SUMMARY OF DISCUSSIONS

OF THE

FIFTH MEETING OF THE NAT SYSTEMS PLANNING GROUP

(Montreal, 4-18 December 1968)

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INTRODUCTION

1. The Fifth Meeting of the NAT Systems Planning Group was held at ICAO Headquarters in Montreal from 4 to 18 December 1968.

2. On 4 December in the morning, and on 18 December in the morning, the Group met in closed session in order to discuss general matters and Agenda Items 6 and 8. All other sessions were open and all participants listed on page iv could fully participate in the proceedings. Iceland and Portugal, which had been invited to the Meeting, did not send representatives.

3. Mr. J.F. Sapin, the member designated by France, acted as Chairman of the Meeting. The detailed consideration of Agenda Items was entrusted to two sub-groups (Items 1 and 5 were handled by one and Items 2, 3 and 4 by the other) and these were chaired by Mr. E.B. Powell from Canada and Mr. A. White from the United Kingdom respectively.

4. Mr. P.G. Berger from the Paris Office of ICAO and Mr. A. Hissink from ICAO Headquarters served as Secretaries of the Meeting.

AGENDA

Item 1 : Determination of preparatory ATS measures required for the start of SST operations in the NAT Region.

Item 2 : Review of developments regarding the application of reduced vertical separation to aircraft operating above FL 290 in the NAT Region.

Item 3 : Review of the possibility to apply "composite separation" (i.e. a form of separation composed of the simultaneous application of reduced lateral and vertical separation) to aircraft operating in the NAT Region.

Item 4 : Review of progress made in the assessment of longitudinal separation in certain parts of the Region, including the possible use of DME for the maintenance of such separation.

Item 5 : Review of the criteria for the assessment of system performance.

***Item 6** : Review of work programme of the Group, including arrangements for the next meeting.

Item 7 : Any other business :

i) Proposed reply to the comments of the Federal Republic of Germany and Sweden on Summary/4;

ii) Action on the letter from Captain Masland, of 19 September 1968.

***Item 8** : Election of the next Chairman.

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* Reserved for consideration by members of the Group only.

LIST OF PARTICIPANTS

Note: Names marked with an asterisk are those of Members of the Group.

State or Organization	Name
CANADA	K. Davis
	*A.L. Elliott
	E.B. Powell
	C.R. Rowsell
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	W.M. Masland

GENERAL MATTERS

1. Request from EUROCONTROL for participation in the Meeting

1.1 Shortly prior to the Meeting, Mr. Sapin, the Chairman of the Group had received a letter from EUROCONTROL indicating their interest, particularly in Agenda Item 1 of this Meeting, and suggesting that they be invited to participate in the Meeting. Consultations with all Members of the Group, conducted by the Chairman prior to the Meeting, had revealed that it was not possible to reach unanimous agreement on the need for EUROCONTROL to be present at the Meeting and the Chairman had informed EUROCONTROL accordingly.

1.2 As this was already the second time that such a request had been received, the Group found that it would be necessary to establish a general rule for handling such requests. It therefore agreed that any such request should be circulated by the Chairman to all Members of the Group by the speediest means consistent with the urgency of the demand and that it should be considered acceptable if 5 of the 6 Members of the Group were in agreement with it.

2. Amendment of the air-reporting procedures applied in the NAT Region

2.1 The Group was informed that, in accordance with the agreement reached at its 4th Meeting, the United Kingdom had forwarded a proposal for amendment of the Regional Supplementary Procedures concerning air-reporting in the NAT Region which corresponded to the changes developed during the 3rd Meeting of the Group.

2.2 This proposal had been circulated to all NAT States for consideration and the target-date for replies had been fixed as 20 December 1968. So far, indications were that the proposal was acceptable.

2.3 It was also noted that the Paris Office of ICAO had taken necessary measures to obtain from States concerned data on the cover of VHF air-ground communication stations used in the NAT Region and had already started with the preparation of the consolidated chart referred to in paragraph 3.4.1 iii) on page 3.3 of Summary /4. (A sample draft showing the data so far received was presented to Members of the Group for information.)

3. Review of the situation regarding Loran A chains "Charlie" and "Delta"

3.1 The Group noted that a proposal for amendment of the NAT Regional Plan intending to include Loran A chains "Charlie" and "Delta" as required radio navigation aids into that Plan, had been circulated to all NAT States and interested user organizations for comment. It was also noted that only two States (Denmark and Sweden) had made substantial comments on this proposal, one (Denmark) indicating that its maritime mobile services appeared to suffer from interference caused by these chains, while the other (Sweden), for reasons related to the application of pertinent ITU regulations, wished to see this matter postponed until it could be discussed at the next NAT RAN Meeting.

3.2 The United States' Member informed the Group that there had been contacts between the USA and the Danish administrations. In addition, in the course of a routine calibration flight it was possible to establish the level of interference and possible remedial measures. Initial results of this flight seemed to indicate that the interference caused to Danish maritime mobile services was not caused by the two chains in question but emanated from another source. It was possible to suggest a number of measures to the Danish administration which would assist at least in reducing the general interference.

3.3 In the light of these explanations, the Group hoped that it would be possible for ICAO to complete action on this matter fairly early.

4. Film on super-sonic and sub-sonic air traffic expected in 1975 in the NAT Region

4.1 Based on traffic forecasts, the United Kingdom had produced a film which recorded the expected traffic movements of supersonic and sub-sonic air traffic in the NAT Region in 1975 during a 24-hour period. The tracks had been produced by a computer onto a cathode ray display and, by application of the time-lapse method, had been reduced to a film of 6 minutes duration.

4.2 From this film it was particularly apparent that major problems would exist in the transition area on the European side of the NAT Region, and especially in the area south-west of the United Kingdom and south of Ireland, and that these problems not only concerned sub-sonic air traffic but, even more so, super-sonic air traffic which, at this stage of their flight, were expected to be in their initial transsonic acceleration.

5. Joint session between the NAT/SPG and the NAT Traffic Forecasting Group

5.1 Taking advantage of the fact that the NAT Forecasting Group had had a meeting in Montreal just prior to the meeting of the NAT/SPG, the Group invited the members of the Forecasting Group to participate in a joint session at which it would be possible to explain the forecasting methods used and to have an exchange of views on subjects of mutual interest. This session took place on 5 December 1968 in the morning.

5.2 At the beginning of the joint session the members of the NAT Forecasting Group (which consists of representatives nominated by Canada, the United Kingdom and the United States of America) gave a brief explanation of their working method and the area covered in their 10-year traffic forecast which is up-dated at yearly intervals. (For further reference see the Report on Agenda Item 2 a) in ICAO Doc 8499, SP/NAT (1965), Report on the Special North Atlantic Meeting (1965).)

Area covered

5.3 The 10-year traffic forecast covers essentially the "principal area" of the NAT Region, i.e. that area where the large majority of traffic between European and North American terminals operates. In addition it was recently agreed that the forecast should also cover polar routes and those south of the principal area.

Periods used

5.4 As was already agreed at the NAT Special Meeting 1965, the forecast should show the expected traffic during the busy period, the busy day and the busy hour, these three periods being defined as follows :

i) busy period to represent that 2-month period of a year where the largest number of movements is expected;

ii) busy day to represent the average daily traffic expected during the busy period. (To obtain this figure the total of the expected movements during the busy period are divided by the number of days of that period.);

iii) busy hour to represent the average hourly traffic of the largest hourly flows during the busy period. (This figure is taken as the largest of the hourly flows in the busy period when averaged for each day of the week separately.)

5.5 The NAT Forecasting Group indicated however that it might be advantageous (and more meaningful) if the method used to obtain the busy period forecasts was revised and improved. Some possible alternatives were outlined, such as moving averages or totals, 75% values, and so-called "standard" busy values, e.g. the 30th busiest hour in the year. The Forecasting Group proposed to include an additional appendix in their current forecast up-dating report, describing the alternatives and inviting comments. In the light of these comments and further work during the year, the advisability of changing the form of the busy period forecasts as from the next up-dating early in 1970 would be considered.

Methods used in forecasting annual traffic

5.6 In the second session the Forecasting Group described their current method of forecasting annual passenger, cargo and other traffic by class of aircraft. For passenger traffic, for instance, this is based on multiple regression techniques, relating passenger levels to measures of economic activity, fares, etc. A surprisingly good fit has been obtained using a measure of U.S. disposable income and one based on fares yields. The forecast numbers of passengers are then translated into numbers of flights, taking into account the characteristics of the aircraft likely to be available to meet the demand and the load factors at which they are likely to operate.

5.7 The Forecasting Group also stated that it did not expect that future reductions in fares would have quite as much effect on the rate of growth of traffic as that observed over recent years. It also pointed out that, with the larger aircraft expected in the years to come, delays in delivery of aircraft to operators might have an effect on the traffic growth.

5.8 In the ensuing discussion the Forecasting Group stated that while possible measures to schedule departures at major terminals in order to avoid traffic congestion during peak hours may have an influence on their forecast, airline strikes, temporary closure of runways or aerodromes and other short-term events were of a too temporary and unpredictable nature in order to be reflected in their long-term forecast.

Summary

5.9 The NAT/SPG supported the proposal of the Forecasting Group regarding the inclusion of an additional appendix in their current forecasts report, outlining possible revised and improved measures for presenting busy period forecasts. It also expressed its general appreciation of the work done by the Forecasting Group and noted that the next up-dated forecast covering the period 1969 to 1978 would be available in early 1969.

5.10 Conclusion

5.10.1 In conclusion the NAT/SPG felt that, as a result of the joint session, the following action should be taken :

i) After receipt of the next up-dated forecast, as prepared by the NAT Forecasting Group, members of the NAT/SPG should review this report and communicate their comments to all other members not later than by 1 June 1969.

ii) In view of the still unsatisfactory situation regarding the distribution of the forecasts prepared by the NAT Forecasting Group, the Group invited its Chairman to address a letter to ICAO requesting it to take appropriate measures to ensure that these forecasts were made available to all NAT States and interested user organizations with the least possible delay after their publication.

5.10.2 With respect to ii) above the Group noted that this matter had been repeatedly raised in its meetings and it therefore hoped that it would now be possible to make satisfactory arrangements. (See Summary /1, paragraph 2.3.5, Summary /2, paragraph 7.16 and Summary /3, paragraph 5.2.5.)

1. Summary of Agenda Item 1: Determination of preparatory ATS measures required for the start of SST operations in the NAT Region

1.1 Introduction

1.1.1 At its 4th Meeting, the NAT/SPG had stated that it believed it to be necessary to give early attention to the ATS measures required for the start of SST operations in the NAT Region if a smooth and efficient integration of this type of traffic into the overall flow of NAT air traffic was to be ensured. To this extent, the Group, at its 4th Meeting, had agreed on a number of subjects under which work should be grouped. It had also stated that adequate documentation would be required prior to the next meeting where this matter was to be discussed so that useful discussions could take place. (The Summary of Agenda Item 5 in Summary/4 of the Group refers).

1.1.2 The Group was therefore particularly grateful to the United Kingdom member who, prior to the meeting, had made available a large amount of supporting documentation concerning the various aspects of the subject and this was used extensively in the preparation of this Summary.

1.2 General remarks

1.2.1 Before continuing into a detailed discussion of various specific aspects of SST operations in the NAT Region, the Group believed it necessary to stress the preliminary nature of its work, which was inevitable in the absence of actual operating experience with the type of aircraft involved. It wished however, also to underline the need for early agreement on a number of basic principles and trends along which further studies should proceed in order to avoid unnecessary dispersal of time and effort.

1.2.2 It should therefore be kept in mind that, whereas the material provided in the subsequent paras. of this Summary constitute the latest and most up-to-date thinking on the operation of SST aircraft in the NAT Region, this is not to be considered as definitive and will continue to be reviewed as and when new or more precise data on the performance characteristics of SST aircraft and the associated operating practices become available. Operational data quoted in this Summary relate in general to the "Concorde" SST.

1.2.3 In the detailed discussions of the various technical, operational and organizational aspects of the use of SST aircraft in the NAT Region, the Group agreed that this should be covered under the following main headings:

i) Separation minima for SST aircraft including

a) horizontal separation (longitudinal, lateral and radar)

b) vertical separation.

ii) ATS route structure in the NAT Region.

iii) ATS organization of the airspace over the NAT Region.

iv) Entry and Exit problems for SST aircraft.

v) Provision of separation between SST aircraft and between SST and sub-sonic aircraft during entry into and exit from the NAT Region.

vi) Procedures for the issue of oceanic ATC clearances to SST aircraft.

vii) Air-ground communication and air reporting procedures for SST aircraft.

viii) Special urgency and distress procedures for SST aircraft.

ix) Possible cost penalties to individual flights resulting from the need to provide ATS to SST aircraft.

1.3 Separation minima for SST aircraft

1.3.1 Horizontal separation

1.3.1.1 The Group agreed that, under this heading, it would be necessary to review in detail the three types of horizontal separation which can be applied, namely longitudinal, lateral and separation based on the use of Primary and/or Secondary Surveillance Radar.

1.3.1.2 Longitudinal separation

1.3.1.2.1 As is the case for all other air traffic, the application of longitudinal separation to SST aircraft must be effected so that dangerous proximities between successive aircraft operating along the same track and at the same level will not occur.

1.3.1.2.2 The 'exposure time' of SST aircraft while operating in the NAT oceanic area is much shorter than that for sub-sonic traffic and will not normally exceed 2-1/2 - 3 hours, depending on the track flown and on the destination. It is therefore believed that initially the provision of 10 minutes longitudinal separation between successive SST aircraft at the Oceanic entry point will be satisfactory. It is possible that this may be revised to a shorter interval as operating experience confirms the anticipated capability of SST aircraft to adhere accurately to their predicated flight profile.

1.3.1.2.3 It is known that the climb-cruise Mach No. achieved by the SST aircraft will depend on the normal flight variables, temperature being the most important in this context, the optimum being contained in a band approximately spread between Mach 1.85 and Mach 2.05. However, due to the very limited operational flexibility of the SST aircraft, which is a consequence of the relationship between its speed and skin temperature on any particular occasion, aircraft operating in succession in the traffic flow can be deemed to have similar optimum 'targets' as the product of similar performance characteristics, certainly within a spread of Mach 0.1, which can therefore be used as a band of variability. (In practice, the spread is more likely to be in the order of Mach 0.02 - 0.03. The wider band can therefore be considered as an additional safety 'buffer' and to contain any further variance in the achieved profile which might be the product of small time/space inaccuracies in the start of acceleration.)

1.3.1.2.4 During a total flight time of 2½ - 3 hours in supersonic cruise an SST aircraft operating at Mach 2.05 would fly approximately 150 NM further than an aircraft at Mach 1.95, two typical limits of the Mach 0.1 band suggested. If the separation provided at the entry point in the NAT Region was 10 minutes (approximately 200 NM at Mach 2.0) the separation expressed in terms of distance would shrink to 50 NM. As the 'worst case', a proximity of 50 NM in the longitudinal axis between successive SST on the same track and level is considered valid for acceptance as 'safe' especially since this will be a very rare event.

1.3.1.2.5 Should an individual aircraft in the traffic flow fail to achieve stable cruise-climb in the permitted 'band of variance' of Mach 0.1 other measures will have to be taken by ATC to avoid the possibility of proximity with successive aircraft in the stream which are maintaining a normal profile. It is believed that in such a case the aircraft with sub-standard performance will need to be diverted from the stream as the only alternative to imposing restrictions on following aircraft which would be economically and operationally undesirable. Reversion to level cruise appears the logical solution, providing vertical separation as described in para. 1.3.2 below. In this way, longitudinal proximity in the climb-cruise plane would not occur.

1.3.1.2.6 In practice the suggested longitudinal separation of 10 minutes between aircraft following the same track would be applied before the commencement of supersonic acceleration, at about FL 250 and at a sub-sonic speed of Mach 0.93 or thereabouts. This will represent an initial separation in distance of about 100 NM between successive SST aircraft but, as the leading aircraft accelerates, its distance from the succeeding aircraft will increase to about 200 NM once the latter has also reached the cruise-climb phase of operation, assuming that both aircraft commence acceleration at about the same geographic position.

1.3.1.2.7 The above concept is valid for an environment in which distance monitoring between aircraft is not possible, either with a self-contained device or by external surveillance. If either of these facilities becomes available a considerable reduction in time separation might be feasible. A new value would need to be established as a product of the reliability of the equipment and the ability of the aircraft and operating crew to react to events as they occur.

1.3.1.3 <u>Lateral separation</u>

1.3.1.3.1 Lateral separation in an ATC environment such as the one in the NAT Region depends on the navigational capability of the aircraft. For SST operations it is unlikely that there will be any wide variation in basic navigation performance, at least during the early years of operation, since it is assumed that all the aircraft concerned will have a similar navigational capability.

1.3.1.3.2 Present intentions are to provide for a navigation installation consisting of triplicated inertial systems with the possible addition, for gross error checking purposes, of an external reference aid. The inertial systems will be required to satisfy the ARINC 561 specification and will be capable of autopilot coupling. The performance achieved by typical INS systems now in operational use suggests that accuracy and reliability will be of a higher order than would be essential to safe operation with tracks separated by 60 NM. With regard to accuracy, it was pointed out that, because of the eventual high traffic density of SST aircraft expected in the NAT area, it will be required that the accuracy of the equipment should be of the highest order. In fact accuracy should be such that where an aircraft is following the ATC cleared track, it should remain within a lateral distance from that track corresponding to half the separation minimum (i.e. 30 NM for the case of 60 NM lateral separation) for practically the whole time. An acceptable performance figure was agreed to be 99.9% of the time.

1.3.1.3.3 It was further pointed out that for SST aircraft the lateral separation depends to some extent on the time required between the detection of a lateral deviation from track and a successful corrective intervention by the pilot. This in turn was again related to cockpit operating procedures which are thus of particular importance.

1.3.1.3.4 Subject to the satisfactory completion of trials with pre-production aircraft it was agreed that ATC planning should be based on the provision of 60 NM lateral separation between adjacent tracks for either opposite or same direction traffic.

1.3.1.4 Radar separation

1.3.1.4.1 The Group agreed that during sub-sonic flight the normal radar separation minima prescribed by the competent authority should be applied to SST aircraft. However whenever an SST aircraft in trans-sonic flight or in flight at supersonic speed is involved, 10NM radar separation should be applied between the aircraft concerned. This value has been used in simulation studies and seems to cater not only for the types of radar normally employed for the surveillance of SST aircraft during trans-sonic flight, but covers also the needs created by the application of the extreme range of the radars when used for SST operation.

1.3.2 Vertical separation

1.3.2.1 The Group agreed that, while operating at sub-sonic speeds SST aircraft will be separated vertically from other aircraft in accordance with normal procedures.

1.3.2.2 During acceleration to supersonic flight, the provision of vertical separation between SST aircraft may not always be feasible. However the flight profiles of SST aircraft in acceleration and those in deceleration are such that an automatic vertical separation is likely to exist between them in the transition area between domestic and NAT airspace. In addition the use of Mode C of Secondary Surveillance Radar offers a potential means of ensuring vertical separation between SST aircraft.

1.3.2.3 Above FL 500 and up to the maximum normal operating level of FL 600 SST aircraft will cruise climb up to the end of cruise ("top of descent"). Normally during this phase only lateral or longitudinal separation can be applied to them. It appears essential that advantage should be taken of the gain provided by the application of the cruise climb technique and ATC procedures must therefore be planned to allow for this. Departures from the optimum flight path, for whatever cause, could require an interim landing for re-fuelling purposes and the consequent delay would add materially to the cost of the operation. (A study dealing with the effects of cruise at non-optimum levels is attached in Appendix 1-A).

1.3.2.4 When operating in an organized track structure with a common cruise climb regime, the provision of vertical separation between SST aircraft is unnecessary since they will not achieve proximate vertical relationship in the cruise phase of flight, separation being maintained in a common horizontal plane laterally and longitudinally. Because of the very slow rate of climb achieved in cruise-climb operation the passage of crossing and/or opposite direction traffic through the level of approaching traffic can only be permitted in two small areas about 900 NM from the mid-point of the route system where sufficient vertical separation can be applied (See Appendix 1-B).

1.3.2.5 For planning purposes "sufficient vertical separation" for the SST aircraft is assumed to be 4 000 ft. This assumption is based on a prediction that the standard deviation of the altimetry system of SST aircraft will probably not exceed approximately 1 000 ft. Should experience with pre-production aircraft show that the predicted standard deviation is smaller, this should be reflected in the separation applied.

1.3.2.6 If a particular aircraft on one of the organized tracks fails to achieve its planned performance and thus its optimum climb and cruise flight profile, it will be necessary, if succeeding aircraft on the same track are not to be blocked, for the slower aircraft to be vertically separated by 4,000 feet at that point where it will be overtaken. To achieve this separation the slower aircraft needs to be cleared to maintain a level cruise at a level ensuring 4,000 feet separation. The following example, illustrating a possible method, could be applied in order to determine the appropriate level:

1.3.2.6.1 Assuming that the affected aircraft achieves its optimum profile but fails to achieve its optimum speed at some point along its cruise climb flight profile and at that point needs to be cleared to begin a constant level cruise, the following aircraft will have achieved the following automatic vertical spacing at the point of overtake:

Note: To provide an additional safety factor, the results shown in the following table were calculated for an along-track spacing of 5 minutes between successive aircraft, i.e. half the separation of 10 minutes referred to in para. 1.3.1.2.

Optimum Speed of following aircraft	Speed obtained by slower aircraft	Time required for successive aircraft to overtake	Automatic vertical spacing at time of overtake	Descent required by slower aircraft
Mach 2.2	Mach 2.1	110 minutes	~ 6600 feet	Nil
Mach 2.2	Mach 2.0	55 minutes	~ 3300 feet	~ 1000 feet
Mach 2.2	Mach 1.9	37 minutes	~ 2200 feet	~ 2000 feet
Mach 2.2	Mach 1.8	28 minutes	~ 1650 feet	~ 3000 feet

From the above table it is apparent that the magnitude of the descent may be calculated by the rule that for a reduction in speed of up to Mach 0.2 from the optimum cruising speed, a descent of 1 000 feet will be required. Each further reduction in speed of Mach 0.1 will require a further descent of 1 000 feet.

1.3.2.6.2 If the slower aircraft also fails to reach its optimum flight level the descent calculated by the above method will be reduced by the difference between its achieved and its optimum flight level.

1.4 ATS Route Structure in the NAT Region

1.4.1 After having reached agreement on the separation values which should be used for planning purposes of SST operations, the Group considered which ATS route structure would have to be established for SST operations in the NAT Region.

1.4.2 It is obvious that, in any ATS route structure, the number of tracks between a given exit and entry area will depend on traffic flow rates. Initially two tracks in opposite directions will probably be sufficient, with the addition of further tracks at 60 NM lateral intervals as traffic demands.

1.4.3 For reasons explained in para. 1.3.2 above when considering vertical separation the track structure will need to consist of one-way tracks, since in a cruise climb regime the overall rate of climb is low; if opposite direction traffic were to be accommodated, there would therefore be about 1 700 miles along the middle of each track in which it would not be possible to provide sufficient vertical separation (accepting the assumption that 4 000 ft. is necessary) to opposite direction traffic. Crossing traffic would therefore have to be provided with longitudinal separation. This might be possible when aircraft position was known with reasonable accuracy and movement rates on a particular track were very low.

1.4.4 As regards the alignment of the ATS route structure, the Group felt that there were 2 major points to be considered. These are:

i) whether the track system should consist of organized tracks as opposed to a completely free track system and

ii) in case an organized track structure is adopted, whether this needs to be varied according to meteorological conditions.

1.4.5 A completely free track structure would involve numerous crossings over the North Atlantic at acute angles such that either the capacity of the system would be extremely limited or vertical separation would have to be applied (see Appendix 1-C). This would preclude the use of cruise climb techniques and hence introduce significant fuel penalties, particularly so in respect of flight levels below the optimum for constant level cruise. The effects of this are shown in Appendix 1-A. In addition, even in the initial years of operation when traffic density remains light, there is an argument for organized tracks, firstly, to separate opposite direction traffic using cruise climb techniques. and secondly, to avoid delay in entry into the NAT track structure to certain SST aircraft. It would seem that the nature of the traffic flow across the Atlantic is such that the period during which departures take place will be rather limited leading to a greater risk of conflict between flights arriving simultaneously at the entry points into the NAT Region.

1.4.6 In order to show the various possibilities regarding the establishment of a track system for SST operations in the NAT Region, the Group decided to include in this Summary the requirements for SST operations in a completely free environment (see Appendix 1-C) and three route structures assuming various conditions concerning sonic boom imposed on SST flights while operating over land areas (See Appendices 1-D, 1-E and 1-F).

1.4.7 The relationship between the selection of a track for an SST flight and the cruise temperature is shown in Appendix 1-G. Appendix 1-H contains a study regarding the influence of meteorological conditions on track selection as observed during the summer of 1968. From these studies it would appear that, at least at this stage of the planning, it would be advantageous to assume that an organized track structure, based approximately on a great circle, should be used in order to cater for the main traffic flow.

1.4.8 In conclusion the Group agreed that, for further planning purposes it should be assumed that an organized track structure based on any one of those shown in Appendices 1-D, 1-E and 1-F (depending on decisions taken with regard to sonic boom) should be used. It should however be understood that the use of such a track structure would not imply that tracks by SST flights outside such a track structure would not be accepted by ATC whenever conditions permitted.

1.5 ATS organization of the airspace in the NAT Region

1.5.1 The Group believed that there would be no requirement to change the present FIR boundaries once SST operations started. However, co-ordination and transfer of control procedures between adjacent ACC's will require detailed attention not only between adjacent OAC's but also between them and ACC's serving the North American and European domestic airspace. This latter applies particularly to the area south-west of the United Kingdom and south of Ireland where the existing problems (see Summary/3 para. 5.2.3 on page 5.3) will be considerably aggravated if early preparatory action is not taken.

1.5.2 As regards co-ordination and possibly delegation of control, it was pointed out that the economic use of the NAT track system by SST aircraft will require the allocation to individual aircraft of the time at which acceleration to supersonic speed should be commenced. The consequence of this may be that the point of start of acceleration may be located outside the area of responsibility of the OAC deciding this time. It will therefore be necessary to develop detailed procedures covering this case. The same appears to apply to SST aircraft which are in acceleration or deceleration and which should not be required to change control during this rather critical phase of their flight.

1.5.3 In this context, the sectorization of airspace within a given control area will also need careful consideration. Simulations conducted in the United Kingdom have shown that a horizontal division of the upper airspace in sectors comprising specified vertical bands is definitely less advantageous when compared with a vertical division. In fact, the selection of sector boundaries should take full account of the nature of the traffic flow and results so far available from studies made in the United Kingdom indicate that sectors enclosing the largest possible portion of the majority of flight paths throughout all levels above FL 250 will probably provide the best solution.

1.6 Entry and Exit problems for SST aircraft

1.6.1 Studies conducted in the United Kingdom had revealed that the problems related to entry into and exit from the NAT Region by SST aircraft were particularly difficult. This is due to the fact that at this stage of their flight SST aircraft will not only be in transition between domestic and oceanic control areas but they will also be in the acceleration or deceleration phase of their flight and this partially at levels which are also used by sub-sonic NAT traffic. Moreover during this stage of flight SST aircraft are likely to be limited in their manoeuvering performance.

1.6.2 As regards the extend of the area within which initial trans-sonic acceleration takes place, for Concorde-type aircraft this may extend horizontally from approximately 100 NM in International Standard Atmosphere (ISA) conditions to approximately 200 NM in ISA + 15° conditions and vertically from FL 250 to FL 400. The speeds attained within this area will range from Mach 0.93 to Mach 1.4. (See page 1-E-7).

1.6.3 Studies in the United Kingdom concerning the resolution of problems created by the crossing of westbound tracks of SST aircraft in acceleration have shown that it will be essential to apply longitudinal separation at the point of crossing and that this could be achieved by varying the time of commencement of acceleration of the aircraft concerned. It was also found that this separation could be less than the longitudinal separation applied between SST aircraft once they are established on their oceanic track since the crossing points are located within radar cover. It is believed that a time interval of 3 minutes between

SST aircraft crossing the same point will be adequate especially in view of the fact that acceleration may be discontinued at the direction of ATC should this become necessary in order to avoid undue proximity between SST aircraft.

1.6.4 Although it is believed that radar cover in the area where acceleration takes place is essential, there may be cases where routes may continue to diverge outside radar cover and before the aircraft concerned are established on the parallel oceanic tracks. It is however believed that there is no need to specify a special form of lateral separation since this seems to be covered by the existing procedures concerning aircraft operating on diverging tracks. Nevertheless, in order to ensure that aircraft in such areas are on the correct track, it may be necessary to establish procedures for monitoring such aircraft to the limit of radar cover.

1.6.5 As regards the problems created by SST aircraft leaving the NAT area and entering domestic airspace, the Group believed that, due to the higher manoeuvrability obtained during the deceleration phase of these aircraft, these could be resolved by the normal application of the agreed separation standards described in para. 1.3 above.

1.6.6 In this respect it was noted that the provision of SST aircraft with Secondary Surveillance Radar (SSR) will be of considerable benefit and it was expected that the ground radar installations used for the control of SST operations will also be provided with the required ground SSR equipment so that optimum use can be made of this system.

1.7 Provision of separation between SST and sub-sonic aircraft

1.7.1 SST aircraft are expected to cruise in the height band between FL 480 and FL 600 while sub-sonic jet aircraft are using the band between FL 300 and FL 400. Under normal circumstance therefore SST aircraft and sub-sonic aircraft will not operate in the same layer of the airspace, except in domestic areas on either side of the North Atlantic while SST aircraft are operating at subsonic speeds or during trans-sonic acceleration.

1.7.2 The provision of separation between SST aircraft in sub-sonic flight and other air traffic will be accomplished by classical means and is therefore not presenting any new problem. However, the separation of SST aircraft in acceleration to supersonic flight but still operating below FL 400 from other air traffic may present difficulties because of the limited maneouverability of SST aircraft in this phase of their flight. It will therefore be essential that, in areas where there is a concentration of sub-sonic traffic, this be effected while the aircraft concerned are within radar cover. (See in particular paras. 1.3.1.4 and 1.3.2.)

1.7.3 Simulation studies conducted in the United Kingdom indicate that a controller, when confronted with a potential conflict between an SST and a subsonic aircraft, tends to move the latter. In order to ease the radar controller's workload it will be necessary to ensure that inbound and outbound flows of SST and subsonic traffic are staggered laterally as far as possible, recognising of course that there will always exist some crossing traffic. This will mean that when establishing the organized tracks for sub-sonic air traffic, due account will have to be given to the SST track structure.

1.7.4 When considering this subject, the Group fully realized that there were a number of extraordinary conditions which might require SST aircraft to descend in the course of their flight to , or even below, the levels used by sub-sonic aircraft operating in the NAT Region. As these were however cases which were not normally expected to occur, it was agreed that these should be treated in a separate section of this Summary (para. 1.10 refers).

1.8 Procedures for the issue of oceanic ATC clearances to SST aircraft

1.8.1 The Group, when considering this subject, realized that it presented one of the major problems caused by SST operations. On the other hand, in the complete absence of any practical experience, it felt that the best method of approach to this question would be to record any work which had so far been done (primarily by the United Kingdom) on this subject in the hope that this will provide food for further thought and possibly provoke discussion thus promoting further progress in this matter.

Basic Philosophy

1.8.2 Essentially oceanic clearances are required to exploit an oceanic track structure so as to give the maximum capacity, which is perhaps better expressed as "to ensure minimum detour and minimum delay" to aircraft in an existing traffic situation, consistent with the need to provide safe separation.

Scope of the clearance function

1.8.3 In order to minimise crossing of tracks in oceanic areas it follows that, where possible, crossings should take place in domestic airspace. This has presented no insuperable difficulty with sub-sonic aircraft because crossing conflicts can be resolved by using radar and vertical separation since the aircraft concerned are reasonably flexible. Consequently, oceanic clearances, as a concept, involve a straightforward assignment to oceanic tracks at appropriate intervals. The problems that arise, and there are many, stem from controller workload and accuracy of ETA's for example, rather than because the concept is complicated. With the SST the situation is different. Aircraft will still have to cross in domestic airspace, and in some areas such as the south-west approaches to the United Kingdom, the crossing will have to occur when aircraft are in acceleration to supersonic speed and are not responsive to control. Furthermore in this phase their flight profiles may not provide similar automatic vertical separation. It seems, therefore, that oceanic clearances will have not only to take account of the correct longitudinal spacing on NAT tracks, but also of the sequencing of outbound crossing SST traffic when necessary. This presents a significantly more complex task than hitherto.

