CIRCULAR 36-AN/31

ICAO CIRCULAR

1953

PROBLEMS ARISING IN AGA FIELD AS A RESULT OF THE INTRODUCTION OF TURBINE ENGINED AIRCRAFT

Published by authority of the Secretary General

INTERNATIONAL
CIVIL AVIATION
ORGANIZATION
MONTREAL • CANADA

This Publication is issued in English, French and Spanish.

Published in Montreal, Canada, by the
International Civil Aviation Organization.
Correspondence concerning publications
should be addressed to the Secretary General
of ICAO, International Aviation Building,
1080 University Street, Montreal, Canada.

Orders for ICAO publications should be sent, on payment:

In Canadian currency ($), to

Secretary General, ICAO,
International Aviation Building,
1080 University Street,
Montreal, Canada.
(*Cable address:* ICAO MONTREAL);

In Sterling or Irish currency (s/d), to

Her Majesty's Stationery Office,
P.O. Box 569,
London, S. E. 1,
England.
(*Cable address:*
WHOLECORN, SEDIST, LONDON);

In French currency (fr), to

ICAO Representative,
European and African Office,
60bis, avenue d'Iéna,
Paris (16e), France.
(*Cable address:* ICAOREP PARIS);

In Egyptian currency (L.E.), to

ICAO Representative,
Middle East Office,
Wadie Saad Building,
Sharia Salah el Dine,
Zamalek, Cairo, Egypt.
(*Cable address:* ICAOREP CAIRO);

In Peruvian currency (soles), to

ICAO Representative,
South American Office,
Apartado 680,
Lima, Peru.
(*Cable address:* ICAOREP LIMA);

In Australian currency (s/d), to

ICAO Representative,
Far East and Pacific Office,
10 Weybridge Street,
Surrey Hills, E.10,
Melbourne, Australia.
(*Cable address:* ICAOREP MELBOURNE).

In Indian currency (Rs.)

Oxford Book and Stationery Company,
Scindia House
New Delhi, India.

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

INTRODUCTION

At the Fifth Session of the Aerodromes, Air Routes and Ground Aids Division (October-November 1952) one day of the meeting (19 November) was devoted to discussions on the following parts of Agenda Item 6, Exchange of technical views on:

6.1 Problems arising in the AGA field as a result of the introduction of turbine-engined aircraft;

6.3 Lighting and marking for ground traffic control;

6.4 Run-up areas near taxi-holding positions.

In accordance with Recommendation No.16 of the Division, which was approved by the Council of ICAO, the following summary of the discussions has been prepared. Although Items 6.3 and 6.4 were not intended originally to be related to Item 6.1 it was found that during the discussions, aspects of both of these items entered into considerations of the needs of turbine-engined aircraft. Similarly, under Item 6.1 it was found that a number of the problems discussed and the solutions suggested applied equally well to modern high speed reciprocating engined aircraft. It has therefore been decided to summarize, in one circular, the discussion on these three items. This circular will serve to supplement the information contained in the following ICAO Circulars:

Circular 17-AN/14, The effect of turbine-powered civil aircraft on the design, construction and equipment of land aerodromes.

Circular 23-AN/20, Problems associated with the advent of turbine-engined airplanes.

Note. - Item 6.2 - Strength of runways, was discussed at another full day's meeting. A summary of the discussions will be found in ICAO Circular 37-AN/32.

THIS PAGE INTENTIONALLY LEFT BLANK

1. - CONDUCT OF THE MEETING

1.1 The meeting was convened under the chairmanship of Dr. K.N.E. Bradfield of Australia who called first upon Mr. W.M. Hargreaves of the United Kingdom to open the discussions. Mr. Hargreaves introduced paper AGA V-WP/8 which, for convenience, is reproduced at Attachment A. He selected the following headings under which to make amplifying remarks:

1) Pavements;

2) Runways lengths;

3) Taxiways;

4) Holding areas;

5) Handling of jet aircraft on aprons;

6) Noise.

The chairman next called upon Mr. W.C. Peck, of the United States, who confined his remarks to the effects of turbo-jet aircraft on aerodrome pavements and dealt with the subject under the following headings:

1) Fuel spillage;

2) Temperature and velocity effect of exhaust gases.

He also mentioned briefly the effect of high tire pressures which was covered more fully in the discussion on Agenda item 6.2 and reproduced in ICAO Circular 37-AN/32.

1.2 The Chairman proposed and it was agreed to conduct discussion on Items 6.1 and 6.4 under the headings suggested by Mr. Hargreaves with particular reference to the effect of turbo-jet aircraft on aerodrome pavements. A discussion on Item 6.3 followed. The opinions expressed represent the views of the speakers and not necessarily those of the States or the organizations to which they belong. In addition to the Chairman and the above-mentioned speakers, the following took part in the discussions: Mr. M.E.P. Pascal and Mr. A.N. Baldino (France), Mr. R.W. O'Sullivan (Ireland), Mr. H.B. Sitter (Netherlands), Mr. H. Weibel (Switzerland), Mr. V.E. Camacho, Mr. J.A. Karran and Mr. J.F. Newbery (United Kingdom), Mr. J.D. Blatt, Mr. A.L. Catudal and Mr. P.A. Hahn (United States), Mr. G. J. Malouin (IATA) and Mr. P. Larsen (Canadair), Mr. J. M. Lerew and Mr. B. M. Hellman (ICAO Secretariat).

2. - PAVEMENTS

2.1 General. The effects or possible effects of heat, blast and fuel spillage were considered, taking into account the important variables involved including the locations at which fuel spillage may occur and where heat and blast effect may be greatest, the height and inclination of the axis of thrust of the engines, the average operating times at each location, the percentage of power used and the types of pavements and materials used. The effects on fittings, markings and on the areas surrounding pavements were also discussed. It was noted that if pavements were damaged by fuel spillage, heat and blast on the same area could greatly accelerate the damage, thus these possible causes of damage could be cumulative. The effects of the use of rockets and of "afterburning" were also mentioned.

2.2 Heat and blast. Studies on civil turbo-jet aircraft operations in the United Kingdom had indicated that, for engine checks after maintenance operations, the time of run-up averaged 1-1/2 minutes per engine and that the normal time of run-up at the end of a runway was of the order of 20 seconds. It was stated that, in the case of the De Havilland Comet aircraft in which the engines are mounted within the wings with their axes of thrust high and parallel to the ground, there was no heat or blast effect on the pavement. Tests conducted in the United Kingdom with turbo-jet engines without afterburning and having gas temperatures at the orifice of about 650° C (1 200° F), had indicated that, if the height of a horizontally mounted engine was 3-1/2 times the diameter of the jet orifice, the effect of heat and blast on the pavement was nil. Tests with engines mounted at a lower height (i.e. hung in pods below the wings) or with their axis inclined towards the pavement had indicated that, in normal operations, the effect on asphaltic or tarmac pavements and the jointing material in rigid pavements could be considerable but that the effect on concrete was nil.

In the United States similar studies on military aircraft operations had indicated that the average time spent with various types of turbo-jet aircraft, including four-engined types, was of the order of 3-1/2 minutes on the starting apron, 14 minutes on the maintenance apron and 30 seconds on the end of the runway for "run-up" prior to taking-off. Approximately 70% power was used to start the aircraft rolling and it was then cut back to 50% power on less for taxying. The figure of 14 minutes was made up of individual cases that ranged from 2 to 40 minutes but in all cases full power was used for only a small percentage of this time. For test purposes a 13-minute period was chosen and divided as follows: 5 minutes at 40% power, 1-1/2 minutes at 100% power, 5 minutes at 40% power and 1-1/2 minutes at 100% power. Tests had indicated that with the most critical type of military turbo-jet aircraft running at 100% power for 21 minutes, pavement temperatures had reached a maximum of 205° C (400° F) but that on an average pavement temperatures for prolonged blasts had not exceeded 93° C (200° F). Field results in actual operations however, seemed to indicate that, at least in some cases, the actual effect on pavements was more severe than was indicated by the tests.

For certain military operations tests were being conducted in the United Kingdom with a material they had called "jetcrete", which consists of a sand aggregate, tar emulsion and cement mix spread in a layer 2 cms - 2.5 cms (3/4" - 1") thick, on any base material. It had given very good results showing no damage at temperatures up to 205° C(400° F), but it was expensive and the technique of laying it was difficult since it sets very quickly. United States experience suggested that protective coverings, particularly if they were prone to cracking, introduced effects that were worse than those experienced with the original paving since the cracks tended to hold spilt fuel.

Further effects of heat and blast noted with military aircraft were damage to the shoulders of taxiways and the area beyond the ends of runways and also the hazard of grass fires. Remedies applied with success included sealing the shoulders of taxiways for a width of 7.5 metres (25 feet) and sealing an area at the ends of runways for a distance of 90 metres (300 feet). It was pointed out that it was always advisable, at sites where there was a risk of grass fires, to keep the grass cut down. Some damage from heat or blast to light fixtures was reported. It appeared that this was largely caused by loose stones being blasted against the glass and breaking it. The amendments to Annex 14 contain recommendations to clear loose stones from pavements. It may be necessary, however, to take special precautions with threshold lights, e.g. locate them outside the lines of runway lights.

In the case of aircraft equipped with rockets for assisted take-off it was the experience of the United States that the temperatures in the core of the exhaust ranged from 2 000° C to 2 900° C (3 600° F to 5 200° F) with velocities from 1 800 to 2 400 metres per second (6 000 to 8 000 feet per second), but that temperatures at 0.75 to 0.9 metres (2-1/2 to 3 feet) below the axis and 7.5 metres (25 feet) to the rear drop to about 370° C (700° F). As might be anticipated the effect on pavements could be considerable.

