for metering accuracy, repeatability, ease of actuation, site access and application.

XII Field Unit Concepts

A field unit prototype would be made of durable, impact resistant materials for rugged handling. For example, the acrylic components would be fabricated from metal or polycarbonate. Components would be designed for specific, tested volumes of pediculicide. The system would consider operators perception, fatigue and repeatability.

During the site visit, the Army suggested the delousing process would most likely occur with the DM-9 blower unit on the ground. The operator would stand alongside the unit, administering the pediculicide to the 17 sites on each subject within a 2 minute elapsed time. The tube and nozzle must accommodate the rapid dispensing. In addition, the method of actuation must be rapid repeatable, and possess mechanical advantage to reduce operator fatigue. The relocation of the meter and existing reservoir to the primary exhaust, the center of gravity of the unit is lower. The meter mounted conduit could be designed with sufficient supports to distribute the units weight. This configuration will stabilize an operational unit by preventing tipping during the inevitable tugging and pulling on the flexible tube.

Foot Pedal Actuation

The obvious mechanical advantage of body weight is evident in a foot pedal actuation design. This concept provides potential for incorporating simultaneous bypass valve switching and device metering. Through connecting linkages, a foot pump, or cable lever, a pedal could lower the membrane hopper while closing the bypass valve and return both (see figure 15).

XIII System Testing

The objectives of system testing were the following:

1. Prove a metering design concept that would reliably disperse consistent powder volumes. Repeated aerosol capture test will be conducted to judge consistency.

2. Determine the effectiveness of triggering time and the effect on suspension and clouding.

3. Determine practicality of alternative flexible tubing (i.e. collapsibility, storage, durability, performance).

4. Quantify nozzle configurations for minimum pressure head, site access (particularly a sleeve cuff), and dispersal effectiveness.

The first test consisted of dry dump metering. The engine was left off and a weighed container held under the meter during actuation. The dispensed material and container were weighed yielding a net volume.

The engine was started and a bag filter was attached. The engine ran at full, RPM for 2 minutes. The net change in weight determined the extent of meter trickle.

The system was run at maximum RPMs into the attached bag filter. The meter was actuated and the bag removed and weighed for net powder dispersement. The process was repeated 10 times; each time the meter was observed through the clear acrylic tube.

The flexible tube and nozzle were connected to the meter conduit for empirical evaluation. The nozzle exit cloud was observed for duration and concentration. The nozzle was inserted into shirt sleeves and actuated for powder dispersement.

