Summary

This report deals with the adequacy of fire fighting facilities at civil airfields. A survey has been made of civil aircraft fires during the years 1948 - 51 and it is concluded that in the absence of further experience it would be unwise to decrease the present cover as there is no evidence that this at present gives reasonable chance of saving life. It is further suggested that a regular international system of reporting aircraft crash fires be considered.

CONFIDENTIAL

F.R. No. 30/1952.

September, 1952.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

FIRE PROTECTION OF AIRFIELDS

by

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Introduction

The Joint Fire Research Organization was requested by the Director of Navigational Services (Aerodromes), Ministry of Civil Aviation to comment on the extent to which modifications of existing standards of airfield fire protection were permissible in the light of records of past fire incidents, and of the results of field experiments. Because of the many variables involved, and of the relatively small number of incidents the data available cannot be treated by ordinary statistical methods, and caution is necessary in reaching general conclusions. Even so, a few strong indications have been revealed by a careful study of the reports.

There was agreement in preliminary discussion that the primary aim in fire fighting is to save life. The aims of salvage, and the interests of public morale, are important but distinctly secondary in consideration. In the following review therefore, the sole standard of judgement is the effectiveness in saving human life, and the following questions are asked:-

(i) Are the present fire-fighting arrangements saving human life in aircraft fires?

(ii) How would a change in the amount or type of current fire protection affect the probability of rescue?

Fire cover has been considered primarily in terms of the nature of the media to be used, and the quantities, and rates of delivery; these factors govern to a large extent the minimum number of fire fighting personnel required, and no mention is made of the numbers necessary for special rescue duties. Moreover, no attention has been given to the question whether a small number of movements should alter the scale of cover provided. A low number of movements does not affect the risk at any one fire but only the risk over a period of time.

Nature of media

The Air Ministry Aircraft Crash Fire Technical Panel carried out a series of tests in 1944/45 to compare fire extinguishing media (1). At the time there was considerable urgency, and although all possible care was taken to achieve standard conditions in the tests, this was not altogether practicable since the tests had to be carried out on a large scale, in the open, under variable weather conditions, and with such appliances as were available, irrespective of whether or not they were the best for the purpose. Briefly, the test apparatus consisted of a mock-up representing part of a fuselage and wing structure, with six tanks of petrol each leaking at the rate of 3 gal per minute. At the start of the experiment a ground fire, involving 40 gal of petrol was spread over 500 to 600 square feet. A dummy body was placed in the fuselage and the moment at which rescue was effected was noted; for various reasons the comparative rescue times in different experiments are now considered to have little meaning. It was possible to extinguish the experimental fire in less than 6 minutes using foam from 1000 to 1200 gallons of water and 400 lb carbon dioxide. In one experiment the fire was extinguished by a large quantity of carbon dioxide alone in about 3 minutes; 100 gallons of water were used for foam in this experiment, but this was stated to be of such poor quality that "it may be reasonably neglected". Within their limitations the experiments appear to indicate conclusively the superiority of a combination of foam and carbon dioxide over any other agents or combinations of agents. The Panel concluded that the "most useful attack on aircraft fires is by means of foam applied rapidly in large quantities, the foam being supported by carbon dioxide".

As a result of the preliminary experimental work an experimental crash tender carrying foam and carbon dioxide was developed. At a test carried out in Kenley in 1946, a fire in a Hudson aircraft in which petrol was leaking from four inner tanks at a rate of 32 gallons per minute was attacked with this tender, and a carbon dioxide tender supported by two water tenders. Five hundred and fifty gallons of water and 1000 lb of carbon dioxide were used; the wing fires were extinguished in 75 and 115 seconds respectively and the whole fire practically extinguished in 4 minutes. It was stated that control was sufficient for rescue to have been possible after 35 seconds of fire-fighting.

The recommendations of the National Fire Protection Association (U.S.A.) (N.F.P.A.) (2) countenance the use of water sprays as an alternative to foam; they recognise that two media should be used, the second being carbon dioxide. It is stated that "the selection of carbon dioxide and foam (with option of fog foam or water spray) is recommended as the most effective means currently avaliable for aircraft rescue and fire fighting." (2)

In the United Kingdom the fact that water spray does not prevent reignition of spilled petrol is considered to be an insuperable objection to its use as an alternative to foam. The recommendations of the Committee on Fire-fighting, Safety and Rescue Organizations for Civil Aerodromes ("The Sandro Committee") (3) in 1946 and those of the International Civil Aviation Organization (I.C.A.O.) (4) in 1948, are based on the combined use of foam and carbon dioxide. The experience of the Joint Fire Research Organization with fire-fighting media strongly suggests that within the limits of present experience these recommendation are sound.

