Reactions of Mosquitoes to the Aircraft Environment.

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INTRODUCTION.

A critical survey of the adequacy of the regulations governing the insecticidal treatment of aircraft arriving in New Zealand from abroad was made during 1946. The purpose of these regulations is to guard against the accidental introduction of insects, particularly vectors of disease organisms and potential economic pests, into this country. New Zealand is fortunate in having no insect-transmitted human diseases whatsoever; but most aircraft coming here from abroad must call at places where such diseases are commonplace and the insect vectors of their causal organisms abound.

Post-war trends in aviation have increased the risk of noxious insects being introduced. More long-distance flights than ever before are now being made to this country. Royal Air Force and civil aircraft have already flown from England to both of our overseas airports, Whenuapai and Ohakea, in less than 60 hours. During such flights landings are made at tropical airfields, some of which are in heavily malarious areas. Various species of the mosquito genus *Anopheles* are found in these places. Many members of this genus transmit the *Plasmodium* causing human malaria. Although *Anopheles* does not as yet occur in New Zealand, conditions here appear favourable for its development, particularly in the north where Whenuapai is situated. As Magath (1945) points out, the risk of airborne introductions of insects leading to the establishment of new foci of potential vectors of disease organisms is greater than that of the introduction of insects actually infected with such organisms. It must be borne in mind that if anophelines once succeed in becoming established in this country, they might become infected with *Plasmodium* by biting some of the many returned servicemen who contracted malaria abroad during the recent war. *Aedes aegypti*, a vector of the viruses of yellow fever and dengue, is another dangerous mosquito found in places on the air routes to New Zealand. Once again, breeding-places which appear to answer the requirements of this species are plentiful in the warmer parts of the country.

Until recent years such places as Singapore and Morotai (Netherlands East Indies) were remote from New Zealand. Ships from these places seldom called at our ports. Even so, there are two
records of the capture of living females of *Anopheles maculipennis* on board vessels after their arrival at Auckland from Samarang (Java) and Singapore (Graham, 1939). These localities, in both of which *Aedes aegypti* and several species of *Anopheles* are abundant, are now but a few hours by air from this country. Although the chances of insects entering and travelling in aircraft as compared with ships are reduced by reason of the smaller dimensions of the former, the greater speed of aircraft would appear to be a factor augmenting the chances of survival of those insects remaining undetected.

There is already an extensive literature concerning insects and air transport. Since the early days of intercontinental aviation it has been realised that insects might be carried from one country to another by means of aircraft. Kiehler (1929) seems to be the first actually to record such carriage. He lists several species of insects collected from the dirigible "Graf Zeppelin" at the conclusion of its first flight from Germany to the U.S.A. Great numbers of insects belonging to many different orders have now been collected on board aircraft. Whitfield (1939) reports the finding of 1,960 insects of 146 species in 2,000 aircraft examined at Khartoum. This total is exclusive of house flies, of which about 1,000 were collected; of the 2,000 aircraft 192 harboured potential vectors of disease organisms other than house flies.

Several workers have made observations on the ability of certain insects to survive air travel. Experimental work in this field has centred on the carriage of mosquito vectors of disease organisms. It is recognised that a wide range of insects of medical, agricultural and pest significance might be carried in aircraft, but in general control measures developed for use against mosquitoes in planes would also be effective against other insects. *Aedes aegypti* has been singled out for special attention because of its importance as a vector of the virus which causes yellow fever.

Griffitts and Griffitts (1931) released 100 mosquitoes in the cabins of three Fokker trimotor airliners about to depart from San Juan, Porto Rico, on the 1,250 mile journey to Miami, Florida. Most of these insects were *Aedes aegypti*, but a few *Culex quinquefasciatus* were included. All had been reared from larvae collected in San Juan. They were allowed to feed from an arm introduced into their cage, and were stained with a 2 per cent. aqueous solution of eosin before the experiment. The average flying time for the journey was nine hours, and the greatest altitude attained was 5,000 feet. One hour and ten minutes were spent at three intermediate landing fields. Careful searching of the machines on their arrival at Miami revealed that 22 living mosquitoes were still aboard. Examples of both species, including both males and females of *Aedes aegypti*, were recovered. It was thus demonstrated that mosquitoes can survive an air journey under the conditions of the experiment, and that these insects do not necessarily leave an aircraft at intermediate stops.

Working in the Belgian Congo, Trolli (1932) conducted experiments with caged *Mansonioides*. Most of these mosquitoes had been
captured in a gorged condition. The first cage was sent by airliner from Léopoldville to Coquilhatville. All but two insects which had become caught in the netting of the cage survived the journey, and were kept alive “for several days” afterwards. This flight took six hours and ten minutes, and the maximum altitude reached was 3,280 feet. A second cage was placed aboard an aircraft the evening before it left Léopoldville for Elisabethville. An overnight stop was made on this journey, which took fourteen hours and thirty-five minutes. The greatest altitude attained was 7,900 feet. On the day following the arrival of the machine at Elisabethville the cage of Mansonioides was examined, after being aboard for four days. All the mosquitoes in this batch were found to be dead. Trolli suggests that shocks on landing, or the effects of the duration and altitude of the flight, might have been responsible for the mortality.

Rouband (1932) records that 100 specimens of Anopheles maculipennis were enclosed in a wooden box and sent by aircraft from Southern Italy to Paris in mid-winter. Conditions of severe cold were encountered during this flight, particularly when crossing the Alps. The mosquitoes were frozen and quite inert when they reached Paris. Nevertheless, they all recovered when placed in a warm, moist atmosphere.

Griffitts, (1933) and McMullen (1933) give the results of further experiments carried out by the United States Public Health Service. Once again the technique employed was to release stained Aedes aegypti into the cabins of aircraft. One series of observations was made on insects sent from San Salvador to Brownsville, Texas, in Ford trimotor airliners. There were six intermediate stops on this thirty-one hour journey, including an overnight one in Mexico. The maximum altitude attained was 14,000 feet. Eight per cent. of the mosquitoes liberated in the cabins of twelve aircraft at San Salvador were recovered at Brownsville. Both males and females were taken, many of the latter being gorged with blood. Some of these were seventeen days old when they reached Brownsville, and had taken their first blood-meal fifteen days before the flight.

Other observations proved that Aedes aegypti could survive the flight from San Salvador to Miami, a journey with ten intermediate stops, including three overnight ones. Four out of a total of seventy mosquitoes from five to twelve days old were recaptured after a journey of seventy-nine hours and forty-five minutes on this route. Stained mosquitoes were also recaptured after the fifty-five hour flight from Cristobal, Canal Zone, to Brownsville, and the thirty-four hour one from Cristobal to Miami. The greatest altitude reached during these flights was 7,500 feet.

