PEST CONTROL

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Insects that affect the health of dairy cattle or are of importance in milk hygiene fall into two main groups. In the first group are those insects that lead a parasitic life, infesting the host animals continuously for long periods, and those that live out of doors and visit cattle briefly to feed. In large measure these parasitic or free-living forms are controlled by application of insecticides to the cattle.

The other group is made up of insects that infest farm buildings. Some of them annoy cattle in barns or sheds or in lots close to farm buildings; others do not attack the cattle directly but spread filth and thereby contaminate milk and dairy products. Control of this group of insects is accomplished largely by treating the premises rather than the cattle.

It cannot be emphasized too strongly that the best means of pest control is to prevent breeding through sanitation, whenever this method is feasible; but in practice satisfactory pest control often requires the application of insecticides. Since the treatment of animals presents an entirely different problem from the treatment of premises, these two approaches are considered separately.

PEST CONTROL ON ANIMALS

Cattle Grubs

Cattle grubs or heel flies (*Hypoderma bovis* (L.) and *H. lineatum* (De Vill.)) are the most damaging insects affecting dairy cattle in temperate regions of the world. In northern areas where winters are severe both species are found, but in southern areas only *lineatum* infests cattle.

Cattle grubs cause losses in three ways. During the spring when the flies are ovipositing they cause panic in the gentlest animals. The flies have vestigial mouth parts and cannot bite, but as they approach to oviposit,

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their buzzing frightens cattle into stampeding. The flies pursue them, and cattle may run until they are exhausted or they may injure themselves in their attempts to escape the insects. Frequently cattle wade into ponds or streams and stand in the water for hours without feeding. This reaction is caused chiefly by *H. bovis*, the northern heel fly, which strikes an animal repeatedly, gluing one egg at a time to the hair. *H. lineatum*, the common heel fly, will sometimes chase animals and cause them to panic, but it will also approach sleeping animals and lay its eggs on any portion of the body near the ground without disturbing the host.

Upon hatching, the larvae penetrate the skin and live within the body of the host for approximately six months. Apparently first-instar larvae of *lineatum* do little measurable damage, as they live within the loose connective tissue of the viscera, chiefly the gullet, and feed on lymph rather than blood. First-instar larvae of *bovis* usually do little apparent damage, but they invade the spinal column and sometimes injure nerves, causing paralysis. In the fall and early winter the first-instar larvae complete their growth within the body, then migrate to the back and cut holes through the hide with their mouth parts. Here they moult (shed their skins) and transform to the second instar. The second- and third-instar larvae spend about a month in the back and then crawl out of the cysts and fall to the ground, where they crawl under any loose material to pupate and transform to adults.

While the larvae are growing in the back, they enlarge the cysts and the holes in the hide through which they obtain air. The grubs produce an antibacterial substance, but occasionally bacteria from outside invade the cysts and form large pus pockets. The larval infestation and the bacterial growth cause much discomfort and reduce milk production.

A standard treatment for cattle grub control has been to kill the second- and third-instar larvae by applying rotenone to the back. The cattle are usually sprayed at monthly intervals with a suspension of 7.5 pounds of 5 % rotenone powder in 100 US gallons of water (or about 4 kg of powder in 375 l). The same mixture may also be applied by scrubbing the backs of the cattle with a brush to force some of the insecticide into the cysts (see Fig. 1). Still another method is to rub the dry 5 % dust into the hair of the back, using care to push dust particles into the breathing holes cut by the grubs (see Fig. 2).

There are many objections to these treatment methods. Usually the weather is cold when grubs are in the back, and wetting the animals in the winter is undesirable. When large numbers of cattle are involved, the labour cost of rubbing dry dust in by hand is sometimes prohibitive. Also, the grubs killed by rotenone die and putrefy within the cyst. Some animals react severely to the dead grubs, and some dairymen consider that less harm is suffered if the grubs are allowed to complete their growth and crawl out.

FIG. 1
SCRUBBING ROTENONE SUSPENSION ON BACK OF COW FOR GRUBS

FIG. 2
RUBBING 5% ROTENONE ON BACK OF COW FOR GRUBS

When there are only a few infested cattle or labour is inexpensive, an alternative method of control may be to squeeze out the living grubs by hand. However, the process is painful to the cattle and unpleasant for the operator.

The methods described above are the only ones recommended for lactating dairy cows in the USA when their milk is being used for human consumption.

Two organophosphorus insecticides, ronnel (O,O-dimethyl O-(2,4,5-trichlorophenyl)phosphorothioate) and O-(3-chloro-4-methylumbelliferone) O,O-diethylphosphorothioate (sold under the trade name Co-Ral, and also known as Bayer 21/199) have been found to be much superior to rotenone for practical grub control. Ronnel is given as a drench or bolus at 100 mg/kg, and Co-Ral is applied as a 0.5 % spray in sufficient quantity to wet the animals to the skin. Either treatment is made only once, between the end of the heel fly season in the summer and before grubs start migrating to the backs in the fall. The treatments are about 90 % effective in destroying first-instar larvae within the body of the host before they do any apparent harm. Unfortunately, both insecticides appear in the milk for a time after administration and in the USA, where no tolerance has been established, they cannot be recommended for lactating cows or for dry cows due to be milked within 60 days. They should not be used on baby calves, but they can be recommended for heifers which are more than three months old but not old enough for milking within the next 60 days.

Botflies

In the American tropics cattle grubs are not a problem, but a related insect, the human botfly (*Dermatobia hominis* (L.)), is even more damaging to cattle than are grubs in the temperate zone. This botfly captures such insects as biting flies or mosquitos and glues its eggs to their bodies. When the egg-bearing flies or mosquitos visit any warm-blooded animal, the larvae hatch from the eggs and penetrate the skin of the host, where they make sores much like cattle-grub cysts. A cow may have hundreds of larvae growing in these painful sores over all parts of the body. There are several generations per year, but the infestations are most severe following periods of mosquito abundance.

There are two approaches to the control of this botfly. One is to apply chemicals to repel or kill mosquitos and thus prevent infestation. Occasional treatment with toxaphene and DDT have been reported as valuable for reducing mosquito populations in beef herds. Where regulations forbid the use of chlorinated hydrocarbon insecticides on dairy cattle, daily applications of pyrethrum sprays may be used.

