MINISTRY OF CIVIL AVIATION

REPORT

of the

Court investigation of the accident to the Tudor IV. Aircraft "Star Tiger" G-AHNP on the 30th January, 1948, held under the Air Navigation (Investigation of Accidents) Regulations, 1922

Presented by the Minister of Civil Aviation to Parliament by Command of His Majesty September 1948

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THE AIR NAVIGATION ACTS, 1920 TO 1947

THE MINISTRY OF CIVIL AVIATION ACT, 1945

THE AIR NAVIGATION (INVESTIGATION OF ACCIDENTS) REGULATIONS, 1922 TO 1935

ORDER directing that a Court investigation be held.

WHEREAS an accident arising out of or in the course of air navigation occurred on or about the 30th January, 1948, to the aircraft G-AHNP "Star Tiger".

AND WHEREAS the said accident is an accident to which the Air Navigation (Investigation of Accidents) Regulations, 1922 to 1935, apply.

AND WHEREAS under Regulation 7 of the said Regulations the Minister of Civil Aviation has power by order to direct that a Court investigation of an accident be held if it appears to him expedient so to do.

NOW THEREFORE I, the Right Honourable Harry Louis Baron Nathan of Churt, T.D., D.L., J.P., Minister of Civil Aviation, in exercise of the said power and of all other powers enabling me in that behalf, hereby order and direct that a Court investigation of the said accident be held in accordance with the provisions of the said Regulation 7.

AND I APPOINT the Right Honourable Hugh Pattison Baron Macmillan, P.C., G.C.V.O., K.C., to hold such investigation.

Dated this 16th day of March, 1948.

(Sgd.) NATHAN OF CHURT,
Minister of Civil Aviation.

The Minister, by subsequent Order of 18th March, 1948, appointed Professor Arnold Alexander Hall, M.A., and Captain John Wynford George James, O.B.E., to act as Assessors for the purposes of the investigation.

To The Right Honourable The Lord Pakenham,

Minister of Civil Aviation.

MY LORD,

By an Order made by your predecessor Lord Nathan on 16th March, 1948, under Regulation 7 of the Air Navigation (Investigation of Accidents) Regulations, 1922, I was appointed to hold a Court to investigate an accident which occurred on or about 30th January, 1948, to the Tudor IV Aircraft "Star Tiger" G-AHNP.

By a further Order of 18th March, 1948, Professor Arnold Alexander Hall, M.A., and Captain John Wynford George James, O.B.E., were appointed to act as Assessors for the purposes of the investigation.

I have now the honour to present my Report together with a copy of the shorthand record of the evidence and proceedings at the Inquiry.

The investigation was held in public at Church House, Westminster. It was opened on 12th April, 1948, and with two short adjournments occupied in all eleven days, concluding on 7th May, 1948. In addition I paid a visit with the Assessors on 4th May to the London Airport at Heathrow where we inspected a sister Tudor IV aircraft, and on 18th May, 1948, the Assessors made a test flight in her.

A list of the parties who appeared at the Inquiry is given in Appendix I, and the names and qualifications of the witnesses who were examined are set out in Appendix II. The Attorney-General, instructed by the Treasury Solicitor in the public interest, took the leading part in the conduct of the proceedings.

All possible assistance in investigating the accident was afforded by the officials of your Ministry and of the British South American Airways Corporation as well as by the other bodies and individuals concerned. I am most grateful to them for their aid and also to the Commandant and Officers at the London Airport for the facilities there accorded. Every effort was made to secure the attendance of all witnesses who could throw light on any aspect of the occurrence and all information available, both factual and technical, was furnished. If the investigation has failed, as unhappily it has, to ascertain with any certainty the cause of the disaster, this is in no way due to any lack of diligence or thoroughness on the part of those who sought to find a solution of the problem.

The Regulation under which the investigation was held, in addition to requiring the Court to state "its findings as to the causes of the accident and the circumstances thereof", also directs it to add "any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and the avoidance of similar accidents in future." When the cause of the accident, as in this case, remains unascertained, it is not possible to make specific recommendations to obviate the recurrence of the cause. But in the course of the proceedings certain matters emerged, not necessarily associated with the accident, which appeared to me and to the Assessors to call for comment, and with regard to these we have made some recommendations.

It is only fitting that I should pay grateful tribute to the part taken in the Inquiry by the Court's Assessors. Without their skilled assistance and ever ready advice I could not have discharged my task and the Report which I now present with their complete agreement is in large measure the product of their expert knowledge.

I join with the Assessors in recording our high appreciation of the services of Mr. E. S. Fay, the Registrar of the Court. In all the arrangements for our proceedings, in marshalling and analysing the large mass of evidence and documents and in assisting us with the drafting of the Report he proved himself invaluable and we cannot overstate our indebtedness to him.

I am, my Lord,

Your obedient Servant,

MACMILLAN.

21st August, 1948.

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REPORT

INTRODUCTION

1. At 3.34 o'clock in the afternoon of Thursday, the 29th of January, 1948, the Tudor IV Aircraft "Star Tiger", belonging to and operated by the British South American Airways Corporation set out from the Airport at Santa Maria in the Azores for Bermuda, on the third stage of a flight from London to Havana. She had a crew of six consisting of a Captain, a Second Officer, a Navigator, a Radio Operator and two Stewardesses, and she carried twenty-five passengers.* The distance from the Azores to Bermuda is approximately 1,960 nautical miles across the open Atlantic and the route is one of the longest in operation for passenger and commercial flights.

2. After her departure "Star Tiger" maintained contact by radio with the Azores until she passed the midway point of her flight when she transferred her contact to the wireless station at Bermuda with which she thereafter communicated. During her flight she also exchanged wireless messages with a Lancastrian aircraft belonging to the British South American Airways Corporation which had left the Azores an hour ahead of her for the same destination by the same route and which safely completed her flight to Bermuda without any untoward incident.

3. At 3.15 o'clock in the morning of Friday, 30th January, "Star Tiger" sent a message by radio to Bermuda asking for a bearing. The radio bearing was obtained and a message giving it was dispatched from Bermuda to "Star Tiger" approximately one minute later. Receipt of this message was acknowledged immediately by "Star Tiger". This acknowledgment was the last message received from her. She was then about 340 nautical miles from Bermuda.

4. A message sent to "Star Tiger" from Bermuda at 3.50 a.m. evoked no answer and all further attempts to get in touch with her failed to elicit any response. An emergency was declared and a search was promptly organised by the United States authorities who operate the Airport at Bermuda. Numerous aircraft and several surface vessels were dispatched on the quest but notwithstanding prolonged and unremitting efforts to locate her no trace of "Star Tiger" was found and to this day nothing is known of what became of her, her passengers and her crew.

5. Such in brief outline are the facts of this lamentable disaster and in the following pages the results are set forth in detail of the investigation which has been held.

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* The passenger list is printed in Appendix III.

PART I

THE TUDOR IV. TYPE OF AIRCRAFT

(*a*) General Description.

6. The Tudor IV. aircraft is an all-metal monoplane, designed and manufactured by A. V. Roe and Co. Ltd. of Manchester, for service as a passenger-carrying air-liner. It is propelled by four liquid-cooled reciprocating engines, designed and manufactured by Rolls Royce Ltd. of Derby. Each engine drives a four-bladed, constant speed, and fully feathering propeller, designed and manufactured by the De Havilland Co. Ltd. of Hatfield.

7. The span of the mainplane is 120 feet, and the length of the fuselage is 85 feet 3 inches. The aircraft is designed to operate at a total weight not exceeding 80,000 lbs., and its fuel tanks, which are carried in the wings, have a total rated capacity of 3,300 Imperial Gallons. Stations are provided on the flight-deck for an operating crew of four; the cabins accommodate a passenger-service crew of two, and thirty-two sitting passengers.

8. A general view and the main dimensions of the aeroplane are displayed in Fig. 1.

(*b*) Evolution of the Type.

9. The design of the Tudor IV. aeroplane was not conceived as an entirely new project; it was evolved by a series of modifications from the well-tried military aeroplane, the Lancaster bomber, which was designed by A. V. Roe and Co. Ltd. for use in the Royal Air Force. After the Lancaster aeroplane had proved itself in every way satisfactory as a flying machine, and after it had been developed steadily by the introduction of minor modifications, it became necessary, to meet the need for further improvement in performance, to undertake a re-design. Although major structural changes were introduced, the general lay-out of the Lancaster was retained. The aeroplane which emerged was first known as the Lancaster Mark IV, but it was later re-named the " Lincoln " and it passed into service with the Royal Air Force in large numbers.

10. In 1943, after the initiation of the re-design of the Lancaster, an aeroplane was conceived by A. V. Roe and Co. Ltd. for use as a passenger-carrying machine. This aircraft, which was eventually to become known as the Tudor I. was to use the wing and tail unit of the Lincoln aeroplane, together with a new fuselage, designed for the accommodation of passengers. The fuselage was to be " pressurised "; that is to say, it was to be so designed as to permit the maintenance of a pressure in the air within the fuselage comparable to that in the atmosphere near the ground, in order that the passengers need not be caused difficulty in breathing should the aeroplane be flown at high altitude. The aeroplane was to use a new version of the Merlin engine more suited to the needs of civil aviation than the military version used in the " Lincoln ".

11. A design based on this conception was started early in 1944. It was planned to provide an aircraft for use by the British Overseas Airways Corporation on the London to New York route. That Corporation specified that the accommodation should provide for twelve sleeping passengers. Eventually, several Tudor I. aeroplanes were built, but the original plan to convert the design of the Lincoln by the introduction of a new fuselage was by no means adhered to. In the end, there were changes in the wing design to permit the

accommodation of more fuel, the twin fin and rudder arrangement used on the Lincoln was replaced by a single fin and rudder, and there were modifications in the design of the tailplane and the under-carriage.

12. It was found that the early Tudor I. aircraft was subject to certain defects, but none was of a fundamental kind, and all were eventually rectified. The aircraft also failed in some particulars to meet the original specification. The British Overseas Airways Corporation then announced that they were unable to fulfil their intention of using aeroplanes of this type, partly because the delivery of the machines in a satisfactory condition had been delayed, and partly because they decided that such aircraft would prove uneconomical for their traffic. The circumstances surrounding the development, testing, and modification of these aircraft, and the considerations relating to their use, were examined by a Committee set up by the Ministry of Supply (The Courtney Committee, 1947). The Committee presented an Interim Report in December 1947 (Cmd. 7307) and a Final Report in July 1948 (Cmd. 7478) but these have no material bearing on the present Inquiry. Eventually, when defects had been removed, the aircraft satisfied the standard regulations relating to safety in flight, and on the assumption that they were operated with due regard to the range which their petrol capacity permitted, their performance exhibited no features such as to suggest any risk in their use.

13. Meanwhile, the British South American Airways Corporation were seeking a passenger-carrying aeroplane for use on their services. They concluded that the Tudor I. aircraft was broadly suited to their needs, though it would require modification in detail. In particular, they required accommodation for sitting passengers rather than for the twelve sleeping passengers for whom the Tudor I. provided, and they required a change in the lay-out of the control compartments. The latter arose out of the considered policy of the British South American Airways Corporation not to carry a flight engineer and it involved the transfer to the pilot's compartment of a number of instruments and controls relating to the aircraft's power plant and to the air-conditioning equipment, from the compartment in which they had been grouped in the Tudor I.

14. A re-design of the Tudor I. aircraft was accordingly undertaken. The fuselage was lengthened by six feet, the accommodation in the cabin was revised to provide seats for thirty-two passengers and the control compartment was re-designed to permit the new disposition of the instruments and controls. The aircraft so produced was designated the Tudor IV. The prototype first flew in April 1947. The aircraft passed the various tests to which it was submitted and was issued with a "Certificate of Airworthiness" in September 1947. Eventually, aircraft of this type passed into service with the British South American Airways Corporation, and at the time when disaster overtook the "Star Tiger", three such aeroplanes were in use, being G-AHNJ "Star Panther", G-AHNK "Star Lion", and G-AHNP "Star Tiger". "Star Tiger" was delivered by the manufacturers on 5th November, 1947, and it was operated until it disappeared on 30th January, 1948.

(*c*) TECHNICAL FEATURES.

15. The following paragraphs deal with those technical features of the Tudor IV aeroplane to which it will be necessary to refer in this report.

(i) *Performance.*

16. When making a long flight, the Tudor IV aircraft is usually operated at an indicated air speed of between 165 and 175 knots. In the mean conditions of operation which obtained during the last flight of "Star Tiger"

(weight 72,000 lbs., indicated airspeed 165 knots) the distance moved in the air per gallon of fuel consumed is about 0.875 nautical miles. Very roughly, this figure varies as $W^{-\frac{1}{2}}$, when W is the weight, at a constant indicated airspeed. It is almost independent of temperature.

17. The maximum permitted weight of the aircraft is 80,000 lbs. If she is fully laden with fuel, this allows a payload of about 4,400 lbs. The maximum payload for which the aircraft has capacity is about 9,800 lbs.; if operated with this load, she must take less than her maximum capacity in fuel, in order that the permitted weight shall not be exceeded.

18. When fully laden with fuel and starting at the maximum permitted weight, the aircraft has a range in still air of about 2,900 nautical miles.

(ii) *The Control Compartment.*

19. The control compartment provides stations for a pilot, a co-pilot, a navigator, and a radio-operator. The flying controls and instruments are duplicated in the co-pilot's position. The engine controls and instruments are distributed in the pilot's cabin. The controls and instruments associated with the air-conditioning system are placed near the navigator's station.

(iii) *The Fuel System.*

20. The fuel systems on the port and starboard sides of the aircraft are identical. On each side, fuel is contained in four flexible tanks accommodated in the wing; they will be referred to as the No. 1, No. 2, No. 3, and No. 4 tanks, the No. 1 tank being in the inboard position, and the No. 4 in the outboard position. The No. 3 and No. 4 tanks are inter-connected. Fuel passes from the No. 1, No. 2 and the combined Nos. 3 and 4 tanks to a distributing tank from which the two engines on the appropriate side of the aeroplane draw their fuel.

21. Fuel cocks are fitted in each of the pipelines which respectively connect the No. 1, the No. 2 and the combined Nos. 3 and 4 tanks to the distributing tank. The cocks on the No. 1 and No. 2 tank lines can be operated manually by control levers situated in a cupboard in the forward passenger cabin. The cock in the line from the combined Nos. 3 and 4 tanks cannot be operated whilst the aircraft is in flight; this cock, which is situated under the inboard engine nacelle, can be operated only when the aircraft is on the ground, and it is normally locked by a bolt in the open position.

22. The fuel systems on the two sides of the aeroplane can be inter-connected through a pipeline controlled by a cock (the "balance" cock) which is operated electrically from the pilot's station.

23. Cocks are provided in the pipes through which fuel passes from the distributing tanks to each engine; they are operated electrically from the pilot's station.

24. Pumps driven by the engines transfer fuel from the tanks and additional electrically driven boosting pumps are provided to ensure an adequate flow of fuel when a high rate of delivery is required, as during take-off. The electric pumps may also be used to transfer fuel from one side of the aeroplane to the other. They are controlled electrically from the pilot's station. and are normally left in operation throughout a flight.

25. Fuel-flowmeters are provided in the pipelines feeding each engine. These instruments measure the total fuel consumed by the engine since the instrument was set to zero. Float-type fuel contents gauges are fitted in the No. 1, No. 2 and No. 3 tanks, and their indications are transmitted

electrically to dials situated in the pilot's station. The indication of the flowmeters is usually in error by less than ½ per cent.; the float gauges are, however, necessarily much less accurate.

(iv) *The Electrical system.*

26. The main electrical supply, at 24 volts D.C., is provided by two 6-kilowatt generators, one of which is driven by each inboard engine. Accumulators having a storage capacity of 80 ampere hours at 24 volts are provided, and are normally charged by the generators.

27. An alternating current supply is provided by two 1.2 kilowatt alternators, one of which is driven by each outboard engine. The alternators require a small D.C. current for excitation.

(v) *The Radio and Radar Installation.*

28. The aircraft carries two identical wireless-telegraphy transmitters, which have a range of several thousands of miles and three wireless telephony transmitter-receivers having a range of about 200 miles. To provide assistance in landing, the aircraft carries an S.B.A. (Standard Beam Approach) receiver. Aerial systems appropriate to these installations are carried, and, in addition, an emergency aerial which can be trailed from the aircraft is available.

29. The radar installation consists of a frequency-modulated radio altimeter, and a "Rebecca" set. The former provides an absolute measurement of height, up to 3,000 feet; the latter is a navigational aid which enables the aircraft to "home" to a "Eureka" beacon on the ground, from a range of about 40 miles. It is used for the approach to an airport in conditions of poor visibility.

30. The telegraphy and telephony installations are operated on D.C. electrical power from the generators or the battery. The "Rebecca" set operates on the A.C. electrical supply.

(vi) *The Automatic Pilot.*

31. The Tudor IV aeroplane is fitted with an automatic pilot supplied by the Sperry Gyroscope Co., Ltd., and designated the Type A.3. The purpose of this instrument is so to control the aircraft that a height and course set by the human pilot is maintained automatically.

32. In this particular automatic pilot, the controlling signals are provided by airdriven gyroscopes. They guide the aircraft through hydraulic mechanisms which apply forces to the aircraft's control surfaces. The hydraulic power is provided by an electrically driven pump.

33. The automatic pilot can be put into operation, or taken out of operation, at the turn of a lever situated in the pilot's compartment. When it is in operation, the human pilot can, if he wishes, override it, though a rather considerable force must be exerted to do so.

(vii) *Emergency Equipment.*

34. The aircraft carries four inflatable rubber dinghies, two of which are housed in each wing. Each dinghy is inflated by a supply of carbon di-oxide gas, stored in a bottle. The dinghies can be released by electrical operation from the pilot's station, by manual operation of levers which are situated below the floor of the passengers' compartment and are accessible through small doors, and by manual operation from the navigator's compartment. Provision is also made for automatic release if the aircraft enters water; this automatic mechanism can be, and usually is, rendered inoperative, to prevent inadvertent operation due to the presence of stray water; should an

emergency develop in flight over the sea, the pilot can, if he wishes, first test the mechanism and then render it operative, so as to secure automatic release of the dinghies when the aircraft makes its emergency landing.

35. Each dinghy is equipped with appropriate emergency rations and distress equipment, and with a radio transmitter.

36. A number of emergency exits are provided in the aircraft.

PART II

THE AIRCRAFT "STAR TIGER" G-AHNP

(*a*) MANUFACTURE AND FLYING RECORD.

37. "Star Tiger" was constructed by A. V. Roe & Co. Ltd. at their Manchester factory in 1947. Her initial test flight was made from Woodfield Aerodrome, Cheshire, on November 4th, 1947. On that occasion the aeroplane was in the air for only half an hour and weather conditions were not suitable for a thorough test. The test pilot was however satisfied that there were no major troubles in handling, and on the next day a full test was carried out. The pilot then reported that "everything went very smoothly indeed". She was then airborne for 4½ hours and her flight terminated at London Airport, where she was delivered to the British South American Airways Corporation. On the next day she made a further test flight at London and at 11 p.m. on the same night, November 6th, she left for Havana via the Azores, Bermuda and Nassau. She returned to London on November 12th and was thereafter consistently employed on the route from London to the West Indies. From the time of manufacture to the time of her departure from London on her last voyage she had flown a total of 575 hours. Apart from local flights in England this time was made up of eleven return journeys across the Atlantic Ocean to the West Indies, on each of which she called at Bermuda, and on most of which she called at the Azores.

(*b*) THE CERTIFICATE OF AIRWORTHINESS.