Griffitts and McMullen thus demonstrate that Aedes aegypti is able to survive periods of almost eighty hours in aircraft and can withstand the effects of flight at 14,000 feet. Furthermore, they show that mosquitoes a fortnight old can survive an air journey as well as newly-hatched insects. This indicates that Aedes aegypti which have lived long enough to become infected with the yellow fever virus have as good a chance of surviving journeys by aircraft as have newly-hatched mosquitoes.
Transactions.

Hicks and Chand (1936) placed caged batches of *Aedes aegypti* in the care of pilots of airliners leaving Karachi. The insects were given a blood meal immediately before departure, and were provided with raisins from which to feed en route. Fifty-six mosquitoes in five lots of two cages each were put aboard Hannibal class airliners leaving Karachi for England. One cage of each batch was located in the pilot's cockpit or in the forward baggage compartment. The other was tied in the rear of the fuselage behind the cabin. Although most of the insects survived the first day's journey, all were dead when Bagdad was reached thirty-six hours after leaving Karachi. These deaths were attributed to the effects of insecticidal spraying, and to the possibility that severe draughts might have affected the occupants of the cage in the rear of the fuselage. Later batches of mosquitoes were placed on board Douglas airliners leaving Karachi for Amsterdam. The longest survival period recorded in these experiments was six and a-half days. The distance covered in this period was 9,580 miles, from Karachi to Amsterdam and back through Karachi to Jodhpur.

Sicé (1939) states that adult female *Anopheles gambiae* were enclosed in test-tubes and sent by aircraft from the French Sudan to Marseilles. A large proportion of these mosquitoes reached France alive, and laid eggs which developed normally in artificial breeding places at ordinary summer temperatures. The second generation insects were perfectly normal. It was thus demonstrated that air travel does not adversely affect the reproductive powers of *Anopheles gambiae*.

There is little published information regarding the actual behavioural reactions of mosquitoes to air travel. With regard to the activity of these insects during air journeys, Griffiths and Griffiths (1931) state that the radio operator of one of the aircraft in which their experiments were carried out was bitten on the face at an altitude of 3,000 feet. In some cases aircraft in which *Aedes aegypti* had been liberated have had to be sprayed with insecticide because those on board were troubled by the attacks of mosquitoes (Griffiths, 1933). Unfortunately there is no record of the altitudes at which these insects were troublesome. Captain A. B. Ikots mentions his being bitten on the leg by a culicine mosquito, *Psorophora ferox* (Humbolt) at about 8,000 feet altitude during a flight from Natal to Belem, Brazil (U.S.A.A.F., 1946). McMullen (1933) records an interesting observation made by Newman during a flight from Cristobal. Newman states that when the motors were started some mosquitoes settled on the cabin roof. These insects did not budge during the flight, but began to fly again when the motors were shut off on landing. Griffiths and Griffiths (1931) observe that on one occasion, immediately after landing at Miami on a flight from Porto Rico, two *Aedes aegypti* flew out from beneath a seat and attempted to bite.

The earliest investigation into the effects of reduced air pressure on insects seems to have been that carried out by Bert in 1877 (Hitchcock and Hitchcock, 1943). Bert records that poplar beetles (*Chrysomelidae*) recovered from twenty hour exposures to reduced
pressure of 9 cm. and 4 cm. although inert and apparently lifeless
during the experiment. These reduced air pressures are approxi-
mately equivalent to those of the atmosphere at 50,000 to 60,000 feet.

Whitfield and Lefroy (Whitfield, 1939) carried out experiments
with varying degrees of vacuum in 1924. They used a specially
built iron pressure cylinder in this investigation. Among the insects
tested were Musca domestica, larvae of Lepidoptera, and adult Tene-
brionidae (Coleoptera). Whitfield states that vacuums (the degrees
of which were lost) were maintained for periods of up to twenty-
four hours and were then suddenly released. None of the insects
concerned showed any signs of distress.

Hicks and Chand (1936) experimented on the effects of reduced
air pressure on Aedes aegypti, using an apparatus designed for test-
ing altimeters. As the insects were enclosed in a glass-fronted
chamber in this apparatus, it was possible to study them during their
exposure to reduced air pressures. Both males and females were
observed during these tests, the females being fully fed beforehand.
The experiments were carried out at air pressures equivalent to those
at altitudes of 5,000 feet and 10,000 feet. In one test two females
appeared to be sluggish in their movements when held at 10,000
feet for one hour. When the apparatus was shaken they seemed less
willing to fly than usual. No such effect was noticed in any of the
other experiments. In all cases the insects appeared normal on the
following day.

Rouland's observations on the effects of reduced air tempera-
tures on mosquitoes travelling in aircraft have already been discussed
(p. 95).

It appears that no experiments have been carried out to deter-
mine the effects of vibration on insects in aircraft. Magath (1945),
however, states: "It has now become evident that, owing to the
vibration of the plane which prevents delicate insects like mosquitoes
from resting during the trip and because of the dryness and high
degree of 'ventilation,' most delicate insects are unable to survive
a long trip. Even though they do, many appear to be incapable of
carrying on their life cycle." These remarks are at variance
with the published results of earlier workers already discussed.
Quite apart from the demonstrated fact that mosquitoes can and do
survive long air journeys, it will be remembered that Newman
(McMullen, 1938) observed Aedes aegypti resting on the cabin roof
of a Ford trimotor aircraft throughout a flight. Vibration during
flight was thus insufficient to prevent these mosquitoes from resting.
The degree of vibration of the fuselage of modern aircraft is at least
no greater than that of obsolescent trimotor machines.

It will be convenient at this stage to summarise the findings of
the investigators whose work is outlined above.

(1) Aedes aegypti can survive during air journeys of up to
six and a-half days, in which 9,500 miles are covered.

(2) Females of this species old enough to have become actual
vectors of the virus of yellow fever can survive an air
journey as well as newly-hatched insects,
(3) *Mansonia* sp. is able to live for several days after a six-hour flight at altitudes of up to 3,250 feet.

(4) The reproductive capacity of *Anopheles gambiae* is unaffected after an air journey.

(5) *Aedes aegypti* and *Culex quadrimaculatus* when present in the cabins of aircraft do not necessarily fly out at intermediate stops made during a journey. They have been known to remain aboard an airliner during an eighty-hour journey despite the fact that ten intermediate landings were made.

