

ATTACHMENT 6 Airplane Performance Operating Limitations

This attachment was established in accordance with Article 84, 233 of this AOR proper, and the ICAO Annex 6, Part I, Attachment C.

The purpose of this Attachment is to provide guidance as to the level of performance intended by the provisions of Chapter 5 as applicable to turbine-powered subsonic transport type airplanes over 5,700 kg maximum certificated take-off mass having two or more engines. However, where relevant, it can be applied to all subsonic turbine-powered or piston-engine airplanes having two, three or four engines. Piston-engine airplanes having two, three or four engines which cannot comply with this Attachment may continue to be operated in accordance with Examples 1 or 2 of this Attachment. This example also applies for Principal National Airworthiness Code effected in 1969.

No detailed study has been made of the applicability of this example to operations subsonic turbine-powered airplanes which the individual certificate of airworthiness is first issued before 1969.

This Attachment is not intended for application to airplanes having short take-off and landing (STOL) or vertical take-off and landing (VTOL) capabilities.

The validity of this example has not therefore been established for operations, which may involve low decision heights and be associated with low minima operating techniques and procedures.

1. Definitions

Accelerate-stop distance available (ASDA). The length of the take-off run available plus the length of the stopway, if provided.

CAS (calibrated airspeed). The calibrated airspeed is equal to the airspeed indicator reading corrected for position and instrument error. (As a result of the sea level adiabatic compressible flow correction to the airspeed instrument dial, CAS is equal to the true airspeed (TAS) in Standard Atmosphere at sea level.)

Declared temperature. A temperature selected in such a way that when used for performance purposes, over a series of operations, the average level of safety is not less than would be obtained by using official forecast temperatures.

Expected. Used in relation to various aspects of performance (e.g. rate or gradient of climb), this term means the standard performance for the type, in the relevant conditions (e.g. mass, altitude and temperature).

Grooved or porous friction course runway. A paved runway that has been prepared with lateral grooving or a porous friction course (PFC) surface to improve braking characteristics when wet.

Height. The vertical distance of a level, a point, or an object considered as a point, measured from a specified datum.

Note.— *For the purposes of this example, the point referred to above is the lowest part of the airplane and the specified datum is the take-off or landing surface, whichever is applicable.*

Landing distance available (LDA). The length of runway which is declared available and suitable for the ground run of an airplane landing.

Landing surface. That part of the surface of an aerodrome which the aerodrome authority has declared available for the normal ground or water run of aircraft landing in a particular direction.

Net gradient. The net gradient of climb throughout these requirements is the expected gradient of climb diminished by the manoeuvre performance (i.e. that gradient of climb necessary to provide power to manoeuvre) and by the margin (i.e. that gradient of climb necessary to provide for those variations in performance which are not expected to be taken explicit account of operationally).

Reference humidity. The relationship between temperature and reference humidity is defined as follows:

- at temperatures at and below ISA, 80 per cent relative humidity,
- at temperatures at and above ISA + 28° C, 34 per cent relative humidity,
- at temperatures between ISA and ISA + 28° C, the relative humidity varies linearly between the humidity specified for those temperatures.

Runway surface condition. The state of the surface of the runway: either dry, wet, or contaminated:

a) *Contaminated runway.* A runway is contaminated when more than 25 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by:

- water, or slush more than 3 mm (0.125 in) deep;
- loose snow more than 20 mm (0.75 in) deep; or
- compacted snow or ice, including wet ice.

b) *Dry runway.* A dry runway is one which is clear of contaminants and visible moisture within the required length and the width being used.

c) *Wet runway.* A runway that is neither dry nor contaminated.

Note 1.— In certain situations, it may be appropriate to consider the runway contaminated even when it does not meet the above definition. For example, if less than 25 per cent of the runway surface area is covered with water, slush, snow or ice, but it is located where rotation or lift-off will occur, or during the high speed part of the take-off roll, the effect will be far more significant than if it were encountered early in take-off while at low speed. In this situation, the runway should be considered to be contaminated.

Note 2.— Similarly, a runway that is dry in the area where braking would occur during a high speed rejected take-off, but damp or wet (without measurable water depth) in the area where acceleration would occur, may be considered to be dry for computing take-off performance. For example, if the first 25 per cent of the runway was damp, but the remaining runway length was dry, the runway would be wet using the definitions above. However, since a wet runway does not affected acceleration, and the braking portion of a rejected take-off would take place on a dry surface, it would be appropriate to use dry runway take-off performance.

Take-off distance available (TODA). The length of the takeoff run available plus the length of the

clearway, if provided.

Take-off run available (TORA). The length of runway declared available and suitable for the ground run of an airplane taking off.

Take-off surface. That part of the surface of an aerodrome which the aerodrome authority has declared available for the normal ground or water run of aircraft taking off in a particular direction.