Time available for the issue of oceanic clearance

1.8.4 The operators will require SST aircraft to commence acceleration to supersonic speed as soon after departure as possible, consistent with any sonic boom restrictions that might be in force. Consequently, the time available for the preparation and issue of the oceanic clearance will be limited if, as seems likely, pre-departure clearances are not feasible at major air traffic generating centres. There will also, of course, be implications on the communication links to be used.

The "starting line"

1.8.5 Whereas ETA's at the oceanic boundary provide a reasonable basis for planning oceanic clearances for sub-sonic traffic, an earlier datum may be preferable for SST's. It may be possible that the elapsed times computed in plans may have a greater variability than the actual elapsed times in flight. If this should be so, then it will be desirable to choose a datum for clearance purposes nearer to the departure airports to ensure high accuracy ETA's. Any error in ETA used for planning obviously could lead to inadequate actual spacing further out over the Atlantic, or alternatively, require a larger longitudinal separation than would otherwise be needed.

Clearance in respect of sub-sonic and opposite direction SST traffic

1.8.6 At present the applicability of oceanic clearances commences at the entry point into the NAT oceanic control area and covers the assignment of the oceanic track and flight level. The allocation of tracks and flight levels in relation to the direction of traffic is normally made after coordination between the OAC's concerned. Traffic conflicts in the transition area between domestic and oceanic airspace are resolved by the ACC which is responsible for that portion of the airspace where they occur. Because of the inflexibility in performance of SST aircraft during their acceleration to supersonic speed in airspace adjacent to, but still outside the oceanic control areas, it will be necessary to study to what extent traffic conflicts can be resolved by normal control methods. If it should be found that this is not possible, the issue of an oceanic clearance for SST aircraft would be considerably complicated. It is however believed that the provision of a suitable track structure in the area in question, together with appropriate control procedures, will permit a solution of this problem.

Conclusions

1.8.7 The factors discussed above all need to be considered in developing an oceanic clearance technique. It is believed that:

i) There should be established positions at which acceleration to supersonic speed should normally be started.

ii) Adjustment of longitudinal spacing of successive SST aircraft on NAT tracks, and sequencing of crossing traffic, should be accomplished by delaying the commencement of acceleration to supersonic speed.

iii) The principle of first-come-first-served could be applied for the west-bound flow through the use of a datum line (meridian) which would need to be as far east as possible but not east of any major traffic generating centre. To avoid a requirement for ETA's at this point, and to facilitate the mechanics of issuing an oceanic clearance, it might be preferable to establish a standard time relationship between this datum line and the various established positions at which acceleration to supersonic speed should normally begin.

iv) As the interval between the moment of take-off of an SST aircraft and the time when the oceanic clearance is needed will be short, it seems likely that filed flight plans received in the OAC will have to be up-dated by the transmission of a departure message via the domestic ATS inter-area communication channels to the OAC concerned. The oceanic clearance may then have to be relayed to the pilot using the same channels should it be found that the present technique of using a special frequency for delivery of the oceanic clearance to the pilot is not suitable.

1.9 Air-ground communication and air reporting procedures for SST aircraft

1.9.1 The SST's requirement in the field of air/ground communications, in the first years of NAT operation, should be fairly similar to those of the sub-sonic jets. Communications will be required with the ATS unit responsible for the area in which the aircraft is flying, for the exchange of air traffic services messages, and this will be provided in the domestic FIR's by the normal VHF facilities.

1.9.2 The main point for discussion is the communication and reporting requirements outside the range of VHF cover - which means the main portion of the ocean crossing from say 10-12°W (or from 15-17°W where Shannon VHF cover is available) up to that point where cover is provided off the Canada/USA seaboard.

1.9.3 Once an SST has started its acceleration and climb to its start-of-cruise level there may be little tactical intervention by ATC required or indeed possible, except in emergency. Since the appropriate longitudinal separation from other aircraft on the same track will have been provided at the start of acceleration, it is open to question whether there will be any requirement for ATC to receive routine position reports from SSTs flying the NAT on an organized track structure when they are outside VHF range. ATC requirements may, in fact, be met by the adoption of procedures whereby SSTs need only report when circumstances arose (e.g. sub-normal performance of the aircraft) causing a departure from the planned profile. It appears however, desirable that at least one position report should be made at or about 30°W which would indicate that the flight is proceeding according to plan. There is also likely to be a requirement for the transmission of information regarding significant weather encountered. For NAT SST flights on random tracks outside the track system, it may be necessary that more position reports are made, but it is thought that these should not be more frequent than every 15 or 20 degrees of longitude.

1.9.4 As regards the contents of air reports, the Group agreed that in view of the special manner in which it was expected that SST operations in the NAT area would be conducted, it might also be useful to review the content of air reports critically in order to eliminate all unnecessary information from them and keep them as brief as possible.

1.9.5 In addition to facilities for making the reports mentioned in the preceding paragraph, the SST will require the most rapid and efficient means of reporting any emergencies which may force it to decend from its normal cruising level and either continue supersonic flight at a lower level, or continue at sub-sonic speed at a level potentially occupied by sub-sonic jets. If it continues cruising at a sub-sonic level it will have to carry out the appropriate reporting procedures.

1.9.6 It is evident that for some years to come the main means of air/ground communication in the NAT Region will be by HF/radiotelephony (RTF) and it will have to be used by SST aircraft at least during their initial operations. The limitations and unreliability of HF/RTF are well known, as also is the fact that overloading can occur on the NAT HF networks leading to delays in the handling of messages.

1.9.7 The efficiency and reliability of HF/RTF can be improved by the use of single sideband (SSB) techniques and recognising this the ICAO Special North Atlantic Meeting (1965) recommended (Recommendation 6 viii/9) that an operational evaluation of HF aeromobile SSB at Shannon, Gander and New York be carried out in a compatible DSB/SSB environment as soon as practicable. It was decided that the ground transmissions would be SSB full carrier (A3H). It is understood that this recommendation has only been partially implemented to-date but that full implementation may be expected soon. It was considered that this evaluation would be an evolutionary phase leading to the introduction of a fully suppressed carrier system (A3J) which would allow the full exploitation of the potentialities of SSB.

1.9.8 It is noted that the report of the COM/OPS Divisional Meeting (1966) Recommendation 4/1, paragraph 4.4.6, comments thus :

> "The COM/OPS meeting considered that the North Atlantic was a good example of an area where the benefits of suppressed carrier SSB could be obtained within a reasonable time. From a pure channel loading viewpoint, and not taking other considerations into account, one or two families serving the main stream traffic area might be assigned exclusively for suppressed carrier SSB operation when approximately 50% of aircraft operating in the area carry appropriate equipment."

1.9.9 For the safe and efficient operation of SSTs it is essential that the best facilities be provided and thus that progress should continue towards the introduction of a suppressed carrier SSB system. The Group considers that, as part of the essential preparatory measures for the start of SST operations, the evaluation of HF/SSB techniques described in para. 1.9.7 should now be actively pursued by the States concerned.

1.9.10 The Prestwick LF/radioteletype (RTT) service which has been operating on an operational trial basis for some years has proved to be a reliable means of passing MET and AIS information to aircraft in the NAT Region. This service will be impossible to maintain indefinitely without considerable expenditure on replacement equipment. As it is a very reliable broadcast service and results in a considerable reduction of cockpit workload, studies should be made whether the continuation and expansion of the LF/RTT service is a requirement for SST operation. In this respect the Group noted that the inclusion of an antenna-layout for LT/RTT into the structure of Concorde aircraft was an optional possibility and that not all operators, having ordered Concordes, had stated such a requirement.

1.9.11 It would be possible to provide VHF cover over most of a NAT organized track structure by means of 3 or 4 ocean platforms, or over the whole of the NAT area by means of a communication satellite. The former would require no airborne equipment additional to that carried by NAT traffic today, while the use of satellite communications would require expensive additional equipment to be fitted to aircraft participating in the system. Both ocean platforms and satellite would be very costly and might be difficult to justify on the grounds of improved communication alone. However, taken in conjunction with surveillance facilities which could also be provided and which would allow the use of smaller separation standards and result in a more economical use of the airspace, it is thought that the use of one or other of these surveillance communications facilities might well be justified when traffic builds up to figures which are forecast for the late 1970's.

1.9.12 An additional facility likely to prove of value to SST operations in due course is the digital data link. This, while not replacing radiotelephony, could reduce its use considerably and also reduce cockpit workload. In the NAT area, it would seem likely that the use of digital data links might be associated with surveillance/communication satellites as an alternative method to radiotelephony.

1.9.13 As regards the forwarding of messages received via air-ground communication channels to the addressee via the aeronautical fixed services, it was noted that, in those areas of the NAT Region where the large majority of SST operations were likely to take place, these were in general satisfactory. It was however noted that even at present there existed a problem concerning the communications between Shanwick OAC and Lisboa OAC (which is still located in Santa Maria.) The Group understood that States concerned are taking necessary measures in order to improve the situation.

1.9.14 Finally, the Group felt that there might be merit in studying the possibility of assigning by the OAC concerned to each SST aircraft a special code sign together with the oceanic clearance which should be used during the flight in the NAT Region and which, by its combined use with the usual call sign would provide to ATC and to other SST aircraft in a readily understood form information on the track on which the aircraft concerned was operating and its sequence number in the flow of SST traffic on this track.

1.10 <u>Special urgency and distress procedures for SST aircraft</u>

1.10.1 As already indicated in para 1.7.4 the Group found it necessary to develop special procedures covering those cases where an SST aircraft in normal cruising flight may be required to descend from its normal cruising level and continue its flight at a lower level. There are at present three distinct cases to be considered:

i) action to be taken by an SST aircraft which is unable to continue its flight to destination and is forced to return.

ii) an urgent descent because an SST aircraft is encountering solar radiation which is above the "action level".

iii) an emergency descent because of engine failure or failure of any one of the critical sub-systems of the aircraft.

1.10.2 The Group agreed that studies regarding a "turn-back" procedure should be made. It was further agreed that such a procedure should envisage that an SST aircraft required to turn back would descend approximately 2000-4000 feet from the level occupied at the time when the pilot decided to return before starting to reverse course and that an ATC clearance should be obtained prior to descend or, if this is not practicable, as soon as possible thereafter.

1.10.3 It is believed that at normal cruising levels used by SST aircraft the occurrence of solar radiation levels high enough to necessitate an urgent descent will be rare. If the proposed "action level" is detected while cruising during normal operations it should be sufficient for an aircraft to descend to a level between FL 400 and 500. Above FL 450 SST aircraft should cruise satisfactorily supersonically without serious penalties in time and fuel. If, however, it proved necessary to descent to a cruising level below FL 450 the pilot would need to weigh the time saved by operating supersonically but at high fuel consumption between FL 400 and 450 against the possible fuel saving to be gained by operating subsonically between FL 250 and 360. Aerodynamic considerations will make it extremely undesirable to cruise at speeds ranging from Mach 0.93 (FL 360) to Mach 1.4 (FL 400). In any case a descend below FL 450 should not be made without first obtaining an appropriate ATC clearance.

1.10.4 It is assumed that an SST aircraft receiving a warning of radiation at the specified level would be required to make an immediate descent and that there would be no time to obtain an ATC clearance. It is not likely that there will be any risk of collision if several aircraft, well spaced longitudinally, made emergency descents to FL 450, continued their flight at, say Mach 1.8, and notified ATC as soon as possible. Calculations show that, even if a number of SST aircraft were operating on the same track with minimum spacing and they descended to FL 450 at different times, the longitudinal spacing between them would not be reduced to the point that a dangerous proximity between successive aircraft could occur.

1.10.5 It was nevertheless agreed to propose the following procedure for further study:

i) In case of need to descent because of solar radiation the pilot shall broadcast on VHF (121.5 Mc/s) his decision to descend by giving his call sign and the code number assigned to his flight by the OAC of entry and the level to which he will descend (see para 1.10.3 above).

ii) The pilot shall contact ATC as soon as possible after having started his descent in order to obtain a new ATC clearance for the level selected or, in case this is unsatisfactory for any other level and other particulars concerning the continuation of the flight.

iii) <u>Descents below FL 450 shall in no case be made without first having obtained an appropriate ATC clearance.</u>

1.10.6 It is obvious that descent into the band of flight levels used by sub-sonic jets due to engine failure or other causes will present a much greater hazard. It will be inevitable that on many occasions there will be some overlap of supersonic and sub-sonic track structures. It may therefore be necessary to deliberately separate horizontally the main track structures should it appear that the number of SST emergency descents into the sub-sonic band is likely to exceed a certain minimum, or alternatively, it may be possible to stagger the SST and sub-sonic tracks to some extent.

1.10.7 If an SST aircraft is forced to descend into the sub-sonic height band its optimum cruising level will depend on a number of factors (e.g. the number of engines operating, the aircraft weight, the ambient temperature). With all four engines operating the optimum sub-sonic cruise level will vary from FL 250 for a heavy aircraft up to about FL 320 for a light one, with a maximum permissible level of FL 360. With one engine inoperative the optimum level will be much the same as for the four engine case, but the maximum permissible will vary between FL 250 and 360. Should two-engine cruise be necessary, the optimum and maximum permissible will vary between FL 180 and 330. The actual level chosen in an individual case will, however, depend on the aircraft's weight and the ambient temperature. It should be noted that in all cases the cruising speed will be Mach 0.93.

1.10.8 The degree of hazard caused by the descent of an SST aircraft into the band of levels used by the sub-sonic aircraft will depend on the sub-sonic track structure in use at the time. An added complication will be the requirement of the SST, when in sub-sonic flight, to continue on the best track depending on the wind field. It will be essential for the SST pilot to have detailed knowledge before take-off of the sub-sonic track structure in use. It would appear that in order to present the least danger of collision, an SST making an emergency descent should:

i) notify the OAC concerned as soon as possible of the emergency, stating its position, flight level, intentions, etc., and if appropriate, request clearance to a more suitable level;

ii) as soon as possible, broadcast information regarding the emergency, including position, flight level, intentions, etc., on VHF 121.5 Mc/s in order to warn sub-sonic jets in the vicinity. (Para. COM 3.3.8 of Doc 7030 requires aircraft on long over-water flights in the NAT Region to guard 121.5 Mc/s continuously, with due regard to equipment limitations and cockpit duties.)

1.10.9 The OAC controller will then issue the most suitable clearance depending on the traffic situation at the time.

1.10.10 In general it would seem that an SST aircraft, required to cruise sub-sonically, should be able to descend and continue its flight below the main stream of sub-sonic jets at its optimum Mach number (for the Concorde - Mach 0.93).

1.11 Studies regarding the relation between start of acceleration of SST aircraft and the NAT ATS system capacity

1.11.1 Studies have been made of the track entry system for SST aircraft on the eastern side of the Atlantic, using the technique of varying the start of acceleration point, both to produce a longitudinal separation of 10 minutes between successive aircraft on oceanic tracks and also, where necessary, to give 3 minutes time interval between aircraft in the trans-sonic phase of flight on crossing tracks in the transition area. These studies have shown that there is danger that the capacity of the oceanic system may be seriously reduced unless care is taken in the development of procedures for assigning the start of acceleration point to each aircraft in succession so that aircraft on crossing tracks are not unduly delayed for separation purposes.

1.11.2 In this respect it should be noted that the delay of start of acceleration imposed on individual aircraft must not exceed a very limited period of time (not more than about 10 minutes) since otherwise the aircraft concerned will not be able to complete their initial trans-sonic acceleration within radar cover.

1.12 Possible cost penalties to individual flights resulting from the need to provide air traffic control to SST operations

1.12.1 Studies of the oceanic system made in the United Kingdom show that the cost penalties to individual SST flights resulting from the need to provide air traffic control will depend greatly on decisions still to be taken with regard to sonic boom limitations.

1.12.2 Assuming a complete ban on over-land supersonic flight, it may be necessary to adopt the track system described in Appendix 1-F. When applying the costing method developed by the Royal Aircraft Establishment of the United Kingdom to this sytem it appears that an average penalty of US$ 200 per aircraft will result, based on the traffic density predicted for 1975. For westbound aircraft the additional complication caused by the necessity of separating aircraft on crossing tracks in the trans-sonic phase will further increase delays and reduce the capacity of the better tracks. This will increase the cost penalty by about 30%.

1.12.3 If the sonic boom restrictions were to be less onerous, the cost penalties would be lower. With no sonic boom restrictions and the consequent use of the track system shown in Appendix 1-D, the cost penalties for flight would be only one-fifth of those quoted above.

APPENDIX 1-A

CONCORDE - CRUISE AT NON-OPTIMUM LEVELS

1. SUMMARY

1.1 The effects of cruising at non-optimum levels have been examined in relation to two typical cruise techniques and for a series of stage lengths extending from 500 NM to 3 000 NM.

1.2 The results show the penalty on block fuel arising from the use of cruise levels which are 2 000 ft. and 4 000 ft. below the optimum level for both cruise climb and stepped level procedures.

1.3 It is seen that for ranges up to 1 000 NM there is little difference in block fuel between cruise climb and stepped level procedures if both are conducted at their respective optimum levels. Between 1 000 NM and 2 000 NM the advantage of cruise climb relative to stepped level becomes more apparent. Moreover, the effect of flying at levels lower than the optima shows increasing penalties on block fuel for both cruise techniques. As range is increased beyond 2 000 NM there is a corresponding increase in the block fuel penalty for the use of the non-optimum technique and non-optimum levels.

2. RESULTS

2.1 The two typical cruise techniques examined in this note are:

i) cruise climb at maximum continuous power, with a rate of climb of approximately 50 ft./MIN ;

ii) stepped level, where power is throttled to maintain a constant level at maximum operating Mach number (Mmo.) appropriate to ambient temperature conditions. In this study, steps of 4 000 ft. have been assumed to apply.

2.2 Figure A-1 shows the approximate variation of start cruise level with stage length for the two optimum procedures.

2.3 Figure A-2 illustrates the variation of block fuel with optimum level, optimum level minus 2 000 ft. and optimum level minus 4 000 ft. for both procedures over stage lengths extending from 500 NM to 3 000 NM.

2.4 It should be noted that the values of block fuel shown on this chart reflect a standard of performance which has been degraded relative to the manufacturer's nominal value, but this does not invalidate any conclusions that may be formed from these results on a comparative basis.

2.5 The following tables compare the order of differences in block fuel between various cruise techniques and cruise levels for a range of stage lengths.

3. STAGE LENGTH 500 NM

3.1 Cruise Climb

	BLOCK FUEL LB.	DIFFERENCE FROM OPTIMUM CRUISE CLIMB	
		LB.	%
OPTIMUM LEVEL	38,800	0	0
-2,000 FT.	39,200	400	1.0
-4,000 FT.	39,800	1,000	2.5

3.2 Stepped Level

OPTIMUM LEVEL	38,400	-400	-1.0
-2,000 FT.	39,000	200	0.5
-4,000 FT.	39,700	900	2.3

4. STAGE LENGTH 1 500 NM

4.1 Cruise Climb

OPTIMUM LEVEL	79,100	0	0
-2,000 FT.	80,600	1,500	1.9
-4,000 FT.	82,500	3,400	4.3

4.2 Stepped Level

OPTIMUM LEVEL	81,100	2,000	2.5
-2,000 FT.	83,100	4,000	5.0
-4,000 FT.	85,700	6,600	8.3

5. STAGE LENGTH 2 500 NM

5.1 Cruise Climb

OPTIMUM LEVEL	126,800	0	0
-2,000 FT.	129,500	2,700	2.1
-4,000 FT.	133,200	6,400	5.0

5.2 Stepped Level

OPTIMUM LEVEL	130,600	3,800	3.0
-2,000 FT.	134,300	7,500	5.9
-4,000 FT.	139,400	12,600	9.9

6. CONCLUSION

6.1 It can be concluded that for ranges up to 1 000 NM there is little to choose between cruise climb and stepped level if both techniques are conducted at their respective optimum levels. In fact, for a stage length of 500 NM the stepped level technique is marginally better. As stage length increases the advantage of cruise climb over stepped level becomes more apparent and, for both techniques, there is marked evidence of the increasing penalty incurred when flying at a non-optimum level.

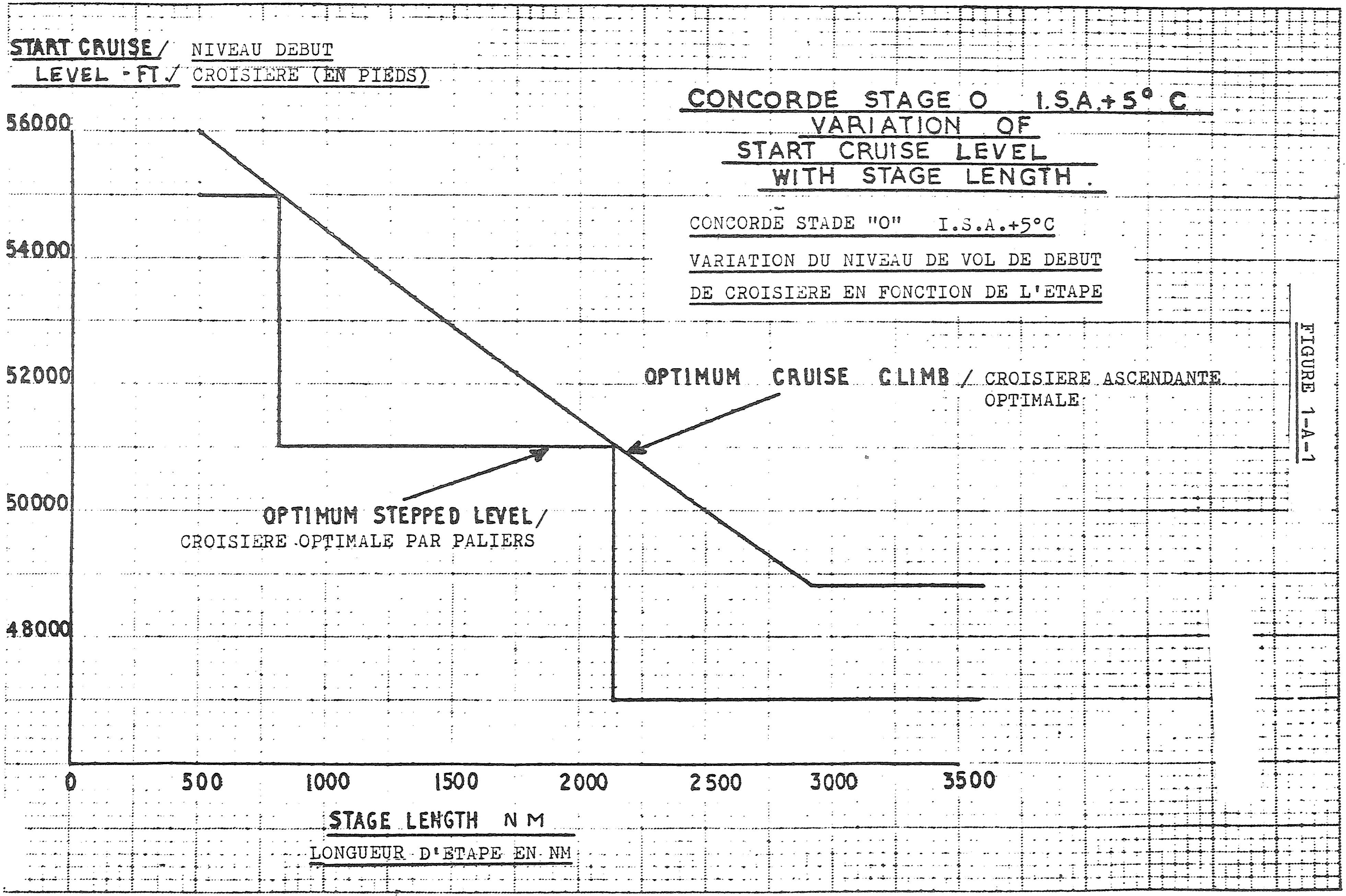

CONCORDE STAGE O I.S.A.+5° C
VARIATION OF
START CRUISE LEVEL
WITH STAGE LENGTH.
CONCORDE STADE "O" I.S.A.+5°C
VARIATION DU NIVEAU DE VOL DE DEBUT
DE CROISIERE EN FONCTION DE L'ETAPE
START CRUISE/ NIVEAU DEBUT
LEVEL - FT / CROISIERE (EN PIEDS)
56000
54000
52000
50000
48000
0
500
1000
1500
2000
2500
3000
3500
OPTIMUM CRUISE CLIMB / CROISIERE ASCENDANTE OPTIMALE
OPTIMUM STEPPED LEVEL/ CROISIERE OPTIMALE PAR PALIERS
STAGE LENGTH N M
LONGUEUR D'ETAPE EN NM

FIGURE 1-A-1

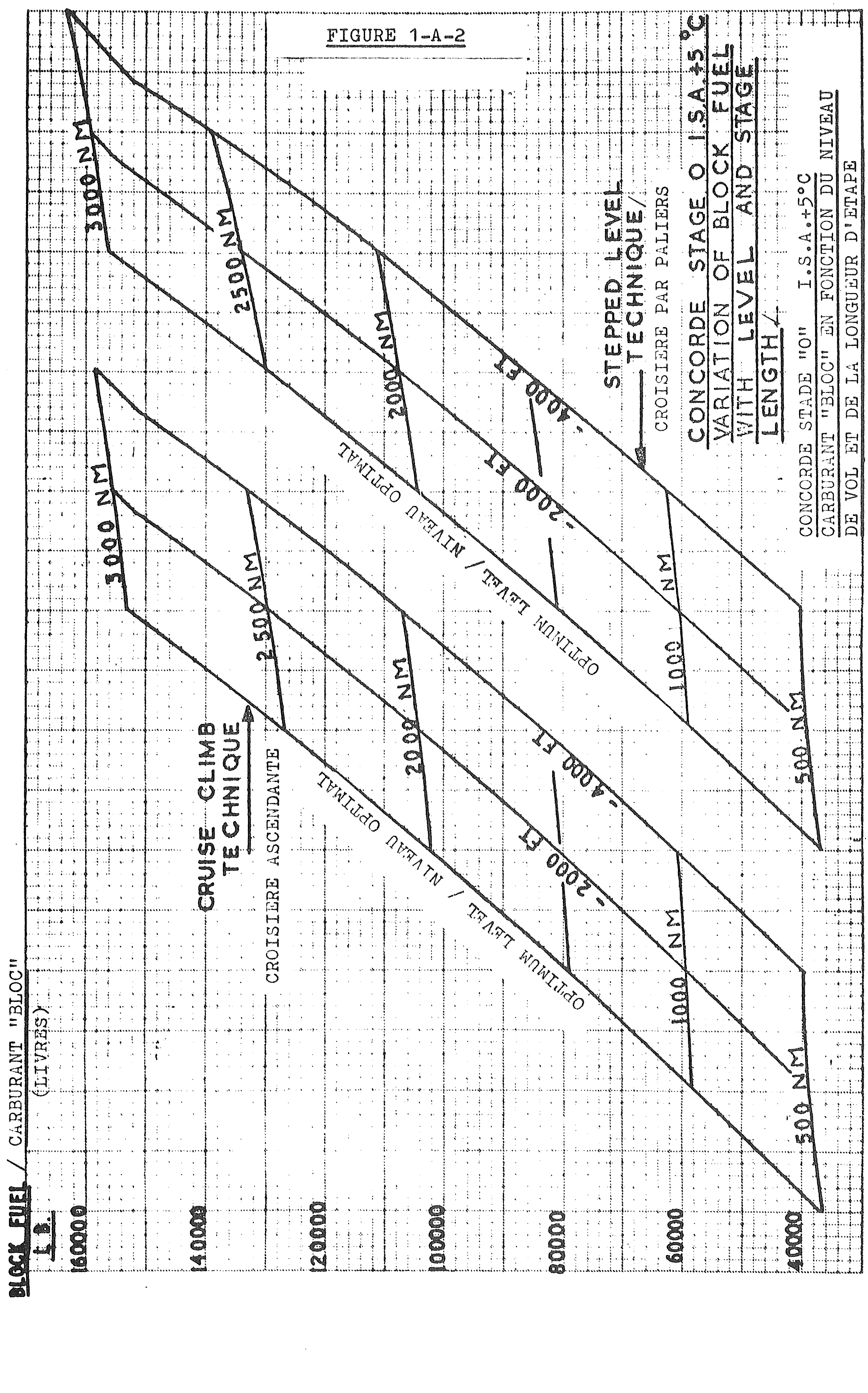
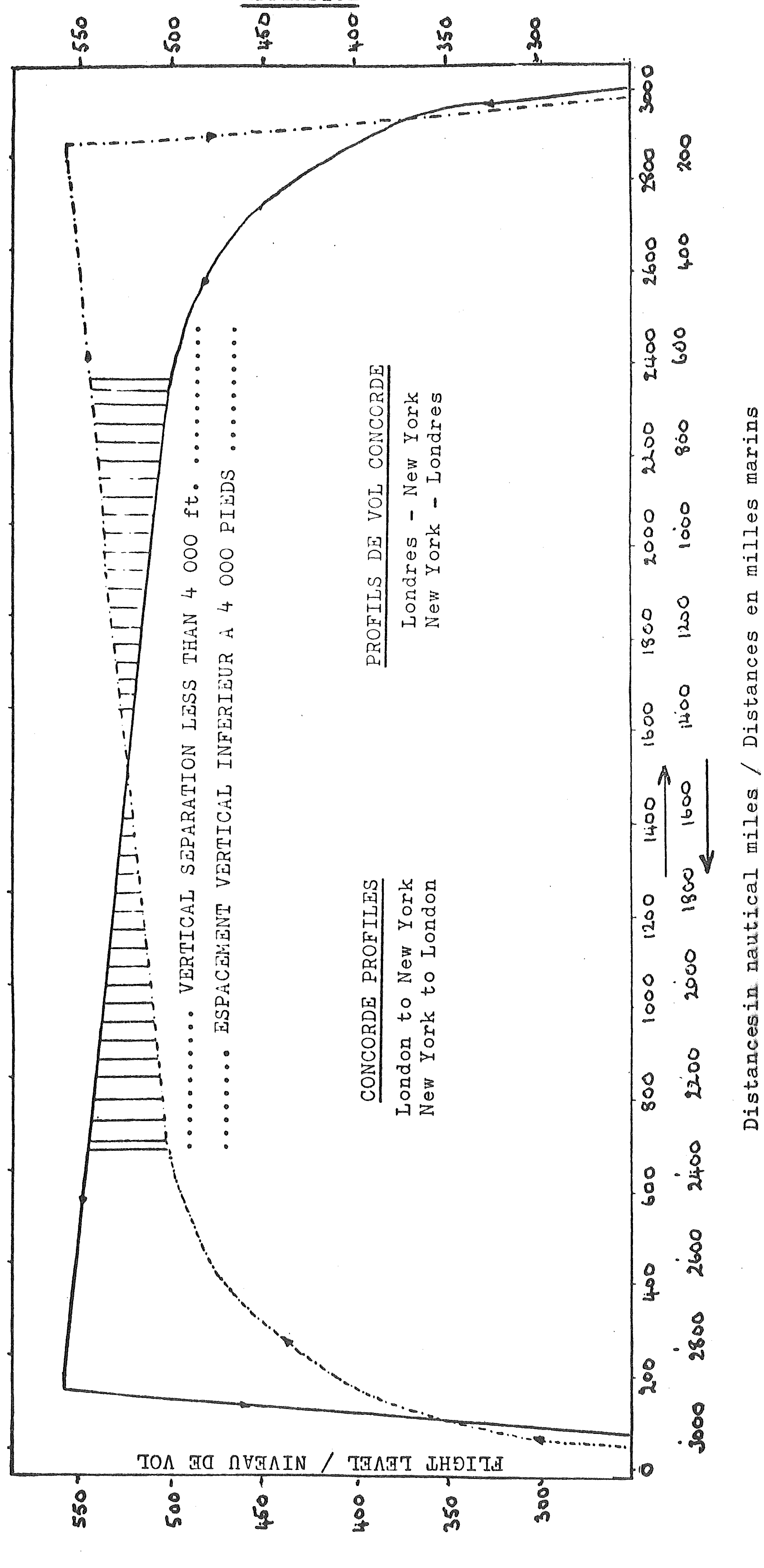
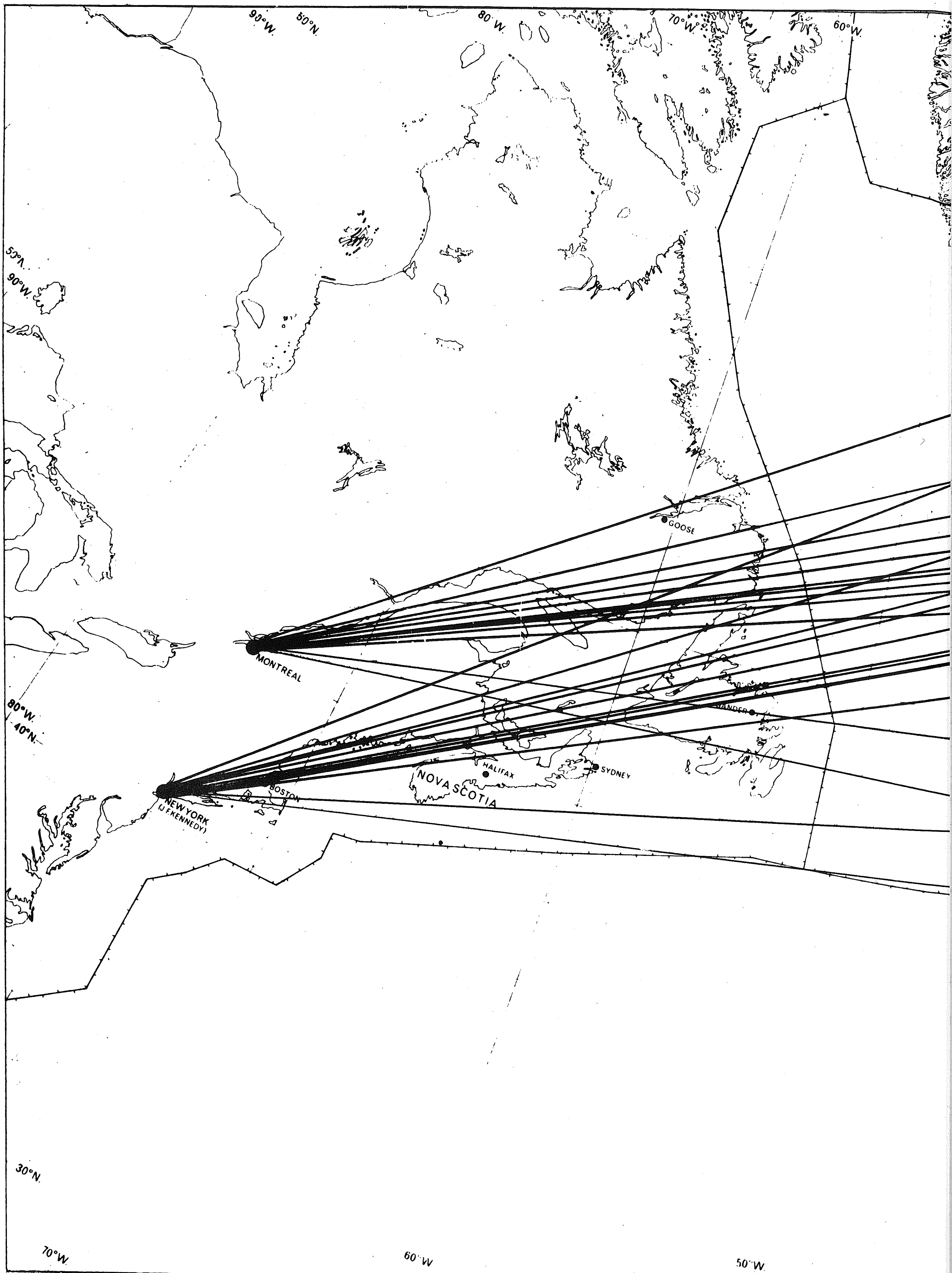