38. The Air Registration Board, under its regulations, advises the Minister of Civil Aviation on the issue of a Certificate of Airworthiness for a civil aircraft. This document certifies that the aircraft is so designed and constructed, and the performance in flight is such that the aircraft is airworthy, and it lays down the conditions under which this certification applies. The certificate is not, however, concerned with the state of repair and maintenance at any time; these matters are certified otherwise, and are discussed in a later section of this report. Nor is the certificate of airworthiness concerned with whether the aircraft is suited in performance, or special equipment, to fly on a particular route; that is a matter for which the operator of the aircraft is responsible. Nor, again, is the certificate of airworthiness concerned with the competence of the crew, or with their number as related to the flight to be undertaken, save that the certificate lays down the minimum number of the crew which may operate the aeroplane under any circumstances whatsoever.

39. Before recommending that an aircraft be granted a Certificate of Airworthiness, the Air Registration Board assure themselves that the design satisfies the British Civil
by the Board, and also, from their experience in these matters, that the aeroplane is satisfactory in every respect as a flying machine.

40. Before the first aircraft of a new type is granted a certificate, the Air Registration Board inspect the design as it progresses, the materials used, the manufacturing processes, and the component parts. Finally the Board satisfy themselves by trials, conducted in the laboratory and in flight, that the aeroplane is airworthy. If further aircraft are then made to the same design, Certificates of Airworthiness are issued without further trials, but the manufacture of each aeroplane is the subject of close inspection.

41. At the time of the disaster to the aircraft "Star Tiger", three Tudor IV aeroplanes had been built. The flight trials required by the Air Registration Board were conducted on aircraft G-AHNJ. These trials were carried out at the Ministry of Supply's Aeroplane and Armament Experimental Establishment, Boscombe Down. This Establishment was called upon to make trials on behalf of the Ministry of Supply, which had ordered the aircraft as agent for the Ministry of Civil Aviation; the opportunity was taken by the Air Registration Board to secure the trials it required at the same time. On 18th July, 1947, G-AHNJ was issued with a Special Category Certificate of Airworthiness, which permitted it to proceed to foreign countries for special trials. On 29th September, 1947, the first Normal Category Certificate of Airworthiness was issued to a Tudor IV aeroplane.

42. On 5th November, 1947, there was issued for "Star Tiger" a Short Term Certificate of Airworthiness, having a duration of two months, pending the issue of a normal certificate. On 2nd December, 1947, she was granted a Normal Category Certificate.

43. The Certificate of Airworthiness granted to "Star Tiger" and to the other two Tudor IV aircraft specified that the total weight of the aircraft and its contents (the "all-up weight"), should not exceed 80,000 lbs. The certificate also made a reservation in the following terms: "Flight in icing conditions: compliance with requirements not yet established". This reservation was made because the de-icing equipment on the Tudor IV aircraft had not been tested for its efficacy in ice-forming conditions of flight. The equipment fitted for the protection of the wings was of a standard type, but it had not been tested on this aeroplane; the propeller equipment, whilst it operated on a standard principle, was of smaller dimensions than that usually employed on previous aircraft. These de-icing installations operate by releasing a fluid on to the wing and propeller surfaces; tests had been carried out to ascertain how the fluid became distributed, and whilst the flow pattern appeared to be satisfactory, it remained to be demonstrated that, in icing conditions, the equipment performed satisfactorily. Before recommending that the reservation on the Certificate of Airworthiness be removed the Air Registration Board awaited evidence on this point. At the time when "Star Tiger" was lost, the evidence had not been provided, either by the British South American Airways Corporation, who were then operating the aircraft, or from any other source.

(*c*) THE MAINTENANCE OF "STAR TIGER".

(i) *The action taken to maintain the aircraft.*

44. The Air Registration Board have two indirect responsibilities for the maintenance of an aircraft. First the Board examine and, when satisfied, approve the schedule of maintenance operations proposed for the type of aircraft by its operators; and second, the Board examine and licence the engineers, who are to be employed by the operators to carry out the inspections of the aircraft. The Maintenance Schedule is revised from time to time in accordance with experience, and any changes must be approved by the Board. The Maintenance Schedule for the Tudor IV. type of aircraft was

approved by the Air Registration Board on 24th September, 1947. The various persons concerned with the maintenance of "Star Tiger" were all licensed, according to their particular functions, by the Board.

45. Among the requirements of the Maintenance Schedule for the Tudor IV. aircraft is a comprehensive routine examination before or at the completion of each 600 hours of flying. "Star Tiger", having completed 575 hours of flying, was accordingly subjected to such a comprehensive maintenance check which was carried out by the British South American Airways Corporation, in January 1947. Immediately after the check, and a test flight, the aircraft departed on the voyage during which she disappeared.

46. An aircraft may not be flown while carrying passengers or goods for hire or reward unless a valid Certificate of Safety for Flight has been granted in respect of it.* This Certificate permits the operation of the aircraft for a period of 24 hours after it is issued. The Certificate is signed by the ground engineer responsible for the inspection of the airframe and the ground engineer responsible for the inspection of the engines both of whom must be licensed by the Air Registration Board. It must also be countersigned by the pilot of the aircraft.

47. Such certificates were issued for the aircraft "Star Tiger" before her departure from London on 27th January, 1948, from Lisbon on 28th January, 1948 and Santa Maria on 29th January, 1948, and they were countersigned in each case by the Commander of the aircraft. The checks upon which the issue of these Certificates of Safety were based were carried out by inspectors employed by British South American Airways Corporation. The correction of engineering troubles which developed on the first stages of the flight was also carried out. None of these troubles was of any consequence in relation to the safety of the aircraft.

(ii) *Matters relevant to the maintenance of the aircraft.*

48. The following matters have to be noted in relation to the standard of maintenance of the aircraft:—

49. (*a*) After the disappearance of "Star Tiger" another Tudor IV. aircraft, which was being operated by the British South American Airways Corporation was withdrawn from service, and examined by a body of experts appointed by the Minister of Civil Aviation. This examination showed that the maintenance of the aircraft had been carried out carefully, and nothing was found to suggest either that there had been omissions or errors—with one exception, which did not affect the safety of the aircraft when in flight. This related to the operation of the emergency dinghies; it was found that the pressure of the gas in the operating bottles was lower than is required to ensure reliable operation.

50. (*b*) Whilst all those concerned with the maintenance and inspection of "Star Tiger" were fully qualified, the investigation revealed that an engineer employed at the time of the accident by the British South American Airways Corporation, and stationed at Santa Maria, had previously been employed by the British Overseas Airways Corporation as an engineer inspector and had apparently been found unsatisfactory as regards his care and skill particularly in the certification of the safety of aircraft. Nevertheless, when he sought another post, again concerned with the inspection of aircraft, the British Overseas Airways Corporation gave this engineer an excellent testimonial for competence, which was entirely in contradiction to their experience as recorded in their files. For this action, the British Overseas Airways Corporation offered no satisfactory explanation. At a

* The Air Navigation (Consolidation) Order, 1923 (as amended), Schedule II, para. 8.

later time, this engineer was taken into employment by the British South American Airways Corporation. The Corporation did not seek written testimonials but they had verbal information through a third party that the testimonials supplied by the British Overseas Airways Corporation existed, and to this extent they may have been misled. They did not ask for any confirmation from the British Overseas Airways Corporation. With such preliminaries the Corporation appointed this engineer to their staff and stationed him, on November 22nd, 1947, at Santa Maria as Station Engineer, a title describing the senior ground engineer on the station.

51. During the period following the appointment there were complaints regarding this engineer's work at Santa Maria from the Commanders of aircraft which passed through the station, and these led to a decision to recall him. The notification of this decision was contained in a letter despatched from the offices of the Corporation on 28th January, 1948. Before this letter arrived, and its contents were acted upon, this engineer inspected and certified as safe the power plant of "Star Tiger" on 29th January, 1948, immediately before she took off on her last flight. There is however no evidence whatever to suggest that, in making this particular inspection, he acted in any way incompetently, or omitted any action which his duty required.

52. (*c*) A record of the maintenance operations carried out on an aircraft is kept, and from an examination of that relating to "Star Tiger" two matters have emerged which call for comment. Firstly, certain defects re-appear regularly in the records, indicating not only that they were not rectified en-route, but also that major checks at the maintenance base failed to eliminate them. Secondly, the aircraft not infrequently took off on passenger-carrying flights over long distances with not unimportant defects unremedied. The records suggest that there was a lack of spare-parts at stations along the route, and that, on some occasions, time was not allowed for full servicing and testing.

53. The records were not well kept; in many particulars they were incomplete.

PART III

THE ROUTE

(*a*) General Description.

54. The journey which this aircraft was undertaking when she was lost was from London to Havana. The first stage in the schedule was from London to Lisbon, where an overnight stop was to be made. The second stage was from Lisbon to Santa Maria (Azores) where the aircraft was scheduled to re-fuel and to set off after a stop of one and a quarter hours for Bermuda. It is this stage, from Santa Maria to Kindley Field, Bermuda, which is now to be described.

55. The geographical disposition of the route is shown in Fig. 2. To aid in reference the route is divided into zones of 5 degrees of Longitude, and those between Azores and Bermuda are numbered from 6 to 13, as shown in Fig. 2. The shortest or "great circle" distance between Santa Maria and Kindley Field, Bermuda is 1961 nautical miles. The route lies entirely over the ocean; no islands or land masses are crossed and no weather ships are stationed on it. The Bermudan group of islands measures 22 miles from North-East to South-West, the total area being 20 square miles. They are about 580 miles east by south from Cape Hatteras, the nearest point on the North American continent.

(*b*) ALTERNATE AIRPORTS.

56. Should a necessity develop during a west bound flight over this route to divert the aircraft to an alternate airport, owing, for example, to unfavourable weather on the primary route, the various airfields in the Newfoundland area, and airfields on the North American coast are available. Their positions are shown in Fig. 2.

(*c*) THE TECHNIQUE OF OPERATION.

(i) *The three phases of the Flight.*

57. When the fuel tanks of the Tudor IV. aircraft are full, she has, as mentioned in para. 18 supra, a range in still air of about 2,900 nautical miles. In the average conditions of wind which prevail in the winter on the route between the Azores and Bermuda, the aircraft, after completing the 1960 nautical miles flight to Bermuda has insufficient fuel remaining to proceed onward to any other airport. Having arrived over Bermuda, the aircraft must land there.

58. A flight by such an aircraft on this route therefore passes through three phases. In the first phase, the aircraft if it should be necessary, can return to the Azores whence it came and there it can land at Santa Maria or Lagens. There comes a point, the " point of no return ", at which the fuel remaining in the aircraft is just sufficient to enable it to make this return journey; if it proceeds beyond this point, it enters the second phase, during which it can no longer return and must proceed onward. During this phase, the aircraft can proceed to Bermuda, or to an alternate airport such, for example, as Gander in Newfoundland. There then comes a point, the " point of no alternate " which is such that, should the aircraft proceed beyond it in the direction of Bermuda, it is no longer able to reach the alternate, and is then compelled to land at Bermuda; this is the third phase.

59. The position of the point of no-return, and of the point of no-alternate depends on the wind conditions prevailing, on the conditions of speed and height at which the aircraft is flown, and on the quantity of fuel with which she departs. At the time she was last heard of " Star Tiger " had passed the point of no alternate and was committed to proceed to Bermuda.

(ii) *The Flight Plan.*

60. Before an aircraft leaves on a flight over a route such as this, a plan for the flight is prepared by the Commander. In the light of the meteorological position and of the weather forecast, the Commander decides the heights and speeds at which he will fly, estimates the probable progress of his flight, estimates the time at which he will arrive at his destination, and estimates the point of no return; these estimates are entered on the flight plan. He also checks that the quantity of fuel he proposes to take will be adequate for the journey, with such reserve as is considered necessary. In the case of British South American Airways Corporation flights from Azores to Bermuda at the time of the accident to " Star Tiger ", the practice appears to have been to allow a reserve sufficient for two hours flying at economical cruising speed. The flight plan includes also an estimate of the position known as the " three-engine critical point ", which is that point at which it would take an equal time to proceed onwards to the destination, or return to the point of departure, using only three engines. This point is significant in making a decision on the best action to take if some mechanical fault should occur which makes it expedient to reach an airport as soon as possible.

61. Copies of this flight plan are lodged with the traffic control and meteorological authorities at the airport of departure, and details from the plan are transmitted to the main Air Traffic Control Centres responsible for the route, as hereinafter described. Details are also transmitted to the traffic control and meteorological authorities at the destination, and to the representatives of the operators at the destination.

(iii) *The Air Traffic Control System.*

62. Under International Agreement, air traffic en route is controlled, in areas, from a central operations office in each area. An aircraft proceeding from the Azores to Bermuda is under the control of the Oceanic Air Traffic Control at the Azores until it has passed beyond Latitude 45° West, when it passes into the control of Oceanic Air Traffic Control at New York, U.S.A.

63. The function of the Oceanic Air Traffic Control Centre is set out in detail in the " Procedures for Air Navigation Services " published by the International Civil Aviation Organisation.* Broadly stated, its duty is to maintain general surveillance over the progress of flights in its area, to give instructions or permission to make alterations of course or height, ensuring that they will cause no danger of collision between aircraft, and to pass to the Commanders of aircraft any information relevant to their passage. Commanders of the aircraft are under obligation to transmit, every hour, to the appropriate Air Traffic Control Centre, a report on such matters as position, speed, height and fuel consumed.

64. On approaching an airport, control of the aircraft is taken over first by the Airport Approach Control, and, when the aircraft is overhead and ready to land, by the Airfield Control Tower.

65. Aircraft flying westward on this route must, under international agreement, fly at an even number of thousands of feet in altitude unless permission to do otherwise is specifically requested of and given by the Air Traffic Control Centre. The height at which the aircraft will fly is notified to the Traffic Control Centre; should the Commander therefore wish to fly at a different height, the new height must conform to the " even thousands " rule, and must be notified.

(iv) *The Radio Communications Systems.*

66. The radio communications system on this route is shown diagrammatically in Fig 3. Whilst in the area of the Oceanic Air Traffic Control Centre, Azores, aircraft communicate with Station CSY at the Azores, which is the station associated with the Traffic Control Centre. On passing into the area of the Oceanic Air Traffic Control Centre, New York, the primary radio contact is with station WSY at New York, the radio station associated with that Traffic Control Centre, but if radio conditions make it desirable, aircraft may instead communicate with station VRT at Bermuda. This station, which is operated by Cable and Wireless (West Indies) Ltd. is linked with station WSY at New York by a high speed radio telegraph, and with Kindley Field Airport Approach Control, Kindley Field Meteorological Office, and the British South American Airways Corporation Office, by teleprinter. Messages addressed to Air Traffic Control, New York, and transmitted to station VRT, are passed to station WSY by the radio telegraphy system. There is also a station, WZT, at Kindley Field, operated by the United States Army Air Force.

* I.C.A.O. Document 2017, RAC/105, " Air Traffic Control."

67. Station VRT consists of a main transmitter, a main receiver, an Adcock high-frequency direction finding station, and a medium-frequency direction finding station. The transmitter can be controlled from the Adcock station by telegraph line. Signals received at the receiving station pass by line to the Adcock station. At the Adcock station, a continuous watch is kept by the Air Guard Operator for signals transmitted by aircraft. The Air Guard's duties are to transmit any messages received from aircraft to the addressee, to send to aircraft signals which are passed to him for transmission, to provide aircraft with bearings based on the use of the high frequency direction finding station, and to ensure that he hears from aircraft which are under his guard at least every 30 minutes. The Air Guard is not concerned with the contents of messages passed through him, nor has he any responsibility to make contact on his own initiative with aircraft for any purpose except to give them bearings he has taken on them at their request or to enquire if all is well should he not hear of them for more than 30 minutes.

68. Commanders of aircraft are under instructions to transmit an "alls-well" message whenever 30 minutes has elapsed since they last had occasion to make contact with the ground station.

69. If the Air Guard has not heard from an aircraft for 30 minutes, and if he is unable to establish contact, a state of emergency is declared. If further attempts fail to establish contact a state of "distress emergency" is declared, and rescue arrangements are put into action.

70. Radio Officers in aircraft are under instructions that, should they wish to break their listening watch at any time, for any period, they should first inform the Air Traffic Control Centre.

(v) *The Meteorological Services.*

71. This route is served by Meteorological Offices situated at Santa Maria (Azores) and Kindley Field (Bermuda). These offices obtain the data on which they make their weather forecasts from the world-wide chain of observation stations on which the international meteorological service is based. An important feature of the Azores-Bermuda route is that there are no observation-ship stations along the route; this is in contrast to the air routes between Europe and North America, which are served by a number of such weather-ships. Furthermore, there is in the area little commercial shipping from which data can be obtained. The weather along the route must therefore be inferred from observations taken on the land-masses and islands of America, Europe and Africa and from such data as aircraft on the route supply. The reliability of forecasts is not as high as it is in areas where more complete data are available. There exists an International agreement under which weather-ships are to be placed along the route, but at the time of the accident to "Star Tiger", this agreement had not been implemented.

72. Under international agreement, Meteorological Offices set up to serve the needs of civil aviation operate under regulations and arrangements which are set out in International Civil Aviation Organisation Document 2016 MET/93 "Meteorology", and which are summarised below in so far as they are relevant for the present purpose.

73. Under these arrangements, the Meteorological Office provides, for the information of the crews of aircraft, as complete a picture as possible of general weather conditions, and provides a detailed forecast for any route and time specified. This forecast indicates such meteorological hazards as may be encountered, the probable intensity of cloud, and the probable

strength and direction of winds at heights specified by the Commander of the aircraft. It also contains a forecast of the weather conditions at the destination, and at any alternate airports specified. This detailed forecast is contained in a folder, which is handed to the Commander of the aircraft to take with him on his journey. The data contained in this folder are provided to meet the request of the Commander of the aircraft or the representative of the Operating Agency. On the latter lies the responsibility for asking for data that will or may be needed.

74. The Meteorological Office also provides data upon which are based routine messages, broadcast every six hours, which contain a forecast of landing conditions at the local airport for the subsequent twenty-four hours. These messages are not directed to any particular addressee, but are for the information of all who may be concerned. It is, for example, on the basis of such messages from Bermuda that the Santa Maria Meteorological Office will provide a landing-condition forecast to each aircraft leaving Santa Maria for Bermuda. Similarly, routine messages are broadcast every half-hour giving the actual weather at the local airport at the time, for the information of aircraft approaching the airport.

75. If, as occurs in a flight from the Azores to Bermuda, the aircraft passes from one traffic control area to another, the Meteorological Office at the point of departure transmits to the office in the next traffic area details of the forecast provided to the Commander of the aircraft for that part of the journey lying in the next area. Thus, at all stages in a flight, the appropriate Meteorological Office is fully aware of the forecast on which the Commander of the aircraft is working, and of the plan for his flight. With this in view, it is the duty of the Meteorological Office to keep a general watch on the development of the weather situation, and, if any information comes to their knowledge indicating the possible occurrence of a significant change in the weather which will affect the aircraft's flight, to make that change known.

76. There are two broad classifications into which air traffic can be divided. The first is that of the scheduled operator, working a regular service over a route, and the second is that of the non-scheduled operator, whose aircraft do not fly particular routes regularly or, in some cases, even frequently. The procedures used for making known changes of the meteorological situation thus anticipate that, in conducting the first class of traffic, the operating agency will have stationed along its routes representatives who are responsible for the general supervision of operations, although the ultimate responsibility must rest, and does rest, with the Commander of the aircraft. The present case is concerned with regular traffic, conducted by a recognised and established airline and it is the arrangements which apply to that case which are here outlined.

77. The Meteorological Office at the point of destination provides to the representative of the operating agency a copy of that part of the flight forecast which applies to the section of the route for which he is responsible and which has been given to the aircraft commander. Should a change in the meteorological situation occur whilst an aircraft is in flight, information on that change is passed to the representative of the operating agency. If, and only if, he should determine that the change is significant to the flight, the data are transmitted to the aircraft, except when a situation of emergency arises, when the Meteorological Office may inform the aircraft on its own initiative. Normally a wind change of 20° or more in direction or of 10 knots in speed is considered to be a significant change.*

* I.C.A.O. Doc. 2016 MET/93, "Meteorology", Apx. "E", para. 3.1.1.1.