Scales of cover

Several scales of fire cover have been suggested for airfields; the principal ones, with which this report is concerned, are summarized diagrammatically in Figure 1. Airfields are graded into classes, and recommended scales of cover are based on the size of the largest aircraft using the airfield. Clearly, the most important consideration is the fuel capacity of the aircraft and as, in general, this will be related to the size, it is not of great importance whether the all-up weight, the landing weight, or fuel capacity, is chosen as the criterion except in aircraft of marginal sizes; in Figure 1 the fuel capacity at landing is plotted against all-up weight of aircraft for 42 civil planes using British airfields. The amounts of water recommended by three scales are shown for the various ranges of aircraft size. Amounts of foam compound recommended are approximately 1/10th of the water figures by volume. This would produce a volume of foam about 8-10 times the water volume.

The actual amounts of foam and carbon dioxide recommended by the 'SANDRO' Committee are based on the results of the Air Ministry tests (1). The modifications suggested by the Fire Services Working Party of the Ministry of Civil Aviation (F.S.W.P.) are only slight except in certain marginal sizes. These were arrived at by allowing a 6 in. depth of foam for the area enclosed by the overall dimensions of the aircraft.

The 'SANDRO' scale recommends the provision of carbon dioxide at the rate of approximately 1/10th that of the water supply by weight (see Table 1)

Table 1

SUGGESTED PROVISION OF EXTINGUISHING MEDIA (SANDRO)

Class of airfield	Water gal	Carbon dioxide lb	Ratio carbon dioxide/water
1	20,000	2,400	0.12
2	13,000	1,200	0.09
3	6,500	1,200	0.18
4	3/4000(say 3500)	360	0.10 (approx.)

Both the 'SANDRO' and the F.S.W.P. scales are substantially below the recommendations of the N.F.P.A. particularly for airfields accommodating the largest aircraft. The N.F.P.A. requirement for aircraft of 90,000 lb all-up weight is 4,500 gallons of water and 2,000 lb of carbon dioxide. It is also required that these shall be discharged in 2½ minutes, a distinctly higher rate than that envisaged in any other scale.

For aircraft above 50,000 lb weight the National Fire Protection Association scales permit carbon dioxide to be used as an alternative to some of the water, and it appears that 1 gal (10 lb) of water is regarded as equivalent to 2 lb of carbon dioxide.

In December 1951 the Ministry of Civil Aviation made alterations in the requirements for small airfields. These are also shown in Fig. 1. They have not been in operation during the period for which the accident reports have been studied. Apart from these alterations it appears from Fig. 1., that the cover in terms of fuel provided for smaller airfields is proportionately higher than that provided for the largest airfields. For instance, in Class III airfields the minimum ratio of foam to all-up weight (based on the Marathon) is 0.33 gallons per lb whilst for Class I airfields (based on the Stratocruiser) it is 0.19 gallons per lb. For the Comet II the figure is even lower (0.16 gallons per lb) but in this case the fuel is kerosine which burns at a somewhat lower rate than petrol. On the basis of fuel capacity at landing the figures are 21 gallons of foam per gallon of petrol for the Marathon and 7 for the Stratocruiser. Thus there is a divergence between figures based on area and figures based on fuel capacity.

In so far as the problem is that of extinguishing an expanse of burning petrol the allowance of foam on the basis of a depth of 6 in. would appear to be reasonable. Experiments with petrol burning in trays of various sizes, however, indicate that the minimum rate of application of foam to make extinction possible is of the order of ⅓/gal/sq.ft/min; above this figure the rate of extinction increases with the increase in rate of application of foam.

The recommendations of the 'SANDRO' Committee are equivalent to an application rate of ⅝ gal/sq.ft/min over an area which may be assumed to be the most severe fire likely to be encountered. It will be seen, therefore, that for large crash fires, this rate is probably of a low order when rescue is at stake.

Reports of incidents

A study has been made of the reports of fire incidents in the United Kingdom during the years 1948/51; since the report procedure was not working fully in 1948 the overall figures are not complete. The data in these reports are broadly classified in Table II.

