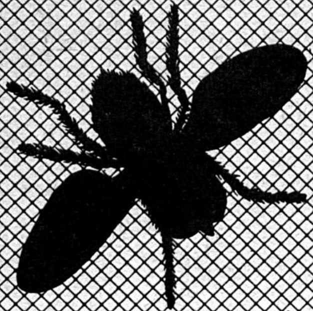
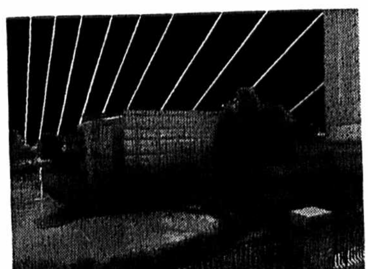


The Control of Domestic Flies

EDITORS
. H. Coffey, Engineer (R)
.F. School, Scientist (R)

Federal Security Agency
Public Health Service
U.S. Communicable Disease Center,
Atlanta, Georgia

A supplement to this brochure, on insecticides other than DDT, will be available in the near future.



Preface

The material presented in this brochure is the forerunner of a manual on the control of domestic flies. Its release at this time is for Communicable Disease Center administrative purposes only and is based upon two considerations:

1. To make the information available to Public Health personnel for use during the 1949 fly-breeding season.
2. To secure criticisms and suggestions from various reviewers ranging from those interested in the technical details of fly control to those whose primary concern is focused on the practical aspects of the problem.

The information contained herein is a composite of the research and experience of the various Divisions of the Communicable Disease Center. The editors gratefully acknowledge the invaluable assistance given to them by the representatives of these Divisions.

Because of the preliminary nature of this draft, illustrations have been held to a minimum. The limited number of copies likewise precludes a general distribution.

It is hoped that the completed manual will be available for the 1950 fly-breeding season. Because of the numerous details involved in the subsequent revision, the editors would appreciate receiving all comments prior to October 15, 1949.

J. H. Coffey H. F. Schoof

June 1, 1949

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The Control of Domestic Flies

During recent years the public has become increasingly aware of flies as possible vectors of human disease. Concurrent with this awareness is the rising public demand for community fly control programs. This civic spirit is frequently based upon the erroneous belief that fly control is a simple matter to be accomplished by one over-all insecticidal treatment during the fly breeding season. The discouraging results of programs organized on such beliefs soon instill in the public mind a negative attitude toward the feasibility of any proposed fly control project. Since effective fly control is economically possible through an organized community program involving sanitary and insecticidal measures, it is essential that the basic principles of fly control be made available to the individual and to the municipality.

The purpose of this manual, therefore, is to present pertinent information on the biology, control, and evaluation of control of the common domestic flies, i.e., those flies found in and around human habitations, such as houseflies and blowflies. Consequently, no consideration will be given to mosquitoes, sand flies, blackflies, and other similar pestiferous flies. The control of these flies presents problems which are beyond the scope of this manual even though the remedial measures herein described may effect the relative abundance of these insects.

THE PUBLIC HEALTH SIGNIFICANCE OF FLIES IN THE UNITED STATES

Flies in their relation to public health can be grouped as:

1. Disease-transmitting flies
2. Myiasis-producing flies
3. Annoying flies

Domestic flies have long been under suspicion as transmitters of filth diseases. Such a reaction on the part of scientists and householders has arisen from observing that the flies frequenting human and animal excrements are also attracted to human foodstuffs. Since flies are well suited structurally for carrying large numbers of microorganisms, infected specimens can easily transfer pathogenic material to humans by resting on the individual or by walking across anything he may handle or consume.

The fact that flies can carry many agents which cause human disease is firmly established. Numerous laboratory experiments have shown that human pathogens can live in or on the fly for a sufficient length of time for them to be transported from the source, whatever it may be, to uninfected humans. In addition, many of these pathogenic organisms have been recovered from naturally infected flies of various species*.

Laboratory experiments and the recovery of naturally infected flies, however, do not demonstrate the significance, if any, of flies in the spread of the numerous diseases which they are suspected of transmitting. Until recently, relatively little evidence has been available on this important aspect. However, in 1948, Watt and Lindsay showed clearly that, in Hidalgo County, Texas, the infection, disease, and death caused by the organisms of bacillary dysentery were materially reduced by fly control.

In summary, it may be said that, in the field of disease transmission, flies have been shown to be important in the spread of one disease, bacillary dysentery, in Hidalgo County, Texas. For other diseases, their significance in transmission under natural conditions is conjectural until the experimental findings and observations have been proved in the field.

In addition to transmitting diseases, flies may pass part of their developmental period within an animal host. This invasion of animal tissue by fly larvae is termed "myiasis". Numerous species of domestic flies belonging to the families Muscidae, Sarcophagidae, and Calliphoridae have at one

*See Francis et al., 1948; Herms, W. B., 1939; Melnick et al., 1947; Melnick, 1949; and Bigham, 1941.

time or another been indicted in cases of human myiasis. Such infections although of prime importance to the individual invaded, rarely are prevalent enough to warrant preventive measures on a community-wide basis.

In contrast to the relative obscurity of human myiasis, the annoying habits of domestic flies are well known to everyone. Almost any species can be classified as a pest, but the housefly is usually the most serious offender.

Activities of other species such as the persistent hovering of the eye gnat, the buzzing of the bluebottle fly, or the stabbing "bite" of the stablefly are also extremely annoying. With the exception of the latter species, the common domestic flies have sponging mouth parts so that their annoyance to man is either by their sound of flight or by the worriment of their presence.

Aside from their public health significance, flies are responsible for an annual economic loss of several million dollars to the livestock and dairy industries.

IDENTIFICATION OF DOMESTIC FLIES

For effective fly control on premises or in a community, the types of flies creating the problem must be known. Since taxonomic knowledge of flies is seldom available to individuals concerned with fly control, a brief, practical discussion of fly identification will be presented.

True flies are two-winged insects belonging to the order DIPTERA. There are numerous species throughout the country, but certain kinds are found more frequently in and around human habitations. These flies are termed "house-frequenting" or "domestic" flies. In general, the prevalent domestic flies are the housefly, *Musca domestica*, and several species of blowflies (*Phaenicia*), which together may constitute 90 to 95 percent of the domestic fly population. The other house-frequenting flies usually occur much less abundantly, but under certain ecological conditions may be predominant, e.g., *Stomoxys calcitrans* (L.), the stablefly, also known as dog fly, along the coast of northwest Florida.

By use of the key presented on page 3, it is possible to identify macroscopically the common domestic flies found in the southern United States. As most of these flies occur in the northern and western United States, the key is also applicable in these parts of the country. Certain northern and western species which are not included in the key can be identified by using the key and the following supplement.

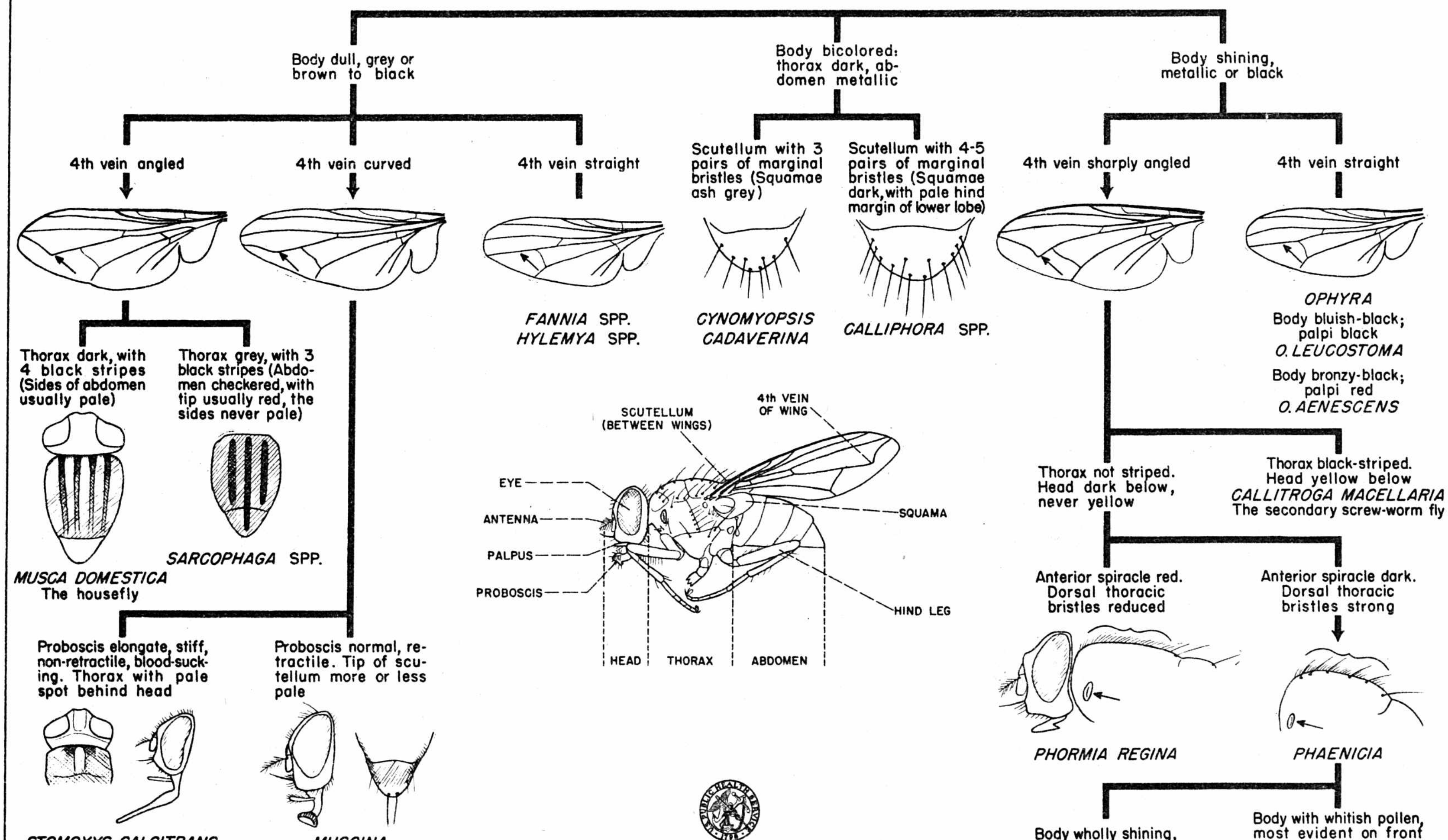
1. a. Specimens keying to *Callitroga* with squamae dark brown, not pale . . . . *Paralucilia wheeleri* (Houghi)
1. b. Specimens keying to *Phaenicia* with squamae dark, not white or yellow . . . . . . *Protophormia terrae-novae* (R. D.)
1. c. Specimens keying to *P. caeruleviridis* with antennae black, not marked with reddish-brown. . . . . *Bufolucilia silvarum* (Meigen)

Individuals interested in more detailed information on the taxonomy of flies should consult the bibliography (p. 32).

BIOLOGY OF DOMESTIC FLIES

The biological details of the different types of flies vary considerably, although the sequence of development is similar in most groups. All flies pass through four developmental stages: egg, larva, pupa, and adult. Biological details of these stages will be given for the housefly, together with rather brief discussions for the blowflies and other domestic flies.

PICTORIAL KEY TO COMMON DOMESTIC FLIES IN SOUTHERN U. S.



PREPARED BY H. R. DODGE
FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
COMMUNICABLE DISEASE CENTER
ATLANTA, GEORGIA
JUNE 1948

THE HOUSEFLY — Musca domestica L.

Life History

Egg: Elongate white eggs, 1/25-inch in length, are deposited in masses of 100 to 150 eggs each in the cracks or on the surface of the breeding medium. After a period of 8 to 30 hours, the eggs hatch, each producing a small, whitish maggot or larva.

Larva: The larva is the active, feeding, developmental stage of the housefly. It is a whitish, cylindrical, legless maggot, the body of which strongly tapers toward the anterior end. After feeding in the breeding medium from 5 to 14 days, the larva attains full growth, at this time being 1/3- to 1/2-inch in length. It now migrates to a drier part of the breeding medium and there forms a seed-like, light to dark brown barrel-shaped case, known as a puparium. When the breeding medium is excessively moist, the larva may leave it and pupariate beneath adjacent debris or in the surface of the soil. Within the puparium, the larva changes into a pupa.

Pupa: The pupa is a nonfeeding, immobile stage during which the complete change-over from a legless maggot to a six-legged, two-winged adult is accomplished. This stage extends from 3 to 10 days, at the end of which time the winged adult emerges by pushing off the end of the puparium.

Adult: At the time of emergence the wings of the adult are still folded in tight pads against the body. After the wings extend and harden, the fly is ready for flight. At this time, the housefly is fully grown, being a grayish insect, 1/4- to 1/3-inch in length with 4 black stripes on the thorax (p. 3) and a pale-colored abdomen. Smaller flies are either adults produced from undernourished larvae or different species.

The total length of time from egg to adult varies from 8 to 20 days depending on environmental conditions, such as food, temperature, and moisture. The adult female is capable of laying eggs within 2¼ to 4 days after emergence and thus under favorable conditions, the housefly can produce 2 to 3 generations per month in the summer. Females may lay eggs at intervals throughout their life span, normally producing an average of 500 eggs per female. Some females have laid over 2,000 eggs. Because of their rapid rate of development and high fecundity, the prevalence of houseflies is readily understandable.

The duration of the life cycle of the housefly and of any of the flies discussed herein will vary with geographic location and seasonal conditions. In any locality, therefore, the biological aspects of the prevalent domestic flies should be studied so that any significant variation in their behavior which could affect the fly control procedures can be capitalized upon.