78. The Commander of an aircraft in flight may, at any time, request meteorological data, and to such a request the Meteorological Office will make direct response. Similarly, the representative of the operating agency may at any time request and obtain information.

79. If requested by the Commander of the aircraft, or by the representative of the operating agency, the Meteorological Office will transmit to the aircraft, before it reaches its point of no-return as shown on its flight plan, either a message containing amendments to the forecast already held by the aircraft for the areas ahead of it, or a message stating that there are no such amendments.

80. The Meteorological Office at the point of destination is responsible for informing the local representative of the operating agency of the forecast given to the Commander of the aircraft at his point of departure, and for advising him, throughout the flight, of forecasts and amendments relating to the primary and alternate airports of destination. He is also informed of any changes foreseen in the meteorological situation.

(vi) *The Meteorological Features of the Route.*

81. In winter months, the wind on this route usually has a component opposing an aircraft making the journey from Azores to Bermuda, and the intensity of this head-wind component increases with height. The following Table shows the velocity of the component of the wind opposing the aircraft which is exceeded on 50 per cent. and 15 per cent of occasions.

TABLE

AZORES—BERMUDA ROUTE

WEST BOUND

Equivalent head winds in knots exceeded on 50 per cent. and 15 per cent. of occasions.

	Dec.–Feb.		Mar.–May		June–Aug.		Sept.–Nov.	
	50%	15%	50%	15%	50%	15%	50%	15%
5,000 feet ...	24	35	16	26	5	11	11	21
10,000 feet ...	31	43	19	31	5	12	17	27
20,000 feet ...	45	62	30	45	27	37	32	49

82. The accuracy of forecasting particularly of wind and cloud is only moderate, for reasons already stated in para. 71 supra. Forecasts of wind strength usually become more accurate as the height to which they apply increases. It is a fairly common experience to encounter head winds which are much stronger than those forecast, particularly in the winter months.

83. Apart from the uncertainties of the winds, the route is not difficult for flying. It is a warm weather route, and there are no serious troubles with, for example, icing.

84. The weather at Bermuda is excellent for landing for a very large proportion of the time. There are occasional tropical storms, and occasional hurricanes, which sweep the island. Ample warning of the coming of hurricanes is usually obtained, so that they do not represent a hazard to aircraft approaching the island. The tropical storms often arrive with little or no warning, but they very rarely last more than two hours.

(vii) *Navigation on the route.*

85. In order to obtain absolute fixes of position on the route between the Azores and Bermuda, use is made of astronomical navigational methods, based on sextant observation of the stars. For this reason, flights on the route are so planned that the greater part of the journey, and particularly the latter part, is made during the hours of darkness.

86. In order to obtain a clear sky for observation, the aircraft must fly above any cloud which is not sufficiently broken, during the short time required to take a fix. In good conditions a star-fix taken by an experienced navigator is unlikely to be in error by more than about 15 miles.

87. Dead-reckoning navigation, based either on a measurement of the wind velocity by observation of drift over the sea, or on the forecast wind, is supplementary to stellar navigation. Drifts can usually be obtained in the hours of daylight, or in strong moonlight, if the aircraft is not above cloud.

88. Radio bearings can be taken from the aircraft on ground transmitting stations, and bearings of the aircraft from Bermuda can be observed by station VRT at Bermuda, and transmitted to the aircraft. For final approach to the Kindley Field, the aircraft can " home " accurately on the Eureka Radar beacon installed there.

PART IV

THE CREW

(*a*) THE NORMAL COMPLEMENT OF THE TUDOR IV.

89. The normal crew complement of the Tudor IV as operated by British South American Airways Corporation consists of a Commander, First Officer, Second Officer and Radio Officer, with stations in the control cabin, and First and Second " Star Girls " or Stewardesses, with stations in the passenger cabin.

90. The Commander, First Officer and Second Officer are Pilots, and their qualifications, training and experience are intended to cover the pilotage, navigation and power control of the aircraft in flight. A Flight Engineer is not carried: see on this paras. 13 supra and 173 infra. Consequently, the control cabin has been designed so that all vital engine controls and instruments can be operated and checked respectively from the two pilot stations.

91. At the discretion of the Commander, he and the other two Pilots share the duties of navigation, pilotage and power control. This procedure is intended to enable one Pilot to be off duty periodically, on the assumption that it is only necessary normally to have one Pilot at the controls once cruising altitude has been reached.

92. The Radio Officer is the only certified Wireless Telegraphy Operator on board and, as such, he is responsible for maintaining the air-to-ground communications in accordance with regulations, except during those short periods covering departure from and arrival at an aerodrome, when air-to-ground communications can be taken over by one or other of the Pilots,

using Radio Telephony. Over some well organised land routes, Radio Telephony can be used extensively, but, in general, the routes operated by British South American Airways Corporation do not come under this category. The Radio Officer is thus expected to be on duty for the whole of a flight in order to maintain continuous radio watch, and he can only be relieved of this duty for very short periods after prior arrangement with the ground stations.

93. " Star Girls " is the title given by this air line to their female stewards or Air Hostesses, and their duties are primarily concerned with the care and welfare of the passengers in flight. They are normally able to be off duty either together or separately at various times during a flight.

(*b*) TRAINING.

94. After initial appointment, facilities and instruction are provided to all grades of flying staff so that they can become qualified to carry out their respective duties in accordance with the standards and practices of the Corporation.

95. This training covers academic and practical requirements and, in the case of Pilots, includes navigation, engineering, Company organisation, pilotage, knowledge of aircraft, route experience and operational ability. The programme is thus fairly comprehensive, but, in the records available, there is no clear indication or guarantee that it is fully implemented, or that the desired standards have been attained. There is also evidence that the intended flying training is not necessarily completed before an officer operates on the routes in his particular capacity, and that this is due to the shortage of aircraft and instructors, and to the lack of suitable weather conditions. One part of the flying course, which is normally carried out at base, is meant to ensure that the Pilot has attained the necessary ability in the pilotage of a particular type of aircraft under all the conditions which he is likely to encounter whilst on service, and this includes such items as general flying, ability to fly accurately on instruments and to carry out the Instrument Approach Procedures applicable to the routes flown by the Corporation. The time allocated to reach the required standard in this extensive section is approximately ten hours, which is low, considering the type of operation involved, and, here also, the records available do not indicate the precise standard required or attained.

96. Before a regular service is introduced, the known ability of Pilots to carry out properly the relevant Instrument Approach Procedures at the various aerodromes on the route is one of the most important aspects of airline flying. There is evidence that this is theoretically included in outline in the training programme, but there are no detailed records kept of the individual procedures carried out at these aerodromes, and no detailed procedure laid down covering this particular section of the Pilots' training to ensure that it is fully covered. There is, in fact, evidence that the Pilots were prepared to plan a passenger carrying flight into aerodromes under conditions which might entail carrying out an instrument approach without having been to these aerodromes before, and without necessarily having practised the particular procedure on the Link Trainer.

97. Another important aspect of instrument flying is that continual practice is required to maintain the proper standard, and regular practice on the Link Trainer is one of the recognised means of attaining this. Whilst there is evidence that the Link Trainer was used by the Corporation, there were no

records available, at the time of the accident, to indicate the times allocated on the Link Trainer or the exercises covered by individual Pilots. This omission has now been remedied, and a detailed Link Trainer programme has been introduced.

98. It is true of air line flying that the number of hours flown does not necessarily measure efficiency or exclude the development of faulty technique which may eventually reach dangerous proportions. There is no evidence that Pilots of the Corporation were given periodic flying checks or refresher courses to ensure that they were maintaining the proper standard, although the Court understands that this has now been instituted. It is also understood that the programme and procedures covering the introduction of a new aircraft to an established route and vice versa have been revised to ensure that every member of the operational crew is fully able to carry out his duties efficiently.

99. Emphasis has been laid on the training programme of the Pilots as it is the most complex and difficult problem in so far as flying staff are concerned. The training programme of the Radio Officers and Stewards follows similar lines, and involves academic and practical requirements, including operating under supervision on the routes until the necessary ability has been demonstrated and experience obtained. The evidence indicates that their programmes are fully carried out, but the records available are not sufficiently detailed to indicate the actual standards required or attained.

100. Pilots' Operating Manuals or Notes are provided by the Corporation for the use of the flying staff, and these provide technical information on the aircraft and procedures relevant to its operation. Normally included in this information are complete details of the emergency procedure to be carried out if an emergency landing on the sea becomes necessary, but no such section was included in the British South American Airways publications regarding their Tudor IV aircraft.

(c) THE CREW OF "STAR TIGER".

101. The crew of "Star Tiger" on her last flight were:—

Captain B. W. McMillan, Commander.
Captain D. Colby, First Officer.
Mr. C. Ellison, Second Officer.
Radio Officer R. Tuck.
Star Girl V. A. M. L. Clayton.
Star Girl H. S. B. Nicholls.

Details of the training, qualifications and experience of each member of the crew were made available to the Court, and there can be no question that they formed an able and experienced team. The witnesses who knew Captain McMillan were unanimous in their appreciation of his high qualities. He had flown 2,912 hours as a pilot in the Royal Air Force and 1,673 hours in command of British South American Airways aircraft. A pilot who had made a flight as First Officer under his command said in evidence that he found him a very steady and capable Commander. The First Officer, Captain Colby, had flown 1,690 hours in the Royal Air Force and 1,403 hours (1,066 of them in command) for British South American Airways. Mr. Ellison, the Second Officer, had flown 1,210 hours in the Royal Air Force, 1,050 of them as First Pilot, and had flown 7 hours as First Pilot and 692 hours as Second Pilot for British South American

Airways. Radio Officer Tuck was described as most experienced and capable; he had had 14 years' experience as a seagoing radio officer and was Senior Radio Officer, North Atlantic Control, Prestwick, from 1941 to 1945. He had flown 1,787 hours on British South American Airways aircraft. All these officers had previous experience of the Bermuda route, but they had not previously flown together as a crew.

PART V

THE LAST FLIGHT OF "STAR TIGER"

102. In the preceding paragraphs of the Report reference has necessarily been made incidentally to various features of the last flight of "Star Tiger". At the risk of some repetition it may be useful to present an account of it in consecutive order.

(*a*) London to the Azores.

103. "Star Tiger" left London Airport on her last trip on 27th January, 1948. As already mentioned she had by then done 576 hours of flying time and had just undergone a complete overhaul. On the previous day she had made a short test flight at London Airport, when certain minor defects were discovered and remedied, and a 24-hour Certificate of Safety was duly issued. When she left London Airport she had 23 passengers and carried the crew of six, mentioned in para. 101 supra. She arrived at Lisbon on the same day. Certain minor defects were reported on this stage of the flight, among them a failure of the cabin heating apparatus and trouble with one of the compasses. Of these the heating failure caused much discomfort to the passengers; the Corporation had previously found the heating system to be unreliable, and on this occasion a part was replaced at Lisbon but it did not cure the trouble. The other defects were remedied during the scheduled overnight stop at Lisbon when the routine inspection was effected and the Station Engineer duly gave his certificate of safety next day. When, however, the aircraft was prepared for the flight to the Azores the port inner engine failed to start. This was found to be due to the failure of the priming pump, and a new pump was fitted. In order to effect this it was necessary to turn off all the port side petrol cocks, including that controlling Nos. 3 and 4 tanks, which, as mentioned in para. 21 supra is not under the control of the pilot. The Station Engineer had no doubt that he subsequently turned this outboard cock on and locked it in the "on" position. The trouble delayed the start by 2½ hours, and "Star Tiger" in fact left Lisbon at 11.45 a.m. on the 28th of January.* Two additional passengers were taken on board at Lisbon. The aircraft arrived at Santa Maria later in the same day.

(*b*) Events at the Azores.

104. At the Azores Captain McMillan received an adverse report from the Metereological Office at the airport and instead of following the normal practice of setting off across the Atlantic for Bermuda immediately after refuelling he decided to stay at the Azores overnight. He went to bed about 9 p.m. saying that he was very tired. What rest he or any of the crew had had at Lisbon

* Except where otherwise stated all times are given as Greenwich Mean Time. Local time at the Azores is 2 hours earlier, and at Bermuda is 4 hours earlier, than Greenwich Mean Time.

is not known, but in the ordinary course they would retire at about 10 p.m. and rise at about 8 a.m. At Santa Maria airport another aircraft of the British South American Airways Corporation was awaiting a favourable opportunity for taking off for Bermuda. This was the Lancastrian G-AGWL, commanded by Captain Griffin; she was carrying freight which was to be transhipped at Bermuda to "Star Tiger". The crews of both aircraft met at the Azores and the two commanders jointly decided upon the night's postponement. On the next morning, 29th January, they went together to the Meteorological Office to obtain a flight forecast, and ultimately decided to fly with one hour's interval between them. Consequently the commander and wireless operator of the Lancastrian were able to give valuable information as to the course decided upon and the conditions encountered by "Star Tiger" on her final flight. By next morning the strength of the adverse headwinds had lessened and after the two commanders and Captain Colby had worked out flight plans for varying heights, they determined to proceed upon a plan at a height of 2,000 feet throughout the journey. This height was chosen as affording a less effective adverse wind component than any other. It also took the aircraft below cloud base and allowed drifts to be taken from the surface of the sea during daylight hours. The Meteorological Officer then compiled a flight forecast folder (Appendix IV) and the two navigators worked out their flight plans. "Star Tiger's" flight plan is reproduced in Appendix V. As will be seen it gives Stephenville (in Newfoundland) as the first diversionary destination, with Lagens (in the Azores) as the second. It gives the flight time as 12 hours 26 minutes and the estimated time of arrival at Bermuda as 3.56 a.m. the next day. The Lancastrian's flight plan differed in giving Lagens and Santa Maria as the two diversionary destinations, but in other respects it bore a marked similarity to "Star Tiger's". This was only natural, since, as the Lancastrian was to leave only one hour ahead, many of the calculations in the two plans were bound to be similar. In fact, however, they contained a common error, from which it would seem probable that only one officer worked out certain of the details and the other accepted them without checking. The two commanders should have checked their respective plans and in fact signed as having done so, but since the errors were not discovered it is doubtful whether they did so. The error was in the distance given for the critical point and will be referred to later in this Report.

105. During the short stay at the Azores "Star Tiger" was given a survey by the ground staff and the 24-hour certificate of safety was completed by the ground engineer (airframes) and the ground engineer (engines). Trouble had again developed on the flight from Lisbon with the same compass and the cabin heater; the former was remedied but the latter was not. The traffic assistant then prepared the load sheet. He found that, with the pay-load carried, the maximum amount of petrol which he could take without overloading was 3,150 gallons. The maximum capacity of the tanks being 3,300 gallons, the Captain then had the choice of leaving passengers behind (there being no freight) in order to take the maximum fuel, or of proceeding with less than full tanks. According to the traffic assistant Captain McMillan adopted the latter alternative and the figure of 3,150 gallons was entered on the load sheet. The "all-up weight" was then calculated to be 36,298 kgs., which was precisely the maximum permitted for that aircraft at that airfield. This "all-up weight" is the equivalent of 79,855 lbs., i.e., 145 lbs. less than the 80,000 lbs. permitted under the certificate of airworthiness. Despite this entry in the load-sheet, however, Captain McMillan in fact appears to have taken a full load of petrol. The engineer for engines said in evidence that the captain instructed him to "fill her up to the gills" and the serviceability log showed a total of 3,300 gallons on departure. The flight plan showed

3,250 gallons of fuel, which would represent the total of 3,300 gallons less 50 gallons allowed for warming up, taxying and take-off. If one accepts that the tanks were full there was a total all-up weight of approximately 80,936 lbs.

106. This overload was soon reduced by fuel consumption and cannot of course have had anything to do with the disaster. Captain McMillan's insistence on full tanks does, however, indicate that he fully appreciated the difficulties occasioned by the prevalent headwinds. The winds on this route not infrequently contain such a headwind component as to prevent a Tudor aircraft with full tanks from reaching Bermuda either with the then customary 2-hours reserve of fuel or at all, and the headwinds did from time to time increase en route beyond the forecast strength. Both commanders would be well aware of these matters, and their appreciation of them must have been heightened by the facts that twice before on westward trips " Star Tiger " had had to divert to Gander in Newfoundland on account of headwinds, and that on an occasion in the previous November another Tudor IV had encountered winds so much stronger than forecast that it had arrived at Bermuda with its petrol gauges showing " nil " and its commander had alerted the air sea rescue organisation and had prepared to " ditch " his aircraft. On the latter occasion the fuel had, in fact, held out, and on arrival there was found to be some 100 gallons left, but the incident had received not a little publicity and must have emphasised the necessity of carrying all fuel possible on this leg of the flight.

(c) THE TRANS-ATLANTIC CROSSING.

107. The Lancastrian took off from Santa Maria at 2.22 p.m. on 29th January and " Star Tiger " followed at 3.34 p.m. The Lancastrian touched down at Kindley Field, Bermuda, at 4.11 a.m. the next day, having had an uneventful crossing. " Star Tiger " was never seen again. She had been heard, however, frequently during her flight, and it is important to consider the wireless signals transmitted by her radio operator in order to see whether they throw any light upon the disaster which overtook her. A composite table was compiled and produced at the Inquiry showing all messages passing to and from both aircraft, and the radio operators of the Lancastrian and of the Bermuda shore station VRT gave evidence. Radio conditions appear to have been good during the night in question and besides normal communications to shore the aircraft on a number of occasions spoke to one another. The first inter-aircraft communication was at 4.11 p.m. when " Star Tiger " asked for and obtained information as to the wind the Lancastrian was experiencing. The prescribed hourly position reports were duly sent out by " Star Tiger " down to the last one at 3 a.m. and a number of other messages of an ordinary or routine nature were passed. Apart from the position reports, whose importance is self-evident, there are three matters dealt with in these messages which call for comment.

108. The first of these concerns the height above sea level at which the aircraft was flying. This is an important matter because of course the lower the altitude the less opportunity there is for dealing with any emergency which might upset the stability of the aircraft. The flight was planned to take place at a height of 2,000 ft. throughout the passage. It is not unlikely that there would be minor deviations from this height, and in fact the Lancastrian's navigation log has height entries varying from a maximum of 2,150 feet to a minimum of 1,500 feet. Those entries however stop at 7.50 p.m. and for the remaining 8½ hours of the flight the height is not logged. The Lancastrian's meteorological log was kept up throughout the flight but the height entries are unreliable since they show a consistent 2,000 feet even when the navigation log shows some other height. In her hourly position reports " Star

Tiger " consistently gave her height as 20,000 feet. This was obviously an error for 2,000 feet and indicates either carelessness in transmission or an error in coding. But on the assumption that 2,000 feet was intended, can this be relied upon as giving the exact height as recorded by the altimeters at the hourly times? This seems unlikely when regard is had to the facts that the same round figure is given on each occasion and that the record keeping was not of a high order, as evidenced by the discrepancies in the Lancastrian's logs. It follows that it is impossible to say with certainty at what height the aircraft was flying at the time when communications ceased.

109. The second matter disclosed by the signals relates to the rule laid down—and wisely laid down—that the radio station guarding any aircraft must not allow more than 30 minutes to elapse without contact. After that space of time without signals it is the Air Guard's duty to call the aircraft. Now during the second half of the flight " Star Tiger " was under the control of VRT, the Cable and Wireless W.T. station at Bermuda. The standing instructions given by Cable and Wireless (West Indies) Ltd. to their staff are explicit on this point (see para. 178 infra). Nevertheless the radio logs show that after receiving a message from " Star Tiger " at 10.10 p.m. VRT did not make contact with the aircraft again till 11.5 p.m., an interval of 55 minutes. Similarly, after receipt of a position report at 11.15 p.m. there was no further contact until 11.57 p.m., an interval of 42 minutes. These incidents may not be without significance when the final loss of contact is considered.

