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The Design of Jettisonable Cockpit Hoods

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SUMMARY

In the past much trouble has been experienced in the design of jettisonable cockpit hoods and even after a considerable amount of development many hoods are not really satisfactory. In order that a successful hood jettisoning mechanism can be produced it is essential that the various problems involved should be realised at the design stage.

Consideration is given in this Note to the jettisoning problems involved in the design of all types of hoods and cockpit covers. Certain basic design criteria are proposed and the various methods of meeting them are discussed. Recommendations on good design practice are given where possible. With the knowledge that is at present available the design of a satisfactory orthodox hood should present no great problems, but the more advanced designs are likely to cause some difficulty.

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1 Introduction

The complexity of jettisonable hoods and the associated design problems have increased greatly in recent years. Very little systematic development was done before 1944 but by that date the problem was urgent, since injury or even death of the pilot as well as damage to the aircraft were being caused by unsatisfactory jettisons, and there were also not infrequent cases of the hood failing to release.

An investigation by Aero Dept., R.A.E., showed that to achieve a satisfactory jettison it is essential for the hood to assume a nose up positive lift attitude immediately on release[3]. Whilst this could be achieved with the instantaneous release of all the attachments when the relative positions of the C.P. and C.G. were correct, tests showed that the only certain method was to hinge the hood about a rear point so that for the initial part of its travel it was constrained to rotate about this point[7]. Finally, the recommendation was made that the hood should be completely released after it had rotated through a small angle[8].

In parallel with this development the test requirements for every new design of hood were made much more rigorous; model wind tunnel, full scale ground and then flight or blower tunnel tests were required. The hoods of most aircraft now flying have been tested in the blower tunnel at A & A.E.E., Boscombe Down (references 10 and 11 are two recent and typical reports and Figs.7-9 show typical tests). As a result of these tests a considerable amount of information became available on the necessary features of a satisfactory hood jettisoning mechanism. Although reports were issued on the various tests the information was never analysed and issued to designers. Consequently the design of many jettisonable hoods is still unsatisfactory and it frequently happens that a hood has to be modified after the prototype has been tested. In addition the rapid development of new aircraft has created problems which have not yet been fully investigated.

The purpose of this Note is to make available the experience which has been gained on the design of jettisonable hoods. It has been found that the present design requirements are not now sufficient to ensure that hoods will always jettison satisfactorily and so these are being revised. The recommendations in this Note are not, therefore, based only on the present requirements but also on several basic design criteria, which are proposed in Section 3 and which underlie the new requirements.

While the information and recommendations given in this Note are the best available, it should be realised that it is not yet possible to give a definite answer to some of the problems that are involved in certain new types of hood. Work is proceeding on these problems and the information will be issued as soon as it becomes available.

This Note deals only with the jettisoning problems of the design of all upwardly jettisonable cockpit hoods and cabin covers. The structural design of the hood is not considered, nor are the problems of the side and bottom escape hatch.

As there is no standard nomenclature a few definitions of the special terms used in this Note are given in Section 2. Attention is drawn to the difference between power operated and forced jettisoning designs. In a power operated design the power is used only to operate the mechanism, undo the locks, etc. In a forced jettisoning design the power is used only to help separate the hood from the aircraft. It will of course often happen that a design will incorporate both systems.

2 Definitions

As there is no standard nomenclature the following list is given of the special terms used in this Note.

"Hood"	Unless otherwise stated, this term has been used to mean "a jettisonable hood or cockpit cover".
"Integral hood"	A design where the windscreen, or the major part of it, is integral with the rest of the hood and jettisoned with it.
"Instantaneous release design"	This is a hood where all the attachment points are released simultaneously when the mechanism is operated.
"Power assisted or power operated design"	In this design the jettisoning mechanism is actuated or assisted by a built-in power supply; the power is not used to assist the hood to leave the aircraft.
"Forced jettisoning design"	In this case the hood is given an initial mechanical impulse to separate it from the aircraft.

3 Design criteria

The present design requirements in A.P.970 for jettisonable hoods are being revised. In order that the design recommendations in this Note may be realistic the following basic design criteria will be used as a basis throughout. As these criteria go beyond the present requirements the reasons for proposing them and the implications involved are given in the following paras. of this Section.

3.1 Flight jettisoning conditions

Criterion 1. It should be possible to jettison the hood at any speed and acceleration within the fully factored flight envelope of the aircraft without danger to the crew, or damage to, or loss of control of the aircraft. If the hood is of a type which can be opened in flight jettisoning must be possible while it is in any position from the fully opened to the fully closed.

The present requirements are that the hood shall make a satisfactory jettison at all aircraft speeds with and without yaw, whilst those for ejector seats are that the seat must operate under all the fully factored flight envelope cases. These two are obviously incompatible: if the hood either will not jettison or is dangerous under these fully factored flight envelope cases, then the successful operation of the ejector seat under these conditions is endangered. This criterion will thus bring the hood jettisoning performance up to the same level as is required by the seat ejection requirements and will improve the chances of the crew in escaping from the aircraft in adverse circumstances.

On all aircraft the jettisoning of the hood must not seriously damage the aircraft as it will often need to continue to be flown after the hood has been jettisoned. (See para. 3.2).

Sliding hoods do not normally open sufficiently far to allow the seat to be jettisoned while they are in the fully open position, and thus it must be possible to jettison a hood while it is in this position.

3.2 Flight without a hood

Criterion 2. It must be possible to fly the aircraft safely at all speeds without the hood.

This criterion is necessary for two reasons.

(1) It follows from 3.1 as the pilot must not lose control of the aircraft immediately the hood is jettisoned, and there will be certain cases when the hood is jettisoned but where the crew do not require to escape, e.g. hood obscured by ice, and often when the aircraft is damaged the jettisoning of the hood will be the first escape operation which will be followed by further attempts to land the aircraft.

(2) Inadvertent jettisons have occurred fairly frequently in recent years and are liable to occur at any speed. As the causes have been very varied, it is unlikely that they can be completely eliminated in the future. Normally after such an inadvertent jettisoning the aircraft should not be seriously damaged and it is essential that the pilot shall not lose control of the aircraft.

While it is desirable that as much protection as possible should be given to the crew after the hood has gone, the bare essentials are that they should retain sufficient control of the aircraft to reduce its speed and altitude, if it is flying at extremes, and to be able to fly at reasonable cruising conditions and to land the aircraft safely.

3.3. Jettisoning while aircraft is stationary

Criterion 3. It must be possible to jettison the hood while the aircraft is stationary.

The necessity for this criterion to be stated definitely has only arisen recently. Previously hoods were sufficiently light for the pilot to be able to push them off the cockpit without undue difficulty and in any case it was normal practice to land with the hood open.

With many present and most future aircraft, however, the hoods are so heavy that it is quite impossible for the pilot or crew to move them unassisted and it is also now the practice to land jet aircraft with the hood closed. On a crash landing or ditching, therefore, it will be impossible on these aircraft for the crew to escape if there has been any damage to the hood opening mechanism.

The problem is especially urgent for jet aircraft operating from an aircraft carrier when they get into difficulties on take-off or landing. The time between the emergency arising and the aircraft being submerged may be very short indeed, it is also quite possible that the aircraft may be travelling at below its stalling speed for the whole period of the emergency, thus probably making it impossible for the hood to be jettisoned in the normal way before ditching. Once the aircraft is submerged it is extremely difficult either to open or jettison the hood due to the very high pressure which rapidly builds up as the aircraft sinks.

There are also other aircraft, e.g. the Canberra, where the hood is so low down the fuselage nose that it cannot be jettisoned before a ditching and from which the only way of escape is through the hood.

3.4 Reliability

Criterion 4. The mechanism must be so reliable and robust that the hood will always jettison when required, will never jettison inadvertently, and will open reliably and easily.

This criterion is mainly self-evident and little comment is necessary. The need for reducing inadvertent jettisons must however be emphasised as the incidence has been rather high and frequently the aircraft is damaged by a hood which would normally be expected to jettison satisfactorily.

4 Aerodynamic design

It has always been agreed that a hood should be jettisoned upwards and should not be slid rearwards along its rails. One objection to the latter arrangement is that the hood usually moves in this manner for normal opening so that if some fault or damage has occurred to the opening mechanism this will also be liable to affect jettisoning and the two will not be independent. The other disadvantage of the sliding jettison is that, if it slides right off the rails, the hood will most probably strike the tail surfaces after release; while if it slides up to a stop, when clear of the cockpit, interference with a rear cockpit or various access hatches is likely. These objections to sliding jettisoning are so serious that this method must be considered unacceptable and all hoods should be designed to jettison upwards. The remarks in this and succeeding Sections are all based on the assumption that the hood is jettisoned upwards.

4.1 Design for jettisoning

4.11 Summary of test results

Early tests showed that a model Spitfire "hood, after release, cleared the tailplane and fuselage by a margin not quite so great as was observed in the flight tests"[1]. This general agreement between model and full scale results has been sustained ever since. If, however, a hood jettisons inadvertently its performance is likely to be far inferior to what would normally be expected, a number of cases have been reported of hoods which normally jettison entirely satisfactorily causing damage to the aircraft structure when inadvertently jettisoned.

The next tests were with an early design of Meteor hood in which the hood was designed to be released instantaneously[2]. (See Definition 3). These tests showed the great importance, when no mechanical restraint for the initial movement after release is incorporated, of simultaneous release of both sides of the hood (see Fig.1); this result has been borne out in subsequent full scale blower tunnel tests. The difficulty of ensuring simultaneous release of both sides of the hood is one of the serious defects of most instantaneous release designs.

Further tests on a model Spitfire hood were then made to determine the effect of varying the aircraft incidence and wind speed and the C.G. position of the hood[3]. "It was found that the behaviour is almost independent of incidence, is slightly better at higher wind speeds and is very sensitive to C.G. change". These tests showed that the essential for a satisfactory jettison is to keep the hood in a positive lift attitude for as long as possible after release.

By this time the Meteor design which had proved unsatisfactory[2] had been redesigned so that the hood was jettisoned complete with the longitudinal retaining rails along which it slid for normal opening and shutting. These rails were hinged at their rear end with a simple fork and pin fitting whereby the rails came free of the pin under centrifugal force when the hood had achieved sufficient angular velocity, see Fig.2. This was the first design to be submitted with the hinged rail feature and on test it proved most satisfactory[4]; the effect of aircraft speed on jettisoning performance was again not very marked, see Fig.3. It was also found that "in most tests the hood and rails lift the pins after turning through an angle of about 30°".

Tests were next made on various Vampire hoods[5]. An instantaneous release type of hood was tested with the C.G. at various positions, see Fig.4, and the results of the Spitfire tests[3] - that C.G. position can make or mar a jettison - were confirmed. A C.G. position was found which gave good jettisoning characteristics; it should be noted that it is the position of the C.G. relative to the C.P. which is important. A model of this hood was also tested with a rail and hinge arrangement, similar to the Meteor design[4], it gave better results than could be achieved at any C.G. position with the instantaneous release design.

During wind tunnel tests of a model Hornet hood, which was of the instantaneous release type, a release was made with the hood open 2 inches full scale[6]. This test indicated that having the hood open this amount did not affect the jettisoning characteristics appreciably. Probably for most designs of hood a small opening of this order will not affect the jettisoning appreciably but large openings may have considerable effect.

From the tests that had so far been made it was concluded that an instantaneously released type of jettisoning mechanism could not be designed satisfactorily without model tests[7]. It was recommended that designs on the lines of the Meteor hood[4] should be adopted for future designs.

The limitations of the simple fork and pin type of hinge were soon discovered and the need for a more advanced design, where the hood was positively freed after a pre-determined angular movement, was realised. Tests were therefore made at various release angles[8], these showed that releases at 0° and 30° both gave unsatisfactory and almost identical results; release at 20° was considerably better, while 10° was easily the best, see Fig.5.

Recent tests have shown that with certain low drag hoods, which have consequent low peak suctions, the hood may be reluctant to move when released. While full scale conditions are likely to be more favourable it is almost certain that the minimum speed at which an unassisted jettison can be expected will be quite high.

