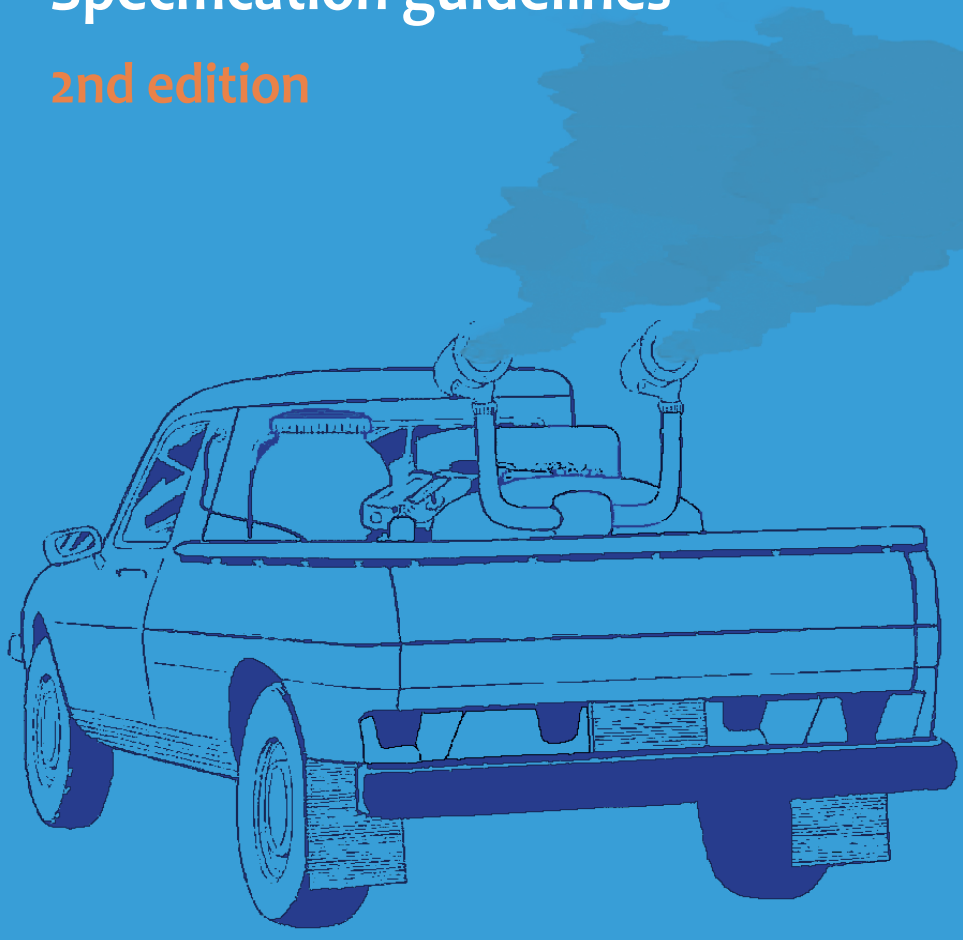
Equipment for vector control
Specification guidelines

2nd edition



World Health Organization

Equipment for vector control

Specification guidelines

2nd edition

Communicable Diseases cluster
Department of Control of Neglected Tropical Diseases
Vector Ecology and Management

World Health Organization

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CONTENTS

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The first edition of this document was published by the World Health Organization (WHO) in 2006 and revised in 2010. Based on experience accumulated and developments in equipment technology, a draft of the second edition was prepared by Emeritus Professor Graham Matthews, Imperial College London, UK.

The draft document was peer reviewed by independent experts and manufacturers of pesticide application equipment. The peer reviewers' comments were considered by a WHO Consultation held at Harper Adams University, Newport, UK (19–20 September 2017). The Consultation was organized in an Open session attended by invited experts, manufacturers of pesticide application equipment and the WHO Secretariat, followed by a Closed session limited to the experts and the Secretariat in which the draft document and all comments received were then reviewed.

The following invited experts participated in the Consultation: Mr Simon Cooper, Engineering Department, Harper Adams University, UK; Dr Muhammad Farooq, Navy Entomology Center of Excellence, USA; Dr Andreas Herbst, Julius Kühn-Institut, Institute of Applied Technology in Plant Protection, Germany; Mr Mark Latham, Manatee County Mosquito Control District, USA; Professor Graham Matthews, Imperial College London, UK; and Mr Allan Were, Abt Associates, USA.

The following representatives of manufacturers participated in the Consultation: Mr John Clayton, Micron Sprayers Ltd, UK; Mr Volker Dietrich, Swingtec GmbH, Germany; Mr Iñigo Garmendia and Mr Andoni Gutierrez, Goizper Spraying, Spain; Mr Joerg Heckel, IGEBA Gerätebau GmbH, Germany; Mr Pedro Augusto de Oliveira Lopes, Guarany, Brazil; Mr Werner Stahl, Mr Mathias Stahl and Mrs Ingrid Hensler, pulsFOG Dr. Stahl & Sohn GmbH, Germany; Mr Bernd Stockburger, MESTO, Germany; Mr Jose Juan Sanz and Mr Fernando Torres, Grupo Sanz, Spain; Dieter Vervaecke, AeroSense, Belgium; and Mr Dave Malone, Innovative Vector Control Consortium, UK participated as an observer.

Dr Rajpal Yadav, Vector Ecology and Management, Department of Control of Neglected Tropical Diseases, World Health Organization, Switzerland represented the WHO Secretariat.

Based on the review and discussion of the document, an advanced draft was prepared by Professor Matthews. The revised draft was then finalized by the WHO Secretariat as the second edition. The WHO Department of Control of Neglected Tropical Diseases thanks Professor G. Matthews, the reviewers, expert advisors and representatives of manufacturers for their important contribution to this work.

GLOSSARY

The definitions given below refer specifically to equipment used in vector control. For additional information, refer to the vocabulary of the International Organization for Standardization (ISO).

cold fog
A fog created by atomization of a liquid without heat.

compression sprayer
Equipment that consists of a container that can be pressurized by a pump and a means of delivering spray liquid through a hydraulic nozzle.

electric sprayer
Equipment that consists of a knapsack container and a pump powered by a rechargeable battery. It is supplied with a recharging unit.

fog (or aerosol)
A term used to indicate a space spray with droplets of < 30 µm diameter (VMD), i.e. droplets with a low terminal velocity that remain airborne for as long as possible.

fog equipment or fogger
Equipment designed to produce either a cold or a thermal fog. It may have a blower to project droplets over a short distance but, due to the droplet size in a fog, dispersal is dominated by natural air movement in the atmosphere. The power of a thermal fogging equipment with a pulse-jet engine can be derived from the fuel consumption, thus 1 litre of gasoline per hour = 12.7 hp (9.37 Kw).

knapsack
Equipment that is mounted so that it is carried on the user's back and held in place by shoulder straps.

lance
A tube that is carried manually and is used to direct the spray at specific targets and away from the user.

lever-operated knapsack sprayer
Equipment with a manually operated pump that is used to discharge spray from a knapsack container.

mist
A spray in which the droplets have a VMD of 50–100 µm. Less than 10% of the volume of a mist should contain droplets of < 30 µm in diameter.

mistblower
Equipment that uses a high-velocity airstream to project mist-sized droplets over a distance of at least 5 m from the nozzle.

nozzle
Equipment that breaks liquid into spray droplets.

portable equipment
Equipment that can be carried by hand, although a shoulder strap may be provided to carry the weight.

thermal fog
A fog that is created using high kinetic and thermal energy to vaporize the spray liquid, which then condenses to form a spray with droplets of VMD < 30 µm. A thermal fog using an oil-based liquid forms a dense white opaque cloud of droplets that reduces visibility. An adjuvant is added to water-miscible formulations to increase the visibility of the fog.

UL (ultra-low volume liquid)
A homogenous liquid pesticide formulation (ready for use undiluted or a suspension) that is used through ULV equipment in ultra-low volume applications.

ULV (ultra-low volume)
The application of the minimum volume that achieves economic control, i.e. usually < 5 L per hectare.

ULV equipment
Equipment that is designed to apply ULV sprays.

VMD (volume median diameter)
Half the volume of the spray contains droplets with a diameter less than that of the VMD; droplets in the other half by volume have a diameter larger than that of the VMD.

1. Introduction

This document provides the specifications for major pesticide application equipment used for control of vectors of diseases. The specification guidelines contained herein are intended to assist national authorities and other public health users in selecting equipment of assured quality for application of pesticides for vector control.

This second edition of the specification guidelines follows a similar format to that of the revised edition published in 2010, in which general requirements are presented in addition to the specific requirements for individual types of equipment. The current guidelines supersede the specifications previously published by WHO for such equipment. This second edition also includes specifications of equipment for application of larvicides as well as those for some additional equipment for adulticides.

The test methods described herein are intended to assess whether the equipment will function for a minimum of three years with appropriate routine maintenance according to the manufacturer's label instructions. Manufacturers shall be requested to provide warranty against manufacturing defects with guaranteed after-sales service on the equipment, any certification required by national authorities regarding materials used in the construction of the equipment, and results of tests that have been carried out for compliance with national or international specifications.

The World Health Organization (WHO) no longer tests equipment used to apply pesticides for compliance with WHO specifications. If a national programme or other agency wishes for a specific item of equipment to be evaluated, it will be its responsibility to arrange a test with a WHO collaborating institution equipped to evaluate pesticide application equipment. Similarly, a manufacturer can arrange for their equipment to be tested at a recognized laboratory, approved by WHO.

If problems occur with equipment that claims to meet the published WHO specification guidelines, feedback to WHO on the performance of the equipment will be welcomed to check the validity of the equipment. Manufacturers are responsible for supplying operating and maintenance manuals in the relevant language, and where necessary. They should provide technical support through an authorized distributor or agency and assist in training local vector control staff in proper use of equipment, its routine maintenance and correct storage practices.

WHO specifications are designed to meet specific requirements of vector control. Where possible, these specifications should also comply with specifications for pesticide application equipment published by the International Organization for Standardization (ISO).

2. Main pesticide application techniques used in vector control

Several different methods of applying insecticides are used to control vectors of diseases. The key methods that involve using pesticide application equipment are briefly described and specifications for the equipment are given in the following sections. The insecticidal treatment of bed nets is beyond the scope of this document and not included. Specifications for pesticide application equipment fitted to aircraft are also not included. In an integrated vector management programme, a combination of vector control techniques may be required. Insecticides and formulations recommended for control of adult mosquitoes and larvae are given on the WHO webpage (www.who.int/whopes/en). Indoor residual spraying, space spraying, larval control and barrier treatment are summarized below.

2.1 Indoor residual spraying

Application of residual insecticide spray deposits on the inside wall surfaces of houses is an important method of controlling mosquitoes that enter houses and that are likely to rest and pick up lethal amounts of spray on contact.[1,2] Currently, indoor residual spraying is one of two core malaria interventions recommended by WHO. The effectiveness of targeted indoor residual spraying for control of dengue is also being investigated now.

A hand compression sprayer is used for indoor residual spraying (Figure 1). Once the spray tank has been pressurised, the operator can concentrate on moving the spray lance fitted with a nozzle at the right speed and distance from the wall to obtain as even a spray deposit as possible. The equipment must be fitted with a pressure control valve to set a fixed pressure,

Figure 1. Indoor residual spraying using a hand compression sprayer fitted with a control flow valve

[1] Manual for indoor residual spraying: application of residual sprays for vector control. Geneva: World Health Organization; 2007 (http://apps.who.int/iris/bitstream/10665/69664/1/WHO_CDS_NTD_WHOPES_GCDPP_2007.3_eng.pdf, accessed 20 March 2018).

[2] Indoor residual spraying: an operational manual for indoor residual spraying (IRS) for malaria transmission control and elimination, 2nd edition. Geneva: World Health Organization; 2015 (http://apps.who.int/iris/bitstream/10665/177242/1/9789241508940_eng.pdf, accessed 20 March 2018).

so that the pressure and the output from the nozzle remain constant while the pressure inside the spray tank gradually decreases while spraying.

An even spray fan nozzle (8002E)[1] is recommended to distribute the spray evenly across each swath applied to the wall surface. The aim of indoor residual spraying is to distribute the dose of insecticide recommended by WHO in 30 mL of spray per square metre (m^2) of area. Electrically powered hydraulic sprayers have been developed that could in the future serve as an alternative type of equipment in places where electricity is readily available to recharge the sprayer's battery. As these have not yet been used for IRS, a provisional specification is given in Annex 1.

2.2 Space spraying using ground-based equipment

Space spray applications of insecticides are used to control flying insect vectors of disease.[2] Space treatments require the production of extremely small droplets (< 30 µm VMD) that remain airborne for a sufficiently long time in the treated area to trap and knock down the flying insects. A space treatment applies a low dose of insecticide that has no residual effect. This is an important factor to protect the environment, especially to avoid any adverse impact on insect pollinators. Space treatments are an important component of integrated vector management to control mosquitoes that are particularly active outdoors.

The types of equipment vary from small aerosol cans (pressure packs) that can treat relatively small areas to larger machines that can operate outdoors. These include thermal and cold fog equipment that can be manually carried or mounted on trucks for area-wide treatments (Figure 2a-d).

Figure 2. Space spraying against mosquitoes: examples of use of a (a) hand-held thermal fogger using an oil-based formulation; (b) knapsack cold fogger; (c) truck mounted cold fogger; and (d) vehicle-mounted thermal fogger

[1] In the ISO specifications there is a colour code for nozzles to indicate the flow rate at a set pressure. The colour of the 8002E nozzle is yellow.

[2] Space spray application of insecticides for vector and public health pest control: a practitioner's guide. Geneva: World Health Organization; 2003 (http://apps.who.int/iris/bitstream/10665/68057/1/WHO_CDS_WHOPES_GCDPP_2003.5.pdf, accessed 20 March 2018).

Space treatments can also be applied inside aircraft cabins using aerosol cans (Figure 3). These specifications do not include aerial spraying, i.e. space treatments applied against disease vectors from aircraft.