Development and Habits

Preovipositional Period: Newly-emerged adult houseflies are incapable of immediate reproduction. The length of time elapsing before the adult becomes sexually mature is of importance in community fly control, since the periodicity of space spray applications can be influenced by the duration of this period. Under optimum conditions, the preovipositional period extends from 2¼ to 4 days, whereas under less favorable conditions, it may last from 2 to 3 weeks.

Breeding Places: Horse and cow excrements are common sources of prolific housefly breeding; other significant sources are: garbage, spilled feed, kitchen slops, cannery wastes, uncovered septic tanks, decaying fruits, piles of lawn clippings, and pig excrement. However, when adult housefly densities are not accounted for by evident breeding sources, it is essential that all accumulations of moist, warm decaying matter be investigated. ANY MOIST, WARM ORGANIC MEDIUM USUALLY CONTAINS SUFFICIENT NUTRIMENT TO BE A POTENTIAL SOURCE OF HOUSEFLY BREEDING.

Overwintering Stages: In the warmer climates, the housefly breeds throughout the year. Even in the colder regions, some continuous breeding has been observed within animal shelters. However, on the question of how the housefly overwinters outdoors in northern areas, the available evidence is contradictory. Some workers state that the adult is the overwintering stage, others, the larva or pupa.

Flight Range: It has been shown experimentally that individual specimens are capable of flying as far as 13 miles. Such data usually are not significant in fly control operations, since these long flights are not characteristic of a major part of the fly population. In most instances, houseflies stay close (200-300 yards) to their breeding sources unless the densities become excessively high or the medium is depleted. When these latter factors operate, then the dispersal of the flies from the original source is governed by the accessibility of new breeding or attractant sites. When such sites are nearby, the flight range of the fly is minimized; if the reverse is true, the flight range is extended accordingly.

Longevity: The length of life of the adult housefly is governed by the prevailing environmental conditions. During the summer, houseflies live an average life of 30 days with a possible maximum of 60 days. In the colder regions of the United States, some adults may survive for periods in excess of 60 days, especially during the winter.

Adult Feeding Habits: The adult housefly is the prevalent fly of the home; approximately 90 to 95 percent of the flies collected in houses belong to this species. In the home, flies are attracted to most human foods. Liquids are sucked directly into the spongy mouth parts of the fly, solids being dissolved in saliva or regurgitated liquid before being fed upon. The regurgitated liquid deposited on feeding surfaces leaves light-colored spots, known as "vomit spots". During feeding the fly may also pass fecal matter which forms dark-colored spots, "fly specks", on the surface.

Outdoors, the housefly feeds on such materials as excrement, garbage, etc. Since it passes frequently from such media to the home, there exists a definite possibility of contact between the householder and any disease organisms found in such outdoor wastes. Disease transmittance is further enhanced by the hairy body and legs and sticky footpads of the adult fly.

Adult Nocturnal Resting Habits: The housefly is active only during the day. At night, the adult usually rests inside houses or shelters on the ceilings, particularly along the edges of cracks or rafters, and on overhead structures such as light cords and wires. Since almost 50 percent of the daily life of the fly inside the home is spent in continuous contact with such surfaces, they should receive primary attention during the application of residual sprays.

BLOWFLIES

The name "blowfly" applies to the large group of flies belonging to the family *Calliphoridae*, representatives of which are listed in the pictorial key as *Callitroga macellaria* (F.), *Phormia regina* (Meigen) and *Phaenicia*. Certain shiny blue or green species are commonly known as bluebottle or greenbottle flies. Since the predominant domestic blowflies belong to the genus *Phaenicia*, a comparison of the biology of *Phaenicia sericata* (Meigen) and the housefly is given in Table I (p. 6).

Two species of blowflies, *C. macellaria*, the secondary screwworm fly, and *P. regina*, the black blowfly, are frequently of significance in domestic fly control, particularly in the vicinity of abattoirs. The secondary screwworm fly lays its eggs on decaying flesh, has a developmental cycle of 9 to 39 days, a preovipositional period of 3 to 18 days, and an adult longevity of 14 to 42 days. Although 10 to 14 generations per season may occur in the southwest, this blowfly is seldom abundant in northern United States.

In contrast to *C. macellaria*, *P. regina* is a cold weather species, being most abundant in the spring and fall in northern areas and during the winter months in southern. *P. regina* breeds principally in animal carcasses but also infects garbage. The developmental and preovipositional periods of this species are similar to those of *P. sericata*.

OTHER DOMESTIC FLIES

The stablefly (dog fly) *S. calcitrans* (L.) is a blood-sucking fly similar to the housefly in general appearance. Under certain conditions this species may become a community problem; e.g., in northwest Florida, localized outbreaks of this species occurred through extensive breeding in celery wastes, peanut litter, and marine grasses. The egg-to-adult cycle of this fly varies from 13 days to 3 months, and the preovipositional period from 8 to 18 days. The larvae breed in manure mixed with straw, silage, and in large accumulations of waste organic materials such as have been mentioned previously. The adults are fierce "biters," attacking domestic animals as well as man. Annoyance commonly ascribed to the "biting housefly" is caused by the stablefly.

TABLE COMPARING BIOLOGICAL HABITS OF THE HOUSEFLY AND A GREEN-BOTTLE FLY

	Housefly, "M. domestica"	Green-Bottle Fly, "P. sericata"
Geographic range (U.S.)	Entire United States	Entire United States
Egg to adult period	8-20 days	9-21 days
Generations per year	10-15	4-8
Preovipositional period	2¼-23 days	5-9 days
Larval habitat	Horse and cow excrements, garbage, any warm, moist, decaying organic matter.	Decomposing flesh or animal matter, excrement, garbage.
Puparium (Pupa)	Usually in drier part of breeding medium; also beneath debris and occasionally in upper surface of soil.	In soil to depth of 1½ inches to 2 feet.
Overwintering stage	Larva? pupa? adult? in colder climate. Breeds continuously in warmer areas.	Larva
Flight range	Usually limited to area in immediate vicinity of breeding media; under certain conditions, may fly 2 to 13 miles.	Disperses widely in search of food and breeding media; may fly up to 10 miles.
Adult longevity	20-60 days	41-56 days
Adult feeding habits	Feeds on liquids or any dissolvable solid; regurgitates and defecates while feeding.	Feeds on liquids or any dissolvable solid; regurgitates and defecates while feeding.
Adult nocturnal resting habits	In buildings, on ceilings and overhead structures.	Outdoors in trees, bushes, grass, and sides of buildings, particularly in vicinity of daytime feeding spots.
Adult diurnal resting habits	Predominant fly in the house; rests on food, walls, furnishings.	Usually outdoors, enters houses in spring and fall; tends to alight on foods rather than walls, etc.

The flesh flies or Sarcophagidae are grayish flies, usually large in size, and having a checkerboard pattern on the abdomen. In these flies the eggs hatch within the body of the female; thus, larvae are deposited rather than eggs on the breeding medium. In one species, *Sarcophaga haemorrhoidalis* (Fallen), the larva-adult cycle is passed in 14 to 18 days. Larval habits are variable; some species breed in carrion and excrement, others infest animal wounds, while many are parasitic upon arthropods. Adult flesh flies are attracted to rotting fruits and vegetables, decaying flesh and excrement.

The little housefly, *Fannia canicularis* (L.),is a small, grayish fly which is frequently mistaken for an "immature" housefly *(M. domestica).* This species is found within houses and, in the early summer months, may be more prevalent than the common housefly. In contrast to *M. domestica*, the little housefly disperses throughout a dwelling rather than congregating in those rooms where food is exposed. In flying, *F. canicularis* exhibits a characteristic jerky and hovering manner. Larval habitats are similar to those of the housefly, the maggots being found in all types of excrement and decaying vegetable and animal matter. The larva is distinguished from those of the housefly and blowflies by its flattened body and lateral processes. Development from egg to adult usually requires 15 to 20 days during the summer months. A closely related species, the latrine fly, *F. scalaris* (F.), is similar to the little housefly in development and activity.

The common eye gnats are small flies *(Hippelates)*, which annoy man by hovering and feeding about the eyes and the natural body orifices. The prevalent species in southern United States is *Hippelates pusio* (Loew) which is particularly abundant in areas where the soil is mucky or sandy and subject to extensive cultivation. The larvae breed in animal excrement, decaying fruit and vegetables, and in freshly cultivated soil. Development from egg to adult can be completed in 12 days, but the usual time is 21 days. Since the adult flies require much moisture, their activity is closely correlated with temperature and atmospheric moisture. In early spring and late fall, eye gnats are active near midday while in hot weather they are most annoying in early morning and late afternoon. On windy days there is little adult activity.

RESISTANT FLY POPULATIONS

During 1947 and 1948, there was definite evidence that the housefly populations can develop a resistance to DDT. Thus, a high degree of fly control obtained in one area may or may not be duplicated in a second area even when the control methods and general environmental conditions are similar.

It appears that in some areas the DDT spray acts as a culling agent, eliminating the susceptible flies while allowing the resistant ones to survive and serve as a nucleus for a future DDT-resistant population. Repeated exposure of subsequent generations to the DDT intensifies this selective process until the majority of the individuals in the population are flies with a high degree of DDT resistance. The time period required before this resistance exerts an influence upon control effectiveness varies, depending upon the environmental conditions and the initial composition of the population. There is some evidence to indicate that this acquired resistance may slowly dissipate once the population is no longer exposed to DDT treatments.

In contrast to an acquired resistance some populations show resistance to the initial application of DDT while other populations apparently do not develop any resistance despite continual exposure to DDT. The explanation of these diversities in fly behavior is a matter of conjecture. Inadequate spray coverage, genetical composition of fly population, intensity of fly breeding, and environmental conditions all have a part in influencing population behavior. In any study of population behavior patterns it is of prime importance that these factors be evaluated. Particular emphasis must be placed upon the necessity for such evaluation before PERFUNCTORILY ASCRIBING CONTROL FAILURES TO FLY RESISTANCE.

The complex problem of fly resistance requires much intensive study before the many perplexing aspects of the question are satisfactorily explained. It is a problem of increasing significance in fly control operations by chemical means, particularly, at present, by the use of DDT.

For further information on the biology of domestic flies, the reader is referred to the bibliography (pp. 32, 33).

SURVEY AND EVALUATION TECHNIQUES FOR FLY CONTROL PROGRAMS

The evaluation of fly control work has received much attention since the advent of DDT as a control measure. From an advisory status, entomological surveillance has progressed to the point where it is now an essential part of the control operations.

Unfortunately, the measurement of fly populations is a difficult matter, and many of the techniques employed on such work are still in the developmental stages; also, the advantages and disadvantages of certain types are subjects of debate. The latter is particularly true with reference to the interpretations of fly trap data (p. 8) and grill counts (p. 11).

EQUIPMENT AND PROCEDURES FOR SAMPLING FLY POPULATIONS

In making fly surveys, principal emphasis is usually placed on adult densities. Surveys on larval populations are infrequent because specific identification of larval forms is difficult, and the detection of larvae in breeding areas is time-consuming. Therefore, when conducted, larval investigations usually are based on observation of potential breeding areas rather than on qualitative or quantitative studies of population densities. Such surveillance should be carried on only by competent observers who are familiar with the breeding habits of flies. By noting the location, extent, and prevalence of the various fly-breeding media, such observers are able to approximate the fly breeding potential of an area. Actual detection of fly larvae in any medium is usually limited to those surveys investigating the source of uncontrolled high fly densities in a community.

In contrast to larval surveys, the principle involved in making an estimation of adult fly populations is to secure a count of the number of flies as related to a standard measure of time or area, number of samples, or any combination of these factors. The importance of this principle is due to the fact that the evaluation of the effectiveness of the fly control practices is based upon a comparison of periodic quantitative samples of the fly population. The devices used in securing these samples as well as the periodicity of their utilization must be uniform – otherwise, an accurate comparison of the data obtained is impossible. So long as this principle is observed, even the simple procedure of counting the number of flies resting on a stanchion in a barn will yield evaluative data which are on a par with those derived by the use of such devices as fly traps and grills.

The various types of equipment for sampling adult fly populations are shown in figures 1–3.

Fly Trap

For qualitative surveys of the fly population, the fly trap is a useful tool. Traps vary in size, but the outlines of their construction are similar. Construction plans for an all-metal fly trap are shown in figure 1. This trap is durable, easy to transport and handle, and has proved satisfactory for the collection of flies.

The operating principle of the trap is simple. Flies are induced to enter the trap by means of an attractant and after entering the trap, fly upward toward the light. Once they pass through the small aperture at the top of the cone and into the cage, little chance is afforded for their escape.

Since success of the fly trapping depends upon getting the flies to enter the trap, the selection of the attractant is of prime importance. Because certain attractants may be more attractive to one species of fly than to another, the bait should contain attrahents which are suitable for the different kinds of flies. A bait of fish scraps will attract copious quantities of blowflies, but the catch of houseflies may be so small as to be totally disproportionate to their actual abundance. Consequently, to obtain a qualitative picture of the domestic fly population, an all-purpose bait consisting of fish heads or chicken entrails together with waste vegetables and fruits is most satisfactory. The baits should be placed in containers about 2 inches in depth and slightly smaller in diameter than the cage cylinder.

In placing traps in the field, the operator should attempt to sample the different sections of the community. Trap schedules can be arranged as desired. One satisfactory plan is to set out the trap in the early afternoon of one day and collect it the following afternoon. The trapped flies are killed by placing the trap in a tight container and exposing them to a fumigant such as chloroform, carbon disulphide or ether, or by spraying them directly with a contact insecticide. Collections are then measured by volume, weight, or actual count.