Further tests are now being made to check the agreement between wind tunnel, blower tunnel, and flight test results.

4.12 General aerodynamic design

It will be seen from the summary of test results given in the preceding paragraph that to obtain the optimum performance the hood must be kept in a positive lift attitude for as long as possible after release. The various ways of achieving this for different designs of hood and the various factors that have to be considered are discussed below.

All the model tests that are discussed in para. 4.11 were on orthodox types of hood. Hoods were (a) the windscreen is integral with the jettisoned portion or (b) the hood is not jettisoned in one piece were not tested. The integral hood is being fitted to a number of new aircraft and is thus of considerable importance, it is considered further below. The second exception, where a single hood is jettisoned in two or more separate parts has never been made satisfactory and, unless some scheme such as is suggested in the next para. is adopted, its use in any future design is most undesirable.

One further type, on which only limited tests have been made, is the hood which is offset from the centre line of the aircraft; a large hood over a side by side cockpit which is divided longitudinally and is jettisoned as two independent parts can be considered as two offset hoods side by side. It is believed that if such a hood, or each part of a dual hood, is treated in accordance with the various design recommendations given in this Note it should be satisfactory, but until more is known it cannot be accepted without wind tunnel tests.

As has already been shown in para. 4.11 the most satisfactory design is one where the hood is constrained to rotate immediately after release through a certain pre-determined angle about a rear hinge point. The tests described in Ref.8 showed that successful jettisons can only be achieved within a severely limited range of release angle and further tests are therefore required to determine the optimum angle more precisely. The hinge should be designed to give restraint in all directions during the period of guided movement - for side restraint see para. 4.14; this is especially important with the integral type of hood as there is likely to be a forward component of the suction which would pull the hood off a plain pin and fork hinge. On reaching the designed angle the hood should become absolutely free of all restraint. No tests have ever been made on the effect of varying the position of the rear hinge; while there is little doubt that any reasonable position will be satisfactory it is desirable that tests should be made to examine this point. Recent tests indicate that low drag hoods are likely to be difficult to jettison due to the lack of aerodynamic force tending to separate them from the aircraft. Wherever this is the case a forced jettisoning system will need to be used.

The instantaneous release type of design is an alternative which has been used in the past but it should not be used for any new design of hood. The chief disadvantages of this type are as follows.

(a) The jettisoning characteristics are very sensitive to relative C.G. and C.P. positions[3,5]. On high speed aircraft it is probably impossible to keep the relative positions within the required limits on account of the shift of C.P. with Mach number.

(b) A satisfactory integral hood cannot be designed on these lines.

(c) It is essential to ensure that the release of both sides of the hood is absolutely simultaneous[2].

(d) Side load and the considerable aircraft incidences that can be achieved with delta wing aircraft are likely to have serious effects.

4.13 Flight envelope cases

No theoretical work has so far been published on the motion of a jettisoned hood, and the tests so far made have all been concerned with jettisons while the aircraft is in level and either straight or yawed flight. Theoretical calculations are now being made on the jettisoning characteristics of various types of hood under varying flight conditions and this work is to be checked as far as possible by tests. Preliminary results indicate that most types of hood, provided that they are properly designed, should jettison safely within all conditions covered by the fully factored flight envelope, but that considerable care will be necessary to ensure that the final release of the hood is at the optimum angle.

It is proposed to issue the results of these investigations, as soon as they become available.

4.14 Yaw case

The aircraft in yawed flight will usually be found to give a design case for the hood; either the case with maximum dive speed and maximum yaw angle for that speed or the speed where the side loads are the greatest proportion of the total. In order to meet this case during the guided part of the hood movement it is recommended that there should be a hinge at the rear of each side of the hood rather than the single rear hinge that is sometimes adopted - these can often be conveniently arranged at the rear end of the hood rails. If the structure and the mechanism are designed for these cases the flight path of the hood after final release should be satisfactory.

The structural and mechanical problems of this case are all dealt with in paras. 5.21 and 5.22.

4.2 Jettisoning in any position

There is no general requirement that hoods must be of the sliding type; the decision is made individually for each aircraft. If the hood is of the non-sliding type then there is no problem here. All hoods of the sliding type must be jettisonable while in any position from the fully closed to the fully open. The main point to be watched in this case is the changed airflow over the hood. The experimental evidence[6] on the actual effect is very scanty but it appears that many hoods will not jettison in the partly open position without assistance.

4.3 Airflow over cockpit after jettisoning

The cockpit area must be designed so that the crew are able to fly their aircraft and do all essential operations appropriate to the speed and altitude of flight after the hood has been jettisoned and this should be possible at all speeds up to the maximum dive speed even if special design provision is necessary.

An orthodox single-seater hood is unlikely to cause any difficulty but with other designs an internal non-jettisonable windshield may have to be fitted to protect the crew. The problem arises particularly when there is a single hood over a tandem cockpit or when the front windscreen is integral with the hood and is jettisoned with it.

When there is any doubt whether sufficient protection has been provided after the hood has been jettisoned full scale tests should be made.

5 Design of the mechanism for jettisoning

The discussion in this Section is based on the assumption that the basic recommendations of Sections 3 and 4 are followed and it should be read in conjunction with the appropriate paras of these Sections.

The successful jettisoning of a hood consists of 3 equally important phases.

1. The release of the hood
2. The period of guided movement
3. The period of free flight

These 3 phases are dealt with in turn below.

5.1 The release of the hood

The ideal hood release mechanism should not only be simple and light but it should require the minimum of maintenance and setting. The mechanism should be robust and foolproof in operation and always release every attachment point simultaneously. The pull-off load should be light at all aircraft speeds and little affected by dirt or minor damage. Manufacture should be simple so that every sample has an equally good performance and it should operate even if the fuselage or hood are slightly distorted. Inadvertent jettisoning should be impossible.

Previously no standard of reliability for hood jettisoning has been laid down and this has meant that the actual standard reached with many designs has been very poor. It is now suggested that a failure rate of not greater than 1 in 20 for all design conditions should be aimed at. The implementation of this suggestion is not easy as obviously a number of trial jettisons with one trial hood under similar conditions would be almost useless. A suggested method of test would be to design a simple test rig which would take unmodified aircraft and could be used to apply suitable loads to the hood, several trial jettisons could then be made on a considerable number of production aircraft.

5.11 Various types of mechanism

The simplest satisfactory type of hood jettisoning mechanism is one in which a fixed hood of rectangular planform is held at its four corners. On pulling the jettisoning handle the two front attachment points are released and the hood is then free to rotate about the rear two. These rear points will be designed to release positively when the hood has rotated through a small fixed angle. The mechanism will be designed so that the pull exerted on the jettisoning handle releases the two front attachment points directly and simultaneously.

A hood will rarely be as simple as this and may be complicated in one or more of the following ways.

(1) It may be designed to slide for normal exit. In this case the most convenient design is usually for the hood to slide in rails which are jettisoned complete with the hood. If this is done the hood can easily be released in any position from fully closed to fully open; it is advisable, however, on release to lock the hood in the rails to prevent it sliding up them.

(2) The hood may be large or fitted to a high speed aircraft. If so, difficulty will be experienced in keeping the pull required within reasonable limits (see para. 5.12). The only possible solution may then be power assistance or complete power operation.

(3) If the hood is large a number of attachment points will probably be necessary. Care will then have to be taken to ensure that they all release simultaneously and that they are not liable to jam when the hood or the aircraft structure is slightly distorted.

(4) The hood may not be of rectangular planform or the designer may have arranged for it to carry part of the fuselage loads. In this case the design will be more difficult, but the basic criteria must still be met. As these unusual types of hood tend to have inferior jettisoning characteristics, great care will have to be exercised.

The above gives a general outline of the problems and a few possible solutions. In the rest of this paragraph the various possible types (manual, power assisted and power operated, but excluding the use of explosive bolts) of mechanism are reviewed and their range of application suggested. In every case the assumption is made that the mechanism is of the recommended rear hinge design.

(1) Simple manual operation: In this case the necessary force has to be exerted by the pilot. As the maximum force that the pilot can be expected to exert is low (25 lb maximum is suggested) considerably ingenuity must be exercised in the design of the jettisoning mechanism of large hoods. A common arrangement is for the handle merely to pull the mechanism over a dead centre: the lift of the hood completing the operation. As the proportion of air loads on the hood to handle pull may be in the ratio of more than 500 to 1 the design and setting have to be very exact - designs of this type usually give trouble by jettisoning inadvertently. A strong recommendation is made that a mechanism of this type should only be used with fairly small hoods on relatively slow aircraft. A suggested limit is to put this type of mechanism only on hoods where the total up load does not exceed 3000 lb. This type should be kept as simple and as straightforward as possible and preferably there should be only one attachment point, apart from the rear hinge, on each side.

(2) Power assisted: Here the operation of the mechanism does not rely solely on the strength of the pilot. One type of design is to arrange for the jettisoning handle to unlock a spring which assists the pilot in exerting the necessary force to operate the mechanism. In this case, if the first pull fails to jettison the hood the mechanism can be designed so that the pilot can make further purely manual attempts. This type of mechanism is not recommended. the lighter hoods do not require it and if the hood loads are sufficiently great to make a purely manual release difficult, then it is better to use a fully power operated design.

(3) Power operated: In this case the pilot merely has to set the mechanism in action. The most obvious design of this type is where a spring supplies the necessary energy. This design is not likely to prove entirely satisfactory as it is heavier and more complicated than the best manual types and is often rather unreliable and difficult to set. Operation by a cordite cartridge should prove more satisfactory, although as yet there is no experience of this type available in this country. Whatever energy source is chosen it should have ample power - at least 10 times the nominal required is suggested. It is essential that adequate power should be provided; present spring powered designs are very lacking in this respect.

As with this type there is no possibility of the pilot making a second attempt to jettison if the first fails, the mechanism must be made as foolproof as possible. The power supply should be duplicated and each unit should be actuated independently and be capable of jettisoning the hood. In most cases a combination of the power operated release mechanism with the forced jettisoning arrangement will be found convenient; this is dealt with more fully in para. 5.23.

5.12 Pull-off load

The hood will usually have to be jettisoned under adverse conditions in an emergency and the pilot will often be far from fit - he may be suffering from lack of oxygen, his arm may be injured, etc. In past designs the pull required has shown a distressing tendency to increase as the design proceeds from prototype to production and from production to service: an increase in the load required of 100% at each of these stages is not unknown. Great care will be needed to avoid the continuance of this tendency. It is suggested that a maximum pull-off load of 25 lb should not have to be exceeded to release the hood under the most adverse flight condition.

For the power operated designs a figure of 15 lb is suggested. It is desirable to keep the pull of a reasonable magnitude so that the mechanism is not operated inadvertently. This suggestion is modified when the hood is operated automatically from the ejector seat, see para. 5.41.

5.13 Use of explosive bolts

One way of securing a jettisonable hood, which is designed as a stress carrying part of an aircraft fuselage, is by means of explosive bolts. Such hoods are held down by a considerable number of bolts and are thus made essentially part of the fuselage structure. Normal entry and exit are through other hatches and the hoods are never normally moved.

It is essential that all the bolts should fire simultaneously and that the danger of any failing to fire must be reduced as much as possible. A considerable amount of work has already been done by the English Electric Co. on this problem[9], but before this method can be accepted as fully satisfactory and reliable a much more searching test programme is essential.

Tests have also been made[9] to check whether the blast pressures, when the bolts are fired, are dangerous to the pilot. The pressures were within tolerable limits and provided that care is taken to shield the pilot from direct blast and flying debris, difficulty should not be experienced in other installations.

It is desirable that the firing of the bolts should be independent of the aircraft electrical supply as far as is possible and in any case provision should be made for at least 2 alternative and independent circuits and sources of supply; there must be no possibility that the bolts can be fired accidentally by an electric fault. It is essential that the complete firing circuit and bolts should be tested periodically and in order that these tests may be affective the complete circuit with all bolts connected up must be tested in situ.