TAS (True airspeed). The speed of the airplane relative to undisturbed air.

V_{So}. A stalling speed or minimum steady flight speed in the landing configuration. (*Note.— See Example 1, 2.4.*)

V_{S1}. A stalling speed or minimum steady flight speed. (*Note.— See Example 1, 2.5.*)

Note 1.— See Chapter 1 and Annexes 8 and 14, Volume I, for other definitions.

Note 2.— The terms “accelerate-stop distance”, “take-off distance”, “V₁”, “take-off run”, “net take-off flight path”, “one engine inoperative en-route net flight path”, and “two engines inoperative en-route net flight path”, as relating to the airplane, have their meanings defined in the airworthiness requirements under which the airplane was certificated. If any of these definitions are found inadequate, then a definition specified by the State of the Operator should be use

3. General

- 3.1 The provisions of 4 to 7 should be complied with, unless deviations therefrom are specifically authorized by the State of the Operator on the grounds that the special circumstances of a particular case make a literal observance of these provisions unnecessary for safety.
- 3.2 Compliance with 4 to 7 should be established using performance data in the flight manual and in accordance with other applicable operating requirements. In no case should the limitations in the flight manual be exceeded. However, additional limitations may be applied when operational conditions not included in the flight manual are encountered. The performance data contained in the flight manual may be supplemented with other data acceptable to the State of the Operator if necessary to show compliance with 4 to 7. When applying the factors prescribed in this Attachment, account may be taken of any operational factors already incorporated in the flight manual data to avoid double application of factors.
- 3.3 The procedures scheduled in the flight manual should be followed except where operational circumstances require the use of modified procedures in order to maintain the intended level of safety.

Note.— See the Airworthiness Manual (Doc 9760) for the related airworthiness performance guidance material.

4. Airplane take-off performance limitations

- 4.1 No airplane should commence a take-off at a mass which exceeds the take-off mass specified in the flight manual for the altitude of the aerodrome and for the ambient temperature existing at the time of the take-off.
- 4.2 No airplane should commence a take-off at a mass such that, allowing for normal consumption of fuel and oil in flight to the aerodrome of destination and to the destination alternate aerodromes, the mass on arrival will exceed the landing mass specified in the flight manual for

the altitude of each of the aerodromes involved and for the ambient temperatures anticipated at the time of landing.

4.3 No airplane should commence a take-off at a mass which exceeds the mass at which, in accordance with the minimum distances for take-off scheduled in the flight manual, compliance with 4.3.1 to 4.3.3 inclusive is shown.

4.3.1 The take-off run required should not exceed the take-off run available.

4.3.2 The accelerate-stop distance required should not exceed the accelerate-stop distance available.

4.3.3 The take-off distance required should not exceed the take-off distance available.

4.3.4 When showing compliance with 4.3 the same value of V1 for the continued and discontinued take-off phases should be used.

4.4 When showing compliance with 4.3 the following parameters should be taken into account:

- a) the pressure altitude at the aerodrome;
- b) the ambient temperature at the aerodrome;
- c) the runway surface condition and the type of the runway surface;
- d) the runway slope in the direction of the take-off;
- e) the runway slope;
- f) not more than 50 per cent of the reported headwind component or not less than 150 per cent of the reported tailwind component; and
- g) the loss, if any, of runway length due to alignment of the airplane prior to take-off.

4.5 Credit is not taken for the length of the stopway or the length of the clearway unless they comply with the relevant specifications in Annex 14, Volume I.

5. Take-off obstacle clearance

limitations

5.1 No airplane should commence a take-off at a mass in excess of that shown in the flight manual to correspond with a net take-off flight path which clears all obstacles either by at least a height of 10.7 m (35 ft) vertically or at least 90 m (300 ft) plus 0.125D laterally, where D is the horizontal distance the airplane has travelled from the end of take-off distance available, except as provided in 5.1.1 to 5.1.3 inclusive. For airplanes with a wingspan of less than 60 m (200 ft) a horizontal obstacle clearance of half the airplane wingspan plus 60 m (200 ft), plus 0.125D may be used. In determining the allowable deviation of the net take-off flight path in order to avoid obstacles by at least the distances specified, it is assumed that the airplane is not banked before the clearance of the net take-off flight path above obstacles is at least one half of the wingspan but not less than 15.2 m (50 ft) height and that the bank thereafter does not exceed 15°, except as provided in 5.1.4. The net take-off flight path considered is for the altitude of the aerodrome and for the ambient temperature and not more than 50 per cent of the reported headwind component or not less than 150 per cent of the reported tailwind component existing at the time of take-off. The take-off obstacle

accountability area defined above is considered to include the effect of crosswinds.

