ENGINEERING CONTROL OBSERVATIONS AND RECOMMENDATIONS FOR INSECT REARING FACILITIES

AT

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ENGINEERING CONTROL RECOMMENDATIONS

In early 1993, the Engineering Control Technology Branch of the Division of Physical Sciences and Engineering was asked to assist in a Occupational Asthma Identification project being carried out by the Clinical Investigations Branch of the Division of Respiratory Disease Studies (DRDS) by evaluating engineering controls used in insect rearing facilities. This was to be done while assisting Patrick Hintz, Environmental Investigations Branch, DRDS with an industrial hygiene evaluation of three insect rearing facilities operated by the Animal and Plant Inspection Service, Plant Protection and Quarantine Programs, U.S. Department of Agriculture. Observations were made at the Pink Boll Worm Rearing Facility in Phoenix, Arizona, August 22-26, 1993; the Mexican Fruit Fly Rearing Facility in Edinburg, Texas, August 28-30, 1993; and the Gypsy Moth Rearing Group at Otis Air National Guard Base, Massachusetts, November 1-4, 1993.

At the time of these surveys, suspected asthma was found in some workers, but the cause of the disease was unknown. It was assumed that insect parts might be a major factor, however, the specific antigens and dose were not established. Thus, there was no guidance as to the sources of hazardous emissions or to what chemicals or substances needed control. Limited resources precluded a comprehensive study of the ventilation and other control systems. Therefore, the controls evaluated in this study were limited to those operations incidental to the industrial hygiene study which was carried out at each facility.

PINK BOLL WORM REARING

The Phoenix, Arizona, facility was started in the 1960's as a temporary facility with an anticipated life of about ten years. Much was constructed from trailers and prefab buildings such that most operations are carried out in separate buildings connected by walkways. The commercial hatching was done in a large warehouse building in an industrial setting about a half mile away.

At the time of this survey, we were given a tour of a new facility that was under construction. Some of the equipment had been installed and it was evident that many operations would be modified. It was difficult to visualize the extent to which the present operations would be altered; however, it appeared that sound engineering principles were used in the design, construction, and selection of controls. This building was scheduled to start operations in early 1994. A follow-back survey should be made to determine the effectiveness of the new controls and production schemes.

The following discussion of the now obsolete operations is provided to document past practices.

Packaging

The packer works in a walk-in cooler (Figure 1) 7.5' x 11.25' x 9' (760 cubic feet) controlled to about 40° F. Personal protective equipment consists of a

dust mask (3M 8710 dust and mist resistant), a short wrap around gown, and leather gloves.

Irradiated canisters (5.5" diameter x 7.75" tall) containing sterilized, adult, pink boll worms are delivered through a 21" square window next to the hood. The canisters are opened in a poorly designed hood, 34" wide, 22" high, and 21" deep with a 9" shelf projection at the bottom. The exhaust from the hood is directed through two cyclones in series and the blower discharge is returned to the room through a cloth filter bag of unknown dust removal efficiency. The irradiated insects are dumped onto a chambered metal tray (1.25" deep, 11.5" square with 1.625" square compartments) sitting in a cardboard tray (16" x 24" x 3") in the hood. After emptying a canister, it is placed over the exhaust (vacuum) line in the hood and bumped hard to clean out the canister. He uses a spatula to smooth off the pile and to fill all the chambers; a 5" x 5" opening in the middle of the tray is protected with a cover. When full, the tray is lifted and an empty tray is placed in the cardboard tray and the hole cover is transferred to the empty tray. The full tray is carried to a table about 4' to the right and placed in a tray holder. A canister contains enough boll worm adults to fill about 1-1/2 to 2 trays, but usually only one tray is filled at a time. After about every third canister, the packer plays catch-up by using the spatula to scoop the overflow from the previous canisters and trays into a new tray. This is when the greatest dust exposure occurs. Much dust was observed escaping from the left side of the hood.

Trays are stacked in the holder starting with a full tray on the bottom, an empty tray is placed on top of it, then full and empty trays are alternated three times, and two full trays are added consecutively such that six full trays interspersed with four empty trays are packed. The sides of the holder are inserted, two packs of blue ice are inserted in the center hole, and a cover is strapped on. Eight holders were filled in this manner in about 1-1/2 hours. Full holders were removed from the cooler and packed into shipping containers placing four blocks of blue ice on the bottom and two on top. Containers were strapped shut, weighed, and loaded on the truck.

When this operation is complete, the blower for the cyclones was turned off and the cyclones were emptied. A wire probe was inserted into a plastic bag. The top of the bag was placed over the cyclone discharge port, crimped together, and held shut with one hand; with the other hand, the packer opened the port and manipulated the probe from outside the bag to assist the emptying of the cyclone into the bag. When the cyclone was empty, the bag was twisted to seal it, removed from the discharge pipe, and then taped shut. The hood and cold room floor were then vacuumed and the floor mopped. The readily accessible parts of the room outside the cooler were also vacuumed and mopped.

The hood in the cold room (Figure 2) is very poorly designed; it has no plenum, and the exhaust is a 3-1/2" pipe projecting 10" into the top of the hood. A refrigeration unit is suspended from the ceiling; high velocity air is discharged at high velocity toward the left of hood. The chilled air is deflected by the wall and passes in front of the hood. As this air blast passes the hood face, the capture velocity of the hood is overcome and air is actually drawn out of the left side of the hood.

RECOMMENDATIONS: This is a very poorly designed situation. For this operation, we would recommend a slot hood similar to that illustrated by ACGIH (American Conference of Governmental Industrial Hygienists) Figure VS-99-05 in Industrial Ventilation, 21st Edition (Figure 3). This hood is designed for a fluidized bed operation but could be modified for insect packaging; the freeboard dimension could be reduced to contain the cardboard tray which, at the time of the survey, had a height of 3".

The exhaust from the overhead cooler should be relocated so that the discharge does not disturb the operation of the hood. A plenum to reduce the velocity of the discharge could be mounted on the wall opposite the hood, such that approximately laminar airflow would enter the hood face.

To prevent exposure to insect parts while emptying the cyclones, hood designs illustrated by ACGIH Figure VS-15-01 (Figure 4) should be appropriate. Because it appears to be necessary to probe into the discharge of the cyclones to ensure complete emptying, the top left and lower right examples of "barrel filling" hoods shown in VS-15-01 may be the best choice. A plastic bag could be inserted into the drum to collect the cyclone debris and twisted shut to seal it before disposal. ACGIH Figure VS-15-02 (Figure 5) should also be considered. The exhaust from the blower for the cyclones should be HEPA filtered to reduce contamination of the cold room.

Egg Stacking and Tray Washing

The worker starts the day by mopping the floor of the storage room (18' x 30' x 10' high, 5400 cubic feet) with a disinfectant solution made up of tap water, condensate from a dehumidifier and a squirt of Versphene SE [Calgon Vestal Corp.] (14.40 percent sodium α-phenylphenate and 12.45 percent sodium p-tert amylphenate). At the same time the tray carts are rotated from front to rear, thereby placing the racks that are to be moved to the hatching area near the door on the opposite side of the room. Before entering this room, all personnel are required to don booties over their shoes and to spray the bottom of the booties with Staphene disinfectant. The booties are reused until degraded before disposal. Mopping takes 10 to 15 minutes.

The Egg Stacking room is about 6' x 18' x 10' high (1100 cubic feet). It has no ventilation, but one 18" cooling fan is located at back of room. Three empty tray racks about 5' long, 30" wide and 6' high with three shelves about 20" apart are placed in the back of the room. Containers of eggs and diet are received from the kitchen in solid sided carts 2' wide x 5' long and 42" high, 240 containers/cart. Closed containers of eggs (cardboard "ice cream" cylinders 3" tall and 4.5" in diameter, the lids have a 3/4" lip that snugly overlaps the top of the cylinder) are transferred from the carts to the taller tray racks and are stacked three high on smaller shelves (44" x 24") suspended 12" below each of the full size shelves. Each layer of 40 egg containers is separated with a coarse 2" x 4" mesh screen. Additional containers of eggs are placed on the upper full size shelves. (The loaded rack trucks are eventually transferred to the hatching room where an additional small shelf is suspended from extensions added to the top of the cart and these containers of eggs are stacked upon it.)

As each rack is filled, it is moved into a dark storage room next to the stacking room. This room holds 63 loaded rack carts, 9 for each day. Before moving the third cart into the storage area, 15 egg containers are taken to the weigh room, weighed for quality control, then replaced on the rack; samples weighed 1950 to 2700 grams. This task takes about 30 to 40 minutes.