(6) *Psorophora ferox* has been known to bite during an air journey at an altitude of 8,000 feet.

(7) *Aedes aegypti* is able to withstand exposure to an altitude of 14,000 feet, although there is a suggestion that its movements become sluggish and that it does not fly as readily as usual when maintained at an air pressure equivalent to that at 10,000 feet.

(8) Poplar beetles become quite inert when maintained at air pressures equivalent to those at 50,000 to 60,000 feet. They show complete recovery when restored to atmospheric pressure, even after twenty-hour exposure to these greatly reduced air pressures.

(9) Although inert and apparently dead after exposure to freezing temperatures during an air journey, *Anopheles maculipennis* shows complete recovery when restored to a favourable temperature and humidity.

(10) The vibration of the fuselage of an aircraft in flight does not prevent *Aedes aegypti* from resting during a journey.

(11) *Aedes aegypti* tends to become active when the motors of an aircraft are shut off at the conclusion of a flight.

Thus insofar as mosquitoes are concerned little has been experimentally demonstrated beyond the facts that these insects can survive long air journeys and do not necessarily leave aircraft at intermediate stops during such journeys. There is very little information concerning the reactions of mosquitoes to the aircraft environment. In fact the literature contains only three direct observations on the behaviour of mosquitoes during air travel, those of Griffiths (1931), Newman and Klots. Furthermore there is but scanty information as to the ability of these insects to establish themselves in a strange environment after surviving flights in aircraft.

At the commencement of the present investigation the following points were seen as being most in need of study:

1. Has exposure to air pressures below normal atmospheric pressure any effect on the behaviour of mosquitoes?
2. Has exposure to low temperatures any effect on the behaviour of these insects?
3. Has exposure to extreme vibration a deleterious effect on mosquitoes?
(4) Does exposure to the aircraft environment shorten the life-span of mosquitoes?
(5) How long an air journey may mosquitoes which are unable to feed en route survive?
(6) Could exotic mosquitoes become established in New Zealand once introduced from abroad by air?

It was decided to undertake research into these problems. The greatest danger arising out of the progressive development of New Zealand's external air services lies in the possibility that accidental introductions of Anopheles or Aedes aegypti might be made into this country. Thus it was obviously undesirable to introduce specimens of either of these mosquitoes for experimental purposes. Consequently Aedes notoscriptus, a species which occurs in New Zealand and has a wide range in the South Pacific area generally, was chosen as the object of this enquiry.

FIELD EXPERIMENTS.

Observations were made on the behaviour of caged batches of mosquitoes during flights in an R.N.Z.A.F. aircraft.

Technique.

Four 9 x 9 x 6 inch cages were made for this study. The sides and roof of each were of mosquito netting, the floor and framework of white-enamelled wood. A calico feeding-sack was attached to an end wall so that captive mosquitoes could be fed with blood from a hand introduced into the cage. One hundred newly-hatched Aedes notoscriptus, seventy-five females and twenty-five males, were transferred to these cages on May 21, 1946. On the following day the females were given a blood-meal and the males were allowed to feed from wads of cotton-wool soaked in sugar-water.

All four cages were distributed within the fuselage of a Douglas Dakota aircraft at Whenuapai airfield on the morning of May 28. No. 1, containing thirty females and ten males, was placed on a cabin seat. Nos. 2 and 3, each holding fifteen females and five males, were located beneath this seat. These three cages were fastened to the cabin wall, so as to be subjected to the full effect of the vibration of the aircraft. Cage 4 also contained fifteen females and five males, and was strapped to the upper part of the wall of the toilet compartment. Just after midday that same day the Dakota left Whenuapai on the first stage of a 12,452 mile return flight to Japan with mail for the New Zealand occupation force. This route was at the time the longest being regularly flown by a single machine anywhere in the world.

The female Aedes notoscriptus were given a blood meal once every three days during the journey. Griffiths (1933) and McMullen (1933) show that under normal circumstances female mosquitoes may feed from crew and passengers at least between the stages of a long flight. Griffiths and Griffiths (1931) and Griffiths (1933) record instances of these insects biting during flight. On the other hand, male mosquitoes are normally unable to feed on board aircraft as they do not suck blood but live on various plant juices. Accordingly, the male Aedes notoscriptus were not supplied with food after the take-off from Whenuapai.
Reactions of Mosquitoes During Air Travel.

None of the eaged insects showed undue activity when the motors were started or during taxi-ing. All of them commenced to fly in agitated fashion when the motors were fully opened out just prior to the take-off run. Their behaviour returned to normal within five minutes after the plane's becoming airborne. The abnormal activity at take-off was attributed to the effect of the sudden pronounced increase in vibration of the fuselage at that time.

A similar marked increase in activity was observed each time the motor was throttled back and the flaps put down when coming in to land. This activity was maintained in some cases until five minutes after the aircraft had halted on the tarmac. It was attributed first to the effect of the pronounced increase in vibration of the fuselage on landing, secondly to that of the final cessation in vibration after the motors had been running steadily for several hours. A possible contributory cause was the marked rise in air temperature experienced during the descent and landing.

Hourly observations of the behaviour of the mosquitoes in all four cages were made during each stage of the flight. The insects behaved normally and made voluntary flights from time to time at altitudes below 10,000 feet and temperatures in excess of 10° C. When altitudes ranging from 10,000 feet to 11,500 feet were attained, and temperatures were still above 10° C., the mosquitoes no longer made voluntary flights and were noticeably sluggish in their movements. They made short flights in response to the stimulus of a sharp tap on their cage. Sluggishness in this case appeared to be due solely to the effects of the reduced air pressure at altitudes above 10,000 feet.

A similar sluggishness with a complete lack of voluntary flights was apparent at altitudes below 10,000 feet when temperatures ranged from 8° C. to 10° C. As behaviour at such altitudes was normal when the air temperature was above 10° C., this reaction was ascribed to the effects of reduced temperature alone.

Sluggishness at altitudes above 10,000 feet when the air temperature ranged from 8° C. to 10° C. was put down to the combined effects of reduced air pressure and temperature.

At temperatures below 8° C. there was no flight response to the tapping stimulus regardless of the altitude. When such temperatures were maintained for any length of time the insects became inert, lying on their backs on the floor of their cage. Some still made occasional feeble movements of the legs and head.

There was no observable differences between the reactions of male and female Aedes notoscriptus to the various conditions of vibration, reduced air pressure, and reduced temperature encountered.