A considerable amount of test work remains to be done before this method of releasing the hood can be considered really satisfactory and reliable.

5.14 Design details

In paras. 4.12 and 5.11 the merits of various types of hood jettisoning design are considered, while in this paragraph the detail design problems that are common to most hoods are dealt with.

The hood jettisoning mechanism that gets into service without needing either redesign or careful control of manufacturing processes is very rare. It has thus come to be assumed that jettisonable hoods will always be a source of trouble and need constant care and maintenance while in service, but this need not be so. Many of these troubles are caused through faulty basic design and can be eliminated, but there are also smaller points which can have serious results. While all the possible sources of detail fault cannot be dealt with in a Note such as this, an attempt is made to give some guidance so that they may be avoided.

The first and most important thing is to realise that these troubles do occur and that only a really well designed hood can give good service. A satisfactory hood jettisoning mechanism is difficult to design and should be approached accordingly.

As has already been indicated many of the present installations are barely satisfactory, and are only made so when carefully maintained and accurately adjusted. These necessarily frequent inspections bring obvious troubles in their train - grit or oil getting into the mechanism, faulty setting, incorrect adjustment, failure to re-engage all the catches etc. The mechanism should be designed so that it does not require frequent maintenance. The ideal to aim at is a mechanism which needs no inspection or servicing but which is designed so that it cannot be replaced incorrectly and does not suffer from any number of test jettisonings, dirt, grease, or normal service handling. The aircraft should be designed so that it is never necessary to remove the hood for normal inspection or servicing of any other part of the aircraft.

One of the features which have most consistently caused trouble has been the use of cable controls and especially those which are not sheathed. While the detail faults have been varied the fundamental trouble has always been lack of rigidity in the whole control circuit.

In order to keep the mechanism as simple as possible and to reduce the possibility of the hood jamming due to distortion of the structure the number of attachment points should be kept to a minimum. Furthermore the mechanism should be designed so that there is no possibility of it icing up - due perhaps, to water accumulating and subsequent freezing on a vital part of the mechanism.

The mechanism should also be designed so that it will not jettison inadvertently. Some designs have been very poor in this respect; a failure rate as high as 1 per 280 hours flying has been experienced while a rate of about 1 per 3000 hours is fairly common. With aircraft flying higher and faster inadvertent jettisons are likely to become more and more dangerous and every effort must be made to eliminate this trouble in new designs. It should be impossible for any part of the mechanism to be in a partly locked position.

Special care should be devoted to the design of the jettisoning handle and its attachment to the mechanism. It should be impossible for the hood to be anything other than fully locked when the jettisoning handle is in the stowed position and it should be sealed in this position.

One further point that needs attention is the fitting of the hood to the structure. At low aircraft speeds the suction forces on the hood are not greatly in excess of the weight of the hood and trouble has occurred through the hood sticking to the structure and thus either preventing or hindering the jettison. In the past the fault has been caused either by the sealing strips or by some structural deformation or tight fitting. The hood should be designed so that, as far as possible, immediately it is released there will be no mechanical force tending to keep it attached to the aircraft structure. In addition the mechanism should be designed so that the likelihood of it jamming or becoming ineffective after a crash landing is reduced as much as possible.

5.2 Period of guided movement

The strength and mechanical problems that will be met in following the design recommendations of paras. 4.12-4.14 are considered in the following paragraphs.

5.21 Provision of restraint during jettisoning

As it must be possible to jettison the hood while the aircraft is in yawed flight, the mechanism must be designed to take side load.

Yaw loads are liable to cause two adverse effects, (a) increase of the release loads due to distortion of the fuselage, hood etc. and uneven distribution of the load, (b) the very considerable side loads during the period of guided movement. (a) is merely an additional factor tending to increase the pull-off load discussed in para. 5.12. (b) is likely to be a design case for every hood. It is not yet known whether it is necessary to restrain the hood up to the full static side load but, wherever possible, the mechanism should be designed to give full restraint and tests should be made to examine the problem. The twin hinge design which makes it easier to meet this case, has already been recommended in para. 4.14.

If full restraint cannot be provided, flight or blower tunnel tests should be made before the hood is accepted.

5.22 Strength of hood during jettisoning

Experience has shown that it is undesirable for a hood to break up during the early stages of jettisoning. A break-up does not necessarily prevent a successful jettison but it will usually reduce the clearance over the fin and sometimes will have far more serious results. The aim should thus be to make the hood at least strong enough to stay in one piece: if the hood is strong enough not to break up during its guided movement it will probably also stay intact during its free flight.

Very little work has so far been done on the strength needed in the hood while it is moving and so the following remarks are of a tentative nature. The most usual type of failure is by the two sides of the hood spreading when the fuselage restraint is removed; hoods which have substantial frames or are of a large radius of curvature are not so prone to this type of failure. A transverse frame member fore or aft of the hood which, while insufficiently strong to prevent the hood from breaking, will keep it in one piece would most likely be of considerable help. No stressing requirements can yet be stated for this case: probably, as the duration of the loads is small and as the hood usually has considerable flexibility, it will be found unnecessary to meet the full static loads. This problem needs to be investigated further.

The other stressing case is that of side load due to aircraft yaw. The hinges and their various attachments should be stressed for the full static load, but it is thought that the main hood structure will not normally need any strengthing for this case.

5.23 Forced jettisoning

For certain conditions - criterion 3 in para.3.3, hoods weighing more than say 50 lb, the special problem with ejector seats mentioned in para. 5.41, and perhaps also the difficulty that may be experienced with certain hoods mentioned at the end of para.4.11 - it may be necessary to provide a means of assisting the hood to jettison. The lines on which such a forced jettisoning system should be designed are considered in this para. and the suggestions are based on the recommended "rear hinge" jettisoning design.

The most satisfactory solution is probably one incorporating a power jack fitted under each side rail of the hood at a suitable distance from the rear hinge point. These two jacks should preferably impart to the hood at least twice the angular momentum required to make it fall clear of the cockpit region when the aircraft is horizontal, thus ensuring that in an emergency one jack will be able to do the work. The mechanism should be designed so that the jacks do not operate before the hood is free to rotate and that they then operate simultaneously. Each jack should be fired independently and they should be arranged only to assist the jettison, thus if both fail to operate the hood should still be jettisonable in the normal way. The case of only one jack firing may be a design case. The mechanism should also be designed so that there will be no effect if one or both of the jacks are fired by any means other than by the operating of the jettison control - neither damage to the hood nor to prevent any subsequent unassisted jettison. The forced jettisoning system may often be combined with the power operation of the jettisoning mechanism which is considered in para. 5.11.

It is suggested that cordite operation of these power jacks will be found to be the lightest and simplest. A mean operating pressure of 1000-2000 lb/sq.in should be aimed at and with this pressure a typical single-seater fighter canopy is likely to require jacks of approximately ½ - 1 in bore × a few inches stroke. Percussion firing of these jacks is recommended as it is likely to be more reliable than electric firing.

Such a forced jettisoning system is now being developed for several aircraft. Theoretical ejection characteristics under all flight and static conditions are also being investigated and results will be published as soon as they become available.

5.3 Period of free flight

Once the hood is completely free of the aircraft the problem is obviously a purely aerodynamic one and if the mechanism has done its job properly then the trajectory will be the optimum for the particular design. The only point that requires watching is the possibility of any loose or discarded parts of the mechanism striking the crew or structure. It is recommended that all parts of the mechanism should remain attached to the aircraft or the hood itself in such a way that they cannot do damage.

5.4 Special problems

5.41 Special problems when ejector seats are used

When the non-automatic ejector seat is used no extra problems are presented to the hood designer other than perhaps the need for making the hood somewhat larger than would otherwise be required.

Special problems occur however with the automatic seat. This is designed so that the pulling of the seat operating blind sets all the necessary operations in motion - including the jettisoning of the hood. Provision must therefore be made for the seat blind to operate the hood jettisoning mechanism. No great difficulty should be found in arranging this but there are two problems involved.

(a) Only a very light load (of the order of 2 - 3 lb) can be used to initiate the operation of the jettisoning mechanism.

(b) The hood must invariably clear the seat trajectory within a given interval and preferably this interval should be very short. The total time from initiating the mechanism to the final clearance of the seat trajectory should not in any circumstances exceed 0.5 sec.

In order to meet (a) a power operated system will be essential, probably of the type recommended at the end of para. 5.11. This load of 2 - 3 lb applies only when the hood is operated from the seat. The usual hood jettisoning handle will normally be required in addition; for this a pull-off load of 15 lb as suggested in para. 5.12 should apply.

The requirement of (b) is not so simple to meet. Very little information is available on the time taken to jettison and it is not known whether the time varies with different designs or whether there is much scatter in the results obtained for any one design. Full scale tests are required to investigate this problem. The forced jettisoning arrangement recommended in para. 5.23 may possibly be essential for all aircraft fitted with fully automatic ejector seats.

If the hood is completely, or almost completely, constructed of perspex the mechanism should be designed so that in an emergency it is possible for the seat to be ejected through it at any time when it should prove impossible to jettison the hood. If the hood consists of perspex windows set in metal frames which would obstruct the ejection path it should be made impossible for the seat to be ejected unless the hood has been jettisoned first. In either case the jettisoning of the hood should not either directly or indirectly (perhaps due to excessively turbulent conditions in the cockpit or around the seat firing mechanism after jettison) precipitate the ejection of the seat.

The problem of operation with a pressurised aircraft is dealt with in para. 5.42 below.

5.42 Cockpit pressure

While a hood will often be jettisoned when there is little or no internal cabin pressure the mechanism should be designed so that a jettison with the full pressure differential plus the most adverse air loads is possible.

The jettisoning control should be designed so that the hood can be jettisoned before the pressure has been released. The link-up with an ejector seat recommended in para. 5.41 should remain the same for all pressurised aircraft; the sequence should be designed to operate irrespective of the cabin pressure.

5.43 Multi-seater cockpits

While a satisfactory single jettisonable hood can be made to cover a multi-seater cockpit, it is desirable that wherever possible each occupant should have a separate hood as usually the large hood will be heavier and far more difficult to design than the small ones. Care must however be exercised if two side by side or two hoods in tandem are used. If two hoods in tandem are provided difficulty is likely to be experienced in getting the rear hood to jettison. For the special problems of side by side hoods see para. 4.12.

5.5 Escape hatches

The jettisoning of escape hatches, and especially those which are on the top surface of the fuselage, must be treated in the same way as any other jettisonable hood. The attitude of considering an escape hatch as a different problem from a jettisonable hood is quite untenable; as much care, development, and testing must be devoted to every new design of escape hatch as of every new design of jettisonable hood. In the future the distinction between hoods and hatches is likely to become less and less marked. Fig.9 shows that if the above design recommendations are not met for an upwardly jettisonable hatch the results can be quite as serious as failure to meet the recommendations for more normal types of hood.

5.6 Standardization of design

Some have urged that there ought to be a measure of standardization of hood design, but at the moment this is not considered feasible for the following reasons.

(a) The hood and its main structural members cannot be standardized because hood sizes and shapes vary so greatly that to make them uniform would often entail considerable structural and aerodynamic modifications to the aircraft.

(b) Because of these major differences the details of the jettisoning mechanism differ also.

(c) The design of hoods is changing so rapidly at the moment that it is impossible to design a standard which would last for any length of time.

At the present the only part which should be standardized is the design and operation of the jettisoning and opening control handle; this has been considered by the cockpit Standardization committee for some time and recently a new recommendation has been issued.

5.7 Routine tests of new designs

The routine tests that are laid down in A.P.970 must be made on all new designs of hood. The static tests should be made before the prototype flies. The full scale flight or blower tunnel tests should be made under the most adverse conditions possible. In every case where the aircraft is fitted with the jettisoning control actuated by the ejector seat the time delay between the initial operation of the mechanism and the hood clearing the ejector seat trajectory should be measured. See also para. 5.41.

In addition to the above tests, if the design of the hood or jettisoning arrangement is in any way unorthodox wind tunnel tests should be made before the design is finalised.