A modified version of the fly trap often is used to obtain "fresh" flies for virological or bacteriological examination. The device, called a "fly cone" or "cone net"* is a mobile trap in which the relative proportions of the cage and cone have been reversed (fig. 2) and a field attractant substituted for the prepared bait. In operation, the cone is placed quickly over the desired attractant or fly concentration so as to trap the specimens below. A dark cloth thrown around the cone drives the flies upward and into the cage, which is removed and covered by sliding a lid across the open end. When flies are abundant, several cages may be required at one site. The "fly cone" may also be

* See Maier, P.P. and Dow, R.P., 1949.

Figure I. FLY TRAP

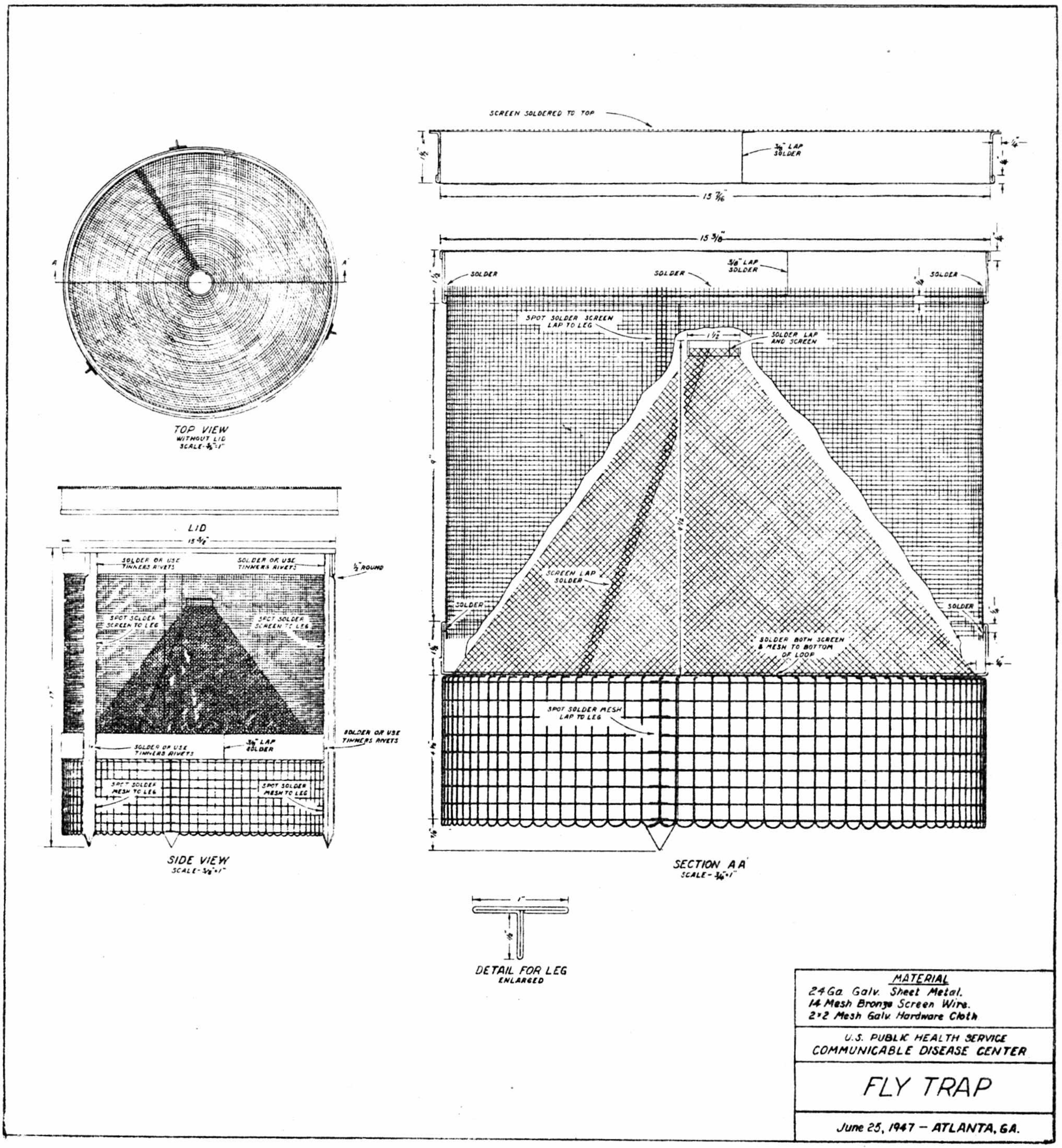


Figure 2. FLY CONE

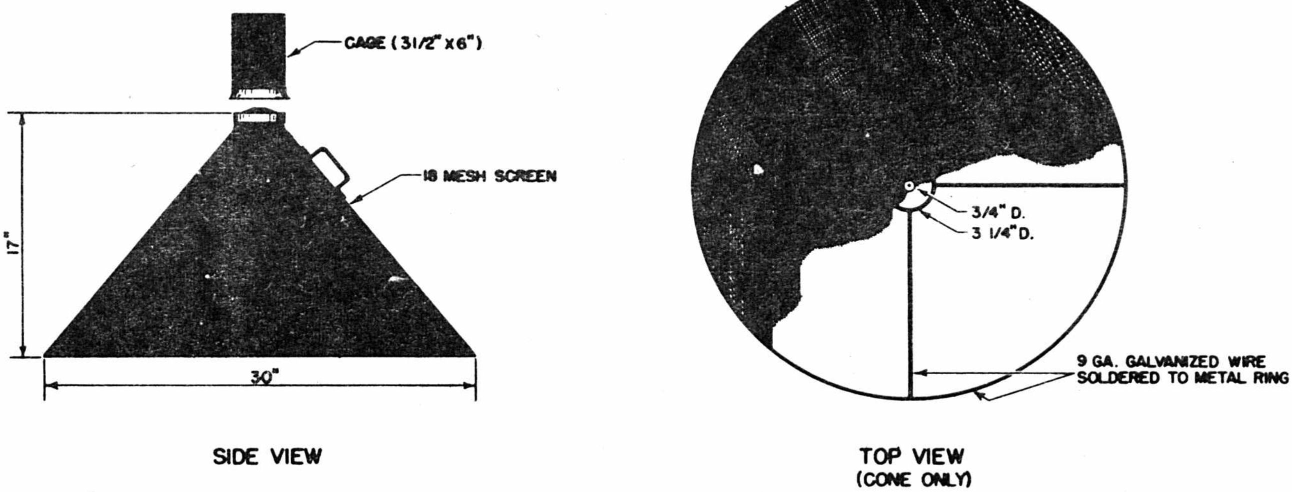
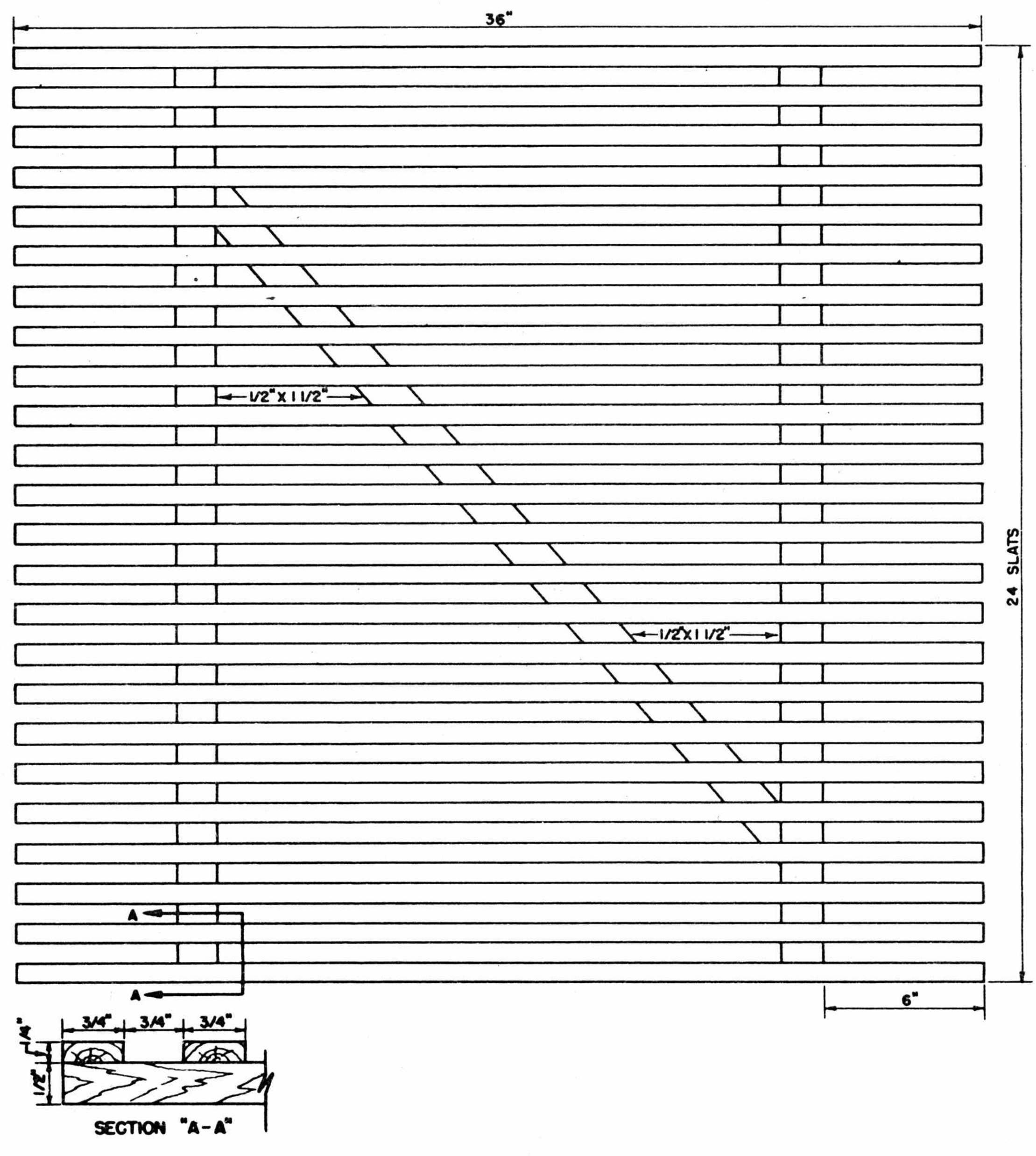


Figure 3. FLY GRILL



used to sweep flies out of grass or other vegetation.

The data derived from fly traps are useful not only in indicating the prevalent species, but also in showing their seasonal abundance. In addition, trap collections may be utilized for quantitative evaluations.

Fly Grill

The grill (Scudder, 1947) is a slatted device for use in making outdoor quantitative fly surveys (fig. 3). For indoor work a smaller grill consisting of 34¼-inch square slats placed ¼ inch apart is employed.

The fly grill is used to measure the concentration of flies at a suitable field attractant such as garbage, manure, etc. Consequently, its usefulness depends upon the individual's ability to locate these attractants and to make accurate counts thereon. The technique is to place the grill over the attractant, momentarily disturbing the flies and then counting the number that return and alight on the slats. The inspector should avoid casting his shadow on the grill or exciting the flies to the extent that they leave the site. In instances where the grill count is not compatible with the visual density of flies, the grill may be agitated several times in order to secure an accurate reading. One reading per attractant is sufficient.

In making grill counts, flies may be counted on a purely quantitative basis, but for efficiency of operation, the determination of the various types of flies is essential. Since this field identification is macroscopic and must be done rapidly, it is essential that the inspector be thoroughly trained in this technique.

For community programs, grill counts are set up on a block basis with the five highest counts in a block being averaged to give the block a rating. In some instances the highest count in a block is the only reading utilized, but this technique is subject to criticism inasmuch as the small size of the sample frequently fails to show the effect of the control measures.

Net

By sweeping an ordinary insect net through fly concentrations, it is possible to secure small samples of the fly population. This method is suitable for quantitative or qualitative surveys where rapid, extended coverage is desired, or where the collection of certain species of flies usually not obtained in trap and grill operations (such as male specimens of *F. canicularis)* is desired.

Fly Baits

Fly baits can be prepared by painting a solution of molasses and vinegar (1:2 ratio) over a square foot of surface area on heavy cards (Brett and Fenton, 1946). After a bait card is exposed for a 5-minute period at a location usually frequented by flies, the number of flies attracted to it is recorded. This method is useful in determining fly densities in barns or houses. Numerous variations of the fly-bait technique are possible (e.g. Griffiths, 1946).

Fly Strips

Strips of sticky flypaper suspended in buildings and outdoors can be used as a relative indicator of fly activity. Such strips should be exposed for a definite time period, after which the number of captured flies can be counted.

Visual Observation

This method is useful when employed by experienced personnel. By counting the flies in a measured area of observation such as a room or a square yard, it is possible to obtain a relatively accurate indication of fly prevalence.

THE INTERRELATION OF EVALUATION AND CONTROL METHODS

The success of a community fly control program is largely dependent upon the coordination of the entomological surveillance and the application of the control techniques. The entomological operations consist of:

1. A precontrol fly survey of the community to determine the cause and extent of the problem and to serve as a guide in recommending control measures.
2. Regularly scheduled postcontrol fly surveys to obtain periodic measurements of fly densities.

These data provide guidance for selecting the control measures and determining the frequency and relative effectiveness of their applications. Thus, the entomological procedures are an integral part of the control program.

Precontrol Surveys

The precontrol survey is conducted before the initiation of control measures. It provides data to indicate where the principal adult fly densities and potential breeding areas are, the prevalent species concerned, and the magnitude of the problem. These data together with those from an environmental sanitary survey will provide a firm basis for cost estimates and the selection of control measures.

