THE DEVELOPMENT OF A SPRAYER FOR USE WITH WATER
SUSPENSIONS OF DDT IN RURAL AREAS OF
LATIN AMERICA

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INTRODUCTION

In the past several years the residual spraying of dwellings with DDT in one
form or another has become a standard public health measure for the control
of malaria. Reports from most malarious areas of the world indicate that suc-
cessful results are being obtained at relatively low cost with this method. The
procedure is still so new, however, that there exists a great diversity of techniques
of application.

Due to the virtual insolubility of DDT in water, this chemical was used
almost exclusively during the World War II years either as an emulsion or an
oil solution. Towards the close of the war in 1945, however, methods for man-
ufacturing finely divided wettable DDT powders were developed. These
wettable powders, used as sprays, in the form of water suspension, are being
widely and increasingly used in the control of agricultural insects, and there
has been an expanding interest in them for use in malaria control work.

Several factors make the use of DDT water suspensions a matter of special
interest to malariologists outside the United States.

1. Water suspensions of DDT appear to be more effective than solutions or
emulsions on earthen surfaces, as the particulate form of the suspensions prevents
the DDT from being absorbed by the porous walls. Since earthen walls of one
sort or another are used in a large majority of rural dwellings, not only in Latin
America but in many areas of the Old World Tropics, the advantages of this
type of spray are obvious.

2. The places where DDT residual spraying is most needed are those relatively
remote rural areas of low income populations where until now it has not been
economically possible to either initiate or maintain the usual types of engineering
control. In such areas transportation methods are poorly developed and the
use of wettable DDT powders obviates the necessity of transporting the bulky
solvents or emulsion concentrates. The cost of solvent under these circum-
stances does, in fact, become greater than that of DDT itself.

3. In any overseas military operation the use of water dispersible DDT
obviates the necessity of transporting the inflammable hydrocarbons used as
solvents. The logistics of supply also dictate the use of water suspension as
this is the form in which the greatest amount of the active chemical may be
transported with the least weight and volume.

4. While water suspensions leave a white residue which is objectionable to
the point of disqualifying them for use in better class homes, most dwellings
to be treated in rural areas of Latin America, and elsewhere in the tropics, are
such that the residue is not objectionable.
5. While thus far water dispersible DDT has been available commercially as a powder containing only 40% or 50% of DDT, it is now apparent that formulations with 90% DDT are becoming available. The use of these will still further cut transportation costs.

The constituents of DDT formulations for suspension in water are quite diverse, (see Chisholm, 1948, for a review of DDT formulations for use as water suspensions) and tests of various commercial products have shown considerable differences in their physical characteristics, certain of which are sufficiently objectionable to render the products unsuitable for use in our area. Some commercial powders settle out of suspension very rapidly when first mixed with water; others may hold up well in suspension initially, but if permitted to settle and then the mixture is again agitated, they form a rapidly settling flocculent precipitate which plugs hand-spray equipment. Present DDT formulations for use as water suspensions seem to have been designed for agricultural purposes in the United States where power equipment, provided with mechanical agitators and high pressure pumps, is used. Such powders are not satisfactory when the attempt is made to use them with hand-pumped knapsack-type sprayers which operate at relatively low pressures and are without means of constant mechanical agitation.

The widespread acceptance of DDT water suspension as the material of choice in residual house spraying programs has, therefore, been tempered by the lack of suitable equipment to dispense it.

BACKGROUND

The first experiments with DDT as a residual spray for dwellings in Panama were made in 1944 (Trapido, 1946) in villages on the middle Chagres River using 5% DDT in kerosene. This is an area of high rainfall, with an average annual precipitation of about 100 inches. Correlated with this high rainfall, house construction is of cane or board walls with roofs of palm thatch or galvanized iron. When, however, in 1946 a program of residual house spraying was started in western Panama (Galindo and Gallardo, 1947), where resides the principal rural agricultural population of the Republic, unanticipated difficulties arose. In this area rainfall is probably less than 50 inches annually and houses are constructed largely with quinche walls and tile roofs. (Quinche walls are made by erecting a framework of poles bound together with vines and plastering this with a mixture of mud and straw. These walls may be painted with a lime whitewash, or left with the earthen surface exposed.) It was found that in order to wet these walls with the DDT kerosene solution it was necessary to use about twice as much solution as had been used in the Chagres River work, where the cane and palm thatch absorbed much less of the insecticide. The cost thus increased to the point where the economic feasibility of the procedure was questioned. It was apparent that a good portion of the DDT solution was absorbed below the wall surface.