6 Design of the hood opening mechanism

Jettisonable hoods may be designed to open in several ways for normal entry and exit of the aircraft or they may be designed never to be used under ordinary circumstances by the crew. The most common type of design is one in which the hood slides aft along rails. The various design problems concerned with the sliding hood are considered below.

The requirement of A.P.970, Chapter 103, para. 3.41 concerns sliding hoods. It should be noted that the hood should remain locked automatically during a crash landing at whatever position it is between fully closed and fully open. It should also be noted that a sliding hood must be operable after a 25g crash landing, see A.P.970, Chapter 309, para. 2.1. Positive stops should be provided at the "open" and "closed" positions.

The hood opening and jettisoning mechanisms should be completely independent, and if both are electrically operated there should be two independent power supplies. If the hood is normally opened electrically it is desirable that an override should be provided to allow for the hood being opened manually either from the inside or outside.

7 Summary of recommendations

So that the recommendations made in this Note may be readily available they are summarised in this Section. The paragraphs in the Note that deal in detail with the various points are given in brackets after every recommendation.

(1) Type of design: The rear hinge type of design should always be adopted; some of the following recommendations will only apply to this type. (Para. 4.12).

(2) Restraint during guided movement: The hood should be positively restrained so that on release it will be constrained to rotate through a small angle about a rear hinge point and then be completely released. These rear hinge points or point should be designed so that:- (a) the hood is prevented from escaping in any direction, including forward, until the required angle is reached, (b) adequate side restraint for yaw loads is provided, and (c) they are not in front of the rear edge of the hood. (Paras. 4.12, 4.13, 4.14 and 5.21).

(3) Forced jettisoning. Under certain conditions it will be necessary to provide forced jettisoning. Where this is required a mechanism powered by cordite operated percussion fired jacks is recommended. (Paras. 3.3, 4.12, 5.11, and 5.23).

(4) Flight after hood jettisoned: Attention should be paid to the airflow over the cockpit region after the hood has been jettisoned and protection should be provided for all crew members where necessary. In cases of doubt a blower tunnel test should be made. (Para. 4.3).

(5) Strength of hood during jettisoning: The hood should be designed to withstand all the air loads of straight and yawed flight during the whole of its guided movement without breaking. If this is impossible it is essential to ensure that broken parts of the hood do not separate until well clear of the aircraft. (Paras. 5.21, 5.22, and 5.3).

(6) After release all parts of the mechanism should remain attached to the aircraft or to the hood in such a way that they cannot do damage. (Para. 5.3).

(7) Operation of mechanism: For designs of hood where the total air load does not exceed 3000 lb a simple manual jettisoning system is recommended; for all other hoods a power operated design will normally be found more satisfactory. It may often be found convenient to use the same power supply for the power operation as for the forced jettisoning of the hood, see recommendation 3. (Paras. 5.11 and 5.23).

(8) Jettison handle load: The load required on the hood jettisoning handle should always be between 15 lb and 25 lb (for the exception when an ejector seat is used see para. 5.41). (Para. 5.12).

(9) Details: Hoods should normally be designed with the minimum of attachment points and there should be no possibility of the hood sticking, due to sealing strips, etc., after release. The mechanism and jettisoning control should be arranged so that the possibility of an inadvertent jettison is reduced to a minimum and so that the hood cannot be partially unlocked without it being obvious. (Para. 5.14).

(10) Reliability: The hood opening and jettisoning mechanisms should be completely independent, the failure of one should not affect the operation of the other. If the hood jettisoning mechanism is electrically operated, including electrically fired explosive bolts, there should be two independent sources of electrical power. A simple means of checking the electrical circuit with the explosive bolts in situ and with the electrical circuit complete should be provided. Whatever the method of jettison a failure rate not greater than 1 in 20 should be achieved. (Paras. 5.1 and 5.13).

(11) Safety precautions: Care should be exercised in all designs to prevent inadvertent jettisoning. The possibility of the mechanism getting over dead centre is the danger that must be avoided with the manual designs, and with all electrically operated designs (explosive bolt arrangement especially) the possibility of an electric fault closing the circuit is the hazard. For the forced jettisoning arrangement it is suggested that the design should be such that if one or both of the jacks are fired by any means other than the jettisoning handle it should have no effect and the mechanism should be strong enough to resist the load without damage. (Paras. 5.11, 5.13, and 5.23).

(12) Seat ejection problems: Where the jettisoning of the hood is operated by the first movement of the seat ejection control the hood should be designed to clear the trajectory of the seat within 0.5 sec of the initiation of the mechanism. In this case the mechanism must be operated by a very light pull; this does not affect the provision of the ordinary hood jettisoning handle which should act independently. (Paras. 5.12 and 5.41).

(13) Jettisoning with cockpit pressure: In all pressure cabin aircraft the hood jettisoning mechanism should be designed so that it can operate with the full pressure differential plus the most adverse air loads. (Para. 5.42).

(14) Multi-seater cockpits: Hoods should be kept small and wherever possible a single hood should not cover more than one occupant. (Para. 5.43).

(15) Hatches: These recommendations apply equally to all types of hood, hatch, cover etc. which are jettisonable upwards. (Para. 5.5).

(16) When the hood opens by sliding along its rails and the mechanism is electrically operated a manual override which can be used either from within or outside the cockpit is desirable. Positive stops should be provided at the "open" and "closed" position and it should remain locked at any other position. (Section 6).

8 Further developments

This Note gives the present state of knowledge on jettisonable hoods. It will be seen that, while satisfactory hoods of an orthodox type can be designed, a considerable amount of development and research is still needed before the position is really satisfactory.

It is expected that it will be possible to issue a Technical Note giving the results of investigations into the optimum release angle of various types of hood in the near future. Work is also proceeding on the design and development of forced jettisoning systems and it is hoped that it will soon be sufficiently complete to allow further information to be published. The other problems are also being investigated and it is intended to issue the results as soon as they become available.

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2	E. Markland D.J. Higton, and R. Hall	Model tests on the release of the F.9/40 cockpit hood. R.A.E. Technical Note No. Aero 1424. April, 1944
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4	A.R. Fox, and F.W. Kirkby	Model tests on the release of the cockpit hood of a twin jet fighter (Meteor III) in the 24 ft wind tunnel. R.A.E. Technical Note No. Aero 1562. December, 1944.
5	A.R. Fox, and B. Stokes	Further hood jettisoning tests on a model single jet fighter (Vampire) in the 24 ft wind tunnel. R.A.E. Technical Note No. Aero 1654. June, 1945.
6	B. Stokes, and A.R. Fox	Model tests on the release of the cockpit hood of a twin engined fighter-(Hornet) in the 24 ft wind tunnel. R.A.E. Technical Note No. Aero 1720. November, 1945.

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8	R. Fail	Model tests in the 24 ft wind tunnel to determine the optimum angle for release of a cockpit hood R. & M. 2644. March, 1948.
9	G. Hinnells	Development of explosive bolts. English Electric Co. Ltd., Aircraft Div., Report No. M T.15, October, 1949, also S & T Memo. No.1/50.
10	-	Meteor Mk.8 VZ473 (2 Derwent 8). Ground hood jettison trials. 3rd part of Report No. A.A.E.E./817,e. October, 1950
11	-	Sea Fury T. Mk.20 VX818 (Centaurus 18) Further ground hood jettison trials on the front hood. 7th part of Report No. A.A.E.E./830,b. October, 1950.

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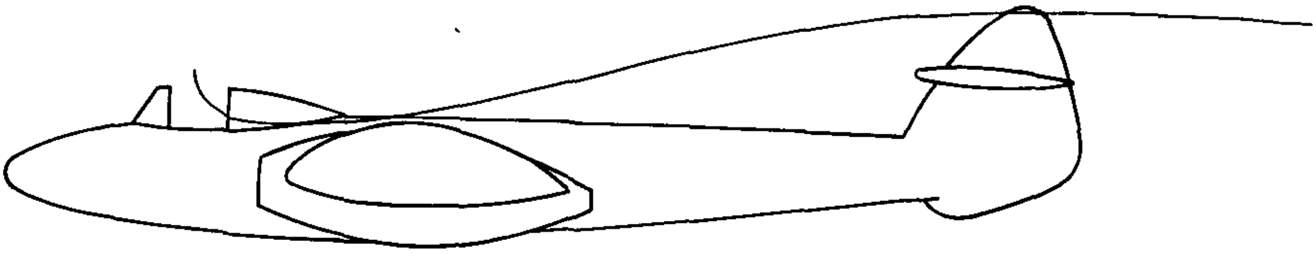


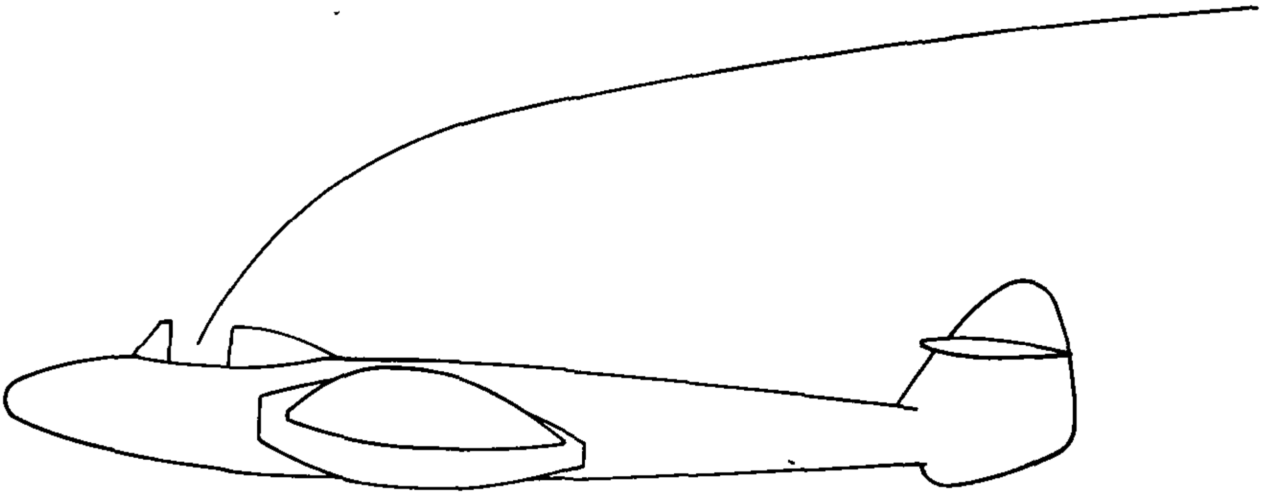
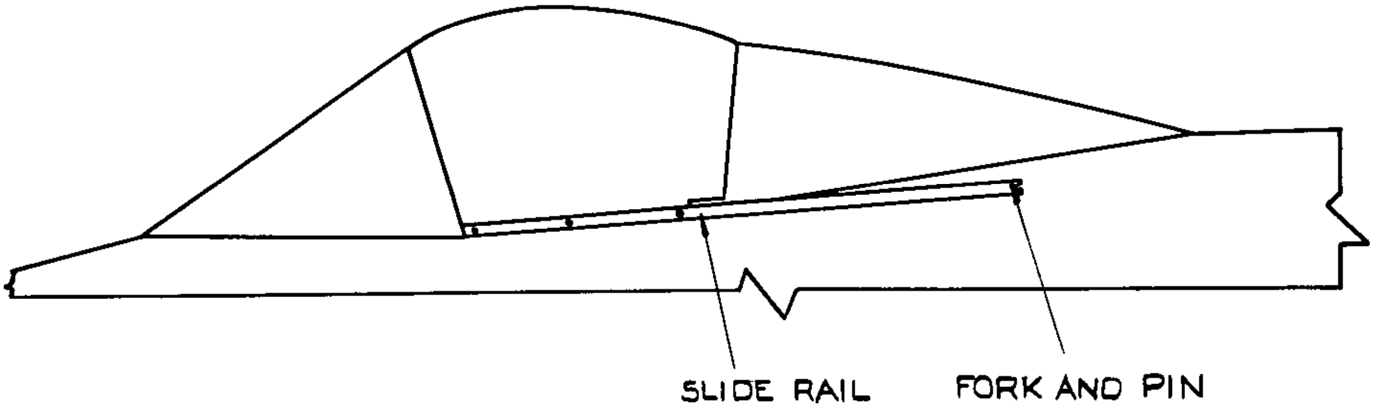