After loading is completed, dirty trays and rack trucks are washed using high pressure water. Washing is somewhat haphazard, depending on how much and how sticky the dirt is. Versephene solution can be introduced in to the spray by the operator at will, but it reduces the pressure of the spray. When the trays were at a convenient height on the carts, they were hand scrubbed (dry) with a Skotch-brite #46 griddle polishing pad. When trays were too high or low, this step was skipped; thus, probably a third of the trays were dry scrubbed. The wash area is outside under a canopy and about 50' from a fairly heavily traveled street. The trays are leaned against a rail for spraying, draining, and drying. Trays measure 3' x 27" x 2.5" deep with a 2" inside lip. Carts are also tilted to allow access to various parts and to the wheels. After washing, the axles of the casters are lubricated; the pivots are lubricated only occasionally.

RECOMMENDATIONS: These operations do not appear to offer much worker exposure. All containers remained closed in the egg stacking room. Some ventilation should be provided for this room as good practice. We would recommend that 50 to 100 cfm of fresh, conditioned air be introduced at the end of the room away from where the egg containers are stacked and that it be vented from the wall closest to the stacking operation to provide cross ventilation.

Tray and cart washing was performed outside, and the dirt on the carts did not appear to be very heavy or sticky. Installation of a cart washing station in which carts are drawn through a series of sprays from fixed nozzles (similar to a car wash) should be considered. It would provide better control of the waste water (some of which might be recycled) and insure uniform washing of all carts and trays. In addition, by enclosing this kind of wash area, the worker would be isolated from potential exposure to biological wastes which may become aerosolized by the high pressure spray.

Egg Preparation

The room for egg preparation (Figure 6) is 11' x 20' x 10' high (2200 cubic feet). The eggs are received on flat paper rings 8" outside x 4" inside diameter stacked on 3" perforated stainless steel spindles 8" long. Each paper ring (about 200 to 250 rings per batch) is separated with a plastic mesh ring. They are divided about equally onto two spindles and placed in a bath with the spindles horizontal. The baths have a cubic top 12" x 11" x 12" high with an overflow of about 3.5" from the top. The bottoms are pyramidal, tapering to about 1.5" and are 18" tall. Net volume to overflow is about 30 liters. They are filled with a solution containing about 1 percent sodium hypochlorite bleach. The spindles rest on a mechanism that oscillates them a few inches up and down in the bleach solution to release the eggs. The employee, wearing rubber gloves, massages the papers and rotates the spindles to help release the eggs. After 15 minutes or so, the spindles are

transferred to a similar tank which contains a very diluted bleach (0.03 percent) solution and are further rinsed for 5 minutes or more. The eggs settle to the bottom of the inverted pyramids and are syphoned into a 1-liter beaker. The eggs are rinsed seven times by decanting the supernatant liquid and refilling the beaker. After the last decantation, the contents of the beaker is poured into 100-ml cylinders, allowed to settle for about 10 minutes and the volume of eggs is recorded. About 100 ml of eggs are dispersed in 2 liters of agar solution in erlenmeyer flasks. The flasks are covered with foil, then delivered to the kitchen where the eggs are titrated into the cylindrical cardboard hatching boxes containing diet (inoculation). The spindles are washed in a sink; the papers are separated from the plastic screen discs and discarded. The spindles and plastic screen disks are returned to the egg laying department. Three batches are processed a day.

The egg washing tanks are supported in racks along one wall such that the tops of the tanks are about 4' from the floor. Two series of three tanks are set up with the 1 percent bleach on the left, an empty tank, and the dilute 0.3 percent bleach tank on the right. Two small canopy hoods (11.5" x 3.5") are located about 15" (varies for each hood) over each series of tanks. Hot wire anemometer measurements indicated air flow of about 750 fpm (210 cfm) at the face of the hoods over the left bank, and about 550 fpm (155 cfm) over the right bank. The hoods taper down to a 6" diameter transition coupling to a 4" diameter flexible duct, then to a 4" to 6" transition tee and a 6" duct to the blower. Airflow of about 10-20 fpm was measured at the top of the tanks with only the hoods operating and 45-50 fpm when the 12-inch oscillating fan on the opposite wall was also operating. Air was recirculated by an air conditioning unit suspended from the ceiling. A large laboratory hood that was not being used was located in a corner to the left of the door as one entered the room.

A full face piece respirator was available, but was worn only when the worker sensed irritation from the hypochlorite odors in the room.

RECOMMENDATIONS: The canopy hoods should be replaced by an enclosing hood or, preferably, a slot hood. Canopy hoods are not very effective unless there is a force, such as temperature differential or inertial force, which directs the vapor or aerosol into the capture zone of the hood. Furthermore, workers frequently bend over tanks and place their heads into the flow of the capture zone. A baffled slot hood similar to that illustrated by ACGIH Figure 3-9 (Figure 7) in Industrial Ventilation, 21st Edition, with perhaps a half inch slot and a flow of 100-150 cfm is recommended for each tank. However, the baffles on the sides of the tank may prevent the worker from reaching into the tank to help dislodge the eggs. An alternative arrangement would be to not use side baffles but to provide a removable, transparent baffle on the front of the tank. Exposure could be further reduced by performing the decantation and washing in an enclosing hood, such as a standard laboratory hood. The oscillating fan should not be used at times when egg washing is being done and should probably be eliminated.

Pupae Stripping

Pupae are received in "Hexcel" (Nomex Honeycomb, Unicel Corp.) on cardboard sheets 16" x 24". The hexcel is pulled from the cardboard over a funnel and the pupae mostly fall out of the hexagonal cells and are directed into a plastic bucket. The funnel is part of a canvas structure laced to a 3/8" steel rod frame. This structure, as seen from above, is a regular trapezoid with bases of 24" and 48". The longer side is at the front, and the top of the back is 5' from the floor. About 33" from the floor is a coarse horizontal screen; the canvas tapers down from the screen forming a funnel with a 6" opening to a 4" long tube 18" from the floor. The bottom of the funnel and tube is inserted into a 12" diameter plastic bucket 10" tall sitting on an 8" platform. The hexcel is knocked a few times against a coarse screen over the funnel to ensure that the pupae are all released. Air flow at the screen was about 10 fpm increasing to about 50 fpm near the floor.

The trailer (Figure 8) is 11' x 23' x 8' high (2000 cubic feet) and is ventilated by a recirculating air conditioner to maintain the temperature and humidity. At the time of the survey, the temperature was about 80° F. and the relative humidity was about 78 to 80 percent. (Target is 82 ± 2° F. and 50 ± 10 percent R. H.) The intake to the conditioning unit is about 20.5" x 10.5", 4" from the floor. The effluent is released from a 14" diameter duct ell about 3" from the ceiling directed towards the front right corner of the room. The unit, located 1' from the rear wall and 3' from the right wall, is about 2' square. Calculations based on airflow measurements at the conditioner inlet panel indicate that the unit be recirculated about 400 to 500 cfm which would provide 10 to 15 air changes per hour. Both rear corners of the room were used for storage and were cluttered with cardboard drums and boxes.

RECOMMENDATIONS: To prevent unnecessary exposure in this operation, stripping should be carried out in an enclosing hood. Although rather clever in design, the canvas structure can be replaced by a more compact dumping station that will fit in a commercial laboratory hood. The hood should be equipped with high efficiency particulate air (HEPA) filtration to allow much of the air to be recirculated. To reduce noise and turbulence, the present air conditioner should be replaced by a well-designed (preferably external) air conditioning and circulating system.

Emergence

The emergence room is very large, containing at least 300 hatching boxes. It is maintained at 84° F. and 50 percent RH. Pupae are weighed (450 g) in trays about 12" x 18" which are then placed in hatching boxes, six trays to a box. Hatching boxes consist of an 18" cube at the tray end and the top and sides taper down to about a 2" square over about 1-1/2' (total length is 42"). The small end of the box is inserted into a pipe cross fitting in a 2.5" PVC pipe. An ultraviolet light, shining through the port of the fitting opposite the box, attracts the emerging moths and they crawl or fly from the box down the tapered area to the PVC pipe. Air flowing through the pipe at about 600 fpm directs the moths into cyclones in a cold room (40° F.). There are eight boxes on a line and the boxes and lines are stacked three high. Thus, moths from 24 boxes are captured by each cyclone in the cold room.

The cold rooms are cooled by means of ceiling mounted, recirculating coolers entering air passes through fiber glass filters. There are four cyclones in the north room (7' x 8' x 9' high) and eight in the south room (7' x 10' x 9' high). The cyclones are shut down once or more a day, depending on the hatching rate, and the moths are dropped into clean 18" trays. The pupae hatch typically 1 percent the first day, 17 percent the second, 37 percent the third, 32 percent the fourth, 9 percent the fifth, 3 percent the sixth, and 1 percent the seventh. The trays and the moths are weighed on balances located outside the cold rooms before being transferred to the radiation unit. Dropping the moths from the cyclones takes about an hour and is a very dusty operation; the workers wear 3M dust masks. Much of the dust is due to displacement of scales from the wings of the moths.