Figure 3. Disinsection of an aircraft cabin

Space treatments affect only flying adult insects; mosquito larvae and pupae are not affected and the low dose has no residual activity. When space treatments are conducted outdoors, sequential treatments in the same area are essential to control the freshly emerging adult mosquitoes, before the females can lay eggs. Thus a minimum of three successive treatments should be applied at a maximum interval of 7 days. Space treatments should be timed to coincide with the period of flight activity of the mosquitoes, e.g. after dusk and before dawn for Anopheles spp., and early morning (after sunrise) and early evening (just before sunset) for dengue vectors.

An insecticide that has irritant effect and can stimulate resting mosquitoes to fly will increase the effectiveness of a space treatment. The timing of treatments, avoiding daylight hours, avoids an impact on non-target insect pollinators. Space treatments, using oil-based or water-based insecticidal products aimed at adult mosquitoes, are most effective if carried out over a large area to minimize the impact of mosquitoes emerging from pupae outside the treated area and then entering the area that has been treated with a fog. This may entail an integration of vehicle and manually carried spray equipment, the latter to cover areas not exposed to fog from a roadside.

Thermal fogging should preferably use specific water-based pesticide formulations for space treatments; if these are not available, an adjuvant, e.g. glycol, should be mixed according to label instructions to optimize the droplet spectrum. A space treatment can also affect male mosquitoes and thus have an adverse impact on mating. Outdoor space treatments do not always penetrate into the inside of dwellings, so in such situations a separate indoor space treatment using hand-held fogger is needed.

2.3 Larval control

Mosquito larvae and pupae can be found in diverse aquatic habitats ranging from small water storage containers to large open bodies of water such as ponds, rivers, rice paddies and drains. For mosquito larval control, a wide range of insecticide formulations such as liquid sprays, granules, tablets, briquettes and matrix-release products can be applied depending on the location and type of habitats, the extent of the area of open bodies of water to be treated and the presence of vegetation covering the water surface.

Larvicides can be applied using different types of sprayers, including compression, lever-operated, electric powered knapsack sprayers or motorized mist blowers, or can be applied with granule applicators for spot or broadcast treatments (Figure 4a-f). Thermal fogging with larger water-based droplets may be used to treat a larval breeding area. Broadcast of ultra-low vo-

Figure 4. Examples of larvicidal application. Clockwise: (a) lever-operated knapsack, (b) motorized knapsack, (c) thermal fogger emitting large water-based droplets, (d) portable pump on a boat, (e) horn seeder granule applicator in vegetated areas, and (f) motorized mistblower adapted to apply insecticide granules to control mosquito larvae

lume (ULV) spray applications with motorized mist-blower or truck-mounted foggers can also be used for area-wide larvicide applications in wetlands or around dwellings to target mosquito breeding containers and other inaccessible sites where water is present.

Care is needed to ensure the correct dosage has been applied and the larvicide products used are suitable for treating water, especially drinking-water for human or animal consumption.

Monitoring before and after treatment is needed initially to locate breeding sites and then to assess the impact of larval control interventions in the treated areas.

2.4 Barrier treatments

Vegetation close to houses, especially near where a latrine is located, can be sprayed with a residual insecticide deposit. The aim is to kill adult mosquitoes that rest in the vegetation before entering houses. The sprays are best applied with a motorized mistblower to project the spray droplets into the tree canopy and bushes where a mosquito may rest (Figure 5). Treatments can affect both male and female mosquitoes.

Figure 5. Barrier treatment using a motorized mistblower

3. Aims, applicability, methods and requirements of specifications

A specification is a list of characteristics that, by measurement or examination, unambiguously defines the difference between acceptable and unacceptable equipment. Measurements require clearly defined methods known to be capable of producing reproducible results.

A specification guideline is an outline specification, expected to be applicable to a group of products that share broadly similar characteristics. Limits for characteristics are included in the guideline if they can be expected to apply to the group of products. Where applicable, methods to be used for measurement of characteristics are defined in the guideline.

A specification of an equipment may differ from the guideline where: (i) evidence is available to show that a guideline characteristic is not appropriate; or (ii) the guideline lacks an appropriate characteristic to distinguish between acceptable and unacceptable equipment.

Specifications for pesticide application equipment should include clauses to address characteristics that have relevance to operator safety, robustness and operational performance.

Some characteristics will relate only to certain types of equipment. The buyer of equipment should have confidence that equipment meeting a specification will be effective, safe to use and perform according to specifications over a sustained period of operation and through several seasons with proper maintenance, including consumable parts.

Although not part of specifications for quality control, pesticide application equipment must be provided with a user manual that details method of operation, including calibration method, safety precautions and maintenance procedures, as well as essential spare parts required for routine maintenance during use of the equipment, preferably through local, authorized technical support.

4. General requirements

This section provides information that generally applies to all pesticide application equipment used in vector control. The general requirements must be followed in addition to specific criteria and tests detailed in subsequent sections for each type of equipment.

The test procedures recommended in this document are not intended to exclude other accepted equivalent methods that may be in use in different countries. However, in the event of disagreement, the procedures described herein shall govern. All pressure tests must be carried out with a safety screen to protect the operator. Pesticides should not be used in testing the equipment unless special arrangements are made for their use and disposal. Where possible, inert materials that have similar physical properties to pesticide formulations and sprays should be used.

The different types of equipment that may be used for various vector control applications, e.g. indoor residual spraying, larviciding and space treatments, included in these guidelines have been described above (Figures 1–5).

The following general requirements apply to pesticide spraying equipment. For equipment used to apply granules, see section 7.

4.1 Materials

All materials used in the construction of equipment must be resistant to corrosion and chemical formulations and will neither deteriorate with normal usage nor affect normal operation of the equipment. This is especially important where it is known that ultra-low volume liquid (UL) formulations may be used. All seals and gaskets used in the above tests shall be capable of operating satisfactorily in their original positions in the equipment. Operating instructions should inform users about the equipment, the correct procedures to clean it after use, the routine to maintain it, and how to store it and protect it from sunlight.

The test method given in section A2.1 in Annex 2 can be used to test these materials. An increase in the weight of a seal or washer material in contact with the pesticide mix of over 5% from its original weight will generally indicate a potential problem.

4.2 Design

The sprayer shall be designed so that the outer surfaces do not trap or retain spray liquid. The sprayer should be stable and stand upright on slopes up to 8.5 ° irrespective of the amount of liquid in the tank. The sprayer should incorporate a conveniently located handle to enable it to be safely carried when not in use.

All fittings assembled shall have no sharp edges or projections that might injure spray workers during a normal operation.

4.3 Weight

The maximum weight of the sprayer shall not exceed the weight specified by national health and safety regulations. In the absence of national regulations, the maximum weight of manually carried equipment should not exceed 25 kg (knapsack carried) or 20 kg (hand carried) when it is filled to the manufacturer's maximum recommended capacity. Larger equipment used on vehicles may weigh up to 250 kg when empty, provided it can be held and lifted by not more than four people, if suitable lifting equipment is not available.

4.4 Leakage

All sprayers used in vector control shall be designed so that leakage of pesticide liquid does not occur. Where hydraulic nozzles are used, the sprayer shall be set up for use with the pesticide tank filled to the recommended maximum level with water to which a suitable non-ionic surfactant at 0.1% and a suitable visible dye have been added. The outside of the tank should be examined and any liquid must be removed with a dry cloth. The sprayer is stood on a clean plastic sheet for one hour. The surface of the sheet and sprayer are examined for leaks. The test shall be repeated with the spray hose and trigger valve at the maximum recommended pressure at the nozzle to check there are no leaks between the spray tank and the nozzle (Figure 6 a-b). The test should then be repeated with the sprayer lying in the horizontal position with the strap side down.

Figure 6. Equipment showing leakage from the trigger valve connection

4.5 Tank capacity

The tank size for the manually carried equipment will depend on the maximum weight that can be carried by an operator. On mechanized equipment, the size of the tank should be related to the period during which the engine can be operated in relation to normal operational requirements. The sprayer tank shall be designed so that it can be drained completely. No liquid should escape from the sprayer tank and associated delivery system, e.g. valves and hoses to the nozzle, or from the nozzle body when the control flow valve is closed.

4.6 Tank markings

The tank shall be graduated with permanent markings at 1 L intervals for tanks up to 10 L capacity and at 5 L intervals for larger tanks. In addition, the maximum level of liquid in the tank shall be indicated. When metal tanks are used, as it is not easy to see the level of liquid inside the tank, the manufacturers should supply a device that allows the operator to see when the liquid has reached the correct level, while filling the tank. Alternatively, some sort of level gauge can be installed on the tank.

4.7 Pesticide tank opening and filter

The tank should have an opening of not less than 90 mm in the minor axis. The aim is to allow the tank to be filled rapidly without spillage or splashing. The filler opening shall be provided with a filter, which is deep enough to avoid creating splashes and capable of holding a sealed water-soluble bag or sachet of insecticide with the correct dosage for one tank load of spray (Figure 7).

> The use of a sealed water-soluble bag or sachet placed directly into the sprayer tank is considered to be a closed transfer system eliminating direct contact between the person mixing the spray and the concentrated formulated pesticide contained in the bag.

Figure 7. Equipment showing large opening and filter to facilitate filling

On certain fogging equipment, where the tank opening is less than 90 mm wide, a filter funnel or closed transfer system shall be used. The tank lid should be attached to the sprayer tank while the tank is filled. When using compression sprayers, the filler opening should be separate from the pump mechanism to avoid having to remove the pump each time the tank is refilled.

Sprayer tank drainage

After use, the tank should be washed and cleaned before further use or storage. To ensure the sprayer is not stored with liquid, the tank shall be designed so that all liquid can be drained from it.

4.8 Straps on manually carried equipment

One or two (for knapsack carried) shoulder straps shall be fitted on manually carried equipment. A lever-operated sprayer should also be fitted with a waist strap to minimize movement of the tank on the operator's body while pumping (Figure 8).

The width of the straps shall be sufficient to avoid discomfort when positioned on the operator's shoulder. If a single strap is used, e.g. compression sprayers, the minimum width is 50 mm. Where two shoulder straps are supplied, the width shall be 50 ± 5 mm. The strap shall be of adjustable length. Neither the straps nor the fittings should fail the durability or drop tests [see test A2.5 in Annex 2].

The material used in the straps shall minimize absorption of water – see test A2.6 in Annex 2.

Figure 8. A lever-operated knapsack sprayer with shoulder and waist straps; these are required to minimize movement of the tank on the operator's body while pumping

4.9 Hose

The hose shall withstand twice the maximum recommended working pressure of the pesticide liquid or air. The hose must not kink (flatten), preventing free flow.

The hose connections must be renewable by the user. If a hose is damaged, it may entail cutting off the leaking part and refitting, provided the length is still acceptable.

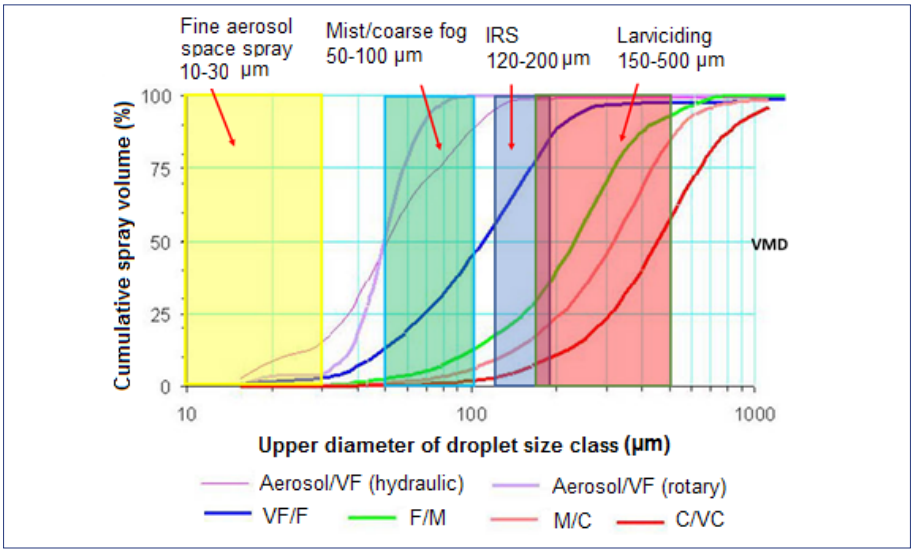
4.10 Droplet spectrum

Droplet spectrum requirements will depend on the type of spray required. There are laser systems that can define the size of spray droplets in flight rapidly, replacing older systems that involved collecting droplets on glass slides coated with magnesium oxide. As the measurements with different laser systems may vary, the data should be checked against reference nozzles.

Space treatments require droplets < 30 µm (VMD) in diameter to remain airborne for a longer time (Figure 9). Ideally, for most vector species, optimally airborne droplets need to be in the 10–15 µm range. Where water is used to measure droplet size, the VMD will be larger than when the pesticide is diluted in odourless kerosene, providing all other operating parameters remain the same.

When applying a residual deposit on wall surfaces, the percentage of spray by volume with droplets < 30 µm should be < 5% at the specified operating pressure at the nozzle to minimize risk of inhalation of small droplets.

Figure 9. Test method A2.10 (Annex 2) can be used for measuring droplet spectra



VF/F = very fine/fine; F/M = fine/medium; M/C = medium/coarse; C/VC = coarse/very coarse spray; VMD = volume median diameter

When applying larvicides to water surfaces, the median droplet size of aqueous sprays should be larger than 200 µm to allow a rapid fall-out of the droplets, unless there is vegetation when application of granules would be recommended. Application of a spray to larval breeding sites over a larger area has also been successful with smaller droplets, e.g. with a mist with droplets in the range VMD 50–100 µm.

When applying insecticides to vegetation around houses to create a "barrier" zone, the droplet size from mistblowers is ideally in the range of 50–100 µm VMD to minimize the rapid fall-out of large droplets from the airflow. The output through a nozzle will depend on the design of the sprayer and shall be specified according to the type of application and the equipment to which the nozzle is fitted.