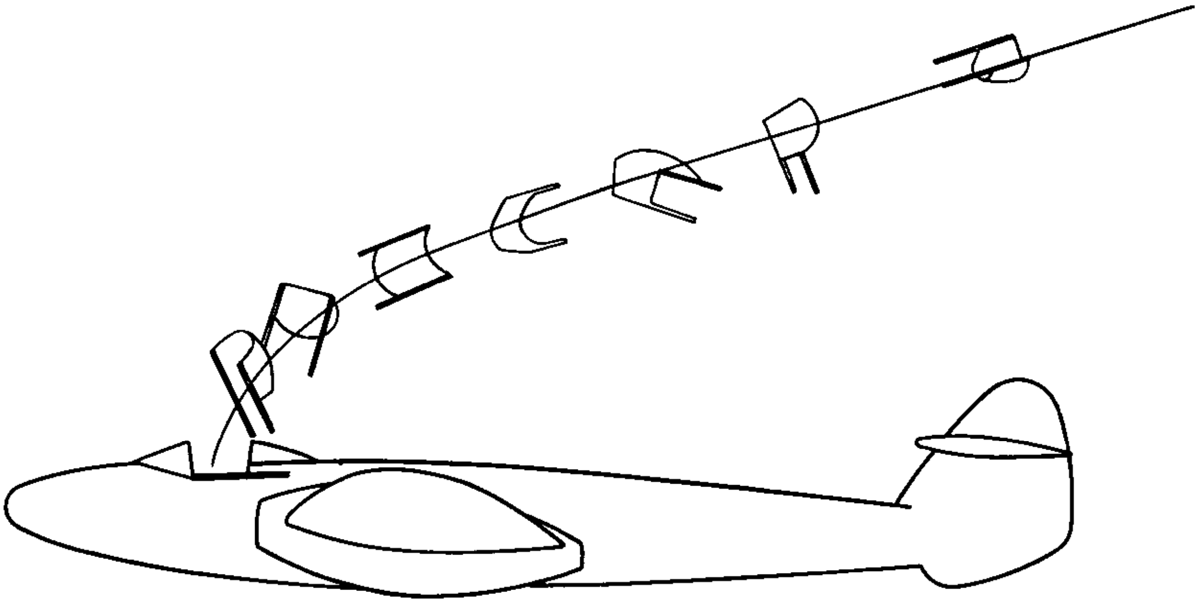
FIG.1. TYPICAL HOOD JETTISON TRAJECTORIES WITH INSTANTANEOUS RELEASE DESIGN

(FROM REF. 2.)

FIG. 2.



SKETCH OF MODEL HOOD

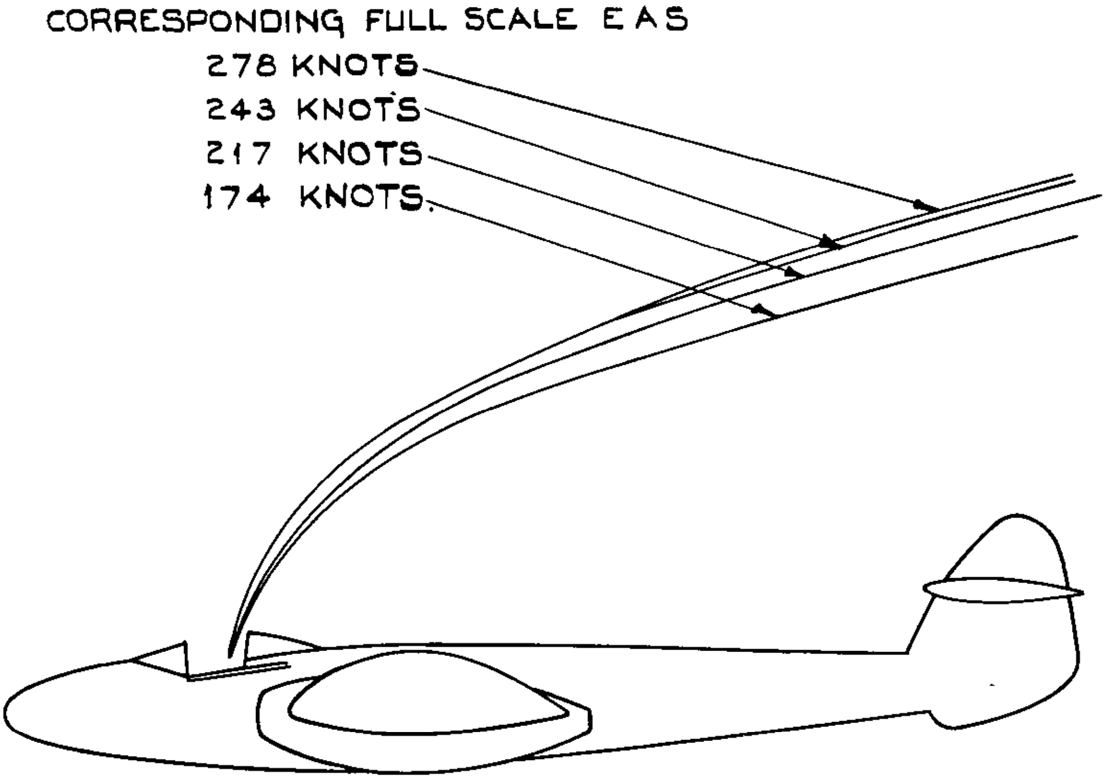


CORRESPONDING E A S 217 KNOTS.

TYPICAL HOOD JETTISONING TRAJECTORY

FIG. 2. HOOD JETTISONING WITH REAR HINGE DESIGN

(FROM REF 4.)

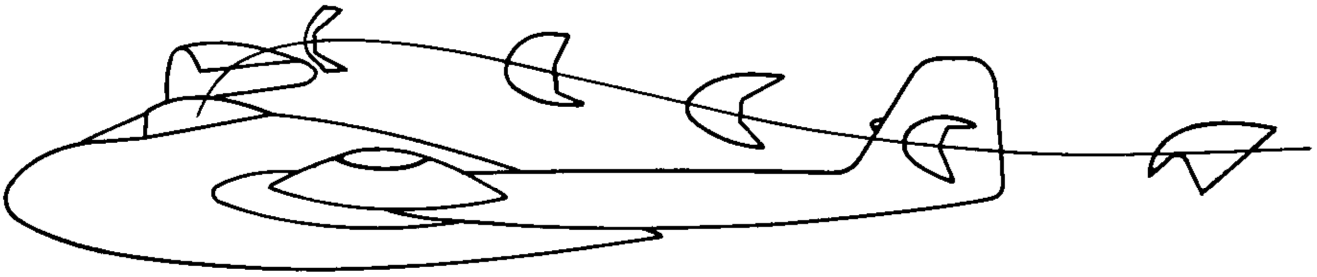


PATHS OF C.G. OF HOOD

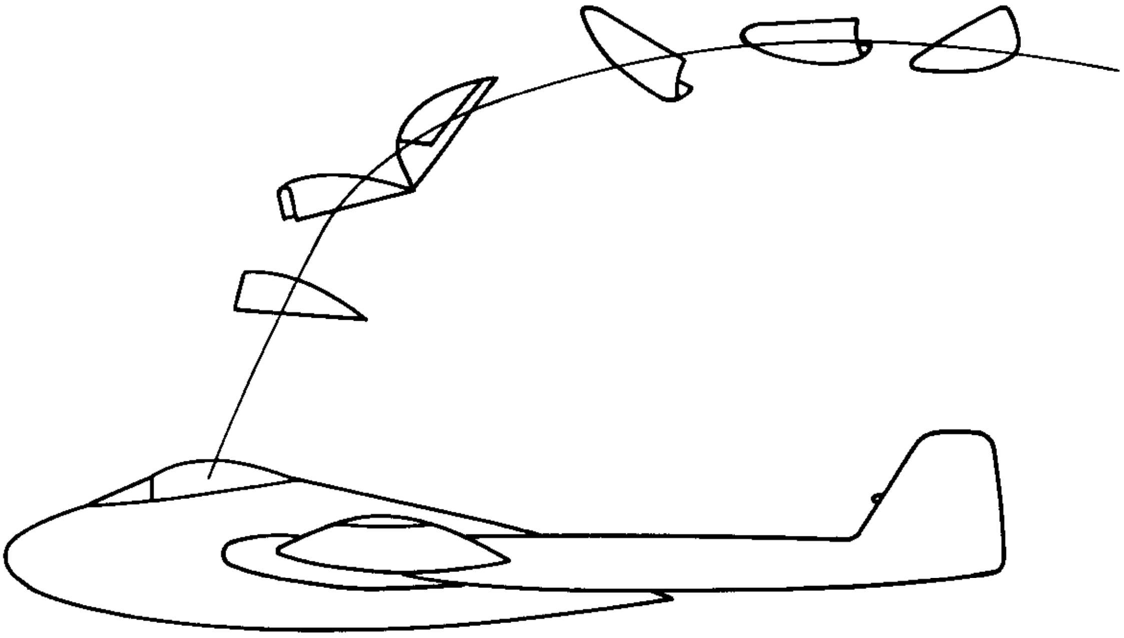
FIG.3. HOOD JETTISONING TRAJECTORIES AT VARIOUS AIRCRAFT SPEEDS WITH THE REAR HINGE DESIGN

(FROM REF. 4)

FIG.4



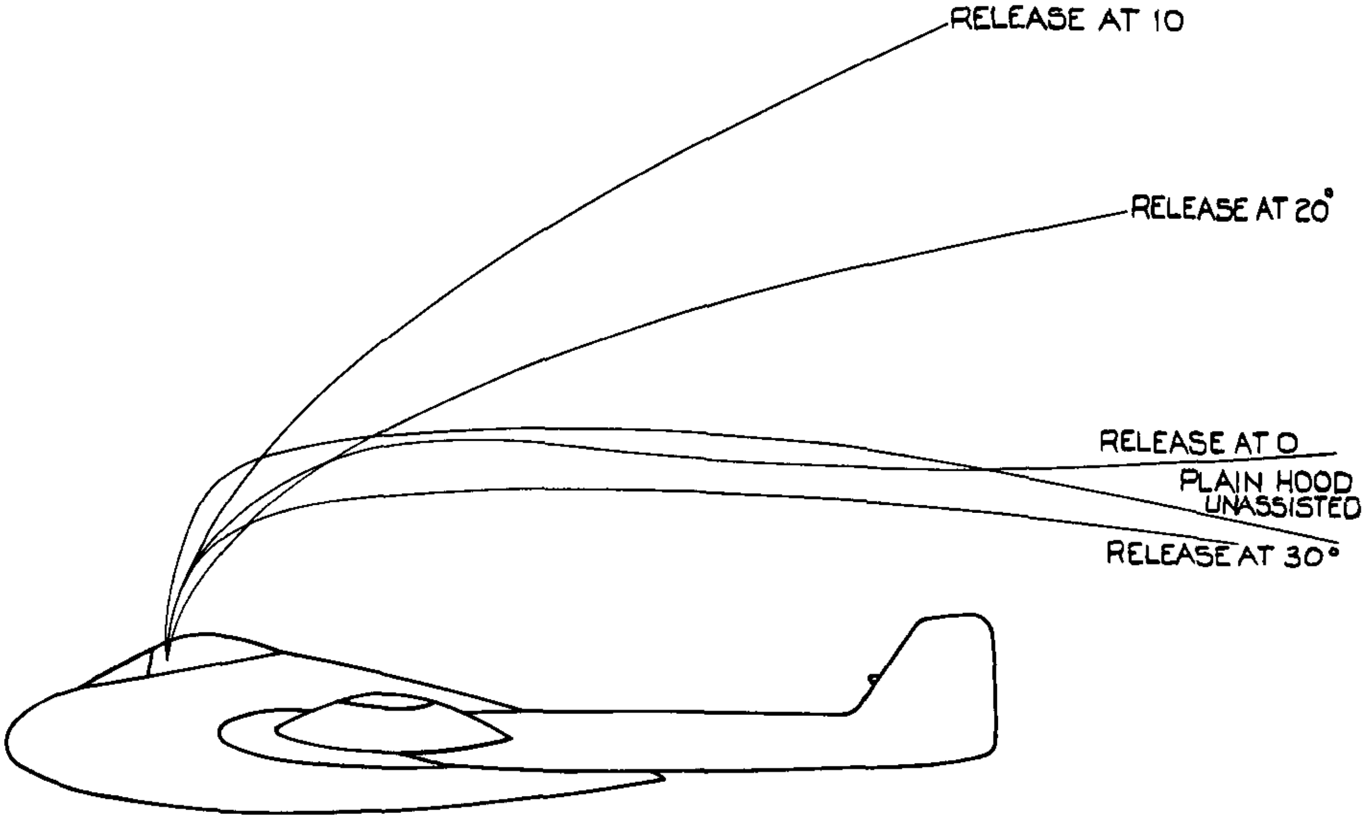
CG OF HOOD 38% OF LENGTH FROM LEADING EDGE
CORRESPONDING EAS 261 KNOTS



CG OF HOOD 44% OF LENGTH FROM LEADING EDGE
CORRESPONDING E.A.S 261 KNOTS

FIG.4. TYPICAL HOOD JETTISONING TRAJECTORIES WITH INSTANTANEOUS RELEASE DESIGN & VARYING C.G. OF HOOD

(FROM REF. 5)