Table II

CLASSIFICATION OF AIRCRAFT CRASH FIRES 1948/51

Cause	1948	1949	1950	1951	Total
Major fires	5	5	7	5	22
*Engine	2	12	11	17	42
*Spillage other leakages	0	1	2	5	8
*Electrical	1	5	7	7	20
Brakes etc.	0	1	3	1	5
*Burst tyres	2	0	0	0	2
*Vampires undercarriage collapse on take-off	0	0	1	1	2
*Miscellaneous	1	0	2	2	5
Total	11	24	33	38	106

*(There were no fatalities in these incidents; all occupants escaped or were aided to escape through the normal exits)

The term "major fire", as used in this report is defined as one where foam was used other than from hand extinguishers. It describes about 1 in 5 of the fire incidents attended by the M.C.A. appliances.

The incidents summarized in Table II can be conveniently considered in two groups; firstly those summarized in Table III in which the crash was off the airfield or where a disintegrating explosion occurred, and secondly, those summarized in Table IV in which the position and nature of the crash did not in themselves prelude successful rescue.

Amounts of foam used

The total quantity of foam compound reported to have been used in the incidents listed in Table II was about 1,200 gals, of which 450 gals were used in one incident and 180 gals in another. In 3 incidents foam was used to cover spilled petrol where there was no fire, 318 gals of compound being used at one of these.

Amounts of carbon dioxide used

The total amount of carbon dioxide reported to have been used in the incidents summarized in Table II was 17160 lb of which 7,800 lb were used in one incident and 3,240 lb in another. 840 lb of carbon dioxide was the largest amount used alone. This was for extinguishing an engine fire in a Stratocruiser at London Airport in 1951.

TABLE III

MAJOR CRASH FIRES OFF AIRFIELD OR IN WHICH A DISINTEGRATING EXPLOSION OCCURRED. 1948/51

Plane	Class	Field	Year	Circumstances	Occupants
Costellation	1	Prestwick	1948	8 miles from airfield	40 killed inc. 6 rescued who died within 24 hours
Mosquito	4	Weston-super-Mare	1948	Blew up on impact - wreckage over wide area.	2 killed
York	1	Northolt	1948	Collision in mid-air	7 killed
Cloudmaster	1	Northolt	1948	3-4 miles from airfield	32 killed
DH 108	4	Blackbushe	1950	3 miles from airfield	1 killed
Dakota	2	Northolt	1950	12 miles from airfield	27 killed 1 thrown clear or made own escape
Halifax	1	Bovingdon	1951	Explosion and wreckage over large area	4 killed
Jet	4	Stansted	1951	Disintegrated in mid-air	1 killed
Firefly	4	Port Ellen	1951	15 miles from airfield	2 killed
Avro jet	4	Blackbushe	1949	Plunged from 1500 feet 1¾ miles from airfield	1 killed
Cierva Air Horse	4	Southampton	1050	2 miles from airfield	3 killed

TABLE IV

MAJOR FIRES ATTENDED BY M.C.A. APPLIANCES 1948/51 ON AIRFIELDS

Aircraft	Class	Airfield	Year	Initial attendance of foam and CO_2 tender		CO_2	Escapes and rescues
Dakota	2	London	1948	1 foam tender 1 CO_2 (delays due to fog)	130 gals	960	20 killed (16 impact) 2 self effected escapes or thrown clear. (Originally 3 but one died)
Grumman Mallard Amp.	3	London	1949	3 foam tenders 2 CO_2	450 gals	7,800	1 self effected escape 6 died (5 inhalation of fumes) and 1 haemorrhage
Firefly	4	Prestwick	1949	1 foam tender	13 gals	-	2 self effected escapes
Rapide	4	Prestwick	1949	2 foam tenders 1 CO_2	55 gals	240	No one aboard - engine starting up
Spitfire	4	Renfrew	1949	2 foam tenders	20 gals	-	1 rescued or escaped means unstated
Viking	2	London	1950	Initial attendance in fog unstated	180 gals	3,240	29 killed - 1 not due to impact. 2 self effected escapes or thrown clear
Firefly	4	Bovingdon	1950	1 foam tender 1 CO_2	35 gals	960	2 rescued by persons other than M.C.A. Brigade (Fire delay of 1 min)
Hermes	1	Hurn	1950	2 foam tender	45 gals	720	8 self effected escapes
Rapide	4	Lympne	1950	2 foam tenders	44 gals	1,800	1 self effected escape
Tudor	1	Bovingdon	1951	2 foam tenders 2 CO_2			7 self effected escapes
Auster	4	Birmingham	1951	1 foam tender	10 gals	-	2 killed - bodies removed in 5 mins. Death due to shock after burns and injuries.