After seven days, the boxes are opened and the trays are removed and cleaned. The tray cleaning room, about 7' x 10' x 9' high, contains a plastic horn shaped hood 2' x 3' with a 1-1/4" flange attached to a 10" duct. The hood face is mounted at about a 30° angle 4' from the floor. A drum containing a plastic bag is placed below the hood and the empty pupae cases are dumped and scraped into the bag. This is also a dusty operation; the room is cleaned with a vacuum after the trays are dumped. The trays are subsequently taken to a wash station where they are scrubbed with detergent and bleach, usually on second shift. The hatching boxes are removed from the racks and washed with high pressure water in the outside parking lot. The pipelines are brushed out with a brush on a 15-foot snake.

RECOMMENDATIONS: The dirtiest places appeared to be two cold rooms which housed the cyclones and the tray cleaning room. The cold rooms keep the moths somewhat dormant; however the moths do continue to slowly crawl and beat their wings, which tends to release scales from their wings. Because of the great numbers, much scale dust is generated and is released when the cyclones are shut down and the moths are dropped. Local exhaust hoods similar to those recommended for the packing room cyclones should be installed here. Cleanup operations in both the cold rooms and the tray cleaning room should be conducted using a HEPA filtered vacuum cleaner. Hatching box cleanup should be conducted in a closed area in order to control the run off.

MEXICAN FRUIT FLY REARING FACILITY

This is a 4-5 year old, well designed facility. Workers enter through a locker room with showering facilities and separate lockers for clean and dirty clothing. It was apparent that workers did not use these facilities since the shower stalls were used for hanging lab coats, storage of boots, etc.

Dyeing

Pupae dyeing takes place at one end of a large storage room (Figure 9) 25' x 30' x 10' high (7500 cubic feet). The location depends on available space and worker preference. The room is ventilated with 500 cfm of conditioned air (75° F., 70-80 percent R.H.) through four 9" x 9" ducts at the ceiling; there are three 12" x 12" air returns. There are also three 54" rotary fans 30" from the ceiling. The room is mostly filled with aging pupae in plastic trays

15" x 30" x 2.5" stacked on a wheeled base. Trays are stacked 28 high with an empty tray on top; the highest full tray is about 75" from the floor, the wheeled base is 10" high.

On the day of the survey, trays of pupae to be dyed were stacked 25 high (68"). About 1630 g of pupae are distributed on each tray and 10 g of fluorescent pigment (Fire Orange A-14-N, Dayglo Color Corp., Cleveland, Ohio). Dyeing is done by removing a tray from the stack, emptying it into a plastic bag, twisting the bag closed, and then shaking it for about a minute to distribute the dye. The dyed pupae are returned to the tray, distributed fairly evenly across the surface, and then the trays are restacked on another base. When a stack is complete, it is moved into a cold room. Workers wear dust masks (8710 Dust and Mist Resistant, 3M Corp.), surgical type gloves, a rubberized apron, and rubber boots. On 8/28, dyeing was done by one worker in about two hours at a location about 3' from one of the rotary fans; on 8/29, two workers did the dyeing in about one hour at a location about 8' from the fan. The temperature of the room was 80° F. and the relative humidity was 50 percent.

Radiation

Dyed pupae that have aged in a cool room 24 hours or less, are loaded into plastic bags using a special funnel. The funnel is an oblong box 6" wide 5" high and 18" long, open at the 6" x 18" top, and tapers to a 2.5" diameter discharge at one end. A plastic bag is placed on the discharge spout and a tray of dyed, chilled pupae is dumped into the box end funnel. It is then lifted and rotated 90° so that the pupae fall into the bag. The filled bags are twisted closed at the top. Seven bags are placed on a tray, and the tray is placed in the cooler. Two workers perform this job: one dumps the trays into the funnel and stacks the empty trays and the trays of bags, the other fills the bags and places them in the trays. The filled bags are subsequently placed in a perforated 4.5" diameter metal cylinder, 18" long. The cylinders are loaded into the radiation machine and exposed to a radiation source to sterilize the pupae.

RECOMMENDATIONS: These tasks did not appear to create a large volume of dust, and the workers do wear disposable dust respirators. If it can be determined that exposures which occur do cause or antagonize asthmatic reactions, the dyeing should be carried out in an enclosing hood. Furthermore, the dyeing could be done in a closed mixing device, perhaps a closed, inclined, rotating cylinder similar, but smaller than that used for screening (see below). The pupae and dye could be dumped from one or more trays into a hopper feeding device and the dyed pupae could be discharged onto other trays. Alternatively, the dyed pupae could be discharged into the bags that are used for radiation, thereby eliminating the need to fill the bags as a subsequent task. Local exhaust ventilation could be used to control emissions which may occur at both the feed hopper and mixer discharge.

Screening

Larvae are washed from the diet and placed on a layer of fine vermiculite (Super Fine Vermiculite (C-4), Strong-Lite Products Corp., Pine Bluff,

Arkansas) in a tray. The larvae pupate are separated from the vermiculite in a rotating screen. The screen (Figure 10) is 24" in diameter and about 5.5' long, inclined at about 10° from the horizontal, and rotates about 6 rpm. The screen on the lower third is slightly coarser than the screen on the upper two thirds. The contents of the trays are dumped and brushed into a 34" x 18" x 12" deep hopper which gravity feeds the screen. The top of the hopper is 51" from the floor; workers stand on a 12" platform when dumping the trays. Trays are stacked 28 high (70" from floor to top) on wheeled carts (10" high). The vermiculite passes through the screen and falls into two bins 24" x 30" x 26" high; a baffle directs the fine and more coarse vermiculite into separate bins. (Later observations noted that vermiculite from both bins are reused indiscriminately.) The pupae are retained on the screen and are discharged into a container on the floor. About 1630 g of pupae are weighed into clean trays and 10 g of dye preweighed in a small cup is dumped on top. There are containers marked to the volume of pupae needed to approximate the 1630 g available. However, during this survey the workers preferred to collect the pupae in a 12" deep by 10" diameter bucket and then pour and weigh the pupae from it onto the trays. About once a week, as needed, the dye is weighed into the small cups.

Sifting and weighing are done in one end of a trailer attached to the main building by passageways about 10' from each end; it is about 14' x 60' x 8' high (6700 cubic feet). The room is maintained at 70° F. and 70 percent R.H. Ventilation is supplied through fifteen 9" x 9" ceiling vents and two 12" x 30" louvered exhaust vents in the end wall farthest from the sifter and 18" from the ceiling. Three rotary, wall mounted fans are equally spaced on each side wall; the three nearest the sifter were not operated during the survey. The sifter is located about a third of the way from the left end and the scale is against the wall to the left of the sifter. No local exhaust ventilation is provided. The vermiculite is damp, and dust emission during sifting was observed to be minimal. The right half of the room is used for storage of stacks of trays.

The dirty trays from the sifting area are washed in large sinks and stacked in a tray wash area. The vermiculite is sterilized by inserting an assembly of three steam lances into the carts in the tray wash room for some time (hours). Sterilized vermiculite is moved into the larval development room under an air inlet. A clean tray is removed from a stack of 28, placed on the vermiculite cart, and two large scoops of vermiculite are distributed over the surface to form about a 1/4-1/2" layer. The trays containing sterilized vermiculite are then stacked on a wheeled cart. Again, the vermiculite is damp and dust emissions appeared minimal.

RECOMMENDATIONS: As noted, there were no observable emissions from the processes and equipment described in this section. However, if warranted, a simple enclosing hood could be designed to apply local ventilation to the rotary screen. Similarly, an enclosing hood could be designed for the area in which the vermiculite is scooped onto the trays. Furthermore, these operations (and pupae dyeing, as well) are performed in the large rooms where the larvae are feeding or pupating; if they could be restricted to small rooms dedicated for these purposes, the workers would be isolated from emissions that the larvae generate.

Diet Preparation

Diet is prepared in a large mixer in a room open to the outside and isolated from the main building (except for the conveyor that penetrates the wall to deliver the diet mix to the adjacent room). Bags of dry ingredients (over 1600 pounds, total) are wheeled in on a dolly, cut open, and then dumped into a 3-foot diameter, cone shaped loading hopper. A screw conveyer lifts the ingredients about 9' and dumps them into a measured amount of water in a heated, ribbon type mixer on the mezzanine. A 315 cfm exhaust fan in the left wall at the level of the mixer operates only when the mixer is in use. After a batch is completed, the diet is pumped into the inoculation area.

RECOMMENDATIONS: This is a short time operation lasting perhaps a half hour a day. Some of the ingredients generate considerable dust when they are dumped into the feed hopper. Local ventilation (Figure VS-15-01) could be applied at the top of the hopper to reduce the emissions into the room.