BLOCK FUEL / CARBURANT "BLOC"
LB. (LIVRES)
160000
140000
120000
100000
80000
60000
40000
CRUISE CLIMB TECHNIQUE
CROISIERE ASCENDANTE
STEPPED LEVEL TECHNIQUE/
CROISIERE PAR PALIERS
3000 NM
2500 NM
2000 NM
1000 NM
500 NM
OPTIMUM LEVEL / NIVEAU OPTIMAL
-2000 FT
-4000 FT
CONCORDE STAGE O I.S.A.+5 °C
VARIATION OF BLOCK FUEL WITH LEVEL AND STAGE LENGTH/
CONCORDE STADE "O" I.S.A.+5°C
CARBURANT "BLOC" EN FONCTION DU NIVEAU DE VOL ET DE LA LONGUEUR D'ETAPE

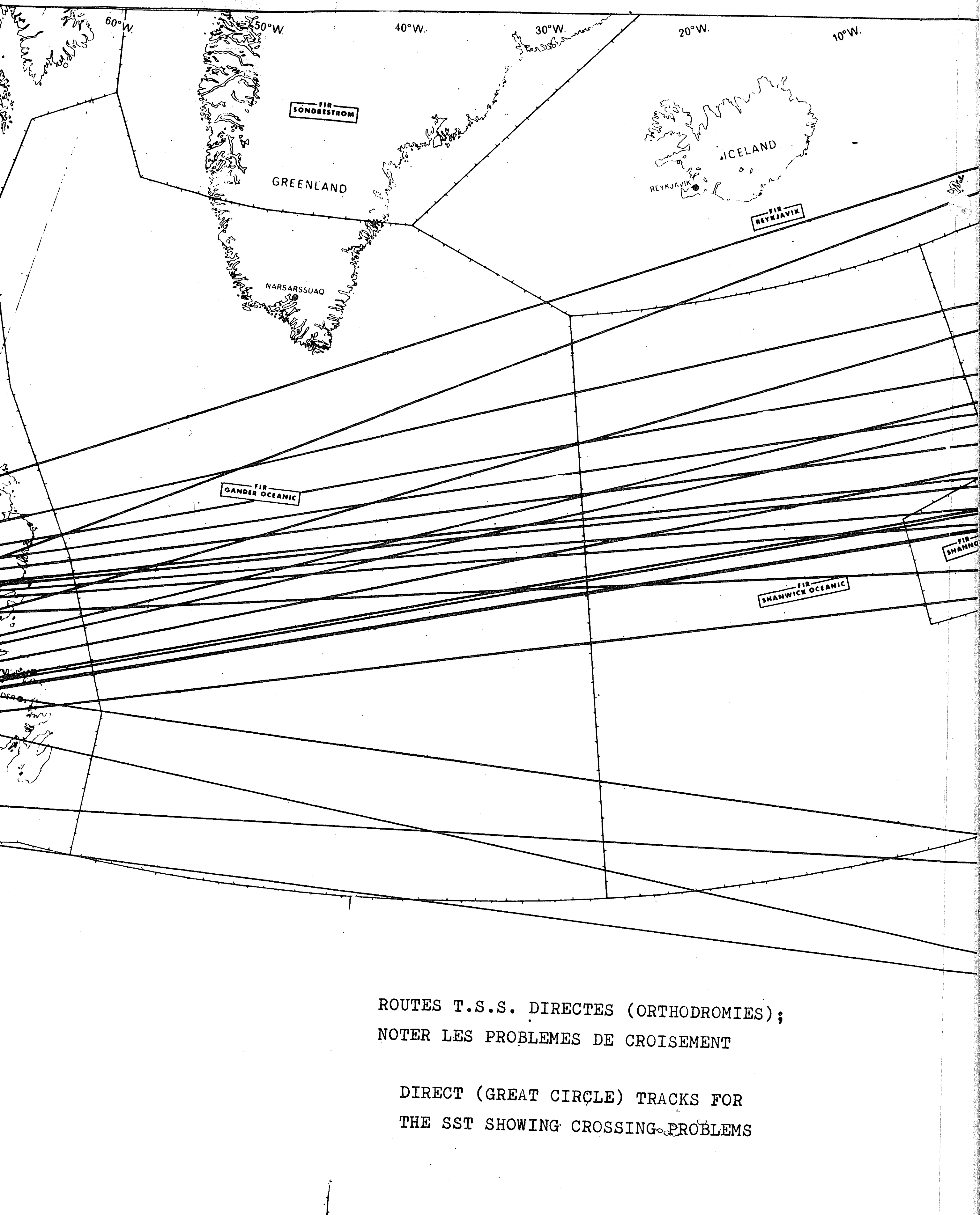
FIGURE 1-A-2

APPENDIX
APPENDICE 1-B



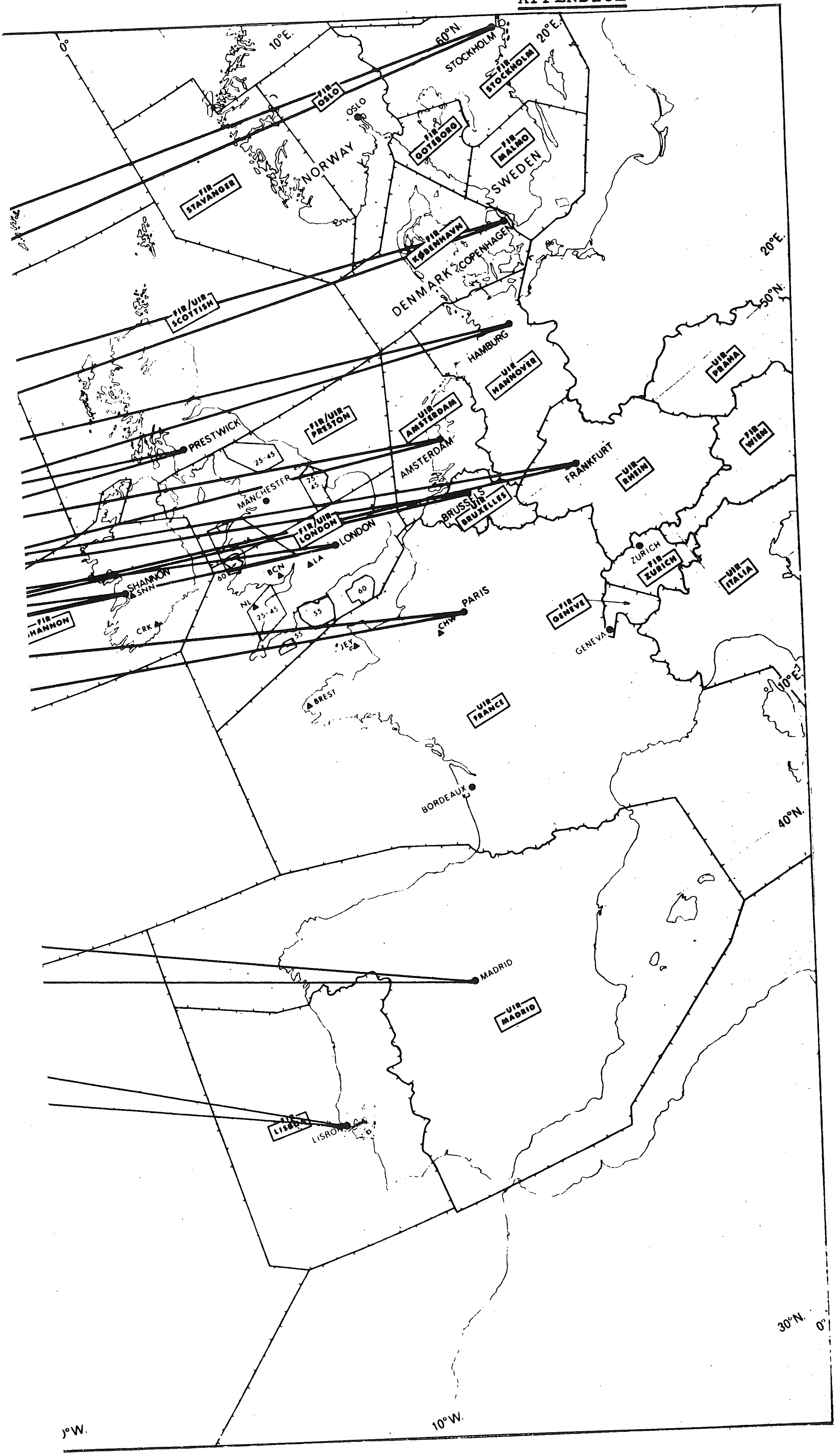


90°W
50°N
80°W
70°W
60°W
50°N
90°W
GOOSE
MONTREAL
80°W
40°N
NEW YORK
(J F KENNEDY)
BOSTON
HALIFAX
NOVA SCOTIA
SYDNEY
30°N
70°W
60°W
50°W



ROUTES T.S.S. DIRECTES (ORTHODROMIES);
NOTER LES PROBLEMES DE CROISEMENT

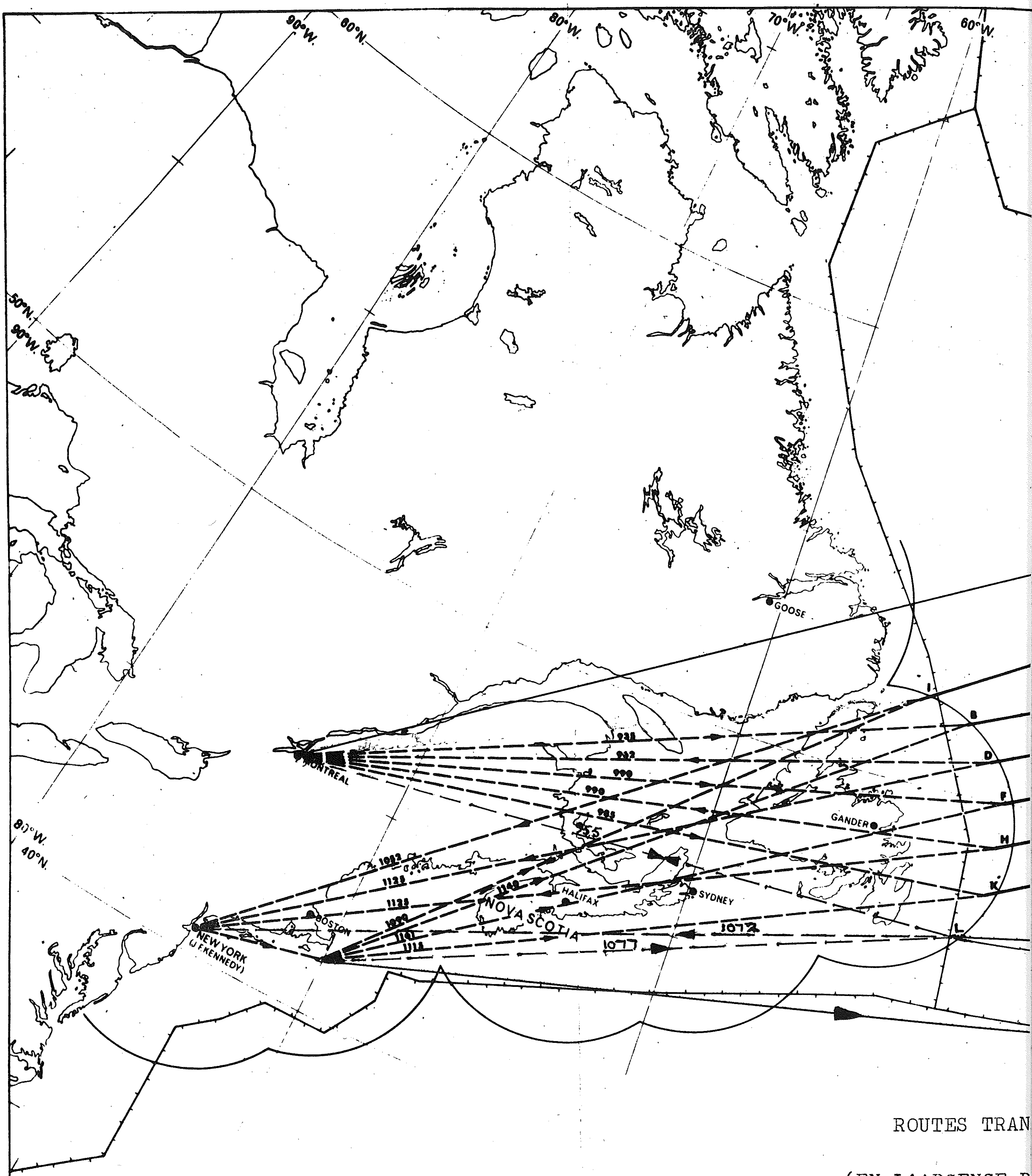
DIRECT (GREAT CIRCLE) TRACKS FOR
THE SST SHOWING CROSSING PROBLEMS


FIR OSLO
FIR STOCKHOLM
STOCKHOLM
OSLO
FIR GOTEBORG
FIR MALMO
NORWAY
SWEDEN
FIR STAVANGER
FIR KØBENHAVN
COPENHAGEN
DENMARK
FIR/UIR SCOTTISH
HAMBURG
UIR HANNOVER
UIR PRAHA
FIR/UIR PRESTON
UIR AMSTERDAM
PRESTWICK
AMSTERDAM
FRANKFURT
UIR RHEIN
FIR WIEN
MANCHESTER
BRUSSELS
UIR BRUXELLES
FIR/UIR LONDON
LONDON
ZURICH
FIR ZURICH
UIR ITALIA
SHANNON
SNN
BCN
LA
PARIS
CHW
FIR GENEVE
GENEVA
CRK
JEY
BREST
UIR FRANCE
BORDEAUX
MADRID
UIR MADRID
LISBOA
LISBON
0°
10°E.
20°E.
60°N.
50°N.
40°N.
30°N.
10°W.

DIRECT (GREAT CIRCLE) TRACKS FOR THE SST SHOWING CROSSING PROBLEMS/

ROUTES TSS DIRECTES (ORTHODROMIES) ET PROBLEMES DE CROISEMENT

	Great Circle Distances in NM/ Distances orthodromiques en NM
London - New York	2989
Paris - New York	3148
Frankfurt - New York	3340
Amsterdam - New York	3156
Brussels - New York	3176
Stockholm - New York	3403
Copenhagen - New York	3339
Lisbon - New York	2917
Hamburg - New York	3301
Madrid - New York	3109
London - Montreal	2815
Paris - Montreal	2983
Frankfurt - Montreal	3160
Amsterdam - Montreal	2971
Brussels - Montreal	2997
Stockholm - Montreal	3176
Copenhagen - Montreal	3131
Lisbon - Montreal	2826
Hamburg - Montreal	3104
Madrid - Montreal	2997



ROUTES TRAN

(EN L'ABSENCE D

POSSIBL

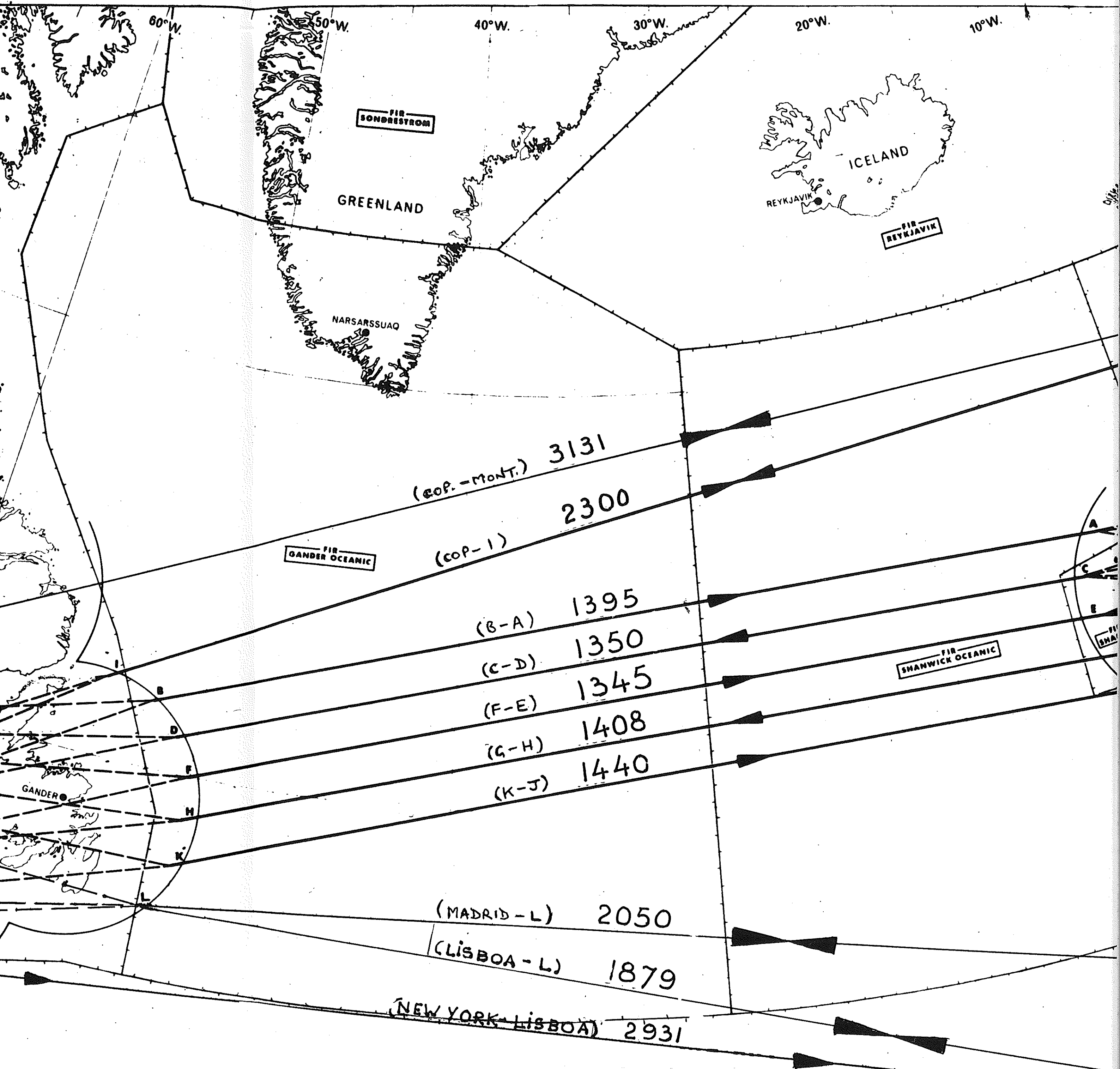
(ASSUM

LEGENDE

1. LES TRAITS EN TIRETE CORRESPONDENT A DES TRAJECTOIRES THEORIQUES SUJETTES A ETUDE ET A ACCORD INTERNATIONAUX.
2. LES ARCS DE CERCLE DELIMITENT LA COUVERTURE RADAR SUPPOSEE (200 NM).
3. ESPACEMENT LATERAL NAT PRIS = 60 NM.
4. LES ROUTES DE COPENHAGUE, MADRID ET LISBONNE FOURNISSENT DES EXEMPLES DE ROUTES A L'EXTERIEUR DES TRAJECTOIRES ORGANISEES.

30°N.

70°W. 60°W 50°W.



ROUTES TRANSATLANTIQUES SUSCEPTIBLES INITIALEMENT D'ETRE SUIVIES PAR TSS

(EN L'ABSENCE DE RESTRICTIONS RELATIVES AU BANG SONIQUE)

X.

POSSIBLE INITIAL NAT ROUTES FOR THE SST

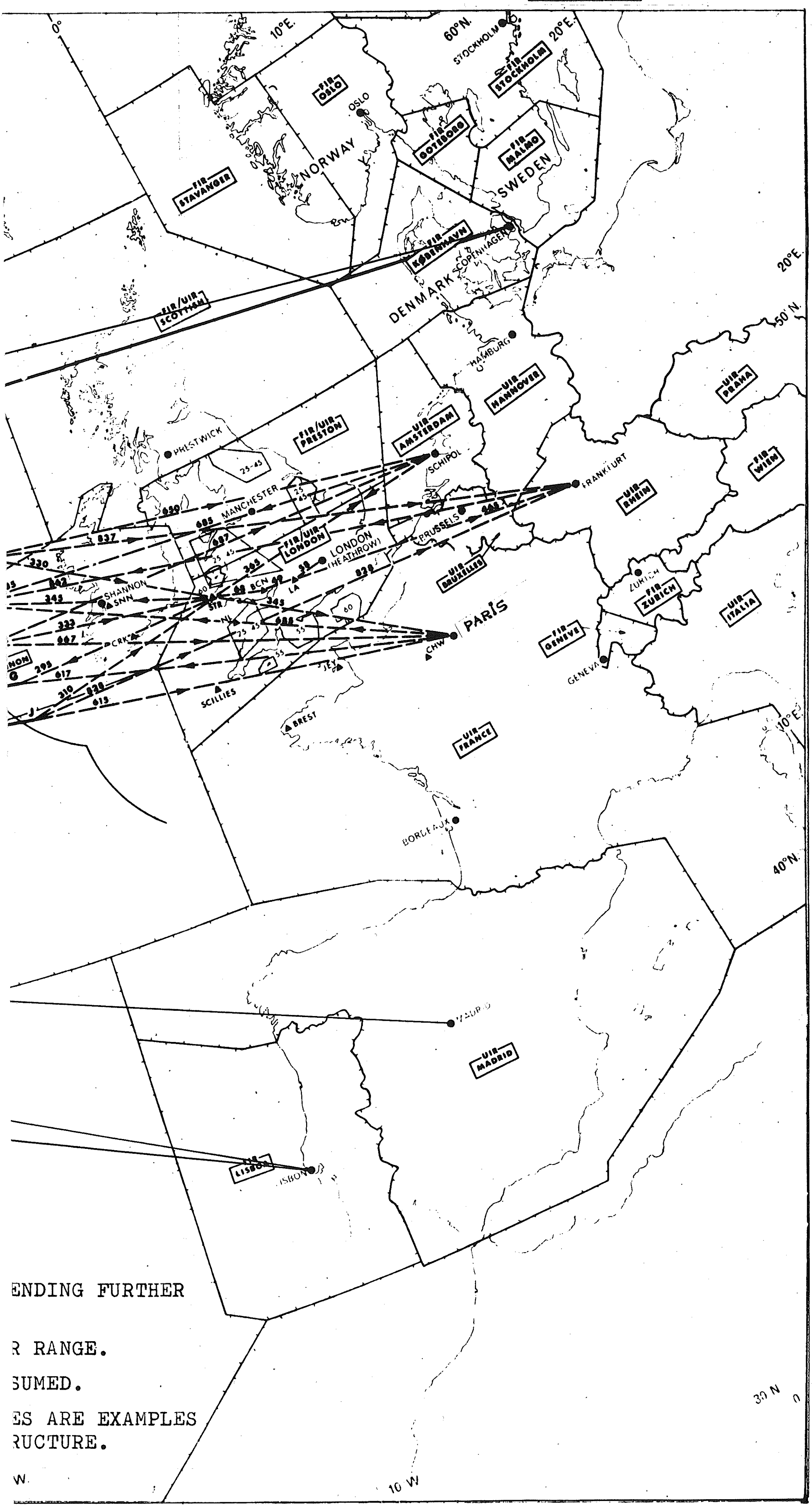
(ASSUMING NO SONIC BOOM RESTRICTIONS)

ENT

LEGEND

1. PECKED LINES ARE NOTIONAL ROUTES P
INTERNATIONAL STUDY AND AGREEMENT.
2. ARCS REPRESENT 200 NM ASSUMED RADA
3. NAT LATERAL SEPARATION OF 60 NM AS
4. COPENHAGEN, MADRID AND LISBON ROUT
OUTSIDE OCEANIC ORGANISED ROUTE ST

50°W. 40°W. 30°W. 20

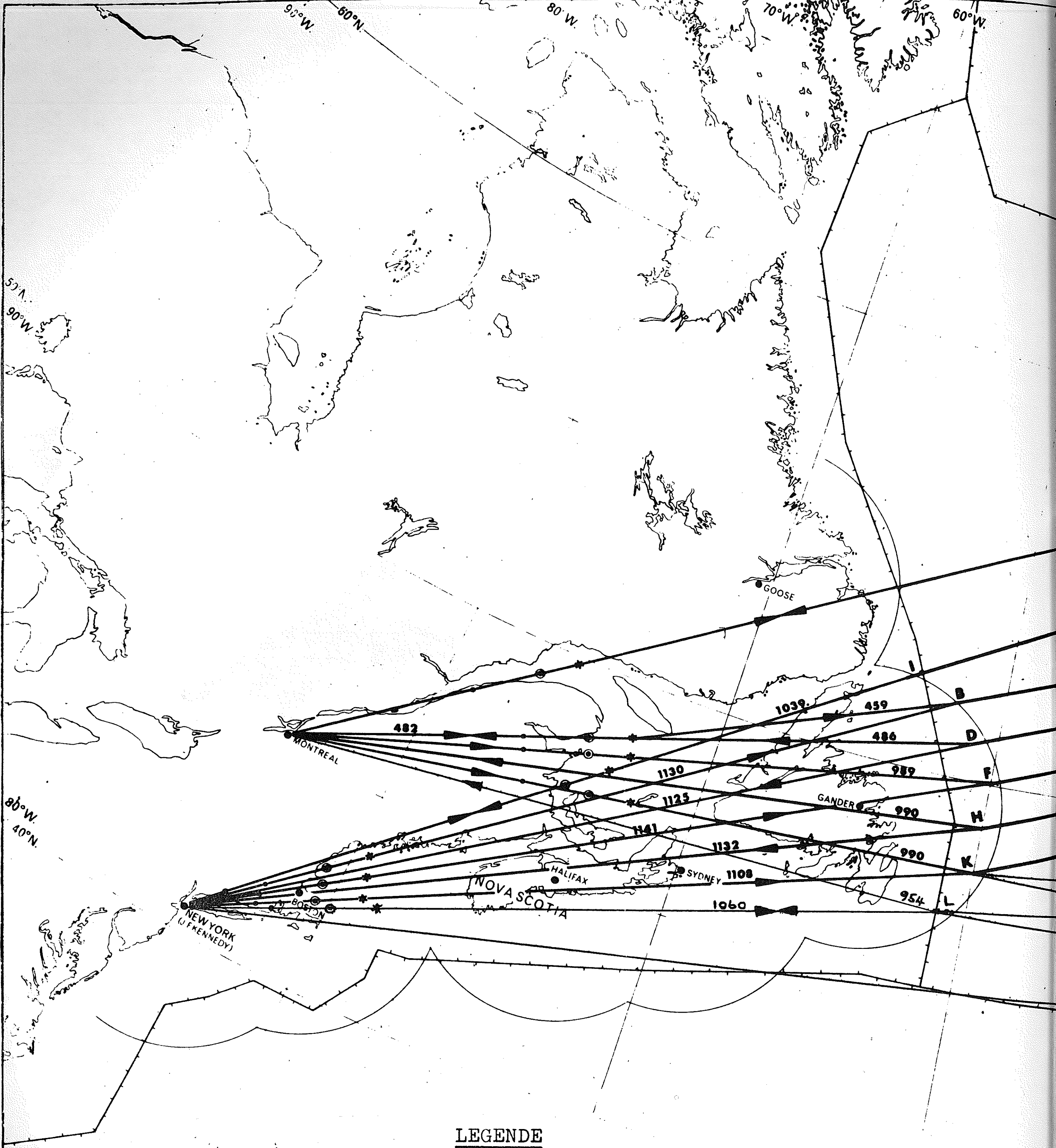

FIR STAVANGER
FIR OSLO
FIR GOTEBORG
FIR STOCKHOLM
FIR MALMO
FIR KØBENHAVN
FIR/UIR SCOTTISH
FIR/UIR PRESTON
FIR/UIR LONDON
UIR AMSTERDAM
UIR HANNOVER
UIR PRAHA
FIR WIEN
UIR RHEIN
UIR BRUXELLES
FIR ZURICH
UIR ITALIA
FIR GENEVE
UIR FRANCE
UIR MADRID
FIR LISBOA
NORWAY
SWEDEN
DENMARK
OSLO
STOCKHOLM
COPENHAGEN
HAMBURG
PRESTWICK
MANCHESTER
SCHIPOL
LONDON (HEATHROW)
BRUSSELS
FRANKFURT
SHANNON
SNN
PARIS
CHW
ZURICH
GENEVA
SCILLIES
BREST
BORDEAUX
MADRID
LISBON
60°N.
50°N.
40°N.
30 N
0°
10°E.
20°E.
10 W
ENDING FURTHER
R RANGE.
SUMED.
ES ARE EXAMPLES
RUCTURE.