CORRESPONDING EAS 217 KNOTS
PATHS OF CG OF HOOD

FIG 5 HOOD JETTISONING TRAJECTORIES AT VARIOUS RELEASE ANGLES WITH THE REAR HINGE DESIGN

(FROM REF 8)

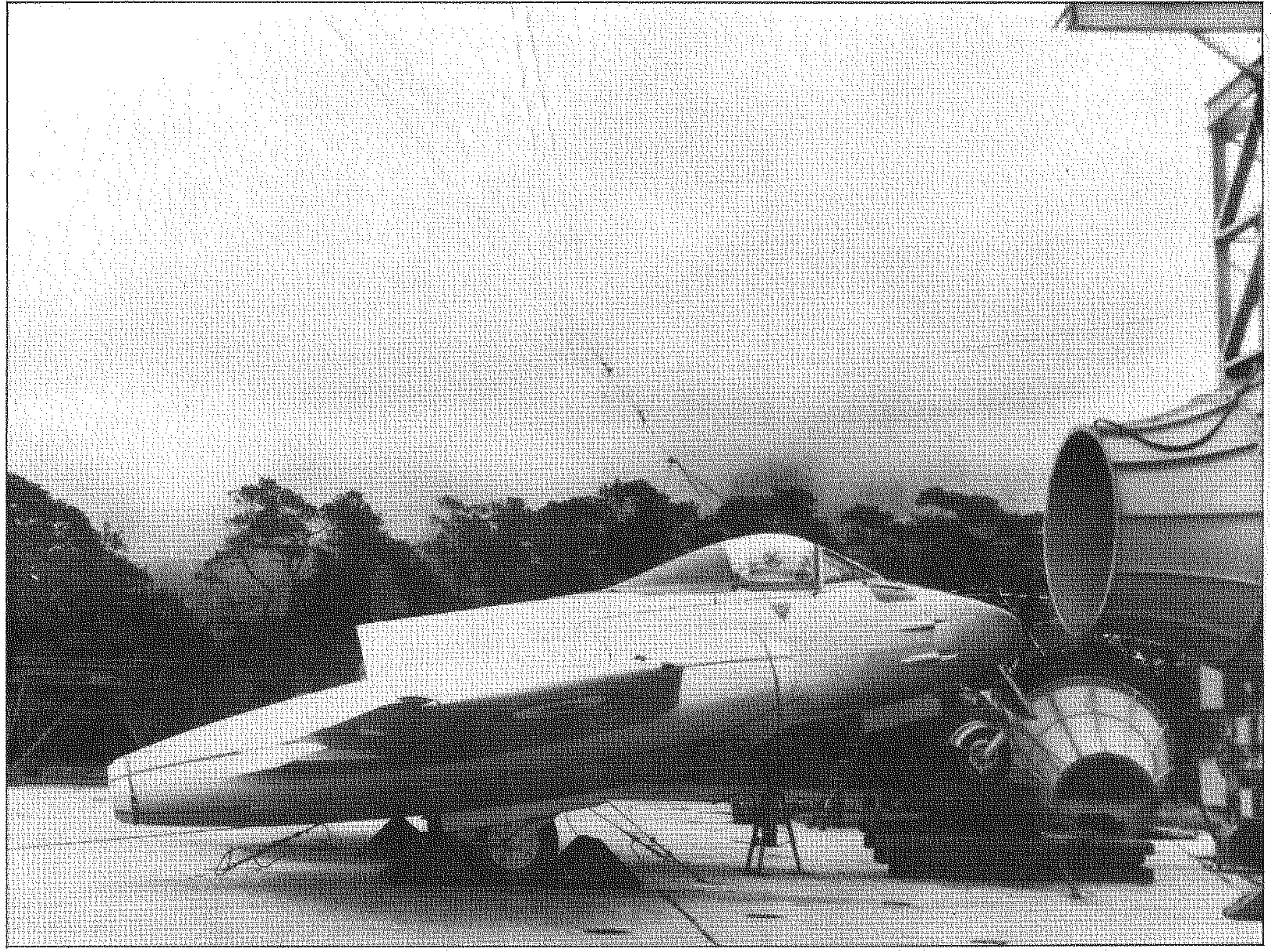


FIG.6. A TYPICAL ARRANGEMENT OF AN AIRCRAFT (METEOR 8) READY FOR A HOOD JETTISONING TEST IN THE BLOWER TUNNEL AT BOSCOMBE DOWN

FIG.7

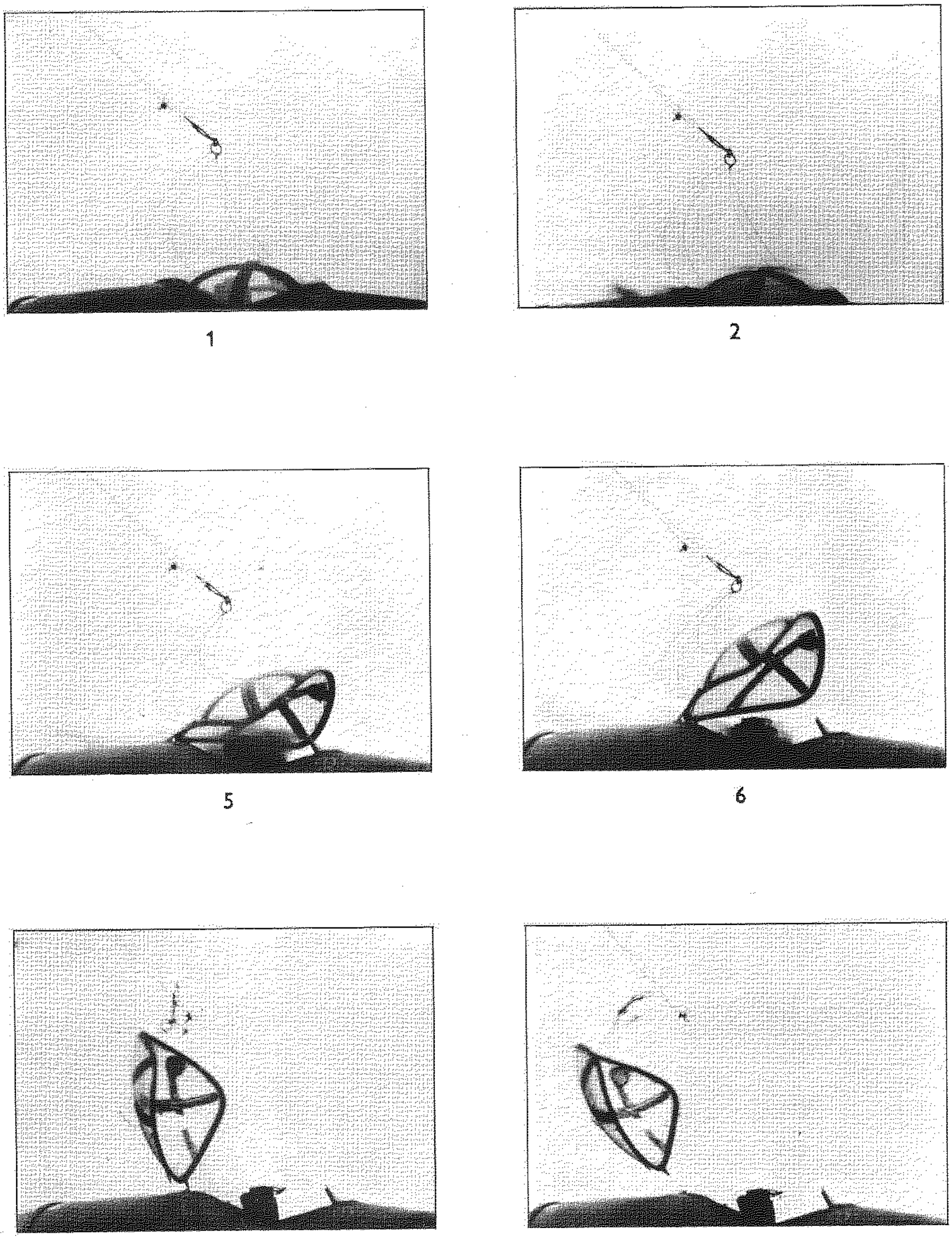

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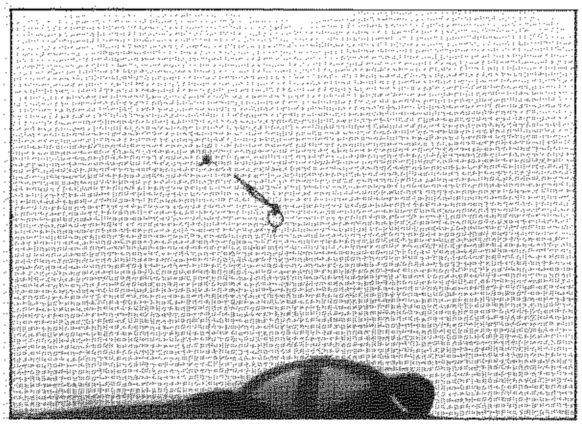
FIG.7 BLOWER TUNNEL TEST