During the last few years research workers have reported on successful experiments with ronnel and Co-Ral applied in the same manner as for

cattle-grub control, and several other systemic insecticides have been found promising in small-scale tests. These organophosphorus compounds do cause slight milk contamination, but it would still seem desirable to use them and discard the milk for a few days after treatment. In livestock-raising areas, cattle are the source of breeding most of the human botflies; so it is desirable to prevent breeding in both meat and milk animals.

Ticks

Many species of tick attack dairy cattle. In the USA the most important belong to the genera *Amblyomma*, *Dermacentor*, and *Ixodes*, but from the world-wide standpoint, ticks of the genus *Boophilus* are of greatest concern, since they are the vectors of Texas fever, or piroplasmosis. The cattle tick (*Boophilus annulatus* (Say)), has been eradicated from the USA except for a small area along the Mexican border, and is kept out of the country by quarantine measures. This species is common in Mexico, and the tropical variety, *Boophilus microplus* (Can.), is common in Australia, South America, Asia, and Africa.

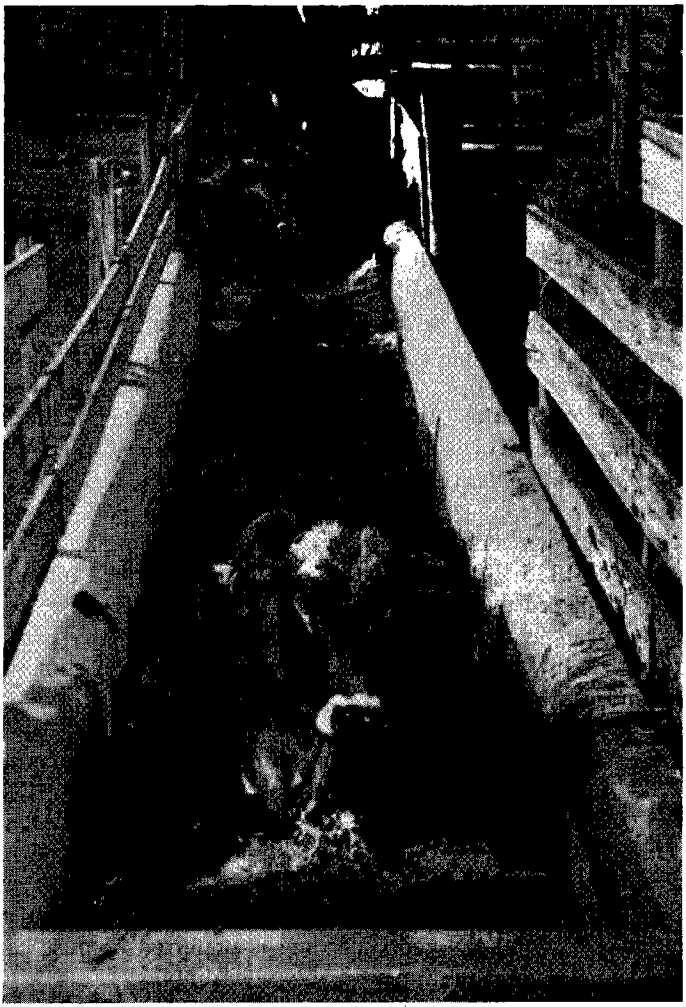
The cattle tick was eradicated from the USA by dipping cattle in an arsenic solution (0.175 %-0.19 % As_2O_3). This old-fashioned treatment has been largely displaced by modern insecticides, but it is still used by many regulatory agencies in connexion with quarantines. In many parts of the world where this dip has been used extensively, ticks have become resistant to arsenic, and the treatment is now ineffective.

For the past ten years the most generally used control for cattle ticks has been to spray or dip cattle in a chlorinated hydrocarbon insecticide (see Fig. 3). Toxaphene (chlorinated camphene containing 67 %-69 % of chlorine) at 0.5 % and 0.5 % DDT (2,2-*bis*-(*p*-chlorophenyl)-1,1,1-trichloroethane) plus 0.03 % gamma-BHC (gamma-isomer of 1,2,3,4,5,6-hexachlorocyclohexane) have been very popular. Dipping is essential in eradication efforts in order to ensure that every tick is reached; but for practical control, where eradication is not the goal, spraying is preferred because cattle are often injured by the rough treatment involved in dipping.

In recent years the fever ticks in many countries have become resistant to the chlorinated hydrocarbon insecticides, and these are being displaced by organophosphorus compounds. At present sprays or dips containing 0.25 %-0.5 % of Co-Ral, 0.15 % of 2,3-*p*-dioxanedithiol S,S-*bis*(O,O-diethylphosphorodithioate) (sold under the trade name of Delnav), or 0.75 % of ronnel are reported to be effective against ticks resistant to arsenic or chlorinated hydrocarbons.

In many countries where piroplasmosis is not a problem two other cattle diseases are caused by ticks. Several species of tick are vectors of anaplasmosis, and tick paralysis is a direct reaction to tick bites.

FIG. 3
DIPPING CATTLE FOR FEVER TICKS



Because the chlorinated hydrocarbon insecticides cause detectable milk contamination, and in the USA there are no tolerances for insecticide residues in milk, the only treatment substances currently recommended for controlling ticks on lactating dairy animals are rotenone and pyrethrum sprays. However, these substances are expensive and have poor residual effectiveness, and where milk contamination is not involved, the chlorinated hydrocarbons or organophosphorus insecticides are recommended as being vastly superior.

Horn Flies

The horn fly (*Syphona irritans* (L.)) is a major pest of dairy cattle. The flies live on cattle almost continuously, leaving them only to oviposit on fresh droppings. Since these droppings are scattered over entire pastures, it is impracticable to prevent breeding in the manure by sanitary procedures. Therefore, the use of insecticides is essential.