Preliminary experiments with water dispersible DDT powders indicated that this material would be more economical, and during the 1947 wet season the
extensive house spraying program of the “Campaña Antimalarica” of Panama, carried on in the interior of the Republic, utilized water dispersible powders. At this point yet another difficulty arose. While the commercial DDT wettable powder used was among the better products of those we tested for its ability to remain in suspension, there was considerable sticking of the release valves of spray-guns, and much plugging of the nozzles of the hand-pumped knapsack-type sprayers used. It was the practice of the peons engaged in spraying to clear plugged nozzles with a pin or a bit of wire. The apertures of the brass nozzles, which had been designed to emit a wet fan-type spray suitable for residual spraying of surfaces, were deformed by this manipulation and released an erratic spray which gave irregular coverage. There was also considerable time lost in clearing the plugged nozzles and valves.

Later in 1947 while visiting the “Division de Malaria” of Venezuela, where the DDT water suspensions were being used in a vast program involving the annual spraying of some 700,000 houses, the same difficulties were observed and it became apparent that the problem was widespread. It was evident that either DDT water suspensions would have to be abandoned, or the formulations for wettable DDT powders and the equipment for dispensing them would have to be improved. While it was to be hoped that commercial manufacturers of wettable DDT powders would improve the quality of their products, there remained the practical problem of devising a sprayer suitable for dispensing existing stocks of water dispersible DDT, particularly since there was no assurance that the improvement of the formulations would reach a point where no difficulty would be encountered with current spray equipment.

The use of water dispersible DDT is contingent on the premise that suitable equipment is available to dispense the material efficiently. Three points are of prime importance in determining what is “suitable” equipment for use in tropical and subtropical Latin America.

1. Persons with the mechanical experience and ability necessary to repair motor-driven equipment are all too rare in this area. The difficulty of effecting repairs to motors is so great that the use of simple hand-operated equipment is dictated by necessity. Motor-driven power sprayers do not work out efficiently because of the great time loss in effecting repairs.

2. Houses are so scattered at the periphery of villages, as well as along rural roads, that it is not feasible to reach them with truck-mounted power sprayers. In addition, there are considerable populations carrying malaria infections in small villages accessible only by cart or with pack animals.

3. Labor costs are lower than in the United States, so that it is more economical to use hand labor rather than motor-operated mechanical equipment.

There is required, therefore, a durable, simple, one-man, hand-operated knapsack-type sprayer capable of efficiently delivering DDT water suspensions.

During the war years the need for a particularly sturdy insecticide sprayer of the knapsack type was recognized by the U. S. Army, particularly for use

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1 On a travel grant from the International Health Division of the Rockefeller Foundation.
with the then new DDT solutions and emulsions. Such a sprayer of stainless steel was developed (Cannon, 1947) and became the Army item of issue, “Sprayer, Insect, Knapsack Type, Lofstrand Model NER 106”.* We received early models of the original 4½ gallon and the later 3 gallon types from the Office of the Surgeon General of the Army for field testing in our residual house spraying experiments. Units of this sort were also purchased by the anti-malaria service of the Republic of Panama for their operations in the interior of Panama, and a considerable number were also used by the “Division de Malariología” of Venezuela. The latest model of this sprayer is designated § 250-A.

With the shift from DDT solutions to water suspensions in Panama it was found that this sprayer, designed for use with emulsions and solutions, was not suitable for use with water suspensions due to the frequent plugging of nozzles and valves mentioned above. We therefore undertook to modify this standard Army unit for use with water suspensions, and report here the development of an apparatus which has proved effective in all field trials.

DESCRIPTION

The basic unit has been described by Cannon (1947) as follows: “It consisted of a 3-gallon cylinder-shaped container, approximately 21 inches long and 7 inches in diameter; a spray gun; a pump; an 18-inch extension; four nozzles; and a hose connection. All metal parts, except the gun handle and filler and pump caps, were made of stainless steel. The handle was aluminum and the caps brass. A pressure gauge attached to the top of the cylinder indicated the operating range of the sprayer, 25 to 45 pounds.”