The methods employed on the precontrol survey largely depend on the size of the program and the type of data desired. Where time is limited this survey may be confined to an over-all visual survey of adult densities and potential breeding sources by a competent observer. For obtaining detailed information, fly trap collections and grill counts should be utilized. Wherever possible, methods used in measuring adult densities on the precontrol survey should be similar to those utilized on postcontrol surveys so that comparisons of the respective data are possible.

Postcontrol Surveys

As in precontrol surveillance the methods and intensiveness of their use on a postcontrol survey vary with the extent of the program and the type of data desired. Irrespective of the magnitude of the program, however, postcontrol surveys should include:

a. Routine periodic inspections of adult fly densities, utilizing the same means for each inspection.

b. Procurement of data from an untreated area for comparison with data from the treated area.

The postcontrol quantitative surveys should be closely integrated with control efforts. These surveys can be pretreatment – to determine the need for applying a control measure; or posttreatment – to serve as periodic "checks" upon the effectiveness of the measures applied. For example, in an urban area a pretreatment grill survey can show whether or not an insecticidal application is warranted, and, if treatment is indicated, the specific localities where the measures should be applied to obtain a maximum degree of control. Such a survey may be on block-by-block basis with coverage dependent upon the particular part of the community inspected; areas of high fly densities or potentials receiving a greater percentage of coverage than areas of low fly densities or potentials. In each block a search is made for all available fly attractants (15-20 minutes per block), one reading being made at each site. The five highest grill counts obtainable are then recorded and averaged, (fig. 4), this average being compared to a stand number (e.g., an average grill count of two to five flies per block), previously selected on an ARBITRARY basis. When a block average is in excess of this standard, control measures are applied.* If space sprays are used, a posttreatment survey 24 hours after application can be made to determine the effectiveness of the measure. Blocks with grill averages still in excess of the standard may then be retreated until the desired level of control is attained. In areas having recurrent high fly densities, space spray applications are frequently made on a ROUTINE weekly schedule. Inspection in such areas is usually confined to posttreatment surveys. When residual sprays are the principal insecticidal measures used, posttreatment inspection may be scheduled at biweekly or monthly intervals.

By comparing block averages from week to week (or on any other time interval), it is possible to rate a block or group of blocks. Emphasis should be placed upon the fact that this rating system is relative and merely interprets the results of one week in terms of those of previous weeks as related to a standard average. It does not compare the total fly populations, since it is only a collation of a portion of the fly population. As yet, the relation of this portion to the total population is undetermined.

In analysis of inspectional data for spray operation and other evaluative purposes, careful consideration must be given to ecological conditions prevailing at the time of inspection. Weather factors such as temperature, wind, and sky conditions influence fly activity, e.g., low grill counts

*The unit of comparison may also be a group of blocks, section, or entire community.

Figure 4. FLY GRILL CARD*

2 TOWN	3 BLOCK NO.	7 TEMP.	9 SKY	10 WIND
TOPEKA KAN.	0731	86°	1	1

11 DATE MO.	DAY	YR.	16 SECT.	17 (TO NEAREST HR) TIME	19 MOISTURE	INSPECTOR
07	14	9	3	11	1	MLD

GRILL READ'G	1	2	3	4	5	TOTAL
20 ATTRACTANT	41	42	11	21	55	
22 SHADE	1	1	1	2	2	
23 M DOMESTICA	016	027	062	001	009	115
26 PHAENICIA	006	039	010	003	021	079
29 SARCOPHAGA	003		001	002		006
32 PHORMIA						
35 MUSCINA		001		001		002
38 OPHYRA						
41 CALLIPHORA						
44 STOMOXYS						
47 CALLITROGA					012	012
50 OTHER						
53 TOTAL	025	067	073	007	042	214

(Left margin: FLY GRILL CARD)

56 BLOCK AVERAGE	59 BLOCK MEDIAN	62 HIGH COUNT
043	042	073

Code (Reverse side of above card)

2 TOWN
1 = MUSK.
2 = CHAR.
3 = TROY
4 = TOPEKA
5 = PHOEN

3 BLOCK NO.
0001 TO 9999

7 TEMP.
32 - 99 = AS IS
100 = 00
101 = 01, etc.

9. SKY
1 = ○
2 = ◐
3 = ◕
4 = ⊕

10 WIND
1 = CALM
2 = LIGHT
3 = GENTLE
4 = MODERATE
5 = FRESH 6 = STRONG

11 DATE:
MO. 01-09 = JAN-SEPT. 10 OCT 11 NOV 12 DEC
DAY 01 TO 31
YR. 48 = 8, 50 = 0, etc.

16. SECT
1 = A
2 = B etc.

17. TIME TO NEAREST HOUR
10 = 9:31 TO 10:30
02 = 1:31 TO 2:30
03 = 2:31 TO 3:30, etc.

19. MOISTURE
1 = DRY
2 = VEG. WET WITH DEW
3 = GROUND WET
4 = GROUND & VEG WET

20. ATTRACTANT:

1. EXCREMENT
   - 11 = COW
   - 12 = HORSE-MULE
   - 13 = HUMAN
   - 14 = FOWL
   - 15 = DOG-CAT
   - 16 = GOAT-SHEEP
   - 17 = OTHER
   - 18 = PIG
2. RUBBISH
   - 21 = BRUSH, GRASS, LEAVES, WEEDS
   - 22 = BOTTLES, BOXES, CANS.
3. COMMERCIAL WASTES
   - 31 = CANNERY
   - 32 = SLAUGHTERHOUSE
   - 33 = TANNERY
   - 34 = WINERY, BREWERY etc.
   - 35 = OTHER
4. MIXED GARBAGE
   - 41 = SCATTERED
   - 42 = IN CONTAINER
5. MISCELLANEOUS
   - 51 = DISH WATER
   - 52 = COFFEE GROUNDS
   - 53 = MELONS
   - 54 = OTHER FRUIT
   - 55 = DEAD ANIMAL
   - 56 = ANIMAL PEN OR YD.
   - 57 = VEGETABLES
   - 58 = BONES
   - 59 = MEAT
6. MISCELLANEOUS
   - 61 = OTHER
   - 62 = SEAFOOD WASTES
   - 63 = STOCK FEEDS

22. SHADE
1 = DIRECT SUNLIGHT
2 = PARTIALLY SHADED
3 = COMPLETELY SHADED

23 TO 53.
SELF EXPLANATORY

56. BLOCK AVERAGE
TOTAL OF 5 GRILL READINGS – 5 = AVERAGE. USE NEAREST WHOLE NUMBER.

59 BLOCK MEDIAN
EQUALS "MIDDLE" NUMBER OF 5 GRILL READINGS.
e.g. READINGS

1	2	3	4	5
009	012	017	016	(014)

62. HIGH COUNT
HIGHEST COUNT OF 5 GRILL READINGS.

PHS [illegible] (CDC) [illegible]

*This card is the type used on experimental community fly control programs. Coding is for IBM tabulation. For smaller programs where less detailed data are desired, simplified record forms would serve equally as well.

in early morning hours may be caused primarily by low temperatures instead of reduced fly densities. Therefore, the entomologist must recognize the effects of environmental conditions upon inspectional data in order to make accurate recommendations to the control supervisor. The latter can then organize his control plans to fit the conditions.

Since effective fly control is possible only through the close coordination of inspection and control operations, it is important that the data for these phases be maintained on a single chart so that they are available to all personnel. A sample chart is shown in figure 5. On this chart the daily activities of both the inspection and control crews are recorded, the former indicating the average number of flies found in each block inspected while the latter records the type of control measure applied in each treated block. The chart represents a continuous picture of the control activities in which both the inspection and control operations are shown.

Although the previously discussed inspection of a community program is based on grill counts, similar information can be obtained through the routine use of any of the other evaluative devices (pp. 8, 10, 11). Usually for large communities where ample funds are available, a detailed surveillance using both grill counts and fly traps is recommended. The grill coverage can be on a block-by-block basis as previously described or by the station method (Watt and Lindsay, 1948). With the latter technique, certain blocks of high breeding potentials are selected as stations, these blocks being covered at regular intervals and the fly grill densities thus obtained serving as criteria for the effectiveness of control in the area. In small towns grill counts and fly traps may be employed on a less intensive scale or replaced by visual observations or sticky flystrips. In these small communities where residual spray treatments and sanitation are the principal control measures employed, and where only a limited amount of inspection is economically feasible, the use of fly traps is suggested. With this device, reliable QUANTITATIVE data can be collected by relatively unskilled personnel with a minimum of effort. Regardless of the means employed, the point to be kept in mind is that entomological surveillance is necessary to effectively guide and evaluate the control operations.

In a community program, the effectiveness of control measures is all too frequently based upon the unreliable criterion of public opinion. To the citizen the abundance of flies is correlated with his awareness of their presence so that when fly densities fall below the annoyance level, the individual accepts them as a normal part of his surroundings and considers the control program a success. No thought is given to the effects of the normal annual variations in fly abundance. A program labeled as a "success" in a year when environmental factors limit fly production may be immediately termed a "failure", when reverse conditions permit extensive breeding. Actually the amount of control could be the same in both years or possibly even more successful during the year of heavier fly breeding. Without reliable evaluative data, however, it is impossible to demonstrate this fact to the public. Therefore, as a means of determining the amount of control obtained by the control measures, it is essential that data on the seasonal and annual trends of the fly population in an untreated area be available for comparison with the data from the treated community. Only in this way can the true status of the control program be determined.

Selection of an untreated area for observation should be based upon its similarity to the treated town in the normal density of the fly population. The size of the untreated area as compared to the treated town is not significant since the amount of data from this source can be collated on an equal basis with data from a small portion of the treated town. In large cities the untreated area may be an outlying section of the city or an adjacent community. For rural residual spray programs, a small collection of premises outside the control area can be used for check purposes. Reduced to the individual level, a comparison of the treated premises with an adjacent untreated home is sufficient for evaluating the effectiveness of the control efforts.

When comparing data from untreated and treated areas, caution must be exercised in drawing definite conclusions from daily or weekly reports, since the natural fluctuations in fly densities are exaggerated over these small time periods. It is possible that a weekly difference of 5, 10, or even 20 flies in the total block averages of the treated and untreated areas may not be significant in itself. Only when a repetition of such a difference occurs over a number of weeks or months is

LEGEND

CONTROL		GRILL COUNT	
|	SPACE SPRAY	0	NO FLIES
/	RESIDUAL SPRAY	BLUE	1-2
L	LARVICIDE	GREEN	3-4
S	SANITATION	ORANGE	5-9
		RED	10 +

Figure 5

MASTER CHART ON DAILY GRILL FLY COUNTS AND CONTROL OPERATIONS

SECTION ____ CITY ______________ YEAR ____

JULY ——— | ——— AUGUST

BLOCK NO. \ DATE	21 FLIES	21 SPRAY	22 FLIES	22 SPRAY	23 FLIES	23 SPRAY	24 FLIES	24 SPRAY	25 FLIES	25 SPRAY	26 SAT. FLIES	26 SAT. SPRAY	27 SUN. FLIES	27 SUN. SPRAY	28 FLIES	28 SPRAY	29 FLIES	29 SPRAY	30 FLIES	30 SPRAY	31 FLIES	31 SPRAY	1 FLIES	1 SPRAY	2 FLIES	2 SPRAY	3 FLIES	3 SPRAY	4 FLIES	4 SPRAY
SECTION A																														
14	6			|	8	/	2								7			|	3											
15	0														4															
16	4														4															
17	2														3															
20	22			|	4										4															
21	29			|	6	S/	3								3															
22	15			|	8	S/	4								3															
SECTION B																														
55		|	30			|	8	/	4							|	9			|	4								
56		|	12			|	4									|	14			|	4								
57		|	4													|	3												
58		|	4													|	3												
59		|	3													|	4												
60		|	4													|	3												
61		|	10			|	3									|	6			|	3								

SECTION A illustrates pretreatment inspection, spray, postreatment inspection cycle.

SECTION B illustrates routine spray cycle followed by postreatment inspection and re-treatment of high-count blocks.

it advisable to consider it of importance.

In concluding this review of evaluation, it should be emphasized again that the grill count technique measures a proportion of the fly population whose relationship to the total fly population is at present an undetermined factor. Because of this unknown relationship, it is not possible to rely upon the grill method for determining the actual amount of fluctuation in the TOTAL fly population.

The previously-mentioned discrepancy between grill count averages and total populations is magnified in those sampling procedures where the highest count in a unit area is considered as representative of that area. Since the grill count is a measure of fly concentration at an attractant, it is readily conceivable that in a series of blocks the single highest samples per block may be the only high counts available, e.g., in a pretreatment survey, Block No. 42 showed a single high grill count of 50, but 20 additional counts were available in the range of 25-45. In a posttreatment survey, 24 hours after spraying, the same block had a high grill count of 62 with all other counts in the 1 to 5 category. It is obvious that the control efforts have been effective, but comparison of the two readings on a high count basis will indicate contrary results. By increasing the number of samples to five per block area, such major discrepancies between actual and calculated results can be minimized. Ten, twenty, or fifty samples per block would further reduce the chance of erroneous deductions, but usually such extensive coverage is not economically feasible on a control program.

CONTROL OPERATIONS

Because of the availability of a considerable amount of literature on sanitary land fills, garbage incineration, and sanitary pit privies, these and similar subjects have been mentioned in the following sections by name only, with little or no detailed description given. Further information can be obtained from the reference material given in the bibliography (pp. 33, 34). Conversely, authentic information on the application of residual sprays, space sprays, and larvicides has had relatively limited publication and, for this reason, the description of the insecticidal phases of fly control has been given more intensive coverage. In view of the disproportionate treatment of the subject matter, it may be desirable to stress to the reader that THE FOUNDATION FOR ALL SUCCESSFUL FLY CONTROL OPERATIONS IS SANITATION.