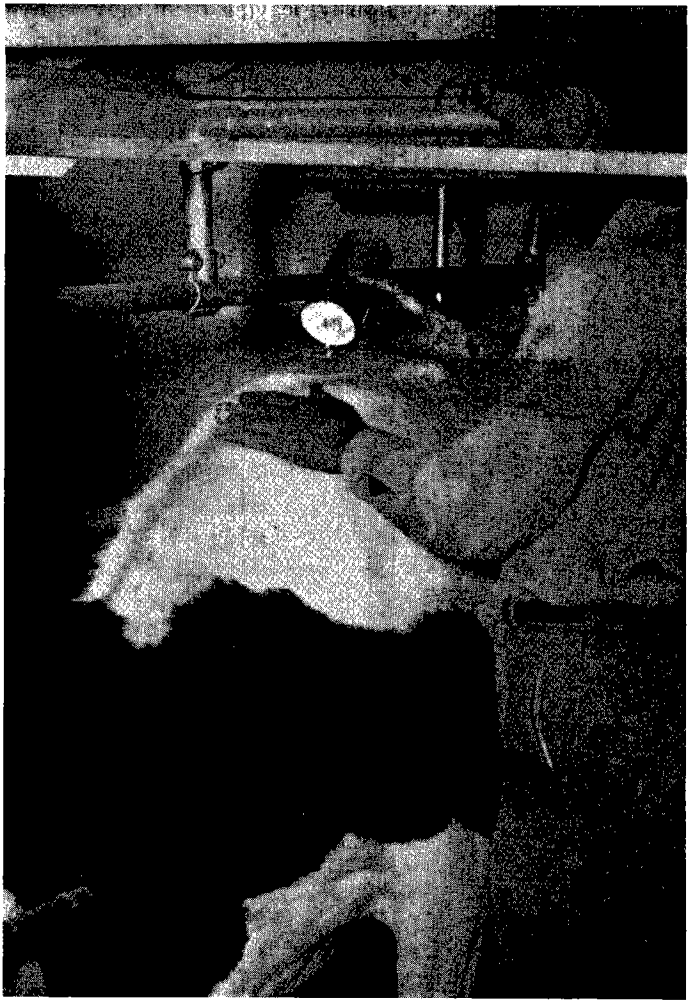
In the USA, where regulations concerning milk contamination are stringent, the only treatments at present recommended are: (1) mist sprays of 3 %-5 % of an organic thiocyanate as an oil solution, or 1 % of pyrethrins plus 10 % of a synergist, as an oil solution or emulsifiable concentrate,

FIG. 4
WET SPRAY WITH TWO-GALLON SPRAYER FOR HORN FLIES

applied once or twice daily at 1-2 US fluid ounces (about 30-60 ml) per animal; (2) water-base sprays containing 0.05 % of pyrethrins plus 0.5 % of a synergist applied at 1 or 2 quarts (about 1 or 2 l) per animal every 3-7 days (see Fig. 4); (3) methoxychlor (2,2-*bis*-(*p*-methoxyphenyl) 1,1,1-trichloroethane) dusted by hand over the back at the rate of 1 tablespoonful of 50 % powder per animal every three weeks (see Fig. 5).

In areas where health authorities do not object to the small amounts of methoxychlor that appear temporarily in milk following the use of sprays, an economical method of treatment for horn flies is to spray dairy cattle

FIG. 5
SPRINKLING METHOXYCHLOR WETTABLE POWDER ON BACK OF COW FOR HORN FLIES



with 0.5 % methoxychlor at the rate of 2 quarts per animal. This treatment protects the animals from reinfestation for about three weeks. DDT and toxaphene at 0.5 % similarly applied are equally effective, but the contamination of milk is greater than with methoxychlor. The organophosphorus insecticides, Co-Ral at 0.25 %-0.5 %, ronnel at 0.5 %, Delnav at 0.15 %, and malathion (S-(1,2-diethoxycarbonylethyl)-O,O-dimethyl phosphorodithioate) at 0.5 % are all excellent in sprays with residual effects of a week or longer.

Stable Flies

Stable flies (*Stomoxys calcitrans* (L.)) are as common as horn flies and much more difficult to control with chemicals. Around dairies stable flies breed in decomposing organic matter, such as spilled feed under the troughs and wet hay or straw bedding. In such situations the best control is proper sanitation. In addition it is often necessary to apply residual sprays to the surfaces of farm buildings where the flies rest between attacks on cattle. These treatments are described in detail in the section on pest control in farm buildings.

Stable flies are strong fliers. Many of them invade dairy premises from breeding sites beyond the control of the dairymen, and chemical treatment of the animals becomes essential. The only approved treatments are pyrethrum and organic thiocyanate sprays used as recommended for horn fly control. Since stable flies prefer to feed on the lower parts of the body, special attention should be given to the legs and belly. If cattle walk through wet grass or wade through mud and water, treatment may be needed twice daily.

Mosquitos

Mosquitos can cause considerable damage to livestock. Where breeding is uncontrolled—such as near salt marshes producing myriads of *Aëdes*, or in freshwater pastures flooded by melting snow, overflowing rivers, or heavy rain—mosquitos may attack cattle in such numbers as to kill them in a single night. The organophosphorus and chlorinated hydrocarbon insecticides cannot be recommended, for two reasons. First there is the constant problem of residues in milk, but even more important is the fact that they do not protect cattle attacked by millions of mosquitos since they do not kill the insects fast enough to prevent them from feeding. The only treatment substances known to be effective are sprays of pyrethrum or thiocyanates. When freshly applied, these insecticides are both toxic and repellent to mosquitos.

Horse-Flies and Deer Flies

Many species of the family Tabanidae, known as horse-flies and deer flies, attack dairy cattle. The larvae may be aquatic, some species are found along shore lines, and still others breed in well-drained upland pastures. Generally they breed over such huge acreages that the dairyman is helpless to prevent breeding and his only recourse is to protect cattle from the flies. When " outbreaks " of tabanids occur, cattle left unprotected in pastures may be killed through loss of blood from the slashing bites of the flies. Even when the flies are not present in outbreak numbers, the bites are so painful that even a few insects can cause the cattle to group together and

stop feeding, with a resultant loss of milk production. Because horse-flies and deer flies go from animal to animal as they feed, the damage they do as vectors of anaplasmosis can be more serious than the annoyance caused by their feeding.

When tabanid outbreaks occur, dairymen may find it necessary to confine their cattle in barns all day, and pasture them only at night. Some dairymen, lacking barns, may resort to smudge fires; the cattle seek out the smoke, which repels the flies. The only insecticides that can be recommended are the pyrethrum and thiocyanate sprays. The residual organic insecticides are not repellent and kill the flies too slowly to prevent attacks.