In all cases mosquitoes which had become sluggish or inert made a complete recovery during the descent preparatory to landing. In the case of inert mosquitoes this recovery became apparent as soon as the temperature rose above 8° C. Sluggishness disappeared when altitudes below 10,000 feet and temperatures above 10° C. were reached. Complete recovery was usually effected within five
minutes of regaining favourable conditions of air pressure and temperature.

During the journey the cabin heating system was defective and temperatures varied more than is usually the case. The reading at Cage 1 on the cabin seat ranged from 5° C. to 27° C., and averaged 17.5° C. The behaviour of the occupants of this cage was abnormal on seven of the sixteen stages of the journey. On four of these stages the mosquitoes were sluggish when the aircraft was at altitudes of 10,000 feet and above, although the temperature averaged 22° C. Sluggishness was apparent during two stages at altitudes above 10,000 feet and at an average temperature of 10° C. On the remaining stage all the mosquitoes were inert for four and a-half hours when the temperature averaged 5° C. and the altitude was 8,000 feet.

The occupants of Cages 2 and 3 beneath the cabin seat experienced a temperature range of 4.5° C. to 26.5° C., the average being 15.5° C. Their behaviour paralleled that of the mosquitoes in Cage 1. Sluggishness was apparent on two additional occasions when the temperature fell to 10° C. at altitudes of 8,000 feet and 8,500 feet.

During flight the temperature in the unheated toilet compartment ranged from 3° C. to 25° C., and averaged 13° C. On eleven of the sixteen stages the mosquitoes in Cage 4 behaved abnormally. During four of these stages the insects were sluggish at altitudes of 10,000 feet or more, while the temperature averaged 17° C. For a total of eleven hours on three stages they were inert at an average temperature of 8° C., at an altitude of 8,000 feet. They were also inert for a further nine hours on two more stages, when at altitudes above 10,000 feet and an average temperature of 6° C.

Iwakuni airfield, Japan, was reached on the tenth day after leaving New Zealand. This airfield is situated on the Inland Sea in the south-western part of the island of Honshu. The temperature range inside the aircraft during the five day stay at Iwakuni was 16° C. to 23° C. All the cages were left in their positions during the stay, and the occupants were fed as usual. Immediately before leaving on the return journey twenty-five males of Culex pipiens pallens, a very common mosquito in this part of Japan, were collected in a disused hanger near the airfield. The female of this species is a vector of the virus of Japanese B encephalitis (Hsiao, 1946). These insects were placed in Cage 1 together with the surviving female Aedes notoscriptus. They were not fed at the time of collection or during the return journey, so as to simulate the conditions of accidental transportation as closely as possible. No females of the Japanese mosquitoes were brought back to New Zealand, in case some accident might have led to their escape and the establishment of the species in this country.

The return flight to New Zealand was accomplished in just over three days. The Culex pipiens pallens males were observed to show the same reactions as Aedes notoscriptus to the effects of vibration during take-off and landing, and to those of reduced air pressure and temperature.
Survival of Mosquitoes During and After Air Travel.

Sixty per cent. of the original seventy-five female *Aedes notoscriptus* survived the eighteen-day journey, in which time 12,452 miles were covered. There was no significant difference between the percentage of survivors in the cages in the heated cabin and the unheated toilet compartment. The range of temperatures to which these insects were exposed during the flight and at airfields where stops were made, was 3° C. to 34° C. This latter reading was made inside the fuselage while on the ground at Morotai (Netherlands East Indies) during the return journey.

The twenty-five male *Aedes notoscriptus*, which were not fed after the departure from New Zealand, survived for periods ranging from two to seven days. Their average survival period was four days. The range of temperatures to which they were subjected in the aircraft was 7° C. to 33° C.

Seventy-two per cent. of the twenty-five male *Culex pipiens pallens* taken aboard at Iwakuni survived the three-day journey to New Zealand. The range of temperatures to which they were subjected during the journey was 5° C. to 34° C.

All the surviving caged mosquitoes of both species were fed immediately after returning to Whenuapal on June 9. These insects were now transferred to a laboratory at Victoria University College in Wellington. Here they were kept supplied with food, cotton-wool pads soaked in sugar-water being pressed against the netting of their cages. From time to time the females were given access to a blood-meal as well.

The life-span of the seventy-five female *Aedes notoscriptus* averaged thirty-seven days, ranging from two to 104 days. These mosquitoes spent their third to twenty-first days inside the aircraft, on the flight to Japan and back. Over the whole survival period the range of temperatures in the laboratory was 6° C. to 19° C., the average being 13.5° C. It must be mentioned that some of the females which died during the flight were small, weakly insects, presumably originating from undernourished larvae. The average life-span of those insects which survived the full journey was sixty-one days.

The feral male *Culex pipiens pallens* lived for an average of forty-four days after collection, the survival period ranging from two to 121 days. The first three days of this period were spent in the aircraft. Although the exact ages of these insects were not known, it is most likely that the great majority were newly-hatched when collected. They were all captured resting on a concrete wall immediately above the surface of a small pool in which their larvae were abundant. The average survival period of the males which survived the air journey, was fifty-seven days. Thus the majority of these Japanese mosquitoes successfully withstood the effects of an air journey of 6,226 miles. Although collected under summer conditions in the Northern Hemisphere and transferred in a matter of three days to winter conditions in the Southern Hemisphere, they lived for an average of six weeks after their journey. Over the whole survival period of the *Culex pipiens pallens* the laboratory temperature ranged from 6° C. to 20.5° C., and averaged 14° C.
LABORATORY EXPERIMENTS.

After the completion of the field work, a series of observations was made on laboratory-reared Aedes notoscriptus of known ages. These insects were subjected to greater degrees of reduced pressure and temperature than were reached in the field experiments, and were also subjected to intense vibration. They were exposed to these conditions for greater lengths of time than mosquitoes are ever likely to be to similar conditions in aircraft.

Technique.

Aedes notoscriptus larvae were collected from natural breeding places. Together with a quantity of the water in which they were living they were transferred to a large glass jar in the laboratory. Here they were supplied with finely ground dried bread as food. Once each week the water in the container was replaced with fresh water from a natural breeding place of the species. As soon as pupae were detected they were transferred to corked 4in x 1in tubes containing a little clean water. These containers were examined once every twelve hours, and any adults which had hatched were transferred to serially numbered tubes of the same dimensions. A hole half an inch in diameter was bored through the centre of the cork of each of these tubes and a piece of mosquito netting was stretched across the bottom of the cork. The mosquitoes were fed by forcing a small wad of cotton-wool soaked in sugar-water down the hole in the cork, and positioning it against the mosquito netting. The numbered tubes of adult mosquitoes were stored in an inverted position in wire racks.