2.3 Fuel spillage. Experience indicated that the most likely areas for fuel spillage were limited to those where refuelling, starting, stopping and acceleration occurred (i.e. on aprons and at the ends of runways). The reason why spilt jet fuel may affect pavements is that it evaporates slowly and therefore remains in contact with the pavement for a relatively long time as compared with aviation gasoline. It tends to soften bitumen but does not affect cement or tar. Once bitumen is softened by these fuels it remains soft and cannot be rehardened. Unless it is replaced it is liable to be picked up on the tires of aircraft and to cause damage to aircraft mechanisms and is itself subject to further damage by heat and blast. Tests indicated that the softening effect of spilt fuel on bituminous pavements could be minimized by the use of dense mixes of well graded and well compacted materials free of holes which hold the fuel. Older pavements, that were well compacted by use, resisted the effects of fuel spillage better than new or unused pavements except that it was found that old dried-out lifeless pavements were susceptible to damage by fuel spillage. It was stated that six months was the minimum period that should be allowed for the curing of bituminous pavements before they will offer a reasonable degree of resistance to the solvent action of jet fuel.

2.4 Conclusions. In both the United Kingdom and the United States it was suggested that special attention should be given to apron areas to ensure that they were resistant to fuel spillage and to the heat and blast effect of turbo-jet aircraft. Methods adopted included the use of concrete with special joint fillers, various types of which are under development, and the use of special surfacing materials (i.e. "jetcrete" in the United Kingdom). Both the United Kingdom and United States agreed that fuel spillage at the ends of runways may be neglected but the United States suggested that special treatment should be given to the first 90 metres (300 feet) of the ends of runways - i.e. concrete and dense, well compacted bituminous pavements had been used. In regard to the areas beyond the ends of runways and the shoulders of taxiways it was suggested that in certain cases special treatment, such as the cutting of grass and the use of some binding or sealing material may be required.

3. - RUNWAYS LENGTHS

Discussion on this subject was more limited and only representatives from the United Kingdom attempted to forecast trends in this matter. It was suggested that take-off requirements, which, for the Comet were comparable to those of modern large piston engined aircraft under standard atmospheric conditions, were not likely to increase and there was some evidence that the position was likely to improve. To meet the accelerate stop case the United Kingdom speakers were in favour of the use of stopways.

In regard to landing requirements, the following factors were mentioned:

a) Increased aerodynamic "cleanness" and the absence of reversible pitch airscrews both tended towards increased landing requirements in relation to take-off requirements;

b) Increases in wing loading also produced the same tendencies but were compensated to some extent by the fact that, at the present stage of development, the weight of fuel consumed by turbo-jet engines for a given journey reduced the landing weight to considerably less than the take-off weight. Methods of controlling landing requirements included the use of non-skid brakes, improved flaps and aerodynamic brakes. The use of tail parachutes and turbo-jet engines with reversible thrust were mentioned but not discussed. The main requirement from the point of view of aerodrome design was the provision of runway surfaces that retain a satisfactory coefficient of friction even when wet.

4. - TAXIWAYS

It was agreed that the principal aims should be to provide for reasonably high-speed taxying and to avoid conditions that would require slowing down and accelerating. It was noted that these aims were also desirable for modern piston-engined aircraft. In both the United Kingdom and United States it had been found that taxiways 22.5 metres (75 feet) wide appeared to meet the requirements of modern large aircraft. In the United Kingdom present practice was to provide fillets of 45 metres (150 feet) inside radius at right angle junctions or bends and that these permitted taxying speeds of the order of 35-40 mph. France and United States speakers suggested that greater radii were needed. It was generally agreed that the existing specifications in Annex 14 may need to be reviewed in the light of future experience particularly in respect to such questions as to whether long straight taxiways with right-angled bends should continue to be used in preference to long gentle curves; whether the radii recommended for fillets were adequate and also whether provision should be made in the Annex for high speed turn-offs from runways and possibly for banked turns on taxiways outside the strips.

5. - HOLDING AREAS

In the opinion of the United Kingdom holding or run-up areas were only required where the aerodrome traffic consisted either of all reciprocating engined aircraft or a mixture of turbo-jets and reciprocating engined aircraft. If an aerodrome was used only by jets there would be no requirement for holding areas. The reasons advanced for this were that with reciprocating engined aircraft, although they might arrive in the order 1, 2, 3, 4 for run-up, they may not necessarily be ready for take-off in that order, i.e. No. 3 may have to by-pass No. 2. With the addition of turbo-jet aircraft which do not require to be run-up except in maintenance areas and on an actual take-off, it was desirable, while not giving them priority over piston engined aircraft, to give them take-off clearance prior to starting up on the apron. If the jet required X minutes to reach the end of the runway, it was given clearance X minutes before its time for take-off and it could then simply taxi straight out to the end of the runway, by-passing any piston engined aircraft that were being "run-up".

In regard to the number of run-up areas needed, experience indicated that for operations from one runway, piston engined aircraft required 2 for 15 operations per hour, 3 for 20 operations per hour and 5 for 30 operations per hour. Where dual runways were used, the requirements were 1 or 2 for 15 take-offs per hour and 4 for 40 take-offs per hour. Views differed on the question of the location of these run-up areas in relation to the ends of runways. Some believed that they should be located close to the ends (i.e. up to the taxi-holding position) while others, including speakers from France and Switzerland, felt that the presence of several aircraft running up close to the end of a runway would create an undesirable and possibly dangerous obstruction and therefore suggested that the run-up areas should be clear of the strip. Current practice in the United Kingdom and United States was simply to widen the taxiway close to the end of the runway so as to provide an area sufficiently large to permit the requisite number of aircraft to be run-up while at the same time permitting others to by-pass the stationary aircraft. In the United Kingdom it had been found that a rectangular area 195 metres x 75 metres (650 x 250 feet) provided for the necessary manoeuvring of 4 large modern transport aircraft onto and off run-up positions and for a fifth to by-pass them, provided that the taxying speed was kept low and care was exercised. (See Figure 1.) Several speakers felt that a rectangular area was costly and wasteful and they demonstrated a variety of grid and annular patterns. (See Figures 2-4 inclusive, which are very approximate sketches and are not necessarily to scale.)

6. - APRONS

In addition to the effects of fuel spillage and heat and blast, which have alreary been reported on in Section 2, discussion of this item ranged from the handling of aircraft on busy terminal aprons by means of tractors or by gravity on sloping ramps, to dispersing aircraft near the ends of runways and using bus transportation.

With centralized terminal aprons at busy aerodromes the following procedure had been found satisfactory in the United Kingdom. Turbo-jet engined aircraft are taxied up to the terminal building nose first, usually at an angle of 45° to the building and parked in this position for unloading. The aircraft remains in this position for servicing and reloading and when the particular aircraft is ready to receive its passengers it is towed by tractor to a more remote part of the apron where the necessary clearance from other aircraft and buildings is available for starting up and taxying. The passengers are then transported by bus over the relatively short distance from the terminal buildings to the aircraft. The question was raised as to why the passengers should not be loaded at the terminal building and the answer was that with existing facilities the process of towing was slow and tedious and that it was also desirable at a busy airport to clear the aircraft from the terminal building as soon as practicable, even though they were not scheduled to depart immediately. It was generally agreed that it was inadvisable to start turbine engined aircraft close to a terminal building and that it was impracticable and uneconomical to tow aircraft by tractor over any great distance such as might exist between the terminal building and the ends of runways.

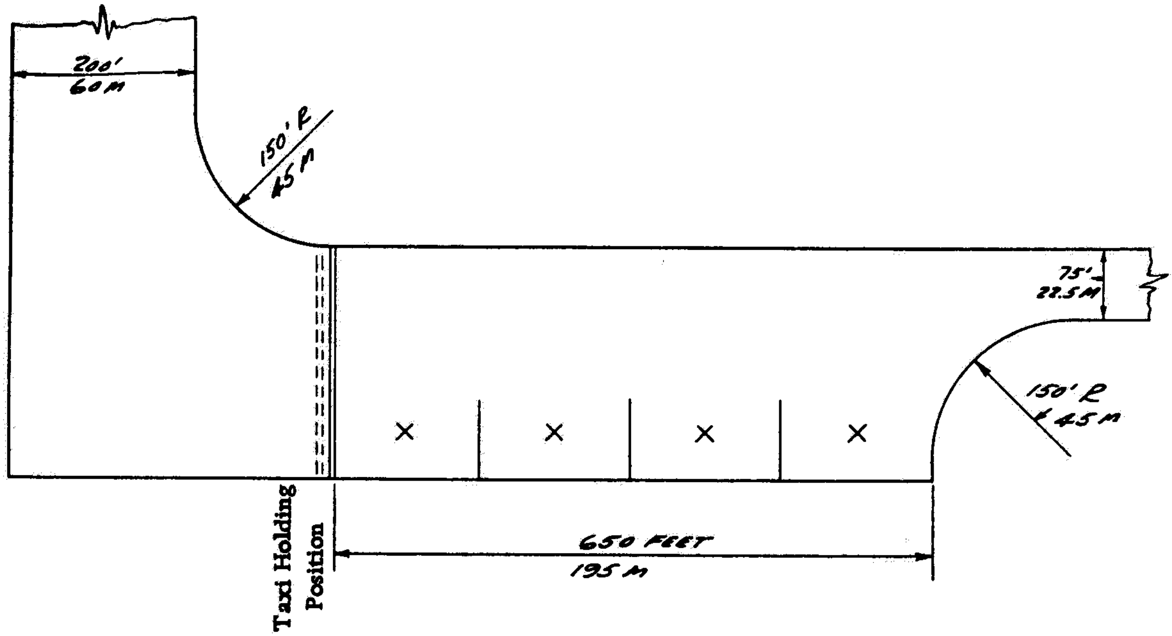


FIG. 1. - RECTANGULAR PATTERN FOR HOLDING 4 AIRCRAFT OF UP TO 45 M. (150') WINGSPAN. - (U.K.)