Lice

Five species of louse commonly attack dairy cattle. One is a biting louse, which obtains its food by chewing hair and particles of skin, and the others suck blood.

The cattle-biting louse (*Bovicola bovis* (L.)) is common in late spring and early summer, and if treatment is neglected millions may be found on a single animal. They have been known to kill calves, and infestations are commonly severe enough to stunt calves and reduce the milk flow in producing cows.

Two sucking lice, *Linognathus vituli* (L.) and *Solenopotes capillatus* (End.), attack both cattle and calves, but they are most common on calves, and are popularly called blue lice. In the summertime calves may be covered with huge patches of blue lice.

The most common louse infesting cattle is the short-nosed louse (*Haematopinus eurysternus* (Nitz.)). Severe infestations may so exsanguinate the cattle that they die of anaemia. Although this insect is usually present in damaging numbers only in the winter and spring, some cattle may be unusually susceptible hosts and may support heavy infestations the year round.

The cattle-tail louse (*Haematopinus quadripertusus* Fahrenh.) occurs most abundantly in the switch of the tail, but when herds are heavily infested it may be found upon other parts of the body.

Cattle lice on calves and dry cows are easily controlled with a number of organic insecticides. DDT at 0.5 % used as a spray or dip to wet the entire body has shown outstanding effectiveness all over the world, but is no longer recommended in the USA because it contaminates fat in excess of the tolerance established for beef animals.

Methoxychlor and toxaphene are safe to use as 0.5 % sprays or dips on non-lactating animals, and one treatment will usually eradicate an infestation. The tail louse is more difficult than the other species to control and twice the usual concentrations of insecticides may be required for this species.

Gamma-BHC at 0.05 % will also kill motile lice, but it has little residual effect, and treatment must be repeated after the eggs hatch.

There is evidence that in some areas lice are developing resistance to chlorinated hydrocarbon insecticides. Fortunately, organophosphorus insecticides are also effective. Malathion at 0.5 % in a spray or dip kills all the lice on an animal, but the residual effect may not last through the incubation period of eggs; a second treatment after three weeks may therefore be necessary.

Co-Ral and ronnel at 0.5 % and Delnav at 0.15 % all control lice when used in sprays or dips to wet the animals thoroughly. Their residual toxicity may not be sufficient to kill nymphs hatching from eggs; therefore the cattle should be examined after two or three weeks, and if lice are found, the treatment should be repeated promptly to kill them before they are old enough to oviposit.

These chemicals are recommended only for calves and dry cows because of the milk contamination hazard. In the USA the insecticide recommended for lactating cows is rotenone, as a 0.5 %-1 % dust rubbed into the hair, or as a spray containing 1 pound of 5 % powder to 50 US gallons of water (or about 500 g of powder in 200 l of water).

Pyrethrum also kills lice, but it must be used in a water-base spray, since mist sprays of oil solutions do not penetrate the hair. The water-base spray should contain 0.05 % of pyrethrins or 0.025 % of pyrethrins plus 0.25 % of a synergist, and should be applied so as to wet the animals to the skin. Both pyrethrum and rotenone must be applied again after two or three weeks, since they are lacking in residual effect and the nymphs hatching from eggs must be killed.

Screw-Worms

Screw-worms (*Callitroga hominovorax* (Cqrl.)) are severe pests in cattle in tropical and subtropical areas of the western hemisphere. During the summer screw-worm flies migrate into the adjacent temperate zones to infest animals. The flies lay their eggs on any abrasions, such as cuts or scratches, and also on sores caused by ticks and horn flies. Infestations are most common in the navels of new-born animals.

Insecticide treatment is essential when screw-worms are present. If left untreated, the infested animals would be literally eaten alive.

For calves and dry cows, very effective treatment methods are wound dressings containing 3 % of Co-Ral or 5 % of ronnel, or sprays containing 0.25 % of Co-Ral or 1 % of ronnel directed into the wound and used to wet the surrounding hair. Calves less than three months old should not be treated over the entire body, but such treatment on older calves usually protects them from reinfestation for three weeks or longer. An application of a phosphorus insecticide merely to treat a wound and its adjacent

FIG. 6
APPLYING EQ-335 SMEAR WITH BRUSH FOR SCREW-WORMS

area needs to be repeated at about weekly intervals until the wound is healed.

Because of the milk contamination hazard, the phosphorus insecticides are not recommended for lactating cows. Wounds on these animals should be treated with a dressing such as EQ-335, which contains 3 % gamma-BHC, 35 % pine oil, 42 % mineral oil, 10 % silica aerogel and 10 % of an emulsifier; or smear 62, which contains 35 % diphenylamine, 35 % benzene, 10 % turkey red oil and 20 % lampblack. The dressing should be applied twice weekly until the wounds heal (see Fig. 6). If a gamma-BHC dressing is used on the navel of a newborn calf, only the minimum amount should be applied because of the hazard of toxicity to the calf.

PEST CONTROL IN FARM BUILDINGS

Insects Causing Hygiene Problems

Flies are the most important filth pests in and around animal shelters and milk barns. One or more species of the genus *Musca*, commonly called houseflies, can usually be found in abundance in most parts of the world, and all are efficient carriers of disease organisms. A number of other muscoid flies—such as *Fannia* spp., *Muscina* spp., and blow-flies—

may be important in some localities. Biting flies of the genus *Stomoxys* often cause severe annoyance to animals while in buildings. Various species of cockroach abound in farm buildings in some regions and may constitute a milk-hygiene problem.

Houseflies breed in moist, decaying organic matter, including manure, straw, spilled feed, and garbage. As all flies do, they pass through four development stages—egg, larva, pupa, and adult. The eggs are usually laid in clusters of several hundred, and a single female may lay as many as 2700 eggs over a period of 30 days. They usually hatch in 10-24 hours. The whitish larvae, or maggots, feed beneath the surface of the material in which they hatch until they are fully grown, usually about 4-10 days. They then crawl to the surface and, if it is dry enough, they may pupate there. If the surface is too wet, they will crawl to a more suitable place. The reddish-brown, barrel-shaped pupal stage lasts for from three days to a month or more, depending on the temperature, after which the adult flies emerge. Mating occurs within a few days of emergence, and the females usually start laying eggs in 4-12 days. There may be as many as twelve generations a year.