110. The third matter concerns weather information and entails a consideration of the weather conditions and information during the flight. The strength and direction of the winds, zone by zone, form part of the forecast given by the Meteorological Office at the departure airfield, and those forecast at Santa Maria will be found in the flight forecast, Appendix IV. That forecast was issued at 2 p.m. and at 4.45 p.m., 2½ hours after departure, Captain Griffin of the Lancastrian transmitted via the Azores a message addressed both to the Air Traffic Control at New York and British South American Airways at Bermuda asking to be furnished with a landing forecast for Bermuda between 3 and 4 a.m. next day, and with a wind forecast for zones 9 to 13 inclusive at 2,000, 6,000 and 10,000 feet. At 5.6 p.m. no reply to this message having been received, the Lancastrian ascertained from Air Traffic Control at New York that the message had not reached them; the message was then repeated and New York was asked to retransmit it to Bermuda. There was still no reply by 5.52 p.m., when the Lancastrian sent the following message direct to the U.S. Army Air Force at Kindley Field Bermuda: " Landing forecast and upper winds urgently required ". This time the information was speedily forthcoming and the required forecast was passed from Kindley Field to the Lancastrian at 6.5 p.m. Winds at 2,000 feet in zone 12 were forecast as 22 knots and in all zones except the last (13) were stronger than the Santa Maria forecast. None of these signals had concerned " Star Tiger ", although its radio operator may of course have overheard them. Meanwhile not only had the Lancastrian received the forecast of stronger winds ahead but also her navigator's calculations had yielded an indication that the winds she was then experiencing in zones 7 and 8 between longitudes 33° to 37° W. were 55 knots as against 40 and 30 knots forecast by Santa Maria. Her estimated time of arrival at Bermuda had accordingly to be recalculated and at 6.49 the Lancastrian passed to " Star Tiger " via the Azores, the message " my flight plan now on revised winds 1328. What do you think? ". This flight time of 13 hours 28 minutes was one hour longer than planned. At 7.45 p.m. the Lancastrian again established direct communication with " Star Tiger " and passed on

Kindley Field's information to her. There was as yet no reply to the messages to Bermuda (apart from Kindley Field), but at 7.3 p.m. New York told the Lancastrian that Bermuda had a message for her and promised to relay it. The relay was not received however but at 8.43 p.m. the wireless station VRT at Bermuda for the first time established direct contact and at once transmitted to both aircraft a wind and landing forecast signed " B.S.A.A. Bermuda " and marked as filed at 4.38 p.m., that is more than 4 hours before despatch and shortly before the Lancastrian had asked for the information. This was immediately followed at 8.51 p.m. by a similar message similarly addressed giving a further forecast and stated to have been filed at 6.24 p.m. There is no significant variation between the three forecasts transmitted from Bermuda to the aircraft (See para. 117, infra). After 8.51 p.m. no further meteorological information (apart from general broadcasts of landing conditions) was addressed to either aircraft until nearly 6 hours later after requests from the Lancastrian in the following circumstances. At 1.26 a.m. the Lancastrian navigator obtained an astral fix which showed him that he was considerably off course. He was then in Zone 12, for which the Azores forecast was " winds light and variable ". His calculations led him to believe that in fact he was experiencing a south westerly wind (233°) of some 48 knots, and his astral fix showed him that during the preceding hour he had been carried approximately 68 miles north of his intended track. Following that discovery, the Lancastrian at 2 a.m. requested VRT for wind information for Zone 13 at 2,000 feet. The reply to the request was " wait ". The request was repeated at 2.15 p.m. and 2.33 p.m. and was answered at 2.42 p.m. when the message " S.S.W. 20 knots " was transmitted from Bermuda addressed not as previously to both aircraft but only to the Lancastrian which had made the demand.

111. Two facts emerge from the history of these meteorological signals; firstly, the striking contrast between the delays involved in obtaining a reply through the ordinary channels and the speed with which the U.S. Army Air Force answered; secondly, the unreliability of forecasts on the crucial portion of this route. The three messages from Bermuda all put the wind at 2,000 feet in Zone 12 as 20 to 25 knots and 350 or 360 degrees, while in fact the Lancastrian's calculations indicated a wind of double that force (48 knots) and a very different bearing (233°). It must be pointed out however that wind calculations deduced from position observations in flight are necessarily inexact.

112. Apart from the above mentioned facts there was nothing out of the ordinary in the messages passing to and from " Star Tiger ". She had not initiated requests for weather information, as the Lancastrian had, but travelling as she was one hour behind her fellow-aircraft which was, as it were, in the position of a " pilot ", this is not surprising. Like the Lancastrian she had amended her flight time and consequently her estimated time of arrival, in the light of the revised winds; the arrival time she had amended from the original estimate of 3.56 a.m. to 5 a.m. by the time of her last position report at 3 a.m. (This was, however, an inaccurate estimate on the face of it, since on the position and speed she gave and in the light of the wind forecast as known to her, the arrival time, properly calculated, would have been about 5.30 a.m.) She had duly left the area of control of the Azores and been taken under the control of VRT Bermuda, acting for New York. Her hourly position reports, which are plotted on the Map (Fig. 2) showed a normal progress and although it is clear that she, like the Lancastrian, had been taken off course by the change of wind, her position report at 2 a.m. showed that her navigator had been able to obtain an astral fix, so that that position was a known one, and not obtained by

dead reckoning alone. The last position given, that for 3 a.m. was by dead reckoning. Up to 3 a.m. on January 30th, therefore, it is a reasonable inference from the known facts that "Star Tiger" had had a steady and uneventful flight. Her officers had received and acknowledged the Bermuda weather forecasts sent out at 6.5 p.m., 8.43 p.m. and 8.51 p.m. but they had not (unless they had overheard) received the revised winds transmitted at the Lancastrian's request at 2.42 a.m.

(*d*) THE LAST SIGNALS.

113. "Star Tiger" was heard twice after the transmission at 3.2 a.m. of her 3 a.m. position report. At 3.4 a.m. her operator requested a radio bearing from VRT. This is obtained by the aircraft's operator transmitting a continuous signal by keeping the key depressed, upon which the receiving station by use of a directional aerial system ascertains the bearing. On that occasion a satisfactory bearing could not be given. The request was repeated at 3.15 a.m. and this time the VRT operator was able to give a first class bearing of 72°. He advised the aircraft accordingly and obtained an acknowledgment of receipt. This was the last signal heard from "Star Tiger".

(*e*) WEATHER CONDITIONS.

114. When last heard of "Star Tiger" was in Zone 12. Bermuda is in Zone 13. The meteorological situation in those zones, as revealed by all the data available, including observations made from aircraft flying in the area around Bermuda at the material time, has been examined. The general conclusion is justified that in the vicinity of the last known position of "Star Tiger", and in any area in which she is likely to have flown thereafter, the weather was stable, there were no atmospheric disturbances of a serious kind which might cause structural danger to an aircraft, and there were no electrical storms.

115. The moon had risen at 1 a.m. at Lat. 52° W.; it was three-quarters on the wane, 19 days old. The Lancastrian on her flight one hour previously had found cloud base to be just above 2,000 feet. It was broken cloud, assessed at six-tenths, but increased in intensity towards Bermuda; the Captain of the Lancastrian had seen stars through gaps in cloud until within 90 miles from destination. He had first seen the powerful marine lights of Bermuda when 25 miles from it.

116. Mr. James Durward, the Deputy Director of Meteorological Office services at the Air Ministry, gave in evidence at the Inquiry an appreciation of the meteorological situation in the two zones at the relevant time, based upon all subsequently available weather information. According to this appreciation the cloud formation seen by the Lancastrian extended from a base between 2,000 and 3,000 feet to a top between 4,000 and 7,000 feet. In Zone 12 it was assessed at from four to seven-tenths, but its density increased to ten-tenths (complete obscurity) in the west of Zone 13. Above it there was a layer of high cloud, alto-stratus, extending westward from the west of Zone 12. This had its base at 13,000 feet and its top at something under 17,000 feet, and like the lower cloud its density increased towards the west. It was assessed at six-tenths in the west of Zone 12 but in the west of Zone 13 it probably increased to ten-tenths and lowered.

117. Mr. Durward also gave an appreciation, upon similar data, of the winds in each zone, and it may be convenient to set this out in tabular form together with the various forecasts and estimates of winds in Zones 12 and 13 already mentioned.

TABLE OF WINDS IN ZONES 12 AND 13 AS FORECAST AND ESTIMATED.

	Zone 12 (55–60° W.)	Zone 13 (60–65° W.)
Wind forecast by Santa Maria	Light and variable	100/15
Winds forecast by Bermuda :		
1. Forecast filed at 4.38 p.m. and transmitted at 8.43 p.m.	360/25	Light and variable
2. Forecast filed at 6.24 p.m. and transmitted at 8.51 p.m.	350/20	ditto
3. Forecast transmitted by Kindley Field at 6.5 p.m.	? *	ditto
Winds assessed by Lancastrian	233/48	250/30
Mr. Durward's appreciation	240/18†	220/40†

Note : The wind is given by compass bearing followed by force in knots ; e.g., 250/30 signifies a 30-knot wind from 250°.

* This entry appears as a query in the Lancastrian's radio log.

† These are Mr. Durward's figures for the winds in latitudes 56–59° W. and 62–65° W. respectively.

118. The bearing of the weather conditions on the navigation of the aircraft is discussed in paras. 135 and 137 infra.

(*f*) EVENTS AT BERMUDA.

119. To complete the summary of the events surrounding the loss of the aircraft, it is now necessary to turn to the Bermuda end of the flight. Here there are three organisations whose activities and co-ordination it is necessary to consider. These are (1) the U.S. Army Air Force, who operate the field and provide the Main Meteorological Office there; (2) British South American Airways Corporation who, through their station manager there were in operational control of the aircraft when she was lost; and (3) Cable and Wireless (West Indies) Ltd., whose W.T. station VRT, was at the time acting as Air Guard to and means of communication with " Star Tiger ".

120. Apart from documentary evidence, the Court had before it the evidence of two witnesses from Bermuda, Wing-Commander Ralph, the British South American Airways' Station Manager, and Mr. Richards, the operator on duty at VRT. The American meteorological officer did not attend: the U.S. Government were invited to make him available as a witness, but did not see their way to do so.

121. The Station Manager said in evidence that when an aircraft leaves the Azores he receives the flight plan and then as a matter of routine transmits a weather forecast for the second half of the journey and for landing. This, he said, accounted for the message sent to both aircraft at 8.51 and filed at 6.24 p.m. In point of fact it is difficult to believe that his recollection was accurate about this, since if the times of filing are correctly recorded the first of the two messages, marked as filed at 4.38 and transmitted at 8.43 p.m. and signed " B.S.A.A." was originated before the Lancastrian asked for weather and was therefore a volunteered message, the sending of which would correspond with the Station Manager's routine. Moreover, if he is right, he must have volunteered two messages and failed to reply to the Lancastrian's direct request. The probable, and as it seems to the Court the correct, interpretation is that the first was the routine message and the second was the reply to the Lancastrian. The delay in transmission was due to the fact that VRT was unable to establish contact with the aircraft earlier.

122. The VRT operator took guard of " Star Tiger " at 8.47 p.m. He admitted the two occasions when contact with the aircraft was lost for 55 and 42 minutes respectively. In explanation he said " I had other traffic on the

air at the time—that may be the reason ". His log, however, showed that he was not busy at the time, and he added " I imagine the air was filled with signals from other stations ", which may have been the case. The wireless log was not of great assistance in elucidating this matter, since a number of signals were admittedly omitted from it, and since it did not record what signals passed but merely noted the character of the signal passing. One thing is clear, however, and that is that on neither of these two occasions did the operator declare the emergency which his written instructions required him to declare after a 30 minutes loss of contact.

123. Between 11 p.m. and midnight there was a power failure on the island. This stopped the teleprinter communication between VRT and the Corporation's offices, but left the telephones unaffected. For this reason Cable and Wireless endeavoured to pass on the 11 p.m. position reports from the two aircraft by telephone to the Corporation but failed entirely to obtain any answer from the latter's office. Wing-Commander Ralph claimed that his office was continually manned, but could not explain this failure to answer the telephone.

124. The next event calling for notice was the Lancastrian's request for winds made at 2 a.m. and repeated at 2.15 and 2.33. The greatest obscurity shrouds the dealing with this message at Bermuda. Of the three requests only one was logged by the VRT operator, and that was recorded at 2.9 a.m. He did, however, log his reply at 2.42 a.m. He said that he did not regard the request as a formal message addressed to the Corporation but as a note or " remark " and that he passed it to Bermuda Approach Control at Kindley Field and received from them the information which he transmitted to the aircraft. He said that he would not ordinarily inform the Corporation of such a message, but could not be sure that he did not do so on this occasion. Wing-Commander Ralph on the other hand stated that the message came direct to him, that he himself obtained the information from the Meteorological Office and that it was he who dispatched the answer viâ VRT to the Lancastrian. It is noteworthy that the Lancastrian's earlier request received an answer signed " B.S.A.A." and addressed to both aircraft, whereas the answer in this instance was unsigned and addressed only to the Lancastrian. This difference in treatment may be thought to support Mr. Richards's version of the matter. Both he and Wing-Commander Ralph were asked why the message was not also addressed to " Star Tiger "; Mr. Richards answered, it may be thought with justice, by saying " it was not my place to do so "; Wing Commander Ralph who obviously could have exercised a discretion to address the reply to " Star Tiger " gave the explanation that he was obtaining further weather information which he intended to send to " Star Tiger " later. It may be added that there appears to be no record of any such inquiry at the Meteorological Office, and that the form in which the information was passed (" S.S.W. 20 knots ") referring as it does to the wind direction by points of the compass and not by compass degrees was not that in which a Meteorological Office would ordinarily issue such a forecast. This again may be thought to be consistent with an informal passing of information by Bermuda Approach Control. It is clear that no formal amendment to forecast was issued by the Meteorological Office and it seems reasonably clear that the Office did not consider that a " significant change ", as defined in para. 75 supra, had occurred.

125. Mr. Richards last communicated with " Star Tiger " when he gave the bearing at 3.15 a.m. At 3.50 a.m. when 35 minutes had elapsed without a signal from the aircraft, he called her again. He got no reply. Thinking that she might have gone over to the direct radio telephony with Bermuda Approach Control used on the last lap of the flight, he asked that control if

they had made contact. They had not. He called "Star Tiger" again at 4.5 a.m. Again there was no response. Fifty minutes had now gone by since the last contact. He could not remember if he informed the Corporation of loss of contact, but said he probably did. The teleprinter sheets from the circuit between his station and Wing Commander Ralph's office were produced: they contain no record of any such message. At 4.40 a.m. (2.40 a.m. local time) he called again, again without response, and then, 95 minutes after the last contact, he declared a state of emergency and notified Oceanic Air Traffic Control at New York, Approach Control at Kindley Field, and the British South American Airways Corporation.

126. No distress message of any kind was heard by Mr. Richards or by any other station. Many operators would have been listening on the relevant wavelengths within the normal range of "Star Tiger's" transmitters.

127. Mr. Richards was asked whether by 4.40 a.m. the loss of contact had not caused him considerable anxiety. He answered: "No, he was not due till 5 a.m."

(*g*) THE SEARCH.

128. Energetic steps were taken once the emergency was declared. At 4.55 a.m. the Search and Rescue Section of the U.S. Army Air Force at Kindley Field was alerted, and by 7.16 a.m. (3.16 a.m. local time) a Fortress aircraft equipped with a radar scanner was in the air. During the day 25 other aircraft took part in the search. All areas of the sea where it was conceivable that "Star Tiger" might have come down were scanned. The search went on until nightfall on February 3rd. Altogether 104 flights were undertaken and a total of 882 aircraft-hours was flown. Many different agencies contributed aircraft and the whole intricate operation was directed by the United States Army Air Force authorities at Kindley Field. Surface craft were also employed. Continuous radio watch was kept. There were a number of false alarms both of radio messages and of objects sighted in the water: all were investigated, without result. Extremely bad weather prevailed throughout the greater part of the search, but even on February 1st when the storm made landing at Bermuda a hazardous operation seven aircraft made sorties. After five days of continuous and intensive effort the search had to be abandoned. It is only fitting that the Court should here record its admiration of the zeal and courage with which it was conducted; it is impossible to exaggerate the service rendered by the United States authorities and by all those who contributed and managed the aircraft and vessels employed. The tragedy of the loss of "Star Tiger" is rendered the more poignant by the fact that all their efforts were in vain. No trace of the aeroplane was found and no trace of wreckage or of any other object connected with her has since been seen.

PART VI

ANALYSIS OF THE POSSIBLE CAUSES OF THE ACCIDENT

129. It is proposed under this head to discuss, in the light of such facts as have been ascertained, certain possibilities which may have occurred in the present case.

(*a*) GENERAL CONSIDERATION.

130. There is good reason to suppose that no distress message was transmitted from the aircraft, for there were many radio receiving stations listening on the aircraft's radio frequencies, and none reported such a message. Thus

there exists first the possibility that there occurred a failure of the aircraft's radio transmitting installation. There may then have happened an accident, either catastrophic or developing, creating a distress which the aircraft's crew were unable to report; a particular case of such a developing situation is that the aircraft may have failed to find Bermuda before her fuel was exhausted, being deprived of that part of her navigational information which depended on radio for its reception. The alternative hypothesis is that an accident occurred with such rapidity that no distress message could be sent, or that whatever occurred became catastrophic in a short time, during which the circumstances were such either that a distress message could not be sent, or that no such message was thought to be necessary until, as it proved, it was too late.

(*b*) THE HYPOTHESIS OF RADIO FAILURE.

131. A total failure of the radio transmitting equipment due to any cause other than a failure of the D.C. electric power supply is extremely unlikely, for the equipment is duplicated and there is available an emergency aerial. Thus, normal types of breakdown are guarded against adequately. A lightning stroke will usually affect only the radio set which is in use at the time, and in addition, it is most unlikely that there were electrical storms in the neighbourhood of the aircraft at 3.15 a.m. or in any area she is likely to have entered thereafter.

132. The D.C. power supply is provided by two independent generators which also charge a storage battery (para. 26 supra). A simultaneous failure of both generators together due to mechanical or electrical fault is highly improbable, but examination suggests that if a failure of one generator were to occur, a mishandling of the circuit breakers by the member of the crew undertaking an investigation might result in failure of the other. However, were both generators to fail, the storage battery would normally provide power for radio transmission and reception for a short time. Though the transmission would be at reduced power, and reception at reduced sensitivity, the aircraft was so close to the Bermuda stations that there can be little doubt that communication would have been possible. Thus, only a total failure involving both the generators and the battery, would effect a failure of radio in these circumstances. The possibility of such an occurrence is remote. The electrical circuits are guarded in design with very ample electrical and mechanical factors of safety. Short circuits occurring in most parts of the electrical installation would be isolated by the protective circuit-breaking or fusing equipment. The generators themselves are protected from over-loading by circuit-breaking equipment, and should an overload cause this equipment to isolate them, the source could be cleared or isolated, and the generators then returned to service. It is very difficult to visualise a situation in which an electrical failure would be likely to affect the battery and both generators, unless there were gross incompetence in the handling of a fault by the member of the crew investigating it, or there were grave omissions in workmanship and inspection, of which there is no evidence.

133. There is to be considered the possibility that the Radio Officer was unable through illness or accident to operate his telegraphy transmitter. He was the only member of the crew skilled in this work. This hypothesis, however, is not of significance for the operation of the radio telephony sets requires no special skill so that they could have been used by any member of the crew. Whilst their range is much less than that of the telegraphy sets, the aircraft would have been within telephonic range of Bermuda shortly after she was last heard by telegraphy.