Casualties, escapes and rescues

There were 177 fatalities in fire incidents, all major fires, which involved 15 aircraft. 34 people (seven of whom subsequently died) escaped without external aid or were thrown clear in aircraft crashes, but there were no instances of living persons being rescued from the inside of aircraft while a major fire was in progress. At least two bodies were removed during the course of a fire.

Of the 177 fatalities, 117 occurred in crashes away from airfields, or in explosions, and as far as can be ascertained 48 of the remaining 60 can be assumed to have died from impact injuries. Full information of the 117 fatalities has not been obtained, but the significance of the observation is that possibly 12 out of a total of 177 deaths, or out of a partial total of 60 which occurred on airfields, might have been prevented had it been possible to bring the fire sufficiently under control for rapid rescue operations to have been attempted.

The 12 deaths through fire occurred in 4 aircraft:

5 in the Grumman Mallard Amphibian
4 in the Dakota (Sabina)
2 in the Auster
1 in the Viking.

The Viking had a total of 29 occupants, 28 being killed by impact.

Although two bodies were removed during the fire in the Grumman Mallard times are not stated, so that conclusions cannot be drawn regarding delay. With the Dakota and also the Viking, fire fighting was impeded by fog, and the rates of delivery of both foam and carbon dioxide were below standard in the initial important stages.

With the Auster the fire appeared to have presented little inherent difficulty, but it was difficult to extricate the bodies from the cockpit and they were not recovered for 5 minutes; the deaths were reported as due to shock as the result of burns and injuries.

From Table II it may be seen that 4 out of 5 fires did not require more foam than that delivered by a hand extinguisher, the majority indeed required only small quantities of carbon dioxide or carbon tetrachloride. For an engine fire in a Stratocruiser, however, over 800 lb of carbon dioxide was used.

These fires are not necessarily of minor importance. Some if not all would have become major fires if left unattended. An instance of this is that of the Rapide (Prestwick) (see Table IV) where an engine was started with no one standing by with an extinguisher. A small fire then rapidly became a large one. When the initial fire is in the electrical equipment, the brakes, or say, in a small spillage of petrol near combustible solids, the fire may develop slowly for a while. Once a certain stage is reached, however, the velocity of spread may itself increase rapidly until a large fire has developed. The initial stages of such a fire may, therefore, last long enough for escape or rescue to be possible. Examples of this type of fire are the Tudor and Hermes in Table IV where 7 and 8 persons respectively escaped unaided; and the Firefly from which 2 persons were aided to escape, the fire following the crash after an interval of 1 minutes.

If, however, a crash causes the severe fracture of petrol lines, or a tank bursts a large fire may be produced at once, and the aircraft may burst into flames immediately upon impact. Such conditions give little opportunity for unaided escape. Fires in the Grumman Mallard, Viking and Dakota (Sabina) appear to have been of this type. The very forces which break up the petrol lines lead to fatalities due to impact so that, in general, crashes with high impact fatalities are associated with fires due to burst tanks (5)(6). Thus, 28 out of 29 died of impact injuries in the Viking and 16 out of 20 in the Dakota. On the other hand in the Grumman Mallard crash which occurred at take-off, only 1 death appears to have been due to impact injuries and 5 to fire. There is another consideration in distinguishing between fires of slow and rapid development. Where the initial stages of growth of fire are such that less than 1½ minutes are available for unaided escape, then with a small aircraft this may be sufficient for all occupants to disembark safely. If the aircraft is a large one, however, there may be too many occupants for evacuation within this brief time. It is noteworthy that of the 9 fires that occurred in Class I and Class III aircraft, 2 were under conditions that were not unfavourable to fire fighting and in these instances the slow initial development of fire permitted escape of the occupants.

It will also be remembered that the same meteorological conditions which cause a crash may hamper fire fighting. Thus the Viking and the Dakota crashed in thick fog which prevented early mobilisation and attendance of adequate fire fighting equipment.