ORIGINAL DESIGN OF REAR HINGE
RELEASE ANGLE NOMINALLY 30°
AIR SPEED; 120 KNOTS,

FIG.7
Cont'd.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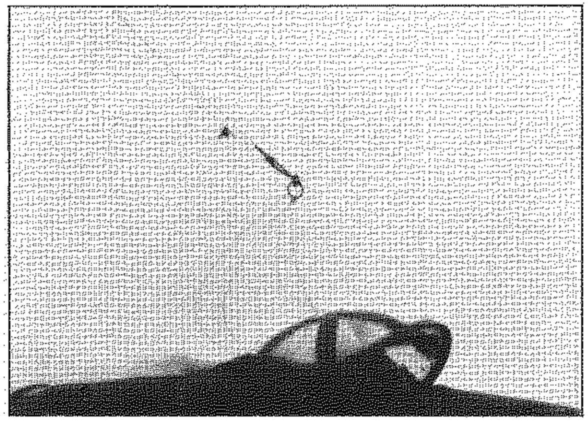
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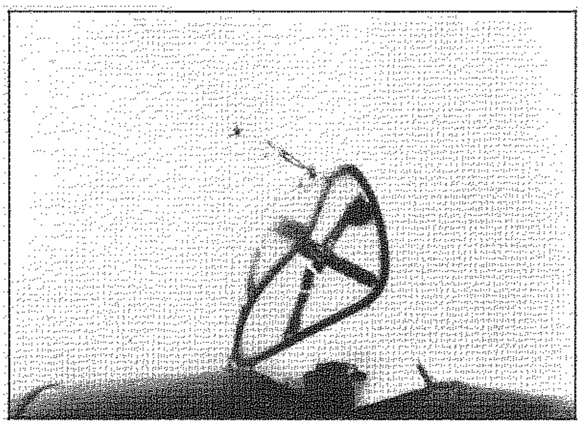
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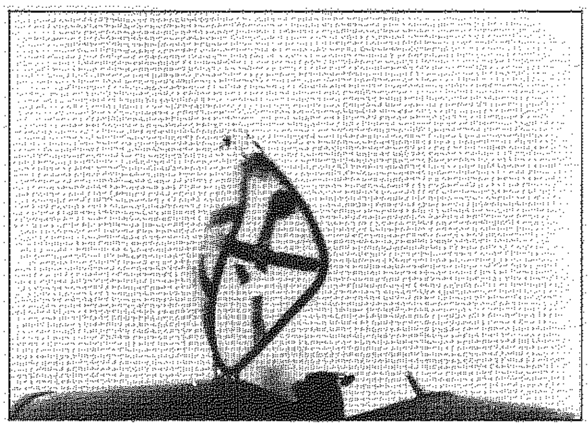
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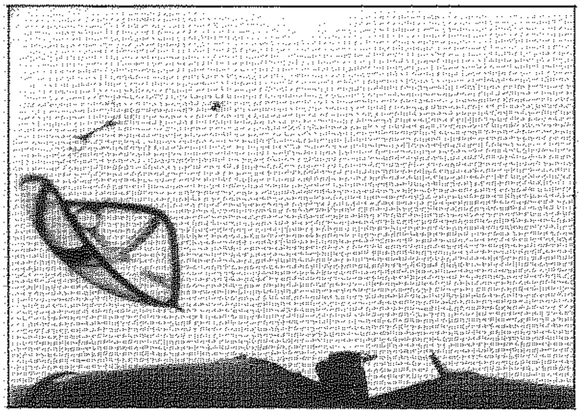
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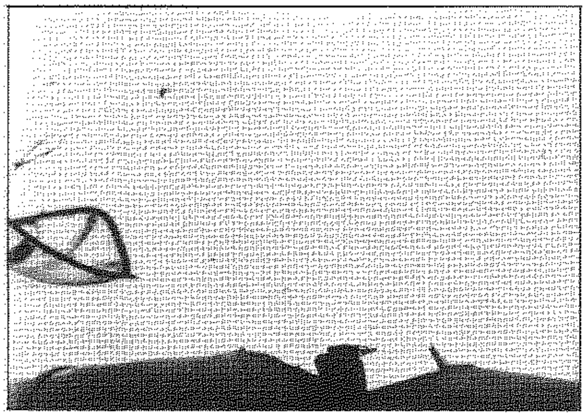
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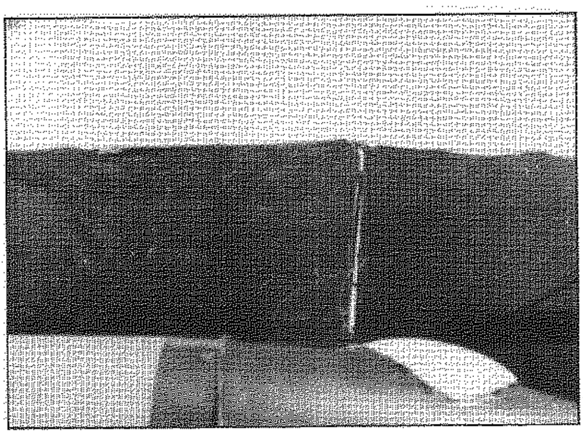
—— CANBERRA FRONT HOOD

APPROXIMATE INTERVALS BETWEEN
PHOTOGRAPHS: 1/30 sec.

FIG.8



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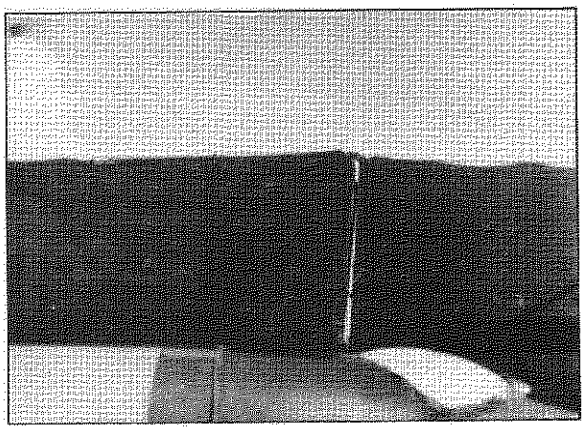

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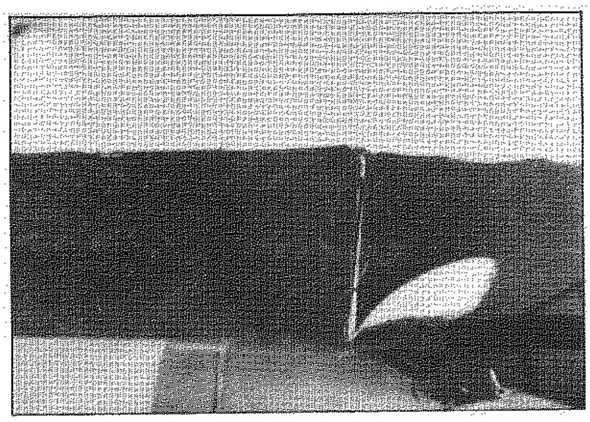

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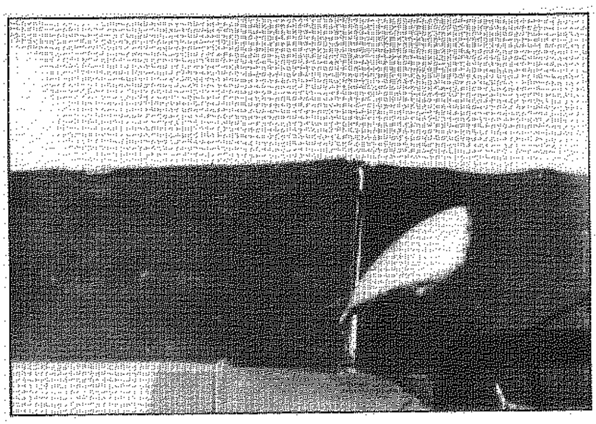

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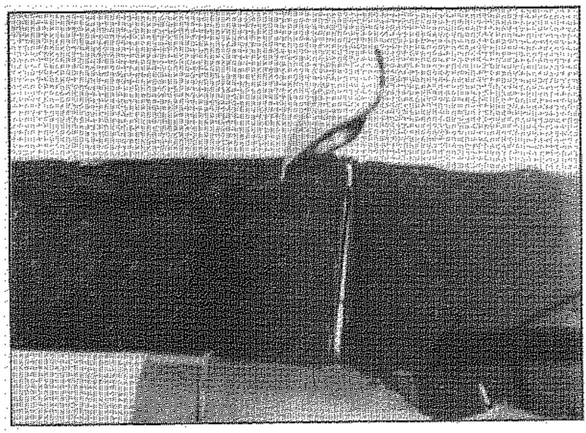

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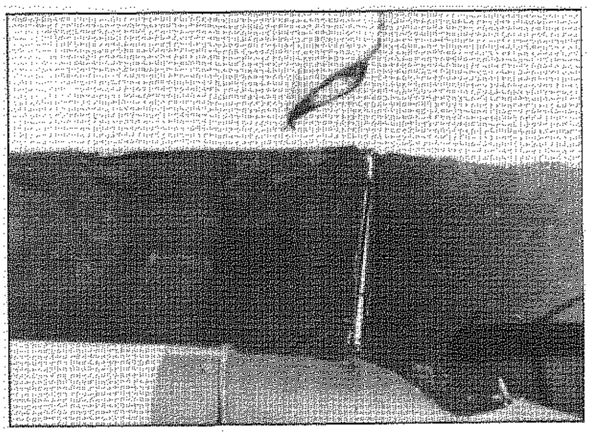

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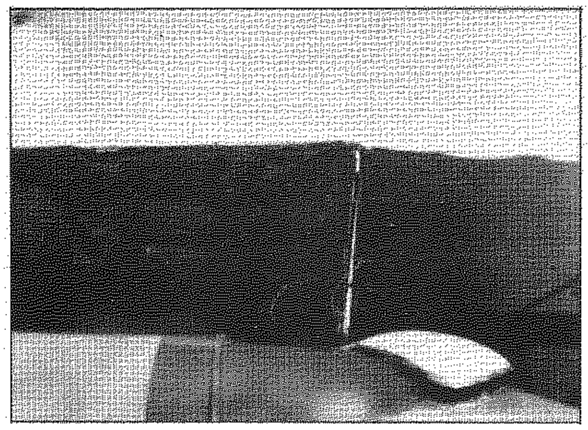
FIG.8. BLOWER TUNNEL TEST ——

MODIFIED REAR HINGE
RELEASE ANGLE 28°
AIR SPEED; 300 KNOTS,

FIG.8
Cont'd.



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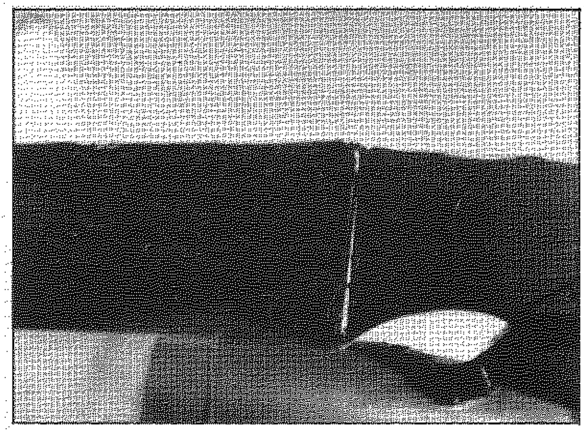

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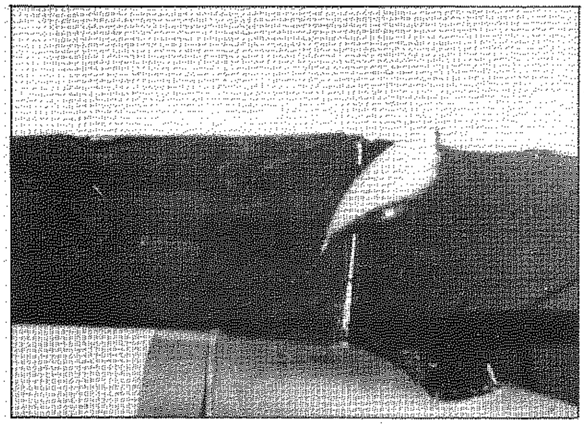

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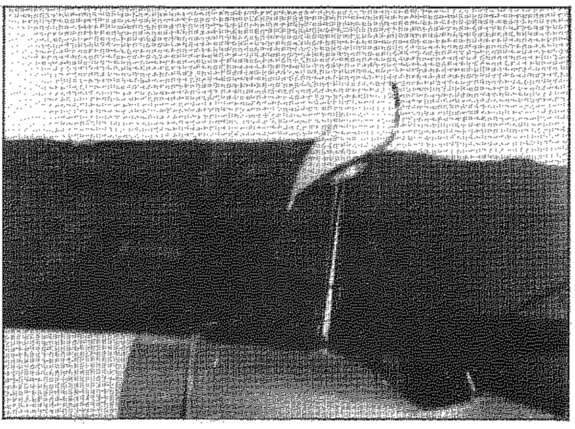