134. A total failure of radio is thus most unlikely. Nevertheless, it is desirable to examine the navigational position which would have arisen had such a failure occurred, in order to reach conclusions on the particular hazard which might then present itself, namely, the inability to find the island before fuel was exhausted. Had the radio failed shortly after 3.15 a.m. the aircraft's navigator would have been set the task of finding Bermuda, which was then distant some 340 nautical miles and 2½ hours flying time, without the aid of radio bearings and without such information on the state of the wind as might have been obtained by radio. His target was in a small group of islands, equipped with powerful marine lights around the coast, the visibility of which from an aircraft flying below cloud (as it readily could have flown in the conditions prevailing) was about 30 miles in all directions. He had about 3¾ hours in which to find his target before the exhaustion of his fuel.

135. The navigator had a radio bearing from Bermuda on his position at 3.15 a.m.; it was a " first class " bearing, and this is unlikely to have been in error by much more than 2°. In using this information, the navigator would make allowance for wind. It is unlikely that he could have measured the wind by observing his drift over the sea, since there was little light, though it is conceivable that he might have lowered his altitude in order to attempt to do so. On the wind strength and direction in the area in which he was flying he had no information from external sources other than that contained in the forecast passed to him by radio at 8.51 p.m. The actual wind conditions did not correspond with those forecast, but of this general circumstance the navigator is likely to have been well aware. His astronomical fixes at 1 a.m. and 2 a.m. had indicated to him that his aircraft was taking a fairly large northerly drift; the forecast had predicted a southerly drift in this area. He would thus proceed from his position at 2 a.m. on the supposition that he should allow for northerly drift; the radio bearing given him at 3.17 a.m. would confirm his general view, and would indicate that he had perhaps allowed for rather too large a drift in making the dead-reckoning fix which he passed by radio at 3 a.m. Proceeding on these data he would set a course which, in the wind conditions actually prevailing, would have brought him within some 30 miles of Bermuda by 5.30 a.m. At that time, he would have expected to be very near the island; the error in the estimated time of arrival which was transmitted by radio at 3 a.m. may be discounted as this error must have been over-taken during the detailed navigational work in the subsequent hours. On this basis, the aircraft could hardly have failed to find the island in a short time, in the conditions of visibility which prevailed.

136. The possibility that failure of power would interfere with the aircraft's course-keeping can be discounted, for though the magnetically controlled gyroscopic compass would cease to operate, there are also available two bowl compasses of high accuracy. If even less tenable suppositions are made about the navigator's work, such as, for example, that after 3 a.m. he computed entirely on the early forecast data, it is still unlikely that a systematic search conducted in the time which his stock of fuel permitted would have failed to reveal the island.

137. Thus it appears that, had the navigator been forced to work without data other than those which he had available at hand, it is very probable that the aircraft would have reached Bermuda. Moreover had there been difficulty in finding the island, the Commander of the aircraft might well have been able to obtain an astronomical fix. To do so would have required a climb through the cloud. There is very little doubt that the top of the cloud was at an altitude of about 17,000 feet. If there had occurred a

complete failure of the electric supply, the pilot would not have been able to change his engine superchargers from low gear, in which they would be running in his flight at 2,000 ft. to high gear, which he would require for flight at high altitude, for this gear change is dependent on electrical power. Also, the electrically driven fuel pressure boosting pumps would have stopped. Calculation shows that at the weight at which the aircraft was operating after 3 a.m. the maximum height the aircraf could reach with the superchargers in low gear would be about 20,000 ft., so that, although inability to change gear would affect the rate of climb, it is almost certain that an altitude at which astronomical observations were possible could have been reached, provided the lack of the fuel boosting pumps did not affect the climb. The effect of lack of fuel boost is difficult to assess as it depends on the aeration of the fuel and other factors but it is quite probable that there would have been no difficulty. A suitable altitude having been reached, no doubt most careful and repeated sextant observations would be made, and a fix with an error of only a very few miles would be obtained.

138. There would accordingly appear to be no grounds for supposing that "Star Tiger" fell into the sea in consequence of having been deprived of her radio, having failed to find her destination, and having exhausted her fuel.

(c) THE HYPOTHESIS OF CATASTROPHIC ACCIDENT.

(A) *Causes which can be eliminated.*

139. The possibility of a catastrophic, or a rapidly developing accident must next be considered. There are some causes of occurrences of this character which, on the evidence available, can be eliminated.

(i) *Constructional Defects:*

140. There are no grounds for supposing that in the design of the Tudor IV aeroplane, or in the manufacture of the particular Tudor IV aeroplane "Star Tiger", there were technical errors or omissions, judged against a standard of agreed good practice. This is not to say that what occurred could not have been caused by some failure of a mechanical kind which, if discovered, could be prevented from recurring by the exercise of engineering skill, but rather that, if there were defects, they were not of a kind which offends against the highest accepted standards of good practice as established at the time when "Star Tiger" was lost.

(ii) *Meteorological Hazards.*

141. Nor are there any grounds for supposing that the loss of "Star Tiger" was caused by any meteorological hazard. The evidence on the meteorological situation, and on the local weather in the region in which "Star Tiger" was lost, is sufficiently complete to render it extremely improbable that she encountered catastrophic ice accretion, or any dangerous type of atmospheric movement or gust, at any altitude at which she may have flown. The possibility that she was struck by static electric discharge may also be eliminated; but even were this not so such discharge is most unlikely to lead to disaster in the air.

(iii) *Errors of Altimetry.*

142. There is little possibility that the aircraft flew into the sea as a result of an error in the indication of height. The aerostatic altimeters indicate height above a datum which is set on the instrument, and which is determined by the local atmospheric pressure at sea-level; should the actual sea level atmospheric pressure differ from that assumed in making the setting, the indicated height will be in error. It is the case that the sea level

atmospheric pressure in Zone 13 was lower than that forecast when "Star Tiger" left the Azores, and thus if the instruments were set at the forecast datum, they would indicate a higher altitude than actually obtained, but only by about five hundred feet. Furthermore, the aircraft was fitted with a radio-altimeter, which reads absolute height, and which, among other things, is used to correct the datum of the aerostatic altimeter. Even were the radio-altimeter unserviceable, errors on the aerostatic altimeter could have caused disaster only if the aircraft were flown at a most dangerously low height.

(iv) *Mechanical Failure of Engines.*

143. The failure for mechanical reasons of one engine is a possibility, but this aircraft could fly entirely safely on three engines, and, indeed, at her weight at the relevant time, on two. The possibility of a simultaneous, or almost simultaneous failure of two or more engines due to mechanical causes is so remote as to be almost inconceivable, having in mind the long record of high reliability possessed by engines of this general type.

(B) *Causes which cannot be eliminated.*

144. The possibilities which cannot, with reasonable certainty, be eliminated may next be examined.

(i) *Fire.*

145. The possibility of fire must be considered. It cannot be shown with certainty on the evidence that it did not occur in this case, but it is nevertheless most improbable. The occurrence of fire during normal steady flight is now very rare. Every precaution is taken in design to prevent it, and this type of aircraft is well supplied with fire extinguishing devices. The power plant is equipped with devices which operate warning lamps in the control cabin if any undue rise of temperature occurs, and with fire extinguishers which can be operated electrically from the control cabin. Furthermore, had any serious fire occurred which was not immediately controlled by the extinguishers, it is unlikely that a distress message would not have been transmitted before a catastrophe resulted, since such a fire would create an obvious emergency, the gravity of which would be appreciated immediately. There is the possibility that a fire occurred as a separate event after a radio failure; this requires the coincidence of two improbabilities. There is the possibility that an electrical fault, which caused a total failure of the power supply and consequently of the radio system, also caused an uncontrollable fire. No reason has emerged for supposing such an event to have occurred. Finally there is the no less remote possibility of hydraulic fluid igniting. A fracture in a part of the aircraft's hydraulic power system could in some circumstances distribute the activating oil in a manner which might result in fire or explosion if there were suitable sources of ignition present. There is no evidence on which any opinion can be formed as to whether such a failure occurred when "Star Tiger" was lost. There is no record of previous trouble of the kind, and the installation in "Star Tiger" satisfied the standard requirements for airworthiness.

(ii) *Mechanical disruption.*

146. The occurrence of a disastrous mechanical disruption of any part of the power plant cannot be ruled out on the evidence, but again the possibility is most remote. The shedding of a propeller or a propeller blade in flight is not unknown, but there is no particular ground for supposing that it might have occurred in this case; the propellers themselves had been examined by their makers and passed as entirely safe immediately before this flight. There are no peculiarities in these parts, rendering them in any way particularly

susceptible to failure. Furthermore experience of this rare occurrence shows that it is usually not completely disastrous, for the propeller flies away harmlessly, or, if it strikes the aircraft, does not cause catastrophic damage. It is, however not impossible that it might cause complete disaster by striking the aircraft. Apart from such damage, the loss of a propeller would cause no difficulty to this aircraft for it is readily able to fly on three engines.

(iii) *Loss of control.*

147. Next there are the possibilities which might result in loss of effective control of the aircraft. The altitude at which she was reported to be flying was 2,000 ft.; it cannot be certain that she was not at times at a lower height. Evidently, when flying at a fairly low altitude such as this, the time available for the recovery from any loss of control is not great.

148. There are first those possibilities which result in damage to, or loss of effectiveness of the controlling surfaces and mechanisms. An immediate possibility of this kind is the inadvertent release of an emergency dinghy whilst the aircraft is flying normally. Were this to happen, the dinghy would usually blow away harmlessly, but if it were to foul the tailplane and become wrapped around its leading edge, it is likely that a loss of control would result and that disaster would follow quickly. Such an event cannot be excluded, but there is no reason whatever for supposing it to have happened. Such a release could not be expected to occur unless the releasing mechanism were actuated, either manually or electrically. The manual releases are protected and clearly marked. The electrical switches are covered with a flap to prevent any accidental actuation. A deliberate release could only have been the act of a madman.

149. In the same general category is the possibility that an article such as a panel from the engine cowling broke loose and fouled the tailplane or elevators. Again, it cannot be proved that this did not occur, but such events are very unlikely to be disastrous; in all probability, were such a panel to break loose, and were it to hit the tailplane, it would do no more than dent it, without causing danger.

150. As to the possibility that some failure in the automatic pilot, which may have been in use, caused a loss of correct control, any such failure would not cause difficulty, even at the low altitude at which the aircraft was flying, provided there was the normal and proper supervision by the human pilot. In common with all mechanical devices, the automatic pilot may break down, but it can be switched out of action, and manual control established, in a very short time. It can also be over-ridden by the human pilot even if it is not switched out of action. Furthermore, the automatic pilot has no large power at its disposal, and it could not, therefore, cause a very rapid manoeuvre in the circumstances prevailing. Thus, if the loss of the aircraft followed on any failure of the automatic pilot, that failure was merely incidental.

(iv) *Loss of Engine Power.*

151. There are next those possibilities which might result in such a loss of engine power that the aircraft was unable to maintain height. We have already discounted such an occurrence arising from mechanical failure, but there remains the possibility that engines were starved of fuel. This could have arisen only if there were to have occurred a serious leakage of fuel, or if fuel cocks were closed. A serious leakage is discounted, for not only is it very unlikely, but it would certainly be noticed. Starvation would eventually occur, however, if one or both cocks in the fuel lines from the Nos. 3/4 tanks, which are normally locked in the " on " position before take-off, had, by error, been left in the " off " position; these cocks cannot be operated

when the aircraft is in flight. Starvation would also eventually occur if either of the cocks controlling the flow from the No. 1 or No. 2 tanks were left "off"; these cocks can be operated in flight. It is relevant to this matter that it is common practice in conducting a long range flight to turn off some tanks, in order to retain a known quantity of fuel in them for subsequent use, though it appears that this was rarely done on Tudor aircraft, and that it was not Captain McMillan's practice to do so. It is also relevant that a statement of the fuel consumed is required in the routine hourly report to the Air Traffic Control Centre, and in order to compute this, reference should be made to the flowmeters and to the tank depth gauges. The readings so obtained often differ, and it is quite usual to quote the larger figure for fuel consumed, working on a pessimistic figure for the fuel remaining. The fuel remaining in "Star Tiger" at 3 a.m. was quoted as 944 gallons; it was probably rather more than this, for the reason just outlined and perhaps because the tanks in the aircraft may have contained a little more than 3,300 gallons at the outset, it having been found on another Tudor IV. that, though the tanks are rated at 3,300 gallons, up to 100 gallons more could be accommodated.

152. Had one or both of the cocks on the Nos. 3/4 tanks been left in the "off" position when the aircraft left Santa Maria, this must have been indicated by the depth gauges in one or both of the No. 3 tanks remaining at the "full" position. Had this at first been discounted as a fault in the guage, it must subsequently have become apparent by reason of the abnormally heavy drain on the other tanks; furthermore starvation of fuel to two engines on one side would almost certainly have occurred before 3.15 a.m., the capacity of the combined Nos. 3/4 tanks being 575 on each side of the aircraft; though the fuel remaining at 3 a.m. may have exceeded 944 gallons, it is unlikely to have been as high as 1,150.

153. The capacity of the No. 1 tank is 480 gallons on each side of the aeroplane. After making allowances for possible errors in the quantity of 944 gallons quoted as remaining at 3 a.m. and for the difference between the fuel consumption of the pair of engines on the two sides of the aircraft, it appears probable that had one or both of the cocks controlling the No. 1 tank been turned off throughout the flight one pair of engines would have been starved of fuel during the half hour following the last signal from the aircraft. This may well be only a matter of coincidence; the fact that one or both cocks were turned off must have been apparent from the reading of the depth gauges in the No. 1 tank, unless one or both gauges were assumed to be faulty. Cocks could have been left off long enough to cause starvation of fuel only if they had been forgotten, unless it is supposed that a passenger turned them off, an event which is most unlikely. In this connection, however, it is perhaps not the best of arrangements that important controls of this kind should be in the passenger compartment; it might not be unreasonable to expect that they would be placed under the observation, and within easy reach, of the operational crew. Supposing, however, that a cock or cocks had inadvertently been left off, and as a result, that there was a failure of power on one side of the aeroplane, the consequences would have been disastrous only if there was lack of attention on the part of the member of the crew then supervising the aircraft's flight. When such a power failure occurs, there is little to call immediate attention to it, apart from the starting of a yawing motion, for the constant speed propellers adjust themselves to maintain the engine revolutions, and there is no obvious change of noise or of instrument reading. If the automatic pilot is engaged, the subsequent path of the aeroplane is a gentle spiral, which would cause a loss of height of about 1,000 feet in a minute. If under manual control, the aircraft can

readily be held on course if prompt action is taken, but if the pilot does not take any action for several seconds a fairly steep dive develops; if no action were taken for about fifteen seconds 2,000 feet of height would be lost before a condition of level flight could be recovered. Such a delay in taking action is most unlikely to occur, and indeed might well be discounted as impossible in daylight conditions when the initial yaw would be easily apparent. Under the conditions which obtained at the material time in the flight of "Star Tiger", the night was rather dark, and the crew had been flying for twelve hours; these are both factors which are known to be capable of exerting a considerable influence on the action taken by a pilot in such circumstances. There is also the remote possibility that the pilot had fallen asleep. Thus, starvation of fuel on one side of the aircraft, taken together with a lapse of immediate attention on the part of the pilot might account for an aircraft which was flying at, or perhaps a little below, 2,000 feet, suddenly losing its height and hitting the sea, but it may well be thought that the combination of events required to bring this about is such as to make it a very unlikely occurrence.

154. If there had occurred an interruption of the supply of fuel to two of the aircraft's engines, and if the pilot had taken action to control the aircraft's motion, he would then no doubt give instructions that the position of the fuel cocks should be checked immediately. Since the cocks are placed in the passengers' compartment, the member of the crew making the investigation must leave the flight deck and walk aft to the cupboard in which the cocks are located. If he then discovered that a cock was turned off, and turned it on, it is probable that power would be available again in a very short time; an experimental check on another Tudor IV aircraft showed that if a tank was sucked dry, and subsequently a new supply of fuel was turned on, no air-locks or other impediments to an immediate restarting of the engines occurred.

(*d*) CONCLUSION.

155. An analysis such as the foregoing cannot hope to be exhaustive, for the history of accidents in the air, as in other media, reveals occurrences which vary in all degrees between clear mechanical failure and clear human failure. The direct evidence which is available in this case, and which is reviewed above, is so indefinite that no conclusion can be reached as to what occurred. Were the analysis more exhaustive and more detailed, the result would be no more conclusive. Yet some misfortune overtook this aeroplane. It may have been one of those discussed in the preceding paragraphs, or a combination of them, or it may have been an event of a kind which has not been considered here. It would be of little profit to add further speculation, but it is relevant to consider the various indirect circumstances which may have had a bearing on the safety of the operation, and this task is attempted in the next part of the report.

PART VII

A GENERAL REVIEW OF THE SAFETY OF THE OPERATION

156. This Part deals with the manner in which the operation of aircraft was conducted over the route by the British South American Airways Corporation, and the manner in which the general services on the route operated, in order to answer the questions "Was it safe to operate the Tudor IV aircraft on this route?" and, if so, "Were such flights, and in particular, the last flight of 'Star Tiger', conducted in a prudent manner?"

157. In the course of the Inquiry various matters emerged which call for comment. As events developed in the particular flight during which the accident occurred, none of the omissions and errors to which attention is drawn could, in the opinion of the Court, have had any direct influence of a disastrous kind. Furthermore, the fact that mistakes were made or carelessness occurred in one place or at one time, is no proof that they occurred at another. Taken together, however, they suggest a question whether the arrangements conduced to a proneness to accident. Accident in the air is most often associated with a combination of errors each of which, taken alone, would not necessarily be disastrous; the extent, therefore, to which care is taken to avoid error, and the extent to which there is forethought in making arrangements to minimise the influence of any possible, even if improbable, misadventure or enforced departure from plan, are relevant in considering whether the probability of a coincidence of errors such as might result in disaster is negligible or not.

(*a*) THE SUITABILITY OF THE AIRCRAFT FOR THE ROUTE.

158. The first question which arises is whether it is safe to operate a passenger carrying aircraft on a route on which there is no airport alternative to the primary destination during the last phase of its journey. In the opinion of the Court this is a safe and acceptable procedure, provided all possible care is taken to ensure that the aircraft will arrive over its destination with sufficient fuel in reserve to permit it to await the passing of any local bad weather which may arise without warning and prevent it landing, and to await permission to land if there should be any congestion of traffic in the area. To secure this condition, close attention must be paid to the development of the weather ahead of the aircraft, and particularly to the strength of the winds ahead of it, so that the crew can maintain a constant watch over the probable consumption of fuel during the completion of the journey. Vigilance is especially needed in assessing the fuel reserve before the aircraft passes its point of no-return and its point of no-alternate. These points should be calculated to allow an adequate reserve of fuel on returning to the point of departure, or on arrival at the alternate airport. Furthermore, calculations of the probable reserves of fuel on arrival, either at the primary destination, or elsewhere, should include allowance for adverse changes in the meteorological situation during the flight and for errors of navigation.

(*b*) THE PROCEDURES USED IN THE FLIGHT.

159. The evidence disclosed that in this flight there was want of care and attention to detail. Though none of the errors made can have contributed to the disaster to " Star Tiger ", and though some of them, taken alone, are small, they are not without significance.

160. The British South American Airways Corporation organisation, as a whole, did not sufficiently ensure that significant changes in the weather ahead of an aircraft would be known to it. The Commanders of the two aircraft, the Lancastrian and " Star Tiger ", which flew the route on the night of the disaster, had not asked the meteorological authorities to give them, before they reached their points of no-return, the routine message stating amendments to the weather forecast; in this they were justified, for their Corporation's representatives on the ground, at the Azores and Bermuda, were responsible for ensuring that intimation of significant changes, whenever they occurred, was sent to them.