Control and extinction

It is notoriously difficult to interpret figures of the amounts of extinguishing media used to control fires, and to draw conclusions from a small number of varying incidents such as those listed in Table IV. Most of the incidents involved Class IV aircraft. Two of these, the Auster and the Firefly, were attended by a single foam tender and the amounts of foam compound used were 10 gallons and 13 gallons respectively. The potential rate of delivery was that appropriate to the class of aircraft but although the fire was controlled rapidly, rescue was not achieved at the Auster incident.

At the other fires in Class IV aircraft the attendance used was higher than that envisaged on airfields catering only for such aircraft and the fires were controlled without undue difficulty.

With the larger aircraft the fire developed comparatively slowly and in the case of the Hermes in which the fire was basically an engine fire, control and extinction were achieved with an attendance less than appropriate for the class of aircraft.

With the Tudor, on the other hand, attendance was sub-standard and there was a shortage of water.

The Grumman Mallard deserves attention since it appears to have been the incident in which live rescue came nearest to achievement. Briefly, a small aircraft crashed after take-off. Although it carried a quantity of paint this would not have been sufficient to bring the effective combustible load up to that of say, a Class II aircraft; the extra hazard lay in the fact that this material was in the fuselage. An explosion was heard at the crash and a large number of appliances were rapidly mobilized; these being 3 foam tenders and the Cardox truck. Two bodies were recovered at an early stage in the fire but it was evidently too late. Of the 6 fatalities 5 were due to the inhalation of the products of combustion, the impact forces being relatively light. The amounts of foam and carbon dioxide used were more than twice that employed at any other fire reported.

Discussion

From the foregoing it is clear that the problem of aircraft crash fires is extremely complicated; incidents range in size from minor occurrences to disasters: but because of the highly inflammable nature of the fuel involved, the smallest fire may be a potential disaster. Incidents vary, not only in size but in the relative importance of the damage caused by impact; the rate at which the fire develops, and reduces the possibility of escape or rescue; the varying times between accident and alarm; the time taken to assemble the crew and for appliances to reach the scene; meteorological conditions, dense fog, snow or high wind which both contribute to the crash and hamper fire fighting; the design of the aircraft; and finally the number and type of appliances.

Examining the records first of all from the point of view of rescue, the outstanding figures for the period under review are:

34 people escaped from aircraft with or without help or were thrown clear. (7 of these died later as a result of injuries and burns.).
165 people were killed by impact or fire, away from airfields
12 people were killed by fire at airfields

In the disintegrating and distant crashes 117 people were killed and 7 escaped. In the fires occurring on airfields 60 were killed and 27 were thrown clear or escaped with or without assistance; of the 60 fatalities 12 died through fire. It would thus appear, at first sight, that the prospects of escape or rescue are greater when the accident occurs on an airfield but the reports suggest that fire fighting had no effect on the number of escapes or live rescues. The implication is that while rescue remains the primary aim of fire fighting, present facilities need to be improved. It does not follow that their improvement need increase the number of appliances. The reports are not sufficiently detailed to permit analysis of the critical times in the incidents in which 12 people died through fire, but the general accounts suggest, that some could have been saved had swifter and more intensive attack been possible. There is a reference in an American journal to one of the incidents covered by this review namely the Constellation that crashed 8 miles from Prestwick airfield in 1948; it is reported that "..... witnesses who reached the scene heard some of the occupants crying for help. Six persons were rescued but died within 24 hours because of burns, shock and injuries." Had the accident occurred on the airfield itself it is impossible to say what the difference would have been, but there would certainly have been a need for the immediate application of large quantities of extinguishing media.

Thus experience and experiments agree in indicating that the rational approach to airfield fire protection is to decide the quantities of extinguishing media necessary to deal with the largest incident from which rescue might be achieved, and to consider also the optimum rate of applying these media. Indications are that past attempts to simulate conditions of rescue are open to serious objection and no significance should be attached to them.

There is considerable agreement that foam should be regarded as the primary medium for extinguishing crash fires. The proposal to allocate foam compound on the basis of that required to give a 6 in. layer of foam over the area included by the maximum dimensions of the aircraft seems reasonable, and is probably as good an estimate as can be made.

To control a fire the extinguishing agent must be applied faster than a certain minimum rate. Above this rate, within limits, the faster the agent is applied the quicker the fire will be out.