GYPSY MOTH REARING GROUP

Quarantine

The quarantine room measures about 15' x 24' x 8' high (2880 cubic feet). Because new or foreign species are being investigated in this room, it is isolated to prevent contamination of the rest of the facility. Entry is gained through a labyrinth of three small chambers. The room is very congested with tables, a sterilizer, a sink, several hoods, and many freezers and refrigerators which had been accumulated over the years. The heat load from the refrigerators and freezers had increased to the point that a large ceiling mounted recirculating cooler was recently installed. The older, smaller unit was retained for use as a standby unit. Several operations by one worker were observed in this room. 1) Refrigerated (dormant) moths were removed from "cottage cheese" boxes. A male and female were weighed on a balance and placed in a clean box which was lined with a ring of paper about 2.5" x 12", and the other moths in the old box were discarded. 2) Pupae in boxes were separated and examined then placed in new boxes. 3) Boxes containing dead moths and egg masses were opened, a vacuum was used to pull out dust and debris, the moths were removed with tongs and placed in glassine envelopes and the paper containing the egg mass was cut, removed, and placed in another box. Much of the time another worker weighed egg masses by opening the boxes and removing and weighing the paper containing the egg mass. The paper was then unstapled and placed in a box with previously weighed strips. Alternatively, free eggs were dumped on the balance and placed in glassine envelopes after weighing. The empty boxes were vacuumed clean for reuse. Container tops were cleaned of markings using isopropanol soaked tissues (this took place for only about 20 minutes).

A fume hood with a 22" square face opening was used to exhaust air from the room. With the hood closed to a 6" opening, the face velocity ranged from 80 to 140 fpm, averaging about 120 fpm to exhaust about 110 cfm. Building air from outside the room was admitted through an inlet on the opposite side of the room through a 6" x 12" rectangular opening, 4" from the ceiling. The air

velocity at the face of this duct ranged from 285 to 515 fpm, average 370 fpm, to provide 185 cfm fresh (from within the building) air. A small exhaust vent, 8" square was located about 3' below and 3' to the right of this inlet. It had an average face velocity of 190 fpm to exhaust about 85 cfm from the room. This places the room under negative pressure, as desired, with about four room changes per hour.

RECOMMENDATIONS: This room should be redesigned to provide more efficient use of space and refrigeration to reduce the heat load. A central refrigeration unit located outside the room with its own ventilation system would remove the heat load within the room. The refrigerant could be piped through the walls to various insulated cabinets having individual controls to maintain the various temperatures. The present room ventilation system with an exhaust so close to the inlet short circuits about 25 percent of the "fresh" make up air to the room; furthermore, major exhaust from the room should not be dependant on the fume hood. The room should be ventilated through a plenum to provide laminar flow across the room as opposed to the turbulence created by the present ceiling unit. Coolant from the central refrigeration unit (perhaps some of the return from the cold boxes) could be used to temper the air supply to a small room air recirculation unit to provide fresh air to the room. A HEPA filtered vacuum should be used to reduce the redistribution of particulate matter when cleaning out the boxes for general cleanup.

Quality Control

Several tasks were performed in the quality control lab, a room 9' x 21.5' x 8' high (1500 cubic feet). The technician observed started with hatching counting and then larvae counting in a standard laboratory hood. Other employees also use this lab which includes a long single slot hood along one side and another hood enclosing a sink where fabric screens are treated with formaldehyde. Both of these hoods were "homemade", built of transparent plastic sheet and wood. The lab was quite busy with three or four people rotating in and out for various tasks. In the afternoon, this technician counted eggs.

Hatching counting was done by opening petri dishes containing two egg mass cores and counting the small immature larvae that had hatched from these cores. The larvae were small enough that they could be drawn by vacuum through the casing of a retractable ballpoint pen. Larvae were counted by opening the boxes and counting the male and female larvae contained therein.

RECOMMENDATIONS: Although this room was somewhat congested with several people performing various tasks, there were no visible emissions being generated and the employees performed most operations within the capture envelope of the hoods. When using the large laboratory hood, there was a tendency for the workers to insert their head, shoulders, and arms into the enclosure. Several of the tasks performed here could be done in a small biological hood with laminar flow which would allow technicians to work comfortably without placing their heads into the capture area of the hood. Although we did not observe the formaldehyde treatment of the fabric screens, we could not ascertain if emissions occurred from this operation. However, since formaldehyde is considered to be a carcinogen, this operation should be

isolated in an area or room with little or no traffic to limit the number of persons who could be exposed to potential emissions.

Egg Counting

Egg counting was done on a table in the "silver room" using a low power bifocal microscope; the eggs were contained in petri dishes. The silver chamber, a room 12.5' x 35' x 6.5' high, is designed for laminar flow. The ceiling is made of 1/4" perforated peg board providing a plenum to uniformly distribute in supply air. The air is exhausted into a plenum which was constructed by furring out a lining 1.5" from the walls along the long sides (starting 9" from each end) and providing a 1.5" entry slot along the bottom. The entry door in the middle of one end is 36" x 75". Most of the room is occupied with racks of maturing eggs and larvae. The room was maintained at 26° C. and 70 percent relative humidity.

RECOMMENDATIONS: The operation observed should be performed using a biological laminar flow hood in a "clean" area. Although ventilation of the "silver room" appeared adequate, egg counting in this room places the employee at risk to exposure to emissions created by the maturing eggs and feeding larvae.

Diet Preparation

The diet is prepared in a room 24' x 35' with a 8.25' ceiling. An 80-liter, steam-jacketed mixer, near the center of the room, is in current use; a 100-liter kettle, recently installed, was not in use. Water metered into the kettle is recirculated and heated, then pre-weighed solids are added manually and dispersed with the help of a long handled whip and recirculation. After all materials are added, a high intensity stirrer is immersed and the batch is stirred until uniform. A panel board can be programmed to add the proper amount of water to the kettle, to control the temperature, and the length of time of agitation. The temperature used is around 180° F. so that vapors are emitted from the kettle. General ventilation is used to dissipate the vapors and heat. When the cooked batch is completed, it is pumped to a filling device which adds a measured amount of diet to six cups at a time. The cups are 3.75" in diameter at the top, 2.5" at the bottom and are 2" deep. The operator injects one or two shots, depending on the use of the cups. Thirty cups are put onto a tray (five rows of six) and the trays are placed on tray carts. When the kettle is empty, it is cleaned with water and another batch is mixed. Depending on demand, two or more batches are prepared daily; a thorough cleaning of the kettle and the immediate area is done after completion of the last batch. The solids for the diet are weighed from large containers in a room about 6' x 11' off the kitchen.

Inoculation of the diet is done in a narrow room 7.5' x 35' adjacent to and along one of the walls of the kitchen. Eggs suspended in an agar solution are injected onto the diet by a device which inoculates six cups at a time. The inoculated cups are lidded and stacked on trays in a tray cart, then moved to a controlled temperature room to age and hatch.

RECOMMENDATIONS: These operations appeared well controlled with minimal exposure. A slot hood (Figure VS-15-01) could be placed on the top of the kettle to reduce emissions and odors emanating while mixing and cooking of the diet.

Tray Washing

Tray washing is done in a bay near the kitchen. Plastic trays are 23" x 20" x 1". The carts, constructed of 1.25" aluminum angle, are 74" high, 47" long, and 23" wide. They contain seven tray racks 9" apart starting about 9" from the floor. Trays are loaded into a tub 24" x 48" x 30" deep containing one gallon of sodium hypochlorite bleach solution (5.25 percent) and enough water to fill the tub to within 2 or 3" of the top when it is full of trays. A canopy hood is 31" above the top of the tub; solid partitions at the back and one end of the tub support the hood. The hood plenum is 54" x 30" x 17" deep. There was a negligible vertical component of air flow measured at the top of the tub.

RECOMMENDATIONS: This canopy hood is ineffective in capturing emissions from this operation. It should be replaced by a slot hood at the top of the sink. This would place the capture zone of the hood at the point of emission and eliminate the potential for the worker to place his head between the emission source and the capture zone of the canopy hood.