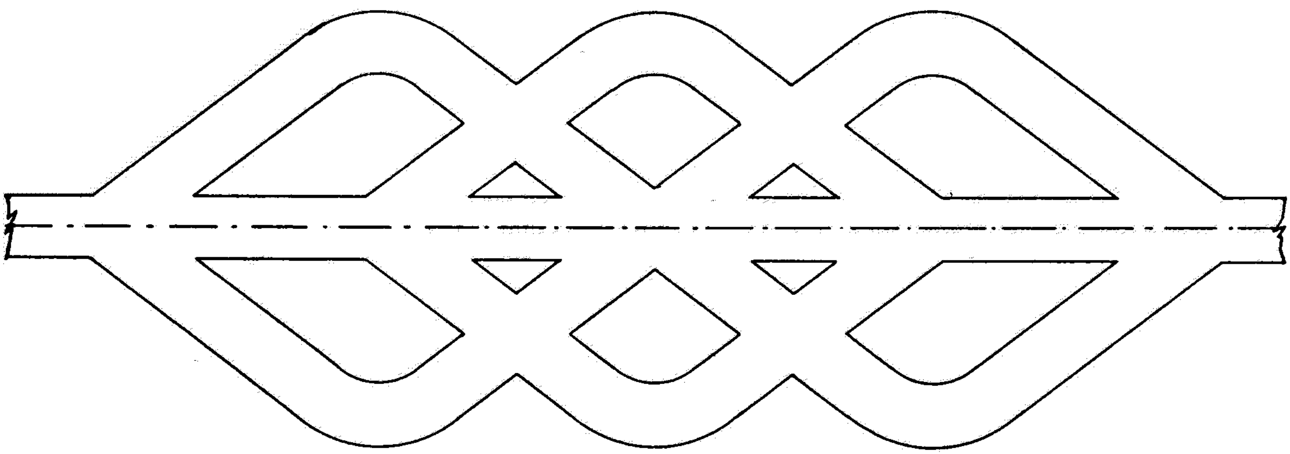


FIG. 2. - PATTERN SHOWING SIX HOLDING POSITIONS (FRANCE) (DIMENSIONS DEPEND ON SIZE OF AIRCRAFT TO BE ACCOMMODATED)

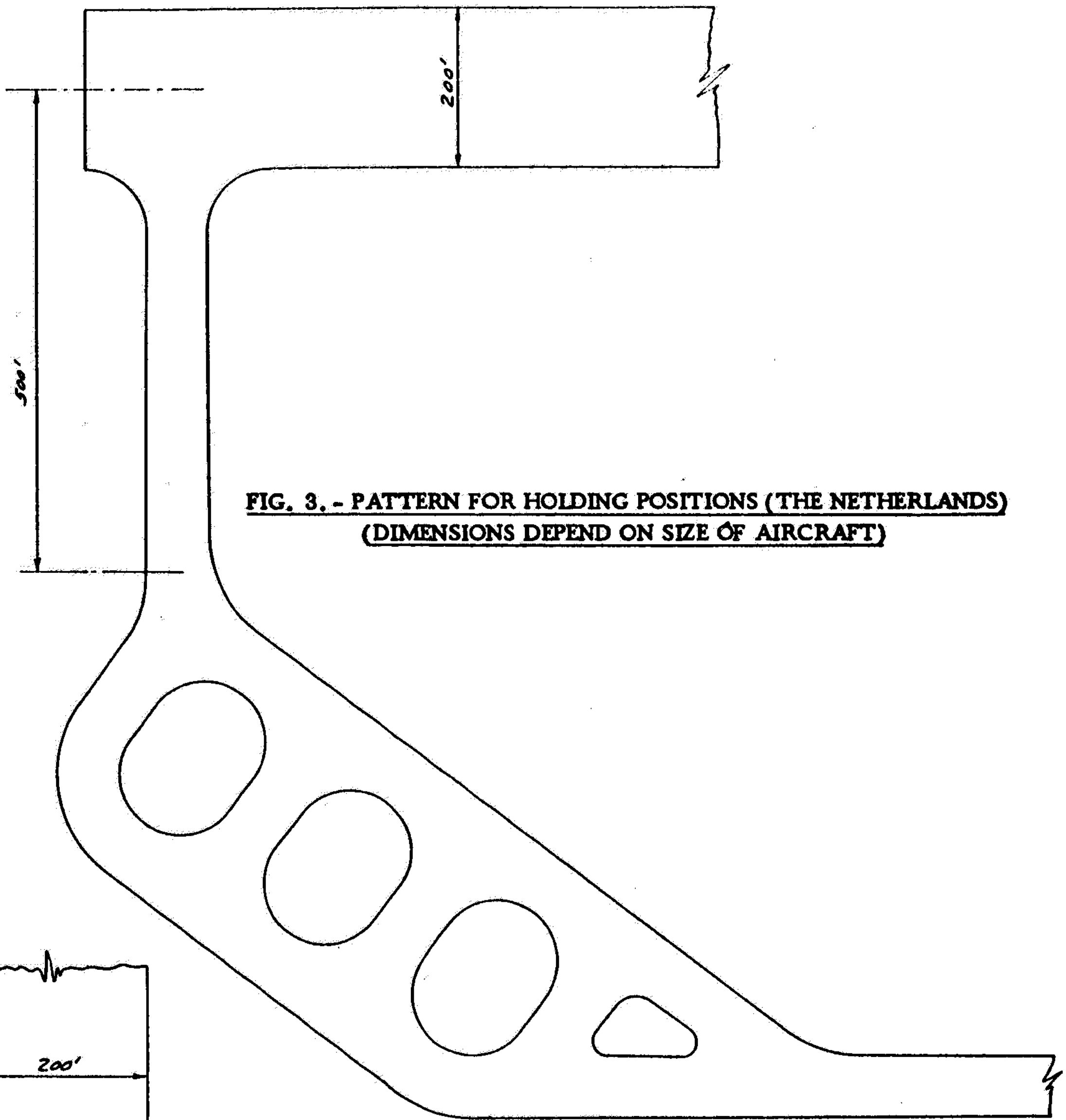


FIG. 3. - PATTERN FOR HOLDING POSITIONS (THE NETHERLANDS) (DIMENSIONS DEPEND ON SIZE OF AIRCRAFT)

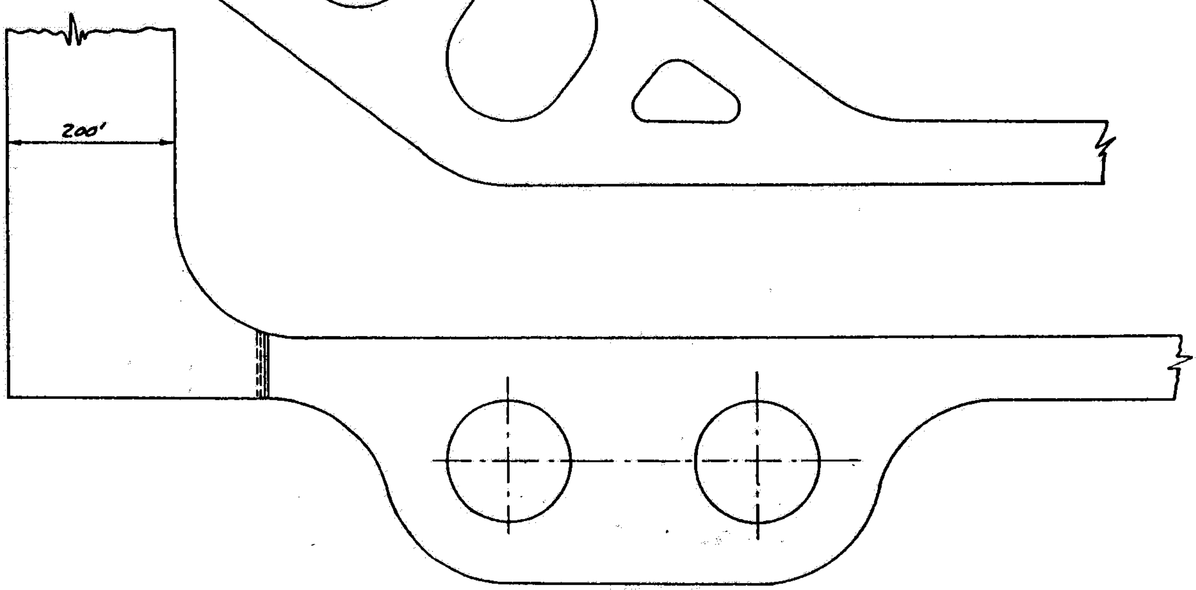


FIG. 4. - ANNULAR PATTERN - DIMENSIONS DEPEND ON SIZE OF AIRCRAFT (AUSTRALIA)

An Australian scheme to provide ramps up to and down from the terminal building was described. On arrival, aircraft would taxi up a 2° - 3° slope either onto or immediately in front of the terminal building and stop on a downward slope of approximately the same magnitude. It would be unloaded and loaded by means of elevators, in or accessible (under cover) to the terminal building. It would also be serviced in this position. When the aircraft was ready to leave, the chocks would be depressed and the aircraft would be allowed to roll down the slope to an area sufficiently remote from the terminal building to permit it to be started up. The advantages claimed for this system were:

a) Turbine engined aircraft could be parked nose to tail close together, thus savings could be made in apron area and in the periphery of the terminal building;

b) No tractors would be needed, thus there would be a saving on this type of equipment and personnel to operate it;

c) Passengers would not be exposed to the weather and no buses would be needed to transport them to their aircraft. The distance passengers would have to walk to board their aircraft would also be reduced. Studies have shown that these savings would, in most cases more than balance the cost of the ramps and elevator equipment.