In the aircraft crash fires described above the data are meagre and incomplete and the circumstances of the crashes vary considerably. There is, nevertheless an indication that the amounts of foam and the rates of delivery are sufficient to achieve control and extinction but not in sufficient time for rescue in those fires which have developed too rapidly for unaided escape. Further controlled experiments might well be made to see the quantitative effect of increased rates of delivery.

Small quantities of carbon dioxide are effective under some circumstances, particularly for fires developing inside the wing of an aircraft, and for what has been described as "knocking out small pockets of fire." Of its use in large quantities however, there are too few records for any positive conclusions to be drawn. In the Grumman Mallard fire it was reported that when 3 streams of foam "did not appear to allay the fire" carbon dioxide was used effectively to enable an approach to be made to the fire. There were no other comparable incidents. Although over 3,000 lb of carbon dioxide were used in the Viking crash, fog had hindered operations in the decisive early stages.

Tests (1) have indicated that the amount of carbon dioxide required to "knock down" flame on an open expanse of petrol is about $\frac{7}{8}$ lb per sq.ft which is approximately twice the amount recommended by the 'SANDRO' committee. Little indication exists of the rates of application necessary but it would appear to be about 3-5 times as much as at present provided. Whilst there can be no doubt that the use of gaseous or vaporizing liquid media to deal with a large expanse of petrol in the open and where there may be an igniting source, is unsound under ordinary conditions of fire fighting, the 'SANDRO' recommendations which are based on the secondary role of carbon dioxide are not unrealistic in terms of local application of carbon dioxide for approach work etc.

It might be expected that improvements in aircraft design will lead to a reduction in the proportion of deaths due to impact in crashes. This will mean that the number of potential rescues per crash will increase, thus increasing the importance of adequate fire cover.

Conclusions and recommendations

(1) One of the chief difficulties in airfield fire fighting is that of getting the appliance to the site in time for effective action.

(2) With the present scales of cover it is possible to extinguish fires i.e. to achieve some salvage.

The evidence of past crash fires suggests, however, that the present scales of cover are inadequate to secure live rescue from fires where the possibility of unaided escape does not exist. This means that the rate of delivery of materials to the fire, though not necessarily the total amounts of materials, are insufficient. At the same time the discharge rate for a limited amount of extinguishing material should not be so high that the difficulties of controlling the higher delivery lead to inefficiencies of usage and uncertainty of extinction within the reduced time available.

(3) Until more experience is available it is considered wise to retain the 'SANDRO' recommendation to provide carbon dioxide to "back-up" the foam. In view of the indications that present methods still leave much to be desired, and of the clear need for almost instantaneous extinction, further consideration should be given to the possibility of experimental work on the use of large quantities of carbon dioxide, for immediate extinction of fire menacing the escape route, where this can be followed by the application of a foam blanket before re-ignition can occur.

(4) It is suggested that controlled experiments should be carried out on various means of cooling the interior of the fuselage during fires.

(5) It is also suggested that an effort should be made to obtain systematic reports of aircraft crashes on an international scale with as many countries as will agree. It cannot be too strongly emphasized that the form used should be prepared with the advice of a competent statician as was done in the case of the Form K433 which is used for National Fire Statistics.

Acknowledgements

The author would like to express his thanks to the Director of Navigational Services (Aerodromes) and the Chief Fire Service Officer of the Ministry of Civil Aviation for their assistance.

References

(1) Aircraft Crash Fires Technical Panel of Air Ministry. First Annual Report 1944-45.

(2) Suggested Aircraft Rescue and Fire Fighting Equipment for Airports. N.F.P.A. No. 403. 1951.