POSSIBLE INITIAL NAT ROUTES FOR THE SST
(Assuming no Sonic Boom Restrictions)/

ROUTES TRANSATLANTIQUES SUSCEPTIBLES INITIALEMENT D'ETRE SUIVIES PAR LES TSS
(Dans l'hypothèse de l'absence de restrictions liées au bang sonique)

Route (In relevant single direction only) / Route (Un seul sens considéré)	Distances in NM via/ Distances en NM en passant par					
	G.C.*	A-B	C-D	E-F	G-H	J-K
New York - London - New York	2989	3040 (+51)	2995 (+6)	3014 (+25)	3003 (+14)	3040 (+51)
Paris - New York - Paris	3148	3210 (+62)	3160 (+12)	3173 (+25)	3150 (+2)	3170 (+22)
New York - Frankfurt - New York	3340	3372 (+32)	3340 (0)	3372 (+32)	3341 (+1)	3383 (+43)
Amsterdam - New York - Amsterdam	3156	3185 (+29)	3160 (+4)	3193 (+37)	3193 (+37)	3230 (+74)
New York - Brussels - New York	3176	3212 (+36)	3180 (+4)	3212 (+36)	3181 (+5)	3223 (+47)
Montreal - London - Montreal	2815	2835 (+20)	2832 (+17)	2843 (+28)	2868 (+53)	2910 (+95)
Paris - Montreal - Paris	2983	3005 (+22)	2997 (+14)	3002 (+19)	3015 (+32)	3040 (+57)
Montreal - Frankfurt - Montreal	3160	3167 (+7)	3174 (+14)	3201 (+41)	3226 (+66)	3253 (+93)
Amsterdam - Montreal - Amsterdam	2971	2980 (+9)	2997 (+26)	3022 (+51)	3058 (+87)	3100 (+129)
Montreal - Brussels - Montreal	2997	3007 (+10)	3014 (+17)	3041 (+44)	3066 (+69)	3093 (+96)
Copenhagen - Montreal - Copenhagen	3131	3131 (0)				
Copenhagen - New York	3339	3352 (+13) [Inbound routing] [retour]				
New York - Copenhagen	3339	3390 (+51) [Outbound routing] [aller]				
Madrid - Montreal - Madrid	2997	3005 (+8) [via L]				
Madrid - New York	3109	3122 (+13) [via L]				
New York - Madrid	3109	3127 (+18) [via L]				
Lisbon - Montreal - Lisbon	2826	2834 (+8) [via L]				
Lisbon - New York	2917	2951 (+34) [via L]				
New York - Lisbon	2917	2931 (+14) [via Nantucket]				

*G.C. = Great Circle / Orthodromie



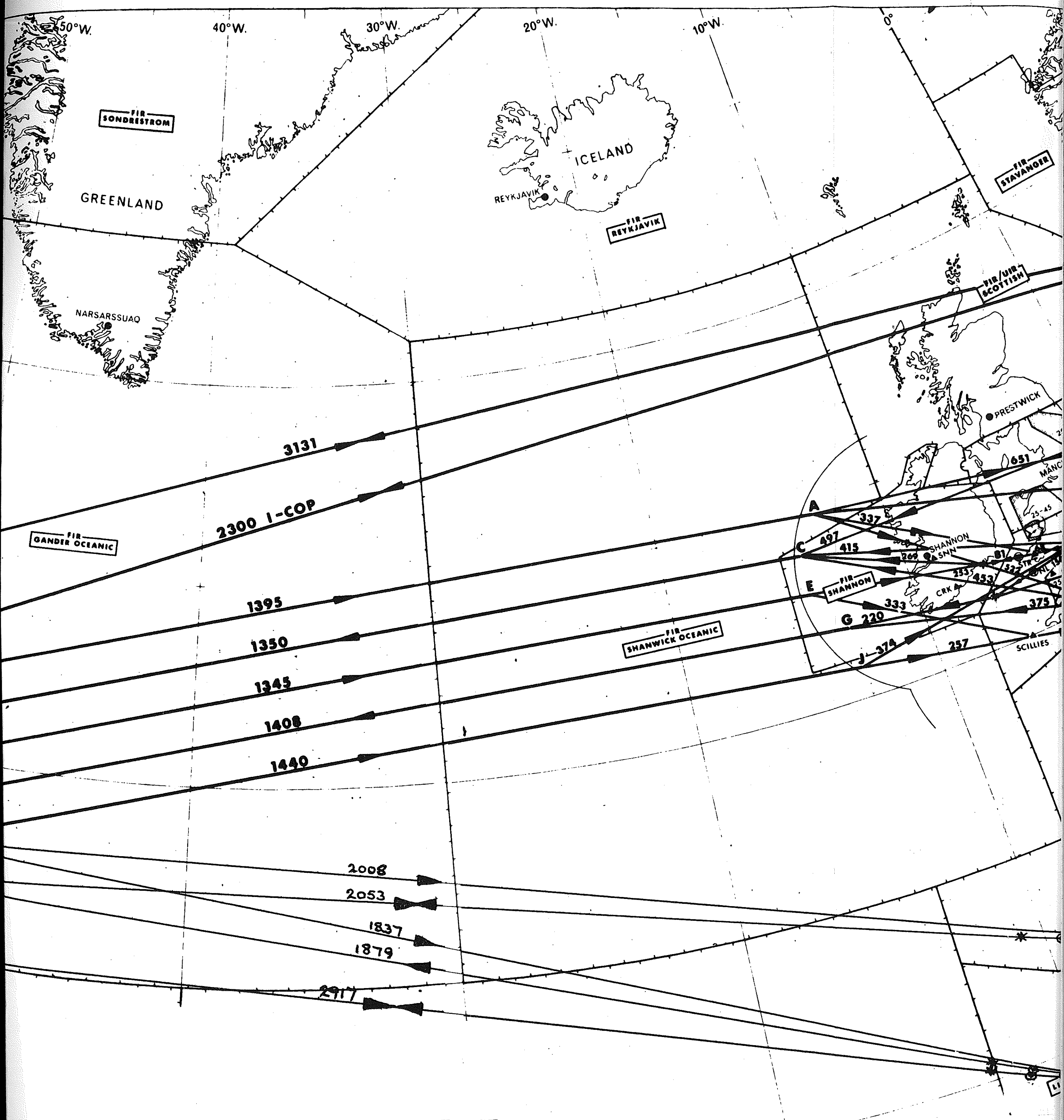
LEGENDE

1. LES ARCS DE CERCLE INDIQUENT LA COUVERTURE RADAR SUPPOSEE (200 NM).

2. SYMBOLES: (•) MACH 0,93.
   (⊙) POINT DE FOCALISATION AU SOL.
   (*) FIN DE PHASE "MANOEUVRES A EVITER" A MACH 1,4.

3. ESPACEMENT LATERAL NAT PRIS = 60 NM.

4. LES ROUTES DE COPENHAGUE, MADRID ET LISBONNE FOURNISSENT DES EXEMPLES DE ROUTES A L'EXTERIEUR DES TRAJECTOIRES ORGANISEES.



POSSIBLE INITIAL NAT ROUTES FOR THE SST

(INITIAL FOCUSSED BOOM ONLY PROHIBITED OVER LAND)

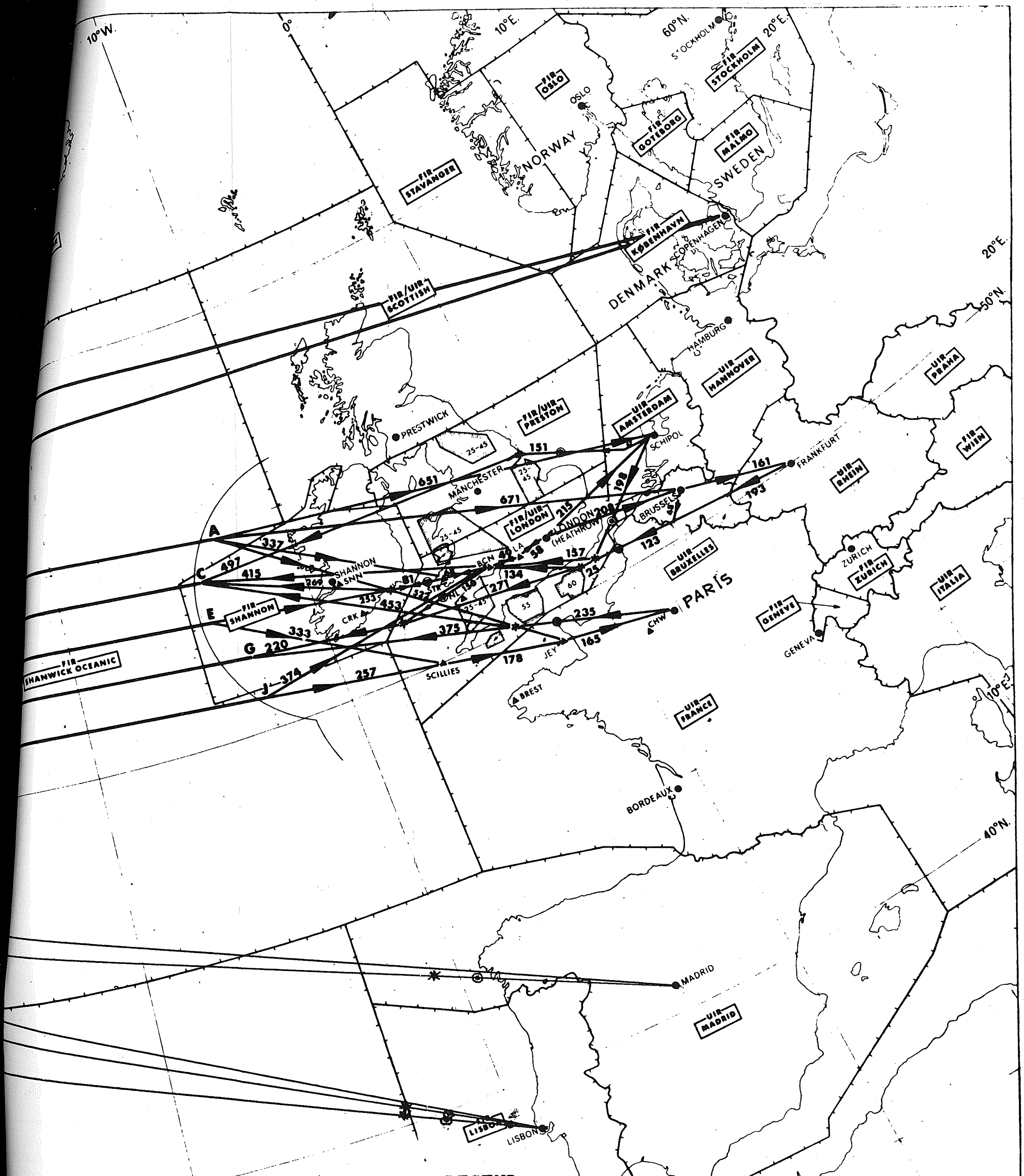
ROUTES TRANSATLANTIQUES SUSCEPTIBLES INITIALEMENT D'ETRE SUIVIES PAR TSS

(BANG INITIAL FOCALISE INTERDIT SUR TERRE SEULEMENT)

LEG

1. ARCS REPRESENT 200 NM A
2. SYMBOL (•) REPRESENTS N GROUND POINT OF FOCUSSE END OF "NOT AMENABLE TO MACH 1.4 IS MARKED (*).
3. NAT LATERAL SEPARATION
4. COPENHAGEN, MADRID AND OUTSIDE OCEANIC ORGANIS

40°W. 30°W.



LEGEND

1. ARCS REPRESENT 200 NM ASSUMED RADAR RANGE.
2. SYMBOL (•) REPRESENTS MACH 0.93.
   GROUND POINT OF FOCUSSED SONIC BOOM IS MARKED (◎).
   END OF "NOT AMENABLE TO MANOEUVRE" PHASE AT
   MACH 1.4 IS MARKED (*).
3. NAT LATERAL SEPARATION OF 60 NM ASSUMED.
4. COPENHAGEN, MADRID AND LISBON ROUTES ARE EXAMPLES
   OUTSIDE OCEANIC ORGANISED ROUTE STRUCTURE.

POSSIBLE NAT ROUTES FOR THE SST
(Initial focussed boom only prohibited over land)/

ROUTES TRANSATLANTIQUES SUSCEPTIBLES D'ETRE SUIVIES PAR LES TSS
(Bang initial focalisé interdit sur terre seulement)

Route (In relevant single direction only)/ Route (Un seul sens considéré)	Distances in NM via/ Distances en NM en passant par					
	G.C.*	A-B	C-D	E-F	G-H	J-K
New York - London - New York	2989	3037 (+48)	3000 (+11)	2995 (+6)	3017 (+28)	3029 (+41)
Paris - New York - Paris	3148	3212 (+64)	3163 (+15)	3162 (+14)	3150 (+2)	3148 (0)
New York - Frankfurt - New York	3340	3406 (+66)	3365 (+25)	3364 (+24)	3372 (+32)	3398 (+58)
Amsterdam - New York - Amsterdam	3156	3176 (+20)	3170 (+14)	3210 (+54)	3254 (+98)	3244 (+88)
New York - Brussels - New York	3176	3196 (+20)	3220 (+44)	3203 (+27)	3227 (+51)	3237 (+61)
Montreal - London - Montreal	2815	2848 (+33)	2843 (+28)	2843 (+28)	2875 (+60)	2911 (+96)
Paris - Montreal - Paris	2983	3023 (+40)	3006 (+23)	3010 (+27)	3008 (+25)	3030 (+47)
Montreal - Frankfurt - Montreal	3160	3168 (+8)	3208 (+48)	3212 (+52)	3230 (+70)	3280 (+120)
Amsterdam - Montreal - Amsterdam	2971	2987 (+16)	3013 (+42)	3058 (+87)	3112 (+141)	3126 (+155)
Montreal - Brussels - Montreal	2997	3007 (+10)	3048 (+51)	3051 (+54)	3085 (+88)	3119 (+122)
Copenhagen - Montreal - Copenhagen	3131	3130 (0)	[direct]			
Copenhagen - New York - Copenhagen	3339	3360 (+21)	[direct]			
Madrid - Montreal	2997	3007 (+10)	[via L]			
Montreal - Madrid	2997	2998 (+1)	[via K]			
Madrid - New York - Madrid	3109	3113 (+4)	[via L]			
Lisbon - Montreal	2826	2833 (+7)	[via L]			
Montreal - Lisbon	2826	2827 (+1)	[via K]			
Lisbon - New York - Lisbon	2917	2917 (0)				

*G.C. = Great Circle / Orthodromie

Possible Initial North Atlantic Routes for the SST

(Appendix 1-E)

(Initial Focussed Boom Only Prohibited Over Land)

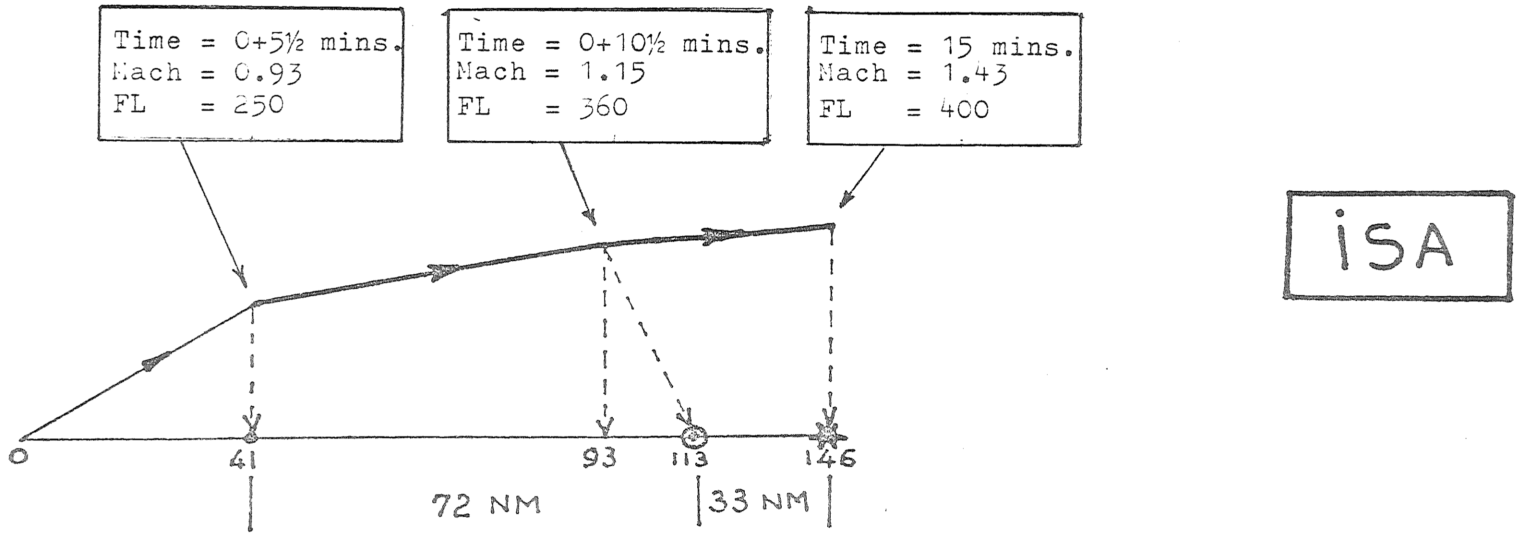
Explanatory Note

1. The North American routes and to an even larger extent, the European routes to and from the oceanic organized track structure are purely notional. Route alignment is, of course, a matter for individual States to decide, consulting adjoining and other States as necessary.

2. The alternate directions of the routes depicted provide increased lateral separation between same direction SST flights. These directions, however, are not sacrosanct. OACs, after proper co-ordination, may assign routes to aircraft in any manner which best suits the particular circumstances, e.g., a westbound route to an eastbound aircraft and vice versa.

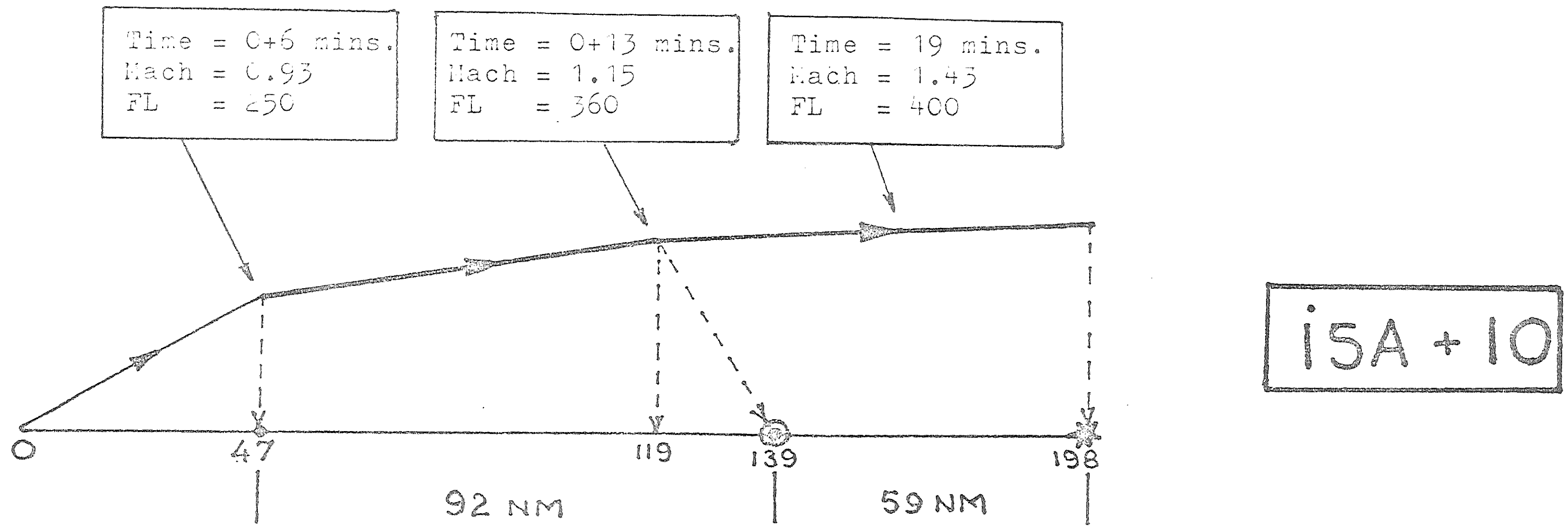
3. The initial focussed boom has been plotted on relevant routes with an arbitrary tolerance of 10 NM from adjacent land.

The symbol ⊙ indicates the focussed boom point. A point 33 NM along track indicates the end of "not amenable to manoeuvre" phase (shown by ✱). Plot a point 72 NM back from point ⊙ which indicates the beginning of phase (shown by ●).



CONCORDE STAGE O ENGINES TAKE-OFF WEIGHT 370 000 lb

The symbol ⊙ indicates the focussed boom point. A point 59 NM along track indicates the end of "not amenable to manoeuvre" phase (shown by ✱). Plot a point 92 NM back from point ⊙ which indicates the beginning of phase (shown by ●).



PARAMETERS TO BE USED WHEN DETERMINING THE "NOT AMENABLE TO MANOEUVRE" DISTANCE BETWEEN MACH = 0.93 AND MACH = 1.43

NOTE ON SONIC BOOM

1. The sonic boom produced by an aircraft moving at Mach 1 or faster is propagated in a direction at right angles to the shock wave. The aircraft can thus be regarded as generating rays of sound (see Fig. 1) which diverge from the flight path at an angle θ given by:

$$\cos \theta = \frac{1}{M}$$

The angle of divergence of the rays thus increases as the speed builds up.

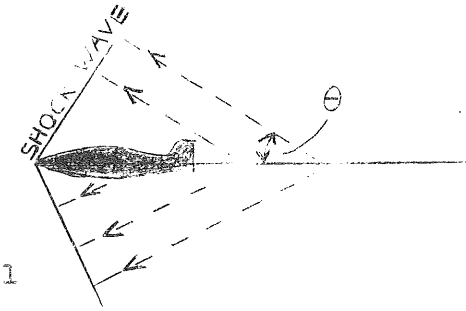


Fig. 1

2. During trans-sonic acceleration the change in speed causes the sound rays to converge so that they may become focussed on some point below the aircraft (Fig. 2).

Focussing of rays

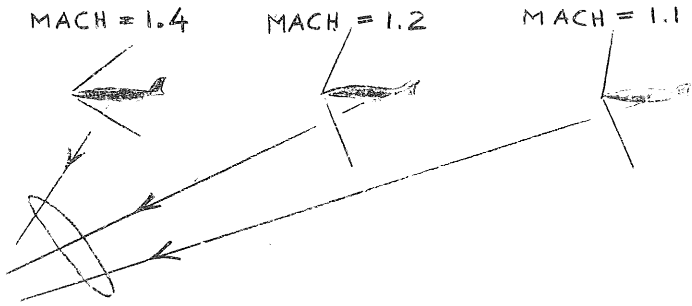


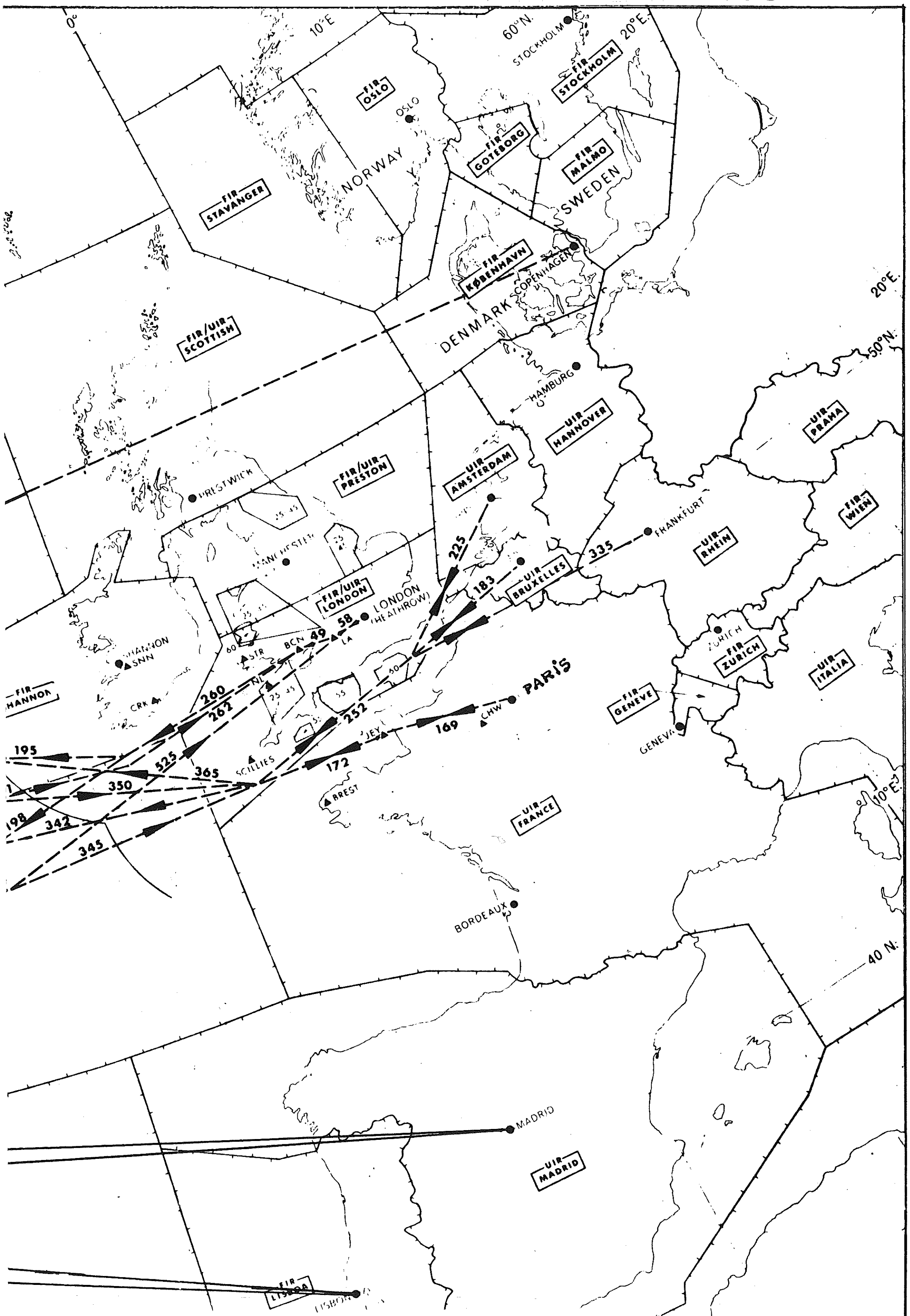
Fig. 2

At the point of focus the sonic boom overpressure can be twice as great as that of the unfocussed boom. In three dimensions the point of focus becomes a horseshoe-shaped curve on the ground. During trans-sonic deceleration the opposite effect occurs - the rays diverge and the boom is quieter than normal.

3. The rays of sound only travel in straight lines in a constant-temperature atmosphere. In the real atmosphere the temperature decreases with height below the tropopause. In this region therefore the rays are refracted upwards. Indeed for any aircraft travelling at less than Mach 1.15 at or above the tropopause, the rays will be refracted upward to such an extent that they will not reach the ground at all.

4. Thus, for a Concorde accelerating from Mach 0.93, no shockwave generated by the aircraft at a lower speed than Mach 1.15 will reach the ground. The aircraft will attain Mach 1.15 about 60 - 70 NM after start of acceleration, depending on the temperature. Because the sound rays are projected forwards (Fig. 1) and refracted upwards, the sound generated by the aircraft at Mach 1.15 only reaches the ground at a point about 20 NM further forward than the point at which the aircraft attains this speed.

5. In total therefore, the sonic boom is only heard on the ground at a point some 80 - 90 NM from the point below the position where acceleration starts. This point forms the apex of the horseshoe curve and the focussed boom occurs there.



LEGEND

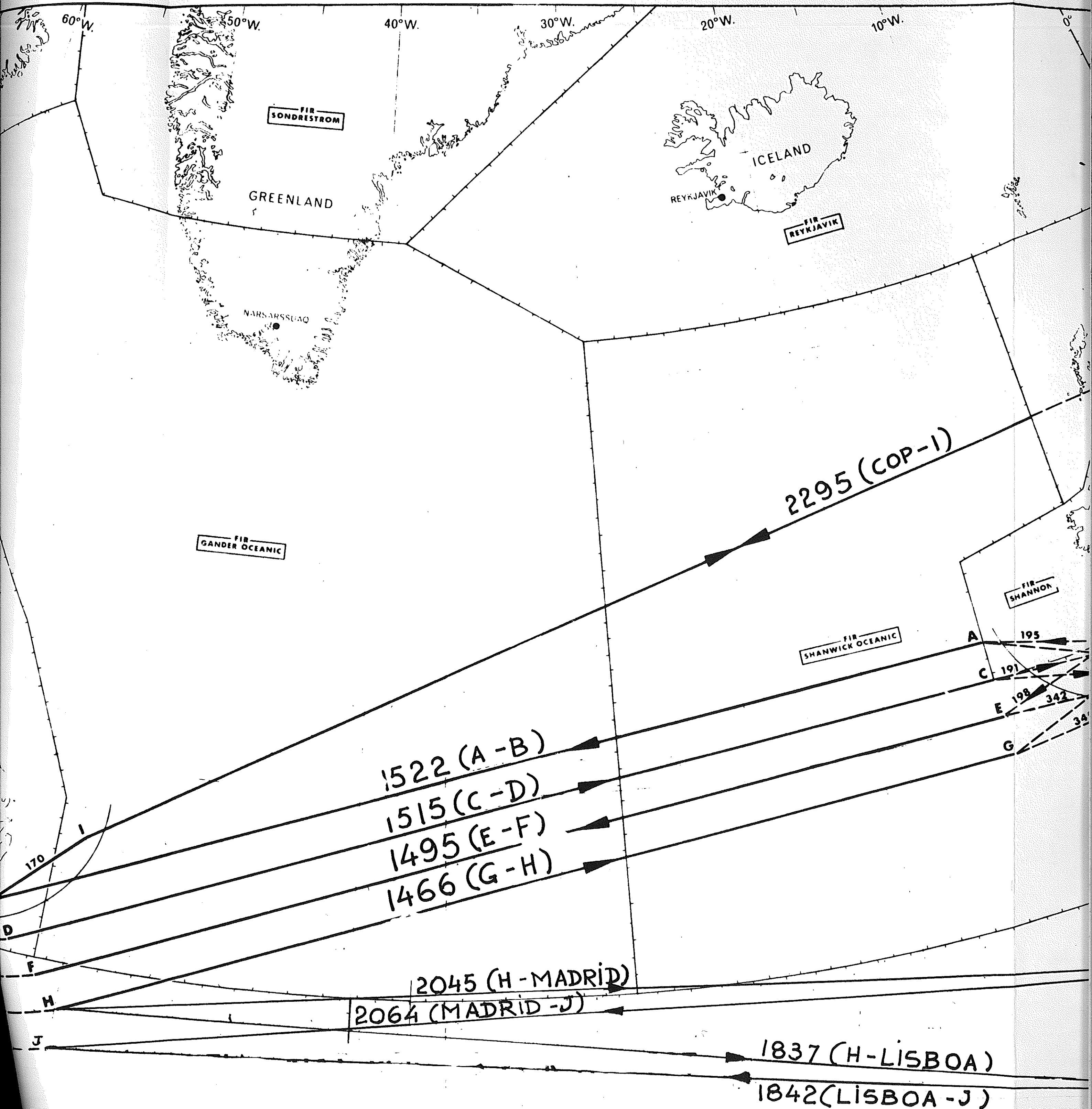
PECKED LINES ARE NOTIONAL ROUTES PENDING FURTHER INTERNATIONAL STUDY AND AGREEMENT.

ARCS REPRESENT 200 NM ASSUMED RADAR RANGE.

NAT LATERAL SEPARATION OF 60 NM ASSUMED.

NATURAL VERTICAL SEPARATION OF AT LEAST 4 000 FT. ASSUMED BETWEEN OPPOSITE DIRECTION, SSTs EAST OF 15°W AND WEST OF 60°W EXCLUDING CLIMB AND DESCENT.

COPENHAGEN, MADRID AND LISBON ROUTES ARE EXAMPLES OUTSIDE OCEANIC ORGANISED ROUTE STRUCTURE.