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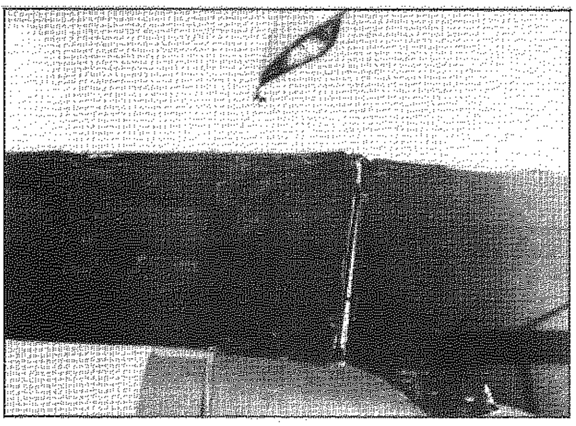

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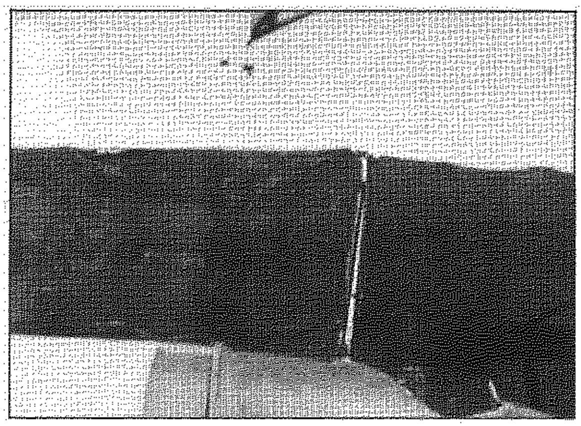
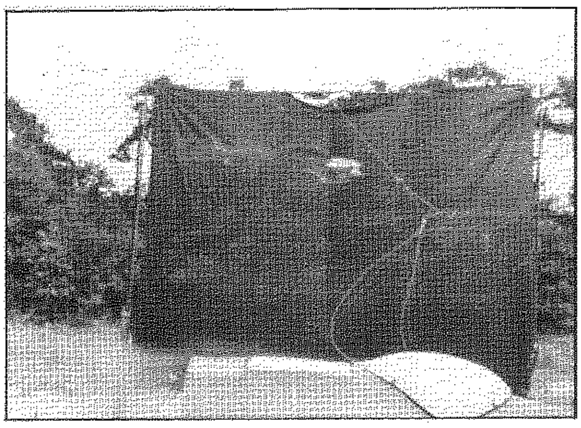


12

——— CANBERRA FRONT HOOD

APPROXIMATE INTERVALS BETWEEN
PHOTOGRAPHS: 1/30 sec.

FIG.9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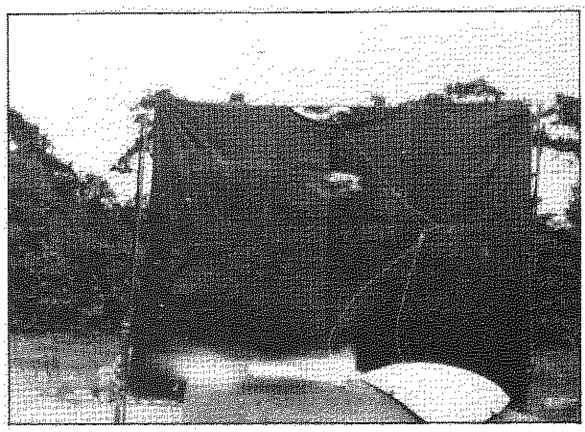
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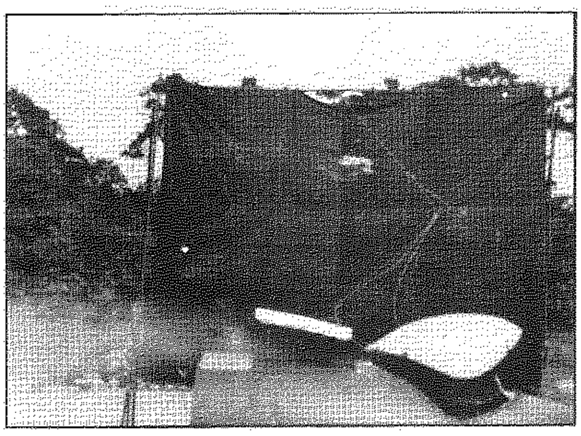
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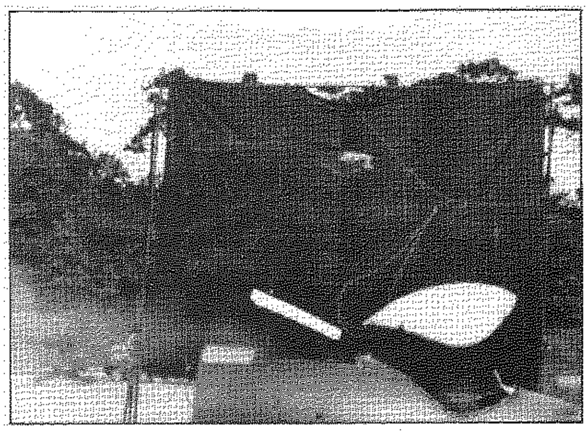
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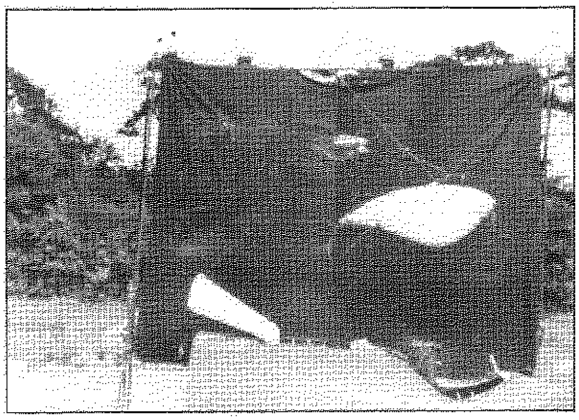
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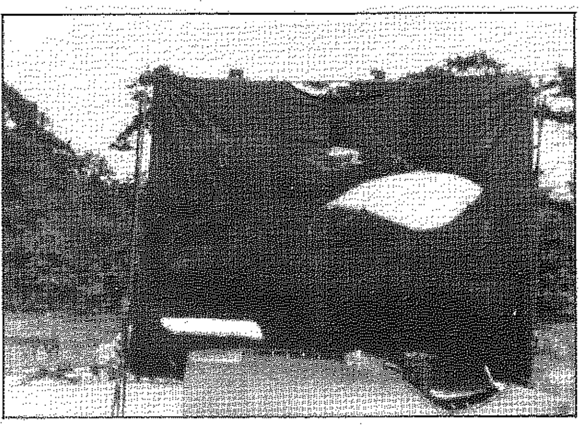
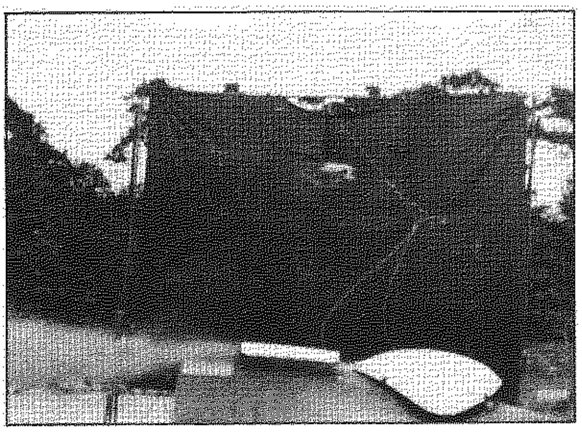

10

FIG.9. BLOWER TUNNEL TEST

NO REAR HINGE TO REAR HOOD.
RELEASE ANGLE OF FRONT HOOD: 20°,
AIR SPEED: 300 KNOTS.



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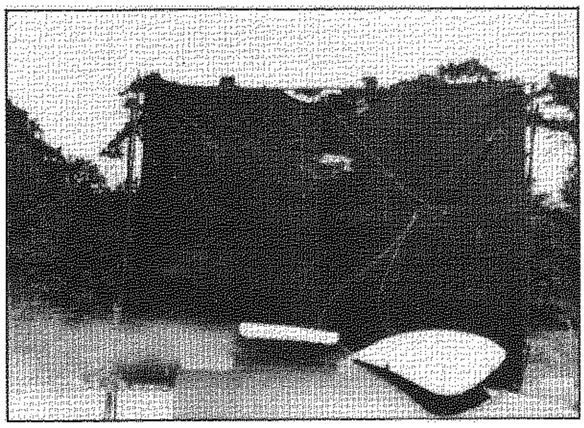

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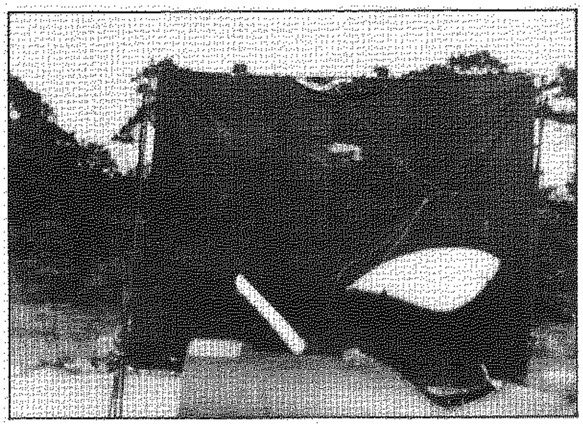

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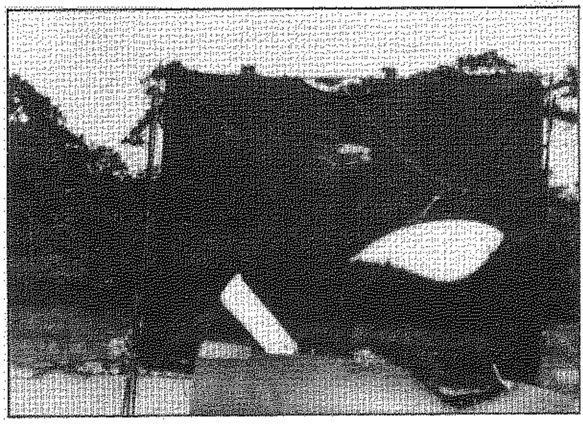

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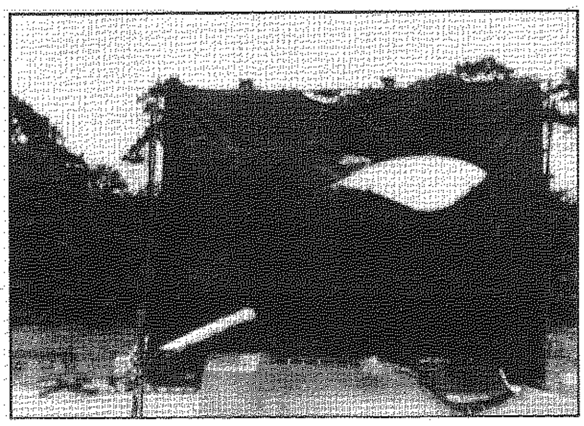

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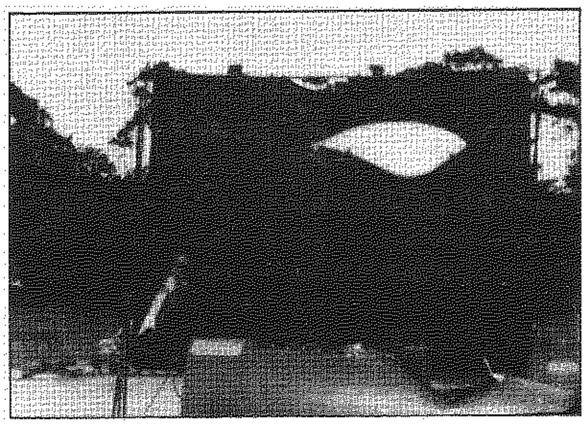

12

——— BOTH CANBERRA HOODS

APPROXIMATE INTERVALS BETWEEN
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