A glass cylinder of 11.5 litres capacity was used as a decompression chamber. It was connected to a manometer graduated in altitudes corresponding to the various degrees of reduced air pressure attained. The chamber was evacuated by means of a hand pump. Altitudes of up to 40,000 feet were simulated with this apparatus. In studying the combined effects of reduced pressure and reduced temperature on mosquitoes, the decompression chamber was sealed off with clamps from the manometer and pump after evacuation, and was placed in a freezing-chamber. Mosquitoes were subjected to intense vibration by placing them in a 4in x 1in tube suspended so as to rest in a loop of copper wire soldered to the arm of an electric buzzer, which was operated by two 1.5 volt dry cells.

The Reactions of Aedes notoscriptus to Artificially Produced Conditions of Reduced Air Pressure and Temperature.

Females of Aedes notoscriptus from one to twenty-one days old were released inside the decompression chamber, which was at a temperature of 15° C. They were stimulated to flight by so manipulating the cylinder that a piece of thread suspended from the top brushed against them. While the insects were flying, air was rapidly pumped from the cylinder. The mosquitoes showed no observable reactions until an air pressure equivalent to that at an altitude of from 9,500 feet to 10,000 feet was reached. At this point those which were in flight dropped dramatically to the floor of the decompression chamber.
As was observed in the field experiments, voluntary flights were very seldom made above 10,000 feet. Flights of very short duration were made in response to the touch stimulus at altitudes ranging from 10,000 feet to about 30,000 feet. At altitudes of 10,000 feet and above the mosquitoes were noticeably sluggish in their movements. This sluggishness became increasingly apparent with decrease in air pressure. Voluntary movements other than a slow paddling of the hind legs and an occasional rubbing of the thorax and wings with the middle pair of legs, virtually ceased above 30,000 feet. Mosquitoes maintained at altitudes ranging from 30,000 feet to 40,000 feet for periods of up to 48 hours did not change their positions on the container wall. In response to contact stimuli movements of a few steps were made, sometimes in a sideways direction. When knocked off their feet by means of the thread attached to the top of the container the mosquitoes showed a sluggish righting response. The abdomens of gorged females of Aedes notoscriptus became grossly distended as the air pressure in the chamber was reduced. At altitudes of from 30,000 feet to 40,000 feet the posterior extremity of the abdomen of ungorged mosquitoes was sometimes curved downwards and forwards beneath the body.

Five male and five female Aedes notoscriptus were transferred to a rubber-stoppered tube which was placed inside the pressure chamber. Air was now pumped from the chamber. When the air pressure outside the stoppered tube was equivalent to that prevailing at just over 30,000 feet, the rubber stopper was blown out. Thus the atmosphere about the tube was decompressed. The insects had till this moment been making frequent voluntary flights, and otherwise behaving in a normal manner. They now dropped immediately to the bottom of the tube, moved a few steps, and became still. When restored to normal atmospheric pressure eight hours later they made an immediate recovery, and resumed normal activity.

Mosquitoes which had been held at a reduced air pressure equivalent to that at an altitude of 40,000 feet, for as long as 48 hours, resumed normal activity as soon as they were restored to altitudes below 10,000 feet. Immediate restoration to ground level from an altitude of 40,000 feet was also followed by an immediate resumption of normal behaviour. It will be remembered that Whitfield and Lefroy (Whitfield, 1939) carried out experiments upon the ability of certain insects to withstand various degrees of vacuum, and concluded that none of these insects showed any signs of distress. Their experiments were carried out in a specially built iron cylinder. Whitfield further states that the results of this investigation are substantiated by the observations of various Imperial Airways captains. These officers informed him that on occasion the descent from conditions of high altitude (12,000 feet or more) and low temperatures was most rapid, but that this had no apparent effect upon the insects subsequently found in their aircraft. It is evident that Whitfield had no means of observing insects while they were actually exposed to varying degrees of vacuum in his iron cylinder. Thus, while drawing the correct conclusion that insects show no signs of
distress after exposure to reduced air pressures even when their restoration to normal atmospheric pressure is extremely rapid, he overlooks the important fact that the behaviour of insects is abnormal during such exposure. As has already been indicated, this fact was first realised by Bert in 1877 (Hitchcock and Hitchcock, 1943). Hicks and Chand (1936) noted an apparent sluggishness in the movements of two female Aedes aegypti held for an hour in an altimeter-testing apparatus at a reduced air pressure equivalent to that at 10,000 feet. They did not investigate the effects of still more reduced pressures and were forced to abandon their experiments at an early stage as their apparatus was required by the airways company from which they had borrowed it.

Although the experimental mosquitoes never made a flight response to the touch stimulus at greater altitudes than about 30,000 feet, they sometimes fluttered their wings without flying. A stroboscopic estimation of the wing-rate at progressively reduced air pressures was made, using a modified form of the apparatus devised by Williams and Chadwick (1943). The technique involves attaching the insects concerned to mounts without causing them injury or interfering with their flight movements. Once mounted, the insects are positioned inside a glass tube which can be evacuated by means of a pump. This tube is placed in front of an Edgerton stroboscope, having a neon-filled bulb of which the flash-frequency is controllable by an adjustable electric oscillator. The flash-frequency of this bulb is tuned to synchronise with the wing-rate of the insects, in which flight is initiated or inhibited by means of a tarsal stimulus.

Aedes notoscriptus could not be induced to make flight movements below a temperature of 8° C. Sporadic movements began between 8° C. and 10° C., the wing-rate becoming progressively more rapid with rise in temperature above this level. Because of an electrical fault in the only stroboscope available at the time, it was not possible to make an accurate series of wing-rate readings. However, no change in the wing-rate could be detected when the experimental tube was evacuated to 40,000 feet at 15° C., although the actual form of the beat appeared to alter between about 25,000 feet and 30,000 feet. It is likely that above this level insufficent "lift" is developed to render flight possible in nature. This conclusion is substantiated by the fact that unmounted Aedes notoscriptus could not be induced to fly at greater altitudes than 30,000 feet. It is of interest to note that Chadwick (1939), working on Drosophila repleta, was also unable to induce flight movements at lower temperatures than 8° C. to 10° C.