5.1.1 Where the intended track does not include any change of heading greater than 15°,

- a) for operations conducted in VMC by day, or

- b) for operations conducted with navigation aids such that the pilot can maintain the airplane on the intended track with the same precision as for operations specified in 5.1.1 a), obstacles at a distance greater than 300 m (1 000 ft) on either side of the intended track need not be cleared.
- 5.1.2 Where the intended track does not include any change of heading greater than 15° for operations conducted in IMC, or in VMC by night, except as provided in 5.1.1 b); and where the intended track includes changes of heading greater than 15° for operations conducted in VMC by day, obstacles at a distance greater than 600 m (2 000 ft) on either side of the intended track need not be cleared.
- 5.1.3 Where the intended track includes changes of heading greater than 15° for operations conducted in IMC, or in VMC by night, obstacles at a distance greater than 900 m (3 000 ft) on either side of the intended track need not be cleared.
- 5.1.4 An airplane may be operated with bank angles of more than 15° below 120 m (400 ft) above the elevation of the end of the take-off run available, provided special procedures are used that allow the pilot to fly the desired bank angles safely under all circumstances. Bank angles should be limited to not more than 20° between 30 m (100 ft) and 120 m (400 ft), and not more than 25° above 120 m (400 ft). Methods approved by the State of the Operator should be used to account for the effect of bank angle on operating speeds and flight path including the distance increments resulting from increased operating speeds. The net take-off flight path in which the airplane is banked by more than 15° should clear all obstacles by a vertical distance of at least 10.7 m (35 ft) relative to the lowest part of the banked airplane within the horizontal distance specified in 5.1. The use of bank angles greater than those mentioned above should be subject to the approval from the State of the Operator.

6. En-route limitations

6.1 General

At no point along the intended track is an airplane having three or more engines to be more than 90 minutes at normal cruising speed away from an aerodrome at which the distance specifications for alternate aerodromes (see 7.3) are complied with and where it is expected that a safe landing can be made, unless it complies with 6.3.1.1.

6.2 One engine inoperative

- 6.2.1 No airplane should commence a take-off at a mass in excess of that which, in accordance with the one-engine inoperative en-route net flight path data shown in the flight manual, permits compliance either with 6.2.1.1 or 6.2.1.2 at all points along the route. The net flight path has a positive slope at 450 m (1,500 ft) above the aerodrome where the landing is assumed to be made after engine failure. The net flight path used is for the ambient temperatures anticipated along the route. In meteorological conditions where icing protection systems are to be operable, the effect of their use on the net flight path data is taken into account.
- 6.2.1.1 The slope of the net flight path is positive at an altitude of at least 300 m (1 000 ft) above all terrain and obstructions along the route within 9.3 km (5 NM) on either side of the intended track.

- 6.2.1.2 The net flight path is such as to permit the airplane to continue flight from the cruising altitude to an aerodrome where a landing can be made in accordance with 7.3, the net flight path clearing vertically, by at least 600 m (2 000 ft), all terrain and obstructions along the route within 9.3 km (5 NM) on either side of the intended track. The provisions of 6.2.1.2.1 to 6.2.1.2.5 inclusive are applied.
- 6.2.1.2.1 The engine is assumed to fail at the most critical point along the route, allowance being made for indecision and navigational error.
- 6.2.1.2.2 Account is taken of the effects of winds on the flight path.
- 6.2.1.2.3 Fuel jettisoning is permitted to an extent consistent with reaching the aerodrome with satisfactory fuel reserves, if a safe procedure is used.
- 6.2.1.2.4 The aerodrome, where the airplane is assumed to land after engine failure, is specified in the operational flight plan, and it meets the appropriate aerodrome operating minima at the expected time of use.
- 6.2.1.2.5 The consumption of fuel and oil after the engine becomes inoperative is that which is accounted for in the net flight path data shown in the flight manual.
- 6.3 Two engines inoperative — airplanes with three or more engines
- 6.3.1 Airplanes which do not comply with 6.1 should comply with 6.3.1.1.
- 6.3.1.1 No airplane should commence a take-off at a mass in excess of that which, according to the two-engine inoperative en-route net flight path data shown in the flight manual, permits the airplane to continue the flight from the point where two engines are assumed to fail simultaneously, to an aerodrome at which the landing distance specification for alternate aerodromes (see 7.3) is complied with and where it is expected that a safe landing can be made. The net flight path clears vertically, by at least 600 m (2 000 ft) all terrain and obstructions along the route within 9.3 km (5 NM) on either side of the intended track. The net flight path considered is for the ambient temperatures anticipated along the route. In altitudes and meteorological conditions where icing protection systems are to be operable, the effect of their use on the net flight path data is taken into account. The provisions of 6.3.1.1.1 to 6.3.1.1.5 inclusive apply.
- 6.3.1.1.1 The two engines are assumed to fail at the most critical point of that portion of the route where the airplane is at more than 90 minutes at normal cruising speed away from an aerodrome at which the landing distance specification for alternate aerodromes (see 7.3) is complied with and where it is expected that a safe landing can be made.
- 6.3.1.1.2 The net flight path has a positive slope at 450 m (1,500 ft) above the aerodrome where the landing is assumed to be made after the failure of two engines. 6.3.1.1.3 Fuel jettisoning is permitted to an extent consistent with 6.3.1.1.4, if a safe procedure is used.
- 6.3.1.1.4 The airplane mass at the point where the two engines are assumed to fail is considered to be not less than that which would include sufficient fuel to proceed to the aerodrome and to arrive there at an altitude of at least 450 m (1,500 ft) directly over the landing area and thereafter to fly for 15 minutes at cruise power and/or thrust.