In large-scale fly control operations, as in any new field of endeavor, techniques, procedures, materials, and equipment are subject to constant change. As an example of recent developments, the reader's attention is called to the final section of this manual which describes a new adhesive spray formulation which will increase the residual effect of DDT on surfaces exposed to weather. Similarly, it is highly probable that other techniques, chemicals, and equipment changes will cause many of the insecticidal procedures to become outmoded within a relatively short time. Nevertheless, it is felt that, despite some superficial changes, the underlying foundation of fly control, i.e., environmental sanitation will remain constant.

HISTORY OF FLY CONTROL

The problem of controlling flies has probably existed as long as man himself and has increased in complexity with man's social development. The measures used for control have also progressed as man moved to higher planes of social and intellectual attainment. Such primitive methods as swishing away the flies which have alighted in undesirable places and swatting those which are persistently annoying are still with us; however, as man learned more about the habits of flies, he devised more resourceful methods for obtaining partial control or abatement. By studying the nature of the breeding cycle, from egg to larva to adult, he was able to reduce annoying fly densities by removing or eliminating potential fly breeding media and attractants. THIS ATTAINMENT STILL STANDS AS THE PRINCIPAL WEAPON IN THE CONTROL OF FLIES AND IS INCLUDED IN OUR MODERN METHODS OF FLY SANITATION. Other control methods have been devised throughout the years, many of which have fallen by the wayside or have been relegated to roles of minor importance. Among these are such methods as baited traps, poisons for ingestion, and sticky flypapers.

The use of wire or cloth screening to introduce a mechanical barrier provides highly effective means of excluding flies from restricted areas, and although it has little effect on the over-all fly population, SCREENING CONTINUES AS ONE OF THE MOST USEFUL TOOLS IN REDUCING POSSIBLE CONTACT BETWEEN FLIES AND HUMANS.

Many chemicals have been used with varying degrees of effectiveness as larvicides, adulticides, and repellents. Probably the most outstanding success was attained in the use of pyrethrum sprays for the control of adult flies inside buildings. Although pyrethrum sprays have proved to be very effective and popular for interior space spraying, they are too expensive for exterior use on large-scale fly control operations.

With the advent of DDT, an entirely new concept of control by chemicals was inaugurated. Making use of the long-lasting properties of DDT, liquid sprays are applied to the surfaces where flies would normally rest instead of attempting to spray the insects themselves. As the liquid sprays evaporate, the crystalline residue of DDT remaining on a treated surface is toxic to the flies which rest on it. Such treated surfaces remain toxic to flies for as long as the DDT crystals adhere to it or are not covered with dust or other materials. Such continued toxicity of the surface over protracted lengths of time has brought about new economies in insect control by chemicals and has made feasible the introduction of large-scale insect control activities. Following the widespread adoption and usage of DDT, many similar chemical compounds have been developed, some of which are equal, if not superior to, DDT in effectiveness, but more time is required to prove the safety or wisdom of their widespread usage. Of the diverse fly control measures at hand, sanitation, screening, residual sprays, space sprays, and larvicides, no single one of them by itself is capable of attaining complete fly control within economic reason. IT IS THE JUDICIOUS COMBINATION AND BLENDING OF THE AVAILABLE METHODS TO MEET LOCAL SITUATIONS IN THE HOUSEHOLD, ON THE FARM, OR IN THE COMMUNITY WHICH DETERMINES THE EFFECTIVENESS AND SUCCESS OF THE PROGRAM. The following sections describe in detail the more important control measures and the manner in which they may be combined for economical, effective control.

SANITATION

THE ELIMINATION OF FLY BREEDING SOURCES THROUGH A SOUND PROGRAM OF ENVIRONMENTAL SANITATION IS OF PRIME IMPORTANCE IN ALL FLY CONTROL OPERATIONS. The principles of good sanitation apply whether the program is operated on a community-wide basis or in an individual industry, farm, or household.

Refuse

In urban areas, inadequate facilities for the storage, collection, and disposal of garbage usually result in widespread sources of fly breeding. Uncovered garbage cans attract large numbers of flies and may afford an excellent medium for larval development. Residues of wet garbage left in the containers after collection may provide sufficient nutriment to permit continuation of larval breeding; thorough cleaning of containers is imperative. In addition, leakage from garbage cans may so saturate the underlying ground with liquids of high organic content that the soil itself becomes sufficiently rich in nutrients to sustain larval development.

The frequency and manner of collection of the wet garbage are highly significant in the curtailment of fly breeding. Wet garbage should be removed from the premises at regular intervals spaced according to the minimal time required for the development of flies from eggs to mature larvae. During the hot summer months, this period is frequently less than seven days; hence, weekly collections would be inadequate to remove larvae from the premises prior to their migration from the breeding media to form puparia in the surrounding soil or debris. It is for the foregoing reason that TWICE-WEEKLY COLLECTIONS OF GARBAGE ARE SO VITAL A PART OF FLY CONTROL PROCEDURES.

Careful handling in transferring the garbage from the storage containers to the collection vehicle and adequate means of transport to the disposal site without spillage must also be emphasized.

Proper disposal of garbage and other waste organic matter warrants very careful consideration. The practice of maintaining open dumps or hog feeding lots within a mile or two of populated areas is generally inadequate. Larval development which has started in garbage storage containers readily moves on to completion at such disposal sites and many of the emerging adults may soon return to the inhabited areas.

The extent of fly breeding in garbage may be held to a minimum only when all three of the operations, storage, collection, and disposal, are properly coordinated and executed.

Without excessive cost to either the property holder or the municipal government, the following sanitary measures concerning garbage can be conducted.

For communities where garbage and rubbish are collected separately, it is recommended that household garbage be stored in covered metal containers of from 5- to 10-gallon capacity. The use of large, heavy oil drums, insanitary bins, open or nonwatertight containers should not be permitted. Collectors should take care that as little residue as possible is left in the containers after emptying and that spillage is eliminated insofar as possible. Property holders should be informed as to the necessity of washing the containers frequently to prevent the formation of hard-to-remove residues. It is advantageous for householders to wrap the waste foods in several folds of paper before placing them in the can. This practice not only prevents fly breeding but also keeps the storage container in cleaner condition and prolongs its useful life.

In those communities where there are combined collections of garbage and rubbish, the use of 20-gallon covered metal containers is recommended. Here, too, the wrapping of garbage before placement in the container is especially desirable and collections should be made at twice-weekly intervals.

No specific recommendations are made as to the detailed system of collection. It is generally a matter of local custom and topography which govern whether collections should be made from yard, curb, or alley. Suffice it to say that summer collection schedules for garbage should be on a twice-weekly basis; the materials should be transferred to the collection vehicles with a minimum of spillage; and the transportation to the disposal site effected in covered, leakproof vehicles.

The twice-weekly collection of rubbish alone is not essential where COMPLETE separation of garbage is in effect.

The disposal of wet garbage on an open dump within flight range of the inhabited portions of the city is contrary to accepted methods of fly sanitation. Even the burning of combustibles on an open dump does not provide a significant degree of control, but serves only as a weak deterrent to fly breeding. Similarly, in the feeding of garbage to hogs, it is a practical impossibility to conduct such an operation without heavy fly infestations. Plans for the elimination of both of these disposal practices should be prepared as a primary step in undertaking a community fly control program. In the elimination of these undesirable practices, the two disposal methods most commonly employed are complete incineration and sanitary land fills. The choice between these two acceptable methods is dependent on cost and the availability of land. Other methods, such as combined sewage and garbage disposal, although satisfactory, are subject to existing local facilities.

Animal Feeds and Excrement

Handling stock feeds and animal excrement in a manner to avoid fly breeding demands constant attention. Finely ground stock feeds when spilled, or allowed to become moist, form excellent media for fly breeding which are capable of supporting phenomenal numbers of larvae per pound of substance. For this reason it is essential that all stock feeds be kept completely dry and that spilled feeds near bins and troughs be removed regularly and frequently.

There seems to be no feasible method yet developed to eliminate all fly breeding in animal excrement which is to be used as manure. There are, however, some measures which can be utilized in the practical handling of manure to significantly reduce fly production. Whenever the season permits, manure should be spread on the fields at daily, or at least twice-weekly intervals. When necessary to hold for longer periods, manure should be stored in such manner as to expose the least possible surface to flies. Indoor storage is usually preferable, but when necessary to stack the manure outside, heaps should be so located that they are not subject to continued saturation by surface waters, since a dry manure will form a hard crust which is unattractive to flies. In no case should a mixture of moist manure, straw, and feeds be allowed to accumulate on the floors of barns, yards, or other animal enclosures. The principal points to bear in mind in the handling of any of the manures are: (1) dry surfaces are unattractive to flies, and (2) a completely dry medium will not permit larval development.

If the animal droppings are not to be used for manure, the problem is simplified in that the excrement may be stored in heaps or bins and treated with larvicides (p. 25). Frequent and complete removal of the droppings, however, appears to be the most effective method of curtailing fly breeding in animal excrement.

Industrial Wastes

Certain industrial wastes comprise localized sources of heavy fly breeding in many urban and rural communities. Some of the industries which commonly produce fly breeding wastes are fruit and vegetable packing houses, abattoirs, meat packing houses, rendering plants, and grain mills. Frequently the proper method of disposal of industrial wastes does not present as difficult a problem as does the responsibility for disposal. In many small cities, industries are permitted to dump fly attractive wastes indiscriminately over the countryside. Where such conditions prevail, the community should enact a law requiring that each industry dispose of its own obnoxious wastes, provided the volume of such wastes is beyond the normal capacity of the local collection and disposal systems. Many industries, when confronted with such a mandate, have found ways of converting former waste materials into salable products. Breweries, for example, have converted their high protein wastes into stock feeds.

Most industrial wastes of fly breeding importance lend themselves to satisfactory disposal by incineration or sanitary land fill. As is the case with garbage and manure, fly breeding industrial wastes should be removed at least twice weekly. Also, the place of storage should be constructed of concrete or other impervious material so that it can be thoroughly cleaned between periods of storage.

Minor Fly Breeding Sources

Although garbage, animal excrement, and industrial wastes undoubtedly produce the greatest number of flies in most communities, there are hosts of lesser problems to which fly control operators should be alerted. The total number of flies emanating from any one of these minor sources usually is small but, because of their number and obscurity, the resulting fly populations may reach and maintain the nuisance level.

The diversity of these usually unnoticed places precludes their individual listing; however, the description of a few will serve as a guide for further investigation. The fecal droppings of dogs are a source of fly breeding* which frequently may be of consequence in residential areas where other fly breeding media are usually scarce. There seems to be little remedy for this item other than the removal of the feces. Another source in residential areas is the compost pile which can, unless properly attended, develop into a low grade fly breeding medium.

In commercial areas, food-handling establishments provide many obscure but productive breeding places. In markets, for example, larval development may occur in the larger crevices of meat-cutting blocks, in meat scraps or other food wastes hidden under low counters, or in piles of sawdust or floor sweepings which contain bits of moist organic matter. In restaurants, fly breeding may occur in heavy accumulations of grease near the cooking ranges and grills, or in moist food scraps, hidden behind or under food-serving counters. Where elevators or dumb-waiters exist, sufficient organic matter sometimes collects at the bottoms of the wells to sustain larval growth.

Since these obscure fly breeding sources can develop whenever moist warm, organic matter accumulates, the control supervisor must be on the alert to detect their presence whenever high fly densities cannot be traced to the more obvious breeding media.

SCREENING

Adequate screening is a highly important measure in any fly control program. Although sanitation

*Principally *Sarcophaga* spp.

and insecticidal control can make tremendous inroads into fly populations, the complete elimination of all flies from a community is not yet economically feasible. Homes, food markets, restaurants, and similar establishments are attractive to flies; therefore, all should be safeguarded by screening.

Since screens may serve as a barrier to egress as well as to ingress of flies, the method of screening should be given careful thought. Screen doors should be hinged to open outward, and those doors adjacent to fly-infested alleys should be used as infrequently as possible. Intake ducts of ventilating systems should be adequately screened to prevent the drawing in of flies from streets and alleys. Electric fans may be used to cause an outward draft at doorways, thus providing an effective auxiliary measure to prevent flies from entering busy doorways.

CHEMICAL CONTROL

For ordinary household use, interior space sprays of pyrethrum and combinations thereof are still satisfactory. However, of the many chemicals and formulations now commercially available, only DDT formulations will be considered for large-scale fly control operations in this manual. This selection is based on the facts that, first, DDT is more economical and effective than the older insecticides and, second, its action and potential dangers due to toxicity are better understood than is the case with most of the newly developed compounds. In its pure state as a powder, DDT is of little value in fly control practices. The most effective and convenient forms for its use are in solution, emulsion, or as specially treated preparations which may be mixed directly with water. Although DDT may be prepared in varying strengths, the most common usage of solutions and emulsions has been at the strength of 5 percent DDT; that of water suspension at 2½ to 5 percent DDT.

DDT Formulations

The formulations for mixing the DDT with the commonly used vehicles are described below:

Solutions: For making a 5 percent DDT solution in common fuel oil, mix in the ratio of 0.37 pounds DDT to each gallon of fuel oil. A convenient approximation of the above ratio is: 2 pounds DDT per 5 gallons of oil. To mix in a 55-gallon drum, 20 pounds of DDT are added to 50 gallons of oil and the drum is rolled until all powder enters solution. This process requires no elaborate mixing plant and takes a relatively short time dependent on the temperature and the amount of agitation provided. With considerable agitation a batch may be prepared in 10 to 15 minutes, whereas with only slight agitation at hourly intervals, the DDT requires 4 hours to enter into complete solution.