Unmounted mosquitoes of both sexes were placed in a glass cylinder at normal atmospheric pressure, and the temperature was progressively reduced from the prevailing room temperature of 15° C. Behaviour was normal above about 12° C., and voluntary flights were frequently made. Between about 10° C. and 12° C. some degree of sluggishness in the movements of the mosquitoes was apparent and fewer voluntary flights were made. From 8° C. to 10° C. the insects were sluggish in their movements. Although voluntary flights were not observed within this range of temperatures, brief flights were made in response to the stimulus of sharply
tapping the side of the cylinder. Between about 3° C. and 8° C. there was no flight response to the tapping stimulus, although sluggish movements and a righting response were still made. The mosquitoes collapsed on the bottom of the cylinder as soon as they were exposed to temperatures below 3° C. They also became inert if held at temperatures below 8° C. for long periods. Some insects of both sexes still made occasional feeble movements, both voluntarily and in response to the tapping stimulus, after they had collapsed on to their backs.

Batches of male and female Aedes notoscriptus were exposed to a temperature of –2° C. for 24 hours, some at normal atmospheric pressure and others at reduced air pressures equivalent to those at 10,000 feet and 30,000 feet. Throughout their exposure to –2° C. these insects were quite inert, and lay on the bottom of the cylinder. Some of them lay with the wings partly spread and the legs in unnatural positions, and seemed as if dead. All of these mosquitoes were stirring within five minutes of their return to room temperature (15.5° C.). Within a further five minutes their behaviour appeared quite normal, and voluntary flights were made.

From these observations and those made during the field experiments already discussed, it appears that exposure to temperatures below about 10° C. interferes not only with the flight movements of Aedes notoscriptus but with the general bodily activity of this mosquito as well.

Survival of Aedes notoscriptus after Exposure to Artificially Produced Conditions of Reduced Air Pressure, Reduced Temperature, and Extreme Vibration, and Under Starvation Conditions.

Aedes notoscriptus of both sexes were exposed to reduced air pressure for varying periods, and after their return to normal atmospheric pressure were kept alive as long as possible. The average room temperature throughout these experiments was 15° C.

Ten males and the same number of females 18 days of age were fed on sugar-water, and were then exposed to a reduced air pressure equivalent to that of the atmosphere at 30,000 feet for twenty-four hours. After restoration to normal atmospheric pressure these insects lived for periods ranging from twenty-eight to sixty-seven days. The average age of these mosquitoes at death was fifty-four days. A similar batch of mosquitoes this time four days of age were exposed to a simulated altitude of 30,000 feet for eight hours each day for a week. These insects lived for periods ranging from twenty-two to ninety-three days after restoration to normal atmospheric pressure. Their average age at death was sixty-four days.

Other batches of Aedes notoscriptus were held at 40,000 feet for periods of twelve, twenty-four and forty-eight hours. The average age of these mosquitoes when subjected to the reduced air pressure was eight days, and at death fifty-four days.

The average life-span of eighty-four male controls was seventy-four days, and of 112 females, seventy days. Thus exposure to reduced air pressures up to that corresponding to an altitude of 40,000 feet for periods of up to forty-eight hours has little significant effect on the life-span of Aedes notoscriptus.
A further series of experiments on the survival of mosquitoes at various air pressures was carried out at -2° C. Ten thirty-four-day-old males and the same number of females were exposed to a temperature of -2° C. at atmospheric pressure for twenty-four hours. They survived for from thirty to fifty-two days after the experiment, and their average age at death was seventy-five days. A similar batch of twenty-seven-day-old mosquitoes were kept at this temperature and pressure for forty-eight hours. Members of this batch lived for from thirty-four to forty-one days after the experiment, and their average age at death was sixty-eight days. Thus exposure to freezing temperatures for periods of up to forty-eight hours also has no significant effect on the life-span of Aedes notoscriptus.

Batches of mosquitoes were maintained at 30,000 feet and 40,000 feet at -2° C. for twenty-four to forty-eight hour periods to determine the effects of exposure to combined reduced air pressures and temperatures. Once again, there was no significant shortening of the life-span of the insects tested.

Subjection to intense vibration at atmospheric pressure and at 30,000 feet did not shorten the life-span of Aedes notoscriptus. Ten males and ten females five days of age were placed in a tube which was vibrated in the apparatus already described. During the eight hours for which these insects were held at 30,000 feet they were continually jarred off their feet and prevented from resting. Nevertheless, they lived for from forty-four to sixty-seven days after the experiment and averaged sixty-two days of age at death. Room temperature throughout this experiment averaged 14-5° C.

Finally, a batch of male and female Aedes notoscriptus were subjected to intense vibration for twenty-four hours at normal atmospheric pressure and a temperature of -2° C. Throughout this experiment the inert mosquitoes were shaken together at the bottom of the vibrator tube. These insects were all twenty-eight days old when tested. After the experiment they lived for periods ranging from forty-one to sixty-one days, and their average age at death was seventy-nine days.

Thus the life-spans of Aedes notoscriptus males and females subjected to various degrees of reduced air pressure, reduced temperature, and vibration, did not differ significantly from those of control insects. Under normal present-day conditions of air transport, insects would seldom have to undergo such extreme conditions of reduced pressure as Aedes notoscriptus survived in these experiments. Furthermore, it is most unlikely that conditions paralleling those of the experiments will ever be maintained in aircraft for longer periods than those for which they were maintained in the laboratory.

An estimation was made of the length of time for which Aedes notoscriptus can live without food. Ten females thirty-five days old were allowed to gorge themselves on blood, after which they were not given any more food. These insects survived for from four to eight days, the average survival period being six days.

Ten newly emerged males and the same number of newly emerged females were never allowed to feed. The males lived for
two to four days, averaging three days, the females two to five days, averaging four days.

Similar numbers of males and females were fed on sugar-water until nineteen days old, and were then deprived of food. In the cases of both sexes the average survival period was four to five days. The room temperature averaged 15·5° C. during these experiments.

As the twenty-five male Aedes notoscriptus used in the field experiment survived for periods ranging from two to seven days and averaging four days, their deaths can thus be attributed to starvation and not to any direct effects of the air journey.

DISCUSSION.

A tendency to underestimate the importance of the part which aircraft might play in extending the ranges of noxious insects is apparent in the writings of some recent authors. This tendency is to be deplored, as it can so easily lead to laxity in aviation insecticidal procedure. New Zealand is perhaps even more vulnerable to insect introductions than those northern countries where most previous research has been carried out. As a general rule the southern lands with their basically more primitive faunas are easily invaded by representatives of successful animal groups from the north. Representatives of such groups, once established, may spread at an alarming rate, being freed from the various biological and other control factors which keep their numbers in check in their own home. The accidental introduction of the White Butterfly Pieris rapae in 1930 serves as a local illustration of this process. Although this insect has now been brought under a partial degree of control it spread at an amazing rate in the years immediately following its introduction and caused widespread damage to cruciferous crops.