This system was designed to meet domestic requirements in Australia where "turn-around" times were short and traffic studies had indicated that the system would be sufficiently flexible to meet operational requirements. Some doubt was expressed, however, regarding its applicability to airports in Europe since on many international services "turn-around" times varied considerably.

Another suggestion was that of eliminating the terminal building apron altogether and dispersing the aircraft at holding positions near the take-off end of the runway to be used. Assuming that the holding positions were served by road and telephone communications, underground refuelling and power supply and that a special vehicle or vehicles were developed for transporting crews, passengers, baggage, freight and aircraft supplies between the aircraft and terminal building - the advantages suggested were:

a) Improved utilisation of an aerodrome because of reduced taxying distances and more accurate timing for take-off. Savings in jet aircraft fuel would also result;

b) Greater flexibility and economy in aerodrome and terminal building design and location i.e. the terminal building could be located away from the movement area and be designed to suit the passengers rather than the aircraft. The terminal building and runway system could then be expanded independently and without interference;

c) Undercover loading of passengers and little or no walking i.e. by bus.

The disadvantages suggested were that the number of vehicles and personnel required to operate them would be large and costly. Movement studies in the United Kingdom had seemed to support the latter point of view, but it was not clear as to what extent the disadvantages may be overcome by the development of special vehicles serving a combination of functions. It was understood that studies on the subject of special vehicles for this purpose were being undertaken in the United States.

7. - NOISE

Reference was made to the report of General Dolittle's Committee to the President of the United States entitled, "The Airport and Its Neighbours", in which recommendations were made regarding zoning and building restrictions in the vicinity of aerodromes with a view, amongst other things, to reducing the effects of the noise created by modern turbo-jet and piston engined aircraft. It was also indicated that other comprehensive studies of this problem were being undertaken in the United Kingdom and Australia and that reports of these studies should be available during 1953. Experience to date had indicated that a number of reasonably successful solutions could be found to the matter of reducing the noise nuisance emanating from maintenance areas. These included special sound proofed testing bays and the screening of maintenance areas by means of plantations of trees, specially constructed screens and the positioning of buildings to act as screens. It was generally agreed, however, that one of the most difficult problems to overcome was that of reducing the noise nuisance of aircraft taking off. One suggestion was to locate aerodromes further from cities, but several speakers cited examples where this had been done and the cities had expanded to meet the aerodrome (not to mention the loss of potential traffic due to the increased time of city to city transit). Apart from zoning, the most promising avenue for research seemed to lie in attempting to find ways and means of reducing engine noise at its source.

8. - LIGHTING AND MARKING FOR GROUND TRAFFIC CONTROL

In the United Kingdom a system of block control has been developed and installed at the London Airport. A brief description of the system was given indicating that, at night, guidance was provided from the tower by switching on the taxiway lights of the whole route to be followed. Automatic Red/Green "Stop"/"Go" signals, similar to a railway block signalling system, were also installed at intervals of approximately 75 metres (250 feet) together with "Stop"/"Go" lights at points where routes intersected. For use by day, in visibility conditions in which it was difficult to see the green taxiway lights, the system was supplemented by indicator boards at intersections and at taxiway turn-offs from runways. Each board has a green "Go" light which indicates the route to be followed across the intersection and a red "Stop" light to indicate that the block ahead is occupied and the aircraft must stop. It was stated that the system had been used in all visibilities in which the lights could be seen and down to about 36 metres (120 feet) visual range.

In the United States a considerable amount of research and experiment has been done on this subject and it was believed that a system had been found which might soon be adopted for national use. The concepts on which this system was based were that:

1) A taxi guidance system at controlled aerodromes should be designed to assist pilots in following instructions from the Tower rather than to take the place of such instructions. It was felt that positive control of ground traffic should always remain the responsibility of the Traffic Controller.

2) At aerodromes without traffic control, or for aircraft without radio, a taxi guidance system should assist pilots in finding their way to major destination areas.

Three types of signs were used:

a) A sign identifying the route;

b) An intersection sign identifying an intersecting route;

c) A destination sign indicating a particular location on the aerodrome to which the route leads.

The studies have led to the following recommendations:

a) A sign identifying the route.

1) Each taxiway should be identified by a letter of the alphabet;

2) A taxiway should have the same letter for its entire length regardless of intersections;

3) Each sign should display the identification letter of only one taxiway;

b) <u>An intersection sign.</u>

1) The sign should show the identification letter of the intersecting route;

2) A runway intersection sign should show the identification number and letters assigned to each end of the runway e.g. a sign 33 - 15 would mean that the 33 end is to the left and the 15 end to the right;

3) The sign should be placed on the near side of an intersection toward which traffic normally moves;

4) It should be placed on each side of intersections if traffic normally moves in both directions;

5) It could be placed on either side of intersections if traffic normally proceeds across the intersections.

c) <u>Destination signs</u>.

1) An outbound destination sign should display the assigned runway number with an arrow or chevron indicating the direction to taxi to that runway end. If the direction is the same for more than one runway, the sign should include all of these runway numbers, each being separated by a dash or chevron;

2) An inbound destination sign should display the name of the destination area (i.e. RAMP, PARK, OPS) with an arrow or chevron indicating the direction;

(Secretariat Note. - For international use it would appear to be desirable to adopt some system of self-evident signs in preference to abbreviations of English words not recognizable in all languages.)

In France a system of taxiway signs and signals similar to that used on highways has been tried out with success. Route indicators in the form of red arrows with red numbers on a cream background indicate the runway to which the taxiway leads. The number of signs at any intersection correspond to the number of runways accessible from that point. For night marking and lighting various automatic systems of signalling were under trial.

A number of speakers stressed the desirability of providing adequate guidance to pilots to enable them to select, during the landing run, a suitable turn-off to enable them to clear the runways as rapidly as practicable. Various types of signs and signal lights were under trial in different States. One of the difficulties encountered that was of providing signals that could be seen easily when the runway lights were at full intensity.

It was generally agreed that the whole subject of visual aids for taxying and ground traffic control was one of considerable importance, particularly from the point of view of improving aerodrome usability and in catering for the higher taxying speeds. It was recommended that the subject should be included on the agenda of the next session of the Aerodromes Air Routes and Ground Aids Division.

ATTACHMENT A

THE EFFECT OF THE OPERATION OF GAS-TURBINE AIRCRAFT UPON AERODROME LAYOUT AND DESIGN WITH SPECIAL REFERENCE TO THE GROUND HANDLING REQUIREMENTS OF THE DE HAVILLAND COMET AND THE VICKERS VISCOUNT 700

(Presented by the United Kingdom)

1. - AERODROME LAYOUT

1.1. - General

1.1.1 It is considered that the introduction of civil gas-turbine aircraft will not raise any major problems of aerodrome design or require major modifications to existing airports. The modern civil airport constructed for the operation of large piston-engine aircraft will require only minor modification to permit frequent operations by civil turbo-jet aircraft. Jet aircraft operation will, however, highlight the disadvantages of inefficient aerodrome design, and inadequate ground handling facilities, and such disadvantages unless removed, will result in a greater economic penalty for the jet as compared with the piston-engine aircraft.

1.2. - Runways

1.2.1 In recent years the introduction of the tricycle undercarriage for large civil aircraft, and the development of the cross-wind undercarriage for smaller types of civil aircraft, has led to a policy of reduction in the number of runway directions provided at any one aerodrome site. At many locations it has been possible to construct only a single runway and yet provide for the great majority of wind conditions. Large piston-engine aircraft equipped with tricycle undercarriages can accept cross-wind components of the order of 20 knots and it is certain that their turbo-jet counterparts will have as good, if not better, cross-wind performance characteristics. In the United Kingdom the design of these aircraft incorporates engine positions close to the fuselage which, in turn, allows a reduction in the area of the fin and rudder and a reduction in the turning moment during cross-wind operations.

1.3. - Runway Length

1.3.1 In general it can be said that where an aerodrome has been planned for the efficient operation of modern piston-engined aeroplanes the introduction of turbo-jet aeroplanes will raise no new problems as far as aerodrome length is concerned, except at aerodromes where high ambient temperatures prevail. It is likely that the trend in jet aircraft development will be towards the production of greater power in order to obtain improved en-route performance at high altitudes, and it may well be that this greater power will more than offset the probable tendency towards higher take-off weights.

1.3.2 For the landing run the turbo-jet aircraft appears to suffer a disadvantage when compared with aircraft equipped with reversible pitch propellers. However, various techniques to shorten the required landing distance of turbo-jet aeroplane are under active investigation, and their present apparent disadvantage may be overcome.

1.4. - Runway Width

1.4.1 Turbo-jet and turbo-prop aircraft will not require wider runways. The width of the instrument runway is governed by a number of factors including instrument flying errors, the location and interpretation of runway lighting and visual aids, and the manoeuvrability of large civil aircraft immediately before touchdown. A width of 200 feet for instrument runways has been considered adequate and the considerations which have led to this decision are not affected by the introduction of jet aircraft.