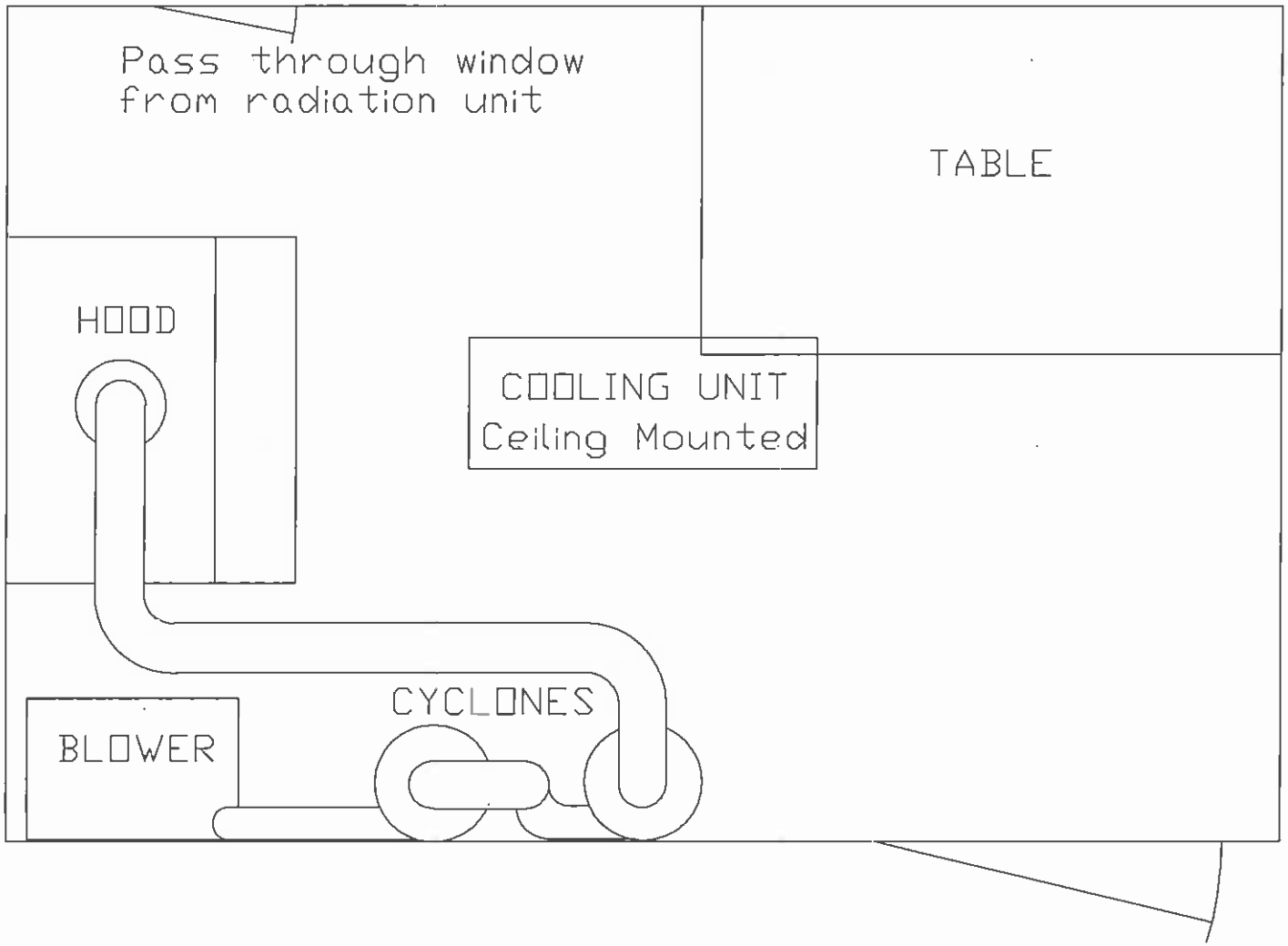


Figure 1. PACKAGING ROOM

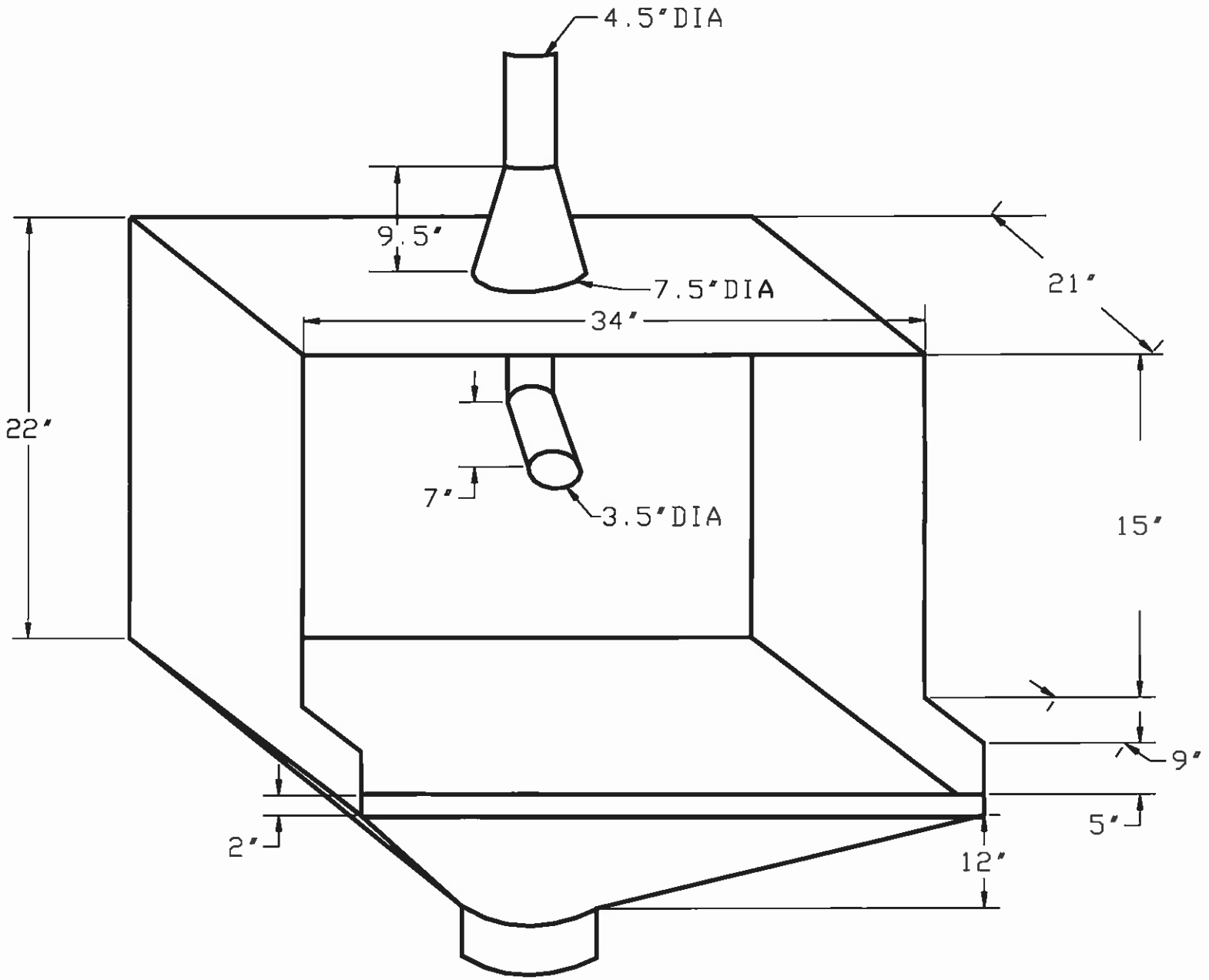
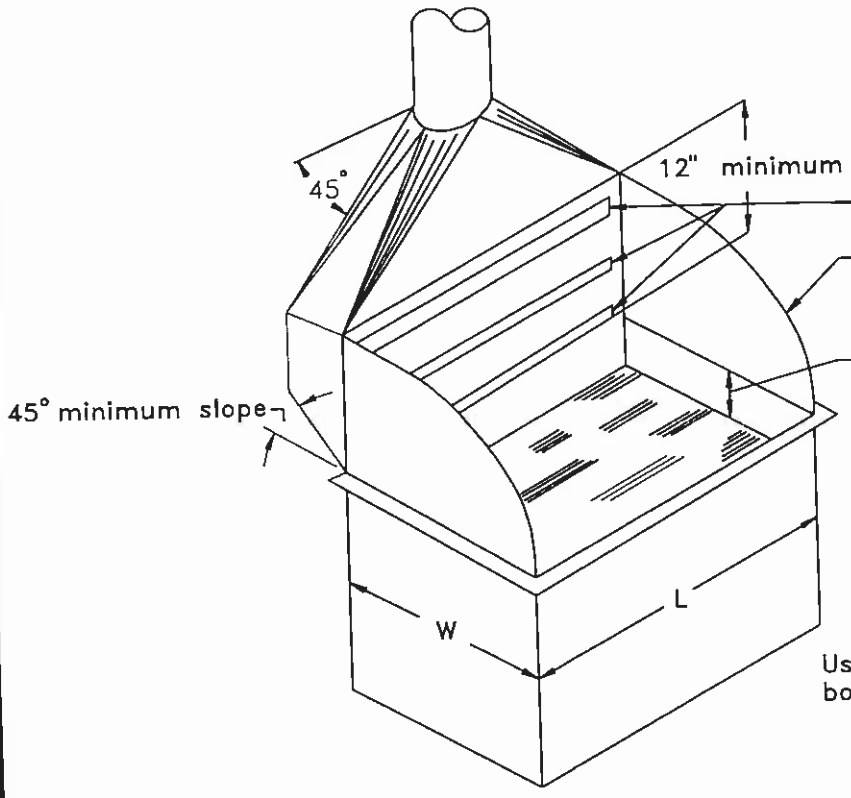


Figure 2. Packaging Hood



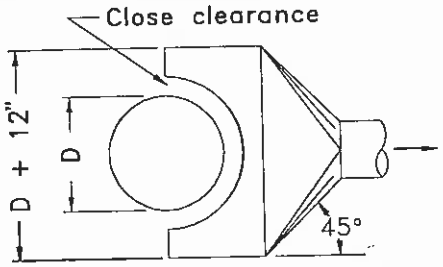
Use at least two slots. One at bottom of hood.