4.11 Noise level where equipment is powered by a gasoline engine and other types of motorized equipment

Ear protectors should be provided and used, if the noise level as measured at the operator's ear exceeds 85 decibels. The requirement to use ear protection should be marked permanently on the equipment and instructions included in the operating manual.

Where the equipment can be remotely controlled, as in a vehicle cab, it is still essential to measure the noise level outside the closed cabin where persons may be standing alongside the equipment, e.g. a maintenance engineer, or bystanders on a pavement alongside the road when a vehicle mounted applicator is used.

The Sound Level Meter shall meet the requirements of IEC 61672-1:2002 (or the equivalent BS EN 61672-1:2003) standard.

4.12 Markings

The equipment operator must be able to easily locate and see details of the name and contact details of the manufacturer, type of machine, date of manufacture or serial number and position of key components affecting routine use of the equipment. Position of any valves or switches to indicate on/off positions, size of nozzle or flow restrictor and position of any other controls must be clearly visible. The type of liquid to be added to any tank must be clearly marked. The markings shall not be obscured or made illegible by exposure to pesticide formulations or solvents and shall be clearly visible to the operator.

4.13 User manual

Pesticide application equipment must be provided with a clear, simple and illustrated user manual that details method of operation, including calibration method, safety precautions and maintenance procedures, as well as essential spare parts required for routine maintenance. The manufacturer should provide the manual in an accepted commercial language in the country in which the sprayer is being marketed.

The manual should contain procedures for:

- initial assembly;
- identification of all replacement parts including an "exploded" diagram;
- settings and calibration;
- Test method A2.10 (Annex 2) can be used for measuring droplet spectra;

- method of applying pesticide;
- minimising the need to dispose of dilute pesticide;
- cleaning and safe disposal of washings;
- routine maintenance and storage, including replacement of nozzles if the nozzle output has increased by >10% due to erosion caused by particles in a spray in routine use;
- safe and accurate field use; and
- safe release of pressure in the sprayer, including pressure in the lance when a control flow valve is used.

It should provide information on:

- safe handling of undiluted pesticides, mixing chemicals and filling the tank;
- disposal of leftover spray liquid and empty pesticide containers;
- nozzle sizes and types, flow rates, spray quality and operating pressures to be used; and
- precautions to minimize the risk of operator and environmental exposure to pesticides.

4.14 Field use

Users of vector control equipment should keep a record of its use on an individual Sprayer History card. This should record the following:

- type of equipment, manufacturer and model;
- serial number of the sprayer;
- date of first use;
- result of each calibration to determine flow rate;
- number of loads of spray applied per day;
- any problems encountered during spray operations, e.g. spillage, nozzle blockage etc.;
- dates of maintenance; and
- spare parts required and date of their use.

Note: New types and brands of equipment require a field evaluation following the initial laboratory testing as set out in this document.

5. Specification guidelines

5.1 Compression sprayers with hand-operated pump

5.1.1 Description

The compression sprayer is mainly used for residual spraying of wall surfaces and applying larvicides.

The sprayer shall consist of a cylindrical tank, equipped with:

- a hand-operated air pump with a two-handed handle and locking device, separate from the tank lid.
- a pressure-release safety device.
- a hose attached at the top of the tank to a dip-tube.
- a shoulder strap fitted with the tank.
- a foot rest attached with the tank to keep it steady while pressurising it.
- a trigger valve with locking-off device, a straight lance, a control flow valve (CFV) and a nozzle.
- certain other accessories as specified by the user agency; e.g. additional lance to extend length of lance.
- a robust system for parking the lance when not in use to protect the nozzle. This should take into account the CFV attached to the lance, e.g. a wider loop or a narrow ridge near top of the tank to accommodate inserting the nozzle plus CFV.

In addition to these general requirements, compression sprayers must also meet the following requirements.

5.1.2 Materials

See section 4.1.

5.1.3 Design

See section 4.2.

5.1.4 Weight

See section 4.3.

5.1.5 Air pump

The air pump shall be capable of pressurizing the tank, with all its fittings attached and filled with liquid up to the maximum liquid charge mark, to the recommended maximum operational tank pressure on completion of no more than 60 full strokes of the pump (Figure 10).

Usually the maximum operational recommended tank pressure shall be 55–58 pounds per square inch (Psi) (~400 kPa or 4 bar).

The pump cylinder shall withstand internal and external pressure up to twice the maximum operating pressure of the spray tank. The pump shall be fitted with a plunger cup that can be quickly replaced when necessary during maintenance.

The check valve within the pump shall prevent any leakage of the liquid into the pump cylinder when the tank is pressurized to the maximum operational working pressure and the check valve is fully submerged.

The pump handle shall be at least 200 mm in length to allow the operator to grip it comfortably with both hands and, if cylindrical, not less than 28 mm in diameter.

Figure 10. Air pump with handle for two hands and fitted with a locking device

5.1.6 Pressure release devices

A pressure release device shall be declared, fitted on the top of the sprayer and shall be capable of completely depressurizing the tank when needed before the lid is opened. The valve should reseal when the lid is refitted to allow normal operation of the sprayer without leakage.

In addition to or integral with the pressure release device, a pressure relief valve may be provided that prevents pressurization in the tank beyond the limits prescribed by the manufacturers ± 10% for safety. If the valve operates, it should reseal to allow normal operation of the sprayer without leakage.

5.1.7 Tank capacity

See section 4.5.

5.1.8 Tank markings

See section 4.6.

5.1.9 Pesticide tank opening and filter

See section 4.7.

5.1.10 Straps

See section 4.8.

5.1.11 Hose

The hose shall be at least 1.2 m long with an inside diameter of not less than 6.0 mm. See also section 4.9 for additional requirements.

5.1.12 Trigger valve and flow rate control device

The type of trigger valve shall be declared and shall not drip or leak when subjected to the test method A2.7 as described in Annex 2. The trigger valve must have a positive lock-off position. The length of the valve lever shall not be less than 100 mm measured from the pivot point. The maximum torque on the lever shall be 1.5 newton metres.

A filter in the trigger valve must be with smaller mesh than the size of the nozzle aperture and not larger than 50 mesh size. If there is no filter in the nozzle body, the nozzle aperture shall not be larger than 0.3 mm. A second filter should be fitted close to the nozzle to prevent the nozzle being blocked while spraying. All filters shall be easily accessible for frequent cleaning.

The length of the lance attached to the trigger valve shall be at least 500 mm and be fitted with a control flow valve to ensure spray is delivered at a constant flow rate as the pressure in the tank decreases when the sprayer tank empties during spray. A constant flow at 1.5 bar (21.8 Psi) is recommended and can be achieved by fitting a red colour 1.5 bar control flow valve (Figure 11).

The screw threads at the outlet of the trigger valve shall be compatible with the nozzle body and lance so that a nozzle can be fitted directly on the trigger valve if any spray application does not require a lance.

An extension lance shall be available that will fit between the trigger valve and lance to facilitate spraying ceilings or taller wall surfaces.

5.1.13 Nozzle

The type of nozzle body, cap and tip and the flow rate shall be declared and comply with international standards. e.g. ISO 10625:2005 (Equipment for crop protection – Sprayer nozzles – Colour coding for identification).

The tolerance limits of the discharge rate shall be within ± 5 % of the specified rate when the sprayer is tested in accordance with the procedure A 2.8 described in Annex 2.

Figure 11. Example of a control flow valve (in red colour)

The output of the nozzle should be checked regularly and shall not increase subsequently due to erosion by more than 10% when subjected to the test described in Annex 3. The previous WHO specifications required fitting of hardened stainless steel nozzles, but modern technology has resulted in ceramic nozzle tips being more durable and thus these can be used.

The spray pattern of the 8002E nozzles should be checked for evenness. Where a patternator is available, it should be tested at the recommended operating pressure.

For indoor residual spraying, use of the 8002E nozzle is recommended and when operated at 1.5 bar pressure it shall give a discharge rate of 550 mL/min.

5.1.14 Droplet spectrum

See section 4.10.

5.1.15 Tank leakage and durability

The maximum working pressure (in bar) shall be declared. The tank, with all its fittings attached, shall withstand an internal hydrostatic pressure of twice the maximum recommended working pressure when subjected to the tank leakage test (method A2.2 in Annex 2) and have no leakage after subjecting the tank to the impact (drop) test (method A2.4 in Annex 2). The sprayer shall be tested with the maximum working pressure and without pressure in the tank when positioned vertically, horizontally and at 45°. The sprayer shall also undergo a durability test (method A2.3 in Annex 2) for 12,000 cycles of pressure and no pressure.

5.1.16 Markings

See section 4.12.

5.1.17 Manual

See section 4.13.

5.1.18 Field use

See section 4.14.

5.2 Knapsack sprayers with manually operated pump[1]

The knapsack sprayer, usually referred to as a lever-operated knapsack sprayer, is mainly used for spraying larvicides (Figure 4a). It is not suitable for indoor residual spraying.

5.2.1 Description

The sprayer shall consist of a knapsack tank, equipped with

- a manually operated pump;
- a sprayer tank fitted with two shoulder straps and a waist strap; the waist strap is needed to ensure that efforts in pumping are transferred to the pump and not moving the sprayer on the operator's back;
- a hose to connect pump output to lance;
- a lance with trigger valve with locking-off device, a control flow valve and a nozzle.

Figure 12. Example of a deep filter which can be designed to show level of water in the tank

[1] Electrically powered knapsack sprayers are now also commercially available, but so far none has been evaluated for indoor residual spraying inside buildings. An interim specification of such a pump is given in Annex 4 should any organization wish to try the units to eliminate the manual pumping needed with a compression sprayer.

- a robust system for parking the lance when not in use to protect the nozzle;
- a deep filter in the tank filler opening (Figure 12); and
- certain other accessories as specified by the user agency, e.g. an additional lance to extend length of the lance.

In addition to the general requirements listed in section 5.2.1 above, the lever-operated sprayer must have the specifications given below.

5.2.2 Materials

See section 4.1.

5.2.3 Design

See section 4.2.

5.2.4 Weight

See section 4.3.

5.2.5 Pump

The sprayer can be fitted with either a diaphragm or piston pump operated manually by a lever, designed for right or left-handed use. The lever should be a minimum of 400 mm long and should have an arc of movement not exceeding 400 mm at the lever end. The end of the lever should be firmly and durably equipped with a handgrip with a minimum sectional dimension of 25 mm and a minimum length of 100 mm.

To achieve the maximum recommended flow rates and operating pressures, the pump should operate within the range of 20–30 lever strokes per min to deliver > 70 L/h of the liquid. At the maximum recommended flow rate, the pressure, measured immediately upstream of the nozzle, should not deviate by more than ± 10%.

The pumping system shall be subjected to a durability test as described in A2.11 (Annex 2).

5.2.6 Pressure chamber

The sprayer shall be fitted with a pressure chamber between the pump and hose inlet. This is normally within the sprayer tank. The capacity of the pressure chamber shall be at least 10 times the capacity of each pump stroke. This part of the sprayer shall withstand twice the maximum working pressure at the nozzle.

5.2.7 Tank size

The tank capacity is normally 15 L. See also section 4.5.

Note: 15 L tanks fit the 25 kg weight restriction, so larger tanks should be avoided. Smaller than 15 L may be lighter but would need to be refilled more frequently.

5.2.8 Tank markings

See section 4.6.

5.2.9 Pesticide tank opening and filter

See section 4.7.

5.2.10 Straps

See section 4.8.

5.2.11Hose

The length of the hose shall be declared and shall be not less than 1.0 m and of a material suitable for the pesticide product(s) specified by the purchasing agency. See also section 4.9.

5.2.12 Trigger valve

The type of trigger valve shall be declared and shall not drip or leak when subjected to the test method A2.7 as described in Annex 2. The trigger valve must have a positive lock-off position. The length of the valve lever shall not be less than 100 mm measured from the pivot point. The maximum torque on the lever shall be 1.5 newton metres.

A filter in the trigger valve must be smaller mesh than the size of the nozzle aperture and not larger than 50 mesh size. If there is no filter in the nozzle body, the nozzle aperture shall not be larger than 0.3 mm. A second filter should be fitted close to the nozzle to prevent the nozzle being blocked while spraying. All filters shall be easily accessible for frequent cleaning.

The length of the lance attached to the trigger valve shall be at least 500 mm and be fitted with a control flow valve to ensure spray is delivered at a constant flow rate as the sprayer tank empties. A constant flow at 1.5 bar is recommended.

A lance with an attachment angled downwards to spray water surfaces can be supplied for larviciding.

5.2.13 Nozzle

The nozzle tip and the flow rate shall be declared and comply with international standards (ISO 10625:2005 Equipment for crop protection – Sprayer nozzles – Colour coding for identification). Tolerance limits of the discharge rate shall not exceed +5% when tested in accordance with the procedure described in section A2.8 (Annex 2).

The output of the nozzle shall not increase subsequently due to erosion by more than 10% when subjected to the test A2.8 described in the Annex 2. The pattern should remain consistent and unchanged.

The choice of nozzle for larviciding can depend on the area being treated. A straight jet nozzle can be used to project the spray further away from the operator to reach deeper areas; larger spray droplets can penetrate and spread over the water surface. Flat fan or cone nozzles can also be used to provide a wider swath.

5.2.14 Droplet spectrum

See section 4.10.

5.2.15 Markings

See section 4.12.

5.2.16 User manual

The manufacturer of the sprayer should include the following information in the user manual:

- Nozzle flow rates, characteristic spray patterns and spray angles at different pressures. For larviciding, a low pressure (1 or 1.5 bar) is appropriate to avoid discharge of very small droplets that may drift downwind.
- Nozzle heights and spacing to give uniform spray volume distribution at target level, when a horizontal boom with standard flat fan nozzles is recommended.
- For flat fan nozzles, the nozzle support system should include a method of ensuring correct orientation of the nozzle within the holder. See also section 4.13 for other requirements.

5.2.17 Field use

See section 4.14.