1.5. - Runway Surfaces

1.5.1 This subject is dealt with in Section 6, entitled "Engineering Aspects of Aerodrome Construction Including the Design of Pavements and Surfaces", and it suffices to say here that the problems of jet blast and fuel spillage on aerodrome surfaces are not serious and can be overcome at small inconvenience and cost.

1.6. - Taxiways

1.6.1 Taxying speeds of from 30 to 40 knots are desirable in order to reduce taxying time and thereby conserve fuel. Taxiway widths of not less than ICAO Class "D" (60 feet) should be planned and ample fillets should be provided at taxiway intersections in order to enable the fast taxying aircraft to turn easily. The inside radius of the fillets should be of the order of 150 feet. At busy aerodromes taxiway access and exits to and from the runway should be planned to facilitate rapid clearance of the runway in use and thereby help towards a high landing rate. These facilities are not special requirements for jet aircraft but will improve the efficiency of the airport for all types of operation. The provision of special run-up positions with by-pass taxiways near the runway ends is fast becoming essential at busy airports where a number of piston-engined aircraft may need to make pre-flight checks at the same time. Such provision will avoid holding up the jet aircraft which will normally obtain taxy and take-off clearance at the terminal apron and will not carry out pre-flight checks at the runway end. Experience at London Airport has shown that a total paved width of 250 feet for run-up bays and by-pass taxiway combined is adequate for current aircraft types. 100 feet of this width is used for the by-pass taxiway, 50 feet is used for aircraft run-up which park with their tails overhanging the paved surface and the remaining 100 feet provides the necessary clearance. The taxiway is, of course, upwind for the run-up area. Any delay in taxying results in a serious penalty for jet aircraft because fuel consumption at idling revolutions may be up to 10 per cent of the consumption at take-off power. As an example, the weight of fuel consumed by the Comet during three minutes idling is approximately equivalent to that of one passenger. No special provision is required for the surfacing of taxiways or "run-up" positions.

1.7. - Aprons and Hardstandings

1.7.1 The accepted principles of terminal apron design are not affected by the introduction of jet aircraft. In new aerodrome construction the terminal area should be planned to reduce taxying distances to a minimum. Small amounts of jet fuel may possibly be spilled at parking-bays, e.g., during refuelling. The most serious effect of spillage is the deterioration of bituminous surfaces and research has been carried out on the development of an impervious top dressing for use on existing aprons and hardstandings. Pending the results of this development it is probably advisable to use concrete in new construction. It may be necessary to deal with fuel spillage by means of sand and bucket in order to prevent any possible fire hazard.

1.8. - Apron Services

1.8.1 The increased fuel requirements of jet aircraft and the necessity of reducing turn-round time may lead to a requirement for underground fuel storage tanks near to the terminal apron and to fixed refuelling points serving the jet parking bays. With this system the movement of heavy fuel trailers on the apron is avoided and simultaneous refuelling of wing tanks can be carried out by means of portable hose and pump gear. Under-wing pressure refuelling will probably be standard on civil jet aircraft types in order to reduce the refuelling time.

1.8.2 The electric power requirements for engine starting are considerably higher for the jet aircraft than for piston-engine aircraft of similar size because higher engine speeds are required for a longer time before starting the jet engine. It will probably be more convenient to establish fixed power points as part of the apron service than to develop the use of portable starter trucks which cause obstruction and are a hazard to aircraft moving on the apron.

1.9. - Runway and Taxiway Surfaces

1.9.1 It is considered that the jet efflux of civil aircraft will not cause deterioration of conventional runway and taxiway surfaces and therefore no special treatment of runway surfaces is required. Run-up to full power is only carried out at runway ends before take-off and the procedure takes 15 to 20 seconds for the turbo-jet and about double this time for the turbo-prop engine. It has been suggested that the runway ends should be paved with concrete for a distance of up to 300 feet but experience in the United Kingdom has shown that frequent operations of military jet aircraft with engine installations similar to those of current civil types has not caused any deterioration of asphalt runway ends and that concrete may not be necessary. All runways, taxiways and apron surfaces should be swept clear of stones which might be drawn into the engines through the inlets. Rain and water lying on runway surfaces do not present a hazard.

1.10. - Visual Aids on Runways and Taxiways

1.10.1 Owing to the high fuel consumption of jet aircraft at low altitudes and during ground operation, it is important to facilitate rapid landing and fast taxying. The value of effective visual aids to approach in this connection and in the avoidance of overshoots is stressed.

1.10.2 By day, the provision of runway threshold markings and runway longitudinal markings, such as those developed for London Airport, are desirable for jet aircraft operations at airports with a high incidence of poor visibility. At London Airport the threshold marking consists of parallel white strips 50' x 7' similar to those shown in Figure 30 of Attachment B in Annex 14. The runway longitudinal markings consist of broken parallel white lines 18" wide and 50' in length with a break of 25' between each. They run parallel with the centreline of the runway and are 15' on either side of it.

1.10.3 Clear indication of runway turn-off points and taxiway routes is necessary, particularly at aerodromes where the taxiway system is complex. Green centre-line taxiway lighting should materially assist in such cases.

1.10.4 The run-up positions mentioned in paragraph 1.6 should be clearly outlined by day and by taxiway lights at night, and the route for aircraft by-passing direct to the runway should be clearly delineated.

1.11. - Noise

1.11.1 The problem of noise is somewhat more serious with turbo-jet than with piston-engined aircraft, particularly when jet engines are running at maximum power for take-off and during maintenance run-ups on the ground. Axial compressor engines such as the "Avon" tend to be less noisy than centrifugal compressor types such as the "Ghost". The operation of jet aircraft, so far as can be foreseen, will not necessitate special noise-reducing provisions near terminal aprons and taxiways, though some measure of soundproofing of buildings would be an advantage for jets as also for piston-engined aircraft. The high noise level area is contained in a cone approximately 45 degrees wide around the jet pipe centre line and there is hope that the noise level in this area can be reduced by improvements in engine design.

2. - REQUIREMENTS FOR THE GROUND HANDLING OF GAS-TURBINE AIRCRAFT

2.1. - General

2.1.1 Gas-turbine aircraft do not require ground handling equipment or techniques radically different from those previously used. However, the considerable advance in performance which these aircraft offer adds emphasis to the need for quick and efficient handling on the ground and it is important that the most suitable equipment and methods should be used. Appendix A gives particulars of ground handling requirements for the Comet Series I turbo-jet and Appendix B gives those for the Viscount 700 turbo-prop.

2.2. - The importance of Efficient Ground Handling

2.2.1 Because of their high cruising speeds, gas-turbine aircraft have a potential revenue-earning capacity greater than have similar-sized piston-engine aircraft. A delay in turn-round will therefore result in greater relative loss in revenue than would have been incurred with a similar delay in the past.

2.2.2 Operators will endeavour to make the most of the high cruising speeds obtainable to reduce their fleet requirements (and, therefore, capital expenditure) to a minimum. This will involve very close scheduling and high utilization which may be possible only if the operator can be certain that his scheduled turn-round times will not be exceeded.

2.3. - Fuelling

2.3.1 Gas-turbine aircraft will normally be refuelled under pressure at comparatively high rates of flow as fuel uplifts are larger than with similar sized piston-engine aircraft.

2.3.2 Pressure refuelling will normally be carried out through under-wing connections which are conveniently accessible and the use of which avoids damage to the upper surfaces of the wings. Connections in present use will pass 200 gallons per minute and, since connections will be available on each side for simultaneous refuelling, it will be possible to refuel at the rate of 400 gallons per minute. Current British civil aircraft fitted for pressure refuelling take an SBAC standard screw-type connection, either 2-1/2 inches or 1-1/2 inches diameter according to the rate of refuelling required for a particular type. American civil practice is to use a bayonet-type connection, and at present the British and American equipment is not interchangeable. Current developments will produce British connections which will be interchangeable with those used on American aircraft and which will handle rates of flow greater than 200 gallons per minute.

2.3.3 At present, kerosene to Ministry of Supply Specification D Eng R D 2482 is required for British civil turbine-engine aircraft. Oil companies will make this fuel available as necessary at civil airports throughout the world.

2.4. - Loading, Unloading and Apron Servicing

2.4.1 Turbo-jet aircraft have shorter undercarriages than have propeller-driven aircraft of similar size and wing configuration. This facilitates the handling of baggage and freight and servicing of the aircraft. Arrangements for apron servicing, such as the replenishing of water tanks and the emptying and re-charging of toilets, will be similar to those on other modern pressurized aircraft.

2.4.2 Ground air-conditioning requirements will be much the same as for other aircraft.

2.5. - Starting

2.5.1 For the starting of turbo-jet and turbo-prop engines considerably more power is required, and for a longer time, than for starting the piston engines used in similar-sized aircraft. Starting cycles follow a fairly uniform pattern. High initial torque is required to get the engine turning but, after the initial acceleration, the power required falls rapidly (and even more rapidly once the engine lights) although some power from the starter is required until the engine becomes self-supporting.

2.5.2 An operator's choice of starting method is likely to be governed by:

2.5.2.1 Reliability; that is, starts must be guaranteed between specified temperature limits.

2.5.2.2 The ability to meet requirements for self-starting or re-starting without external equipment and for starting in emergency with something less than the normal ground equipment.