Houseflies frequent such filthy materials as manure, human faeces, and sputum, from which they may transport pathogenic organisms to milk or milking equipment. These organisms may be carried on the feet or hairy legs of the flies or deposited in the excreta. Moreover, flies regurgitate a part of the stomach contents on to the surface where they are feeding, and this may cause heavy contamination.

They may carry the organisms of typhoid, dysentery, cholera, tuberculosis, and yaws; in fact, they carry most diseases that can be spread by mechanical contamination.

Fannia and *Muscina* are similar to houseflies in their breeding-places and habits, and they may carry the same diseases. However, they are less widespread and usually less abundant than houseflies and play a proportionally less important part in hygiene problems.

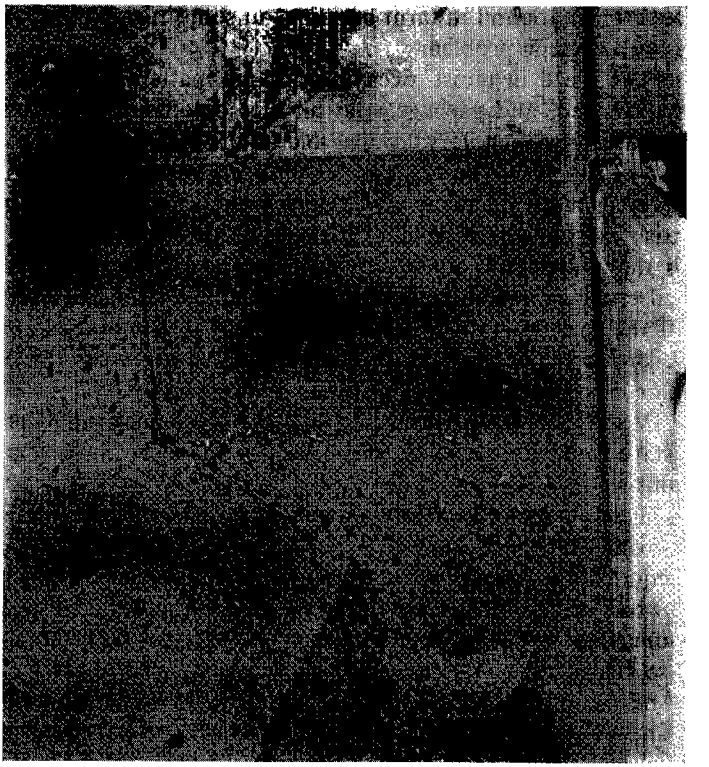
Stomoxys seldom breeds in dense manure, but will breed readily in manure mixed with straw, in rotting hay, peanut litter, strippings from celery or other vegetables, and even in wind-rows of seaweed along beaches. It may cause some contamination of milk or milk utensils, but is of most importance in barns because of its annoyance to man and animals during milking.

Blow-flies vary widely in their breeding habits. The larvae of some species live in excrement, others in carrion, and others in mixed organic material. In some localities they may be abundant enough to cause a hygiene problem.

Cockroaches are less conspicuous than flies because they hide during the hours of daylight. Heavy infestations may therefore occur in barns, especially where feed is stored, without attracting much attention (see Fig. 7).

FIG. 7

PERIPLANETA SPP. FEEDING, PHOTOGRAPHED BY NIGHT



The insects are feeding on food left overnight in a feed trough—a practice conducive to increased cockroach infestations. During the daytime cockroaches will hide in the pipes of milking stanchions, in feed-storage rooms, inside walls and attics of dairy barns, and in debris near the barns.

They are a menace to proper hygiene, however, since they travel from excrement to animal feed, milk, or utensils in the same manner as flies. Although cockroaches have rarely been proved to be connected with particular outbreaks of disease, their microbe-carrying ability has been repeatedly demonstrated experimentally.

Cockroaches pass through three developmental stages—egg, nymph, and adult. The eggs are deposited in a chitinous capsule, the ootheca, which may be carried about by the female until the eggs hatch, stuck to a wall or other surface, or simply dropped in a protected place. The nymphs are similar to the adults in appearance except for smaller size and the absence of wings. They moult several times before emerging as adults. Nymphs and adults feed on many materials, including almost all types of organic matter. The

time required for development varies widely with the species, ranging from six weeks to more than a year for a complete generation.

Sanitation

Sanitation is the first and most important step in the control of insect pests, despite recent advances in the use of insecticides. Sanitation will be much easier if the barns and holding pens are properly located and constructed. They should be situated on the highest available ground, so that neither rain nor subsurface water will collect and create conditions favourable for fly breeding. Good drainage is essential and is more easily achieved on high than on low ground. Concrete floors in barns are also essential to the best sanitation. Properly designed concrete floors improve drainage and make cleaning easier. Keeping the soil of holding pens or corrals dry and hard-packed will also help to minimize fly breeding. Where the soil is moist or the drainage poor, 4-6 inches (10-15 cm) of gravel on the ground-surface of the holding pens will create a fairly hard surface in which few flies will breed, provided wastes are raked up and disposed of regularly.

The most important sanitation step in fly control is the proper disposal of manure. If possible, manure should be removed daily from barns and scattered on fields, spread thinly so that it will become too dry to support fly-breeding. If this is impracticable, the manure should be stored in boxes or pits where flies are unable to reach it. Boxes or pits made of concrete are the most satisfactory. Another method is to pile the manure in a rectangular stack, preferably on a concrete base. The manure should be packed down with a spade and the sides of the stack made vertical. A ditch should be dug around the stack and filled with crude oil. Heat generated in the tightly packed manure will kill many maggots and drive the others to the surface, from which they will fall into the oil-filled ditch and be killed.

Spilled feed, vegetable refuse, and garbage should not be allowed to accumulate in the open, as they provide breeding-places for flies and food for cockroaches. Such materials should be cleaned up promptly and kept in tightly closed containers until they can be burned or buried. Damp straw, hay, and other vegetable refuse should be eliminated to prevent *Stomoxys* breeding, and carrion should be eliminated to prevent blow-fly breeding. In some regions privies may require attention to prevent blow-fly breeding. Trash should not be allowed to accumulate, as it provides harbourage for cockroaches.