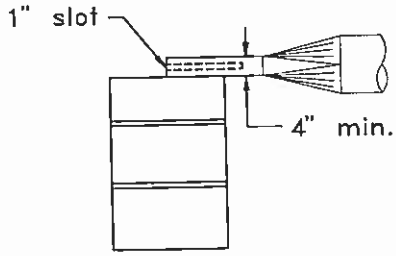
$Q = 150 \text{ cfm/ft}^2$ of bed (150LW)
Slot velocity = 2000 fpm
$h_e = 1.78\ VP_s + 0.25\ VP_d$
Minimum duct velocity = 3500 fpm
W not to exceed 36"

Free board must be maintained to prevent material carryout.

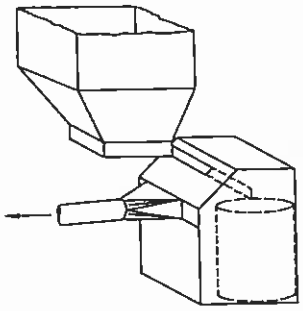
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*FLUIDIZED BEDS*	
	DATE *12-90*	FIGURE *VS-99-05*

FIGURE 3

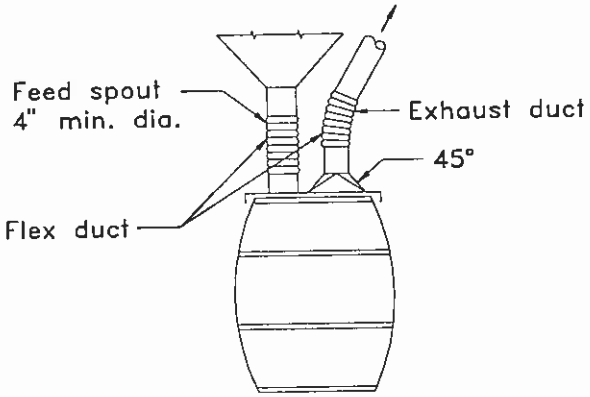




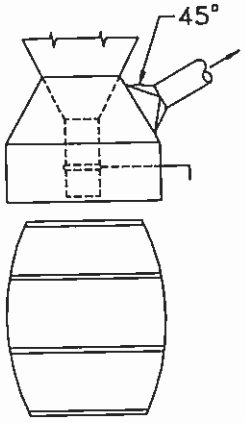
Q = 100 cfm/ft^2 barrel top (minimum)
Minimum duct velocity = 3500 fpm
h_e = 1.78 VP_s + 0.25 VP_d



Q = 150 cfm/ft^2 of open face area
Minimum duct velocity = 3500 fpm
h_e = 0.25 VP_d (45° taper)



Q = 50 cfm x drum diam. (ft)
Minimum duct velocity = 3500 fpm
h_e = 0.25 VP_d



Q = 300–400 cfm
Minimum duct velocity = 3500 fpm
h_e = 0.25 VP_d

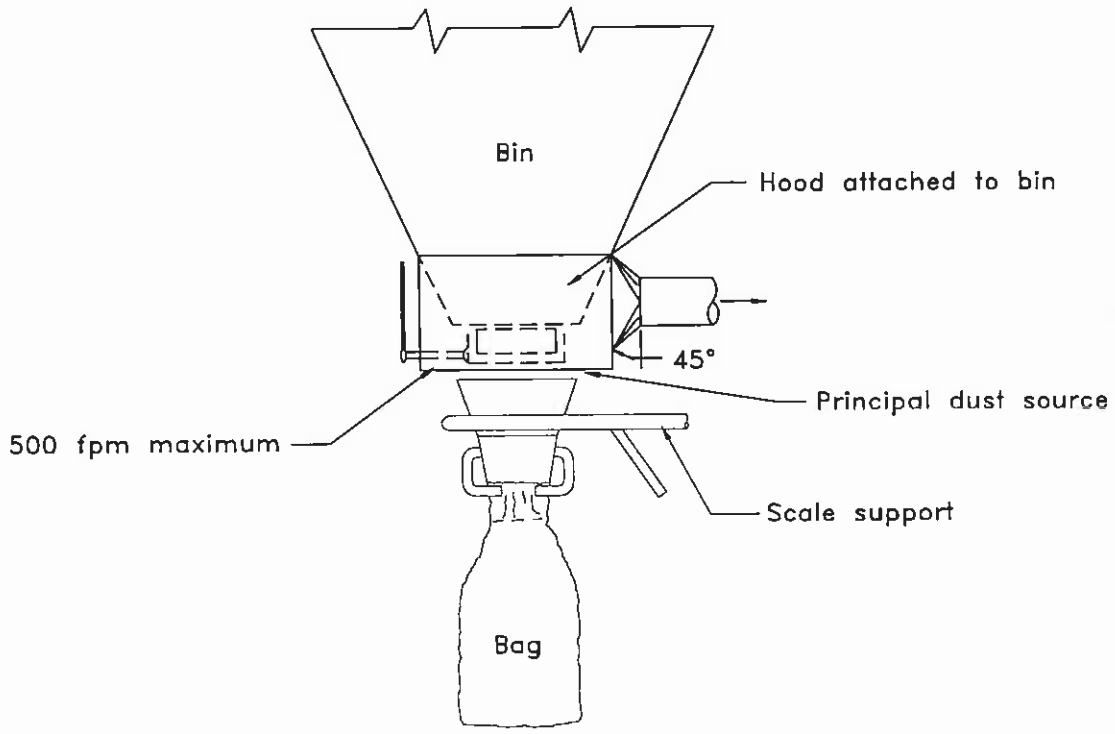
Note 1: Air displaced by material feed rate may require higher exhaust flow rates.

Note 2: Excessive air flow can cause loss of product.

Reference: 10.15.1

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*BARREL FILLING*	
	DATE *1–91*	FIGURE *VS–15–01*

FIGURE 4



Q = 400–500 cfm – non–toxic dust
1000–1500 cfm – toxic dust

Minimum duct velocity = 3500 fpm
$h_e = 0.25\ VP_d$

Note: Care must be taken such that too much air is not used, as valuable product will be pulled into the exhaust system.

Reference: 10.15.2

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*BAG FILLING*	
	DATE *1–91*	FIGURE *VS–15–02*