2.5.2.3 The weight of equipment to be carried in the aircraft.

2.5.2.4 Capital and recurring costs.

2.5.3 These requirements can at present best be met by electric starting and this method is currently preferred for civil aircraft. When still more power is required for starting it may be advantageous or necessary to use some other method.

2.5.4 Some types of modern aircraft required electrical power as high as 600 amperes for ground servicing, excluding engine starting. In addition to these loads, gas-turbine aircraft impose further heavy electrical loads for starting. Details of these requirements for the Comet Series I and Viscount 700 are given in Appendices A and B. Powerful engine-driven generator sets are, therefore, required, unless a means of taking power from the airport mains is provided. Ground power units have been developed to meet this requirement for high starting and servicing loads. The first to be manufactured were driven by a four-cylinder petrol engine and were capable of dealing with loads of 600 amperes at 28 volts, continuously and 1 000 amperes for a short period for engine starting. A later model suitable for starting and the Ghost engines in the Comet is powered by a six-cylinder Perkins oil engine and will provide at ICAN sea level 600 amperes at 28 volts continuously and 1 400 amperes at 24 to 28 volts for engine starting. An improved version of this model with a more powerful engine will maintain this output at such places as Nairobi or Johannesburg. The latest Murex ground power unit uses a Rolls Royce petrol engine giving 105 hp at ICAO sea level, and gives 550 amperes at 112 volts for starting, and 100 amperes at 28 volts, for other servicing, which are the requirements of the Comet Series II.

2.6. - Taxying and Marshalling

2.6.1 Directional control whilst taxying is equal to that of similar-sized piston-engine aircraft but, as turbo-jet or free turbine turbo-prop engines must use high initial revolutions to start the aircraft rolling unnecessary halts should be avoided and marshalling instructions should be clear and precise to prevent unnecessary blast disturbance.

2.7. - Special Precautions

2.7.1 One or two obvious precautions are necessary in ground handling of turbine-engine aircraft. It is dangerous to stand too close to engine inlets or outlets when engines are running. With turbo-jet engines caution must be exercised at a greater distance from the jet inlets than with turbo-props, as hats and other small articles are readily drawn into the engine. With turbo-prop engines, the safety distance in front is the same as for any other propeller engine.

2.7.2 Care should be taken when parking gas-turbine aircraft to ensure that the jet efflux does not cause danger or discomfort to passengers or damage to other aircraft or buildings. Such danger and discomfort is most likely to occur during maintenance run-ups to full power and normal precautions are satisfactory at taxying and idling revolutions.

2.7.3 The propellers of turbo-prop aircraft, unless they are fitted with a parking brake, can be turned quite easily when the engine is not running and may even windmill in a high wind. Care should be taken, therefore, to ensure that passengers and ground crew do not walk under propellers even when the engines are not running.

2.7.4 As foreign bodies entering turbine engines can readily cause expensive damage, it is usual to fit intake guards for ground running and to apply covers while aircraft are parked. Engines with axial compressors are more susceptible to such damage so that with this type it is most important to use guards and covers.

2.8. - Fire Services

2.8.1 Fire risks during the ground handling of gas-turbine aircraft are not very different from those associated with piston-engine aircraft but two points need special attention. In the event of a false start, an occurrence which should be extremely rare, a quantity of fuel will be spilled on the pavement. Precautions should be taken against spilt fuel being ignited by jet exhaust when the engine starts. Very small quantities of fuel are spilled when shutting-down turbine engines but the accumulation of such spillage is unlikely to cause any increase in fire risk and can be mopped up with bucket and sand.

2.8.2 It is considered that apron refuelling of piston-engined aircraft should not take place within 100 feet of the tail of a gas-turbine aircraft manoeuvring on the apron under power.

2.8.3 Grass is sometimes burned some distance behind turbine engines, especially in dry climates, and suitable precautions must be taken against any fire being started in this way.

3. - MANOEUVRING IN THE TERMINAL AREA

3.1. - Introduction

3.1.1 The problem of slip-stream interference from aircraft manoeuvring under their own power in terminal areas has always existed to some extent, but fears have been expressed that the introduction of jet transport aircraft would severely increase the problem and that special areas for parking jet aircraft would have to be set aside on aprons where both jet and piston engined aircraft have to be handled simultaneously. Experience with the "Ghost" engined Comet at London Airport has shown that for this type of aircraft the problem has been over emphasized and with minor exceptions the Comet can be handled in just the same way as any other aircraft. Furthermore it is not anticipated that later types of jet aircraft will need radically different ground handling techniques. Slightly larger clearance may be necessary when more powerful engines are brought into service but only if the initial thrust to start the aircraft rolling is greater than that used by the current type of Comet. Turbo-prop aircraft present no difficulties whatsoever. The handling technique used at London Airport is described below.

3.2. - London Airport Apron

3.2.1 The apron at present in use at London Airport combines the features of the two most common types of terminal apron i.e., those where aircraft park on one side only of a taxiway and those with parking on both sides of the taxiway. The apron is approximately 1 350 foot long with a 100 foot wide taxiway running east and west. There is a parking area along the whole length of the northern side of this taxiway generally 300 feet wide but tapering from 300 feet to zero in the last 600 feet at the east end. Also at the east end is another apron south of the taxiway 700 feet long and 100 feet wide. The parking line on both sides of the taxiway is 100 feet from the centre line.

3.3. - Clearances on which the technique is based

3.3.1 The clearances are based on the "Ghost" engined Comet and it is assumed that the maximum thrust used on the apron is that required to get the aircraft rolling from a standstill (about 7 000 rpm). The safety limit behind the jet orifice for this amount of thrust is 120 feet or, since the jet pipes are 40 feet from the tail, 80 feet behind the aircraft. When there is petrol refuelling taking place on the apron these clearances are increased by 20 feet. Normal wingtip clearances are allowed.

3.4. - Ground Handling Technique

3.4.1 On arrival at the apron under its own power the jet aircraft turns off the taxiway and runs forward into its parking position, stopping when it is behind the parking line. The engines are switched off in this position. Before starting engines to leave the apron the aircraft is turned by tractor until it is facing the taxiway and is therefore on the same heading as all the other parked aircraft. During starting up an area as wide as the wingspan and extending for a distance of 80 feet from the tail is kept clear. On receiving permission to taxy the jet aircraft moves straight forward until it reaches a position which will provide the necessary clearance between other aircraft before turning to move along the taxiway. The drawing at Appendix 'C' shows the path which should be followed by a Comet when leaving the apron when an adjacent piston-engined aircraft is being refuelled as this is the case in which the greatest clearance must be allowed. As stated above it is considered that the refuelling operation is not endangered provided that when the tail of the Comet is pointed towards the refuelling point a minimum clearance of 100 feet from the tail of the jet aircraft is maintained. The positions of refuelling points vary in relation to the wingtip between aircraft types but for the purpose of illustration a distance of 28 feet has been assumed. It has also been assumed that the wingtip clearance between the aircraft parked in a row is 30 feet. Since the outer jet pipe is 40 feet from the tail and the clearance between the tail and the refuelling point must be at least 100 feet, then the Comet must taxy straight ahead until its nearest jet pipe is outside a circle with a radius of 140 feet centred onthe refuelling point; beyond this point the turn can be started. In the case illustrated it must move forward for a distance of 108 feet. Allowing for a turn on to the centre line of the taxiway the drawing shows that the line of parked aircraft can be as close as 80 feet to the centre line of the taxiway. If the distance between the Comet wingtip (when parked) and the refuelling point of the neighbouring aircraft is less than 58 feet - either because the refuelling point is nearer the wingtip than 28 feet or because the aircraft are parked closer together than 30 feet - then the Comet must go further forward before turning and consequently the line of parked aircraft must be at a greater distance than 80 feet of the centre line of the taxiway. Conversely if the distance between the Comet wingtip and the refuelling point is greater than 58 feet then the Comet need not be taxied forward so far before turning, and the line of parked aircraft can be closer to the centre line of the taxiway; for example:

Distance between Comet wingtip and refuelling point	Distance the Comet must taxy forward before turning	Distance between the line of parked aircraft and centre line of taxiway
43 feet	123 feet	95 feet
73 feet	88 feet	60 feet

As an approximate guide the Comet should taxy forward at least its own length (90 feet) before turning on to the centre line of the taxiway, so that if the line of parked aircraft is 100 feet or more from the centre line of the taxiway, Comets will experience no difficulty in operating on an apron shared by conventional aircraft types. Lines of parked aircraft are unlikely to be parked much nearer than this as otherwise insufficient wingtip clearances will be provided.

4. - MAINTENANCE RUN-UP AREAS FOR JET AIRCRAFT

4.1 Sufficient experience has not yet been gained to be dogmatic about the provision of special running-up facilities for jet aircraft, but Messrs. de Havilland have indicated that the problem is not likely to be as serious as at first imagined. No special precautions have been taken at Hatfield, where jet aircraft have been run-up to full power with the jet orifices facing grass areas. It has been found that over a considerable period of time an area of approximately 100 feet has been denuded of grass, but that the ground itself has not been seriously affected; a hedge 200 feet behind the run-up position has not been damaged in any way.

4.2 Until more evidence is available it can be assumed that a hardstanding of the type described in paragraph 1.7.1 will be adequate and that no difficulty should be experienced if measures to deal with fuel spillage are taken and if an area behind the jet engine is kept clear for 100 - 150 yards.

4.3 The problem of noise is a matter for some concern, but noise screening walls may ultimately provide a solution. Research is proceeding, and it is hoped that in the near future positive results will be achieved.