5.3 Motorized knapsack mistblowers

Motorized mist blowers have been used for rapid treatment of open bodies of water for larval control in urban areas and to treat eaves of houses and foliage as a barrier treatment to reduce number of mosquitoes entering houses (Figures 5 and 13a).

Figure 13a. Motorized knapsack mistblower

5.3.1 Description

The sprayer shall have an engine-driven fan to produce a high-velocity airstream into which the pesticide liquid is metered and projected over at least 10 m upwards into trees.

- The engine, mounted on a knapsack frame shall be provided with an easy starting mechanism.
- A fuel tank shall be mounted below the engine.
- All moving parts and the exhaust shall be guarded to prevent injury due to burning.
- Engine controls, including a stop switch and speed control, shall be mounted so that they are visible in front of the operator, when in use (Figure 13b).
- A non-absorbent padded backrest shall be fitted to the knapsack frame to comfortably rest it on the operator's back.
- The mounting of the engine must dampen vibrations during normal operation.
- All parts that are regulated while operating the equipment shall be permanently and identifiably marked.

Figure 13b. Showing controls on the lance of a motorized knapsack mistblower

In addition to the general requirements listed above, the motorized mistblower must meet the following requirements:

5.3.2 Materials

See section 4.1.

5.2.3 Design

See section 4.2.

5.2.4 Weight

See section 4.3.

5.2.5 Engine

The sprayer shall be supplied with a two- or four-stroke engine, weighing less than 12 kg.

5.2.6 Fuel tank capacity

The capacity of the fuel tank shall allow field operation for at least one hour, without the engine stopping.

The fuel consumption shall be < 2 L/h when the engine is operated at optimum speed.

The type of fuel and fuel mix shall be permanently indicated on the fuel tank, filler cap or on the machine.

5.3.7 Formulation tank capacity

See section 4.5.

5.3.8 Tank markings

See section 4.6.

5.3.9 Tank opening and filter

See section 4.7.

5.3.10 Straps

Two straps with padding over the shoulder are required to protect the operator from engine vibration. Each strap shall be adjustable and at least 75 cm in length. The width of strap shall be at least 50 ± 5 mm. The strap when subjected to the absorbency test method A2.6 shall not increase in weight by more than 10%. Any material in the backrest should also meet the same absorbency criteria as for the straps.

5.3.11 Blower

A blower is driven by the engine to provide an air volume (approximately 1000–1500 m^3/hour), which with the nozzle fitted to the end of the air discharge tube emits 750 m^3/hour ± 5% projected at a velocity of approximately 100 m/s. The blower/engine combination should only be operated at a single maximum/optimum speed since reducing the engine speed will result in inadequate atomisation required for a "mist" spray". The engine should only be set to a low or idle setting when the spray switch is turned off and the operator is moving short distances between the spray sites

5.3.12 Discharge system

Air from the blower shall be ducted in a tube to the nozzle. The air duct shall be flexible to facilitate direction of the spray by the operator. The spray tank is usually slightly pressurised by ducting air from the fan into the spray tank to deliver spray to the nozzle. The flow rate is

affected by the height of the nozzle relative to the level of liquid in the tank. A pump may be fitted to deliver spray liquid from the pesticide tank to the nozzle, so that flow of liquid at the nozzle is not affected by the level of liquid in the spray tank.

A 50-mesh or finer filter shall be positioned in the liquid flow line so that the restrictor or nozzle will not be blocked.

The flow rate of liquid spray to the nozzle is controlled by pre-selected restrictors, positioned in-line before the nozzle.

The velocity of the air shall not be changed during an application as variations in the air velocity will affect the droplet size.

Delivery of the liquid spray to the nozzle is controlled by an on/off valve attached to the air duct in front of the operator.

5.3.13 Droplet spectrum

An air shear or rotary atomizer can be positioned at the end of the air delivery tube to produce droplets with a VMD in the range of 50–100 µm.

Note: Some mist blowers are fitted with a very low flow rate restrictor that have a VMD < 50 µm and have been used for "space" spraying. Such a small restrictor may get blocked easily if the pesticide formulation has large particulate matter.

5.3.14 Droplet projection

The sprayer when operated at the recommended engine speed should project the droplets to at least 10 m horizontally and 6 m vertically in the still air. There shall be at least 5 droplets per cm^2 to indicate greatest distance up to which droplets were projected.

5.3.15 Durability

The sprayer shall be subject to a minimum of 50 hours' operation over a 10-day period, with one period of 8 hours' operation included to represent a full day's operation in a vector-borne disease outbreak area. All stoppages shall be recorded, with reasons for the stoppages and details of any repairs carried out. Data on fuel consumption shall be collected.

5.3.16 Noise level

The equipment shall be permanently labelled to indicate the need to use ear protection if the noise level exceeds 85 decibels close to the operator's ear.

5.3.17 Markings

See section 4.12.

5.3.18 Manual

See section 4.13.

5.3.19 Field use

See section 4.14.

5.4 Portable hydraulic sprayers

The portable hydraulic sprayers (Figure 14) can be fitted on a boat (as were used to apply larvicides to control larvae of blackfly, *Simulium* spp., in rivers) and a vehicle to spray larvicides.

Figure 14. A portable hydraulic sprayer

5.4.1 Description

The sprayer shall consist of:

- an engine driven pump, with suitable handle for lifting;
- a hose to connect pump output to lance or spray boom;
- a trigger valve with locking-off device, control flow valve and nozzle;
- a robust system for parking the lance when not in use to protect the nozzle;
- a suitable container for the spray liquid to prevent spillage of the liquid;
- a deep filter in the tank filler opening; and
- certain other accessories as specified by the user agency; e.g. additional lance to extend length of lance.

In addition to these general requirements listed above, the portable hydraulic sprayer must meet the following requirements.

5.4.2 Materials

See section 4.1.

5.4.3 Design

See section 4.2.

5.4.4 Weight

See section 4.3.

5.4.5 Engine

The sprayer shall be supplied with a two or four-stroke engine, weighing less than 12 kg.

5.4.6 Pump

A positive displacement reciprocating pump shall be fitted that can deliver up to 10 L/min of volume at 6 bar pressure. Normally it will be used at lower flow rates and pressures.

5.4.7 Tank size

The tank capacity shall be at least 10 L.

5.4.8 Tank Markings

See section 4.6.

5.4.9 Pesticide tank opening and filter

See section 4.7.

5.4.10 Straps

See section 4.8.

5.4.11 Hose

The length of the hose shall be declared and shall be not less than 1.5 m with an inside diameter of not less than 6.0 mm and of a material suitable for the pesticide product(s) specified by the purchasing agency. See also section 4.9.

5.4.12 Trigger valve

The trigger valve shall not drip or leak when subjected to the test method A2.7 (described in Annex 2). The trigger valve must have a positive lock-off position. The length of the valve lever shall not be less than 100 mm measured from the pivot point. The maximum torque on the lever shall be 1.5 newton metres.

A filter in the trigger valve must be of smaller mesh than the size of the nozzle aperture and not larger than 50 mesh size (with an aperture not larger than 0.3 mm if there is no filter in the nozzle body). The equipment must be fitted with one or more additional filters having a mesh size that prevents passage of particles that would cause nozzle blockage. At least one filter should be fitted close to the nozzle.

The length of the lance attached to the trigger valve shall be at least 500 mm and be fitted with a control flow valve to ensure spray is delivered at a constant flow rate to offset variation

in speed of pumping. A control flow valve with 1.5 bar specification is recommended. The end of the lance can be angled downwards to spray water surfaces.

5.4.13 Nozzle

The nozzle tip and the flow rate shall be declared and comply with international standards (ISO 10625:2005 Equipment for crop protection – Sprayer nozzles – Colour coding for identification). Tolerance limits of the discharge rate shall not exceed +5% when tested in accordance with the test method A2.7.1 (described in Annex 2).

The output of the nozzle shall not increase subsequently due to erosion by more than 10% when subjected to the above test. The pattern should remain consistent and unchanged.

5.4.14 Droplet spectrum

See section 4.10.

5.4.15 Markings

See section 4.12.

5.4.16 Manual

See section 4.13.

5.4.17 Field use

See section 4.14.

5.5 Portable cold foggers (aerosol generators)

Portable or manually carried knapsack cold foggers (Figure 15) are used for space treatment within buildings, houses and outdoor locations that are inaccessible to vehicles.

5.5.1 Description

The cold fogger shall be a hand-carried or a knapsack-mounted aerosol generator with a system for producing an aerosol for space treatment. It shall have an engine that is provided with an easy starting mechanism.

Electrically powered units, suitable for indoor use, shall meet the same requirements for spray tank and droplet size.

For engine driven cold foggers:

- The fuel tank shall be mounted below the engine.
- Engine controls that are needed for application as well as an engine stop switch shall be mounted such that they are visible in front of the operator.
- The engine/blower unit shall be mounted on a knapsack frame that shall be designed to carry it comfortably on the operator's back. The system of mounting shall dampen vibrations.

- A knapsack frame shall have a non-absorbent padded backrest.
- All parts that are regulated while operating the equipment shall be permanently and identifiably marked.

Figure 15. A portable cold fogger (aerosol generator)

In addition to these general requirements, the portable cold fogger must meet the following requirements.

5.5.2 Materials

See section 4.1.

5.5.3 Design

See section 4.2.

5.5.4 Weight

See section 4.3.

5.5.5 Fuel tank

The capacity of the fuel tank shall allow field operation for at least one hour, without the engine stopping. The type of fuel and fuel mix shall be permanently indicated on the fuel tank, filler cap and on the machine.

5.5.6 Pesticide tank

The capacity of the interchangeable or fixed pesticide tank shall be 1 L or more, with a clear gauge to indicate the volume of liquid in the tank. A built-in filter or filter funnel shall be supplied with the equipment except when a ready-to-use container is used. If the tank is pressurized at more than 50 kPa, a device capable of completely depressurizing the tank before the tank is opened shall be provided.

5.5.7 Tank markings

See section 4.6.

5.5.8 Pesticide tank opening and filter

See section 4.7.

5.5.9 Straps

See section 4.8.

5.5.10 Blower

A low-pressure compressor or blower shall be fitted to provide sufficient air volume and velocity to atomize the spray liquid and project the cold fog droplets away from the operator.

5.5.11 Nozzle

A vortical nozzle is supplied to shear the spray into droplets with a VMD < 30 µm at the recommended output (in L/h) for the water and oil based formulations.

A liquid cut-off valve is required, so that the fogging treatment can be stopped at any time (note: the spray liquid will also cease to flow if the engine is stopped). The flow of liquid to the nozzle shall be controlled by a fixed, but interchangeable, restrictor or by a control valve fitted before the nozzle. The flow rate settings should be marked on the valve or on the restrictor. The flow rate for each setting of the valve or for each restrictor shall be listed in the user manual.

The tolerance limits of the discharge rate shall not exceed +5% when tested in accordance with the test method A2.8 described in Annex 2.

The output of the fogging equipment shall not increase subsequently due to erosion by more than 10%.

5.5.12 Droplet spectrum

See section 4.10.

5.5.13 Cold fogger durability

The sprayer shall be tested operating for a total of 50 h without operational failure and without problems of restarting the engine. The durability test shall be conducted with water using the largest restrictor, with the flow of water interrupted by opening and closing the fogging tap at intervals of 15 min.

5.5.14 Markings

See section 4.12.

5.5.15 User manual

See section 4.13.

5.5.16 Field use

See section 4.14.

5.6 Vehicle-mounted cold foggers

The cold fogger (Figure 16a, b) shall be an aerosol-generating machine, mountable on a flat-bed truck or a trailer, a boat, an amphibious vehicle or a drone. Vehicle-mounted cold foggers are used for outdoor space treatments requiring no residual spray deposit.

Note: Some of these cold foggers have been used for barrier treatments, and to apply liquid larvicides if the droplet size can be increased.

Figure 16. Vehicle-mounted cold fogger (a) and the cold fog being generated by it (b)

5.6.1 Description

The various parts of the cold fogger shall be mounted on a corrosion resistant frame to fit a suitable truck. The requirements are:

- There shall be a pesticide tank and additional tank to enable pesticide to be flushed from the system.
- The equipment shall be fitted with an appropriate control system that can be operated from the vehicle cabin.
- A fuel tank that shall have sufficient capacity to operate the sprayer for at least 2 h.
- All individual tanks shall be permanently and identifiably marked and have a drainage facility.
- The engine exhaust and moving parts shall be guarded to prevent injury.
- The engine shall be fitted with a timer (an hour meter).

In addition to these general requirements, the vehicle mounted cold fogger sprayer must meet the following requirement.

5.6.2 Materials

See section 4.1.

5.6.3 Design

See section 4.2.

5.6.4 Weight

See section 4.3.

5.6.5 Pesticide tank

The capacity of the pesticide tank shall be not less than 50 L. If the tank is not translucent and graduated, there shall be a metering measuring device to measure and indicate the volume of liquid in the tank. The cap of the tank should not leak during travel on rough terrains.

A filter funnel shall be supplied to facilitate filling without spillage, when the tank opening is less than 90 mm wide (and must be consistent with ISO tank filling aperture sizes; see ISO 9357:1990 Equipment for crop protection – Agricultural sprayers – Tank nominal volume and filling hole diameter).

5.6.6 Fuel tank

The type of fuel shall be clearly indicated on the filler cap.

5.6.7 Air compressor or blower (if fitted)

A corrosion-resistant air filter shall be fitted to the air compressor or blower to retain particles of over 100 µm in diameter.

5.6.8. Discharge system

All equipment shall have a manual flow control that can be on a fixed setting. The flow rates for different settings of the flow control device should be listed in the manual. Also the minimum flow rate possible should be specified. There can be an optional provision for providing a regulated flow control device to adjust output in relation to the vehicle speed.

A warning device in the vehicle cabin shall indicate to the operator when flow to the nozzle has stopped and no droplets are being emitted from the nozzle. This could be when the pesticide tank becomes empty or for any other reason.

Note: Some systems using instrumentation that detects the speed (rounds/min, RPM) of a positive displacement pump display the results as mL/min or L/h whether there is flow to the nozzle or not.