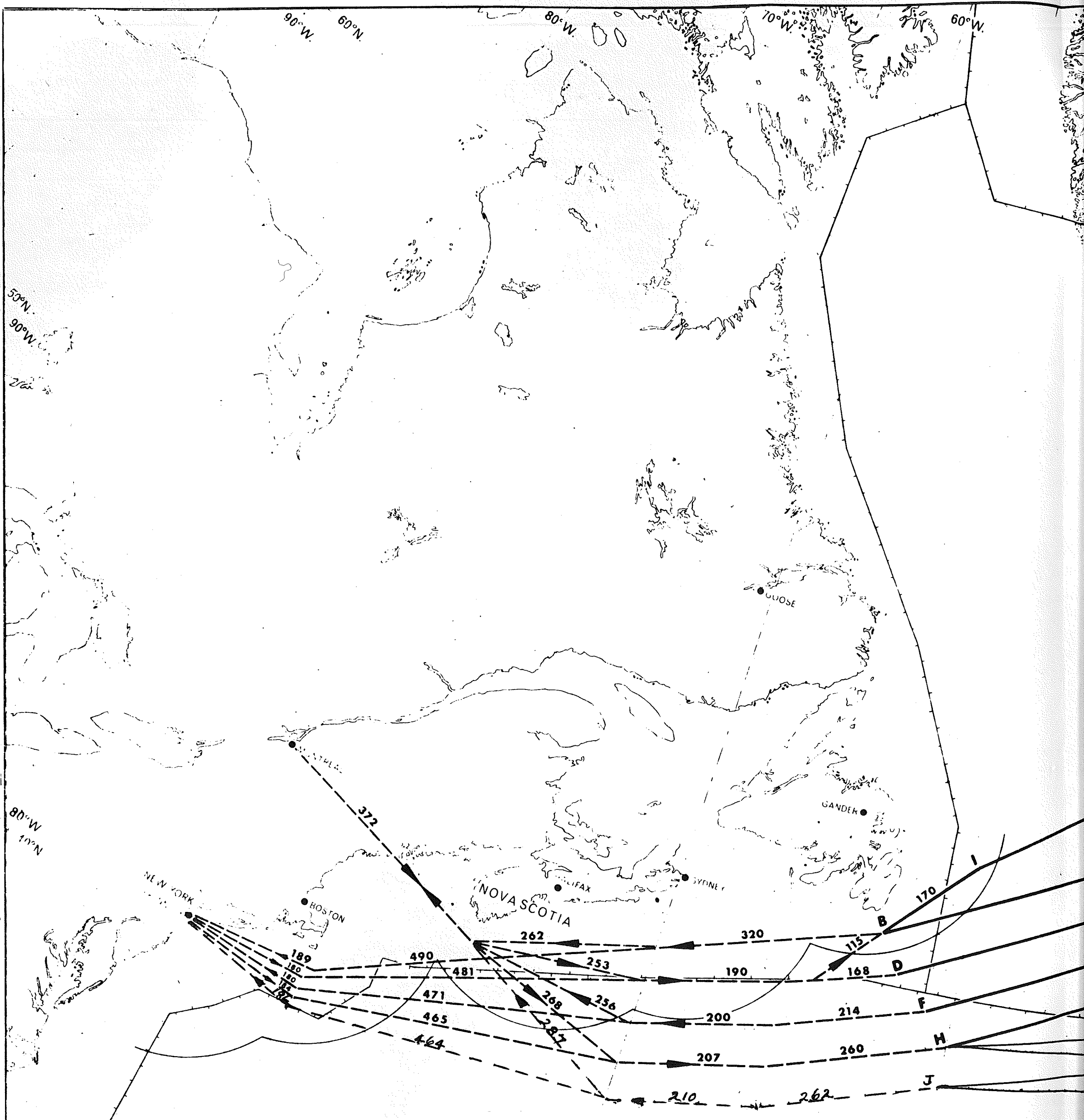


POSSIBLE INITIAL NAT ROUTES FOR THE SST
(ASSUMING SONIC BOOM RESTRICTED TO OVER SEA)

ROUTES TRANSATLANTIQUES SUSCEPTIBLES INITIALEMENT D'ETRE SUIVIES PAR TSS
(BANG SONIQUE SUR MER SEULEMENT)

1. PECKE INTER
2. ARCS
3. NAT I
4. NATUR ASSUM 15°W
5. COPEN OUTSI

40°W. 30°W.



LEGENDE

1. LES TRAITS EN TIRETE CORRESPONDENT A DES TRAJECTOIRES THEORIQUES SUJETTES A ETUDE ET A ACCORD INTERNATIONAUX.

2. LES ARCS DE CERCLE DELIMITENT LA COUVERTURE RADAR SUPPOSEE (200 NM).

3. ESPACEMENT LATERAL NAT PRIS = 60 NM.

4. UN ESPACEMENT VERTICAL NATUREL D'AU MOIN 4 000 FT. EST ADMIS ENTRE TSS DE SENS OPPOSES A L'EST DE 15°W ET A L'OUEST DE 60°W, SAUF EN MONTEE/DESCENTE.

5. LES ROUTES DE COPENHAGUE, MADRID ET LISBONNE FOURNISSENT DES EXEMPLES DE ROUTES A L'EXTERIEUR DES TRAJECTOIRES ORGANISEES.

30°N.
70°W.
60°W
50°W.

POSSIBLE INITIAL NAT ROUTES FOR THE SST (Assuming Sonic Boom Restricted to Over Sea)/

ROUTES TRANSATLANTIQUES SUSCEPTIBLES INITIALEMENT D'ETRE SUIVIES PAR LES TSS (Bang sonique sur mer seulement)

Route (In relevant single direction only)/ Route (Un seul sens considéré)	Distances in NM via/ Distances en NM en passant par				
	G.C.*	A-B	C-D	E-F	G-H
London - New York - London	2989	3083 (+94)	3094 (+104)	3125 (+136)	3165 (+176)
Paris - New York - Paris	3148	3227 (+79)	3225 (+77)	3243 (+95)	3268 (+120)
Frankfurt - New York - Frankfurt	3340	3473 (+133)	3471 (+131)	3489 (+149)	3514 (+174)
Amsterdam - New York - Amsterdam	3156	3363 (+207)	3361 (+205)	3379 (+223)	3404 (+248)
Brussels - New York - Brussels	3176	3321 (+145)	3319 (+143)	3337 (+161)	3362 (+186)
London - Montreal - London	2815	3038 (+223)	3094 (+279)	3125 (+310)	3165 (+350)
Frankfurt - Montreal - Frankfurt	3160	3428 (+268)	3435 (+275)	3466 (+306)	3505 (+345)
Paris - Montreal - Paris	2893	3182 (+199)	3189 (+206)	3220 (+237)	3259 (+276)
Amsterdam - Montreal - Amsterdam	2971	3318 (+347)	3325 (+354)	3356 (+385)	3395 (+424)
Brussels - Montreal - Brussels	2997	3276 (+279)	3283 (+286)	3314 (+317)	3353 (+356)
Copenhagen - Montreal	3131	3419 (+288) [via I - B]			
Montreal - Copenhagen	3131	3395 (+264) [via B - I]			
Copenhagen - New York	3339	3464 (+125) [via I - B]			
New York - Copenhagen	3339	3431 (+92) [via B - I]			
Madrid - Montreal	2997	3195 (+198) [via J]			
Montreal - Madrid	2997	3152 (+155) [via H]			
Madrid - New York	3109	3186 (+77) [via J]			
New York - Madrid	3109	3161 (+52) [via H]			
Lisbon - Montreal	2826	2973 (+147) [via J]			
Montreal - Lisbon	2826	2944 (+118) [via H]			
Lisbon - New York	2917	2964 (+47) [via J]			
New York - Lisbon	2917	2944 (+27) [via H]			

*G.C. = Great Circle / Orthodromie

APPENDIX 1-G

CONCORDE
EFFECT OF CRUISE TEMPERATURE ON TRACK SELECTION

1. SUMMARY

1.1 A study has been made to ascertain whether significant savings in fuel and time could be achieved by deviating from the Great Circle track in search of a cooler environment, having regard to the extra distance that would be involved in the course of this operation. The examination has been confined to a typical North Atlantic route where the length of time spent in cruise would provide the best scope for exploring a wide variation of temperature. The results of the examination show that an operation of this nature could only be a worthwhile consideration if the temperature variation across the Great Circle was on average 1°C in not more than 30 NM.

1.2 Since a temperature gradient of this magnitude would be encountered on only infrequent occasions, it is unlikely that there will be any economic benefits to be derived by changing track from the Great Circle.

2. DISCUSSION

2.1 For the purpose of this study the sector London - New York has been selected for examination and consequently the results are influenced by the meteorological pattern which is found on the North Atlantic. In this area, the temperatures at 100 mb. are generally from ISA to ISA +10°C, and between London and New York the cooler temperatures are usually found south of the Great Circle. The justification for changing the track would be the certainty that by so doing the average forecast temperature on the new track would be more favourable than the average forecast temperature for the Great Circle. The problem is therefore reduced to determining what amount of extra air distance can be tolerated in a cooler environment before the nominal fuel requirement is exceeded.

3. RESULTS

3.1 In this study the Great Circle track from London to New York is taken as 3 000 NM.

3.2 Two hypothetical methods of deviating from the Great Circle have been assumed. In the first instance the maximum displacement is assumed to occur at mid-distance and is achieved by flying direct to the point at mid-range. In the second instance a track parallel to the Great Circle is assumed to be flown; this is achieved by heading off 45° at the start and end of cruise.

3.3 Figure 1-G-1 shows the variation of maximum displacement at mid-range with track distance. From this it can be seen that for a maximum displacement of 250 NM the additional overall distance would vary from 205 NM to 40 NM. However, the average temperature band encompassed by these two methods could be markedly different, since in one case there is only a very gradual deviation from the nominal track during the initial and final stages of cruise, whereas the parallel-track technique offers a better probability of capturing a wider temperature band for a longer period.

3.4 Figures 1-G-2 and 1-G-3 show the variation of block fuel with distance and temperature for both Stage 0 and Stage 1 engine ratings. From these diagrams it is possible to determine the additional stage distance that can be tolerated in exchange for a given temperature improvement.

3.5 From Figure 1-G-2 it is seen that the block fuel for a 3 000 NM stage in ISA +5°C is 154 600 lb. This same fuel would permit a total stage distance of 3 045 NM in ISA conditions. The additional 45 NM would allow a maximum displacement of between 260 NM and 55 NM, depending on which procedure was used to deviate from the nominal track. Therefore the temperature gradient across track would have to be better than 5°C in 260/55 NM or 1°C in 52/11 NM before any benefit would be derived from the change in track. Within the temperature bracket of ISA to ISA +10°C and for distances from 3 000 NM to 3 200 NM the range of temperature gradient is found to vary between 56 NM and 5 NM per 1°C.

3.6 Figures 1-G-4 and 1-G-5 show the variation of block time with distance and temperature for both engine ratings. Using these diagrams it is possible to determine the time savings that could be effected by changing track for colder climates.

3.7 With a nominal distance of 3 000 NM the block time is approximately 3hrs. 28mins. in ISA +5°C. The same block time can be achieved by flying an extra 40 NM in ISA conditions provided that there is no change in the average wind component along the new track. The extra distance of 40 NM corresponds to a cross track displacement of between 240 NM and 50 NM so that the required temperature gradient would have to be better than 1°C in 48/10 NM for any time saving to result. However, if the average wind component were to increase by more than 5 KT for every 1°C drop in temperature the potential time saving would be lost.

3.8 The meteorological situation on the North Atlantic is such that the 100 mb winds on the London - New York Great Circle are mainly westerly and tend to decline slightly to the south of this track. In general, therefore, there is a favourable combination of lower headwinds and colder climates to the south of the Great Circle on the westbound route but there is little probability of finding the steep temperature gradient necessary to produce significant savings in fuel and time.

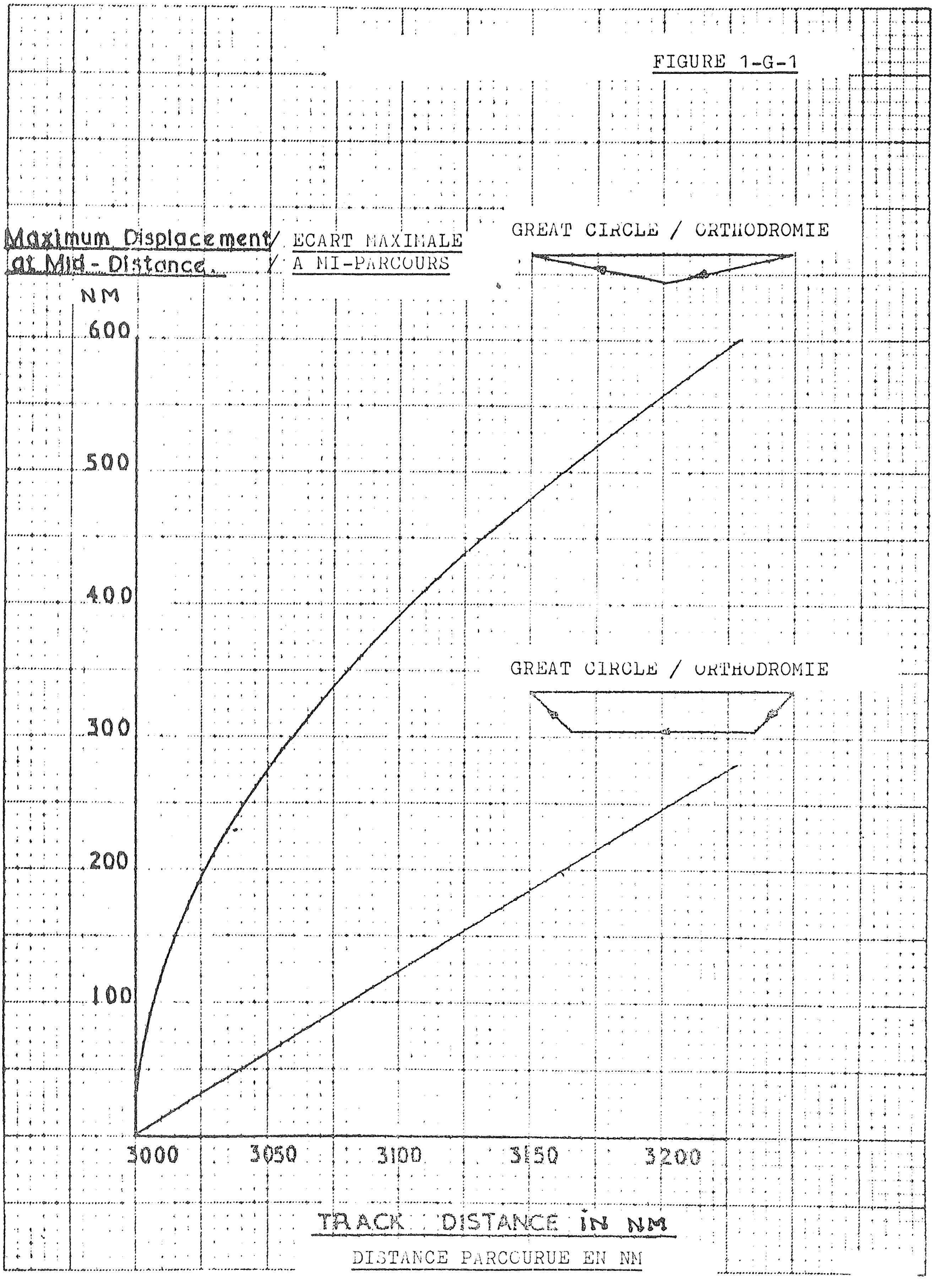
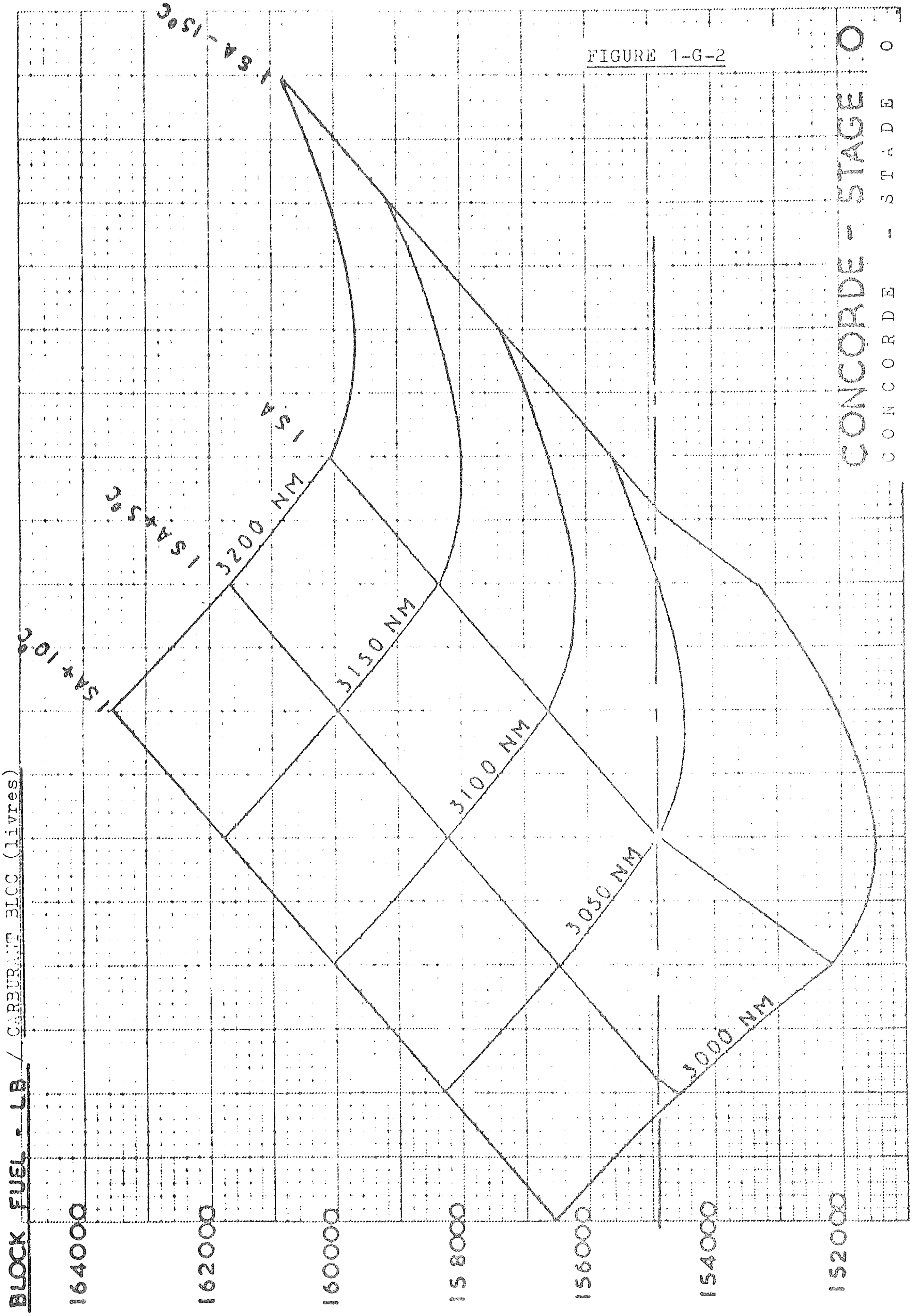


FIGURE 1-G-1
Maximum Displacement at Mid-Distance. / ECART MAXIMALE A MI-PARCOURS
NM
600
500
400
300
200
100
GREAT CIRCLE / ORTHODROMIE
GREAT CIRCLE / ORTHODROMIE
3000
3050
3100
3150
3200
TRACK DISTANCE IN NM
DISTANCE PARCOURUE EN NM



BLOCK FUEL - LB / CARBURANT BLOC (livres)
164000
162000
160000
158000
156000
154000
152000
ISA-15°C
ISA
ISA+5°C
ISA+10°C
3200 NM
3150 NM
3100 NM
3050 NM
3000 NM
FIGURE 1-G-2
CONCORDE - STAGE O
CONCORDE - STADE O

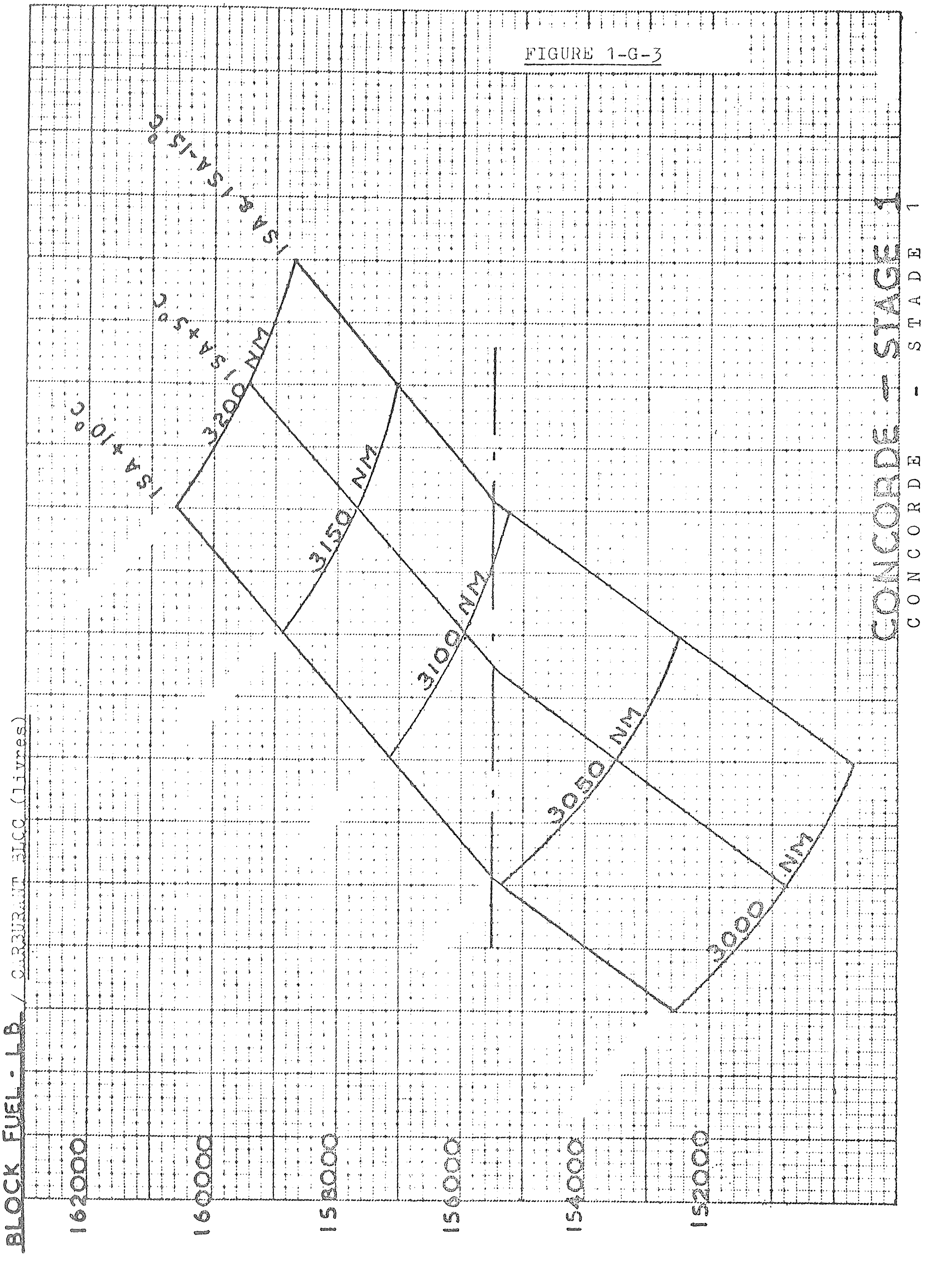


FIGURE 1-G-3
BLOCK FUEL - LB / CARBURANT BLOC (livres)
162000
160000
158000
156000
154000
152000
ISA & ISA-15 °C
ISA+5 °C
ISA+10 °C
3200 NM
3150 NM
3100 NM
3050 NM
3000 NM
CONCORDE – STAGE 1
CONCORDE - STADE 1

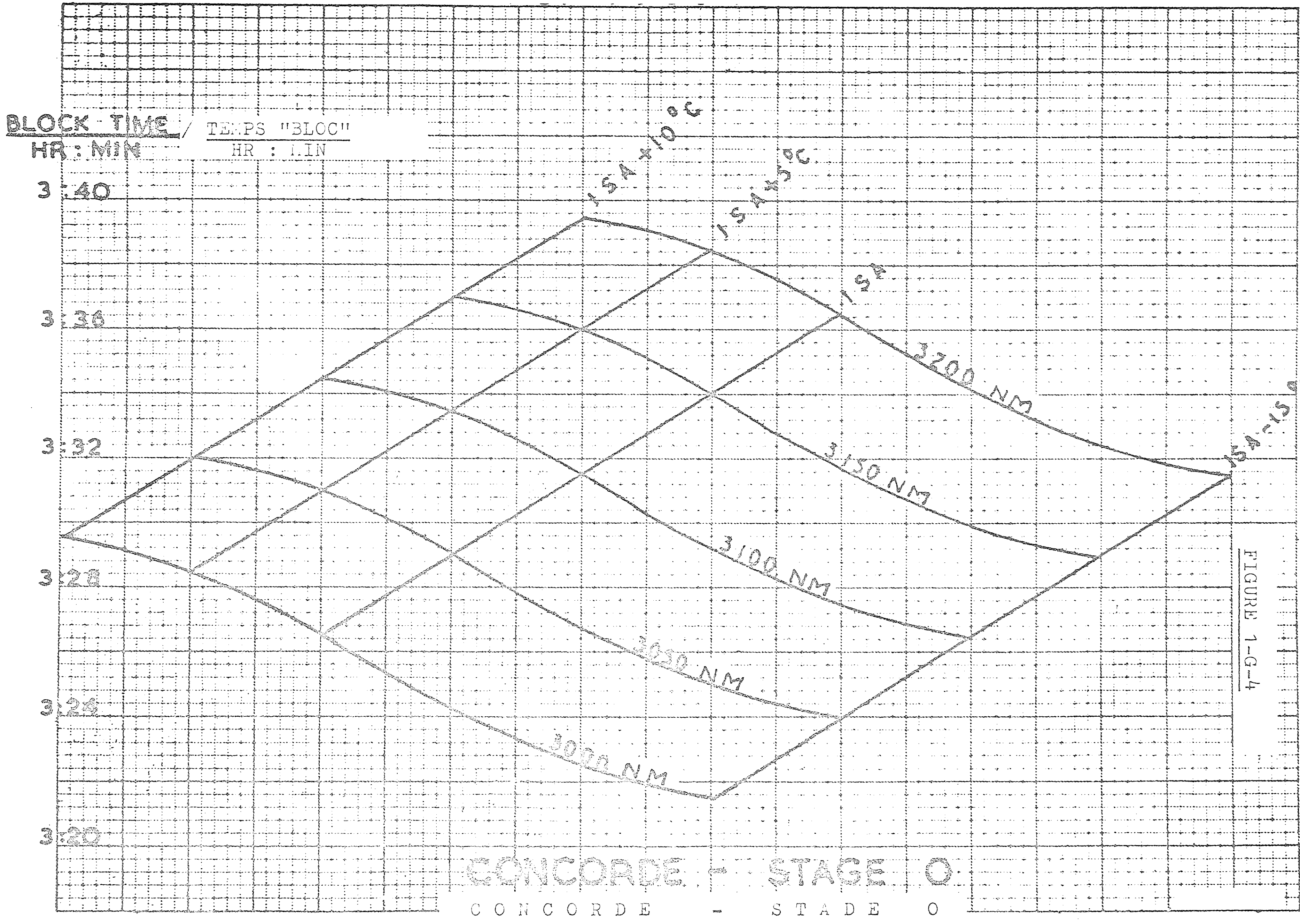

BLOCK TIME / TEMPS "BLOC"
HR : MIN
3:40
3:36
3:32
3:28
3:24
3:20
ISA+10 °C
ISA+5 °C
ISA
ISA-15 °C
3200 NM
3150 NM
3100 NM
3050 NM
3000 NM
CONCORDE - STAGE O
CONCORDE - STADE O

FIGURE 1-G-4

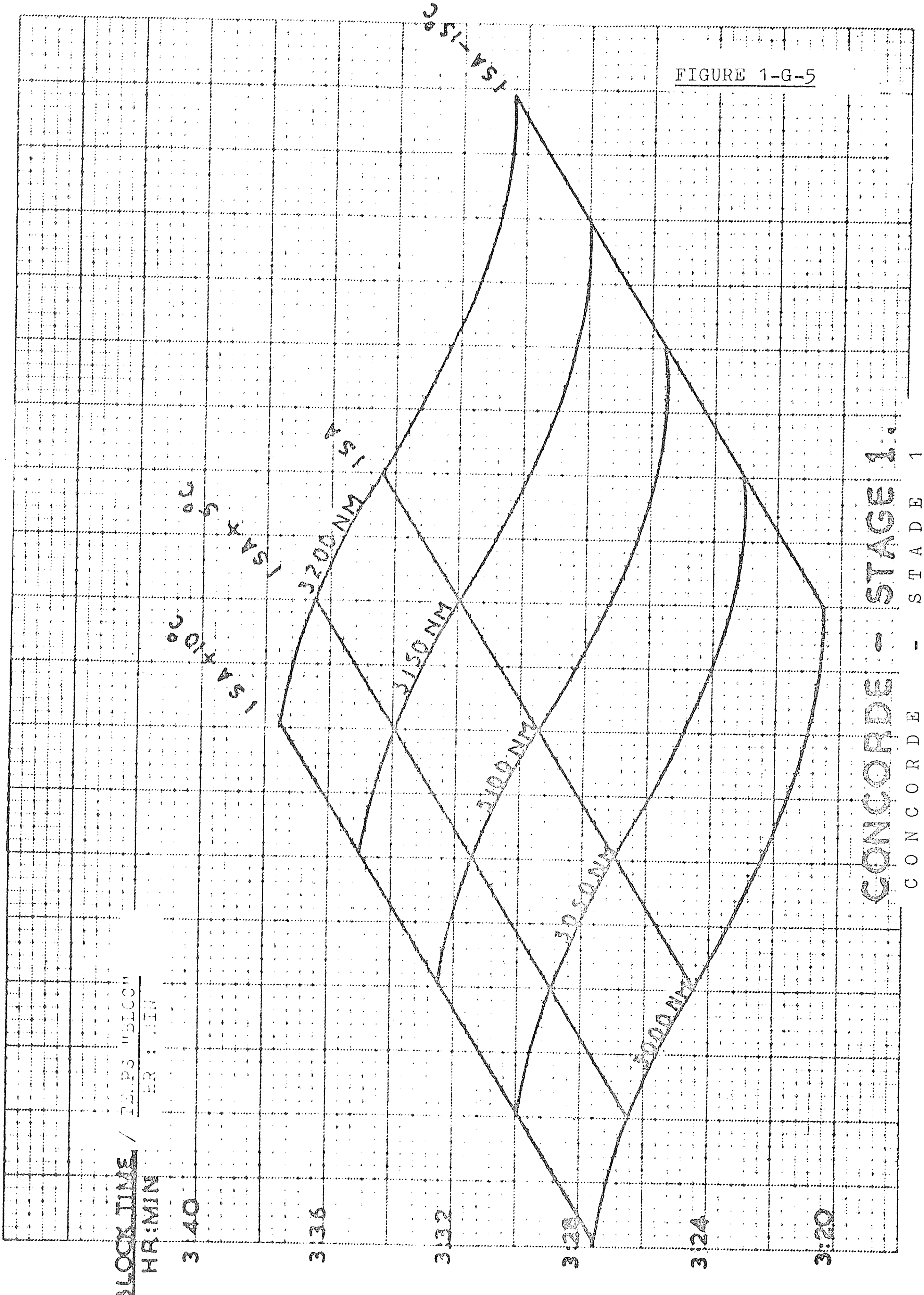


FIGURE 1-G-5
BLOCK TIME / TEMPS BLOC
HR:MIN HR : MN
3:40
3:36
3:32
3:28
3:24
3:20
ISA-15°C
ISA
ISA+5°C
ISA+10°C
3200 NM
3150 NM
3100 NM
3050 NM
3000 NM
CONCORDE - STAGE 1
CONCORDE - STADE 1

APPENDIX 1-H

CONCORDE EXERCISE

(1 June - 31 August 1968)

LONDON - NEW YORK

1. ROUTE ANALYSIS

1.1 The distributions of upper level wind velocity and temperature in the North Atlantic region were minutely examined on the 92 days under review. IMB computer flight plans for four sample tracks were completed in 28 days (i.e. four equally-spaced weeks) and a detailed inspection of the effect of environmental conditions on track selection was made on the remaining 64 days. On pages 1-H-2 and 1-H-3 and in Figures 1-H-1 and 1-H-2 the sector minimum fuel time, wind component and temperature deviation found on the routes examined on the 28 days are summarized. The meteorological situations prevailing on the 64 days and the conditions necessary to justify routes not following Great Circles are summarized on page 1-H-7.

2. TRANSITION AREA

2.1 On 17 days out of this period the cross-sectional diagrams of the transition stage of flight indicated high temperature deviations or steep temperature/altitude gradients. The UK MET Office prepared charts of temperature distribution of 50 mb intervals from 500 mb to 70 mb for these days and the temperature deviations effective on three sample climb routes were examined. These are summarized on page 1-H-8 and illustrated in Figures 1-H-3 to 1-H-17.

3. TRACK ANALYSIS

3.1 Sample used: 4 weeks covering the following periods:

1 - 7 June
30 June - 6 July
28 July - 3 August
25 - 31 August

3.2 Data: 100 mb charts.

3.3 Grid (for extraction of wind velocities and temperature deviations):

i) Cover extends from 5°E to 85°W and 30°N to 70°N (in centre).

ii) It comprises 177 graticules, each covering 2.5 degrees of latitude and 5 degrees of longitude (5 degrees of latitude and 10 degrees of longitude north of 60 N)

i.e. : 150 NM N/S and 150 NM E/W (around 60 N)
210 NM E/W (around 45 N).

3.4 I.B.M. Computation

For each of the 28 days the computer:

i) completed a full flight plan;

ii) determined Route Mean Temperature Deviation;

iii) determined Route Mean Wind Component;

iv) determined Sector Minimum Fuel Time.