Discussed and illustrated here are only those details relevant to adaptation of the unit for use with DDT water suspensions. In figure 6 is shown the head of model NER-106, while figure 7 illustrates the most recent model, § 250-A. Considerable difficulty was encountered in field use of the original models due to air leakage at the soldered seams about the head of the tank (figure 6), so that in the latest model (figure 7) all seams are electric welded, and the head stamped out of one piece of metal with the exterior elements screwed in place and airtight seals effected with easily replaceable gaskets. The parts referred to below are labeled on plate II, figures 7 and 8.

MODIFICATIONS

General

As been mentioned above, the great fault of the existing model was the frequent plugging of the nozzle and the sticking of the spray-gun valve. While we at first considered somehow modifying these two elements it was pointed out that these were essentially well designed and the real problem lay in devising a filter which could remove from the DDT mixture those particles which caused the trouble.

* Manufactured by the Lofstrand Company, Rockville, Md.
It was apparent that a basket-type filter of large capacity was necessary, which would be easily accessible for washing, and replaceable without the use of tools, if damaged. It was desirable to have this filter inside the tank where it would be least subject to damage with rough use. The filter had to be of a sort that would remove all particles too large to clear the nozzle or which might plug the valve in the spray-gun, and yet be of sufficient capacity to permit the evacuation of a tankful of suspension without itself becoming completely occluded.

It was also considered desirable to have an interchangeable arrangement of an air-pressure relief-valve to exhaust any residual air-pressure in the tank before opening it for refilling with liquid, and an air-valve of the automobile tire type so that pressure in the tank could be obtained from a compressed air reservoir, for work in situations where a truck-mounted compressor was available.

Field experience dictated the desirability of having a removable standpipe which would permit the tank to be filled with liquid to a standard level, leaving an adequate air space at the top.

The filter

The basic sprayer as used by the Army was provided with two filters. One, of #30 wire-screen was set on a lip inside the filler opening and was 7.5 cm. long and 3.1 cm. in diameter. This served to remove coarse particles only. The second filter was of #100 wire-screen 4.7 cm. long, 0.6 cm. in diameter, and with a surface area of 9.1 sq. cm. This was located in a metal housing at the point where the hose was attached to the head of the tank. Its purpose was to remove such occasional foreign particles as might be found in solutions or emulsions. When these sprayers were used with DDT water suspensions it was found that the #30 filter would pass almost all particles including those that would plug the nozzle, while the #100 filter would hardly pass any of the suspension, and became plugged almost immediately. In practice, the small #100 wire-screen filter was removed before use with DDT water suspensions.

In order to have a filter inside the tank and still available for ready examination and cleaning, if necessary, we removed the outlet pipe from its fitting beside the pump cylinder (Figure 7, E) and arranged a bypass through the filler-cap (figure 8, H). By this means it was possible to place a large capacity filter at the bottom of the outlet pipe inside the tank, where it would be protected during use, and still available for cleaning each time the tank was opened for refilling with water suspension. It remained then only to devise a filter of sufficient capacity so that it would not become completely plugged during the evacuation of a tankful of the water suspension and still pass all particles which would not stick in the gun-valve or plug the nozzle.

A cone-shaped fitting of brass (see figures 1, 11 and 14) was "sweated" with solder to the lower part of the outlet pipe, with its lip 8.5 cm. from the end. This cone was threaded at bottom to receive the similarly threaded collar of a cylindrical screen filter. The heavy brass cone above the filter proper prevented the shoulders of the filter from catching on the rim of the filler-hole when the
outlet pipe was removed for the filling of the tank. Filters of various types of wire screen were made and field tested. The data on the measurements of the various materials tested for possible use as filters are summarized in Table I.