Tolerance limits of the discharge rate shall not exceed +5% when tested in accordance with the test method A2.9 described in Annex 2.

The output of the fogging equipment shall not increase subsequently due to erosion by more than 10%.

5.6.9 Cut-off valve

A cut-off valve shall be provided, which will automatically close when any part of the equipment is turned off or ceases to function.

An automatic pressure release device must be fitted if a pressure system above 50 kPa (0.5 bar) is used in the equipment.

5.6.10 Droplet size

The nozzle shall deliver a droplet size of no larger than 30 µm VMD for space sprays at the optimum operating parameters and flow rates for the formulations to be used. In equipment that allows a change in the droplet size, release of larger size droplets may be opted for in certain other applications. See also section 4.10 and test method A2.10 in Annex 2.

5.6.11 Control panel system

The remote control panel in the cabin of the vehicle shall be provided with permanently labelled switches for turning off the machine and for turning on and off the pesticide flow. The design of the remote control system must ensure that pesticide does not enter the vehicle cabin.

The remote control panel may be fitted with the following:

a) an air pressure gauge for blower type equipment, or a tachometer for rotary nozzle equipment (to monitor the speed of the rotary nozzle in revolutions per minute [RPM]).
b) an air pressure valve or sensor for blower-type equipment as a safety device if the pressure drops (this can substitute the need for an air pressure gauge in blower-type equipment mentioned above).

Provision of additional gauges to indicate the fuel and pesticide formulation levels in the respective tanks could be an advantage.

Note: These may currently be an option, but may become an essential requirement in the future.

5.6.12 Durability

The equipment shall be able to operate without operational failure and without problems of restarting the engine, when operated at the maximum airflow, for not less than a total of 50 h within a period of no more than two weeks. There should be an 8 h test within the 50 h. The fuel and formulation lines, pump and other components should withstand durability tests without leakage.

5.6.13 Noise level

The equipment shall be labelled to indicate the need to use ear protection if the noise level exceeds 85 decibels. During the fogging operation, when the operator is in the vehicle cabin, the noise level shall not exceed 100 decibels 3 m from the machine at any time.

5.6.14 Markings

See section 4.12.

5.6.15 Manual

See section 4.13.

5.6.16 Field use

See section 4.14.

5.7 Manually carried thermal foggers

Manually-carried (portable) pulse-jet thermal foggers (Figure 17) are mainly used for space spray treatment within buildings, houses and outdoors for treating areas inaccessible to vehicles, with a volume median diameter of droplets < 30 µm. Portable thermal foggers (pulse-jet) of special design are available, allowing the application of a water based space treatment fog. Some foggers are adapted to allow applications of larvicide formulations with larger droplets than those used for space treatments.

5.7.1 Description

A portable thermal fogger shall have a thermal energy nozzle into which the insecticide liquid (both oil and water-miscible formulation) is metered.

Figure 17. A portable (hand-carried) thermal fogger

A portable pulse-jet thermal fogger is an open pneumatic nozzle system using a kinetic and a thermal energy source (pulse-jet combustion chamber without any rotational parts), which produces the required pneumatic pressure to atomize the fogging liquid into the droplets of desired sizes and to meter the liquid pesticide (both oil and water-miscible formulation) into the nozzle.

The machines shall be provided with:

- a battery starting mechanism consisting of batteries, ignition coil, and a spark system;
- a small manually- or battery-operated air pump to pressurize the fuel line when starting the machine unless the fuel injection system is non-pressurized;
- a "handle" to enable carrying the equipment easily and safely; and
- a robust frame to hold the different components;

All hot surfaces must be adequately guarded to avoid burn injury of the operator during and immediately following an operation.

All parts that are regulated while operating the equipment shall be permanently and identifiably marked.

The sprayer shall have clearly visible safety instructions marked on its body to warn operators not to leave a fogger unattended while in operation.

In addition to these general requirements, the portable thermal fogger must comply with the following requirements.

5.7.2 Pulse-jet type foggers

Pulse-jet type equipment must have a resonator made of steel that is resistant to temperature up to 1050 °C, e.g. austenitic steel No. 1.4845.

Note: manufacturers must supply a certificate that their equipment meets this requirement. See also section 4.1.

5.7.3 Design

See section 4.2.

5.7.4 Weight

The weight of the equipment, when filled to the manufacturer's maximum recommended capacity for operation, shall not exceed 20 kg.

5.7.5 Pesticide tank and fittings

The fogger may be fitted with a fixed or detachable tank, the capacity of which shall be clearly indicated. If the tank is not translucent and graduated, means for measuring the volume of liquid in the tank such as a dip-stick shall be provided.

The filler opening shall be on the top of the tank if the tank is permanently fixed at the unit, and a filter funnel shall be provided to facilitate filling when the opening is < 90 mm. If the opening is in a different position of a permanently fixed tank, an angled filter funnel must be supplied to facilitate filling.

The lid of the pesticide tank opening shall be airtight when in place and depressurizes as soon as the tank lid is loosened, if the tank pressure exceeds 0.5 bar (50 kPa).

5.7.6 Fuel tank

The capacity of the fuel tank shall enable the operator to discharge a full pesticide tank continuously at the minimum recommended flow rate without refilling the fuel tank. The fuel and pesticide tanks must not be refilled while the equipment is hot. The type of fuel shall be indicated on the unit. The fuel cap shall be leak-proof.

5.7.7 Air pump

The engine of a pulse-jet fogger must start with less than 15 strokes if fitted with a manual pump, and within 30 sec of an automatic electrically operated pump.

5.7.8 Flow control

Control of the flow rate of liquid to the nozzle shall be by a fixed but inter-changeable restrictor or through a control valve. The flow rate for each restrictor or control valve setting should be marked on the machine or declared in the user manual. There shall be a manually operated on/off valve. An automatic cut-off switch must be fitted to prevent further flow of pesticide to the nozzle when the engine stops working.

Tolerance limits of the discharge rate shall not exceed +5% when tested in accordance with procedure A2.9.1 described in Annex 2.

The output of the fogging equipment shall not increase subsequently due to erosion by more than 10%.

5.7.9 Droplet size

The volume median diameter of the droplets shall be < 30 µm at the recommended standard output of oil and/or water based formulations when used for space treatments. A thermal fogger with a design for the application of water-based larvicide sprays shall have a separate orifice/attachment to select bigger droplet sizes up to 100 µm. See also section 4.10.

5.7.10 Straps and fastenings

A single strap shall be provided. For details see section 4.8.

5.7.11 Durability

The durability test shall be conducted with water or mineral oil using the largest restrictor, with the flow of liquid interrupted by opening and closing the fogging tap at intervals of 15 min. The fogger shall be able to operate for 50 h without operational failure or problem in restarting the engine.

5.7.12 Noise level

The equipment shall be permanently labelled to indicate the need to use ear protection if the noise level exceeds 85 decibels.

5.7.13 Markings

See section 4.12.

5.7.14 User manual

See section 4.13.

Note: The user manual must have clear safety instructions to warn operators that this type of equipment MUST NEVER be left unattended while in operation.

5.7.15 Field use

See section 4.14.

Note: When specially designed water-based fogging formulation is applied, pulse jet engines of minimum 24 horsepower [hp] (= about 2 L/h fuel consumption) may be used. An adjuvant containing a polyalcohol (glycol, glycerine) or emulsifying oil may be added to the water portion in order to retard evaporation and to improve the dilution/emulsion of the pesticide in the water. Some commercial pesticide formulations are readily prepared to be applied as a water-based fog.

A pulse jet thermal fogger shall be designed in a way to protect highly sensitive active ingredients of a water-based pesticide formulation against any heat influence, and additionally in order to fog wettable powder formulations (suspensions) without undesired side-effects such as choking and blocking of the fogging nozzle.

5.8 Vehicle-mounted thermal foggers

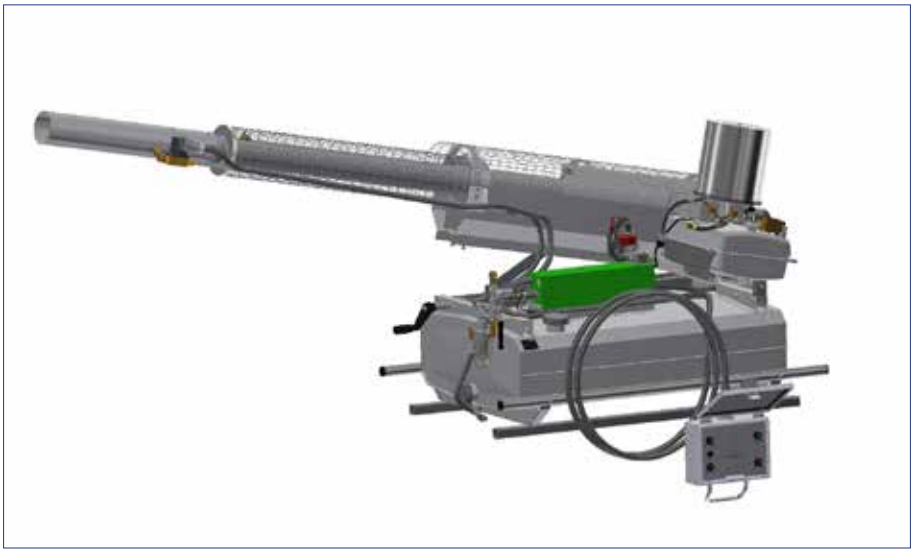
The vehicle-mounted pulse-jet thermal foggers (Figure 18) shall be an aerosol-generating machine, mountable on a flat-bed truck or a trailer, a boat, an amphibious vehicle or a drone. The vehicle-mounted thermal foggers are generally used for outdoor space treatments leaving no residual spray deposit.

5.8.1 Description

The various parts of the thermal fogger shall be mounted on a corrosion resistant frame to fit on a suitable truck.

- There shall be a pesticide tank, and an additional tank to enable pesticide to be flushed from the system if wettable powders are used, or a pump system with a reverse function to allow automatic suction of remaining liquid in the conduits.
- The equipment shall be fitted with an appropriate control system that can be operated from the vehicle cabin.
- A fuel tank shall be fitted that has sufficient capacity to operate the sprayer to enable a full pesticide tank to be emptied during the spray operation.
- All individual tanks shall be permanently and identifiably marked and have drainage facility.
- The engine exhaust and moving parts shall be guarded to prevent injury.

Figure 18. A thermal fogger suitable for mounting on a vehicle



5.8.2 Materials

See section 4.1.

5.8.3 Design

See section 4.2.

5.8.4 Weight

See section 4.3.

5.8.5 Pesticide tank

The capacity of the pesticide tank shall be not less than 50 L. If the tank is not translucent and graduated, there shall be a metering measuring device to measure depth and thus indicate the volume of liquid in the tank. The cap of the tank should not leak during movement of the carrier vehicle on a rough terrain.

A filter funnel shall be supplied to facilitate filling without spillage, when the tank opening is less than 90 mm wide; this needs to be consistent with the sizes of the ISO tank filling apertures (see ISO 9357:1990 Equipment for crop protection – Agricultural sprayers – Tank nominal volume and filling hole diameter).

5.8.6 Fuel tank

The type of fuel shall be clearly indicated on the filler cap.

5.8.7 Discharge system

The fogging equipment should have a manual flow control that can be operated on a fixed setting. The flow rates for different settings of the flow control device should be listed in the manual. Also the minimum flow rate possible should be specified.

Tolerance limits of the discharge rate shall not exceed +5% when tested in accordance with procedure A2.9 in Annex 2.

The output of the fogging equipment shall not increase subsequently due to erosion by more than 10%.

5.8.8 Cut-off valve

A cut-off valve shall automatically close when any part of the equipment is turned off or ceases to function.

An automatic pressure release device must be fitted if a pressure system above 50 kPa is used in the equipment.

5.8.9 Droplet size

The nozzle of the fogging equipment shall deliver droplets of no larger than 30 µm VMD in space sprays. See also section 4.10 and test procedure A2.10 in Annex 2.

If a special design of a thermal fogger is available to produce a droplet spectrum not exceeding 100 µm for larvicidal applications, the orifice or attachment to select bigger droplet sizes up to 100 µm shall be used to evaluate the droplet spectrum.

5.8.10 Control panel system

The remote control panel in the vehicle cabin shall be provided with permanently labelled switches for turning on and off the machine and the pesticide flow independently. The design of the remote control system must ensure that pesticide does not enter the vehicle cabin.

5.8.11 Durability

The equipment shall be able to operate without operational failure and without problems of restarting the engine, when operated at the maximum airflow, for not less than a total of 50 h within a period of no more than two weeks. There should be an 8 h test within the 50 h. The fuel and formulation lines, and the pump and other components, should withstand durability tests without leakage.

5.8.12 Noise level

The equipment shall be labelled to indicate the need to use ear protection if the noise level exceeds 85 decibels one metre from the machine. During operation in streets, the noise level shall not exceed 100 decibels one metre away from the machine at any time.

5.8.13 Markings

See section 4.12.

5.8.14 User manual

See section 4.13.

Note: The user manual must have clear safety instructions to warn operators that this type of equipment MUST NEVER be left unattended while in operation because of the higher risk of fire.

5.8.15 Field use

See section 4.14.

6. Aerosol dispensers

There are international specifications regarding the manufacture of aerosol dispensers. The following section is included as a general indication of what is required for use in aircraft.

6.1 Aircraft disinsection

Aerosolized aircraft disinsection products are used for the control of flying and crawling insects in aircrafts that can be harmful for humans, plants or animals.

WHO guidelines include three recommended aircraft disinsection techniques with aerosolized products: pre-flight, blocks-away, and top-of-descent. All spaces accessible from the interior should be treated. The doors of overhead luggage racks should be closed only after spraying has been completed.

6.2 Single-use and multi-use discharge systems

Both single-use ("one-shot") and multi-use ("multi-shot") aerosol dispensers are used for aircraft disinsection. The main difference between both discharge systems is the activation of the nozzle. Once the nozzle of a one-shot aerosol has been activated with one single press, all contents will be discharged as a single continuous spray. When using a multi-shot aerosol, the nozzle has to be continuously depressed until complete discharge or the correct quantity is released.