Emulsions: Emulsions are made by diluting a concentrated solution of DDT with water. Concentrated solutions are commercially available in varying strengths, usually containing from 25 percent to 35 percent DDT. To these concentrates, emulsifying agents have been added to permit the mixing of oil and water and to provide a reasonably stable EMULSION. Concentrates may be prepared without too much difficulty by dissolving 125 pounds DDT in 31.5 gallons of xylene. Addition of one gallon of emulsifier (Triton X-100 or X-155*) to this solution produces 41 gallons of 35 percent** DDT concentrate. In order to obtain a 5 percent emulsion, one part DDT concentrate is added to 6 parts of water and agitated. At temperatures above 75° F., the resulting emulsion should be stable for several hours.

The type of equipment necessary for the preparation of concentrates is dependent on the total or daily rate of consumption of the materials. Quantities of 30 gallons or less may be mixed by rolling in a drum or by a simple stirring in an open-topped container. Since considerable agitation is required to prepare the conentrated solutions, power agitation is recommended for large-scale programs. With sufficient agitation, DDT will enter solution in xylene in from 15 to 30 minutes. In northern areas, or for cool weather operations in southern areas, the preparation of 25 percent DDT concentrates is recommended because the DDT may precipitate from 35 percent DDT

* The use of the commercial name Triton is for convenience in completing a formula. Other emulsifying agents made by different manufacturers may serve equally well; however, the quantity used may differ and should be ascertained from the manufacturer.

** Not a true percentage (Weight/volume).

solutions at temperatures of less than 50° F.

The formula for mixing 25 percent DDT concentrates is: 82 pounds DDT, plus 31.9 gallons xylene, plus 3.15 quarts Triton X-100 or X-155. This formula yields 40 gallons of concentrate.

With regard to the mixing of xylene concentrates, a few words of caution are not amiss. Xylene is highly inflammable and great care should be exercised in its handling. Since the fumes are toxic, mixing should be performed outdoors or in a well-ventilated enclosure. Xylene is also highly irritating to the skin; hence workers must be cautioned to avoid severe skin burns, particularly near the eyes. The wearing of rubber gloves, goggles, and respirators is recommended as a safety precaution. Because xylene causes rapid deterioration of rubber hoses and gaskets, mixing plants should use oil-resistant rubber tubing, or better still, metal piping wherever possible.

Water Suspensions: The preparation of specially prepared water-miscible DDT powders allows DDT to be mixed directly with water. The strength of the powders and ratio of mixing varies with the different manufactured products and are fully described on the labels of the containers. A given quantity of the powder is added for each gallon of water and stirred until no residue remains. The stirring usually requires from 5 to 20 minutes and can be performed by hand or machine. When spraying, the mixture must be agitated at frequent intervals to prevent the DDT from settling.

Selection of Formulations: Of the foregoing formulations, each has variable advantages and disadvantages dependent on where it is used and how it is applied. For example, when considering residual applications on rough surfaces of barns, sheds, or other outbuildings, all three formulations may be used interchangeably. Since the water-wettable mixtures cause heavier white streaking of the treated surfaces, they should not be used wherever appearance is a factor.

On the interior surfaces of rough-finished homes and buildings, either the oil solution or emulsion may be used. Better homes and buildings, as a rule, should not require interior residual sprays. If desired, however, it is advisable to restrict residual spray applications in such places to oil solutions which have been prepared with water-white, odorless kerosene.

For exterior space spraying with power equipment, oil solutions or water emulsions appear preferable and both have proved to be highly effective. Of these two, the oil solutions appear to yield slightly better break-up of the liquids into mists and fogs but require a higher degree of care in application because of the inherent danger of damaging foliage. Water suspensions have been used effectively in space spraying machines, but some difficulties have been experienced due to the clogging of the nozzles on the spraying apparatus.

Residual Spray Methods

In the application of DDT residual sprays, it is essential that the insecticides be applied to the surfaces as uniformly as possible in order to provide a regular pattern of DDT crystals when the liquids evaporate. All three liquid forms, solutions, emulsions, and water suspensions will provide the desired pattern when properly applied.

The method of applying residuals will vary according to the extent and type of surface being treated. For example, on small areas such as household screens, the liquid insecticides may be applied with an ordinary paint brush. For moderately large areas such as home interiors, sheds, or small barns, it is preferable to use a common compressed air spray can of from 2- to 4-gallon capacity. (The ordinary household atomizing sprayer cannot be used effectively for applying RESIDUAL sprays.) The nozzle which is standard equipment with the spray cans may be adequate for occasional use. However, the specially designed flat-spray nozzles described below are warranted on large-scale work.

For applying residuals to extensive surfaces, power driven sprayers are most efficient. Most commercial insecticide sprayers can be adapted for residual spray work by adjusting the working pressure of the liquid and providing suitable nozzles. The working pressure of the machine is usually set at from 40 to 60 pounds per square inch. Quick-acting shut-off valves are used at the nozzle end of the hoses, the trigger valves supplied with the 4-gallon hand spray cans usually being adequate for this purpose. A metal wand approximately 2 feet in length between valve and nozzle is desirable. For best results, a calibrated nozzle, designed to issue liquids in a flat spray* should be obtained.

Flat spray nozzles are constructed to give forth a spray pattern of known angular width and a given output in gallons per minute for a standard working pressure. For example, The Spraying Systems Company's** 50-04 nozzle issues a spray with an angular width of 50 degrees at the rate of 0.4 gallons per minute under an operating pressure of 40 pounds per square inch. The calibration of the nozzle to be used is dependent on the nature of the surface being treated. The following table will serve as a guide in the selection of flat spray nozzle for ordinary usage with liquids containing 5 percent DDT.

Angle (Degrees)	Output (Gal./Min.)	Surface
50	0.4	Very rough, dry surfaces such as unpainted wood, composition board, and masonry, and especially exterior surfaces where wind may affect spray operation.
50	0.1	Delicate interior wall surfaces where extreme care must be taken to avoid spotting and streaking.
80	0.2	Ordinary interior surfaces where spray is unaffected by winds and only moderate care is required to avoid spotting and streaking.

With experience, operators may proficiently use nozzles of intermediate calibration for the more common surfaces of their particular community or locale.

The rate of application for liquid insecticides containing 5 percent DDT has become reasonably well standardized. Laboratory experiments have shown that a residual application of 200 milligrams of DDT per square foot of treated surface is highly effective for fly control. This dosage of DDT can be obtained by applying a 5 percent DDT liquid at the coverage rate of approximately 1,000 square feet of surface per gallon of insecticide. (The actual rate to obtain 200 mg. per sq. ft. is 943 sq. ft. per gal. insecticide.) Fortunately, the correct dosage can be closely approximated in most cases by applying the liquid 5 percent DDT spray to the surface "up to the point of run-off" That is, the surface should be thoroughly wetted by the spray without having any excess liquid run down the wall. When treating extremely porous surfaces with emulsions or suspensions,it is advisable to reduce the strength of the liquid to 2½ percent DDT, thus providing more liquid to compensate for the excessive absorption. The dosage will then be increased to 2 gallons per 1,000 square feet to provide the desired quantity DDT crystals on evaporation. For high-gloss walls with little or no absorption, a finer nozzle (e.g. 50-01) may be used and the 5 percent DDT spray applied two or more times to secure the desired crystal formation on evaporation. As an alternative method, the strength of the insecticide may be increased to 10 percent DDT and applied with the 50-01 nozzle at the rate of ½ gallon per 1,000 square feet.

When applying the sprays to wall surfaces, the nozzle may be moved in either a vertical or horizontal direction to suit the conditions. Care should be exercised in application to move the nozzle in a regular swath pattern, at a uniform speed, with the nozzle held approximately 18 to 24 inches from the surface being treated. Irregular or haphazard application techniques will result in unequally treated, ineffective surfaces.

Space Spraying Methods (Exterior)

Exterior space spraying with mists and fogs, sometimes called "area spraying", is an increasingly popular method of applying insecticides for community programs. Although the principle has been used for agricultural purposes for many years in dispersing insecticidal dusts, it is only with the development of the newer liquid insecticides and specially designed equipment that the dis-

* Such nozzles are manufactured by Spraying Systems, Inc., Bellwood, Illinois, for approximately $1.20-$2.00 each. Other equipment manufacturers may also provide equally good nozzles.

** Manufacturer's name used for the sake of illustration only. Similar products of other manufactures may prove equally good.

persion of very fine droplets of liquid insecticides has become feasible. Many equipment manufacturers now construct machines which break up liquid sprays into tiny air-borne droplets. Although differing in detailed construction, the machines are essentially similar in principle. They consist of: (1) a hydraulic pump to provide pressure for the liquid; (2) a device for breaking the liquid into small droplets, (usually accomplished by nozzles) and (3) a fan to develop an air blast to provide the droplets with an initial velocity in a given direction. Some manufacturers have added combustion chambers to their machines to heat the air before it comes in contact with the liquid, thus providing very fine particles which cause the insecticide to appear as a fog instead of a mist. Such fogs are properly termed thermal aerosols.

Regardless of the specific piece of equipment used, be it a mist or fog producing machine, the aim to be accomplished is the breaking up of a liquid insecticide into minute droplets and applying them as uniformly as possible over a large area of the community being treated. The application should be made in sufficient quantity to kill the adult flies which are resting or flying in that area. The size of droplet, strength of solution, and quantity of liquid per unit area are all interdependent. From experience thus far, it appears that the optimum application rate for efficient fly control ranges between 0.3 and 0.5 pounds DDT per acre. Such an application rate yields only from 3 to 5 milligrams of DDT per square foot, producing little, if any, residual effect. Using a 5 percent DDT liquid, an application rate of approximately 0.4 pounds DDT per acre can be obtained by applying 1 gallon of insecticide per acre.

The dependable operating distance of the space spray machines in fly control work appears to be on the order of from 100 to 200 feet. Many examples may be cited to show fly kill beyond this range, but favorable kill at longer ranges is not dependable. Attempts to operate at extended ranges may account for some of the failures which have occurred in communities where space spray for fly control has been attempted. In routine operations, it is advisable to treat each block as a unit, maneuvering the machine through the streets, alleys, or other ways of access to bring the sprayer within 100 to 200 feet of all portions of the block. This is the only means of approaching the uniform coverage over the entire block which is so essential to the successful operation of a space spraying program.

The considerations involved in selecting a droplet size are that the droplets should be small enough to be air-borne for a reasonable distance from the spray machine, yet large enough to subside in sufficient numbers to give an effective lethal dosage on the area undergoing treatment. Droplets that are too small are carried far by the wind currents and are so widely dispersed that, on subsidence, their numbers are insufficient to provide a lethal effect. Conversely, excessively large droplets are not sufficiently air-borne to travel a reasonable distance from the machine, resulting in excessive dosages and wasted material close to the machine. From field experience, it appears that the optimum spray composition should possess droplets in the range of from 20 to 100 microns in diameter with the average droplet diameter being approximately 70 microns.

Since most of the spray machines available commercially can produce sprays of variable coarseness, they can be adjusted to issue a spray approximating the apparent optimum. Although it is desirable to measure the spray composition with microscopic tests, gross observation can be very useful. Sprays of the correct composition are barely discernible at a distance of from 50 to 100 feet away from the machine; however, when a clean glass slide is held in a horizontal position, the accumulation of droplets can be seen with the unaided eye. Sprays which are too coarse appear as a light rain, most of the droplets subsiding before traveling about 75 feet. Exceedingly fine sprays and thermal aerosols contain an abundance of droplets in the very low ranges of 10 microns or less in diameter and appear as fogs or smokes. When too great a proportion of the spray composition is in the low ranges, the results of fly kill are erratic. The droplets are subject to extreme reaction, even mild wind conditions making the spray uncontrollable. Very fine fogs may float several hundred feet away from the machine but glass slides placed on the ground at a distance of 100 feet will collect only 2 or 3 droplets, which is insufficient for control purposes. From gross observation, then, the optimum spray composition should appear as a very fine mist or a very heavy fog. (The foregoing should not be considered a refutation of INTERIOR space spraying studies where the droplets in the lower ranges are most efficient.)

Application: With ground operated equipment, the attainment of the uniform application of from 0.3 to 0.5 pounds DDT per acre in a community is difficult. There are many obstacles which prevent the movement of the spray machine to favorable positions and, secondly, the equipment itself usually applies a heavy dosage near the machine, tapering to a light dosage at more distant points. Both of these factors should be borne in mind by the machine operators and attempts made to compensate for them by manipulation of the direction of the spray and movement of the vehicle. From field experience, good results have been obtained in spray distribution by driving 5 miles per hour in a cross-wind direction. With the machine regulated to an output of 1 gallon of 5 percent DDT insecticide per minute, a swath of 100 feet in width can be treated at an average rate of approximately 0.5 pounds DDT per acre. By manipulating the air nozzle in an up-and-down motion and taking advantage of wind currents, a reasonably uniform coverage can be obtained.

In situations where heavy foliage, dense populations, congested motor traffic, and unfavorable terrain occur, highly skilled machine operators are required to perform effective work.

All three types of DDT formulations (solutions, emulsions, and water suspensions) may be used in the space-spraying operation but reports from field activities appear to favor the solutions or emulsions over the water suspensions. The latter produce heavier spotting on surfaces, particularly automobiles, and may clog the nozzles on the spray machines. Although other strengths have been used, the 5 percent emulsion or solution appears to be most common. Some field observations indicate that the oil solutions are slightly more effective than emulsions, possibly due to the toxic or irritant properties of the oil itself. The use of the oil solutions, however, requires greater alertness on the part of the operator to avoid "burning" of foliage within close range of the machine nozzle. Leafy surfaces which are thoroughly wetted with oil will suffer severe damage and discoloration. The selection of the formulation for use in ground operated space spray machines must be governed in part by local conditions.