In field tests it was found that screen of mesh finer than $\$50$ quickly became occluded by a cake of the suspension and collapsed from the normal working pressure of about 30 lbs. per sq. inch within the tank. Such a caked and collapsed filter is illustrated in figures 9 and 10. Filters of $\$40$ and $\$50$ wire screen proved satisfactory. It will be noted in Table I that the diameters of the wires from which these screens were fabricated were not the same. The heavier wire in the $\$40$ resulted in the dimensions of the apertures being very close to those of the $\$50$. While there was no tendency for filters of $\$40$ or $\$50$ wire screen to collapse, it was considered advisable to re-enforce the screen filter with an internal cylinder of perforated bronze, which would give

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<th>WIRE SCREEN DESIGNATION</th>
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<td>$$100$</td>
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<td>No. wires per inch</td>
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<td>Wire diameter (mm.)</td>
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<td>Diameter of apertures of perforated bronze in mm.</td>
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<td>Diameter of aperture of nozzle in mm.</td>
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strength and rigidity, so that there would be less likelihood of damage by laborers in passing the outlet pipe and filter in and out of the tank through the filler-hole with each refilling. The diameter of the apertures in the perforated bronze available, 0.97 mm. was not adequate to screen out particles which would plug the nozzle with its aperture of 0.90 mm.; but the combination of $\$40$ wire screen with apertures 0.54 mm. x 0.40 mm., and a diagonal of 0.67 mm., with the perforated bronze as an internal support, gave excellent results. The greatest dimension of the apertures in this screen, the 0.67 mm. diagonal, would not pass particles which would plug the 0.90 mm. nozzle aperture, and yet the filter did not itself become occluded. (If perforated bronze of suitable aperture size were available, it might be economical to use this alone and dispense with the screen.) In a test of this filter by a field crew of the "Campaña Antimalaria" of Panama, 94 tanks of DDT water suspension were passed through the apparatus without failure of the gun-valve or plugging of the nozzle with the insecticide. The nozzle became plugged once with a particle of rubber abraded loose from a new hose.

In final form the filter (see Figures 2, 11 and 14) consists of a brass collar, knurled on the outside, and threaded on the inside to screw onto the cone-shaped
fitting permanently “sweated” to the outlet pipe, with the cone lip 8.5 cm. above end of the pipe. Below the knurled outer portion are cut two steps, each 1.0 mm. deep. To the lower and inner step is soldered a perforated bronze cylinder 7.0 cm. long by 2.9 cm. in diameter, open at both ends. Over this, and soldered to the upper and outer step, is a $40 copper wire-screen basket 8.0 cm. long and 3.1 cm. in diameter with its end covered with the same material. This has a surface area of 85.5 sq. cm. The outlet pipe projects through the center of the cylindrical filter and ends about 0.5 cm. from the bottom of it, making it possible to evacuate all but a fraction of a pint of the liquid in the tank.

With the arrangement here outlined it will be noted that the filter is exposed and available for rinsing in clear water each time the tank is opened for refilling. In the event of damage, the filter may be replaced by hand, without the use of tools, as it turns easily with only hand gripping of the knurled collar.

**Filler-cap bypass**

The most essential feature of the filler-cap bypass is that it be so constructed that the filler-cap itself may be rotated to open or close the tank independent of the hose, bypass, or outlet pipe. This is necessary since it would be too awkward to have to turn the hose with each rotation of the filler-cap in opening or closing the tank. The arrangement which accomplishes this is illustrated in Figures 3, 12, and 14. The bypass is turned out of a single piece of metal and the upper end of the outlet pipe is “sweated” with solder into its lower end. The upper portion of the bypass passes through a hole drilled in the filler cap and is threaded on the outside to screw into the end of the hose. A rubber gasket fits around the upper step of the bypass element (see figure 3) effecting an airtight seal between the filler cap and the tank.

**The pressure relief valves**

The transfer of the outlet pipe to the filler-cap position leaves a threaded hole in the head of the tank which provides a good location for a pressure-relief valve. Two types of valves were made (see figures 4 and 5).

The basic idea for individual sprayers of this general type, rather than large truck-mounted units with extension hoses, is the facility with which scattered rural houses may be reached on foot where roads are bad or nonexistent. Nevertheless, in practice these units are also used to a considerable degree in towns where the spraying operations are close by the DDT truck. Under these circumstances it is efficient to be able to put air-pressure in the sprayers from a truck-mounted compressor and air reservoir. We therefore mounted an automobile tire type air-valve in a plug which could be screwed into the head of the tank at the point where the outlet-pipe had been removed (see Plate II, figure 8, 1). This valve is also suitable for releasing the air-pressure in the tank when the liquid has been expended and before the filler-cap is opened. For use in remote areas where compressed air would not be available we also made another air-relief valve operated by finger pressure (Figure 5). These two types
of valves are easily interchangeable with a wrench and provide for efficient operation under a wide latitude of field conditions.