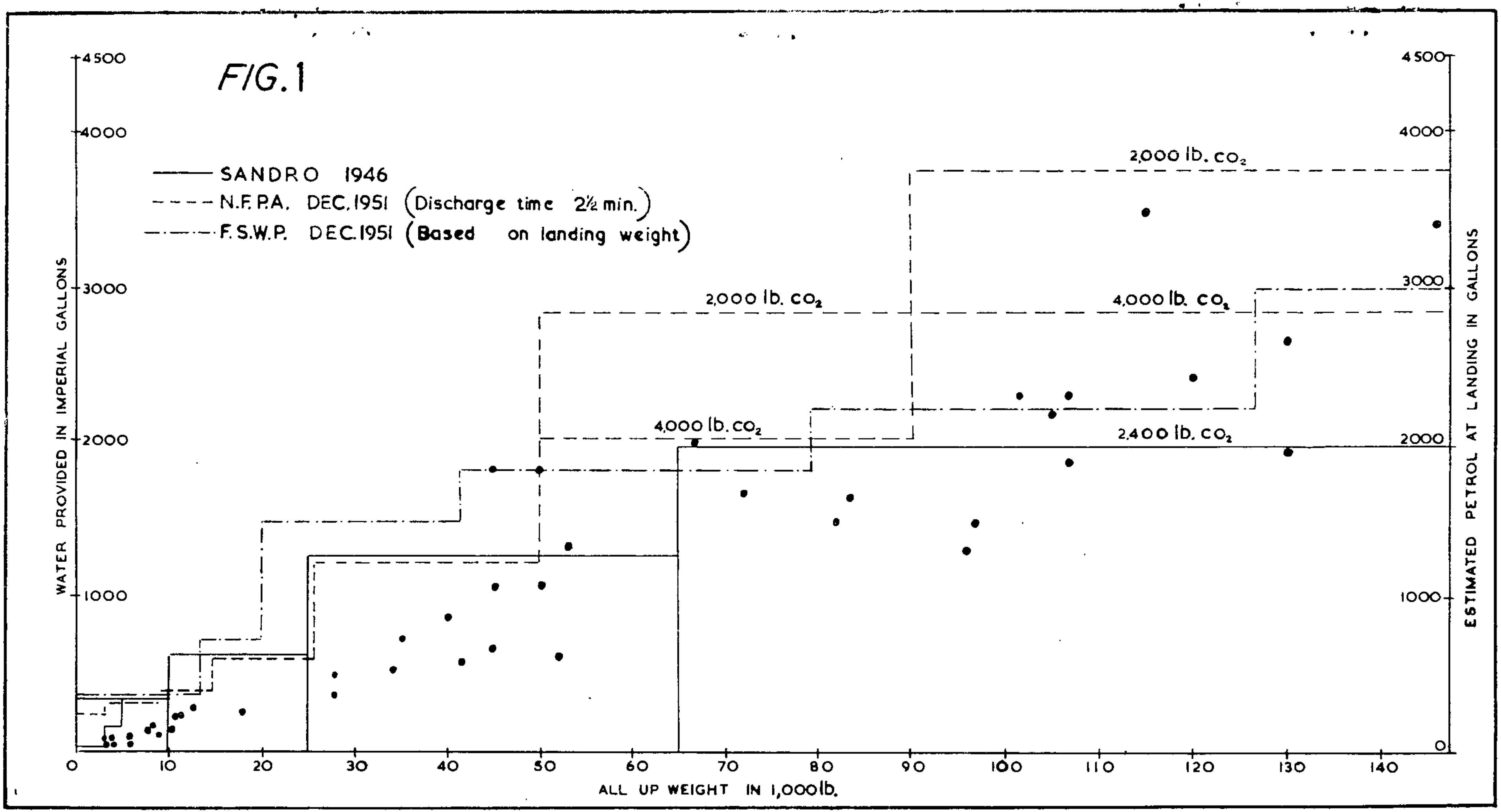
(3) Report of the Committee on Firefighting Safety and Rescue Organization for Civil Aerodromes in the United Kingdom 1946.

(4) Crash Fire and Rescue Equipment at Aerodromes. Int. Civil Aviation Org. Montreal, Canada. 1948.

(5) K. H. Swainger. "A Note on Aircraft Impact Accident Fires." Min. Aircraft Production. 1944.

(6) W. Tye, O.B.E., F.R.A.E.S. "Modern Trends in Civil Aeroworthiness Requirements." J. Roy. Aer. Soc. 56 (Feb.) 1952. 73.

FIG. 1


SANDRO 1946
N.F.P.A. DEC. 1951 (Discharge time 2½ min.)
F.S.W.P. DEC. 1951 (Based on landing weight)
2,000 lb. CO_2
4,000 lb. CO_2
2,000 lb. CO_2
4,000 lb. CO_2
2,400 lb. CO_2
WATER PROVIDED IN IMPERIAL GALLONS
ESTIMATED PETROL AT LANDING IN GALLONS
ALL UP WEIGHT IN 1,000 lb.
4500
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140