Application of Insecticides by Aircraft: The use of aircraft in the dispersal of insecticides on community insect control programs is becoming more common. It must not be assumed that aircraft dispersal is the acme of control procedures; it is simply another method of applying space sprays, a method which is most effective when very large areas are involved. In flying over the buildings and treetops, aircraft are able to overcome many of the obstacles usually encountered in space spraying with ground operated equipment; thus specially trained pilots are able to achieve much more uniform applications of the insecticides. Despite this advantage, however, it is still necessary to conduct sanitation measures and a small amount of space or residual spraying by ground apparatus. The latter activity is required to cover areas not accessible from the air and to make spot retreatments.

In aircraft dispersal, the insecticides may be applied as either thermal aerosols or sprays. Dependent on the type of plane and its dispersal equipment, the insecticides commonly used are 20 to 30 percent DDT in Velsicol (AR-60)* or 5 percent DDT in fuel oil. The recommended application rate for fly control is from 0.3 to 0.5 pounds DDT per acre. Flights are usually made in swaths of approximately 100 feet width at altitudes of from 75 to 150 feet. When necessary to fly at higher altitudes because of obstructions, loss of accuracy in swath placement results. The frequency of application is the same as for ground operated space spray machines (p. 28).

Despite its advantage of yielding the most uniform insecticidal coverages, aircraft dispersal involves definite hazards which frequently make its use unwise. The low altitudes at which flights must be made can lead to accidents, the consequences of which may be disastrous to the entire program. For this reason aircraft dispersal is not warranted in those cities where effective control can be secured by sanitation, ground machines, and other methods.

* Product of Velsicol Corporation, Chicago, Illinois. The use of the trade name is only for convenience in completing the formula. Other commercial solvents may serve equally well; however, the quantity used may differ and should be ascertained from the manufacturer.

Larvicides

The role of larvicides in fly control operations is usually restricted to those locations where a superabundance of larvae is found in a compact breeding area. With the larvicides presently available, the large quantities or frequent applications required to obtain a high degree of larval kill make their more general use in light breeding media economically unsound.

Although not ideal larvicides, any of the three DDT formulations previously described may be used effectively against fly larvae. When heavy larval breeding is found in a mass of organic matter, it is expedient to saturate the outer surfaces with one of the liquids. Many of the freshly emerging flies and some larvae will be killed by the DDT before leaving the medium. The residual effect from the DDT is of short duration on surfaces of this type, so that applications must be made at intervals of from 2 to 3 days for as long as larval activity persists.

In the event that local conditions warrant more extensive use of larvicides, operators are referred to the studies of McDuffie et al. (1946). These workers report larval control with several chemicals, notably paradichlorobenzene and orthodichlorobenzene. Both of these chemicals gave good kill of housefly larvae in simulated pit latrines when applied to the surface of the medium at the rate of 10 to 20 grams of paradichlorobenzene and 15 to 25 milliliters of orthodichlorobenzene per square foot. Smaller dosages were satisfactory if followed by retreatment in 2 to 4 days. These same workers found orthodichlorobenzene and acetylene tetrachloride to be effective against blowfly larvae in carcasses. When these chemicals were sprayed at the rate of 1 pint per 25- to 50-pound carcass, the larvae were killed almost instantly. These chemicals were also highly effective when diluted 1 to 4 with fuel oil. Although McDuffie et al. found DDT to be relatively ineffective against the larvae, they state: "It is highly desirable to add 5 percent of DDT to all the larvicides, except perhaps benzene hexachloride, because of the effectiveness of the residue on the adult flies that visit the carcass."

Recent laboratory experiments by Baker* indicate that a satisfactory degree of control of housefly breeding in cow manure may be obtained by spraying the surface of the medium with chlordan emulsions. With a 1.0 percent emulsion sprayed at a rate of 50 and 100 milligrams toxicant per square foot, 97 percent of adult housefly emergence was prevented. The same percentage of control was obtained by using a 5 percent dust at a rate of 100 milligrams per square foot.

In any larvicidal treatment of manures, care must be taken to see that the larvicide, as employed, will not cause any injurious effects to the animals present, or to the crops on which the manure will be subsequently applied.

OPERATIONAL PROCEDURES

The preceding discussion of control methods has dealt with each technique as an independent unit or function. Since none of the techniques is capable of complete universal control, this section of the manual will show how to blend the various techniques to obtain maximum effectiveness under the varying field conditions. In undertaking this description, it is assumed that the outlining of procedures for a farm, a rural community, and an urban community will be sufficient to cover the greater portion of all possibilities.

Farms

On farms and other rural premises, the fly breeding problem is usually restricted to individual properties. The distances between homes and other establishments is usually so great as to nullify the effects of infiltration of flies from outside sources. Around such premises the principal fly breeding sources are: animal excrement, stock feeds, and household garbage.

THE FIRST STEP IN CONTROL IS TO LOCATE THE MAJOR BREEDING SOURCES AND DEVISE SANITATION MEASURES FOR THEIR ELIMINATION (pp. 17, 18). Household food wastes, if not fed to animals, should be buried. Since each burial should be covered with at least 24 inches of earth, it is advisable to store the garbage in a covered metal container until a sufficient amount is accumulated for burial (p. 18). The privy, although difficult to make absolutely flyproof, should be of the modern deep-pit design with reasonably tight shelter and seat construction.

* Unpublished manuscript.

The bins containing foods for livestock should be kept dry at all times and all accumulations of spilled feeds removed (p. 18). Animal excrement should be removed from the barns frequently and thoroughly. If impractical to spread on the fields at daily intervals, it should be stored in such a manner as to minimize breeding (p. 18). The manure spreader itself should not be overlooked; frequently, sufficient manure clings to the device to support a sizeable number of larvae.

When all corrective sanitary measures have been applied, the next step is to apply residual DDT sprays to the interior surfaces of sheds, privies, and barns (EXCEPT THOSE USED FOR DAIRY PURPOSES*). When spraying the privy, the wand should be inserted through the seat hole to apply the spray to the walls of the pit. In the barns or other animal shelters, care should be taken to avoid direct spraying of animal feeds and drinking water. DO NOT APPLY THESE 5 PERCENT DDT SPRAYS TO THE ANIMALS. Upon completion of spraying of the barns and outbuildings, the house itself may be treated. Applying the spray to the screens, porches, and possibly the kitchen, is in many cases sufficient (p. 21). There is additional benefit in spraying the other rooms of the house for incidental control of other household pests such as moths, bedbugs, mosquitoes, and some cockroaches.

Since oil solutions and emulsions may produce explosive mixtures, operators are warned to extinguish all fires, pilot lights, etc., inside buildings undergoing treatment. Varnished surfaces of furniture and floors should be protected against spotting by the sprays.

The foregoing combination of sanitary measures and residual spray applications should provide relatively fly-free conditions on a farm. In many areas, one application of residual spray in the early summer is sufficient for the entire fly breeding season. However, the residual toxicity of the treated surfaces to flies is markedly reduced after two to three months; therefore, in southern regions, surfaces may require retreatment at 60- to 120-day intervals.

If warranted, incidental larvicidal treatment of manure heaps, privy pits, or animal carcasses should be made at frequent intervals (p. 25).

Rural Communities

Rural communities usually have all of the fly breeding problems of the farm plus the added difficulty of infiltration of flies from nearby properties or establishments. For this latter reason, the community fly control program must be a cooperative affair rather than one of isolated individual effort. The results of individual sanitary measures or spray operations are of little value unless similar action is taken throughout the entire neighborhood. In the rural community, animal excrement, garbage, and industrial wastes usually comprise the principal sources of fly breeding.

THE FIRST PHASE OF THE PROGRAM SHOULD BE THE ELIMINATION OF BREEDING AREAS THROUGH SANITATION. The storage, collection, and disposal of garbage should receive first consideration (p. 17). If an organized garbage collection system exists, it should provide daily pick-up service in the business area and twice weekly service in the residential areas. Property holders should be instructed in the proper methods of storing garbage between collections (p. 18). Disposal of the collected garbage by sanitary land fill is recommended since incineration is usually too expensive for small communities (p. 18). Arrangement for the part-time use of earth moving equipment for the operation of the land fill can usually be made with the highway or streets department. If an organized garbage collection service does not exist in the community, garbage must be disposed of on individual properties. This can be accomplished in a sanitary manner by burial. To avoid excessive manual work, garbage, combustible rubbish, and noncombustible rubbish should be

*The Food and Drug Administration considers the small amounts of DDT appearing in the milk of cows treated with DDT to be a potential hazard to consumers. Therefore, it is considered inadvisable to use DDT sprays on dairy animals, in dairy barns, feed rooms, milk rooms, milk-processing plants, or in any situation where they may contaminate milk used for human consumption. As a substitute for DDT in dairy barns, etc., methoxychlor, the methoxy analog of DDT, is recommended. Available information indicates that this insecticide should be used as a 5 percent wettable-powder spray applied at a rate of 1 gallon per 1,000 square feet. To minimize clogging of the spray nozzle, the strainer should be removed. In instances where, even with the modified nozzle the 5 percent spray is troublesome to apply, a 2.5 percent spray applied at a rate of 1 gallon per 500 square feet is suggested. While spraying, this mixture must be agitated frequently to prevent the methoxychlor from settling. Recent reports (Peffly et al., 1949, and USDA Bull. E-762, rev., 1949), have stated that under laboratory conditions, methoxychlor is almost equal to DDT in its residual qualities against houseflies. In addition, DDT-resistant flies have been found only partially resistant to methoxychlor. Under field conditions, promising but somewhat erratic results have been obtained.

segregated. Noncombustibles may be hauled to a community disposal site and combustibles may be burned on the property. Garbage should be stored in covered metal containers and disposed of at no greater than 3- to 4-day intervals. With proper planning a small area will provide burial space for a surprisingly large amount of garbage.

Domestic animals should also receive considerable attention to prevent excessive fly breeding in the excrement (p. 18). With small domestic stock, fowl for example, burial is the simplest solution. For larger animals, cows, and horses, the droppings should be cleaned up daily and stored compactly (p. 18), preferably in bins or racks, until hauled away. The exposed surface of the stored material may be treated with larvicides (p. 25) at frequent intervals to deter larval development.

Wastes from canneries, packing houses, and similar industrial establishments require special attention. Each establishment should assume the responsibility of disposing of its waste in an approved manner (p. 19).

Food stores and restaurants must provide adequate facilities for handling their wastes.

In unsewered areas, all privies should be of modern sanitary construction, properly maintained, and reasonably flyproof. A thorough search for fly breeding sources (pp. 4, 17-19) should be conducted throughout the residential and business areas.

With fly breeding sources reduced to a practical minimum, the need for an insecticidal program may then be analyzed. Since the buildings and residences in most rural communities are widely scattered, applications of DDT by the residual spray method (p. 21) are usually the most feasible. In residential areas, residual sprays should be applied to the interior surfaces of all privies, barns, and animal shelters. In the better homes, the spraying of porch ceilings and walls and screen doors should be sufficient PROVIDED THE SANITARY MEASURES HAVE BEEN PROPERLY EXECUTED. In the lower class homes where screening is inadequate, garbage containers substandard, and domestic livestock more frequently encountered, it may be advisable to extend the residual application to complete interior coverage. In addition, exterior spraying of garbage cans, and surfaces exposed to weather should be done with formulations containing a "sticker" (p. 31).

With proper sanitation and screening, most business establishments will need no treatment; however, food handling and food serving establishments being highly attractive to flies, will undoubtedly require at least partial interior treatment. In performing the spray operations in food handling establishments, extreme care should be taken to avoid contamination of foodstuffs, serving dishes, and utensils with the toxic chemicals. Out-of-doors, the spraying of screens, vestibules, and walls protected by canopies should be performed.

In large industrial establishments, the extent of interior treatment should be commensurate with the degree of fly infestation. For small establishments, complete interior coverage is usually in order.

The application of larvicides on a broad scale is not recommended; however, their use on certain industrial wastes and large accumulations of animal excrement may be warranted (p. 25).

A thorough residual spray coverage of all available resting surfaces in a community requires a considerable amount of time when measured in man-hours. In order to obtain both effectiveness and economy, plans must be carefully laid to coordinate the spraying program with the fly breeding season. The residuals should be applied early in the season to deter any sizeable build-up of the fly population. While a single application may be adequate in northern areas, many southern communities must plan for at least partial retreatment of the surfaces after a period of 60 to 120 days.

To summarize for the rural community, an extensive sanitation program coupled with carefully applied DDT residuals and selective larviciding will successfully reduce the fly population to a point well below the nuisance level.

Urban Communities

Fly control problems in urban areas differ from these in rural communities in degree only. The maintenance of livestock on individual properties, a common practice in the rural community, is less customary in urban areas. The principal sources of fly breeding are food wastes from restaurants, households, stores, and industrial wastes.

IN UNDERTAKING A CITY-WIDE PROGRAM, INDIVIDUAL AND COMMUNITY SANITATION ARE

OF PRIME IMPORTANCE. The storage, collection, and disposal of garbage require maximum consideration. Ordinances should be passed and enforced to assure adequate containers for the storage of food wastes or industrial wastes pending collection (pp. 18, 19). Sufficient trucks should be made available to provide at least twice-weekly collections of garbage in the residential areas and daily collections in commercial areas during the fly breeding season (pp. 17, 18). Collection crews should be informed as to the necessity of avoiding spillage in their routine operations. And lastly, the ultimate disposal of the garbage must be performed in a fly-free manner (p. 18). The need for adequate handling and disposal of garbage cannot be overstressed since it requires the complete cooperation of everybody in the community.