Hoops (1934) gives the broad range of malaria as all latitudes from 50° N. to 40° S., but states that it is also found beyond these extremes. As yet there has been no authenticated case of an outbreak of disease in a new focus being due to the introduction of an insect vector by aircraft. Nevertheless great outbreaks of malaria have occurred in comparatively recent years, although ships and not aircraft have been responsible for introducing the vector insects. Thus an epidemic of malaria occurred in Mauritius in 1867–68. As was subsequently demonstrated, this was due to an introduction of Anopheles by a sailing ship from Madagascar. The mosquitoes soon established themselves in Mauritius and became infected with Plasmodium on biting gametocyte-carriers among the Indian and African labourers on the island.

It is not known with certainty whether the much-quoted introduction of Anopheles gambiae into Brazil in 1931 was brought about by fast destroyers or pioneer aircraft from West Africa. This introduction resulted in malaria epidemics which by 1938 had caused about 20,000 deaths. The spread of Anopheles gambiae in Brazil was only arrested by a protracted and extremely expensive campaign initiated by the Rockefeller Institute (Soper and Wilson, 1943).
By analogy with these cases, and considering that Anopheles thrives to a latitude of 40° S. and beyond, there is every reason to suppose that an introduction of this mosquito into New Zealand could have disastrous results. It has now been shown that mosquitoes are unaffected in any significant degree by exposure to the conditions of vibration, reduced pressure and temperature of the aircraft environment, even when these conditions are far more extreme than are those normally encountered in air travel. The results of the field work undertaken with Aedes notoscriptus and Culex pipiens pallens and of the laboratory experiments on the former, point to the conclusion that adequate measures to guard against the airborne introduction of insects into this country are necessary now and will continue to be necessary in the future.

In the last analysis, New Zealand would be largely safeguarded from introductions of noxious insects by air if all overseas airfields used by planes coming to this Dominion were "sanitary airfields" in the terms of the International Sanitary Convention for Aerial Navigation (Anon., 1938). During my field investigation certain airfields on the Japan-New Zealand route were found to be in a poor state of mosquito control, and both adult and larval anophelines were captured within the bounds of air stations in Australia, the Netherlands East Indies, and the Philippines.

Even if all overseas airfields used by aircraft on their way to New Zealand were under adequate mosquito control, there would still remain the possibility that noxious insects might fly in from outside the controlled area or be brought in among passengers' effects and cargo. Thus an efficient scheme for insecticidal spraying of aircraft is essential. Such a scheme should involve carrying out insecticidal spraying on each stage of a journey so as to safeguard intermediate landing fields in other countries as well as the New Zealand terminal. There has been some controversy with regard to the best time for carrying out this spraying. Spraying after the loading of passengers and cargo but before take-off is recognised procedure in some countries. Others prefer that spraying should be carried out in flight, and still others that it should be performed by a ground-crew orderly after landing.

There are three main disadvantages attached to the last-mentioned system. The first is that there is always a possibility that any insects on board an aircraft might fly out as the spraying orderly enters. This possibility is enhanced in the light of observations that mosquitoes travelling in an aircraft become active at landing, and that treatment with aerosols has the secondary effect of stimulating insects to hyper-activity (U.S.A.A.F., 1946). The second is the fact that the aircraft must remain sealed for at least five minutes after the completion of spraying, thus causing delay in disembarkation and unloading of cargo. Finally, a control system depending on ground spraying on arrival alone offers no safeguard against the risk of accidental introductions following forced landings at emergency airfields where insecticidal facilities are not available.

An important point with regard to spraying in flight arises from the present study. Using Aedes aegypti as a test insect David
and Bracey (1944) report that this mosquito is much more susceptible to an insecticidal mist when actually in flight than when at rest. Mosquitoes in flight contact a much larger number of spray droplets than resting insects, and it appears that the rate of movement of the insect in relation to the droplet and the relative momenta are also important. David and Bracey exposed batches of *Aedes aegypti* to an insecticidal mist containing pyrethrins. Some of these insects were chloroformed and inert during exposure to the insecticide, some were wingless, some had been chloroformed but had recovered, and others were quite normal. Sixty-two per cent. of the normal insects and 58 per cent. of those which had been chloroformed and had subsequently recovered, died within twenty-four hours of the experiment. Only 12 per cent. of the chloroformed mosquitoes and 13 per cent. of the wingless ones died in the same period. David (1945) shows that *Aedes aegypti*, *Musca domestica* and *Drosophila* spp., all collect a very large number of spray droplets on their wings when in flight. These droplets are later distributed to other parts of the body when the insects clean their wings with their legs. When the wings of *Aedes aegypti* and *Musca domestica* are removed just after exposure to an oily spray mist, the kill as recorded twenty-four hours later is reduced by about 50 per cent. as compared with a group in which the wings have not been removed.

In view of the fact that *Aedes notoscriptus* at least will not fly voluntarily at temperatures below 10° C. or at altitudes above 10,000 feet, insecticidal spraying carried out during flight beyond these limits is unlikely to be effective. This objection to spraying in flight still holds good in the case of aircraft with pressurized cabins, for these have many unpressurized spaces in which insects might travel. A second objection to carrying out insecticidal treatments during flight is that air currents set up within many types of aircraft may tend to dissipate the spray mist before it has had time to take effect.

On the whole, the system with least disadvantages seems to be that of spraying before take-off. Besides guarding against the dangers of insects leaving aircraft before spraying has been carried out and of accidental introductions of insects attendant upon emergency landings at airfields where insect control facilities are not available, this system does away with unnecessary delays after landing. As already remarked, mosquitoes on board aircraft tend to become active when the motors are first fully opened out. It would appear that the most favourable time for spraying is after the motors have been tested at full revolutions during "cockpit drill" and before commencing the take-off run, as air currents set up within the fuselage when the plane is moving at speed might cause premature dispersion of the spray mist.

Insecticidal spraying in aircraft may be carried out with some form of manually operated spray-gun or by means of a fixed automatic system. The former system has been favoured to date. Pyrethrum aerosol bombs as developed a few years ago for use by the armed forces of the U.S.A. (Anon., 1942) offer a convenient and satisfactory means of spraying when in the hands of competent operators. A serious drawback attached to manually-operated
systems, however, is the factor of unreliability of the human element. Too often the men undertaking insecticidal spraying have not a proper understanding of the nature or importance of their task, and their attitude results in the treatment being carried out in an unsatisfactory manner. This applies particularly to members of aircrews detailed to carry out spraying, as these men often see the task as being a little beneath the dignity of their office.