6.3 Description

The aerosol dispensers shall be of a non-refillable type, with a capacity specified by the purchasing agency. They shall consist of a container and a valve or release mechanism/discharge system, such that when the valve is activated the entire contents will be discharged in the form of an aerosol spray with a specific discharge rate.

The regulations of governments and of the International Air Transport Association (IATA) relating to the carriage of restricted articles by air must be complied with. The aerosol spray produced must be non-flammable, free from human toxicity risks, non-irritant to either passengers or aircrew, and non-injurious to materials used in aircraft construction. The finished product shall be clean, uniform and free from any defects that might impair its utility, such as any form of sediment or foreign particles, as, for example, dirt or metal waste.

Container

It is recommended that the metal container is constructed in one piece, except for the top, without side or bottom seams. The outside of the container shall be clearly marked with the percentage of the active ingredients, the net weight of the contents, the expiry date and

the batch number, as well as with clear instructions for operation and mandatory information regarding health and safety. Lithographing should be used to provide this information, but where this is not possible securely affixed labels are acceptable.

Contents

The product formulations used for filling the container shall be one of those recommended for the purpose in the current International Health Regulations (IHR, 2005). The use of a non-flammable propellant with a low global warming potential value is strictly recommended. An application rate of 35 g of the formulation per 100 m^3 is advised.

Dip tube

The dip tube may be made of either metal or plastic and must be so constructed that it touches the bottom of the container. To prevent any restriction to the flow up the tube as a result of direct contact with the bottom, the lower end shall be provided with a Z-cut (or with two V-shaped notches at opposite sides of the tube) that shall be about 1.5 mm in depth.

Valve

For a single-use aerosol dispenser, the valve or release mechanism must be so designed that once it has been opened it is impossible to close it again or in any way interrupt the flow. The dip tube and the valve must be effectively sealed together so that discharge can take place only through the valve orifice. The valve and dip tube assembly must be sealed into the container in such a way that it is completely leak-proof.

Valve cap

A cap must be provided to cover fully the external portion of the valve and to give protection from accidental damage or discharge. It may be constructed of either metal or plastic but must have sufficient rigidity to provide the requisite protection and have a clearance of not less than 3 mm above the valve. If made of plastic, it must not show any shrinkage or distortion when stored over a period of 18 months after manufacture. Three 3-mm diameter holes must be provided at points equidistant around the side of the cap in such a way that discharge will continue even though the cap may be replaced.

Secondary packaging

The secondary packaging (e.g. cardboard box) provided for the dispensers must clearly display the following information in such a way that it can be seen under storage conditions:

- product name;
- name of the active substance plus weight percentage;
- number of units contained;
- batch number;
- mandatory health and safety information; and
- applicable transport information.

6.4 Performance

Filling

The filling of the dispensers shall be such that when operated at any time during a period of 24 months from the date of manufacture, the minimum amount discharged is not less than that stated on the dispenser.

Evaluations of the stability of the packaging and packaging/formulation interactions must be performed at different end-points (storage at ambient temperature) in the framework of the claimed shelf-life.

Discharge rate

When operated according to the manufacturer's instructions, the rate of discharge of a dispenser shall be 1.0 g ± 0.2 g/sec 27 °C. The aerosol produced shall comply with the following physical requirements:

- not more than 20% by weight of the aerosol shall consist of droplets of diameter greater than 30 µm; and
- not more than 1% by weight of the aerosol shall consist of droplets of diameter greater than 50 µm. These requirements may not necessarily be met during the discharge of the last 10% of the contents.

Heat stability

No leakage, distortion or other defect shall arise when the dispenser is tested as described in airline requirements.

Material compatibility

Aircraft manufacturers and airline operators require that aerosol dispensers are certified according to the AMS 1450 specification and/or Boeing D6-7127 specification. These specifications are intended to ensure that the contents of the aerosol will not induce corrosion of metals, crazing of plastics, staining of carpets or otherwise adversely affect the fabric of the aircraft.

Biological performance

The procedure for assessing the effectiveness of aerosol dispensers is given in the WHO Guidelines for testing the efficacy of insecticide products used in aircraft (2012).[1]

[1] Guidelines for testing the efficacy of insecticide products used in aircraft. Geneva: World Health Organization; 2012 (http://whqlibdoc.who.int/publications/2012/9789241503235_eng.pdf, accessed 20 March 2018)..

6.5 Test procedures

Determination of droplet size

A recommended method for the determination of droplet size of aerosols is given in Annex 2.

Rough usage test

The full dispenser shall be dropped under its own weight from a height of 75 cm onto a hardwood surface so that it receives successive impacts (i) end down, (ii) top down, and (iii) sideways.

Heat-stability test

The full dispenser shall be immersed in warm water until the contents of the container reach 54 °C. This may be accomplished by immersing the full container for 3 min in a water-bath that is maintained at 60 °C. Leaks may be detected by bubbles issuing from the surface of the container.

7. Equipment used to apply pesticide granules

The granules have often been applied from aircraft, or by using a motorized knapsack sprayer adapted to apply granules for mosquito larval control. Under the circumstances, manually carried granule applicators used specifically for mosquito control are not generally available.

Several different designs of manually carried granule applicators have been marketed for use in agriculture and could be used for mosquito larval control.

Insecticides formulated as granules for mosquito larval control vary in the size, content and the recommended quantity to be applied, so each type of equipment must be calibrated with the insecticide product before field use.

7.1 General requirements

Materials

All materials used in the construction of the granule applicator equipment must be resistant to corrosion and chemical formulations, and will not deteriorate with normal usage and affect normal operation of the equipment.

Design

The granule applicator shall be designed so that the outer surfaces do not trap or retain granules. The granule applicator should be stable and stand upright on slopes up to 8.5 °, irrespective of the quantity of granules in the hopper. All fittings assembled shall have no sharp edges or projections that might injure workers during normal operation.

Weight

The maximum weight shall not exceed the weight specified by national health and safety regulations. In the absence of national regulations, the maximum weight of manually carried equipment should be 25 kg (knapsack) or 20 kg (hand carried) when it is filled to the manufacturer's maximum recommended capacity.

Hopper

The hopper (container) shall be provided with a tight lid so that granules cannot be spilt while operating the equipment. Due to the tight lid, any dust that may be with the granules shall not escape from the hopper. The hopper shall not be mounted on the front of the operator. Neither the hopper nor any metering system shall cause granules to break up and create dust.

The load of granules in the hopper on portable equipment will depend on the maximum weight that can be carried. The hopper shall be designed so that it can be emptied completely. On small equipment, if the hopper opening is less than 90 mm wide, a funnel or closed transfer system shall be used to fill the hopper.

Flow control

A device should be incorporated into the flow line to regulate the quantity of granules released as a single dose or when granules are being spread over a wider area.

Straps on manually carried equipment

The width of the strap shall be sufficient to avoid discomfort when positioned on the operator's shoulder and shall be 50 mm ± 5 mm. The strap shall be of adjustable length. Neither the straps nor the fittings should fail the drop tests.

Markings

The equipment operator must be able to easily locate and see details of the name and contact details of the manufacturers, the type of machine, date of manufacture and serial number as well as the position of key components affecting routine use of the equipment. The position of any valves or switches to indicate on/off positions and the position of any other controls must be clear. The type of granule that can be applied with the equipment must also be clearly indicated. The markings shall not be obscured or made illegible by exposure to pesticide formulations and shall be clearly visible to the operator.

User manual

Pesticide application equipment must be provided with a clear, simple and illustrated manual that details the method of operation, including calibration method, safety precautions and maintenance procedures, as well as the essential spare parts required for routine maintenance. The equipment shall indicate the granule sizes, the range of doses that can be applied and whether it can distribute the granules over an area or is a spot applicator. The manufacturer should provide the manual in an accepted commercial language in the country in which the sprayer is being marketed.

The manual should contain procedures for:

- initial assembly;
- identification of all replacement parts including an "exploded" diagram;
- setting and calibration;
- minimizing the need to dispose of unused granule pesticide;
- cleaning;
- routine maintenance and storage;
- safe and accurate field use; and
- precautions to minimize the risk of operator and environmental exposure to pesticides.

7.2 Manually-carried (shoulder-mounted) granule applicators

The "Horn seeder" consists of a shoulder slung bag made with rubberized or neoprene-treated material and a delivery tube.

- The applicator shall have a bag with a zipped opening to allow easy filling of the bag.
- The bag shall be fitted with a tapered metal discharge tube at its lowest point.
- Within the tube a device shall be positioned to adjust flow of granules.
- The weight of the unit when fully loaded shall not exceed 12 kg.

Granules are applied by swinging the discharge tube from side to side in a figure 8 pattern with sufficient velocity to distribute the granules evenly over a 7 m swath width. One swing or swath pass is made for each step.

7.3 Hand-carried granule applicators

The unit shall consist of a tube to contain the granules that fall by gravity to an outlet.

- The tube shall have a hand-operated mechanism, which on activation allows a fixed quantity of granules to fall from the tube.
- The section holding the granules shall have a wider opening than the delivery tube to facilitate filling and be fitted with a lid to avoid spillage.
- The quantity of granules released can be adjusted.
- The diameter of the tube shall be not less than 70 mm.
- The weight of the unit when fully loaded shall not exceed 5 kg.
- A shoulder strap may be fitted.

The unit should be designed to apply a small quantity of granules to discrete distinct breeding sites, where larvae are present.

7.4 Knapsack granule applicators

The unit shall consist of a container designed to allow the granules to fall by gravity down to a delivery tube, held in front of the user.

- The container shall have a large opening to allow quick filling; the diameter of the opening shall be not less than 12 cm.
- The opening shall have an inset filter to prevent large lumps or other debris entering the container.
- The container shall be fitted with a tight lid to prevent escape of any dust.
- The container shall be fitted on a frame with straps to fit comfortably on the operator's back.
- The delivery tube shall be fitted with a dose regulator and an on/off valve.
- The delivery tube may be fitted with a device to spread the granules.

The applicator unit should be designed to apply a very small quantity of granules that can be spread over discrete distinct breeding sites, where larvae are present.

7.5 Motorized knapsack mistblowers adapted for distribution of granules

The unit shall consist of a container fitted above an engine-driven fan to produce a high-velocity airstream into which the pesticide granules are metered and projected over a swath covering at least 5 m from the operator.

- The engine, mounted on a knapsack frame, shall be provided with an easy starting mechanism.
- A fuel tank should be mounted below the engine.
- All moving parts and the exhaust shall be guarded to prevent injury to the operator.
- Engine controls, including a stop switch and speed control, shall be mounted so that they are visible in front of the operator, when in use.
- A non-absorbent padded backrest shall be fitted to the knapsack frame to fit comfortably on the operator's back.
- The mounting of the engine must dampen vibrations during normal operation.
- All parts that are regulated while operating the equipment shall be permanently and identifiably marked.

In addition to the general requirements listed, the motorized knapsack granule applicator must have the following requirements.

Granule container

The container (Hopper) shall be designed to allow the granules to fall by gravity to the delivery tube. The inlet to the container shall be at least 120 mm wide to facilitate filling and be fitted with a mesh to prevent particles larger than the granules entering the container. It shall be fitted with a tight lid.

Fuel tank capacity

The capacity of the fuel tank shall allow field operation for at least one hour, without the engine stopping. Fuel consumption shall be < 2 L/h when the engine is operated at optimum speed. The type of fuel and fuel mix shall be permanently indicated on the fuel tank, filler cap or on the machine.

Straps

Two straps with padding over the shoulder are required. Each strap shall be adjustable and at least 75 cm in length. The width of strap shall be declared and shall be at least 50 ± 5 mm wide. The strap when subjected to the absorbency test method shall not increase in weight by more than 10%. Any material in the backrest should also meet the same criteria as for the straps.

Discharge system

Air from the blower shall be ducted in a tube to the nozzle. The air duct shall be flexible to facilitate direction of the dry granules by the operator. The flow rate of granules shall be controlled by a pre-selected restrictor or device, positioned inline before the outlet. An on/off valve attached to the air duct in front of the operator is used to control whether granules are applied.

The granules should be dispersed over a distance of at least 5 m.

Durability

The granule applicator shall be subject to a minimum of 50 hours' operation over a 10-day period, with one period of 8 hours' operation included to represent a full day's operation in a vector control programme. All stoppages shall be recorded, with reasons for the stoppages and details of any repairs carried out. Data on fuel consumption shall be collected.

Noise level

The equipment shall be permanently labelled to indicate the need to use ear protection if the noise level exceeds 85 decibels.

8. Personal protective equipment

Pesticides applied to control vectors of disease are generally applied in environments with people, so only the less toxic pesticides are recommended. Nevertheless, those applying the pesticides and those involved with maintenance of equipment should be provided with appropriate personal protective equipment (PPE). Thus coveralls, gloves, face mask and footwear to minimize exposure to pesticides should be worn as directed.

International standards have been published that cover protective clothing worn by spray operators applying liquid sprays. ISO 27065:2017 is the International Standard that addresses the performance requirements for protective clothing worn by operators handling liquid pesticide products.[1]

Pesticide handling includes mixing, loading, application and other operations such as cleaning equipment and containers. The above said ISO standard includes requirements for garments (e.g. shirts, jackets, trousers and coveralls) and partial-body garments (e.g. aprons, smocks, protective sleeves, hoods/caps). Requirements for garments and partial-body garments constructed with multiple layers or materials are also included in this standard. Directive 89/686/EEC on personal protective equipment of the European Agency for Safety and Health at Work sets out requirements relating to the design, manufacture and supply of PPE.

Different standards apply to specialized items of PPE, including respiratory protective equipment. An FAO/WHO guideline on the use of personal protective equipment is under development and will provide further details.

[1] https://www.iso.org/standard/54133.html.