**Combination standpipe, funnel & preliminary filter**

The modified sprayer described above is a complete self-contained unit. Such sprayers are used in groups of 6 or 8 by crews operating from a truck carrying the DDT mixtures. For each such unit we have found useful an added device which serves three purposes (see figures 13 and 14).

1. There is a tendency for laborers to fill the tanks with liquid to the top. This leaves little or no air space and the tank requires a number of pumpings before the liquid is exhausted. A standpipe inserted in the filler-hole permits the tank to be filled only to a standard height, leaving adequate air space at top. If such a standpipe is fixed in the filler-hole of each sprayer, however, it is not possible to rinse and invert the tank for cleaning. We therefore made a removable standpipe of a heavy brass cylinder with a lip on top to rest on the rim of the filler-hole. This can be inserted in the filler-hole only at the time the tank is being filled.

2. To reduce wastage of the DDT mixture a funnel for filling tanks is desirable. We combined a funnel with the standpipe so that we had a funnel with an elongated spout. The tank is thus easily filled to a standard level without wastage.

3. While the filter at the foot of the outlet pipe is adequate to keep the spray line clear it is also desirable to have a preliminary screening of the material entering the tank. For example, on one occasion a crew parked their truck with open tanks of DDT mixture under a tree, to take advantage of the shade. The tree being in blossom dropped flower parts into the DDT mixtures and a considerable quantity of plant fibers was recovered from the surface of the filter. The preliminary filter was made by soldering in place inside the funnel a cone of #40 wire screen about 0.5 cm. from the funnel itself. This gave a combination standpipe, funnel, and preliminary filter which has proved very serviceable. Only one such unit is needed with each crew.

The device now being used (Figure 13) consists of a brass funnel 15 cm. in diameter and 10 cm. deep. At the bottom of this is soldered a brass tube 12 cm. long from the collar which fits against the rim of the filler-hole. The funnel portion is lined with a #40 wire-screen filter soldered to the upper rim of the funnel, but so arranged that it stands about 0.5 cm. away from the funnel itself. The 12 cm. tube used as a standpipe allows about 2½ gallons of liquid in the tank and leaves an air space equal to about ½ gallon at top.

This may be easily modified to meet individual needs. If it is desired to leave a greater air space in the tank, the standpipe may be lengthened. The 15 cm. x 10 cm. funnel is of adequate capacity for use in Panama where the DDT is run into the tanks from a faucet fitting a one inch pipe. Where a larger pipe and faucet are used to secure more rapid filling of the sprayer tank, as in Venezuela, the funnel, and therefore the surface of the wire screen filter, may be enlarged to accommodate the more rapid flow of DDT mixture.
SUMMARY

The importance of the use of DDT water suspensions, as contrasted with emulsions or solutions, is outlined from the point of view of logistics of supply, economy, and superior results obtained on earthen wall surfaces commonly encountered in Latin America and elsewhere in the tropics. The need in this area for a simple hand-operated apparatus to dispense water suspensions of DDT, rather than motor-driven equipment, is justified.

The development of a knapsack-type hand-pumped sprayer for use with DDT water suspensions is reported. The basic unit modified for this purpose is the Army item of issue, “Sprayer, Insect, Knapsack Type, Lofstrand Model.”

The important feature of the new unit is the large capacity filter of #40 wire-screen placed on the end of the outlet pipe where it is protected inside the body of the tank, yet available for cleaning each time the tank is opened for refilling with insecticide. The filter is constructed so that no particles can enter the hose which will either plug the nozzle or cause the gun valve to stick; yet the filter has sufficient capacity not to become plugged itself in evacuating a tankful of DDT mixture.

The sprayer is fitted with interchangeable air-relief valves, one of which may also be used to secure pressure in the tank from a compressed air source, where such is available.

With each group of sprayers used by a field crew there is a combination standpipe, funnel, and preliminary filter. This provides for the filling of sprayers to a standard level, and reduces wastage in filling the tanks.