Furthermore, certain parts of aircraft which may harbour insects are inaccessible to hand-operated spraying equipment. These parts are notably the interiors of wings and tail, and the cavities into which the undercarriage is retracted.

An automatic spraying system delivering a measured quantity of spray to all the enclosed spaces of aircraft would appear to offer the only fully satisfactory solution. Such a system, incorporating a reservoir of insecticide under pressure from which spray would be distributed through an arrangement of narrow pipes, could be controlled from the instrument panel in the cockpit. Routine insecticidal spraying could thus be incorporated into the pilot's "cockpit drill" before take-off. This system would have the double advantage of rendering all the enclosed spaces of aircraft accessible to the spray, and of greatly reducing the factor of unreliability of the human element. Its chief disadvantage would be the possibility of mechanical breakdown, but this could largely be eliminated by incorporating an examination of the spraying equipment into the routine inspections of the aircraft.

Mackay (1938) and Snow (1945) deal with practicable automatic spraying apparatus for use in aircraft.

In addition to the insecticidal techniques already discussed, treatments of all enclosed spaces of aircraft with residual D.D.T. should be given consideration. Madden (1945) considers such treatments to be of definite value, greatly reinforcing but not replacing normal insecticidal spraying. The United States Army Air Force Board (1946) concludes that "disinsection of aircraft can be accomplished by the combined use of properly applied D.D.T.-pyrethrum aerosols and D.D.T. residual treatments, but not by either of these methods alone."

Despite every care taken to guard against the carriage of insects by aircraft, there remains a slender possibility that some insects may be transported on parts of a machine quite inaccessible to any form of spraying. Only recently, for instance, a beetle was observed to travel from Fiji to Aitutaki on the outside of the fuselage of an R.N.Z.A.F. Dakota aircraft. New Zealand airfields handling overseas traffic should be kept under strictly supervised mosquito control to guard against the risk of noxious insects being introduced in this way, and against the much more likely contingency that foreign aircraft without adequate insecticidal apparatus might introduce such insects. As a further safeguard against the latter contingency an efficient ground organisation for carrying out insecticidal spraying in incoming planes should be maintained at the airfields concerned. All aircraft arriving from overseas should be required to halt at a designated place on the taxiway and remain there until
the spraying requirements have been satisfied before proceeding to
the tarmacs for disembarkation of passengers and unloading.

Sinton (1938) emphasises that a minimum number of ports of
entry for foreign aircraft should be sanctioned so as to lessen the
risk of insect introductions by reducing the number of places into
which such introductions could be made. At present New Zealand
has only two overseas airports for land-based planes, Whenuapai
and Ohakea, and one, Mechanics Bay, for flying boats. Insect-control
facilities established by the R.N.Z.A.F. during the recent war are
available at each of these stations. In order that the maximum
benefit may be derived from these facilities no other airports in the
Dominion should be permitted to receive air traffic arriving from
abroad, at least until the mosquito-control organisation is established
on a more permanent basis than is at present the case.

SUMMARY AND CONCLUSIONS.

In an investigation into the reactions of mosquitoes to the air-
craft environment, it was found that:

1. When exposed to reduced air pressures corresponding to
those prevailing at altitudes of about 10,000 feet to about
30,000 feet male and female Aedes notoscriptus are sluggish
in their movements and very rarely make voluntary flights.

2. When exposed to reduced air pressures corresponding to
those prevailing at altitudes of about 30,000 feet to 40,000
feet these mosquitoes do not fly even in response to contact
stimuli; they seldom move about voluntarily, but will move
a few steps in response to contact stimuli, and still show a
sluggish righting response when knocked off their balance.

3. When exposed to temperatures of 10° C. to 12° C. male and
female Aedes notoscriptus show some degree of sluggishness
in their movements; fewer voluntary flights are made as
the temperature falls, although brief flights are made in
response to contact stimuli at temperatures ranging down
to 8° C.

4. Aedes notoscriptus will not fly even in response to contact
stimuli, when exposed to temperatures below 8° C.; members
of this species become inert and appear as though dead
if exposed to temperatures below 3° C., and if maintained
at 3° C. to 8° C. for long periods.

5. The life-span of Aedes notoscriptus is not significantly
shortened by exposure to vibration sufficiently intense to
prevent the insects from resting, for periods of up to
twenty-four hours and under various conditions of reduced
air pressure and temperature.

6. Exposure to the aircraft environment does not shorten the
life-span of Aedes notoscriptus in any significant measure,
provided that the mosquitoes concerned are able to feed at
normal intervals.

7. Under laboratory conditions, male Aedes notoscriptus sur-

vived for an average of four days after being deprived of
food; this survival period did not vary on exposure to
actual and simulated conditions of the aircraft environ-
ment; the average survival period of females under similar conditions was a little longer than that of the males.

8. As male *Culex pipiens pallens* brought from Japan by air survived afterwards for an average of six weeks at New Zealand winter temperatures, and by analogy with known cases of mosquito introductions in other lands, it is likely that exotic mosquitoes could become established at least in the warmer parts of this country once introduced from abroad by air.

9. *Aedes notoscriptus* and *Culex pipiens pallens* travelling in aircraft fly about in agitated fashion when the motors are first fully opened out and for some five minutes afterwards; similar activity is shown during landing and until a few minutes after the aircraft becomes stationary.

10. On being restored to normal conditions of air pressure and temperature *Aedes notoscriptus* rapidly recovers from the state of inactivity induced by exposure to reduced air pressures and temperatures.

It is concluded that:

1. The most favourable time for carrying out insecticidal spraying on board aircraft is immediately before turning into the wind for the take-off run.

2. A pyrethrum-base insecticide should be sprayed from an automatic system controlled from the instrument panel in the cockpit.


4. In the last analysis the safeguarding of New Zealand from insect introductions depends in large measure on the adequacy of insect-control measures taken at overseas airports used by planes flying to this country.

5. Until all international airports are obliged to be maintained under strict insect control, and until all aircraft flying to the Dominion are equipped with fully effective apparatus for insecticidal spraying, an adequately equipped mosquito-control organisation must be maintained at all New Zealand airports handling overseas traffic; the numbers of such airports should be kept at an absolute minimum in order that the efforts of this organisation may be concentrated within as small an area as possible.

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