Annexes

Annex 1. List of ISO International Standards applicable to the pesticide application equipment used in agriculture, as some sprayers are used also in vector control

ISO 5681:1992	Equipment for crop protection – Vocabulary. [under review; will be replaced by ISO/AWI 5681]
ISO 5682-1:2017	Equipment for crop protection – Spraying equipment – Part 1: Test methods for sprayer nozzles
ISO 10625:2005	Equipment for crop protection – Sprayer nozzles – Colour coding for identification
ISO 19732:2007	Equipment for crop protection – Sprayer filters – Colour coding for identification
ISO 4102:1984	Equipment for crop protection – Sprayers – Connection threading
ISO 19932-2:2013	Equipment for crop protection – Knapsack sprayers – Part 2: Test methods
ISO 10988:2011	Equipment for crop protection – Knapsack motorized air-assisted sprayers – Test methods and performance limits
ISO 19932-1:2013	Equipment for crop protection – Knapsack sprayers – Part 1: Safety and environmental requirements

Annex 2. Specific test methods used for various types of equipment

A2.1 Corrosion or chemical resistance test

The corrosion or chemical resistance test is a simple test in which an equipment sample is immersed in water for 24 h at a temperature of 20–30 °C, followed by removal of surplus liquid and drying of it for 24 h at the same temperature. Any adverse effects on the material are then determined, such as any visible effect (e.g. deformity), change in physical properties (e.g. flexibility) or weight change. Alternatively, components made of elastomers, such as gaskets, should be immersed in (i) a mixture of equal parts of diesel and gasoline and (ii) 10% aromatic hydrocarbon in water, to assess their suitability for use in the equipment. The weights of each sample of material shall be recorded before and after immersion.

A2.2 Leakage test

Compression sprayer

The sprayer to be tested shall be set up for use with the pesticide tank filled to the recommended maximum level with water to which a suitable non-ionic surfactant at 0.1% and a suitable visible dye have been added. Any liquid on the outside of the tank is wiped. The sprayer with the tank is stood upright within a safety cage on a clean plastic sheet for one hour. The pump is operated to pressurize the tank to twice the maximum operating pressure. Then the test is repeated twice, first with the tank set at an angle of 45 ° and then set horizontally. The surface of the sheet is examined for leaks and the sprayer checked for any pressure drop. The same test should be repeated in all these positions with no pressure in the tank; no leakage should occur.

Other equipment

The sprayer shall be set up for use with the pesticide tank filled to the recommended maximum level with water to which a suitable non-ionic surfactant at 0.1% and a suitable visible dye have been added; any liquid on the outside of the tank is wiped. The pump is operated to pressurize the delivery system to the trigger valve and the sprayer is stood on a clean plastic sheet for one hour. The surface of the sheet and sprayer are examined for leaks.

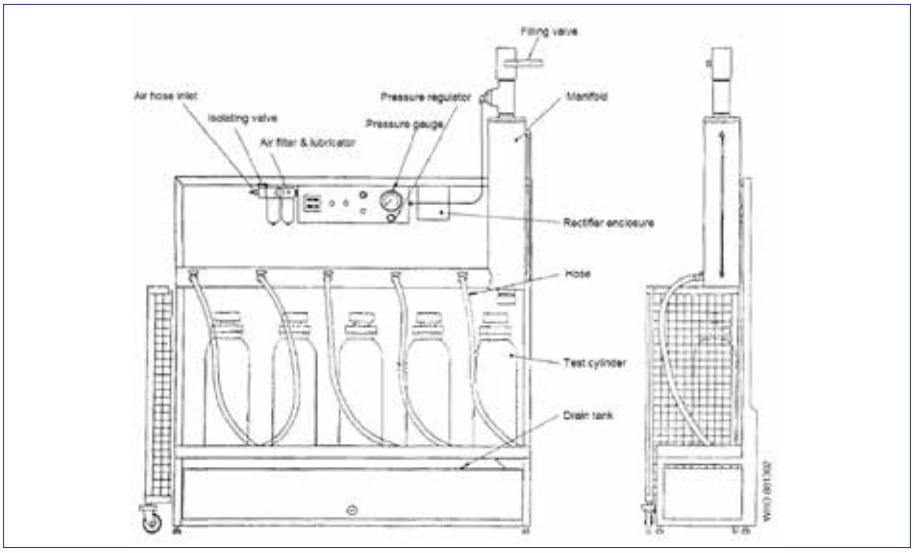
A2.3 Tank fatigue tests

A2.3.1 Tank fatigue test for compression sprayers

To measure whether the sprayer tank can withstand repeated pressurizations, the sprayer, completely full of water, is attached to an apparatus, e.g. see Figure 19. The dip tube or tank outlet connection is connected to the manifold, preferably by the sprayer hose. Compressed air is introduced through the manifold via a pressure regulating valve and controls so that a pressure of 500 kPa (5 bar) is applied for 15 sec and then released for 15 sec, i.e. to complete two cycles per min. This cycle is repeated 12 000 times, unless a drop in pressure caused by tank failure shuts down the apparatus. A counter in the apparatus indicates the number of cycles completed.

An alternative test rig design can also be used.

Figure 19. Diagram showing the test rig for determination of fatigue failure in compression sprayer tanks



A2.3.2 Alternative tank fatigue test apparatus

To measure whether the sprayer tank can withstand repeated pressurizations, the sprayer, completely full of water, is attached to a test apparatus. The test apparatus is a software-controlled system consisting of inlet and outlet pressure valves (Figure 20). The dip tube or tank outlet connection is connected to the manifold in-between the two valves. The maximum and minimum pressure, tank filling and emptying rate/time, hold time, permissible pressure drop during hold time and number of cycles are specified through the control software. Compressed air is introduced at a pressure higher than that of the maximum filling pressure through the manifold via a pressure regulating valve. During a cycle, the inlet valve opens, the tank is filled to maximum pressure, the unit holds for the specified time and the outlet valve opens to release the pressure to the minimum set pressure. The number of cycles is counted and the apparatus shuts off after the set number of cycles. If maximum pressure is not achieved in a set time or if the pressure drops more than that of the permissible drop during hold time, it is an indication of a leak. The system sends an audio alarm and shuts off.

Figure 20. a. Testing tank fatigue of a compression sprayer using a computerized system (source: Navy Entomology Center of Excellence, FL, USA); b. Fatigue test monitored using a laptop

A2.4 Tank drop test for compression sprayer

To determine whether the sprayer can still operate effectively after being accidentally dropped from the operator's back, the compression sprayer tank, pressurized to maximum recommended pressure, with its tank filled with water to the recommended maximum operational volume, will be dropped from a height of 60 cm onto a flat wooden surface (suggested 20–30 mm thick by 800 mm square), placed on a level floor and surrounded by a metal cage to protect the tester from injury. This drop is repeated in total six times upright and six times tilted at 10° in a simulation of how the tank hangs on the shoulder. The sprayer should continue to function normally after the test and meet the leakage test requirements.

A2.5 Strap drop test

The sprayer tank shall be filled to the recommended maximum level with water. The whole sprayer is then suspended by its strap(s) and lifted 30 cm above a solid horizontal support (a pole of 75 mm diameter) before being allowed to drop freely and hang by the strap(s) (Figure 21). This strap drop test shall be repeated 25 times. The strap(s) and fittings shall not be damaged by the test.

Figure 21. Test to determining whether the strap is strong enough to take the weight of the sprayer

A2.6 Strap absorbency test

The straps and any padding shall be removed from the sprayer and weighed when dry. The straps are then completely immersed in water for 2 min. On removal any surplus liquid is shaken off and the straps are hung freely to drain for 10 min before re-weighing. The increase in weight after immersion should not exceed 10% of the dry weight. However, under humid conditions it may be necessary to leave the straps to dry overnight (8+ h) before reweighing.

A2.7 Trigger valve durability test

The trigger valve shall be mounted on a test rig (Figures 22a and 22b) that is designed to open and close the valve at 10–15 cycles per min by means of a cam, applying less than 500 kPa to the valve face. The spray line shall be fitted with a nozzle to deliver 0.75 L /min of a suspension of 20 g/L silica (see Annex 3 for specification of the silica used in this test) in water at 300 kPa to test the abrasion resistance of the valve components. The nozzle may discharge directly or through appropriate piping into a reservoir from which the liquid is returned under pressure to the inlet port of the valve. The test suspension shall be changed after every eight hours of use. The mechanism shall open the valve in not less than 0.1 sec and not more than 0.2 sec. After an initial test of 500 cycles at 100 kPa, the test shall continue for 50 000 cycles of operation at 300 kPa. Finally, the test shall be repeated with the input pressure to the valve set at 1000 kPa for 500 cycles. Alternatively, a pneumatically controlled test apparatus can be used using pneumatic timers, valves and counters. The test rig should shut down if the valve under test fails.

Figure 22. a. Equipment used to test the durability of the trigger valve on sprayers, and b. a trigger valve positioned on the durability test equipment

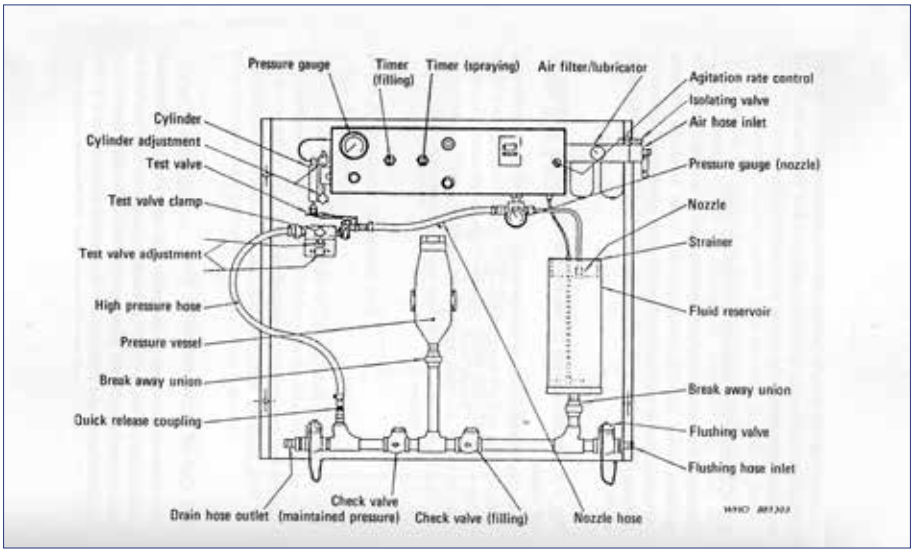
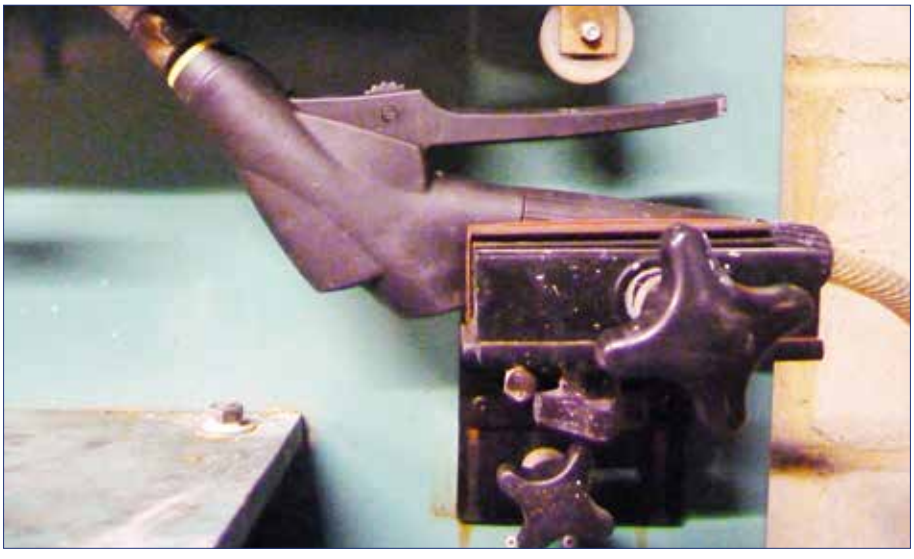


Figure 22. b. A trigger valve positioned on the durability test equipment



Alternate trigger valve test apparatus

A software-controlled apparatus as shown in Figure 23 can be used to test the abrasion resistance of the trigger valve components. The test apparatus may consist of a storage tank, a pump and a reciprocating lever. The pump may draw liquid from the bottom of the storage tank and push it through the trigger valve and the nozzle. The cam shall open and close the valve at 10–15 cycles per min. The mechanism shall open the valve in not less than 0.1 sec and not more than 0.2 sec. The nozzle, fitted at the end of the spray line, should deliver 0.75 L of a suspension of 20 g/L silica (see Annex 2 for specification of the silica used in this test) per min, and discharge liquid back into the storage tank. A pressure transducer, on each side of the valve, shall monitor the pressure upside and downside of the valve, which is set by the software. A bypass valve can be used to set the pressure on the trigger valve's upside, higher than the set pressure downside. The number of strokes of the cam should be counted by software for the number of cycles completed. If the pressure on either side of the valve falls below the set limit in the software or the number of cycles completed, the system shall shut off and send an audio alarm. After an initial test of 500 cycles at 150 kPa, the test shall continue for 50 000 cycles of operation at 300 kPa. Finally, the test shall be repeated with the input pressure to the valve set at 750 kPa for 500 cycles. The test suspension shall be changed after every eight hours of use.

Figure 23. A software-controlled apparatus to test the abrasion resistance of the trigger valve (source: Navy Entomology Center of Excellence, FL, USA)

A2.8 Nozzle test – output

A2.8.1 Compression and other hydraulic sprayers

A test rig shall consist of an electrically operated solenoid valve to control the flow of water from a compression sprayer fitted with a control flow valve for exactly one minute. The water can be collected in a measuring cylinder during one minute or in a pre-weighed beaker so the weight of the output from the nozzle can be determined.

A2.8.2 Spray pattern

The spray pattern from the nozzle shall be evaluated according to ISO 5682-1:2017. Using a test rig similar to that for testing the spray output, the nozzle is mounted centrally 450 mm above an inclined patternator consisting of a series of channels, ideally 25 mm wide, to collect liquid across the spray swath in tubes, mounted at the lower edge of each channel.