FIGURE 5

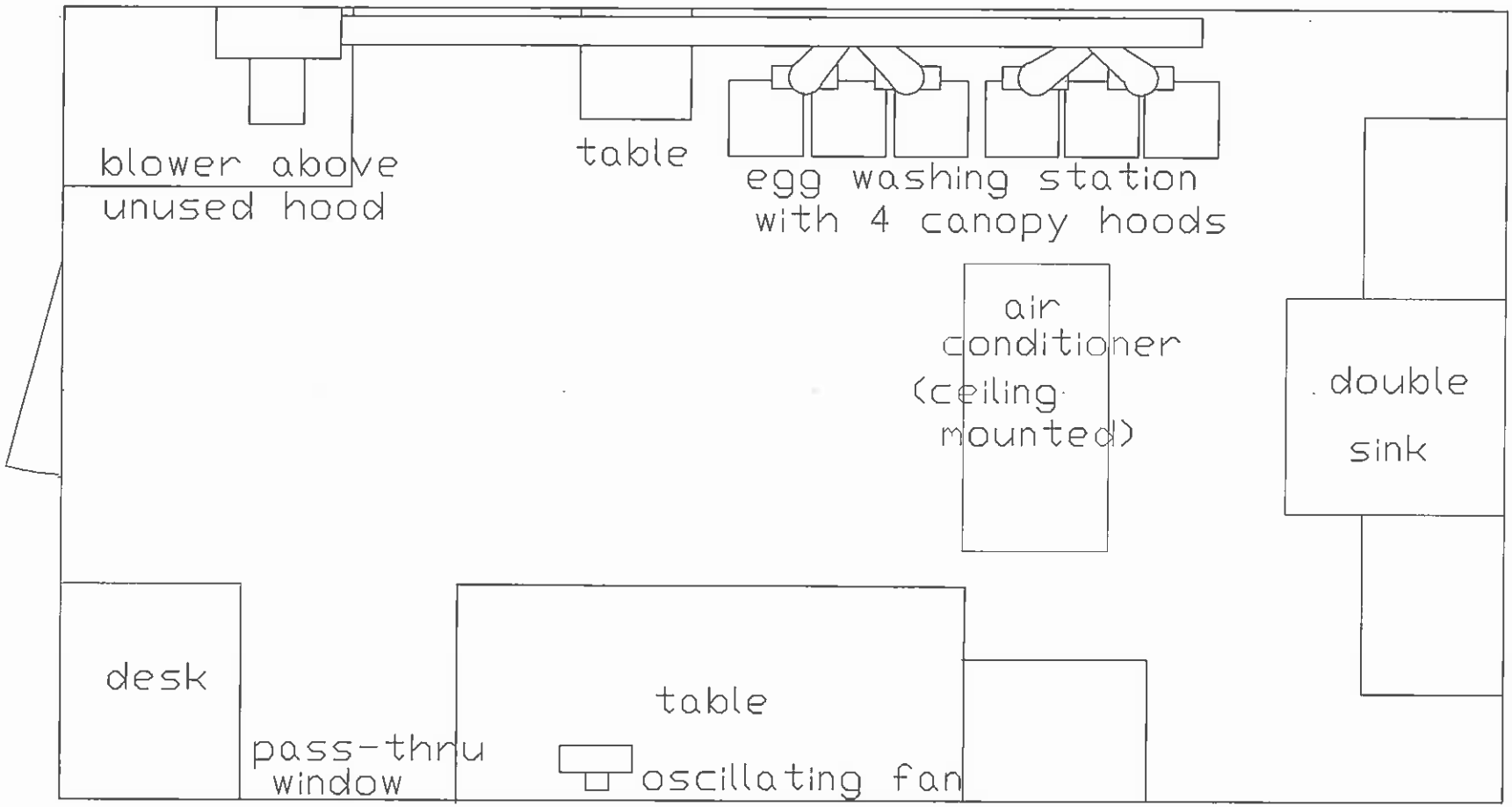
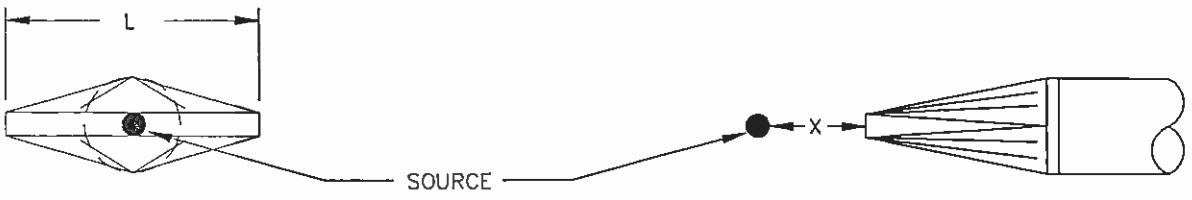
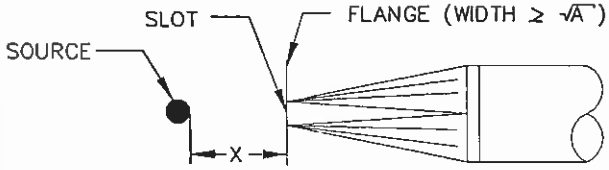


Figure 6. EGG WASHING ROOM

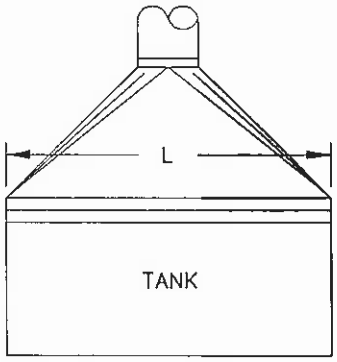


FREELY SUSPENDED SLOT
Q = 3.7LVX

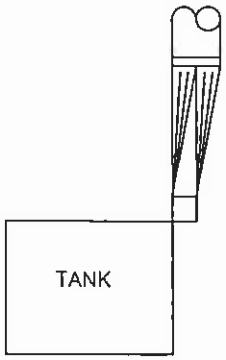


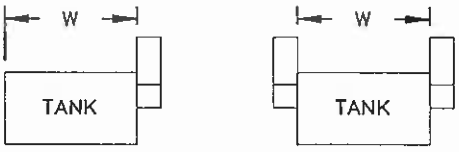
Q = REQUIRED EXHAUST FLOW RATE, CFM.
X = DISTANCE, HOOD FACE TO FARTHEST POINT OF SOURCE (USUALLY ON CENTERLINE OF HOOD), FT.
V = CAPTURE VELOCITY AT DISTANCE X, FPM.
L = LENGTH, OF HOOD, SLOT, TABLE, TANK, ETC., FT
W = WIDTH, OF TABLE, TANK, ETC., FT
A = HOOD FACE AREA, FT

FLANGED SLOT
Q = 2.6LVX

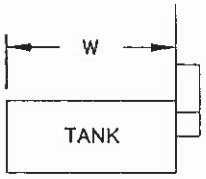


FLANGED SLOT
Q = CLW





SLOT ON TANK
Q = CLW
ONE-HALF Q IN EACH SLOT IF SLOTS ON BOTH SIDES



FLANGED SLOT
Q = CLW

L = LENGTH OF SLOT, FT.
W = WIDTH OF TABLE OR TANK, FT.
C = CONSTANT, VARIES FROM 50 TO 500, USUAL CHOICE IS 150 TO 250. FLANGED SLOTS REQUIRE LOWEST EXHAUST. SEE CHAPTER 10.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*FLOW CAPTURE/VELOCITY*	
	DATE *1-88*	FIGURE *3-9*