Screens and Electric Grids

Well-fitting screens on windows and doors assist in keeping flies out of barns and milk-rooms. Screened doors should swing outwards. Screens of copper, bronze, aluminium, plastic, or one of the rust-resistant alloys

should be used in humid climates, but galvanized screens are satisfactory in dry climates. Screens with 14 meshes to the inch will keep out houseflies, but finer screens will also keep out some other insects.

Electric grids, mounted in the open or attached to windows and doors, help in the elimination of flies. They consist of parallel wires, about 1/4 inch (or 6 mm) apart, connected to a high-voltage, low-amperage circuit, which electrocute flies that land or try to pass through. Flies can be attracted to the grids with a bait, such as molasses, milk, or fruit waste.

Insecticides

Some use of insecticides may be needed to maintain a high degree of pest control, since some breeding will probably occur despite the best efforts at sanitation. Insecticides may be used as residual applications in sprays or dusts, as space or contact sprays, in baits, and in ribbons or cords. In many areas flies have become highly resistant to some of the best insecticides, which greatly complicates the problem of control. Some countries restrict the kinds of insecticides that may be used in dairy barns or other situations where they might contaminate milk.

Residual applications

Residual treatments provide the best control of flies where the problem is not complicated by resistance. Sprays may consist of a solution of the insecticide in deodorized kerosene, an emulsion made by adding an emulsifiable concentrate to water, or a suspension of a wettable powder in water. The sprays should be applied to all surfaces where the flies settle—not only the walls and ceilings of the dairy barns themselves, but also the surrounding vegetation, other barns, stables, sheds, pig pens, poultry houses, fences, and garbage cans. The surfaces should be wet to the point of run-off. The amount will vary with the type of surface and the formulation. Usually 1-2 US gallons per 1000 square feet (or 4-8 l per 100 m^2) will be required.

DDT is the most effective insecticide in areas where flies have not become resistant to it. Emulsions or suspensions containing 5 % of DDT will provide residues that control flies for several weeks or months. However, after DDT was found in the milk of cows kept in treated barns, it was no longer approved for use in the USA in dairy barns or other situations where it might contaminate milk or food. It can be used, however, in other farm buildings and out of doors. When flies have become resistant to DDT, other insecticides must be used.

Gamma-BHC at 0.5 %, methoxychlor at 5 %, chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane) at 2%, or toxaphene at 5 % in emulsions or suspensions, may also be used as residual insecticides. Their residual action is not as long as that of DDT. In the USA chlordane and toxaphene are not approved for use in dairy barns because of residues

in milk; gamma-BHC and methoxychlor may be used in some parts of dairy barns but not in milk-rooms. All these insecticides usually give control of DDT-resistant flies for a few years, but, like DDT, they are chlorinated hydrocarbons and DDT-resistant flies become resistant to them also.

A number of organophosphorus insecticides have given control of flies that were resistant to the chlorinated hydrocarbons, but in some countries flies have also become resistant to these insecticides. Their residual action is not as prolonged as that of DDT. Those that have been approved for use in parts of dairy barns, but not in milk-rooms, in the USA include malathion, ronnel, and diazinon (O,O-diethyl O-(2-isopropyl-4-methyl-pyrimidinyl-6) thiophosphate at 1 % in emulsions or suspensions. In some countries Co-Ral and other compounds have also been used successfully.

Attempts have been made to lengthen the period of control obtained with the organophosphorus insecticides by adding 2.5 %-5 % of sugar to

FIG. 8
TREATMENT OF COCKROACH HIDING-PLACES

In spraying for the control of cockroaches it is necessary to treat the hiding-places. An inspection with a flashlight has shown these hollow stanchion pipes to be heavily infested.

the sprays. Although this has extended the effectiveness of deposits under some conditions, it has not been uniformly successful, the added periods of protection have usually been short, and it has caused mould to grow on the treated walls under warm, humid conditions. The use of sugar in this way is not at present recommended by the US Department of Agriculture.

Insecticides applied for the control of houseflies will kill many cockroaches, but for the best results residual insecticides should be applied to their harbourages. To find the harbourages it may be necessary to move objects next to walls, and to search behind and below hard-to-move objects with a flashlight (see Fig. 8). Very heavy infestations often occur inside hollow walls if any access holes are available. A careful search at night, with a light, will often reveal infestations many times more heavy than suspected from a daytime inspection. It will ordinarily be necessary, as a minimum, to spray the floors, walls up to about 1 metre, baseboards, and under and around feed-troughs and cabinets.

The best residual insecticide for the control of cockroaches is chlordane, but its use in dairy barns is restricted. Gamma-BHC may be used in places where chlordane is not approved, but the residual effect does not last as long. In the USA one species, *Blattella germanica* (L.), has become resistant to these insecticides, and malathion or diazinon are employed as substitutes. Malathion should be used at 2 % and diazinon at 0.5 % in an emulsion, suspension, or oil solution. They may also be applied as dusts in situations where the visible residue is not objectionable, will not be removed by cleaning operations, and will not contaminate milk or feed. Sodium fluoride applied as a dust will also control cockroaches, but it is less effective than the other materials, must be applied more heavily, and must be handled carefully because of its hazard to warm-blooded animals.