5. - THE EFFECT OF NOXIOUS GASES FROM JET EXHAUSTS

5.1 Information on some investigations carried out by the Ministry of Supply has not been received. Their analysis of the combustion products of the gas turbine on leaving the combustion chamber showed only 4.3 parts in 10 000 by weight of carbon monoxide. This is considered to be the only toxic product of jet exhausts. Oxidization can continue after leaving the combustion chamber so that the proportion of carbon monoxide in the exhausts leaving the jet pipe should be even lower. Exhaust gases leave the jet pipe at a high speed and temperature so that the rate of diffusion is very large and when they have mixed with the atmosphere to such an extent that the mixture is cool enough to breathe without acute discomfort, the dilution would be about 10 times greater. If air contaminated by jet exhaust is cool enough to breathe naturally it is quite harmless.

5.2 The exhaust gases from piston engines have a high carbon monoxide content due to incomplete combustion and low air/fuel ratio (about 1/5th of the air/fuel ratio of gas turbines). Concentrations of 4 parts in 10 000 occur at road crossings where traffic hold-ups are prevalent. The exhausts of reciprocating engines are much more poisonous than those of gas turbines, and since no harmful effects have been experienced from the running of reciprocating engines in relatively confined spaces near terminal buildings there can be no objection on the grounds of toxic effects to the running of gas turbines under similar conditions.

5.3 There is, therefore, no justification in the assumption that the advent of the jet aircraft will necessitate either major alterations in the principles of terminal building design, or extensive precautions to avoid an outbreak of new occupational diseases, as a direct result of noxious gases from turbine exhausts. The Ministry of Supply figures show that far from increasing the concentration of poisonous effluent in terminal areas, jet aircraft will in fact be less dangerous in this respect than piston-engine aircraft. Furthermore, pollution of terminal areas by the exhaust of jet aircraft is likely to be less than the pollution of busy road crossings by the exhaust of motor vehicles. For all practical purposes it can be assumed that there is no cause for alarm and no further research is proposed.

6. - ENGINEERING ASPECTS OF AERODROME CONSTRUCTION INCLUDING THE DESIGN OF PAVEMENTS AND SURFACES

6.1. - General

6.1.1 The design of paved surfaces so far as load-bearing is concerned presents no new problems as compared with the design for piston-engine aircraft. The only new problems introduced are those of the effect of heat and blast from jet exhausts, and the spillage of fuel oil either or both of which may affect the surfacing of the paved areas.

6.2. - Heat and blast effects

6.2.1 The temperature of the surface layers of the pavement will be raised by the hot gases from the jet orifice impinging on the surface. The extent of this rise in temperature will depend on:

i) The temperature of the gases at the orifice;

ii) The height of the orifice above the surface of the pavement and the angle of inclination of the jet to the horizontal;

iii) The length of time for which the gases impinge at any point.

6.2.2 When the aircraft is in motion, the length of time during which jet impinges on the surface is short, and the increase in temperature of surfacing material is small. Damage, whatever the height and inclination of the jets, is therefore improbable.

6.2.3 Where the angle of inclination of the jet to the horizontal is less than 2 degrees and the height of the jet orifice above the pavement surface is greater than four times the diameter of the orifice, sustained blasts of five or six minutes will produce a relatively small rise in temperature of the pavement. Such conditions would not damage any of the normal surfacing materials e.g. concrete, asphalt or tarmacadam, in use on airport paved areas. With the increasing use of the nose-wheel undercarriage it is very probable that all gas-turbine aircraft designed for civil use will satisfy these conditions and that the problem of damage to paved areas by heat and blast will not arise at civil airports.

6.2.4 As the angle of inclination of the jet increases beyond 2 degrees and as the height of the jet orifice above the surface is reduced, the temperature reached by the surface under a standing aircraft with the gas-turbine operating at high power will increase and damage may occur to surfaces constructed of the normal materials. In the case of tarmacadam (and asphalt to a less severe degree) the binder will first soften, then flow, and under extreme conditions, the aggregate will be blown out completely disintegrating the surface over a fairly large area. A concrete surface will withstand a far higher temperature than either asphalt or tarmacadam but under extreme conditions "spalling" (large flaking) of the surface may occur and finally there will be spontaneous cracking of the slabs. Under these conditions the jointing material between adjacent slabs may be blown out.

6.2.5 Experiments are proceeding to find a treatment of the surface which will prevent the damage described above and a certain amount of success has so far been achieved. It is necessary, however, for the behaviour of experimental areas to be observed over a long period and under widely varying conditions of climate and loading before any recommendations can be formulated.

6.3. - Spillage of fuel

6.3.1 Fuel spillage may occur on aprons and aircraft standings, and at running-up positions, but is unlikely on the runways themselves. The fuel will combine with the bitumen binder in asphalt and permanently soften the surface. Tar binders in tarmacadam are affected to a much smaller degree. Bitumen and other materials used for sealing the expansion joints in concrete pavements are also affected by fuel droppings.

6.3.2 The resistance of the surfacing to fuel spillage may be increased by tar spraying and by binding with small well-graded grit. In the case of asphalt surfaces some degree of protection can be given by the use of a hard straight-run bitumen as a binder and the treatment of the surface with a cement wash. This treatment should be repeated periodically to maintain the cement seal on the surface. Experiments are proceeding with various types of paint to seal asphalt surfaces against fuel spillage. Other experiments are being made to find a sealing compound for expansion joints in concrete which will not combine with jet fuel. These experiments are not yet complete.

6.3.3 The following is a suitable specification for the application of the cement wash:

> Thoroughly mix cement and water in the proportions of 1 cwt of cement to 17-20 gallons of water. Brush the mixture thoroughly into the surface of the pavement at the rate of 1 gallon of the mixture to about 30 square yards of pavement, using stiff brooms.

6.3.4 It is essential to obtain the thinnest possible film of cement, in intimate contact with the surface. If the quantities used are excessive, or if the mixture is too thick, the cement skin will flake off when dry. For these reasons spraying of the mixture is not satisfactory and brushing is essential.

APPENDIX A TO ATTACHMENT A

COMET SERIES I PHYSICAL DATA AND GROUND HANDLING REQUIREMENTS

1. - PHYSICAL DATA

1. 1. - General Dimensions

Length	93 feet	
Wing Span	115 feet	
Wheel track	28 feet	5-1/2 inches
Wheel base	31 feet	11 inches
Height to top of fuselage	15 feet	6 inches
Height to top of fin rudder	28 feet	6 inches

1. 2. - Clearances

Wing tip to ground	9 feet	3 inches
Tail of fuselage (under tailplane) to ground	9 feet	
Height from ground to bottom of passenger doors	8 feet	6 inches
Height from ground to baggage door (under fuselage)	5 feet	
Height from ground to fuselage under nose wheel with nose doors open	4 feet	6 inches
Centreline of outboard jet pipes to ground	6 feet	
Angle of centreline of jets	0 degrees	

1. 3. - Turning Circle

Turning circle of outer wheels (taxying)	142 feet diameter
Turning circle of wing tips in bay with 4-wheeled bogie undercarriage	160 feet minimum 230 feet recommended

1. 4. - Tyre Pressure

On 4-wheeled bogie 115 lb/sq inches for 105 000 lb all-up weight
Each main undercarriage 47 600 pounds per 4-wheel bogie.

1.5. - Safety Distances - Ghost Engines

	Danger	Discomfort
At maximum rpm	(5 feet from inlet (85 feet from exhaust	10 feet from inlet 240 feet from exhaust

If engines are to be run-up to full power it is advisable to position the aircraft so that the jet-pipe efflux is clear of obstacles within 100-150 yards.

2. - FACILITIES REQUIRED ON THE APRON

2.1. - Apron Power

2.1.1 Type of Connexion Between Aircraft and Power Unit. - For BOAC aircraft, American three-pin ground socket Reference AN 2552-1.

2.1.2 Engine Starting. - 28-volt system: Variation of current over starting cycle is initially 1 400 amperes dropping almost immediately to 700 amperes and then to 400 amperes at end of cycle which is normally of 30 seconds duration. It is very important that no attempt be made to start engines unless aircraft accumulators are fully charged and adequate ground power is available. If ground accumulators are used they must be fully charged and in good condition. If the above conditions are not met, serious damage to the aircraft power unit may result. It should be appreciated that the ground and aircraft power supplies are used simultaneously during starting.

NB. - Intercommunication between cockpit and ground is fitted.

2.1.3 Servicing and Pre-flight Checks. - Variation of current is 25 amperes to 400 amperes depending on number of checks required at any one time.

2.1.4 Ground Power Unit Requirements. - Murex Ground Power Unit 1 400 amperes at 20 to 24 volts plus 600 amperes at 28 volts, or eight 12-volt 80 ampere-hour accumulators in series-parallel.

2.2. - Ground Air Conditioning

Standard 8 inches Normalair house.

2.3. - Fuelling

2.3.1 Fuel Required. - Aviation kerosene to Specification DEngRD 2482.

2.3.2 Method. - Underwing pressure refuelling is normally used up to 200 gal/min per side through SBAC standard (Lockheed-Avery) 2-1/2 inches connexion. Refuelling panels are located in the wheel wells and aircraft electric power is required during refuelling. Should pressure-refuelling equipment not be available the tanks can be gravity-filled through fillers provided in the wing top surfaces.

2.3.3 Defuelling. - Fuel may be off-loaded through the pressure refuelling connexions.

2.3.4 Maximum Fuel Up-take at One Time. - Ghost engines, Mk I Comet 6 050 gallons, Mk Ia Comet 7 050 gallons.

3. - GROUND MOVEMENT

3.1 Taxying distance should be kept to a minimum to conserve fuel (taxying consumption can be 70 per cent of cruise consumption at operational altitude).