Note: For i) the London - New York Great Circle Route (3044 NM)(GC)
" " Rhumb Line " (3183 NM)(RL)
" " Polar Curve " (3281 NM)(PC)
" " Free Choice "
(See Figure 1-H-1.)

3.5 Conclusions

i) Mean Route Temperatures:

Polar Curve Route is 3° warmer than Great Circle Route; Rhumb Line Route is 3° cooler than Great Circle Route on average.

ii) Mean Westerly Wind Component:

Approximately 9 KT weaker on Polar Curve Route than on Great Circle Route;
5 KT stronger on Rhumb Line Route than on Great Circle Route in the first 14 days.
Variable within 10 KT range in second 14 days.

iii) Minimum Fuel Time:

Polar Curve Route takes 13 mins. longer than Great Circle Route;
Rhumb Line Route takes 5 mins. longer than Great Circle Route.

iv) The best route, i.e. "Free Choice" coincided exactly with Great Circle on 26 occasions in latitude and longitude, and on 28 occasions (100%) in time.

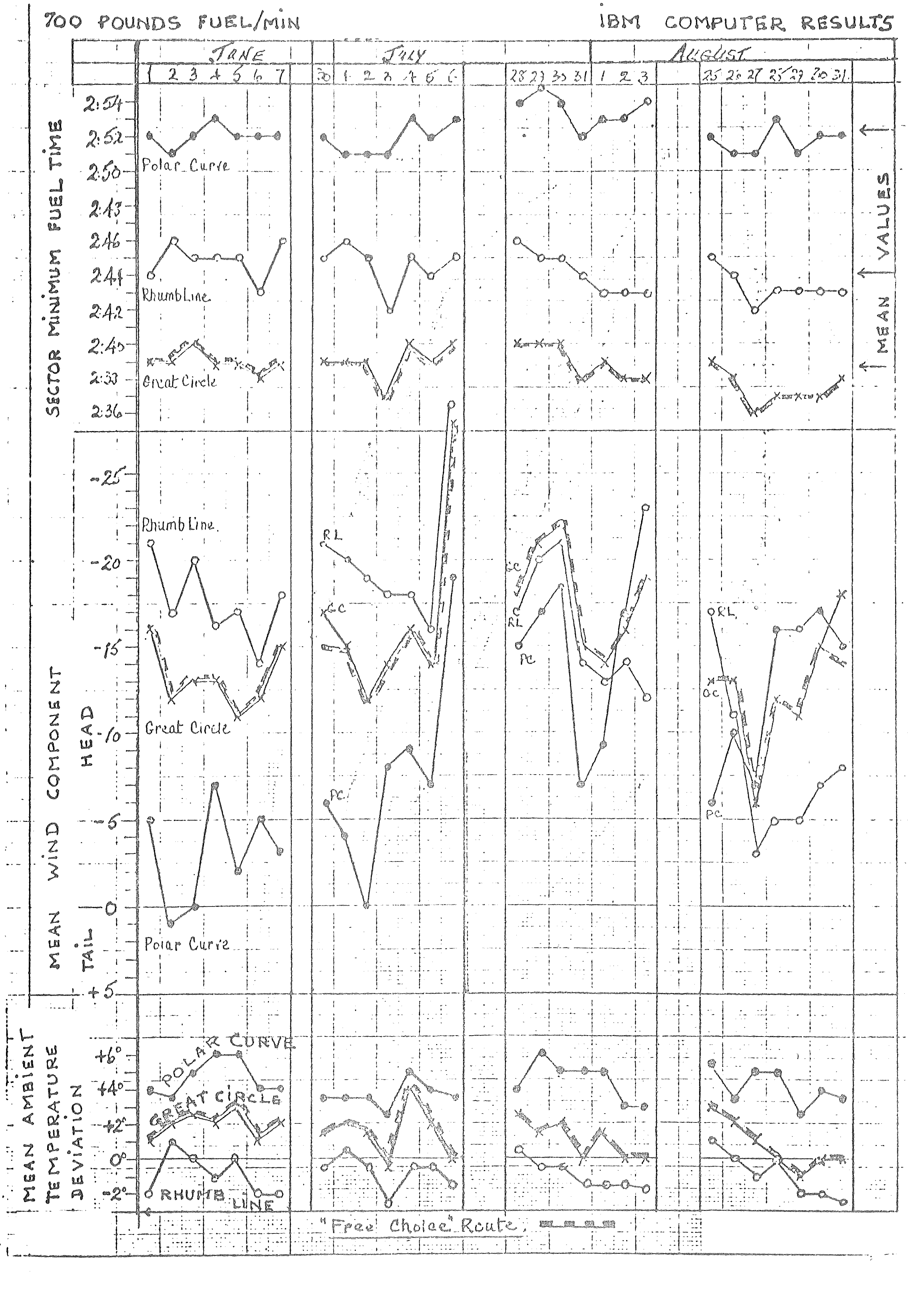
On 30 June the computer found a free choice route with a head wind component of -15 KT compared with -17 KT on the Great Circle Route, and on 31 August a route with a head wind component of -14 KT compared with -18 KT on the Great Circle Route (see Figure 1-H-2). Mean Temperature Deviations on the free choice route and on the Great Circle were identical on these occasions and, because of the additional ground distance (+5 NM and 8 NM), <u>sector times</u> on the free choice routes had exactly the same values as those on the Great Circle Route.

v) There is no evidence of any benefit resulting from following a route other than the Great Circle.

<u>Note</u>: The computer calculates to 1/10th of a minute, gives a print out for every minute, and gives total sector time allowing for tenths on route stages.

LONDON - NEW YORK TRACK ANALYSIS

FIGURE 1-H-1




POLAR CURVE 3081 NM
3049 NM
GREAT CIRCLE 3044 NM
3052 NM
RHUMB LINE 3183 NM
GREENLAND
Goose Bay CYYR
Frobisher CYFB
HUDSON STRAIT
Fort Chimo CYVP
Knob Lake CYKL
Seven Islands CYZY
Stephenville CYJT
Sydney CYQY
Moncton CYQM
Halifax
Montreal CYUL
Quebec
Boston KBOS
Idlewild KIDL
St. Johns
CYQX
Strait of Belle Isle
NEWFOUNDLAND
C. Farewell
Prince Christian OUDV
Narsarssuak OUDV
Sondrestrom CUSF
Santa Maria CSAZ
Lages CSLA
AZORES
Flores
C. Finisterre

FIGURE 1-H-2

4. THE REMAINING 64 DAYS

4.1 After a close examination of the 64 days in the summer period not processed by the computer, it would seem to be most improbable that conditions existed on any of them which could have caused the "Free Choice" track to be displaced from the Great Circle Route. None of these days showed any significant variation in pattern or structure from the spread contained within the 28 day sample.

4.2 As a spot check two of the most likely looking cases to cause such a displacement (7 and 23 July) were examined specifically and the temperatures and wind components on the Great Circle and Rhumb Line were averaged arithmetically. In the first case an improvement of 3.5°C and 0 wind component was noted and in the second it was 2.5°C and a gain of 11 KT wind component. As the Rhumb Line is displaced an average of 210 NM from the Great Circle improvements at this rate would hardly be likely to allow any appreciable saving in fuel by moving off the minimum distance track.

4.3 Apart from these two cases there was virtually no likelihood of any of the other days differing from the results already achieved.

4.4 The conditions required to justify consideration of a track off the Great Circle are summarised below:

Mean Distance	Mean Temp. Gain expected	Fuel/Time Saving	Extra Track Length	Extra Track Time	Overall Time Factor	Reqd. Distance Saving	Reqd. W/C* Improvement on cruise
210 NM	3° cooler	-1½ mins.	140 NM	+7 mins.	+5½ mins.	110 NM	55 KT
120 NM	2° cooler	-1 min.	48 NM	+2½ mins.	+1½ mins.	30 NM	15 KT
60 NM	1° cooler	-½ min.	15 NM	+1 min.	+½ min.	10 NM	5 KT

*Wind component

4.4.1 Thus, to break even with the Great Circle fuel times,

one could fly 120 NM south of the Great Circle, find 2°C cooler, but require a 15 KT wind component improvement;
one could fly 60 NM south of the Great Circle, find 1°C cooler, but require a 5 KT wind component improvement.

4.4.2 The likelihood of finding a 5 KT wind component improvement at 60 NM south of the Great Circle is remote.

4.5 In the 28 days analysed by the IBM computer the wind components on the Great Circle and on the Rhumb Line (an average 210 NM south of the Great Circle) were:

	Great Circle	Rhumb Line	Remarks
1st week	-13 KT	-19 KT	Rhumb Line 6 KT worse
2nd week	-16½ KT	-20 KT	Rhumb Line 3½ KT worse
3rd week	-18 KT	-16 KT	Rhumb Line 2 KT better
4th week	-12½ KT	- 8 KT	Rhumb Line 3½ KT better

4.6 As proved on 31 August 1968, the computer selected a track partly 2 degrees south of the Great Circle with a 4 KT wind component improvement which, however, resulted in no gain in sector fuel time.

4.7 Finally, it is considered that the free choice track will, very occasionally, move off the Great Circle, but that the resultant gain in sector fuel will be insignificant.

5. TRANSITION AREA

5.1 Of the 92 days examined 17 days revealed, on the meteorological cross-sectional diagram of the climb and transition area, conditions of high ambient temperature deviation or steep temperature/height gradients. These diagrams were set aside for detailed study. The UK MET Office prepared special charts showing temperature distribution at 50 mb intervals from 500 mb to 70 mb for the area from London to 20°W for every one of the 17 days.

5.2 Three routes were considered:

i) Route B : (London - Shannon - Great Circle - New York)

ii) Route A : (Route B + 45°), i.e. approximately via Prestwick

iii) Route C : (Route B - 45°), i.e. approximately via the Scilly Islands.

(See Figure 1-H-3.)

5.3 The distribution of temperature deviation with height on these three routes is illustrated in Figures 1-H-3 to 1-H-17.

5.3.1 Route Temperature Differences : As compared with Route B via Shannon.

	Route A	Route C
5.3.2 At FL 250	Ranges from 1° warmer to 1.5° cooler than Route B	Ranges from 1° warmer to 0.5° cooler than Route B
5.3.3 At FL 400	Ranges from 3° warmer (on 3 occasions) to 2.5° cooler than Route B. Mean value (for 17 days): 0.5° warmer.	Ranges from 4.5° warmer (on 1 occasion) to 4.5° cooler than Route B. Mean value (for 17 days): 0.75° cooler.

5.4 Fuel quantity required to climb from FL 250 to FL 400 relative to mean ambient temperature deviation

Temperature Deviation	Fuel required		Distance covered during this height change
+ 5°	13 900 lb.)	1°C = 340 lb. (approx.)	138 NM
+ 2°	12 880 lb.)		124 NM
ISA	12 200 lb.)		115 NM
- 2°	11 710 lb.)	1°C = 245 lb. (approx.)	108 NM
- 5°	10 980 lb.)		97 NM

5.4.1 The data in the above table are also illustrated in graphical form on Figures 1-H-3 to 1-H-17. (A route with 2° cooler temperature could save 600 lb. fuel between FL 250 and FL 400 on a 300 NM + climb.)

5.4.2 A climb of 300 NM + along Route A or Route C would place the aircraft approximately 200 NM to the north or south of the Great Circle track between Shannon and New York and, on a parallel track system, increases the required track distance by approximately 110 NM, the flying time by approximately 6 minutes and the fuel required by approximately 4 000 lb., which en route wind and temperature conditions could not be expected to reduce appreciably.

6. TEMPERATURE DATA

6.1 Route Analysis

6.1.1 The isotherms (marked in terms of temperature deviation from ISA) depicted on the UK meteorological 100 mb prognostic charts used for the purpose of this study were based on forecast values of temperature. Although the slow-moving circulation systems and generally slight temperature and wind gradients of the lower stratosphere largely justify persistence-type forecasts, particularly during the summer period, the actual temperatures for 0000 GMT were adjusted for the 1200 GMT operation by synoptic forecasting techniques which associated temperature changes with the development and movement of troughs and ridges in the contour pattern, which were in turn related to the main features of tropospheric circulation.

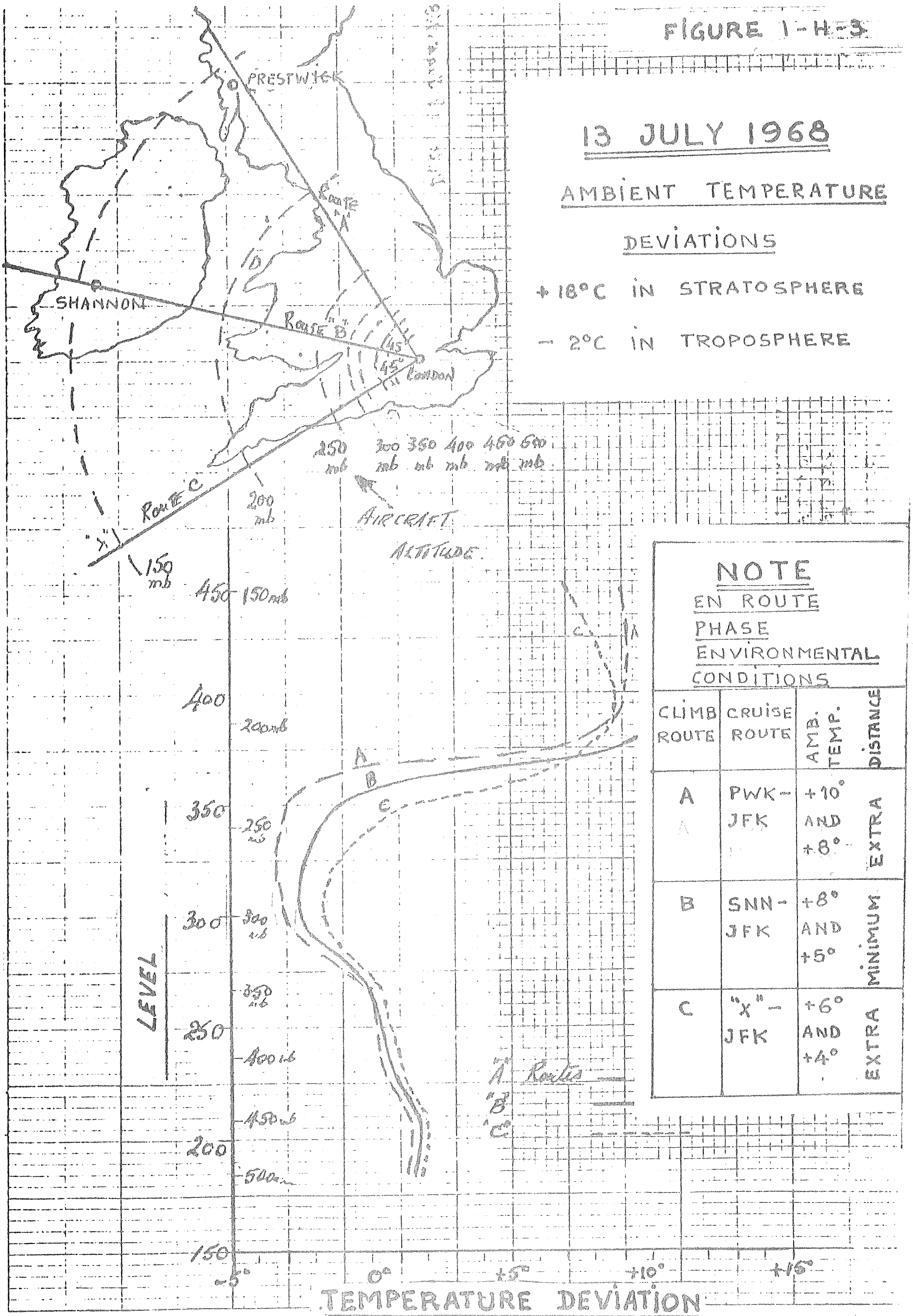
6.1.2 A recent study involving the completion of a London - New York flight plan on forecast and, subsequently, on actual conditions on every day for a year revealed the following comparison in route mean temperature deviations: the forecast values agreed with the actual within ± 1°C on 61% of all occasions, within ± 2°C on 89% of all occasions and within ± 3°C on 98% of all occasions.

6.1.3 It is considered that the prognostic charts presented temperature data for the planned time of flight with a high degree of accuracy and that the conclusions drawn on pages 1-H-2 and 1-H-7 truly apply to Concorde operations at the 100 mb level on the North Atlantic during the summer period.

7. TRANSITION AREA

7.1 No synoptic forecasting techniques were applied in the production of the special UK meteorological charts for the transition area, which presented actual temperatures in all cases.

FIGURE 1-H-3



NOTE

EN ROUTE PHASE ENVIRONMENTAL CONDITIONS

CLIMB ROUTE	CRUISE ROUTE	AMB. TEMP.	DISTANCE
A	PWK–JFK	+10° AND +8°	EXTRA
B	SNN–JFK	+8° AND +5°	MINIMUM
C	"X"–JFK	+6° AND +4°	EXTRA

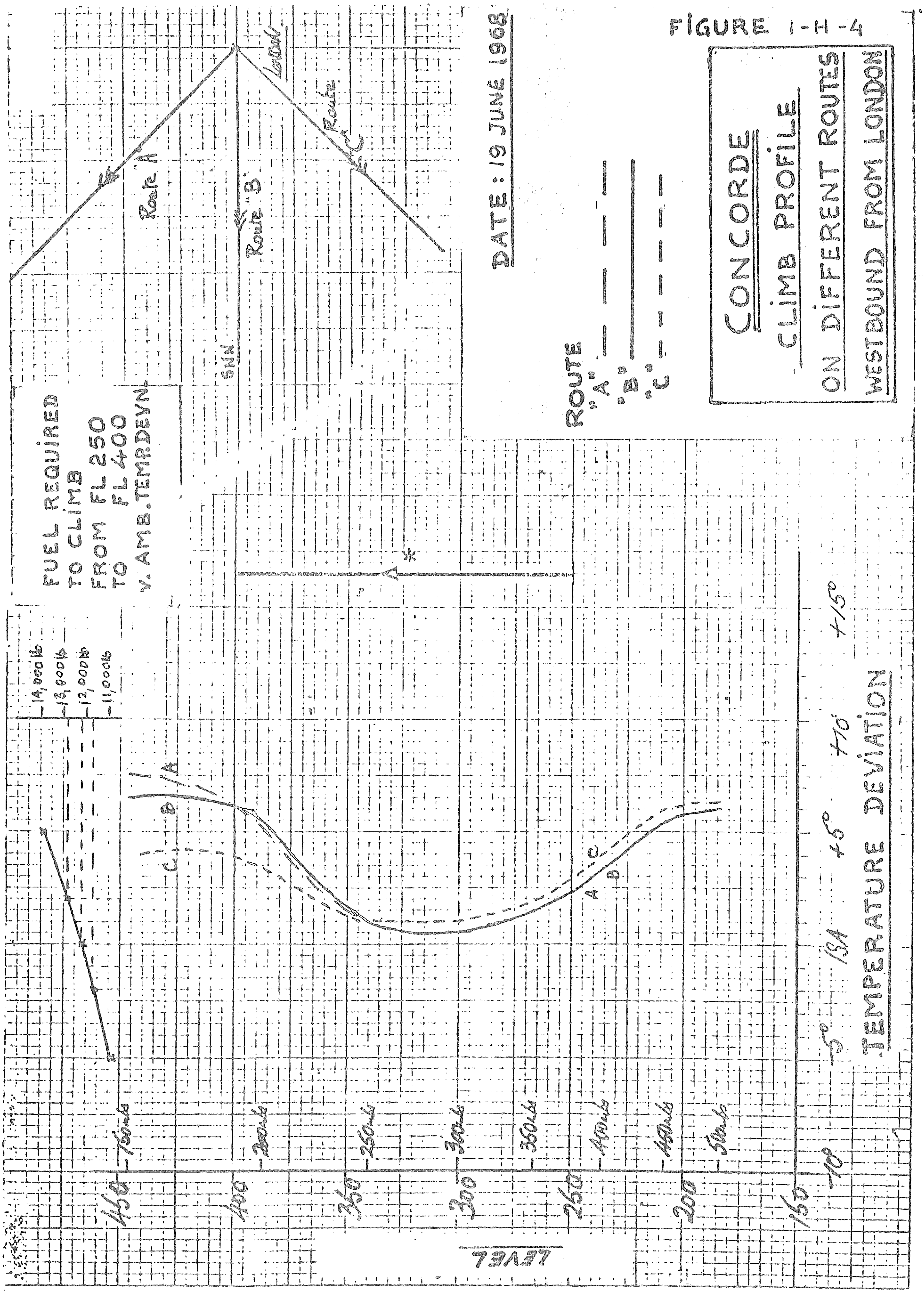


FIGURE 1-H-4
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
DATE: 19 JUNE 1968
ROUTE "A"
"B"
"C"
LONDON
SNN
Route "A"
Route "B"
Route "C"
FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
v. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
TEMPERATURE DEVIATION
-10°
-5°
ISA
+5°
+10°
+15°
LEVEL
450
400
350
300
250
200
150
150 ml
200 ml
250 ml
300 ml
350 ml
400 ml
450 ml
500 ml
A
B
C

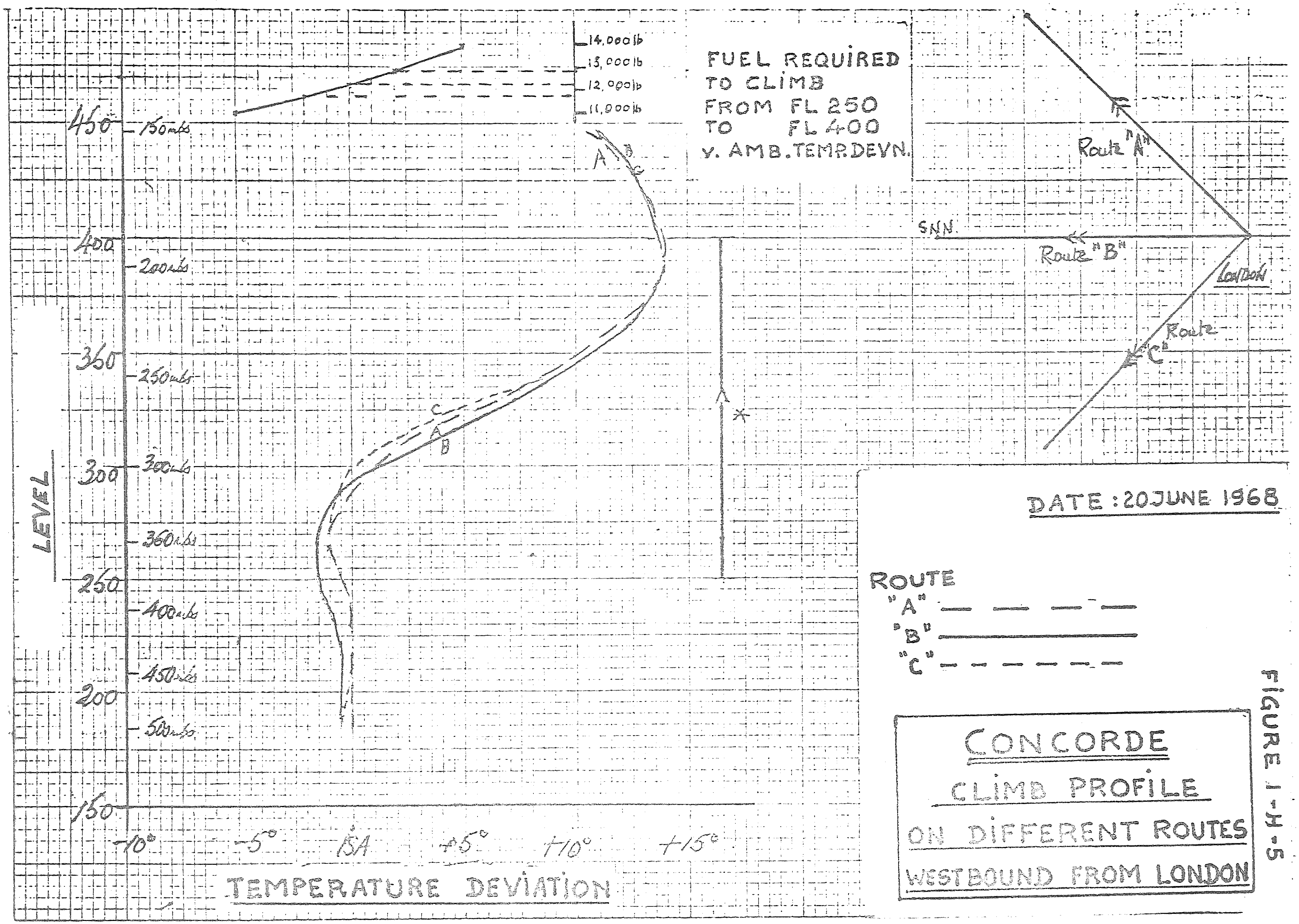

FUEL REQUIRED TO CLIMB FROM FL 250 TO FL 400 V. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
Route "A"
Route "B"
Route "C"
SNN
LONDON
LEVEL
450
400
350
300
250
200
150
150 mbs
200 mbs
250 mbs
300 mbs
350 mbs
400 mbs
450 mbs
500 mbs
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
A
B
C
DATE: 20 JUNE 1968
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

FIGURE 1-H-5

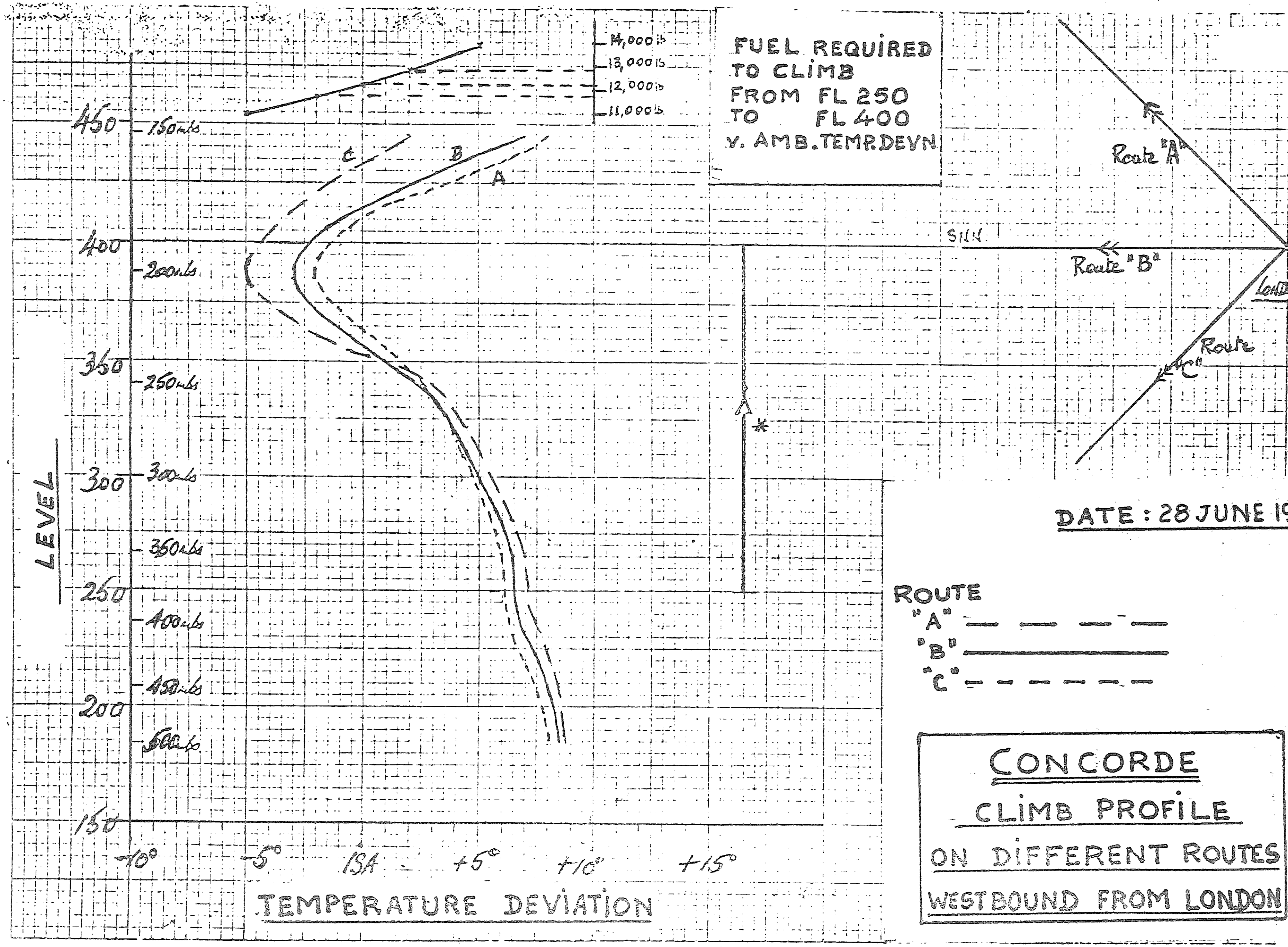

FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
v. AMB. TEMP. DEVN.
14,000 lbs
13,000 lbs
12,000 lbs
11,000 lbs
LEVEL
450
400
350
300
250
200
150
150 mbs
200 mbs
250 mbs
300 mbs
350 mbs
400 mbs
450 mbs
500 mbs
A
B
C
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
SNN
Route "A"
Route "B"
Route "C"
LONDON
DATE : 28 JUNE 1968
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