ACKNOWLEDGEMENTS

The ideas incorporated in the final sprayer evolved from discussions with my colleague, Dr. Graham Fairchild, Medical Entomologist of the Gorgas Memorial Laboratory. The Armament Shops of the Corozal Ordnance Depot performed the actual metal work, through arrangements made by Col. Thomas Page, M.C., Medical Inspector, U. S. Army Caribbean, and authorized by Col. E. S. Gruver, Ordnance Officer, U. S. Army Caribbean. I am also indebted to officials of the Lofstrand Company who provided the basic units for modification.

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PLATE I

SCALE DRAWINGS OF MODIFIED SPRAYER FOR USE WITH DDT WATER DISPERSIBLE POWDERS

Fig. 1. The foot of the outlet pipe showing the conical brass fitting to which the filter is screwed.

Fig. 2. The filter, cut away in part, to show the internal threads by which it is screwed onto the conical brass fitting in fig. 1, and the internal supporting cylinder of perforated bronze.

Fig. 3. The filler-cap and bypass, cut away in part, to show internal fitting and location of rubber gasket. The outlet pipe at right is "sweated" into the bypass with solder. The threads at left screw into the hose fitting.

Fig. 4. The air-pressure valve by which a compressed air reservoir and line may be used to secure pressure in the tank.

Fig. 5. Air-pressure relief valve. This finger-operated valve is interchangeable with the air-pressure valve illustrated in fig. 4.
PLATE II

THE HEAD OF THE TANK IN THE DEVELOPMENT OF THE DDT WATER SUSPENSION SPRAYER, WITH ESSENTIAL PARTS LABELED AS FOLLOWS:

A. Hose
B. Pump handle
C. Air pressure gauge
D. Spray-gun
E. Fitting for outlet pipe (standard model)
F. Pressure-relief valve (standard model)
G. Filler-cap
H. Filler-cap bypass for outlet pipe (modified model)
I. Air-pressure valve (modified model)

Fig. 6. The standard Army model NER 106 with soldered seams.

Fig. 7. The latest standard model $250 for use with DDT solutions and emulsions. The top and bottom are secured to the cylinder wall by means of an electric welded seam. The various elements shown screw into the head of the tank and are provided with airtight gasket seals. Air leakage experienced with model NER 106 (fig. 6) is thus avoided.

Fig. 8. The sprayer modified for use with DDT water suspensions. The hose and outlet pipe have been removed from their location at the right (see fig. 7) and now pass through the filler-cap. An air-pressure valve is screwed into the hole at the right through which the outlet pipe formerly emerged.
PLATE III

Development of the Filter

Fig. 9. An early model filter of $60$ wire screen without internal support. The filter was so fine that the particulate DDT and its inert diluent caked on its surface, completely occluding the openings. Pressure in the tank then caused the filter to collapse.

Fig. 10. The filter of $60$ wire screen shown in fig. 9, after collapse.

Fig. 11. The definitive filter. Above is an assembled filter at the end of the outlet pipe and the cone-shaped fitting onto which it is screwed. Below there are illustrated the component parts of the filter, from left to right; a “basket” of $40$ copper wire-screen, a cylinder of perforated bronze, a knurled brass collar to the shoulders of which the “basket” and cylinder are soldered, and the brass cone-shaped fitting to which the filter is screwed by hand. The rule in the photograph is 6 inches long.
Fig. 12. The filler-cap bypass, assembled below and disassembled above. The outlet pipe at the right is "sweated" into the bypass with solder. The bypass goes through a hole in the filler-cap and is screwed into the hose at left. The rubber gasket shown in figure 3 is not included in this photograph. The rule is 6 inches long in all photographs on this plate.

Fig. 13. The combination standpipe, funnel and preliminary filter.

Fig. 14. A general view of the various parts fabricated for the modification of the sprayer for use with DDT water suspensions, assembled and disassembled.
PLATE V

FIELD USE OF THE DDT WATER DISPERSIBLE SPRAYER IN PANAMA

Fig. 15. The removable portion of the sprayer unit consisting of the nozzle, extension-rod, spray gun, hose, filler-cup and bypass, outlet pipe and filter in the hands of a native. The filter is being rinsed in clear water after use.

Fig. 16. The village pump at Puerto Caimito, Panama, provides water for mixing the wettable DDT used in spraying that village. The DDT water suspension is being mixed in the oil drum on the tailboard of the truck. The drum is fitted with an ordinary water faucet from which the suspension is drawn into sprayers.