Space sprays

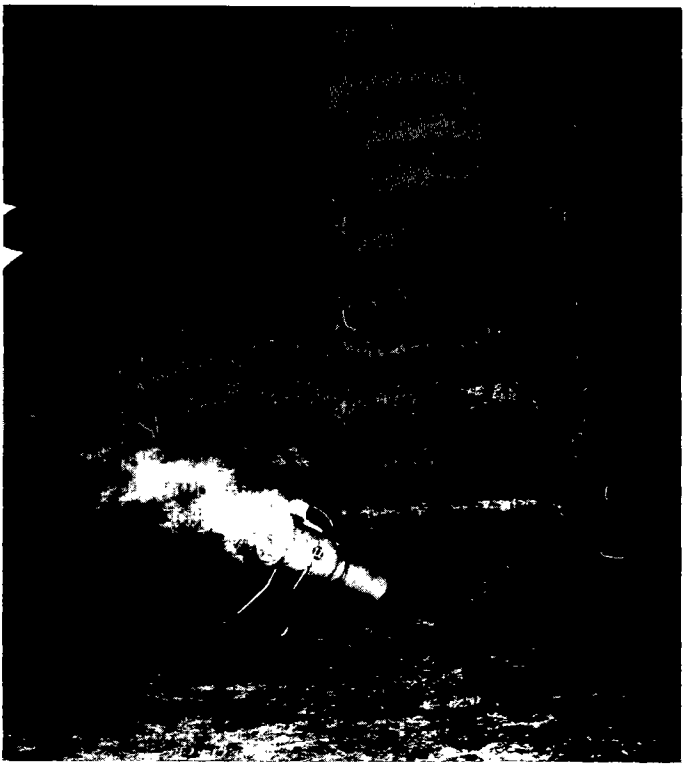
Space sprays generated with hand or power sprayers or aerosol dispensers are employed to kill the flies that are active in barns at the time of treatment. They are released in finely divided mists or aerosols that remain suspended in the air for an appreciable period and permeate all the space in the barns (see Fig. 9). They have little or no residual action and must be applied daily to maintain good control. They are not effective in open barns. The insecticide most widely used is pyrethrum at 0.1 %-0.2 %, together with 1 %-2 % of a synergist such as *n*-propyl isome, piperonyl butoxide or sesame oil.

Space sprays rarely give satisfactory control of cockroaches.

Baits

Poisoned baits control houseflies in some places where sprays fail, including unscreened dairy barns in some regions. If properly applied they

FIG. 9
SPACE-SPRAYING



An electrically driven generator produces a space spray by mechanically breaking the insecticide solution into an ultrafine mist or aerosol.

can be used in most farm buildings without harming animals or contaminating milk. They may be applied as scattered dry or liquid baits, as paint-on baits, or in bait stations.

Commercial ready-to-use baits are satisfactory and convenient; if they are not available baits can be made with emulsifiable concentrates or wettable powders of malathion, diazinon, ronnel, DDVP (2,2-dichlorovinyl dimethyl phosphate) or O,O-dimethyl 2,2,2-trichloro-1-hydroxyethylphosphonate (sold under the trade name of Dipterex).

Liquid baits are made by mixing 10 % of sugar, molasses, or syrup and 0.1 %-0.2 % of the insecticide with water. A convenient dry bait is made by mixing 1 %-2 % of the insecticide with dry sugar; it is well to add a little lampblack so that the bait will not be mistaken for ordinary sugar.

A cornmeal bait is recommended for use on moist surfaces, where a dry sugar bait would dissolve. While stirring 1 pound (450 g) of coarsely ground cornmeal, slowly add 1 tablespoonful of peanut oil, 6 tablespoonfuls of a

25 % wettable powder or 3 tablespoonfuls of a 25 % emulsifiable concentrate of the insecticide, and 2 ounces (55 g) of powdered sugar. Stir with a paddle until all the meal particles are coated. Five minutes' stirring ensures proper mixing of 1-5 pounds. Mixing of larger quantities by hand is not recommended.

The effectiveness of baits depends largely on the selection of the most suitable formulation and its proper application. It is necessary to determine where the flies are feeding and congregating and to apply the baits liberally in such places. The sweetening agents are not powerful attractants, and the baits must be so well distributed that the flies will not fail to find them. Once found, the flies feed on them eagerly. The poisons act very quickly, and spectacular immediate kills are often seen, but it is usually necessary to make daily applications for several weeks until fly-breeding in the area has been greatly reduced. Thereafter applications twice a week may be sufficient, but if infestations increase daily applications should be resumed.

Ready-to-use baits should be applied according to the directions on the container. Home-made liquid baits should be applied with an ordinary sprinkling can. It is well to plug about half the holes so that the bait will be spread thinly in strips 4-6 inches (10-15 cm) wide. Liquid baits are particularly good for application to concrete floors where flies gather and feed. Ordinarily about 1 US gallon per 1000 square feet (4 l per 100 m^2) is sufficient, but if infestations are very heavy larger quantities may be needed. On floors or other surfaces covered with dirt or litter, the bait should be sprinkled on sheets of tin, wood, paper, or other material. Liquid baits should be applied daily until breeding has been controlled, usually after 2 or 3 weeks; semi-weekly treatments may be adequate thereafter.

Dry sugar bait may be applied conveniently from a shaker-top can or glass jar, and should be sprinkled in narrow strips on floors, walkways, window sills, and other places where flies gather. It is a particularly good formulation for use in feed-storage rooms, but care must be taken not to contaminate the feed. This bait should be used only on dry, firm surfaces. On loose materials, such as straw, the bait may fall where flies cannot get it. About 2 ounces per 1000 square feet (60 g per 100 m^2) is generally sufficient, but if flies are very numerous more may be needed.

Cornmeal bait is useful on slightly moist surfaces where sugar bait would melt and on dry surfaces as well. It should be applied about twice as heavily as the sugar bait.

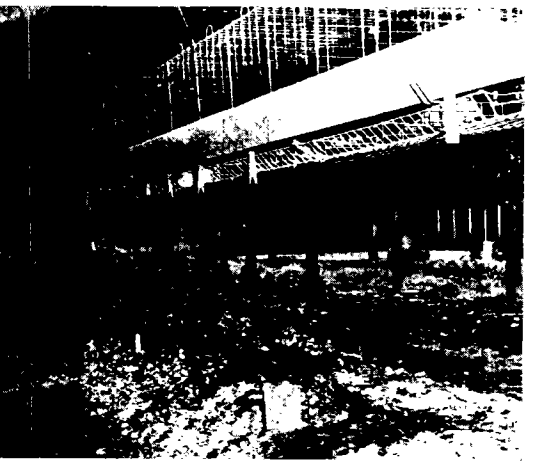
Houseflies in dairy barns may come from near-by pig pens, calf pens, or poultry houses. Neither a dry bait nor a liquid bait gives good control of flies in animal pens in which the ground is muddy, trampled, or littered. A paint-on bait is often effective in these places (see Fig. 10 B). It is applied with a paint-brush to fly resting-places near by, such as posts, railings, or the outer surfaces of fences, where animals cannot lick it. It may also be

FIG. 10

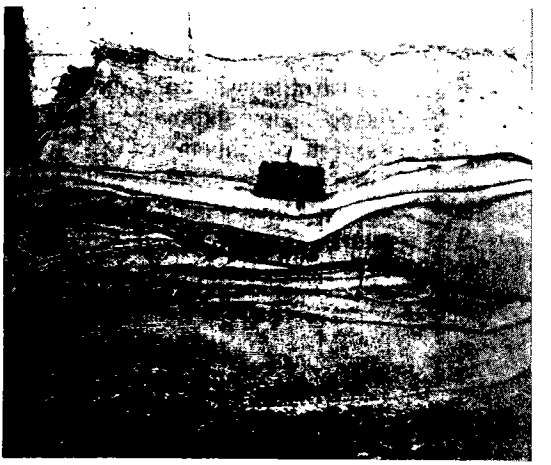
USE OF BAIT STATIONS AND PAINT-ON BAITS FOR THE CONTROL OF FLIES

A

B



C



D

E

A: Bait stations should be well distributed through barns at places where flies are observed to feed or congregate.