FIGURE 1-H-6

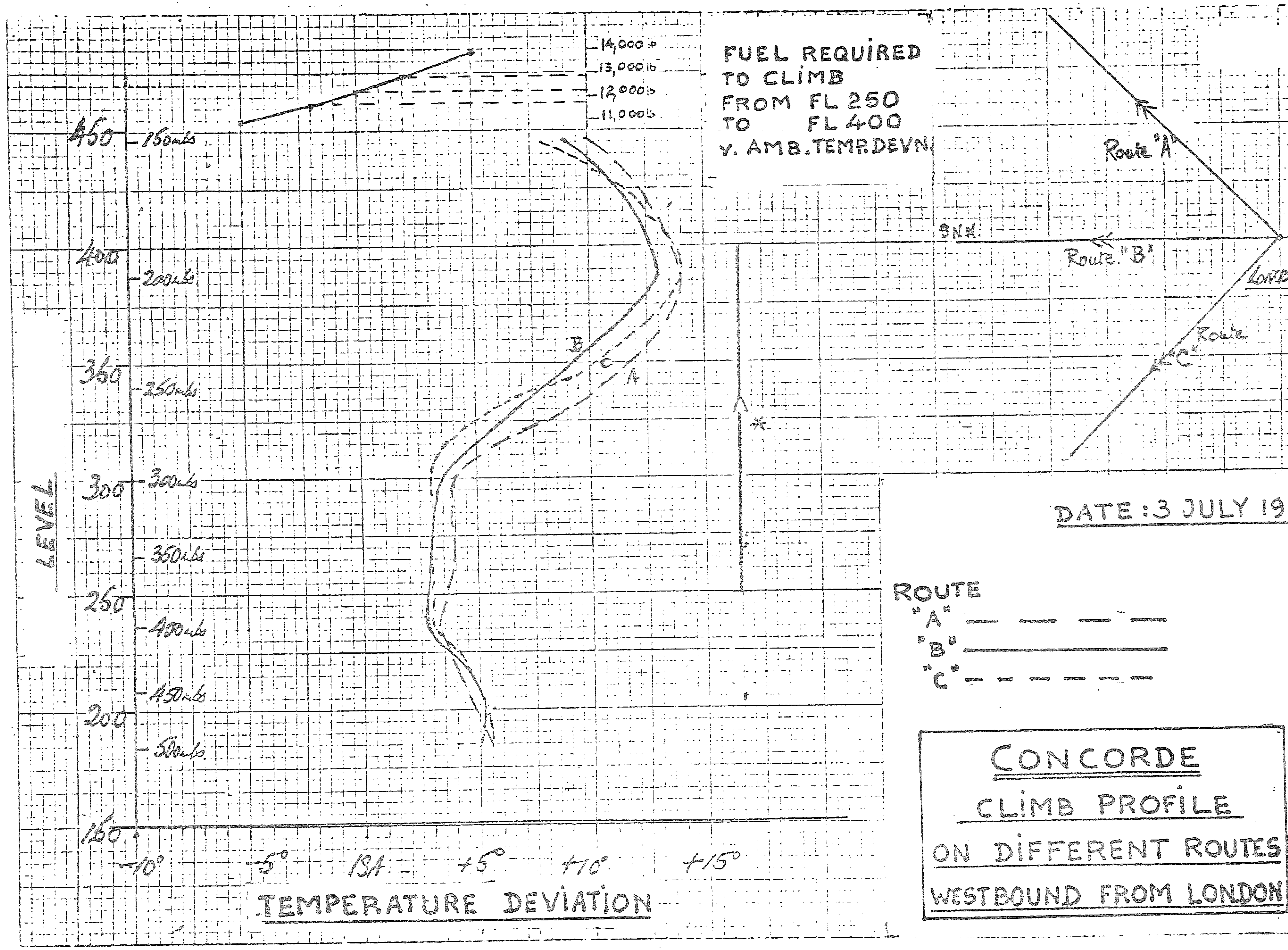
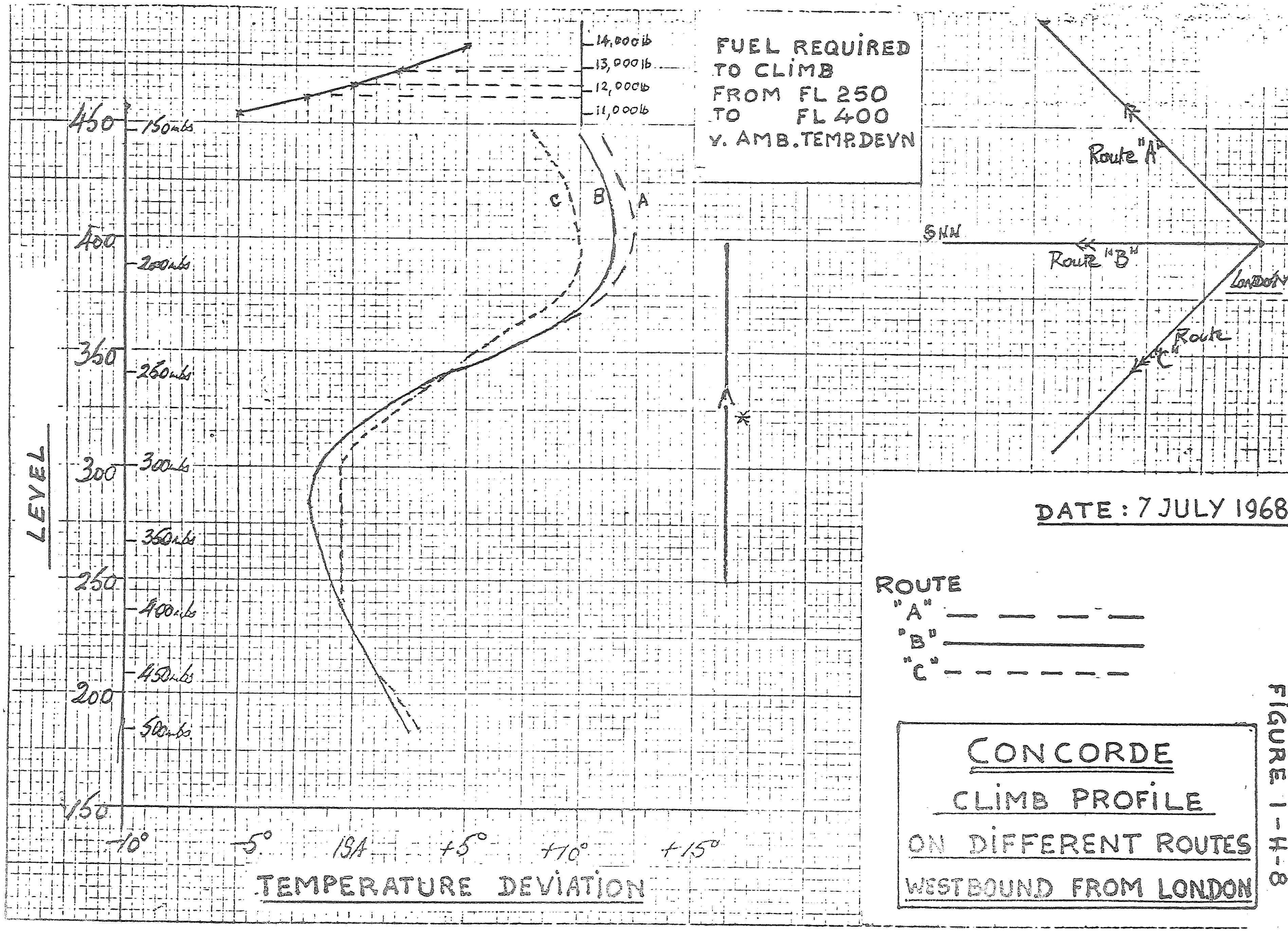

FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
v. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
Route "A"
Route "B"
Route "C"
SNN
LONDON
LEVEL
450
400
350
300
250
200
150
150mbs
200mbs
250mbs
300mbs
350mbs
400mbs
450mbs
500mbs
B
C
A
*
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
DATE: 3 JULY 1968
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

FIGURE 1-H-7


FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
V. AMB. TEMP. DEVN
14,000 lb
13,000 lb
12,000 lb
11,000 lb
150 lbs
200 lbs
250 lbs
300 lbs
350 lbs
400 lbs
450 lbs
500 lbs
450
400
350
300
250
200
150
LEVEL
C
B
A
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
SNN
Route "A"
Route "B"
Route "C"
LONDON
DATE: 7 JULY 1968
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
FIGURE 1-H-8

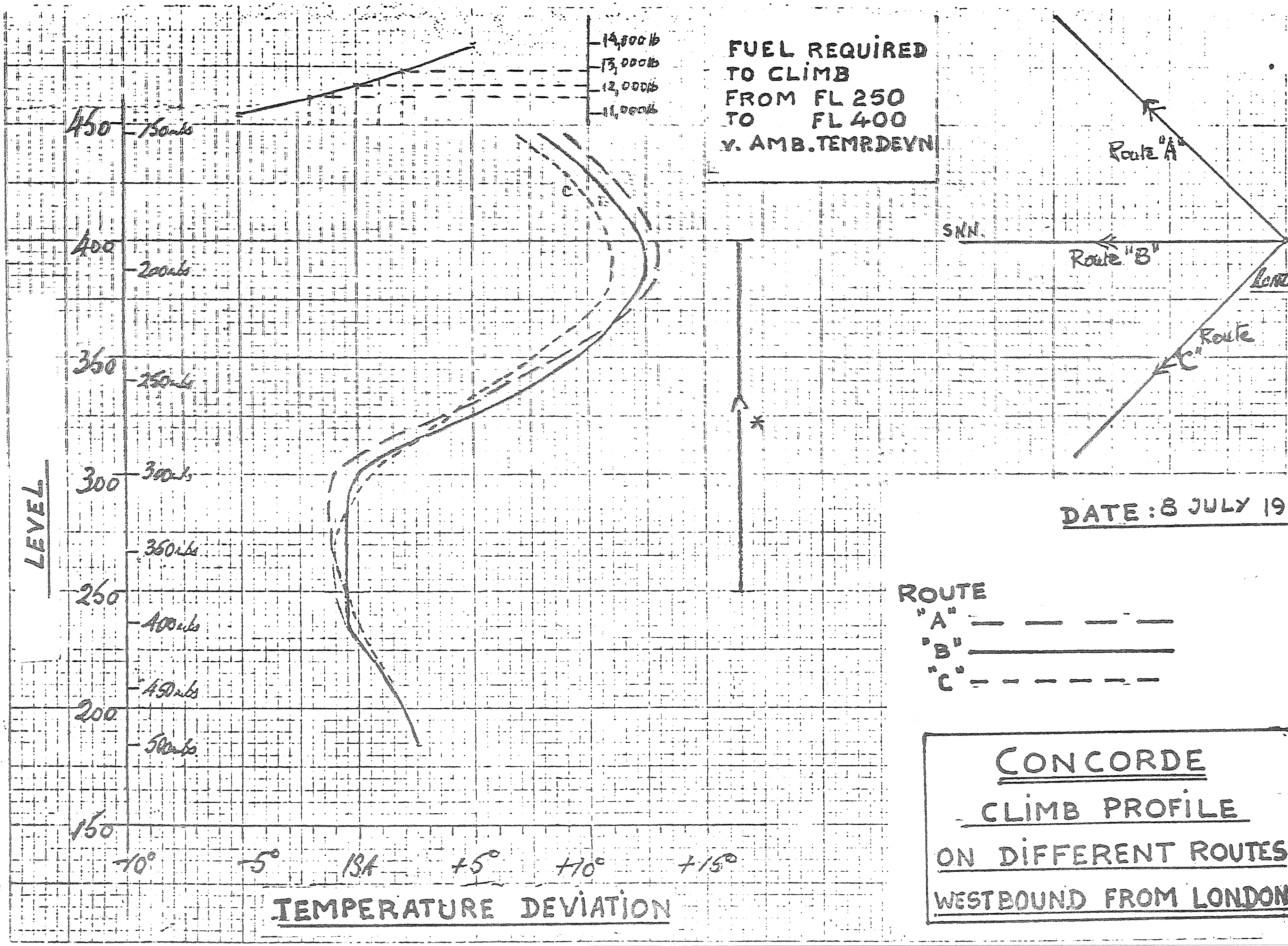
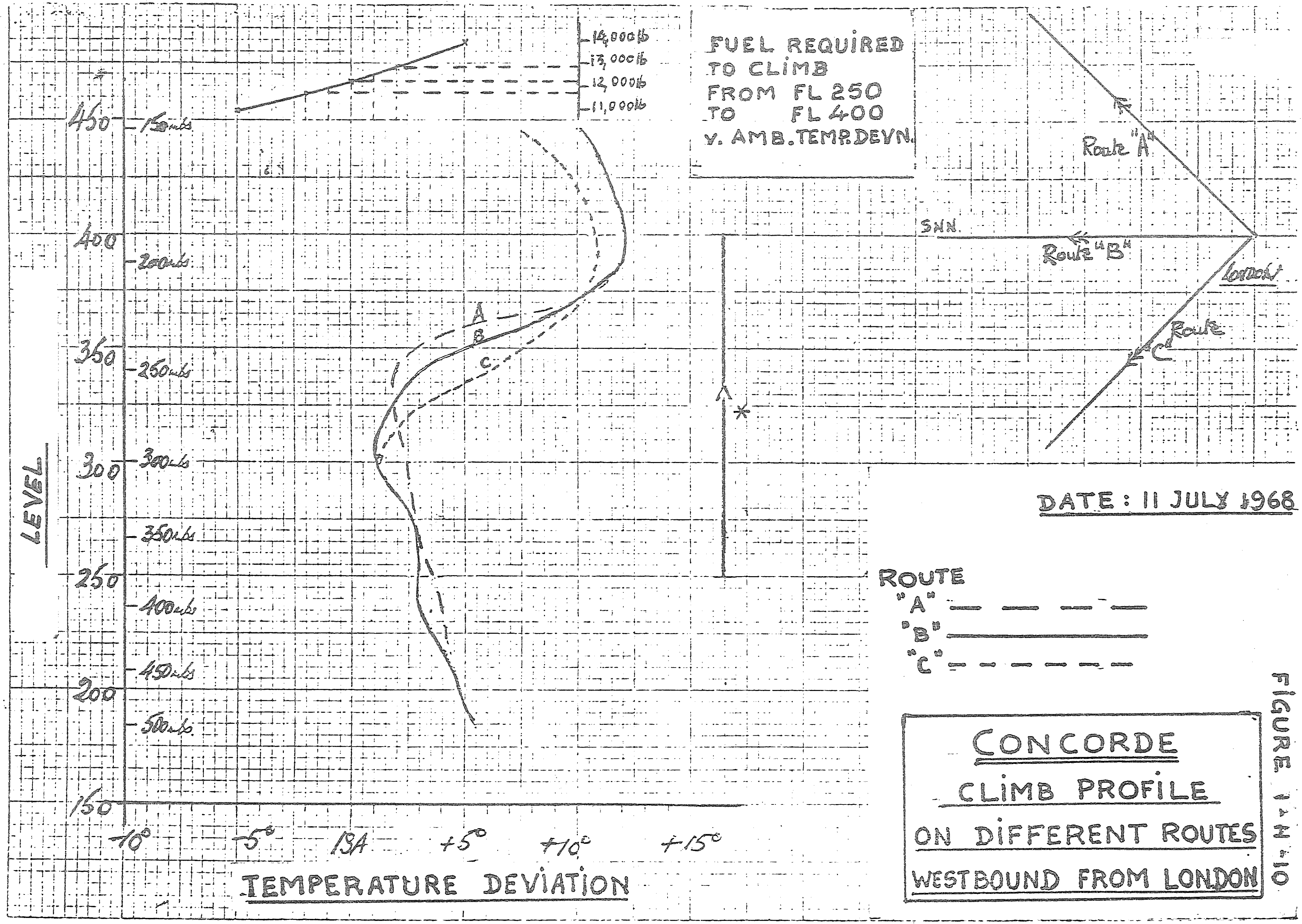

FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
v. AMB. TEMP. DEVN
14,000 lb
13,000 lb
12,000 lb
11,000 lb
Route "A"
Route "B"
Route "C"
SNN.
LONDON
DATE: 8 JULY 1968
ROUTE
"A"
"B"
"C"
LEVEL
450
400
350
300
250
200
150
150 mbs
200 mbs
250 mbs
300 mbs
350 mbs
400 mbs
450 mbs
500 mbs
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

FIGURE 1-H-9


FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
v. AMB. TEMP. DEVN.
14,000lb
13,000lb
12,000lb
11,000lb
Route "A"
SNN.
Route "B"
London
Route "C"
LEVEL
450
400
350
300
250
200
150
150 lbs
200 lbs
250 lbs
300 lbs
350 lbs
400 lbs
450 lbs
500 lbs
A
B
C
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
DATE: 11 JULY 1968
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
FIGURE 1-H-10

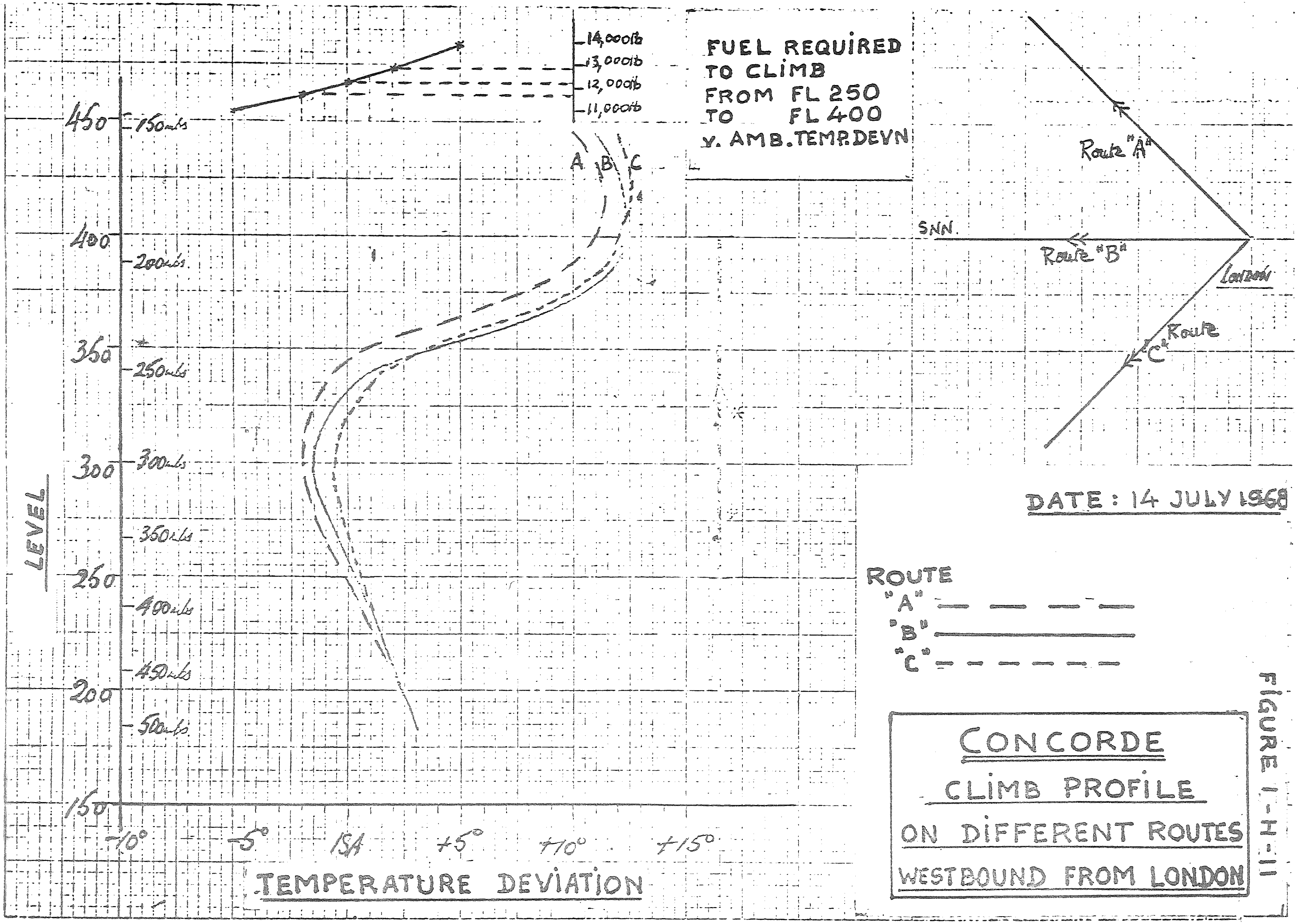

14,000lb
13,000lb
12,000lb
11,000lb
FUEL REQUIRED TO CLIMB FROM FL 250 TO FL 400 v. AMB. TEMP. DEVN
A B C
Route "A"
SNN.
Route "B"
LONDON
Route "C"
DATE: 14 JULY 1968
LEVEL
450
400
350
300
250
200
150
150 wks
200 wks
250 wks
300 wks
350 wks
400 wks
450 wks
500 wks
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

FIGURE 1-H-11

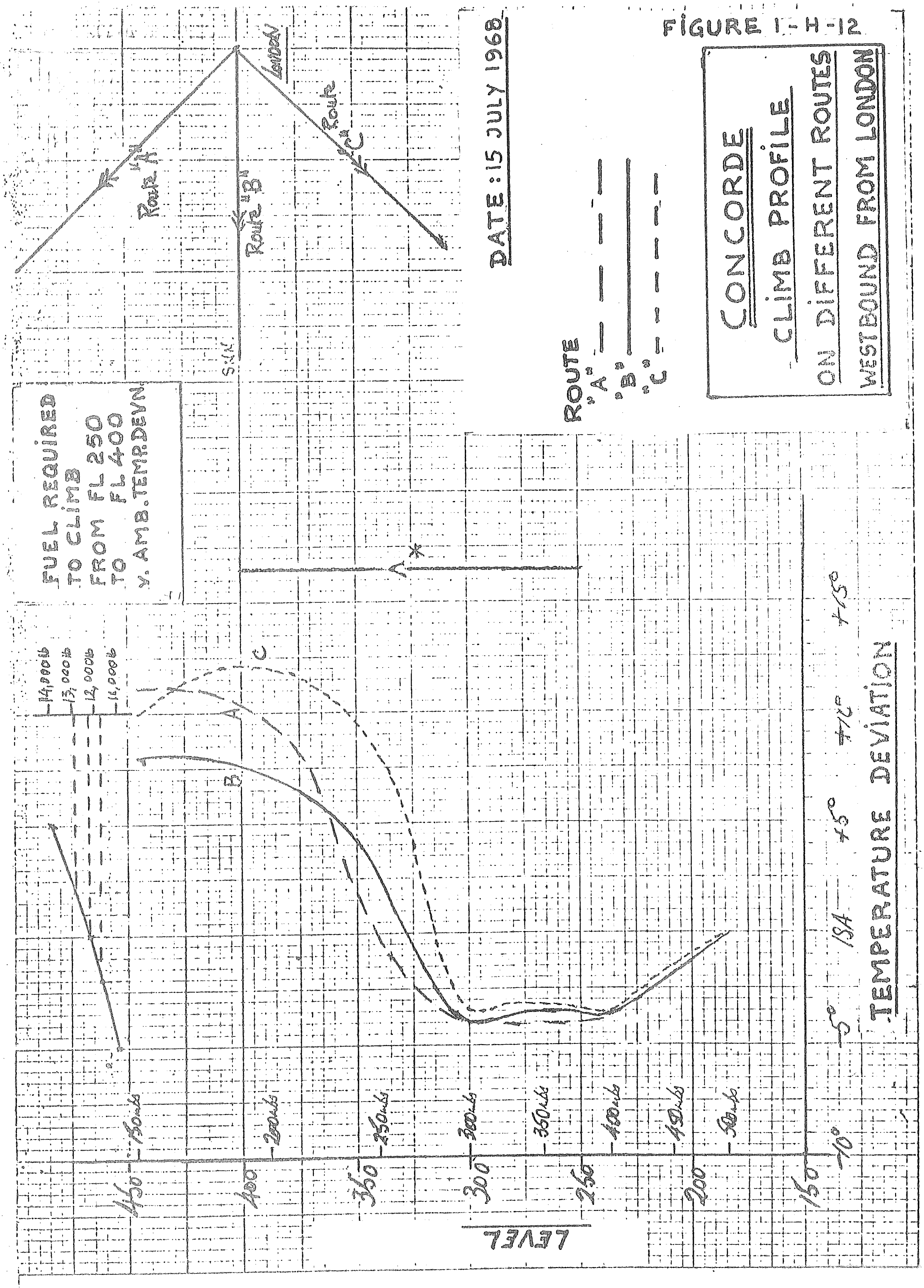

CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
DATE: 15 JULY 1968
ROUTE "A"
"B"
"C"
London
S.W.
Route "A"
Route "B"
Route "C"
FUEL REQUIRED TO CLIMB FROM FL 250 TO FL 400 v. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
A
B
C
150 lbs
200 lbs
250 lbs
300 lbs
350 lbs
400 lbs
450 lbs
500 lbs
450
400
350
300
250
200
150
LEVEL
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION

FIGURE 1-H-12

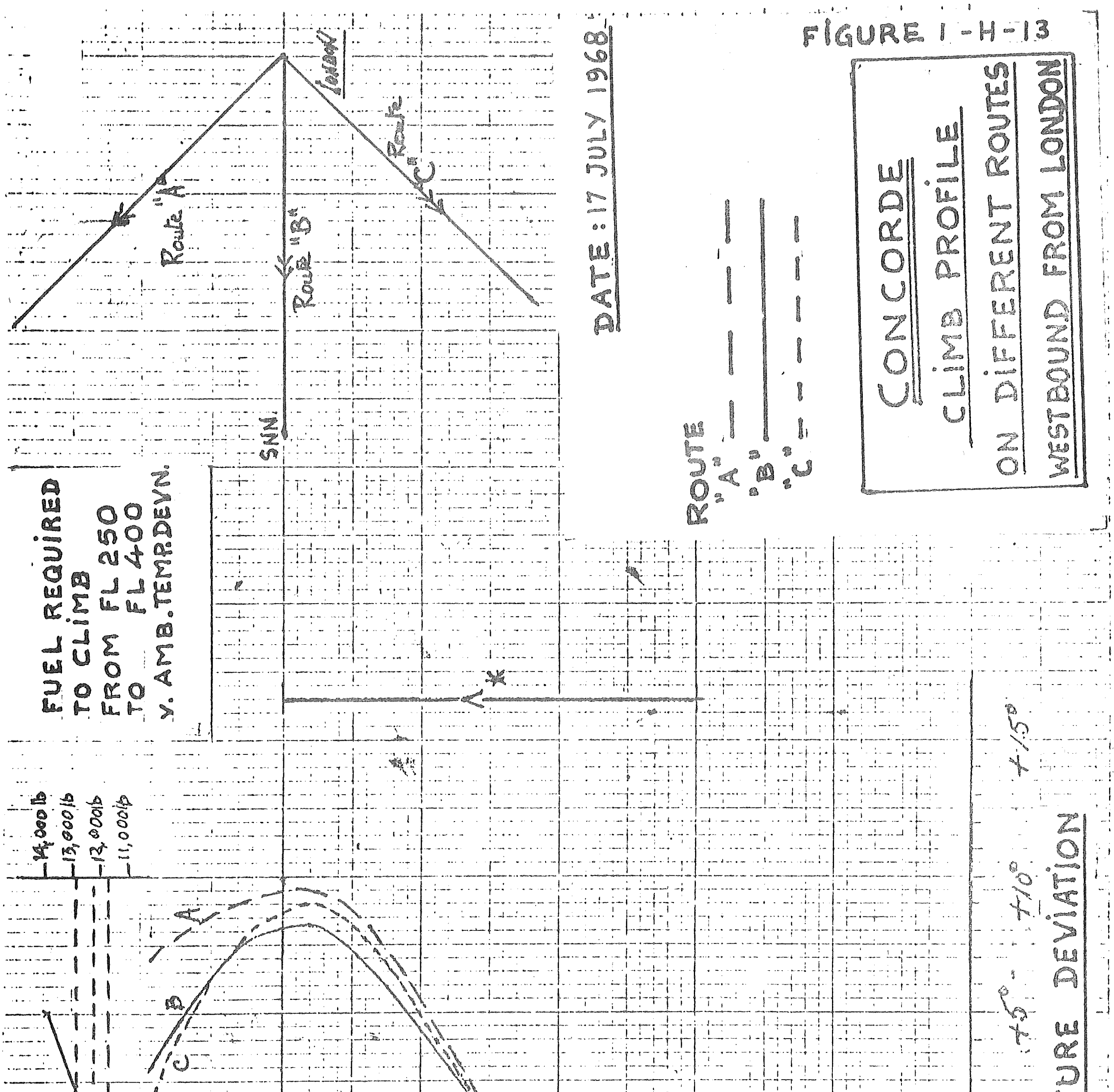
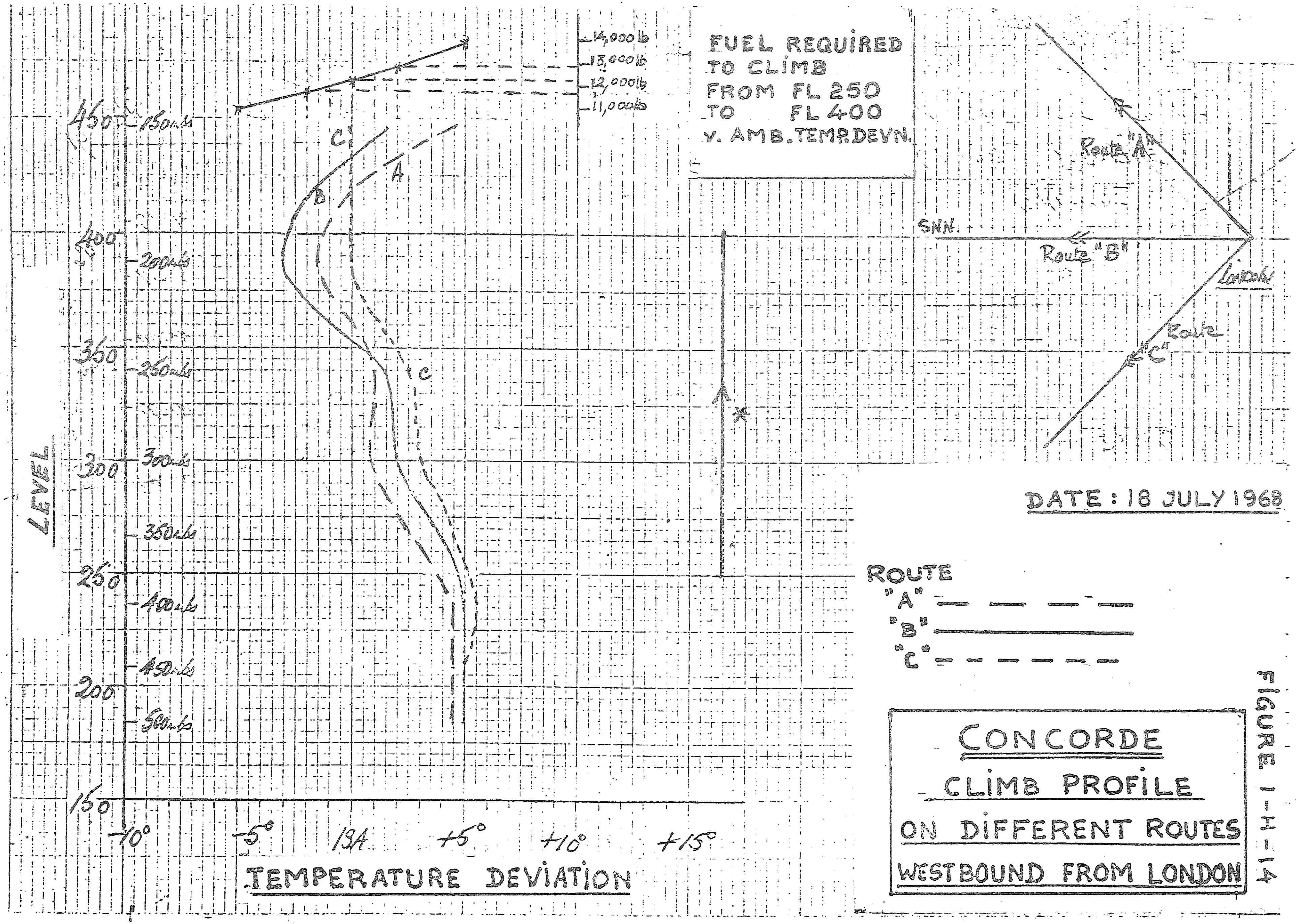


FIGURE 1-H-13
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
DATE: 17 JULY 1968
ROUTE "A"
"B"
"C"
LONDON
Route "A"
Route "B"
Route "C"
SNN
FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
V. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
A
B
C
150 lbs
200 lbs
250 lbs
300 lbs
350 lbs
400 lbs
450 lbs
500 lbs
450
400
350
300
250
200
150
LEVEL
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION


FUEL REQUIRED TO CLIMB FROM FL 250 TO FL 400 v. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
Route "A"
SNN.
Route "B"
LONDON
Route "C"
DATE: 18 JULY 1968
ROUTE
"A"
"B"
"C"
CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
FIGURE 1-H-14
LEVEL
450
400
350
300
250
200
150
150 mbs
200 mbs
250 mbs
300 mbs
350 mbs
400 mbs
450 mbs
500 mbs
A
B
C
-10°
-5°
ISA
+5°
+10°
+15°
TEMPERATURE DEVIATION