FIGURE 7

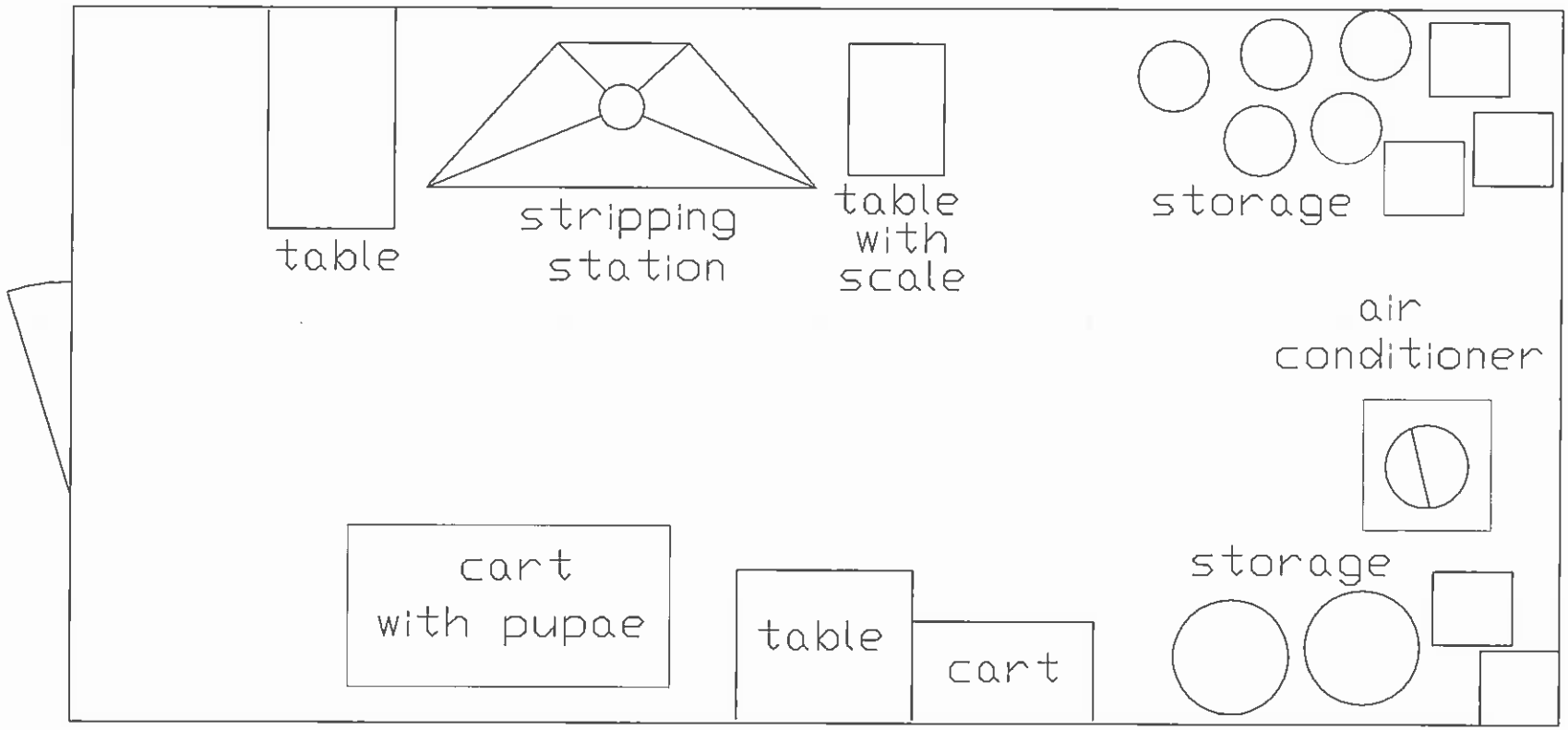


Figure 8. PUPAE STRIPPING ROOM

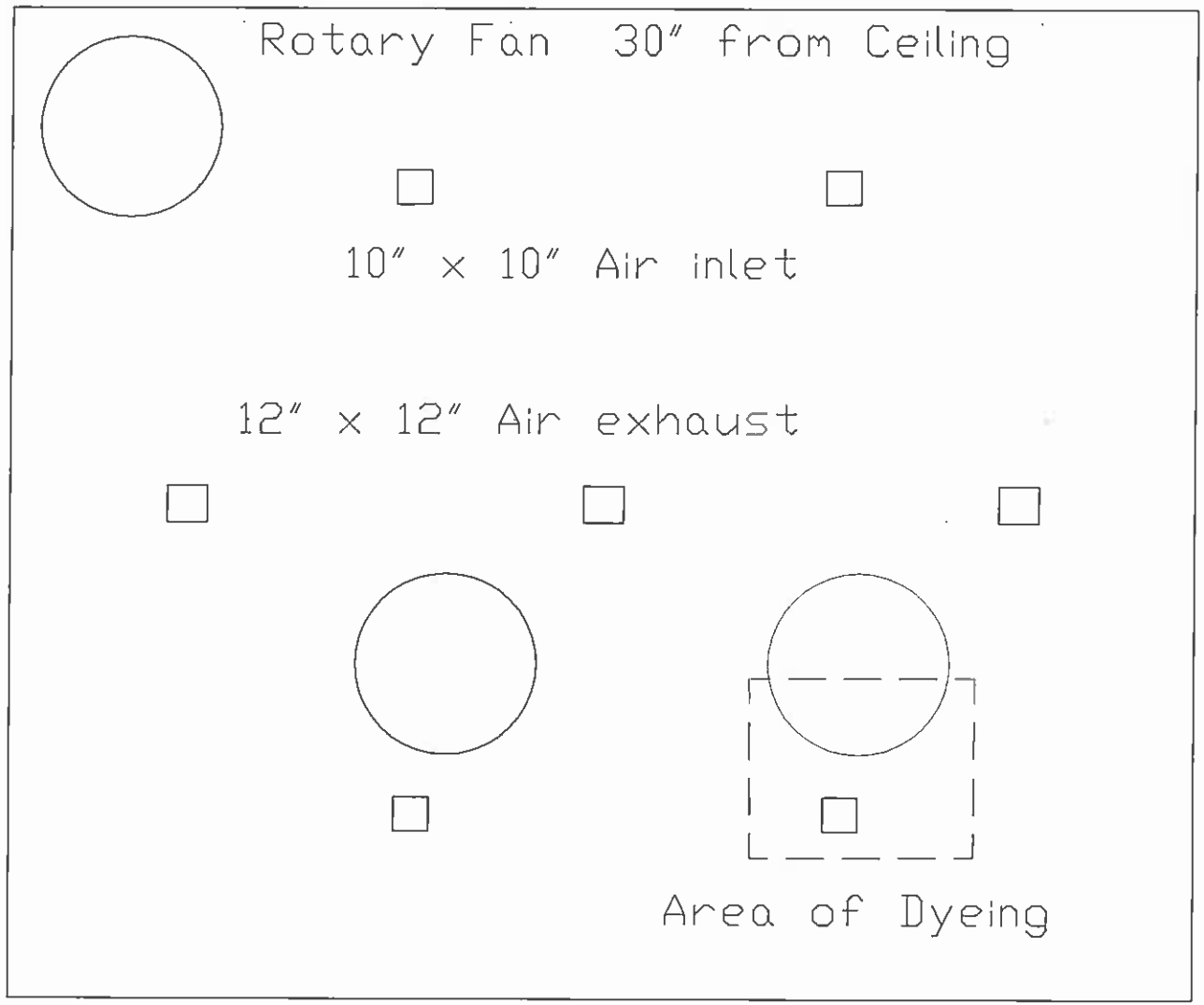


Figure 9. PUPAE DYEING

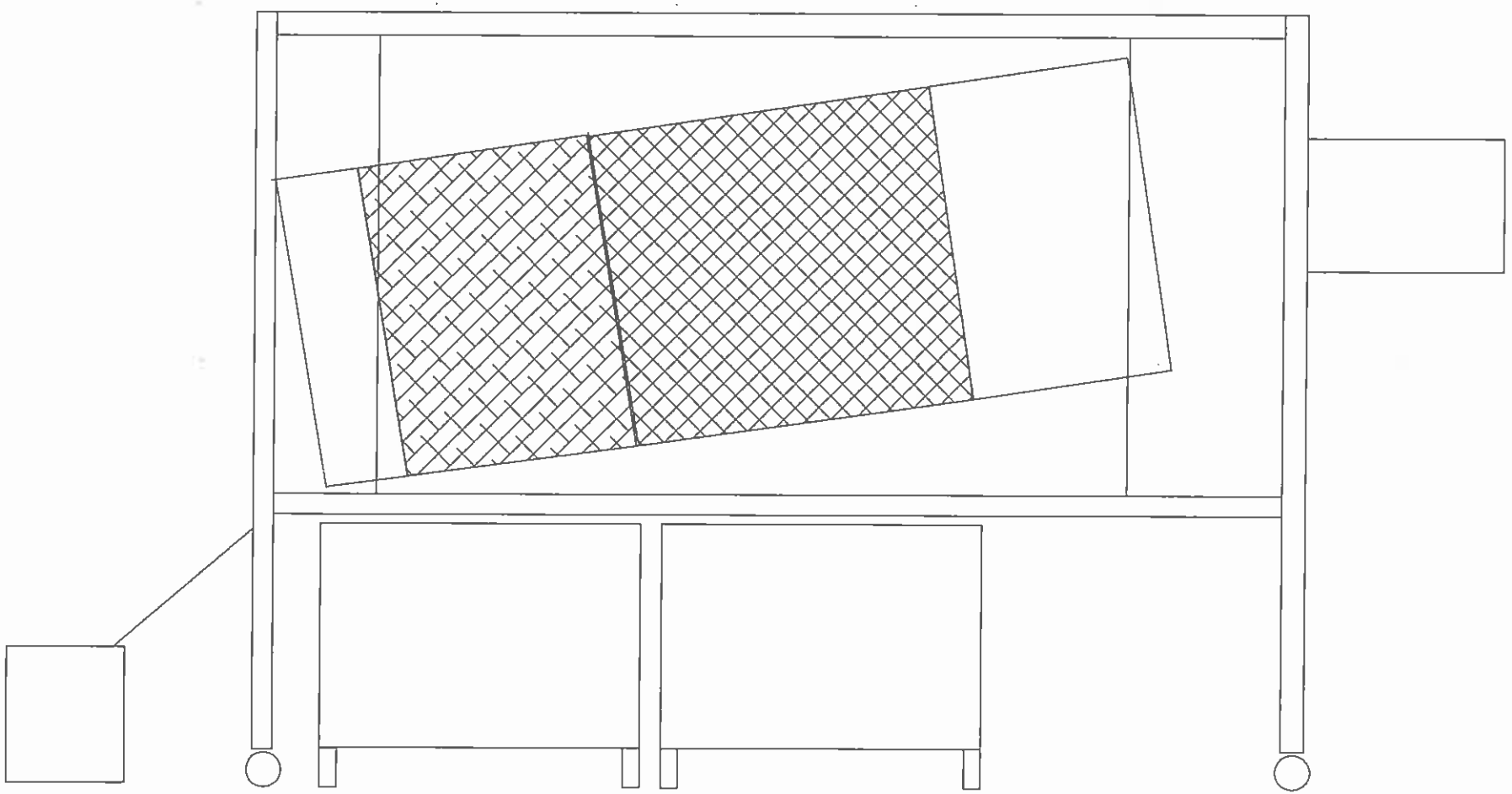


Figure 10. PUPAE SIFTER