Wastes from industrial and commercial establishments must also receive proper attention (p. 19). If the wastes from a given establishment are beyond the normal capacity of the municipal garbage collection system, regulations should be passed causing the establishment to remove and dispose of its wastes in a satisfactory manner. Certain industries such as rendering plants and stockyards should be forced to take measures to reduce their fly nuisance.

In those instances where the maintenance of poultry or other livestock are permitted in residential areas, the practices would best be abolished; but as a minimal control measure, the property holders should be forced to maintain a high degree of sanitation (pp. 18, 19).

It is in the urban community program that space or area spraying becomes highly effective and economical (p. 22). Here, the multitude of breeding sites, attractants, and outdoor resting places are in close proximity, thus providing a maximum number of targets for each application of the airborne spray. Conversely, the efficiency of a residual spraying program decreases in urban areas because the ratio area of wall surface to be treated with respect to each individual fly breeding source is far greater than a similar ratio in rural areas.

The frequency with which space spraying should be applied is determined by the conditions of fly prevalence and fly breeding in each block or site under consideration. For example, a fine residential block with garbage cans as the only source would have a much lower normal level of fly population than an industrial block containing a stockyard. Hence, the rapidity with which the fly population could return to the nuisance level after a space spray treatment would be much slower.

Dependent on the level to which it is desirable to reduce the over-all fly population and degree of sanitation in the environment, the frequency of space spraying in the cleanest residential sections may be required at intervals of from 2 to 4 weeks. In those residential sections where garbage sanitation is not especially well maintained, or where the keeping of livestock is permitted, it may be necessary to shorten the interval between spray applications to a weekly or biweekly schedule. Very poorly kept residential blocks and commercial areas will undoubtedly require weekly and possibly semiweekly application.

Certain selected sites with especially difficult sanitation problems such as open garbage dumps, rendering plants, and hog feeding lots may require semiweekly or even daily applications of space sprays. Such frequency is not economically feasible except as a temporary measure over a very restricted area in which the aim is only to hold the fly population at a reasonably low level to reduce migration.

Field experience in several locations has shown that on badly infested open dumps, an application rate of 1 pound of DDT per acre for a period of 10 days will reduce the fly populations by more than 90 percent. With constant vigilance and a few well-placed larvicidal treatments, low levels of counts can then be maintained with semiweekly application of space sprays. In general, it may be said that the requirement of space spray applications at less-than-weekly intervals indicates the presence of a major sanitation problem requiring immediate attention.

In making the actual application with space spraying machines, the procedure to be followed is the same whether using mist sprays or fogs. The usual minimum area to be treated is the city block. Taking advantage of the wind currents, alleys, vacant lots, and convenient driveways, the spray should be applied as uniformly as possible over the entire open area in the block. A convenient rule of thumb is:

"When sprayed at the rate of 1 gallon per minute, a 5 percent solution applied while moving at 5 miles per hour yields an average coverage of 0.5 pounds DDT per acre over a swath 100 feet in width."

Although complete interior coverage of homes and buildings in an urban community is not economically feasible, the efficacy of a limited number of strategically placed residual applications must not be overlooked. For example, in residential areas wherever privies exist or animals are housed, the residual spraying of the interiors of sheds and outbuildings should be performed. Some favorable results have been obtained by applying residual sprays directly on metal garbage cans, but the frequency with which this spray must be repeated prohibits its wide-scale use. In commercial areas, a few well-placed exterior applications in the immediate vicinity of garbage can racks at stores and restaurants will prove highly beneficial. This is particularly true if treated surfaces are partially protected by a roof or canopy. Certain industrial establishments lend themselves to effective residual treatment, for example, the underside of a canopy over a loading platform at a produce warehouse. Although not the usual practice, in some cases it may be advisable to apply residual sprays to such exposed places as the sides of buildings and pens at a stockyard. This would be true only when the activity in the establishment was of very short duration, for example, a State or County Fair. Unless some type of "sticker" (p. 31) is introduced into the formulation, reasonably good results from exterior residual applications on unprotected surfaces cannot be expected beyond 1 or 2 weeks duration.

To summarize, then, with respect to residual applications in urban programs, they should be used only in those locations where a reasonably large proportion of the immediately surrounding fly population is likely to rest.

Until improved techniques or more efficient chemicals are developed, the application of larvicides must be relegated to a minor role in urban fly control activities (p. 25). Larvicidal efforts thus far have proved exceedingly costly, either in volume of materials required or in time consumed in making a thorough application. In brief, the occasional larvicidal treatment of industrial wastes, manure heaps, and animal carcasses is warranted but sanitary measures are usually more effective and frequently less costly than larviciding.

In reviewing the operational procedures for the urban program, it can be seen that THE MOST IMPORTANT SINGLE ITEM IS SANITATION, that is, the elimination of fly breeding sources wherever possible. The insecticidal measures, though important, are only auxilliary in nature, their purpose being, (1) to reduce or deter fly breeding until sanitary measures are effected, or (2) to supplement sanitation where complete elimination of the fly breeding source is impossible. The use of space spraying, residual spraying, and larvicidal application must be judiciously blended into the over-all sanitation program to effectively and economically reduce fly prevalence.

ORGANIZATION OF COMMUNITY FLY CONTROL PROGRAM

The community fly control program should logically be made a function of the local health department. The health department is in constant touch with restaurants, dairies, and other establishments with regard to sanitary conditions. It is also aware of privy locations and areas where possibility of transmission of disease by flies is the greatest. In many cities, the collection and disposal of refuse is under the direction of the health department and it is also possible that scientifically trained supervisory personnel may be available.

The detailed organization of a community fly control program should be given close scrutiny else a significant reduction in efficiency and effectiveness may be followed by a rising unit cost.

For efficient use of man-power and materials, it is essential that all control programs be provided an inspection force, to guide the sanitation and spraying activities, and to measure the effectiveness of the control methods employed. The activities of the inspection and control units should be so closely blended and correlated that they appear as a single operations force.

Competent personnel should be employed throughout the entire staff. One well-trained inspector or one skillful spray operator can be more effective in the long run than several less productive workers. Both, inspectors and spray operators, should be capable of understanding fly ecology and control methods from the practical viewpoint in order that they may be given some latitude for the exercise of judgment in their daily routines.

Before commencing a program of any magnitude, a system of adequate records and maps should be devised. Due to the vagaries of the fly breeding cycle, both seasonal and annual, it is necessary that a reasonable amount of records be maintained in order to be certain that the measures and techniques in practice are truly effective. It is possible that some sharp decline in fly populations may result from external causes and is not wholly attributable to the practices of the program (p. 14). When such sharp declines occur, the control units may be lulled into a false sense of security until the aid rendered by unsuspected outside force is withdrawn.

The operating maps should show all blocks in the city with a reasonable degree of accuracy and a simple system of block identification should be devised. With few exceptions, the city block is the smallest areal unit of the control program.

In order to present some idea as to the type and number of personnel required in conducting a fly control program, the following description is devised and based on a city of approximately 100,000 population in which a reasonably high degree of fly control is expected.

1-Manager or Supervisor: In this person, the responsibility for the efficiency and effectiveness of the entire program is vested; he is the over-all administrator of the program.

1-Technical Expert: An entomologist, engineer, or other scientifically trained person who, by reason of his educational background, can keep abreast of new developments in municipal sanitation, fly biology, control practices, equipment, and insecticides.

4-Entomological Inspectors: Subprofessional personnel, preferably with some biological training or experience, to make surveys of fly populations.

2-Engineering Aides: Subprofessional personnel, preferably with engineering training and experience to give detailed direction to spray crews, summarize technical data, and make sanitary surveys and inspections.

4-Spray Machine Operators: Skilled workers, capable of absorbing the new techniques and procedures and exercising judgment in their use. Must be able to read maps and keep simple records of daily activities. Should be able to make minor repairs and adjustments on spray apparatus.

4-Assistant Sprayers: Semiskilled workers to drive trucks, relieve regular sprayers for intervals, and assist in making residual spray applications.

1-Clerk: For miscellaneous office routine.

The number of personnel for foregoing descriptive list may be varied according to the size of the city, area covered, degree of control desired, amount of sanitary measures effected, and the degree of cooperation from the citizens as a whole. Regardless of the size of the roster, however, the functions, and proportion of time allotted to each will resolve into approximately similar ratios.

In order to weld the inspection and spraying forces into a single operating unit, the use of the sample Control Chart (fig. 5, p. 15) is suggested. The chart provides for the symbolic recording of all activities pertaining to each individual block in the city. By posting the chart on a daily basis the supervisory personnel can, at a glance, review entire sections of a city with regard to fly counts, detailed spray operations, and sanitation measures effected by the day or by the block. In addition to its value as a daily operational guide, the chart becomes a permanent record of seasonal activities.

At the close of each operating season, it would be advisable for the Supervisor and Technical Expert to prepare comprehensive reports of the season's activities. In addition to reporting on fly abundance, control measures, and results, a complete cost summary should be included together with carefully considered recommendations for modification of activities for the following season. Such a report will be not only informative, but will provide a sound basis for improved effectiveness and greater economies in subsequent years.

SAFETY AND PRECAUTIONS IN CHEMICAL CONTROL METHODS

In any program involving the widespread use of insecticides and chemicals, especially in close proximity to human habitation, it is advisable to point out some of the inherent dangers involved lest familiarity with the products breed undue contempt. It must not be overlooked that DDT is toxic to humans and warm-blooded animals if administered in sufficient quantity. In the minute doses required in fly control operations, it is difficult to conceive of injurious effect resulting to humans except through gross misapplication. However, it must be remembered that the relative weight of the form of life under consideration is an important factor in DDT toxicity. For example, a dose which may be harmless to an adult human may be fatal to very small animals and fish. Similarly, while favorably impressed that such minute doses are lethal to flies and mosquitoes, one must also be cognizant of the fact that beneficial insects such as bees and lady beetles may also be affected. Before spray operations begin, the location of apiaries should be ascertained from the agricultural agent.

These factors, together with a reasonable degree of caution to avoid excess dosages of solutions or emulsions on foliage and the avoidance of direct blasts from space spray machines on automobiles, call for constant alertness on the part of all persons engaged in the dispersal of insecticides.

FLY RESISTANT POPULATIONS vs. EFFECTIVE FLY CONTROL OPERATIONS

In recent months, much concern has been shown by workers in the field of fly control regarding the resistance of certain fly populations to DDT residual sprays. Some have felt that because of this resistance, their programs might collapse unless they changed to other chemicals or modified their spray procedures.

Although resistant fly populations are known to occur (p. 7), there is little reason to fear complete failure of a well-balanced control program. Insofar as the sanitation phases of the program are concerned, DDT resistance is of no consequence. AS DDT IS NOT A SUBSTITUTE FOR SANITATION, THE SANITARY MEASURES SHOULD ACCOUNT FOR THE MAJOR REDUCTIONS IN FLY POPULATIONS.

Furthermore, the "apparent resistance" of flies in some instances has been shown to result from misapplication of the sprays or the use of substandard formulations. It is imperative that each residual spray operator understand that under-dosages and irregular spray patterns will not yield effective surfaces (pp. 21, 22): that spray machine operations strive to apply their mists and fogs uniformly over the area being treated at the prescribed range (p. 23), and that supervisors maintain constant checks on the outputs of the various crews to insure the proficiency of their work (p. 30). Only when these and other factors in the control operations (age of treatments, potency of insecticides, amount of fly breeding, etc.), have been checked and rechecked, and the fly population still fails to succumb to these measures, is it time to consider changes of chemicals or other means to combat DDT resistance in the fly population.

NEW FORMULATION FOR EXTERIOR APPLICATIONS OF DDT RESIDUALS

Between the time of completion of the main portion of this manual and its publication, a new development in the application of DDT residuals has been announced by the Technical Development Division of the Communicable Disease Center. Partially completed laboratory tests show that the addition of an adhesive agent to DDT formulations will cause a significant increase in the length of time over which residual treatment of exposed exterior surfaces will remain toxic to flies. If, in field tests, this "sticker" formulation also proves successful, it will provide a means of applying effective residuals to garbage cans and the numerous exterior surfaces found at stockyards, abattoirs, and food warehouses, in alleys, and around dwellings. These and many other possibilities are yet to be explored in the use of the new adhesive DDT sprays.

To date, the adhesive has been tested in only xylene emulsion sprays containing 5 percent DDT. The possibilities of its use in oil solutions and water miscible mixtures have not been determined.

The adhesive agent used in the tests was ordinary pine gum rosin. The formulation for preparing 25 percent DDT concentrates containing rosin is as follows: to 36 gallons of xylene add 105 pounds DDT. When all DDT is dissolved, add 1 gallon of Triton (X-100) and mix for several minutes. To this solution, add 42 pounds of pine gum rosin which has been broken into small lumps (less than ½ inch in size).

OPERATORS ARE CAUTIONED TO MIX THE INGREDIENTS THOROUGHLY AND IN PROPER SEQUENCE, OTHERWISE A GUMMY MIXTURE WILL RESULT. A power mixing plant is essential for large-scale programs. To make a 5 percent emulsion from the 25 percent DDT concentrates containing rosin, dilute in the ratio of 1 to 4 with water, that is, 1 quart of concentrate to 4 quarts of water. The addition of rosin makes emulsification more difficult; therefore, operators must agitate more thoroughly and be on guard against separation of the liquids. Extra care is required in the cleaning of spraying equipment to avoid clogging of the nozzles.

Based on the results of the preliminary tests, the use of the new adhesive sprays is recommended wherever there is need for applying residuals to exterior surfaces only. Sprays containing the rosin sticker leave an objectionable shiny deposit, therefore, SUCH FORMULATIONS ARE NOT RECOMMENDED FOR USE INDOORS OR IN LOCATIONS WHERE APPEARANCE IS A FACTOR.

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