3.2 Pilot's cockpit checks should be carried out during engine starting and taxying. No further checks are required at the runway entrance.

3.3 It is desirable that both taxying and take-off clearances be received at the bay before starting engines.

3.4 Safety distance for following aircraft, while taxying, 150 feet.

3.5 Normal speed for taxying 30-40 kt.

4. - TOWING

4.1 The aircraft is normally towed from the nose wheel. The brakes are hydraulically operated and the system must be pressurized before attempting to move the aircraft. The towbar cannot be removed until the steering gear is re-engaged.

5. - ENGINE COVERS AND GUARDS

5.1 Air-intake and jet-pipe covers are to be fitted at all times on the ground and removed immediately before starting engines. Air-intake guards are to be fitted for ground running.

APPENDIX B TO ATTACHMENT A

VISCOUNT 700 PHYSICAL DATA AND GROUND HANDLING REQUIREMENTS

1. - PHYSICAL DATA

1.1. - General Dimensions

Length	81 feet	2 inches
Wing span	94 feet	0 inches
Wheel track	23 feet	10 inches
Wheel base	24 feet	9 inches
Height to top of fuselage	14 feet	6 inches
Height to top of fin and rudder	26 feet	0 inches

1.2. - Clearances

Wing tip to ground	9 feet	0 inches
Height from ground to bottom of passenger doors	6 feet	9 inches
Height from ground to baggage door	6 feet	9 inches
Height from ground to fuselage under centre section	3 feet	9 inches
Height from ground to bottom of nose chassis doors when open	2 feet	8 inches

1.3. - Turning Circle

Turning circle of wheels taxying, 66 feet diameter
Turning in bay, diameter of wing tip turning circle 120 feet.

1.4. - Tyre Pressure

85 pounds per square inch

1.5. - Safety Distance from Engines

Inlet, as for another propeller
Exhaust, 30 feet.

1.6. - Air Velocity Behind Jet Pipes

At maximum rpm 500 feet per second at jet pipe exit, 250 feet per second at 16 feet from jet pipe exit.

1.7. - Special Equipment Required

Propeller guards as at present used.

1.8. - Distance of Exhaust Outlet from Tail

38 feet.

2. - FACILITIES REQUIRED ON THE APRON

2.1. - Apron Power

2.1.1 Type of Connexion. - For BEA aircraft, socket by Films and Equipment Ltd., to American design.

2.1.2 Engine Starting (28-volt system). - Current required at normal temperatures, after first 2 second 1 100 amperes for 1 second falling rapidly to 500 amperes at 10 seconds and then to 150 amperes.

2.1.3 Servicing Load. - Not expected to exceed 200 amperes.

2.1.4 Pre-flight Check. - Not expected to exceed 50 amperes.

2.1.5 Ground Power Unit. - Murex Ground Power Unit. Those used by BEA have 50 hp oil engine. Where a Murex truck is not available, two normal battery trucks with full-charged accumulators can be used for starting. When starting on external power the internal battery system is not used.

2.2. - Ground Air Conditioning

Standard 8 inch Normalair hose.

2.3. - Fuelling

2.3.1 Fuel Required. - Aviation kerosene to Specification DEngRD 2483.

2.3.2 Method. - Normal tankage, 75 gal/min. per side through 1-1/2 inch SBAC Standard (Lockheed Avery) connexions, or overwing through SBAC flush-cap filler. Long-range tanks, overwing through SBAC flush-cap filler.

2.3.3 Defuelling. - 40 gal/min. per side through pressure fuelling connexions.

2.3.4 Maximum Fuel Uplift. - 1400 gallons normal
1720 gallons long range

2.3.5 Water Methanol. - 37-1/2 gallons per side, refuelled over-wing.

2.4. - Servicing Pipe Connexions

2.4.1 Toilet Pipe Union. - 4 inches diameter external coupling suitable for Air Service Training (AST) or Roylyn for emptying, 1 inch diameter AST for flushing and filling.

2.4.2 Waste Drain. - 1 inch AST Special or Roylyn.

2.4.3 Fresh-water Refilling. - System capacity 6 gallons 1 inch diameter Avery coupling; without pressure filler only the urn, one-third of total capacity, can be filled.

3. - GROUND MOVEMENT

3.1 Taxying distance should be short to conserve fuel.

3.2 Fuel consumption during taxying, 180 gallons per hour.

3.3 Safety distance for following aircraft as for piston-engine aircraft.

3.4 Normal speed of taxying, 15 to 25 knots.

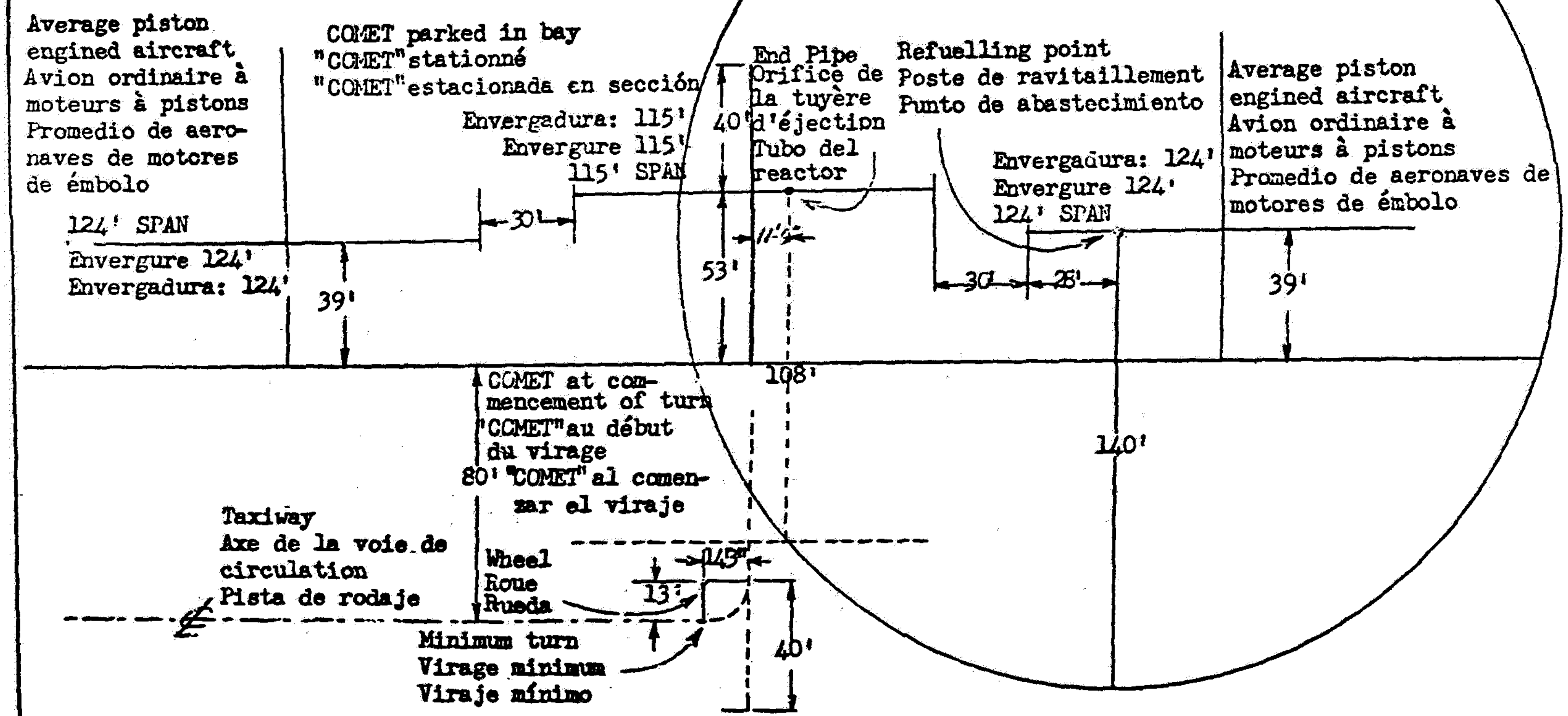
4. - TOWING

4.1 Type of attachment: Spigot on nose-wheel axle fitting.

4.2 Suitable type of tractor: David Brown Fordson - Clarkator 6.

4.3 Maximum angle of nose wheel when towing: 50 degrees.

COMET JET AIRCRAFT - Manoeuvring from apron to taxiway adjacent to a refuelling operation*
AVION "COMET" A REACTION - Evoluant de l'aire de stationnement à une voie de circulation pendant qu'un autre avion fait le plein d'essence à ses côtés*
AERONAVE DE REACCION "COMET" - maniobra de la plataforma a la pista de rodaje en espera del abastecimiento de combustible*



* **See** Note on next page.
Cf. Note à la page suivante.
Véase Nota en la pagina siguiente.

Note

Distance COMET must taxy straight forward before turning is 108' - assumed:

1) Aircraft parked in straight line parallel to ℄ of taxiway.
2) 30' clearance between wingtips.
3) Average piston engined aircraft's wingspan - 124'.
4) Distance between wingtips and outboard refuelling points - 28'.
5) Distance wingtips to nose - 39'.

- END -

PRICE: $0.25 (Cdn.)	(Montreal)
Equivalents at date of publication:	
L.E. 0.090	(Cairo)
3.75 soles	(Lima)
1s. 8d.	(London)
2s. 3d.	(Melbourne)
Rs. 1-4-0	(New Delhi)
90 francs	(Paris)