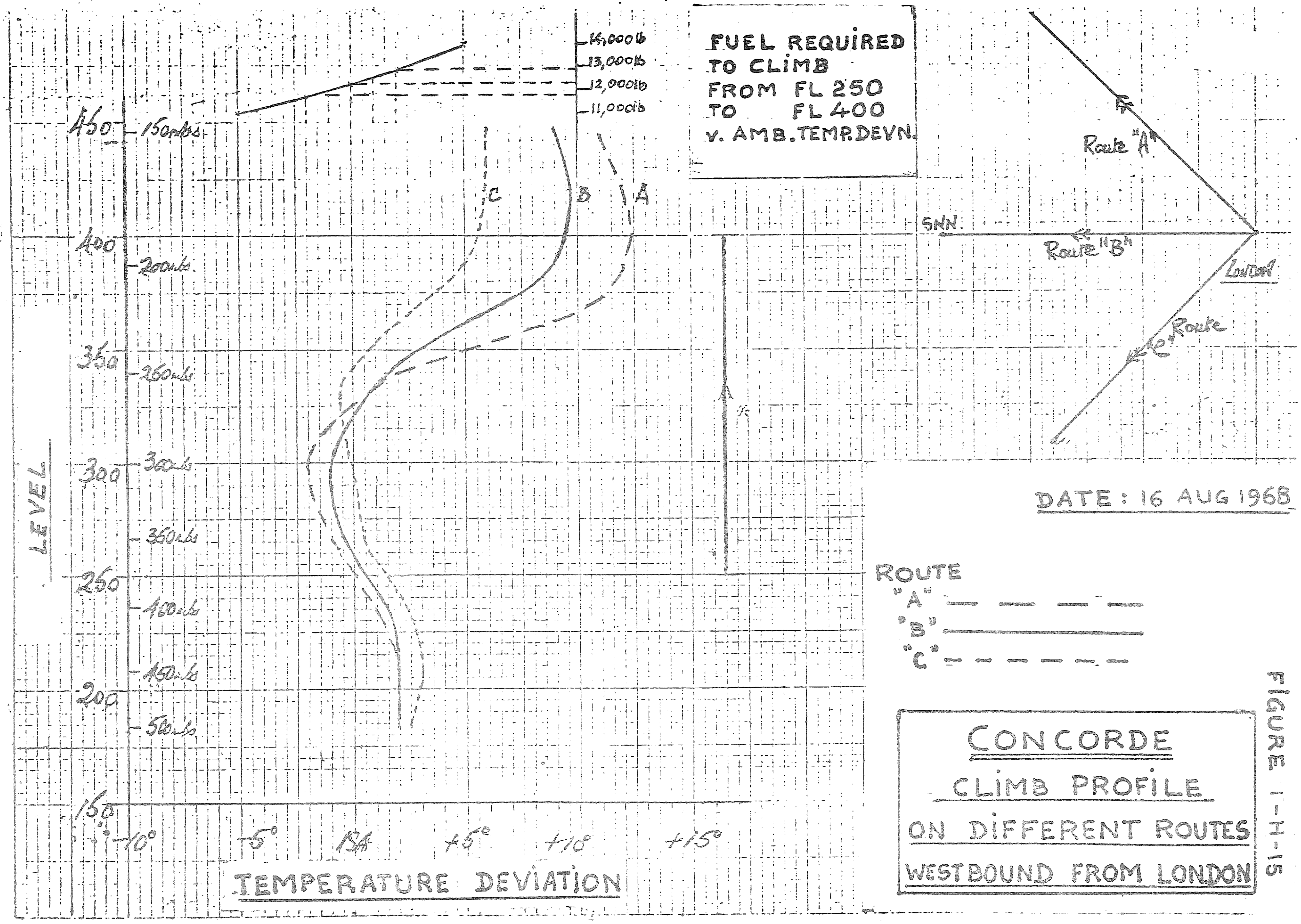
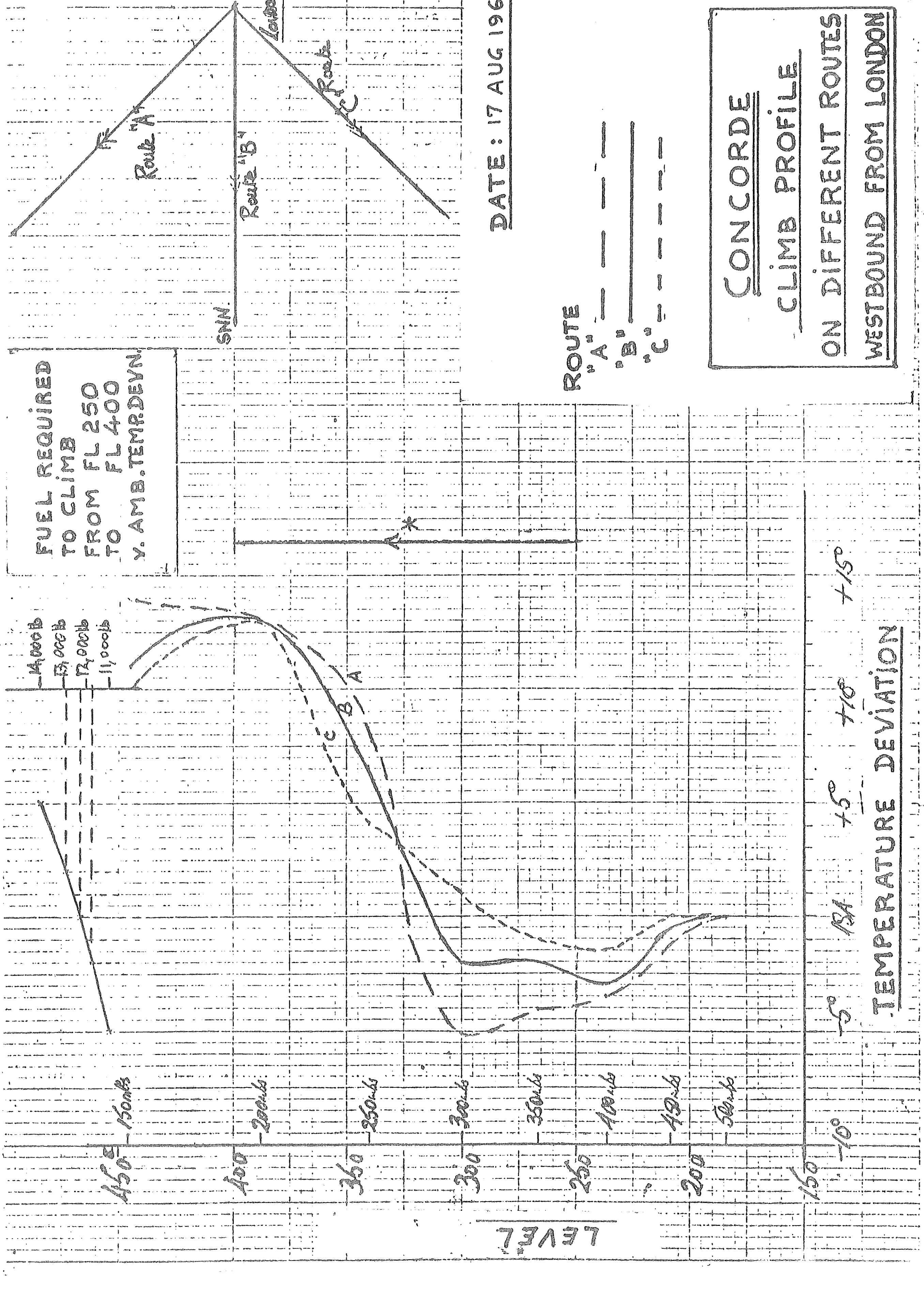


FIGURE 1-H-15

CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

FIGURE 1-H-16


CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON
DATE: 17 AUG 1968
ROUTE
"A"
"B"
"C"
London
Route "A"
Route "B"
Route "C"
SNN
FUEL REQUIRED
TO CLIMB
FROM FL 250
TO FL 400
V. AMB. TEMP. DEVN.
14,000 lb
13,000 lb
12,000 lb
11,000 lb
150 mb
200 mb
250 mb
300 mb
350 mb
400 mb
450 mb
500 mb
450
400
350
300
250
200
150
LEVEL
-10°
-5°
+5°
+10°
+15°
ISA
TEMPERATURE DEVIATION

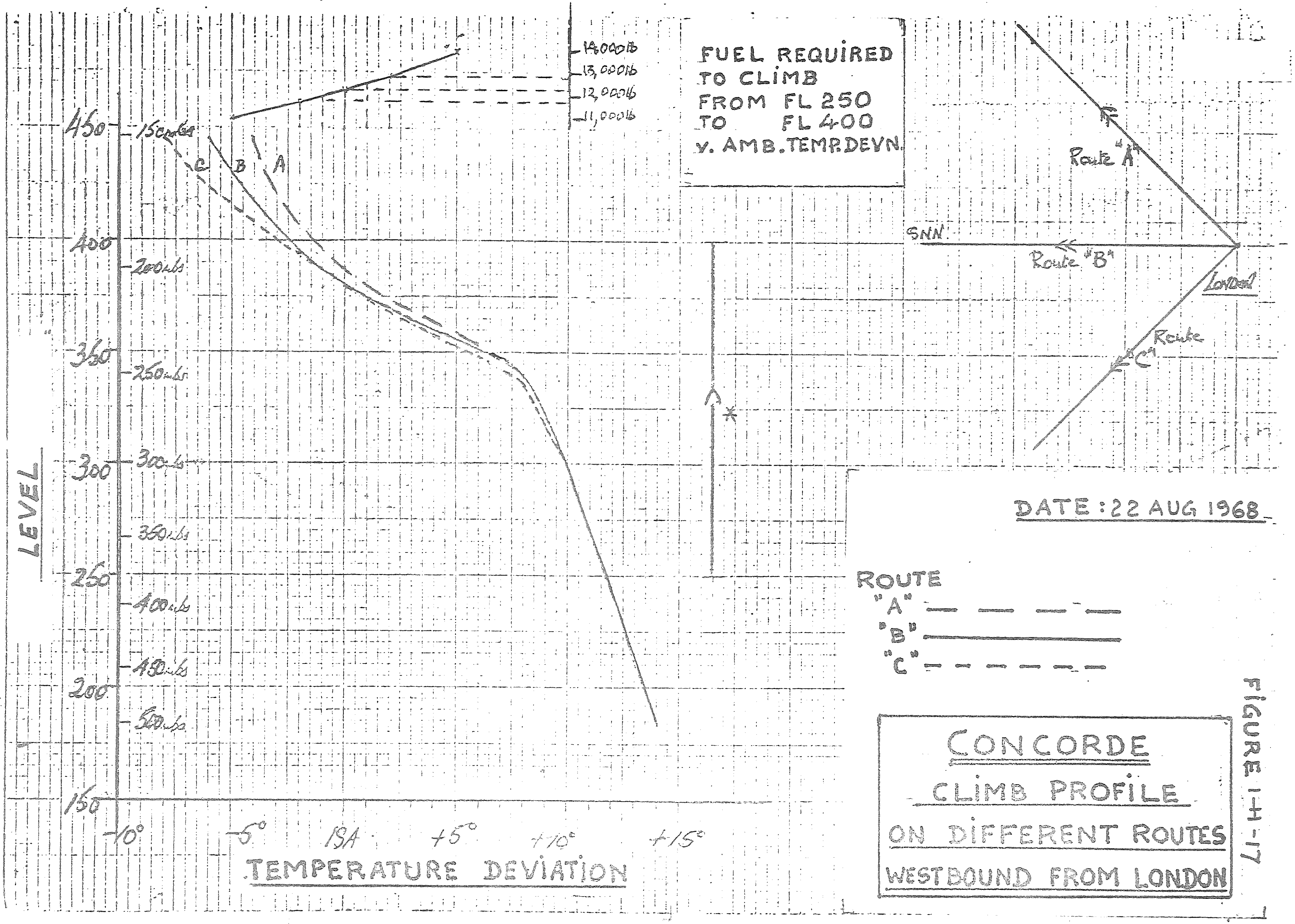


FIGURE 1-H-17

CONCORDE
CLIMB PROFILE
ON DIFFERENT ROUTES
WESTBOUND FROM LONDON

APPENDIX 1-I

OAC CLEARANCE PROCEDURES

1. The formulation and issuing of oceanic clearances to SST aircraft will present problems very different from those associated with sub-sonic jets.

2. With sub-sonic aircraft it is sufficient for the oceanic planning controller to issue a clearance for an aircraft to enter the oceanic area at a particular point and flight level. The clearance is "strategic" in that its aim is to provide separation from other aircraft for the whole of the flight in one or more oceanic control areas. It is the responsibility of the appropriate domestic controller to see that the aircraft enters the oceanic area at the correct point and level and this he achieves by the application of "tactical" control. However, owing to the SSTs performance characteristics in trans-sonic and supersonic flights, this aircraft will not be amenable to "tactical" control except to a very limited extent. The "strategic" clearance for the SST must take into account the need for separation from other outbound SSTs - not only in relation to aircraft on the same NAT track but also in relation to aircraft on other tracks which cross in the transition area. The clearance will not, however, be required to take into consideration sub-sonic aircraft and inbound SSTs in the transition area. These aircraft will be separated from the outbound SST by discrete tracks, flight profiles or "tactical" ATC procedures.

3. The overall problem which will occur in clearing SSTs will be influenced by the following factors:

a) The higher speed of the SST;

b) Its limited ability of response to "tactical" ATC measures due to the restricted manoeuvrability when flying at supersonic speed;

c) Its requirement to fly supersonically (at a height according to its speed) as soon as possible after take-off, subject to any sonic boom restrictions;

d) Its probable requirement to use a cruise/climb technique rather than cruise in level flight;

e) The greater sensitivity of the SST to certain potentially hazardous conditions such a cumulonimbus cloud, precipitation and turbulence, when in the trans-sonic and supersonic stages of flight.

4. It is considered that a "strategic" planning function similar to that carried out by OAC in respect of sub-sonic aircraft crossing the North Atlantic will be more than ever necessary for SST aircraft. Once an aircraft is in supersonic flight there will be little effective intervention possible by ATC except in emergency and all OAC clearance functions will need to be completed before an aircraft starts its trans-sonic acceleration and climb. Owing to the cruise climb cruising regime expected to be required by SST aircraft the oceanic planner will be left with only two dimensions available for separation instead of the three available to the planner dealing with sub-sonic jets. If, due to preceding supersonic traffic, the planning controller is unable to clear an SST on the track requested with no time restriction, the options left to him will be to clear it on a different track (so there must be enough tracks to take the expected traffic having due regard to the minimum longitudinal separation which will be agreed) or to delay it so as to provide the required separation with respect to the previous aircraft on the preferred track. Possibly he will have both to delay the aircraft and re-route it onto another track. It must be borne in mind that the economic penalty of deviations from the optimum flight path will be very much greater for an SST than for a sub-sonic jet. In any case the "strategic" clearance will have to be decided on by the OAC planner and received by the pilot a specified number of minutes (say 2 to 5 minutes) before the aircraft is due to reach its designated point for starting trans-sonic acceleration, so that the pilot will, for example, have time to make the necessary input into the inertial navigation system should he be cleared on a NAT track other than that planned. Not only must the "strategic" clearance have been received by the pilot but it must also be known to the domestic controller who will be controlling the aircraft in its trans-sonic phase.

5. This paper deals primarily with clearance problems likely to be experienced on the European side of the North Atlantic. The principles are however applicable generally, although the time available for the issue of oceanic clearance will vary with individual circumstances, e.g. for departures from coastal terminals with an early trans-sonic acceleration the oceanic clearance will be required on take-off.

6. Assuming that sonic boom restrictions will prevent trans-sonic acceleration taking place over land, possible routes from London and Paris to an optimum over sea point for the start of trans-sonic acceleration and climb will require a flying time of approximately 15 and 18 minutes respectively. There will be very little time for the OAC planner to receive the departure time, consider the situation, formulate a clearance and have this clearance issued via the domestic controller concerned for the pilot in good time before the aircraft reaches the start of acceleration point.

7. The possibility of issuing oceanic clearance before take-off has been considered in view of the time factor mentioned above. In order to do this the OAC planner would need to know in advance at what time an SST would take-off, or he would have to specify himself at what time it should take-off. Unless an SST was given priority treatment at airports the organisational problems involved in this at major airports would be so complex that this procedure is not believed to merit serious consideration during the initial years of SST operation. However, in the case of airports with light traffic pre-departure clearance should be possible. Indeed, should SST air-craft operate from Prestwick or Shannon, pre-departure oceanic clear-ance will be essential in view of the location of these airports in relation to Shanwick OAC. (This procedure is already in force for sub-sonic jets.)

8. Longitudinal separation can be applied by delaying air-craft either in the air or on the ground, in order to provide the required spacing behind preceding aircraft. As stated above, except in special cases, the establishment of longitudinal separation for SSTs by pre-departure clearance is not considered feasible. Without radical changes in methods of airport operation, e.g. the provision of special runways for SSTs. A method of delaying an SST aircraft while it is airborne and flying sub-sonically without increasing the distance flown is to delay the start of trans-sonic acceleration. In the case of a Mach 2.0 aircraft such as the Concorde, the rule is to delay the start of trans-sonic acceleration by double the amount of delay required in supersonic cruise, (e.g. if the start of trans-sonic acceleration is delayed by 10 minutes - about 100 NM along the route - a delay in supersonic cruise of approximately 5 minutes will result). It is envisaged that on routes south of Ireland delays at supersonic cruise of up to a maximum of about 8 to 10 minutes will be possible. The critical factor in deciding the maximum amount of delay possible being the radar cover available to monitor the aircraft while climbing through levels which might potentially be occupied by sub-sonic jets.

9. Delays in the air by orbiting at sub-sonic speed (one 360° turn would take a Concorde 6 minutes at Mach 0.93) are theoretically possible but are not considered practicable, mainly for economic reasons. When traffic builds up delays on the ground (i.e. pre-departure oceanic clearance) or scheduling of take-offs may eventually prove to be the only way of handling the traffic, but as stated above, there will be considerable organisational problems to solve before these procedures could be used at major terminal, unless SSTs are given priority over other traffic.

10. It would seem that arrangements whereby SST aircraft are fed on to a single NAT track at specified time intervals should not be too difficult while traffic density is low. Even so, where traffic from two or more terminals is likely to use two or more tracks on a random basis, additional problems arise if tracks need to cross in the transition area when SSTs are accelerating. Owing to aircraft performance characteristics "tactical" intervention by ATC will be undesirable in this stage of flight and the crossing problem will have to be allowed for in the "strategic" clearance. One method of doing so might be by vertical "profile" separation. While the feasibility of this will depend to some extent on the minimum vertical separation to be laid down it does not seem likely, in respect of routes studies to the south west of the UK, that profile separation could normally be relied on. The other method of solving the crossing problem would be by timing the flights so as to provide a specified minimum time separation at the crossing point.

11. This method would appear to be quite feasible but not too easy to apply as it would have to be applied by delaying the start of trans-sonic acceleration of one of two conflicting aircraft; this delay being coordinated with any delays required to provide longitudinal spacing on the NAT tracks. Added to this is the complication that SSTs will be accelerating in the area and accurate estimates of the time they will cross given points will not be easy to calculate in a manual ATC system. Since aircraft at the crossing points will be monitored by radar the values of the longitudinal separation applied can be less than would be the case if there was no radar cover. A note on the variability of the trans-sonic acceleration of the Concorde is contained in Appendix 1-J. If in a very exceptional case the longitudinal separation could not be maintained and the development of a hazardous situation was observed on radar, the ATC "tactical" intervention which would then be necessary might mean that one SST would have to abandon its supersonic acceleration. It is obvious that the presence of these crossing points in the transition area and the need to apply time separation would affect the achievable capacity of a North Atlantic SST track structure.

12. The crossing problem in the transition area could to some extent be obviated by rationalizing the route structure so that traffic from a particular terminal used a particular NAT track. This system would have repercussions on economics owing to the different lengths of the various tracks but may merit serious consideration provided the track structure adopted shows that the differences will not be excessive.

13. Appendix 1-K consists of a diagram showing possible westbound tracks in the vicinity of the eastern boundary of the North Atlantic area. Three westbound North Atlantic tracks are shown. (The corresponding eastbound tracks are omitted for clarity.) Trans-sonic routes and acceleration points are indicated for traffic out of London and Paris together with a third route along the English Channel which might be feasible for traffic from Brussels and Amsterdam.

14. In order to assist in the orderly provision of oceanic clearances and make for an efficient North Atlantic SST operation, it is considered that the following principles must be adopted regarding SST operations in the area where trans-sonic acceleration will be carried out:

a) ATC radar should cover at least the portion of the SST's flight path from the start of trans-sonic acceleration until the aircraft has climbed through levels used by sub-sonic jets, i.e. up to about flight level 400 (except in areas where the density of sub-sonic traffic is so low as to render this unnecessary).

b) As SSTs are not amenable to "tactical" control during trans-sonic acceleration other aircraft must be kept clear of their path during this phase. Simulation suggests this should not present any great problem.

c) The "tactical" problem should be eased by the inter-relationship of SST and sub-sonic routes, i.e. discrete tracks should be provided as far as possible.

15. The situation will be eased by the fact that, during the first few years of SST operation, a single type of aircraft only is likely to be operating on the NAT routes. (When other aircraft are introduced in due course it is hoped that their performance characteristics will be sufficiently different so as to provide for a natural vertical separation during much of the flight.) Within certain tolerances this single type of aircraft should have a standard basic performance (i.e. all aircraft should have the same performance in the same ambient conditions) and a standard navigational capability. This means that aircraft flying on the same NAT track, starting their trans-sonic acceleration at the same point spaced by a specific number of minutes, will retain the same spacing in minutes when they are cruising supersonically, plus or minus a small variation. The distance between successive aircraft will vary from approximately 10 NM per minute when sub-sonic to approximately 20 NM per minute when cruising at about Mach 2.0, but the time interval will remain substantially the same. This suggests that a procedure could be devised so that the longitudinal separation is based purely on the time SSTs are due over designated acceleration points and not according to the time they are due to enter an oceanic control area; as is the case with sub-sonic aircraft. A time relationship would have to be laid down between different acceleration points. An alternative procedure for the application of longitudinal separation would be by the establishment of a datum line chosen so that all westbound SSTs would have achieved their cruising Mach number before reaching it. For transatlantic routes from London and Paris, south of Ireland, the datum might be represented by the meridian of 15°W, although in order to allow for aircraft acceleration being delayed it would probably be preferable to use 20°W. An estimated time for passing the datum should be included in the flight plan.

16. Although the SST is likely to be introduced into a mainly manual oceanic clearance environment at the European end, it would seem that, when SST traffic starts building up, the calculations required will make the need for some automated processes essential.

17. Another factor which could effect the start of acceleration and consequently the application of longitudinal separation, will be the presence of potentially hazardous meteorological conditions in the transition area. It is considered inadvisable for SSTs to fly through convective cloud, precipitation and turbulence during the trans-sonic acceleration and supersonic stages of flight. Where these conditions are present above FL 250 in the transition area it may prove necessary for trans-sonic acceleration to be commenced at a different location or at a level higher than FL 250 when this is practicable.

18. When meteorological conditions occur in the transition area which may make it difficult or impossible for an SST to continue on the planned track and profile, the crew of the aircraft, due to their airborne radar, are likely to be in a better position than ATC to assess the situation and decide on the best course of action. Of course, any "tactical" changes of flight plan to avoid flying in adverse meteorological conditions may effect the timing of the particular SST on its NAT track and will have repercussions on following aircraft.

19. It is clear that there will have to be very close liaison and coordination between the oceanic planner and the domestic controller responsible for the area in which trans-sonic acceleration are carried out in view of possible amendments to clearances due to "tactical" manoeuvres. If European/NAT transition areas are located to the south-west of the UK there will not only have to be very close coordination between the oceanic planner and the appropriate domestic centre but also between that centre and the appropriate sectors of Paris and Shannon ACCs.

APPENDIX 1-J

NOTE ON THE VARIABILITY OF THE TRANS-SONIC ACCELERATION OF THE "CONCORDE" SST AIRCRAFT

1. General

1.1 The characteristics of the "Concorde" and, we believe, of other SST aircraft will be such that during the acceleration manoeuvre it will be economically undesirable or even potentially dangerous to alter the programmed flight path. For this reason, air traffic control should arrange separation from other SSTs accelerating on the same path or on converging paths by controlling the times at which such aircraft start the acceleration manoeuvre. We assume that such planning will take account of the expected performance characteristics of both aircraft, having regard to their estimated weight and the expected meteorological conditions, but that there will be residual uncertainties which must be met by planned separations between aircraft on the same or converging tracks. Such uncertainties arise from meteorological forecast errors and from variation in aircraft conditions (weight, thrust, drag). We examine each of these in turn.

2. Errors in Wind Forecast

2.1 Information on this subject is based on a paper by C.S. Durst which appeared in the July 1960 issue of the Journal of the Institute of Navigation. From his figures the standard error of a 24-hour forecast at the relevant flight level (200 mb) is about 33 KT. Now the SSTs should be able to use a more recent forecast than that made 24 hours prior to the flight. Assuming that it is not older than 6 hours before the flight, we may halve the forecast error to 16 KT.

2.2 In considering the case of two aircraft on converging tracks we are concerned with the difference between forecast errors between places about 150 NM apart. Durst quotes for this separation a correlation coefficient of 0.8 between wind estimate errors. The corresponding standard difference of errors is 10.5 KT. This difference will affect the planned separation of two Concorde aircraft during the acceleration phase by 0.39 minutes.

2.3 For aircraft on converging tracks there is a further effect of wind errors on separation because, even if the wind error would be constant over the region, it would affect each aircraft differently. Present planning of the system for London and Paris traffic westbound into the Atlantic involves tracks converging at about 30°. The differential effect of a wind error on two converging aircraft varies with the direction of the error vector with respect to the track. Assuming that such error is randomly distributed in direction, the standard error of 16 KT corresponds to a standard error of wind differential on 30° converging tracks of 5.9 KT. This corresponds to a difference in acceleration times of 0.23 minutes.

2.4 For aircraft on converging tracks, this difference is additive to the former estimate of 0.39 minutes to allow for the variation of error with lateral spacing, giving a total of 0.62 minutes to represent the standard variation in planned separation due to errors of wind estimation.

2.5 For aircraft following each other on the same track we are concerned with actual wind variations in the same place over a small interval of time (since we can assume that both aircraft use the same forecast). Between winds at times 24 hours apart Durst found a correlation factor of 0.7. Over a period of one hundredth of this time the correlation factor should be 0.997 assuming linear variation. The expected wind change is 3.9 KT, corresponding to a change in separation of 0.15 minutes.

3. Temperature Errors

3.1 We have no corresponding data on variation of errors of temperature measurement to that of Durst on wind measurement. However the seasonal standard deviation of temperature at 200 mb is 6°C. Assuming similar correlation coefficients with distance and a lower relative standard of temperature forecasting than wind forecasting, a standard difference in temperature error of 30°C* is "guesstimated" for places 150 NM apart. This corresponds to a change in separation of aircraft on converging tracks of 0.4 minutes. For aircraft following each other on the same track the separation change would be about one half of this, say 0.2 minutes.

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* The errors of measurement of temperature are of the order of 1°C. This itself would contribute a standard error to a temperature difference between two stations of about 1½°C.

4. Errors in Aircraft Weight Estimation

4.1 For variations in aircraft conditions data given in the report of the Concorde Fuel Reserves Working Party is used. Here a standard error of estimation of take-off weight of 500 lb. is suggested. This corresponds to an error in transition time of one aircraft of 0.03 minutes. The error in separation between two aircraft would be 0.04 minutes.

5. Variations in Thrust and Drag

5.1 These may be considered together. A rough estimate suggests that over the critical part of the transition manoeuvre a 1% change in thrust would affect the excess of thrust over drag by about 2.8% and a 1% change in drag by about 1.8%. Now the scatter of engine performance is about 2.5%. If one regards the standard deviation as one third of this and remembers that there are four independent engines, the overall deviation of thrust is 0.42% giving 1.15% variation of thrust excess over drag. The working party report gives 0.2% standard deviation of drag under cruise conditions for the Concorde. On the dubious assumption that this also applies to trans-sonic conditions there is a further variation of 0.36% in thrust excess over drag. Now conversion of these changes in thrust excess into changes in aircraft performance is indeterminate because the thrust excess is distributed between angle of climb and forward acceleration in an arbitrary way. The simplest assumption is that a given percentage change of thrust excess produces the same effect on performance as the same percentage change in weight.

5.2 On this basis the above changes in thrust and drag result in changes in acceleration time of 0.23 minutes and 0.07 minutes respectively. The corresponding changes in the separation of two aircraft are 0.32 minutes and 0.10 minutes. These figures apply equally to aircraft on converging tracks and aircraft on the same track.

6. Summary

6.1 The standard deviations of the various factors causing variation in planned separation for aircraft on converging tracks and the same track respectively can be summarised as follows:

Errors due to	S.D. for aircraft on:	
	Converging Tracks	Same Track
Wind Estimate	0.62 minutes	0.15 minutes
Temperature Estimate	0.40	0.20
Weight Estimate	0.04	0.04
Thrust Variation	0.32	0.32
Drag Variation	0.10	0.10
Root Sum of Squares	0.81 minutes	0.42 minutes

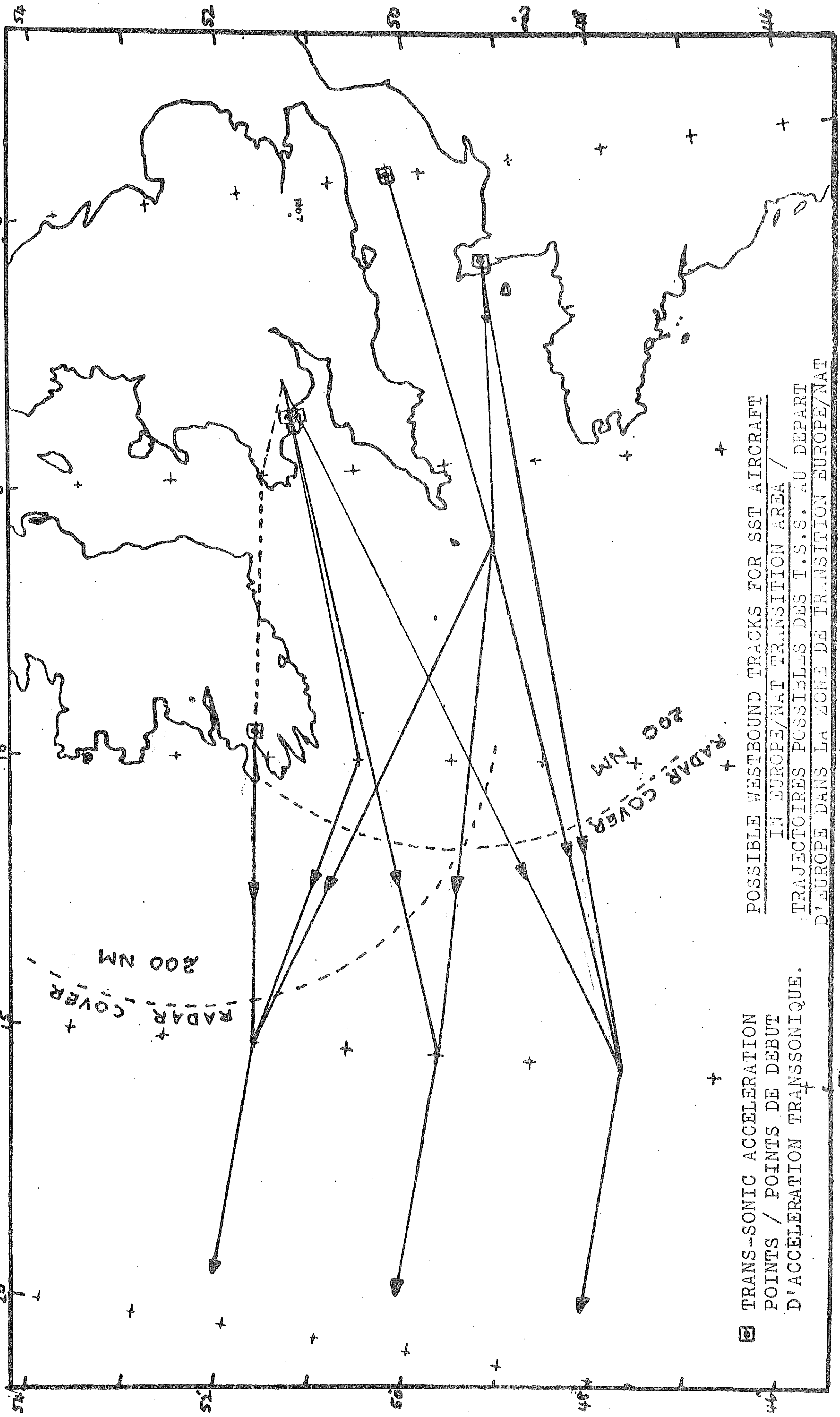
6.2 All the above variations, with the possible exception of the drag variation (not an important item) can be regarded as approximately Gaussian in form with zero mean. Since they are mutually uncorrelated, the root sum of squares represents the standard deviation in the separation due to all causes. If the planned separation is taken as three times the standard deviation together with 0.5 minutes or 10 miles at supersonic speed as the minimum uncertainty in position, whether determined by radar or other short range navigational aid, the resulting separation in round figures is thus 3 minutes for converging tracks and 2 minutes for the same track. With these planned separations the actual separations should shrink to less than the minimum of 10 NM on about 1 in 1 000 occasions. On some of these occasions the automatic difference in levels will be such that no interference with aircraft will be necessary or that only a small height adjustment need be made. However on a few occasions the controller monitoring the situation may be forced to request such a change in level that one aircraft must abort its mission.

7. The Domestic-Oceanic Transition

7.1 Two aircraft accelerating within domestic airspace may be allocated the same or different oceanic tracks and such allocation should be made before the transonic acceleration begins. In the event of two successive aircraft being allocated the same oceanic track their required separation at the entry point into oceanic airspace will probably be not less than 10 minutes, at least in the early years of SST operation. If their transition phases are programmed to give this separation at the oceanic entry point they should be amply separated during transition itself. It has been shown, however, that a planned separation of 10 minutes before transition starts may, in rare cases, be reduced during transition to 7 minutes if the aircraft accelerate on converging tracks or to 8 minutes if they accelerate on the same track. In this case an acceptable solution (perhaps the only acceptable solution) is to allow the first aircraft to enter the oceanic airspace with reduced separation but requiring the following aircraft to operate at reduced speed. A 5% speed reduction should be sufficient even when the separation is reduced by 3 minutes.

7.2 In the case where the two aircraft are allocated different oceanic tracks they may be much closer in the transition phase. The most difficult case is where an SST aircraft departing from Paris is allocated a more northerly track than an aircraft departing from London. Here the planned oceanic entry times must be not closer than 3 minutes apart. This restriction on the mutual independence of tracks will tend to reduce the capacity of the system.

APPENDIX 1-K


POSSIBLE WESTBOUND TRACKS FOR SST AIRCRAFT IN EUROPE/NAT TRANSITION AREA /
TRAJECTOIRES POSSIBLES DES T.S.S. AU DEPART D'EUROPE DANS LA ZONE DE TRANSITION EUROPE/NAT
TRANS-SONIC ACCELERATION POINTS / POINTS DE DEBUT D'ACCELERATION TRANSSONIQUE.
RADAR COVER 200 NM
RADAR COVER 200 NM