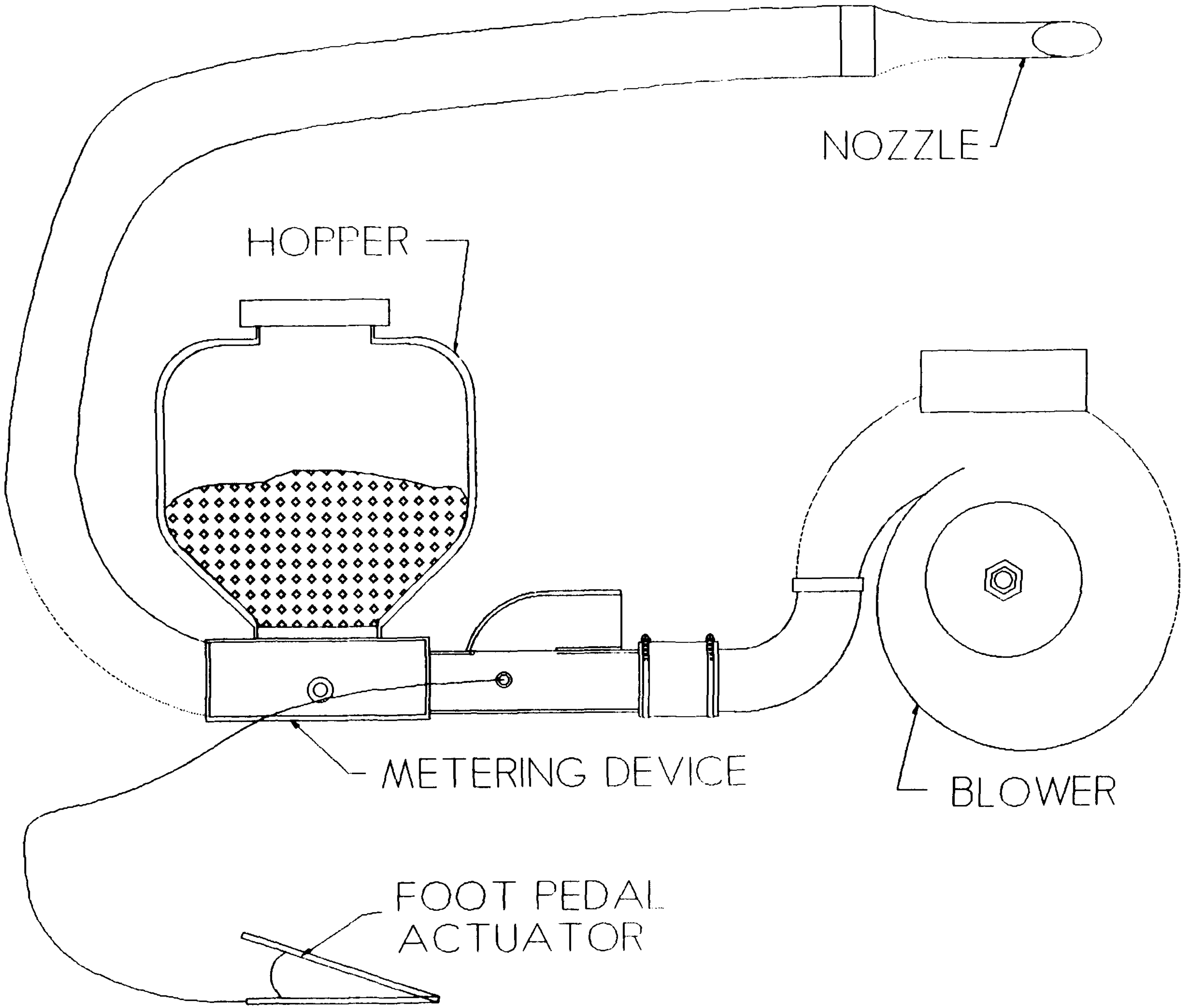

FIGURE - BREADBOARD MASS DELOUSING SYSTEM

XIV Results

The results of the system tests are listed in table 2. The inclined membrane meter had an average dry dump of 3.52 grams. The 2 minute blow by test resulted in 0.3g trickle. The metering actuation had an average 2.31 grams. Empirical tests demonstrated good clouding characteristics from the nozzle. The nozzle was easily inserted in a coat cuff with the nozzle end above the elbow. The powder application in the shirt sleeve was uniformly distributed on the skin in the biceps area and to greater extent on the surrounding clothes.

The dry dump auger test resulted in precise and consistent metering of 1.9 grams. Blow-by testing caused leakage of 4.1 grams for the 2 minute duration. The spring loaded cover was installed on the funnel. The auger was actuated several times to ensure the presence of powder behind the cover. The second blow-by test produced no powder accumulation. The metering test had an average metered weight of 1.71 grams. Similar to the inclined membrane, the empirical tests demonstrated good clouding, and uniform application.

XV Conclusions

Several observations were made while testing the sliding membrane system. When the blower is abruptly shut off from full RPMs to zero, the system undergoes rapid depressurization. While running, the reservoir slowly accumulates the system pressure through seams in the meter. As result of the depressurization, the reservoir has a greater pressure than the attached tubing; a small amount of unmetered powder is forced into the waning air flow. The reservoir was unvented; a filtered vent would stabilize the pressure while containing the pediculicide. Maximum RPMs raise the static pressure and velocity of the system. Neither of these parameters significantly contributed to the metering function. High velocity is undesirable when accessing the sleeve cuff. An RPM of 5000 (approximately mid-throttle), performed suitably. Lastly, an unattended tube and nozzle will whip due to the rapid exhaust.

As an additional visual test on the auger system, air was allowed to exhaust the meter conduit without attached filter or tube at maximum RPM. Under these conditions, the intrusion of the funnel served to constrict the conduit; causing it to act as a nozzle. The capillary action at the funnel, aspirated the powder around the seal resulting in visible leakage. As verified by the metering test and visual nozzle tests, no leakage occurred during normal operation.

Table 2: System Tests

A. Inclined Membrane

Dry Dump Metering

1.	4.2g
2.	3.6g
3.	3.1g
4.	3.4g
5.	3.5g
6.	3.3g
Avg.	3.52g

2 minute blow-by at maximum RPMs 0.3g

Metering Tests

1.	2.4g
2.	2.9g
3.	2.2g
4.	2.0g
5.	2.2g
6.	2.7g
7.	2.1g
8.	2.1g
9.	2.4g
10.	2.1g
Avg.	2.31g

B. Vertical Auger without seal flap

Dry Dump Metering

1.	1.9g
2.	1.9g
3.	1.9g
4.	1.9g
5.	1.9g
6.	1.9g
Avg.	1.9g

2 minute blow-by at maximum RPMs w/o seal flap 4.1g
2 minute blow-by at maximum RPMs w/ seal flap 0.0g

Metering Tests with seal flap

1.	1.7g
2.	1.2g
3.	1.4g
4.	1.5g
5.	2.6g
6.	1.8g
7.	2.1g
8.	1.4g
9.	1.9g
10.	1.5g
Avg.	1.71g

In both cases, the metering resulted in an instantaneous and compact clouding of a suspended (aerosol) powder. Metered powder was consistent and uniform. The proof-of-concept and breadboard prototypes were invaluable to the advancement of this unique and challenging application. The testing conclusions verify the technical feasibility of the DM-9 delousing system application.

XVI Recommendations

The two systems perform comparably. The auger is more complex; requiring an independent power source and more expensive stainless steel components. The inclined membrane can be easily incorporated into the foot pedal design.

The results of prototype testing yielded areas for continued research, such as, troubleshooting, dispersal effectiveness testing, and field unit testing. Additional research will provide precise design revision to improve performance. Further fabrication and testing will define expected life-cycle performance and operational reliability.

Phase II efforts should concentrate on concurrently optimizing the two designs. Design enhancements would be incorporated, such as, an integrated foot pedal actuation, practical tubing and nozzle, improved seals, reservoir filter vent, and mass producible components. Field prototypes of each design, incorporating all feasible enhancements would be fabricated and tested. The development of field testing performance criteria and protocols would clearly define the requirements of a field unit prototype. From the testing results preliminary operating, service and maintenance procedures would be developed.

A thorough producibility then be conducted on the components of each design. The study will analyze alternative materials and processes for each of the designs. New materials and alternative fabrication techniques can improve quality and reduce cost. Recommendations will be made for advanced materials with promising characteristics. Incorporation into the next generation unit will rely on interchangeability and availability of components.

Following this study, a single design would be recommended as preproduction prototype. A more advanced preproduction prototype would be fabricated. This unit will represent a fully serviceable, self-contained (add-on) field unit. Independent testing would be recommended to verify the performance of the unit. Revised operating and service procedures should be developed. The final design configuration would be compiled on Level II drawings.

Phase II research will define the requirements for eventual first article testing and transition to tactical units.

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