B: Paint-on baits are useful where the ground is muddy or littered, but must be carefully placed so that animals cannot lick them.

C: When flies invade dairy barns from nearby poultry houses, bait stations set in the manure may provide control.

D: Houseflies are gathering on this bait station 10 minutes after exposure, even though the barn is well kept.

E: Myriads of dead flies accumulated around 7 bait stations in 48 hours in an unsanitary barn.

used in barns, applied to window frames, on ceilings around electric lights, or in other spots where flies like to rest. Molasses, corn syrup, or a thick sugar-and-water slurry containing 1 %-2 % of the insecticide makes a satisfactory paint-on bait. In open areas paint-on baits will remain effective for a week or more if not destroyed by rain.

Bait stations are useful for the control of flies gathering on manure or muddy surfaces. They are especially suitable for the treatment of accumulations of manure under caged poultry, if the flies in the dairy barns are coming from such locations, and have some advantages for use inside the barns.

A convenient bait station consists of a paddle made by fastening a 4-inch (10-cm) square of screen wire to a slender wooden handle about 6 inches (15 cm) long. The wire is coated with a bait containing 50 % sugar, 46 % sand, 2 % insecticide, and 2 % gelatine or, better yet, Bacto agar. The sugar is first mixed thoroughly with the sand. Boiling water is then poured slowly over the gelatine or agar, while it is stirred, until it has absorbed as much as it will hold and starts to liquefy. The liquid is poured over the sand-sugar mixture and stirred thoroughly. The insecticide is then added and thoroughly mixed in. Additional water may be needed to make a putty-like mixture which can be spread on the screen wire without running off. The paddles should be allowed to dry for about 24 hours.

In use, the wooden handles of the bait stations are thrust into the soil around the edges of pens or into the manure in poultry houses, to hold the baits in a vertical position with the lower edges just touching the surfaces (see Fig. 10 C). They should be spaced 5 or 10 feet (1.5-3 m) apart where flies are numerous. They will remain effective for several weeks unless destroyed by rain. For use inside dairy barns they can be tacked along walls or on window frames. They are especially useful in feed rooms, where they can be laid on sacked feed without danger of contamination (see Fig. 10 A). About 50 well-placed stations will provide control in most barns. They take longer than scattered baits to produce a high degree of control, but a single application remains effective for several weeks (see Fig. 10 D, E).

Baits may also prove useful for the control of some species of cockroach. In the USA a bait consisting of 75 % cornmeal, 2 % Dipterex, and 23 % of a sweetening agent (dextrin, powdered sugar, or a soft-drink syrup) gives good control of *Periplaneta* spp. in dairy barns but not of *Blattella germanica*. The bait should be scattered liberally in cockroach harbourages and feeding-places as revealed by a night examination with a flashlight.

Ribbons and cords

In some regions cloth ribbons or cotton cords treated with parathion (O,O-diethyl-O-*p*-nitrophenyl thiophosphate) or diazinon have given satisfactory control of houseflies when suspended from the ceilings of barns or

FIG. 11
PROTECTIVE CLOTHING FOR APPLICATION OF RESIDUAL SPRAYS

Applicators who will spend much time applying residual sprays should wear protective clothing. The long spray-rod facilitates treatment of ceilings as well as lower parts of walls and hard-to-reach places. The nozzle should produce a flat, fan-shaped spray pattern. A power sprayer with 100 ft. (about 30 m) of hose may be parked outside the barn if necessary.

FIG. 12
SPRAYING METHOD FOR UNPROTECTED OPERATOR

Occasional applications of the sprays approved for use in dairy barns may be made without special clothing, but operators should avoid inhalation of the spray and wetting of the skin or clothing.

sheds. The cords or ribbons are impregnated by dipping in a 5 %-10 % solution of parathion or a 25 % solution of diazinon. Sweetening agents may be added. The cords or ribbons may be coloured as a safety precaution. Because of the high mammalian toxicity of parathion it is well to use only cords or ribbons that have been prepared by commercial formulators. The directions printed on the package should be carefully followed. The usual rate of application is 30 feet of cord per 100 square feet of floor area (or about 9 m of cord per 10 m^2 of floor area).

Larvicides

It is well to avoid the use of chemical fly larvicides if possible, since they are liable to hasten the development of resistance. However, if other methods fail, it may be necessary to use them in the manure from the dairy barns, and perhaps in nearby poultry houses as well. In the absence of resistance, chlordane, gamma-BHC, diazinon, malathion, or parathion will give satisfactory control when applied at 3-6 ounces per 1000 square feet (90-180 g per 100 m^2). Emulsions give the best penetration of the manure, but dusts or kerosene solutions may be preferred in poultry houses if it is desired to keep the manure dry.

Precautions

Insecticides are poisonous. Careless handling and improper application may cause harmful effects on operators, animals, or food products.

Read the directions on the label carefully before preparing sprays.

Do not expose the skin to insecticides unnecessarily (see Fig. 11).

Avoid breathing large amounts of mist or dust (see Fig. 12).

Do not contaminate feed, feed troughs, drinking fountains, or milking utensils.

Cut off the power before applying residual sprays to electric wires or fuse boxes.

Do not strike matches or smoke when applying inflammable sprays.

Do not spray oil solutions near open flames or electric coils.

Do not apply oil solutions to animals in amounts that will wet the skin.

Keep baits and insecticides where children, pets, and livestock cannot reach them.

Wear gloves when installing parathion-treated ribbons or cords.