161. It is not possible to state with any accuracy what in fact was the strength or direction of the winds in Zone 13 at the material time, and accordingly it is not possible to assert that a significant change of weather

ought to have been forecast by those at Bermuda and notified to the aircraft; nor indeed is it possible to say with absolute certainty that such a change had in fact occurred. If the Lancastrian's calculations and Mr. Durward's appreciation (see Table, para. 117, supra) were correct, there had been a significant change, but it must be remembered firstly that wind data deduced, as the Lancastrian's were, from an aircraft's position observations are necessarily inexact, and secondly that an *ex post facto* appreciation, in the absence of local data such as weather ships would provide, cannot be more than an approximation. Whatever the truth of that matter may be, however, the evidence remains clear that the British South American Airways Corporation's machinery for ascertaining and transmitting to their aircraft information of significant changes was not altogether satisfactory. It is doubtful whether the Corporation had clearly realised their obligations under the international procedures, for at one time they endeavoured to show at the Inquiry that the matter was not their responsibility at all.

162. The flight plans filed by the Commanders of the Lancastrian and "Star Tiger" show that the point of no-return was calculated on the basis of flying back at the same altitude as was used for the outward flight, and arriving with all fuel exhausted. Such a point of no-return makes an allowance for waiting on arrival only in so far as it may be possible to return at a different altitude, at which a more favourable wind is available. There is no clearly calculated allowance for changes of weather, errors of navigation, and fuel reserve. On this unacceptable basis, the point of no-return filed by "Star Tiger" was correct; that filed by the Lancastrian was incorrect, being too far from the Azores by some 80 miles. The three-engine critical point filed by both aircraft was incorrect; both stated the distance as 815 nautical miles, whereas, on the wind forecast, it should have been 1,090 nautical miles. The flight plans containing these errors were signed by the Commanders of the aircraft as having been checked. It is evident that no such check can have been made, since otherwise these errors must have been noticed. Whilst the points should have been, and no doubt were re-calculated whilst in the course of flight in accordance with the wind conditions actually encountered, these data are left in the flight plan for the guidance of the Meteorological Office and the representatives of the operating agency in discharging their task of keeping general watch over the flight; there is no justification for misleading them by careless calculation.

163. Before leaving Santa Maria, the Commanders of both the Lancastrian and "Star Tiger" consulted with the Meteorological Office, and surveyed the weather situation. The Lancastrian planned only to return to the Azores as an alternative to proceeding to Bermuda; "Star Tiger" planned to use Stephenville as an alternative destination. The landing forecast for Stephenville showed that conditions there were likely to be no better than moderate, and possibly bad, at the time the aircraft would have arrived. Both Commanders took with them in the Flight Forecast (Appendix IV) general weather forecasts covering the Azores-Bermuda route, wind data for that route at 2,000 ft. altitude, and a synoptic chart showing the general distribution of atmospheric pressure. As will be seen from the Flight Forecast they took no written data for winds at other heights; the Commander of "Star Tiger" took no written data on weather and wind forecasts for the area in which he would have had to fly if forced to proceed to Stephenville. That they did not take such data does not mean that they had not surveyed the position in the Meteorological Office, and had not committed the general position to memory, but on these matters reliance on memory is not necessary, and it is indicative of a somewhat careless attitude that more data, which might have proved valuable if difficulties had arisen, were not taken.

164. The fuel reserve with which aircraft operated by this Corporation and proceeding to Bermuda set out was normally sufficient for two hours flying. (It is understood that a three hours reserve has since been prescribed.) The reserve must allow for deterioration of weather in the journey ahead of the aircraft, for awaiting the passage of local bad weather, which had not been forecast and which would prevent immediate landing, for delays due to traffic control at the airport, and for navigational errors. In view of the transient weather conditions at Bermuda and the moderate accuracy of wind forecasts on the route, two hours fuel reserve cannot be regarded as a sufficiently cautious provision, there being no other place of landing available. There is this to be said however about the assessment of what constitutes an adequate reserve of fuel; in conducting commercial aviation on any route, and particularly on a route of this kind, a fine balance must be struck between economy and adequacy of reserve. Every hour's reserve of fuel carried on this flight reduces the payload by about 25 per cent. That is the figure upon which a balance must be struck by the operator between safety and economy. An excess of caution over that for which the situation can be considered reasonably to call, is bought at a crippling cost to economy, but an excess of economy is equally bought at an unacceptable cost to safety.

(*c*) THE ALTITUDE OF THE FLIGHT.

165. "Star Tiger" and the Lancastrian planned to fly the whole journey from the Azores to Bermuda at an altitude of 2,000 ft. This altitude is lower than is usual in long distance operations, and, indeed, the evidence is that no previous flight conducted by the British South American Airways Corporation had taken place throughout at this height. Should a mishap occur such as to cause the aircraft to lose height, there is rather little time in which to make a recovery. Nevertheless, provided normal vigilance is maintained, there is no reason to regard this altitude as unsafe.

166. The navigation log of the Lancastrian shows that during parts of the journey she flew below 2,000 ft. (see para. 108 supra). On a number of occasions she was at 1,500 ft. but in no case was the Oceanic Air Traffic Control Centre informed, as the regulations require. Though the normal height of "Star Tiger" was also 2,000 ft. it may be that she also was at times lower. The flight was planned and conducted at 2,000 ft. because it would have been impossible, in the forecast winds, to have made the journey at higher altitude. The forecasts of winds on this route are somewhat unreliable at all heights, but they are particularly unreliable at low heights. Thus, in the conditions which obtained "Star Tiger" and the Lancastrian could remain in the air long enough to reach Bermuda only if they flew in a very restricted band of height, where the forecast was particularly doubtful in accuracy. Attention has already been drawn to the absence of a clear allowance of fuel to deal with adverse changes of wind, and it would appear to be not unreasonable to suggest that such an allowance is more than ever necessary in these particular conditions, and indeed that a larger allowance than is considered adequate for high altitude operation should be required.

167. In fact, "Star Tiger" had a larger allowance than the two hours reserve on which these operations were usually based, but only because she was overloaded with fuel. The evidence was clear that no particular attention had been paid to the need for increased allowances when flying at these low altitudes.

(*d*) THE OVERLOAD AT TAKE-OFF.

168. The overload with which "Star Tiger" took off from Santa Maria exceeded the permissible maximum by some 900 lbs. There can be little

doubt that the commander was aware of this; he had been informed that he must either take 3,150 gallons of fuel, or fewer passengers; having stated that he would do the former, and signed the loading sheet accordingly, he gave instructions for the loading of 3,300 gallons of fuel (para. 105 supra). This overload had the effect of reducing the safety of his flight at the very early stages, and particularly at the take-off.

(*e*) THE POSSIBILITY OF FATIGUE.

169. The normal schedule of the flight called for operation, without change of crew, from Lisbon to Bermuda, with a stop of about 1½ hours at the Azores. This requires a period of activity totalling about 19 hours. In fact, there was in this case an unplanned overnight stop at the Azores.

170. The operational crew carried by the aircraft numbered four, three being interchangeable in duty covering pilotage and navigation, and the fourth being the radio officer. Thus the radio officer could not be relieved; under the normal schedule he was charged with keeping a continuous watch throughout the period apart from the short time spent at the Azores. This period required by the normal schedule is, in the opinion of the Court, too long; there should either have been a planned 12 hour stop at the Azores, or a second radio officer should have been carried.

171. Having in mind that there are no special facilities provided in the Tudor IV aircraft to enable the other members of the crew to rest when off duty, it may be thought that the schedule imposed too great a strain on them also. A seat in the passengers' compartment might be available but adequate provision for rest in aircraft operating particularly tiring schedules is more usually held to consist of a crew rest room, equipped with a bed.

172. It would appear to be a justifiable comment, therefore, that if the normal schedule was to be operated, a second radio officer, and special facilities for rest, should have been provided, or alternatively that the schedule should have allowed 12 hours stop at the Azores.

(*f*) THE NUMBER AND TRAINING OF THE CREW.

173. There are at least two views on how an aircraft similar to the Tudor IV should be operated. There are those who hold that a Flight Engineer, who is concerned solely with the operation of the power plant, is essential; there are others who hold that it is better to combine these duties with those of pilotage, and to carry officers who are fully qualified for pilotage, navigation, and power plant operation. If the first plan is followed, a station is provided in the aircraft at which the controls and instruments relating to the power plant are grouped; under the second, these controls and instruments are dispersed in the pilots compartment. The latter policy was followed by British South American Airways Corporation. The wisdom of the choice is undoubtedly a matter of opinion. The Court is satisfied that if the pilots are suitably qualified the control layout in the Tudor IV aircraft was such that the aircraft could be operated satisfactorily by the crew provided, in all respects except those already mentioned in considering the possibility of fatigue.

174. The training programme laid down by the Corporation is technically comprehensive, but the time allocated to flying training is such that there is room for doubt whether the desired standards can be reached in all aspects of the programme. Examination of the training records shows some evidence that the flying training programme was not necessarily completed owing to lack of instructors or of aircraft thereby indicating that an officer could be

operating on the route without having completed his training programme. That training which is so essential to safety should thus be interrupted is regrettable.

175. There is evidence that Commanders of British South American Airways Corporation aircraft were prepared to plan operations into airports, using instrument approach procedures, without having had previous knowledge of these airports. Indeed, the Commander of "Star Tiger", on the last flight, planned to use Stephenville as an alternative airport, though he had never been there, and though the landing forecast suggested that the conditions there might well have made an instrument approach essential. It is also apparent that in certain instances Commanders of aircraft were required to carry passengers in their first flight over a route, without first having flown the route under instruction and supervision, and without having performed to the required standard an instrument approach at each airport on the route.

176. There is also evidence that there were no periodic checks to ensure that operational crews remained up to the required standard in skill and knowledge, though such checking is generally recognised to be essential if high standards of safety are to be maintained.

177. Examination of the notes provided by British South American Airways Corporation to their pilots shows that the data they contained were not complete. In particular, the absence of procedures for emergency landing on the surface of the sea (para. 100, supra) is a serious omission in view of the long ocean crossings involved and the effect which a lack of such instructions might have on efficient action if such a landing occurred.

(g) THE HANDLING OF WIRELESS SIGNALS.

178. Cable and Wireless (West Indies) Limited were under a duty, once the aircraft had passed the half-way point in its journey, to provide it with Air Guard service. This duty they acknowledged. Their instructions to their operators at station VRT contain the following paragraphs:—

"DEGREES OF EMERGENCY.

1. Emergency.—When radio contact with aircraft fails for 30 minutes.
2. Distress Emergency.—When radio contact failure has lasted for two hours, or when an SOS message is received from the aircraft."

"REPORT PROCEDURE.

In all cases an emergency will be reported by Station VRT to Bermuda Approach Control Center (BACC) immediately, also to Aircraft Company.

Station VRT will remain on stand-by continuously (in cases such as 2). VRT will (with the help of RL) endeavour to monitor all frequencies likely to be used by the aircraft including 500 kcs and report all developments and signals to BACC, also the Bermuda representative of Owners of Aircraft as well as WSY."

179. The Court regards the carrying out of the above instructions as a safety precaution of the highest order and cannot pass without criticism the failure of the wireless operator to comply with them. Three times during "Star Tiger's" flight communication ceased for more than 30 minutes. The operator's explanation that the relevant wavelength was probably crowded with other messages may be accepted as regards the second of these occasions, when 42 minutes elapsed, and may conceivably be correct as regards the first, when 55 minutes elapsed. On the third and final occasion

when messages ceased, the operator called the aircraft after 35 minutes, an interval not open to criticism. Nor was there anything improper in his first reaction to that failure of contact: he thought that "Star Tiger" might have gone over to direct radio telephone communication with Approach Control and accordingly communicated with that Control. But having ascertained from them that they were not in contact with the aircraft he seems to have failed to realise his responsibility. He should then have declared an emergency. Instead he allowed another half hour to elapse and then called "Star Tiger" again. He failed to raise the aircraft, and again did nothing. His statement that he "probably" informed the Corporation (para. 125 supra) is not borne out by the evidence. In fact the emergency was not declared until 95 minutes after the last contact. Had it been declared one hour earlier, as it should have been, the search operations could have been commenced earlier. There is this to be said for the VRT operator; he was working a very long spell of duty, having started at 4 p.m. on January 29th and not being due for relief until 12 noon on January 30th. This was apparently due to shortage of staff. On the other hand it should be mentioned that he had an assistant on duty with him and that he had had 56 hours off duty before starting this watch. Whatever the cause may be, his attitude during the 95 minutes following lack of contact was not consistent with the spirit in which an Air Guard should approach his duties.

(*h*) THE ICING LIMITATION ON THE AIRCRAFT.

180. The Certificate of Airworthiness granted to "Star Tiger" contained a reservation on flying in icing conditions, pending the checking of her de-icing installation. This did not amount to a legal prohibition but was in the nature of a "warning note" to the pilot. On the Azores-Bermuda route, icing is rarely encountered, but if the aircraft were forced to divert to an alternate airport in the Newfoundland area, it would have to fly in a region where icing conditions are frequently encountered in the winter. Such diversions have been by no means uncommon. The de-icing equipment should therefore as a matter of prudent operation have been fully checked, and the reservation cleared from the Certificate of Airworthiness, before the aircraft was operated for the transport of passengers on this route.

181. The view of the matter taken by the British South American Airways Corporation was apparently that the test could await the arrival of suitable icing conditions over England. This cannot be accepted. Icing conditions suitable for the test could have been found, at any time, in the Iceland, Greenland and North American areas, and these areas were easily within reach.

(*i*) THE EXAMINATION OF INCIDENTS.

182. An important contribution to safety in the air is provided if arrangements are made for a careful examination of any incidents or minor accidents which may occur, in order to eliminate their causes and to warn the crew of aircraft of the circumstances in which they arise. On the evidence produced at the Inquiry, the Court has formed the opinion that no such organisation existed in the British South American Airways Corporation, or, if it did exist, it was ineffectve.

(*j*) THE MAINTENANCE OF THE AIRCRAFT.

183. The record of maintenance of "Star Tiger" cannot be regarded as satisfactory for the reasons already mentioned in paragraphs 52 and 53.

PART VIII

RECOMMENDATIONS

184. The criticisms and comments made on various points throughout this Report have indicated the matters to which attention should be given for further ensuring safety, but it may be useful to summarise the more important of them.

(1) The programme for the training of crews should be more comprehensive, and in particular pilots ought to have adequate experience of airports to which passenger-carrying flights are planned.

(2) The instructions to pilots should contain specific directions as to the actions to be taken in the event of having to land on the sea.

(3) The question of the adequacy of fuel reserves should receive special attention on this route.

(4) Provision should be made for adequate resting facilities for the crew on so exacting a route, and in particular there should be either a 12 hour stop at the Azores or two radio officers should be carried who could relieve each other.

(5) Greater care should be taken in the preparation of Flight Plans.

(6) Strict compliance with the provisions of maintenance schedules is desirable.

(7) The organisation at Bermuda should be overhauled so as to ensure that there is constant attendance of officials at all appropriate hours, that the regulations as to maintaining contact with aircraft are observed, and that all signals are promptly dealt with.

PART IX

CONCLUSION

185. In closing this Report it may truly be said that no more baffling problem has ever been presented for investigation. In the complete absence of any reliable evidence as to either the nature or the cause of the disaster to "Star Tiger" the Court has not been able to do more than suggest possibilities, none of which reaches the level even of probability. Into all activities which involve the co-operation of man and machine two elements enter of very diverse character. There is the incalculable element of the human equation dependent upon imperfectly known factors; and there is the mechanical element subject to quite different laws. A breakdown may occur in either separately or in both in conjunction. Or some external cause may overwhelm both man and machine. What happened in this case will never be known and the fate of "Star Tiger" must remain an unsolved mystery.

MACMILLAN.
A. A. HALL.
J. W. G. JAMES.

E. S. FAY. *Registrar.*

APPENDIX I

APPEARANCES

The ATTORNEY-GENERAL (The Rt. Hon. Sir Hartley Shawcross, K.C.) and Mr. RODGER WINN (instructed by the Treasury Solicitor) on behalf of the Crown.

Mr. LESLIE G. SCARMAN (instructed by Messrs. Stanley & Co.) on behalf of the Air Registration Board.

Mr. ALAN GOODFELLOW and Mr. ALASTAIR R. PATERSON (of Messrs. Beaumont & Son) on behalf of British South American Airways Corporation.

Dr. H. B. VAUGHAN-EVANS (Resident Legal Adviser) on behalf of A. V. Roe & Co., Ltd.

Mr. KENNETH JOHNSTONE (instructed by Messrs. Claremont, Haynes & Co.) on behalf of Rolls-Royce Ltd.

Mr. G. W. TOOKEY (instructed by Messrs. Mills, Curry & Gaskell) on behalf of the Sperry Gyroscope Co. Ltd.

Mr. JOHN F. DONALDSON (instructed by Messrs. Parker, Garrett & Co.) on behalf of Lady Coningham.

Mr. CHRISTOPHER SHAWCROSS (instructed by Messrs. Lovell, White & King and Messrs. Neve, Beck & Co.) on behalf of relatives of deceased passengers.

Mr. PETER BUCKNILL (instructed by Messrs. Ingledew, Brown, Bennison & Garrett) on behalf of the Navigators' & Engineer Officers' Union.

Mr. ERIC MYERS (instructed by Messrs. Bircham & Co.) on behalf of Cable & Wireless, Ltd.

The Hon. QUINTIN M. HOGG (instructed by Messrs. Wildman & Co.) on behalf of Mr. Stanislaw Orosz.

Major J. L. B. H. CORDES on behalf of the Guild of Air Pilots.

Mr. E. J. G. BLACKBURN (Executive Committee) on behalf of the Radio Officers' Union.

Mr. BEN SMITH (National Organiser) and Mr. SOLOMONS on behalf of the Association of Scientific Workers.

Mr. LAURENCE C. VASS represented the United States Government and the U.S. Civil Aeronautics Board.

Professor H. AMORIM FERREIRA represented the Portuguese Government.

APPENDIX II

LIST OF NAMES AND QUALIFICATIONS OF WITNESSES

R. Connor, Project Engineer, A. V. Roe & Co., Ltd.

S. D. Davies, Chief Designer, A. V. Roe & Co., Ltd.

Squadron Leader A. K. Cook, Test Pilot, A. V. Roe & Co., Ltd.

W. Tye, Chief Technical Officer, Air Registration Board.

A. E. G. Elliott, C.B.E., Director and Chief Engineer, Rolls-Royce, Ltd.

G. W. Stallybrass, of the Ministry of Civil Aviation.

Air Vice Marshall D. C. T. Bennett, former Chief Executive of British South American Airways Corporation.

R. F. Swingler, of De Havilland Propellors Ltd.

C. A. Richardson, Aeronautical Manager (United Kingdom) Sperry Gyroscope Co., Ltd.

Group Captain C. F. Sarsby, Chief Engineer, British South American Airways Corporation.

W. Edwards, Station Engineer at Lisbon, British South American Airways Corporation.

L. E. Bishop, Ground Engineer (Air frames), at Santa Maria, British South American Airways Corporation.

J. Lee, Ground Engineer (Engines) at Santa Maria, British South American Airways Corporation.

Mont Follick, Member of Parliament (passenger).

Colonel K. W. Hogg (passenger).

J. N. Blows, Traffic Assistant at Santa Maria, British South American Airways Corporation.

L. A. Mountford, Petroleum Engineer, Shell Petroleum Co. Ltd., at Santa Maria.

Captain R. F. Griffin, British South American Airways Corporation (Commander of Lancastrian G-AGWL).