A2.8.3 Mistblowers

The flow rate should be measured with the engine operated at optimum speed so the liquid output in a high velocity air steam cannot be collected to measure; the usual technique is to fill the spray tank to the 10 L mark and record the time it takes for the liquid level in the tank to decrease to 5 L (5000 mL/time in seconds or minutes). Measurement of the level must be done when the level of liquid is horizontal in the sprayer.

A2.9 Foggers

A2.9.1 *Cold foggers*

Start the fogger and adjust the engine speed to establish proper insecticide tank pressure, and fill the insecticide lines. This may require letting some "run out" in order to fill the lines. Remove the discharge tube from the nozzle and hold it at the same level. Activate the control valve to start discharge and let it discharge into a spare cylinder until the flow is steady. Then collect the discharge for one min and measure it in a graduated cylinder. The volume collected is the flow rate in mL/min.

A2.9.2 *Thermal foggers*

Use a similar technique as for a cold fogger, or after ensuring liquid is in the line between an empty pesticide tank and nozzle, put a known volume in the tank and run the machine until the tank is empty. For accurate measurement, the sprayer should be in exactly the same position (preferably level) before and after operation. The volume required to refill and the time of run will determine the flow rate.

A2.10 Nozzle test for droplet size

The sizes of spray droplets are measured using a recognized non-intrusive laser system attached with a computer to display the data (Figure 24). The nozzle is positioned to direct spray through the laser beam. The nozzles may be directed so that the width of the spray passes through the beam or, alternatively, the centre of the spray pattern is sampled. Nozzles shall

normally be placed 25 cm from the laser beam when measuring the droplet spectrum. The numerical data from different instruments will vary, so the data should be considered in relation to standard reference nozzles. The temperature at the time of measuring shall be recorded, with details of nozzle operating pressure and output.

Different laser systems can be used in droplet size tests.

Figure 24. Measuring the spray droplet spectrum of a vehicle-mounted cold fogger

Phase Doppler Particle Analyzer (PDPA)

The PDPA is a point measurement system that consists of a laser generator, transmitter, receiver and a signal processing unit. The size and velocity of the droplet is measured while it passes through an intersection of two beams by the receiver (Figure 25), and data are transmitted to the processor and computer. By use of different transmitter and receiver lenses, droplets from 0.5 µm to 2000 µm in size can be measured. A typical combination is 500 mm and 300 mm lenses on transmitter and receiver, respectively, to achieve a size range of 0.5–213.5 µm. The system can be used with a software-controlled traverse system which allows continuous measurements in a sweep mode. To capture a representative sample, the spray cloud can be scanned from one end to the other in one dimension (such as from top to bottom) and in the middle in the other direction (such as horizontal). Droplet size characteristics are calculated by the specific software and data can be exported to an Excel spreadsheet.

Figure 25. Phase Doppler Particle Analyzer showing spray through laser beams

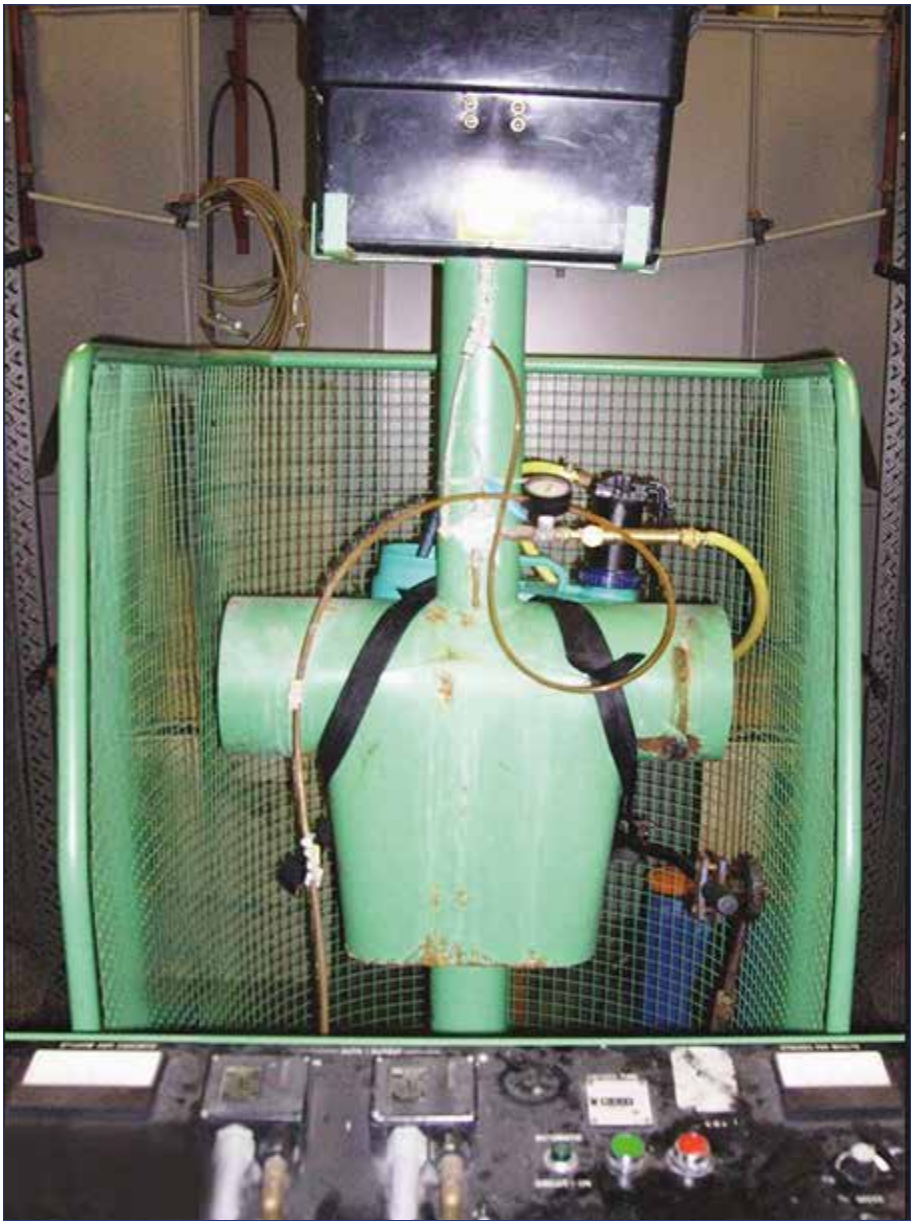
A2.11 Sprayer durability test – lever-operated knapsack sprayer

The sprayer, full of water, is mounted on a rig designed to simulate being carried on the back of a user (Figure 26). The lever is linked to a mechanism powered by an electric motor to operate the lever at a speed of up to 30 strokes per min.

Note: An efficient pump will require fewer full strokes of the pump.

The water from the hose is delivered through a nozzle, delivering 1.6 L/min at 3 bar pressure (or when used for larviciding, the unit will normally operate at a lower pressure, say 1 bar) into a tank above the sprayer, so that just before the sprayer tank is emptied, the water is released from the upper tank to refill the sprayer. Pressure sensors shut down the equipment if the pressure drops below 2.5 bar or exceeds the set pressure due to any blockage in the spray system. The test is operated for a minimum of 250 h.

Figure 26. Lever-operated knapsack sprayer on test rig



Annex 3. Output of hydraulic nozzles used on sprayers

The volume of spray emitted through hydraulic nozzles can change after use, especially when water contains small particles of sand, which can erode the nozzle orifice.

The spray operator should always calibrate the nozzle output regularly by putting water in the sprayer and collecting the spray in a measuring cylinder or a jug for a minute. The output of an 8002E flat fan nozzle should be 550 mL/min at 1.5 bar, with a control flow valve fitted on the lance. If the output has increased by more than 10%, the nozzle should be replaced to avoid excessive discharge of the spray liquid leading to application of overdose of the insecticide.

The operator should also check the distribution of spray from the nozzle by spraying a dry surface with water by moving the nozzle from top of the wall to bottom keeping a distance of 45–50 cm from the surface. The wetting of the surface should show if the spray pattern is even over a swath of about 75 cm wide.

The durability of nozzles can be checked by spraying a suspension of silica powder in water (see properties of the abrading powder below).

The abrading powder shall be a synthetic silica powder with the following chemical and physical properties:

Bulk density	160 Kg/m^3
Specific gravity	1.95
Average particle size	0.022 µm
Colour	White
Refractive index	135–165 Gardner-Sward test units
Surface area	140–160 m^2/g
pH (5% water suspension)	7.3
Loss at 105 °C	5%
Loss at 1200 °C	10%
SiO_2 content	87%
CaO content	0.5%
$Fe2O_3$ content	0.2%
$Al2O_3$ content	0.6%
NaCl content	1.0%

Annex 4.Manually carried sprayers with electrically operated pump

Electrically powered knapsack sprayers are now commercially available, but so far none has been evaluated for indoor residual spraying inside buildings. The following is thus an interim specification should any organization wish to try the units to eliminate the manual pumping needed with a compression sprayer.

The electric sprayer can be used for residual spraying of wall surfaces and applying larvicides.

A4.1 Description

The sprayer shall consist of a knapsack tank, equipped with:

- an electrically operated pump, powered by a rechargeable battery;
- shoulder straps, and opening not less than 90 mm diameter with tight fitting lid, fitted with a leak-proof valve;
- a device to set the pressure of liquid delivered by the pump – the pressure should be adequate to open the control flow valve and provide agitation in the tank;
- a return flow to the tank can be fitted to provide some agitation in the tank;
- a hose to connect the pump output to the lance;
- a straight lance with trigger valve with locking-off device, control flow valve and nozzle for indoor residual spraying;
- a robust system for parking the lance when not in use to protect the nozzle;
- a deep filter[1] that shall be fitted in the tank filler opening;
- a recharging unit for the batteries, which is suitable in the country the equipment is intended to be used; and
- certain other accessories as specified by the user agency, e.g. an additional lance to extend the length of the lance.

In addition to the general requirements listed above, electrically powered knapsack sprayers must be fitted with the following devices.

A4.2 Materials

See section 4.1.

A4.3 Design

See section 4.2.

A4.4 Weight

See section 4.3.

[1] Note: The filter should prevent blockage of the spray nozzle (usually 50 mesh is adequate) and sufficiently deep set so that when filling the tank, the operator can see the level at the bottom of the filter when the tank is filled to maximum level. The diameter is determined by the diameter of the filler opening on the spray tank.

A4.5 Battery

The battery shall be provided to operate an electrically driven pump for at least 4 h actual spraying at 1.5 bar pressure.

The battery must be protected from pesticides and easily removed to allow recharging (Figure 27). A recharging unit with an indicator should be provided to ensure the battery is charged. Instructions for recharging shall be included in the user manual. A battery management system to protect the battery from overcharging and high temperatures shall be provided to ensure that the battery has a long life in a good condition.

Note: Ideally, it should be possible to recharge the battery fully within 4 h, although batteries will usually be recharged during the night. Some type of indication on the sprayer to show the battery power left would be helpful.

Figure 27. Sprayer showing battery in position in separate compartment below the spray tank

A4.6 Pump

The pump should be able to provide sufficient pressure to open the pressure regulating valve on the lance and provide agitation of the spray by recirculation of liquid into the tank.

Note: Materials used to construct the pump need to be tested to ensure pesticide formulations used in vector control do not adversely affect the pump.

A4.7 Spray tank

The tank capacity is normally 15 L. See also section 4.5.

The tank filler hole shall be at least 90 mm wide.

Notes:

a) Larger tanks that can hold 15 L liquid and space for air are suggested as it would enable spraying insecticide quantity equivalent to two sachets (considering that currently one sachet is mixed with 7.5 L of water to spray on 250 m^2 surface area in IRS).

b) There is considerable research and development of batteries in progress. Currently, a lithium ion battery is relatively light and can provide the power, but is subject to restrictions, such as they cannot be transported on aircrafts. Alternative batteries, such as lead acid gel batteries, tend to be much heavier than lithium ion batteries and recharging may be less effective. Areas in which this type of equipment is used should have a good electricity supply to recharge batteries. A set of replacement batteries may be needed where this equipment is used.

A4.8 Hose

The length of the hose shall be declared and shall be not less than 1.0 m and of a material suitable for the pesticide product(s) specified by the purchasing agency.

A4.9 Trigger valve

The type of trigger valve shall be declared and shall not drip or leak when subjected to the test method described below (see Annex 2, test A2.7). The trigger valve must have a positive lock-off position. The length of the valve lever shall not be less than 100 mm measured from the pivot point. The maximum torque on the lever shall be 1.5 newton metres.

A filter in the trigger valve must be of a smaller mesh than the size of the nozzle aperture and not larger than 50 mesh size (with an aperture not larger than 0.3 mm if there is no filter in the nozzle body). A second filter should be fitted close to the nozzle to prevent the nozzle being blocked while spraying. All filters shall be easily accessible for frequent cleaning.

The length of the lance attached to the trigger valve shall be at least 500 mm and be fitted with a constant pressure valve to ensure spray is delivered at a constant flow rate as the sprayer tank empties. A constant flow at 1.5 bar is recommended.

An extension lance shall be available that will fit between the trigger valve and the lance to facilitate spraying of ceilings.

A lance with an attachment angled downwards to spray water surfaces can be supplied for larviciding.

A4.10 Nozzle

The nozzle tip and the flow rate shall be declared and comply with international standards. Tolerance limits of the discharge rate shall not exceed ± 5% when tested in accordance with the procedure A2.8 described in Annex 2.

The output of the nozzle shall not increase subsequently due to erosion by more than 10% when subjected to the test described in test A2.9 in Annex 2. The pattern should remain consistent and unchanged.

For indoor residual spraying, the 8002E nozzle is recommended and operated at 1.5 bar pressure to provide a discharge rate of 550 mL/min.

A4.11 Droplet spectrum

See section 4.10.

A4.12 Markings

See section 4.12.

A4.13 User manual

See section 4.13.

A4.14 Field use

See section 4.14.

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