C. J. Boyden, Meteorological Officer at Santa Maria.

Captain W. J. Rees, of British South American Airways Corporation.

J. Durward, M.A., Deputy Director of Meteorological Office Services, Air Ministry.

A. P. J. Flynn, of the Ministry of Civil Aviation.

Captain G. H. Womersley, of British South American Airways Corporation.

J. A. MacGillivray, Radio Superintendent, British South American Airways Corporation.

F. W. Bunker, of British South American Airways Corporation (Radio Officer of Lancastrian G-AGWL).

J. R. J. B. Richards, of Cable & Wireless (West Indies) Ltd. (Air Guard Operator, Bermuda).

A. H. Brooks, Assistant Signals Officer, Ministry of Civil Aviation.

Wing Commander R. J. Ralph, Station Manager at Bermuda, British South American Airways Corporation.

Captain E. T. Kippenberger, of British South American Airways Corporation.

Major J. Stocks, Inspector of Accidents, Ministry of Civil Aviation.

J. C. K. Ship, Senior Civil Aircraft Technical Officer, Aircraft and Armament Experimental Establishment.

R. W. Amey, Chief Inspector, Aeronautical Inspection Directorate, Ministry of Supply.

E. Lloyd, Design Surveyor, Air Registration Board.

Group Captain A. H. Purvis, Chief Civil Test Pilot, Aircraft and Armament Experimental Establishment.

J. H. Orrell, Chief Test Pilot, A. V. Roe & Co. Ltd.

Captain A. G. Store, Operations Manager, British South American Airways Corporation.

Captain W. L. Holt.

F. C. Palmer, of British Overseas Airways Corporation.

APPENDIX III

Passenger List

			From	*Destination*
1.	Air Marshal Sir Arthur Coningham...	British	London	Bermuda
2.	Fisher, E., Mr.	,,	London	Bermuda
3.	Bardwell, A. T., Mr.	,,	London	Bermuda
4.	Bardwell, J. A., Mrs.	,,	London	Bermuda
5.	Mulligan, A. J., Mr.	,,	London	Bermuda
6.	Mulligan, T. R. J., Mr.	,,	London	Bermuda
7.	Mulligan, M. J., Mrs.	,,	London	Bermuda
8.	Sutherland, J. M., Mr.	,,	London	Kingston
9.	Knuckel, R., Mr.	Swiss	London	Kingston
10.	Packshaw, Mrs.	British	London	Kingston
11.	Nabel, E., Mr.	Stateless	London	Kingston
12.	Nabel, S., Mrs.	,,	London	Kingston
13.	Nabel, M., Master	,,	London	Kingston
14.	Nabel, E., Miss	,,	London	Kingston
15.	Hawley, S. M., Mr.	British	London	Kingston
16.	Riddock, G. K., Mr.	,,	London	Kingston
17.	Brooks, Mr.	,,	London	Kingston
18.	Staley, R. C., Mr.	,,	London	Kingston
19.	Davis, Mr.	,,	London	Kingston
20.	Strong, G., Mrs.	,,	London	Havana
21.	Cabrett, H. G.	,,	London	Havana
22.	Klein, E., Mr.	Czech	London	Havana
23.	Klein, I., Mrs.	,,	London	Havana
1.	Jauregui, J. E., Mr.	Mexico	Lisbon	Havana
2.	Figueroa, M. P., Mr.	,,	Lisbon	Havana

(62741) W.t. 1151—V32 9/48 D.L.

APPENDIX V.

FLIGHT PLAN.

BRITISH SOUTH AMERICAN AIRWAYS
F. 205B.

Statistical Dist. A. to B: 1,960 NMLS.

SERVICE No. MW. 14. AIRCRAFT G-AHNP. Date: 29/1/48.

FROM "A" SANTA MARIA to "B" BERMUDA.

Commander MACMILLAN (*Capt.*)
First Officer COLBY (*Capt.*)
Second Officer ELLISON
Radio Officer TUCK
Stargirl Miss NICHOLLS
Miss CLAYTON

E.T.D.—15·30 Flt. Time 12 H. 26 M. E.T.A.—03·56
1st Diversion STEVENVILLE Fuel Carried 3250
2nd Diversion LAGENS Fuel Required 2660

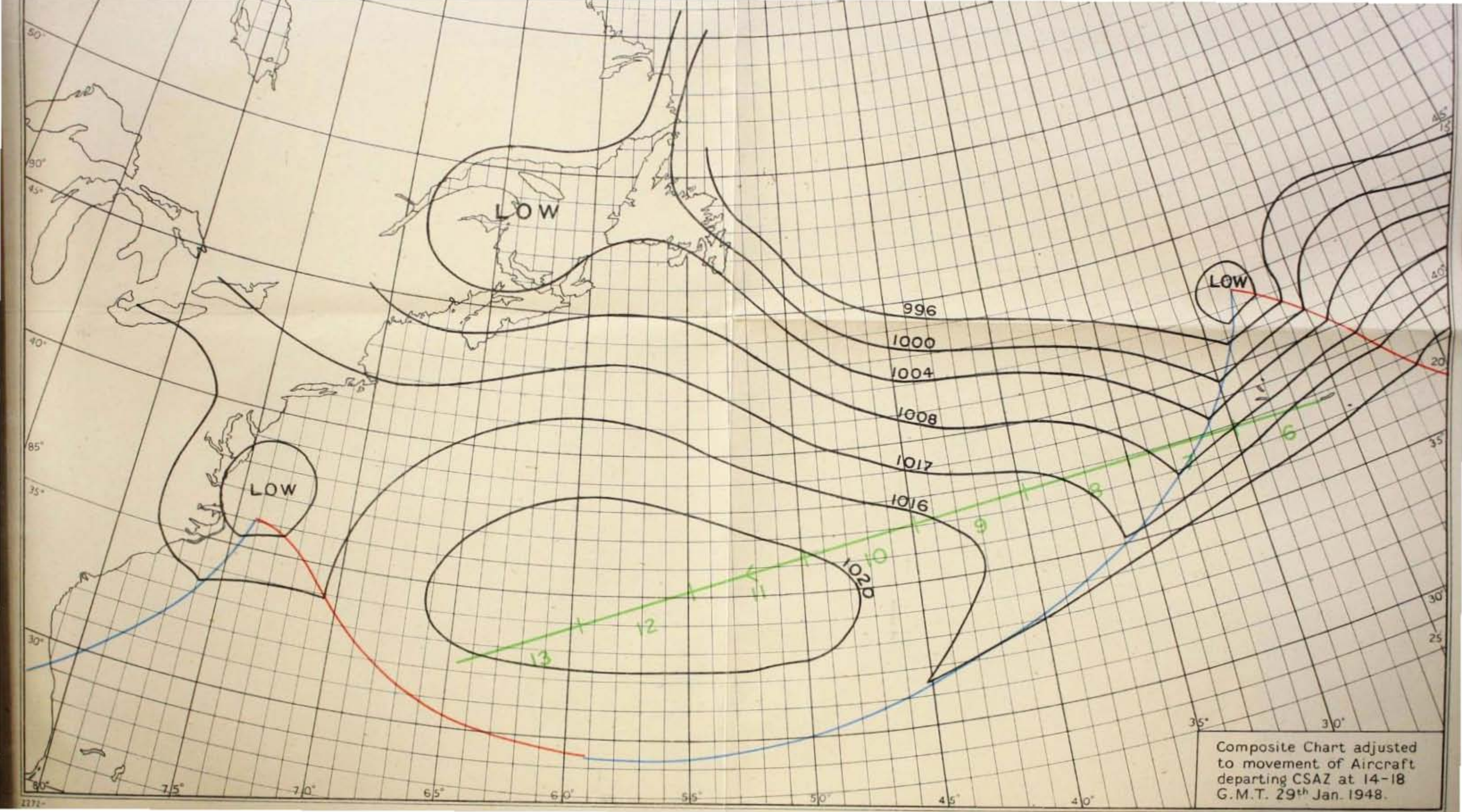
—	Route From	Route To	Track Reqd.	W/V	Co. True	Varn.	Co. Mag.	Devn.	Co. Comp.	RAS	Hgt.	Air Temp.	TAS	G/S	Dist. to go	Time	E.T.A.
Endurance 16 hrs. 00 mins.	SANTA MARIA	30W.	272	250/50	266 (T)	19W.				175	2000	+9	180	133	232	1:44½	1·44
Still Air Range 2860 N. Miles	30W.	35W.	269	270/40	269 (T)	22W.				175	2000	+8	179	139	240	1:43½	3·28
Critical Point 8·15 dist.	35W.	40W.	267	290/30	271 (T)	23W.				175	2000	+6	178	149	241	1:37	5·05
= 5 hrs. 32 mins.	40W.	45W.	263	300/28	268 (T)	23W.				175	2000	+6	178	154	243	1:34½	6·39
Radius of Action 1975 dist.	45W.	50W.	260	300/25	265 (T)	23W.				175	2000	+6	178	158	247	1:34	8·13
= 9 hrs. 22 mins.	50W.	55W.	257	300/15	260 (T)	22W.				175	2000	+7	179	168	251	1:29½	9·43
	55W.	60W.	255	L & V.	255 (T)	20W.				175	2000	+7	179	179	254	1:25	11·08
	60W.	BERMUDA	252	100/15	250 (T)	19W.				175	2000	+9	180	194	252	1:18	12·26
															1960		

NOTE.—
1. C.P. is the Point from which it takes equal time to proceed to Destination or Return using Three-engine Airspeed.
2. R. of A. is the last Point from which you can Return.

CHECKED—B. W. McMILLAN, *Commander.*

TOTAL TIME 12:26

NOTES FOR STATION OF DEPARTURE ALL TIMES G.M.T.



Composite Chart adjusted to movement of Aircraft departing CSAZ at 14-18 G.M.T. 29th Jan. 1948.

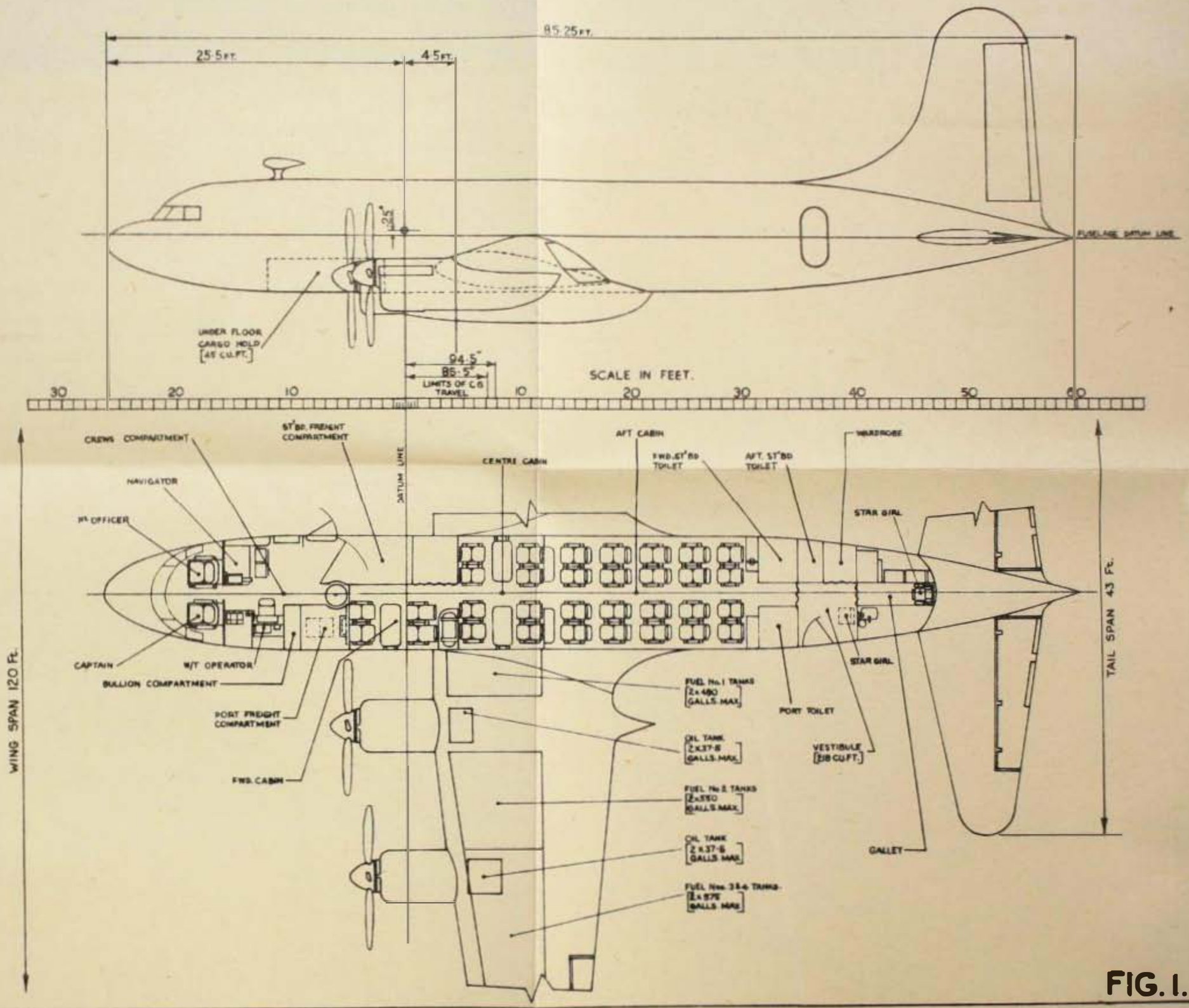

85.25 FT.
25.5 FT.
4.5 FT.
FUSELAGE DATUM LINE
UNDER FLOOR CARGO HOLD [45 CU.FT.]
94.5"
85.5"
LIMITS OF C.G. TRAVEL
SCALE IN FEET.
30 20 10 10 20 30 40 50 60
CREWS COMPARTMENT
ST'BD. FREIGHT COMPARTMENT
DATUM LINE
CENTRE CABIN
AFT CABIN
FWD. ST'BD TOILET
AFT. ST'BD TOILET
WARDROBE
NAVIGATOR
1st OFFICER
STAR GIRL
CAPTAIN
W/T OPERATOR
BULLION COMPARTMENT
PORT FREIGHT COMPARTMENT
FWD. CABIN
FUEL No. 1 TANKS [2 x 480 GALLS. MAX.]
OIL TANK [2 x 37·5 GALLS. MAX.]
FUEL No. 2 TANKS [2 x 550 GALLS. MAX.]
OIL TANK [2 x 37·5 GALLS. MAX.]
FUEL Nos. 3 & 4 TANKS [2 x 575 GALLS. MAX.]
PORT TOILET
STAR GIRL
VESTIBULE [218 CU.FT.]
GALLEY
WING SPAN 120 Ft.
TAIL SPAN 43 Ft.

FIG. I.

STATION DESIGNATOR OR NAME	BERMUDA		STEPHENVILLE		SANTA MARIA	SANTA MARIA	
PERIOD OF VALIDITY (G.M.T.)	0001 to 1200	to	0001 to 1200	to	2000 to 0800	1500 to 2000	to
SURFACE WIND DIRECTION AND SPEED IN KNOTS	070 degrees 10 knots		310 degrees 15 knots		280 degrees 25-35 ks	210 degrees 30-40 kts.	
GUSTINESS							
WEATHER	Cloudy		Occasional snow showers.		A period of heavy showers at first followed by occasional showers.	Cloudy, occasional slight rain.	
SURFACE VISIBILITY	10 miles.		10 miles occasionally 2 miles and very occasionally ½ mile.		6 miles but 1 mile in showers.	6 miles occasionally 2 miles.	
HEIGHTS ARE ABOVE AERODROME LEVEL AMOUNTS IN TENTHS — LOW CLOUD — LOWEST LAYER — AMOUNT, TYPE	7/10		9/10 Sc.		8/10	3/10 becoming (8/10 in rain	
HEIGHT OF BASE	3,000 feet		2,000 feet occasionally 1500 feet and very occasionally 500 feet		500 feet in showers	600 feet " (500 feet	
HEIGHT OF TOPS	5,000 feet		5,000 feet				
SECOND LAYER — AMOUNT, TYPE					6/10 Cu. becoming 8/10	8/10	
HEIGHT OF BASE					2,000 feet " 1200 feet in showers	1,000 feet	
HEIGHT OF TOPS					8,000 feet	5,000 feet.	
MEDIUM CLOUD — AMOUNT, TYPE	Ci.						
HEIGHT OF BASE							
REMARKS					Frontal passage 2000- similar with frontal passage about 1700 G.M.T.	2100 hrs. Lagens	

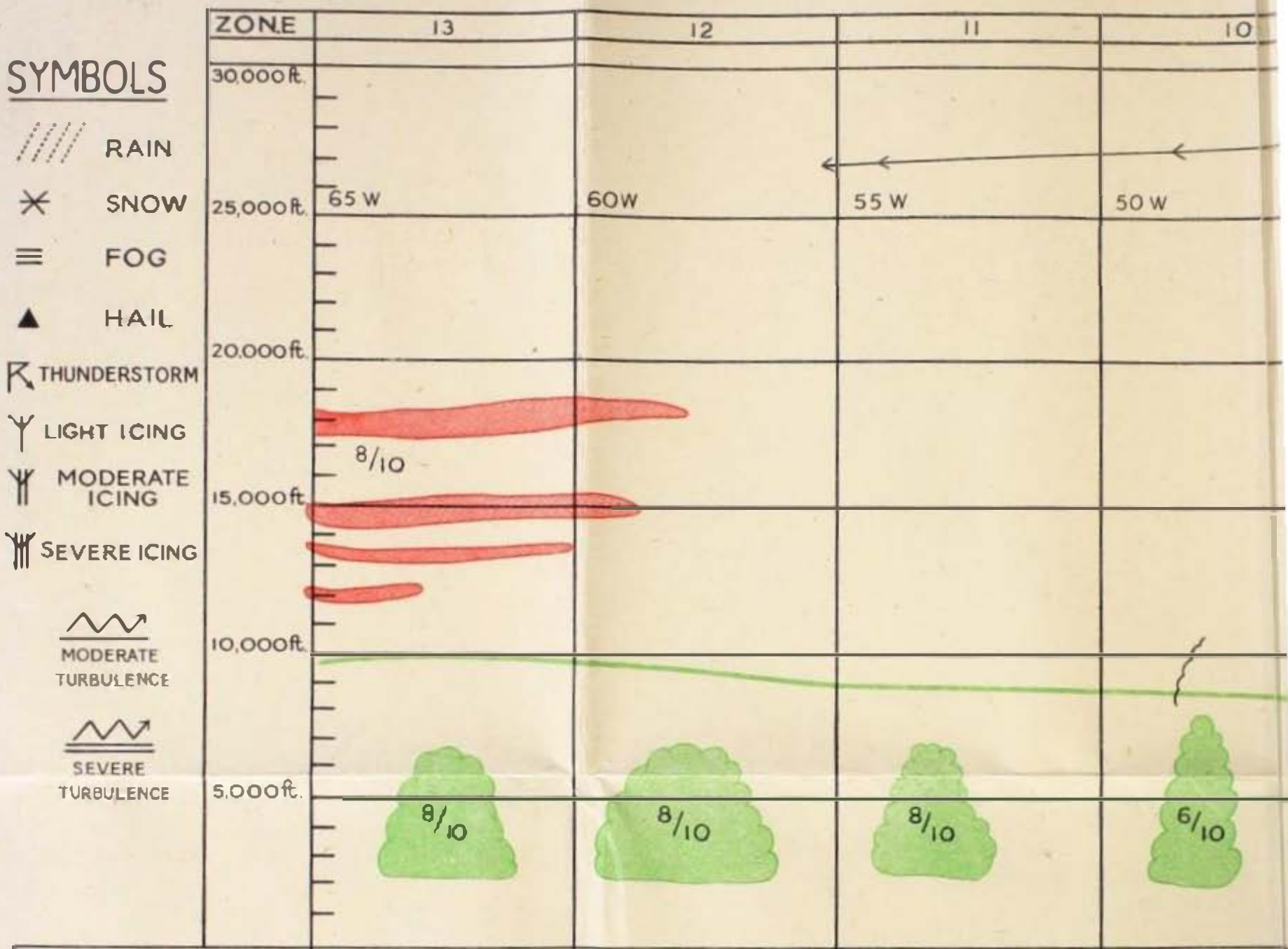
METEOROLOGICAL OFFICE Santa Maria ISSUED AT 1400 G.M.T. 29 January 1948 J. Hodkinson FORECASTER

FORM 2405

AIR MINISTRY, METEORCL

FLIGHT FORECAST

ROUTE Santa Maria – Berm



	13	12	11	10
SIGNIFICANT WEATHER				
REMARKS				
BASE OF LOW CLOUD	2000 FT	2,000 FT	2,000 FT	2,000 FT
SURFACE VISIBILITY	10 MLS	10 MLS	10 MLS	10 MLS
M.S.L. PRESSURE	1021	1022	1021	1018

WINDS AND TEMPERATURES

..... Feet											
2,000 Feet	100	15	+9	NIL		+7	300	15	+7	300	25
..... Feet											
..... Feet											
..... Feet											

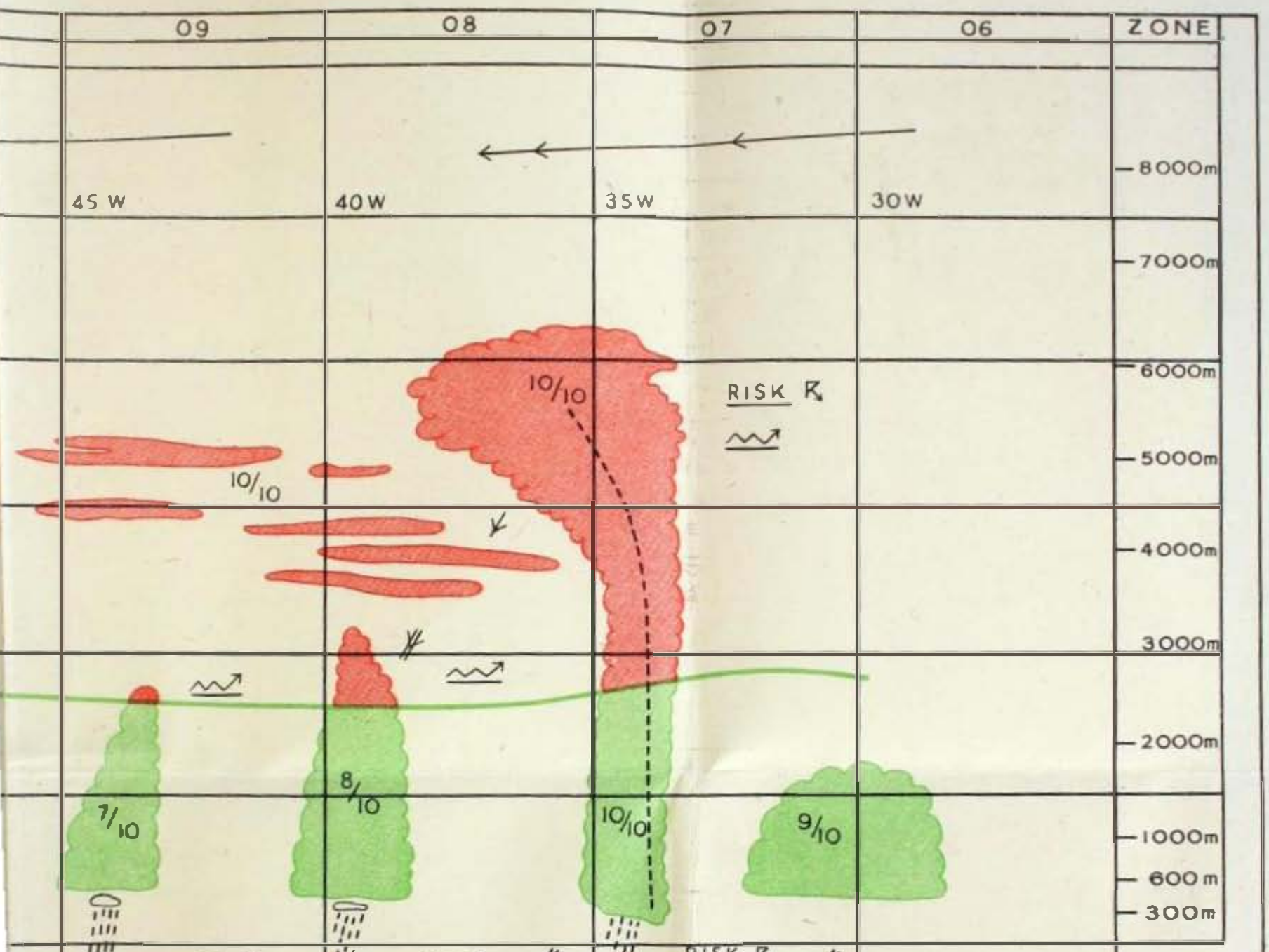
METEOROLOGICAL OFFICE
SANTA MARIA

ISSUED AT 1400 GM
29TH JANUARY 194

2272 (HS) 932 2750 6/48 (Ty.P).

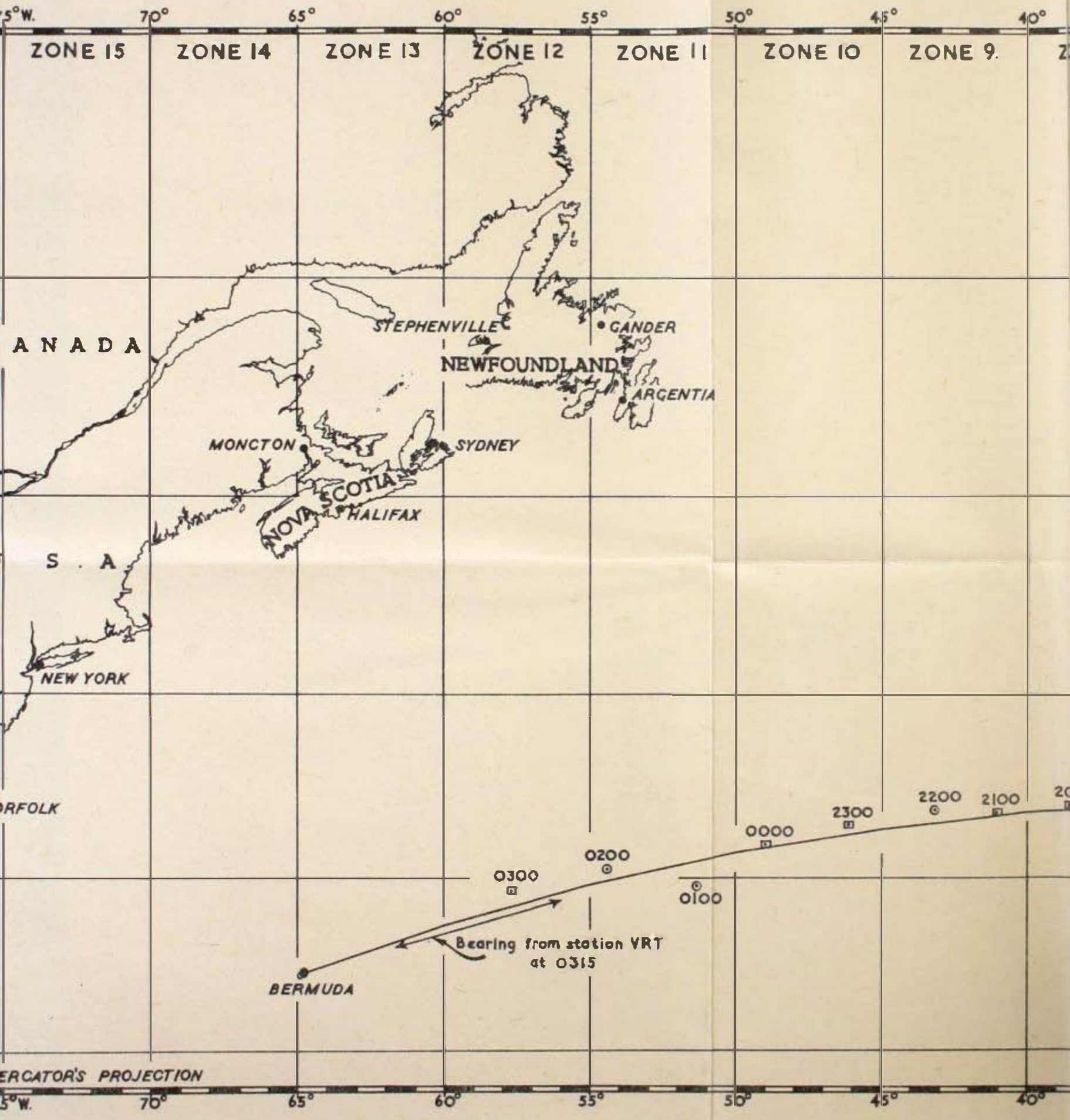
OGICAL OFFICE

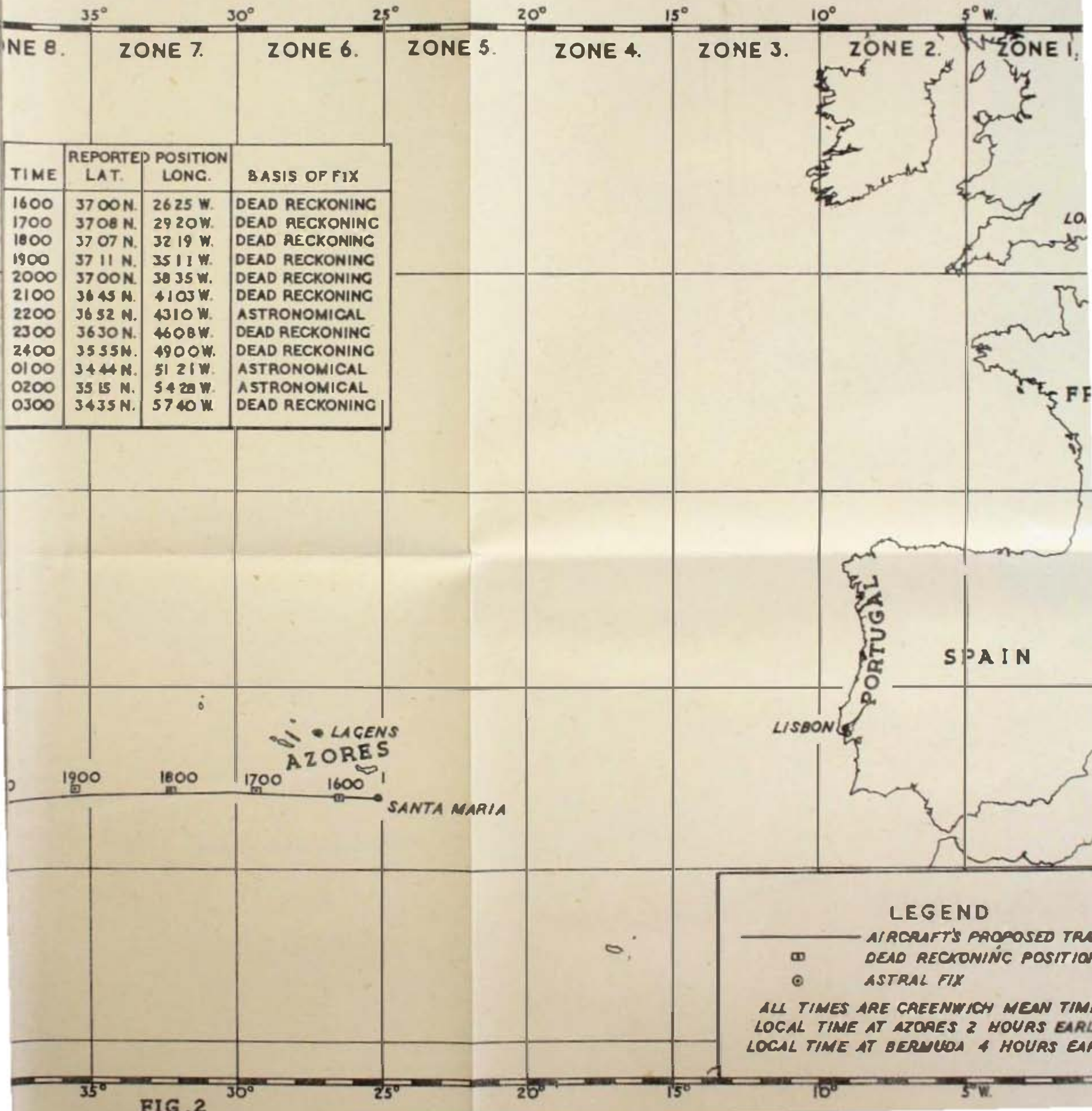
TRACK G/C ETD 1500-1800 GMT 29th January 1948



	09	08	07	06	ZONE
	OCCASIONAL SHOWERS	HEAVY	ACTIVE COLD FRONT WITH SHARP WIND VEER		
	2,000 FT PATCHES 1,000 FT IN SHOWERS	2,000 FT PATCHES 800 FT IN SHOWERS	600 FT	1,000 FT	Heights are above M.S.L.
	10 MLS.	10 MLS PATCHES 2 MLS IN SHOWERS	2 MLS	8 MLS	
	1014	1011	1006	1010	
°C					
					....metres
+6	300 28	+6 290 30	+6 270 40	+8 250 50	+9 ....metres
					....metres
					....metres
					....metres

Sgd. J. HODKINSON FORECASTER


5°W.
70°
65°
60°
55°
50°
45°
40°
ZONE 15
ZONE 14
ZONE 13
ZONE 12
ZONE 11
ZONE 10
ZONE 9.
ANADA
STEPHENVILLE
GANDER
NEWFOUNDLAND
ARGENTIA
MONCTON
SYDNEY
NOVA SCOTIA
HALIFAX
S . A
NEW YORK
RFOLK
2200
2100
2300
0000
0200
0300
0100
Bearing from station VRT
at 0315
BERMUDA
ERCATOR'S PROJECTION



TIME	REPORTED POSITION LAT.	LONG.	BASIS OF FIX
1600	37 00 N.	26 25 W.	DEAD RECKONING
1700	37 08 N.	29 20 W.	DEAD RECKONING
1800	37 07 N.	32 19 W.	DEAD RECKONING
1900	37 11 N.	35 11 W.	DEAD RECKONING
2000	37 00 N.	38 35 W.	DEAD RECKONING
2100	36 45 N.	41 03 W.	DEAD RECKONING
2200	36 52 N.	43 10 W.	ASTRONOMICAL
2300	36 30 N.	46 08 W.	DEAD RECKONING
2400	35 55 N.	49 00 W.	DEAD RECKONING
0100	34 44 N.	51 21 W.	ASTRONOMICAL
0200	35 15 N.	54 28 W.	ASTRONOMICAL
0300	34 35 N.	57 40 W.	DEAD RECKONING

FIG. 2

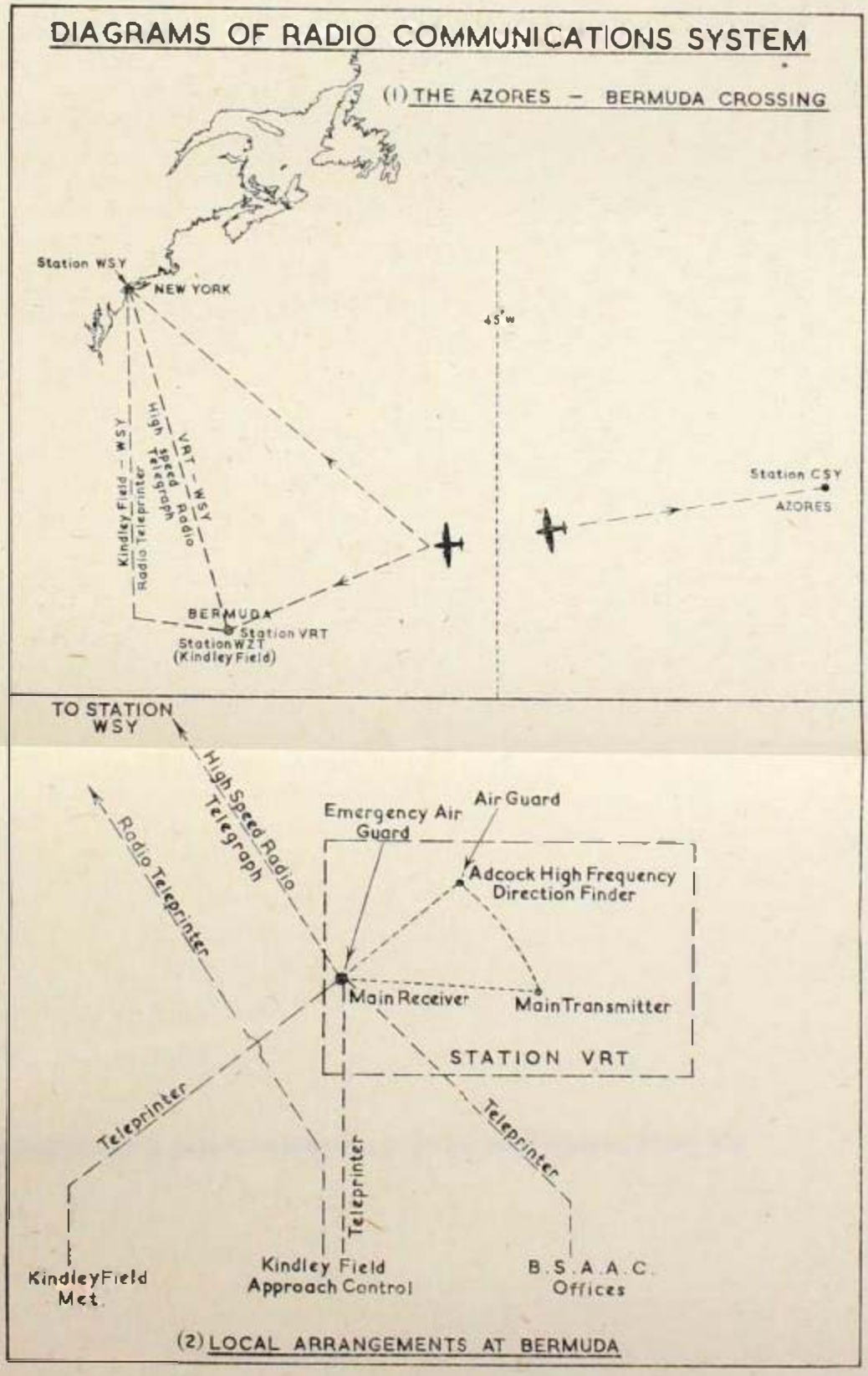

DIAGRAMS OF RADIO COMMUNICATIONS SYSTEM
(1) THE AZORES – BERMUDA CROSSING
Station WSY
NEW YORK
45°W
Kindley Field – WSY
Radio Teleprinter
High speed Telegraph
VRT – WSY
Radio
Station CSY
AZORES
BERMUDA
Station VRT
Station WZT
(Kindley Field)
TO STATION WSY
High Speed Radio Telegraph
Radio Teleprinter
Emergency Air Guard
Air Guard
Adcock High Frequency Direction Finder
Main Receiver
Main Transmitter
STATION VRT
Teleprinter
Teleprinter
Teleprinter
Kindley Field Met.
Kindley Field Approach Control
B.S.A.A.C. Offices
(2) LOCAL ARRANGEMENTS AT BERMUDA

FIG. 3.

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