6.3.1.1.5 The consumption of fuel and oil after the engines become inoperative is that which is accounted for in the net flight path data shown in the flight manual.

7. Landing limitations

7.1 Aerodrome of destination — dry runways

7.1.1 No airplane should commence a take-off at a mass in excess of that which permits the airplane to be brought to a full stop landing at the aerodrome of intended destination from 15.2 m (50 ft) above the threshold:

- a) for turbo jet powered airplanes, within 60 per cent of the landing distance available; and
- b) for turbo-propeller airplanes, within 70 per cent of the landing distance available.

The mass of the airplane is assumed to be reduced by the mass of the fuel and oil expected to be consumed in flight to the aerodrome of intended destination. Compliance is shown with 7.1.1.1 and with either 7.1.1.2 or 7.1.1.3.

7.1.1.1 It is assumed that the airplane is landed on the most favorable runway and in the most favorable direction in still air.

7.1.1.2 It is assumed that the airplane is landed on the runway which is the most suitable for the wind conditions anticipated at the aerodrome at the time of landing, taking due account of the probable wind speed and direction, of the ground handling characteristics of the airplane, and of other conditions (i.e. landing aids, terrain).

7.1.1.3 If full compliance with 7.1.1.2 is not shown, the airplane may be taken off if a destination alternate aerodrome is designated which permits compliance with 7.3.

7.1.1.4 When showing compliance with 7.1.1 at least the following factors should be taken into account:

- a) the pressure altitude of the aerodrome;
- b) the runway slope in the direction of the landing if greater than +/- 2.0 per cent; and
- c) not more than 50 per cent of the headwind component or not less than 150 per cent of the tailwind component.

7.2 Aerodrome of destination — wet or contaminated runways

7.2.1 When the appropriate weather reports or forecasts or a combination thereof indicate that the runway at the estimated time of arrival may be wet, the landing distance available should be at least 115 per cent of the required landing distance determined in accordance with 7.1.

7.2.2 A landing distance on a wet runway shorter than that required by 7.2.1 but not less than that required by 7.1 may be used if the flight manual includes specific additional information about landing distance on wet runways.

7.2.3 When the appropriate weather reports or forecasts or a combination thereof indicate that the runway at the distance available should be the greater of:

- a) the landing distance determined in accordance with 7.2.1; or
- b) the landing distance determined in accordance with contaminated landing distance data with a safety margin acceptable to the State of the Operator.

7.2.4 If compliance with 7.2.3 is not shown, the airplane may take off if a destination alternate aerodrome is designated for which compliance is shown with 7.2.3 and 7.3.

7.2.5 When showing compliance with 7.2.2 and 7.2.3, the criteria of 7.1 should be applied accordingly. However, 7.1.1 a) and b) need not be applied to the wet and contaminated runway landing distance determination required by 7.2.2 and 7.2.3.

7.3 Destination alternate aerodrome

No aerodrome should be designated as a destination alternate aerodrome unless the airplane, at the mass anticipated at the time of arrival at such aerodrome, can comply with 7.1 and either 7.2.1 or 7.2.2, in accordance with the landing distance required for the altitude of the alternate aerodrome and in accordance with other applicable operating requirements for the alternate aerodrome.

7.4 Performance considerations before landing The operator should provide the flight crew with a method to ensure that a full stop landing, with a safety margin acceptable to the State of the Operator, that is at least the minimum specified in the Type Certificate holder's aircraft flight manual (AFM), or equivalent, can be made on the runway to be used in the conditions existing at the time of landing and with the deceleration means that will be used.

Example 1

1. Purpose and scope

The purpose of the following example is to illustrate the level of performance intended by the provisions of Chapter 5 as applicable to the types of airplanes described below. The Standards and Recommended Practices in Annex 6 effective on 14 July 1949 contained specifications similar to those adopted by some Contracting States for inclusion in their national performance codes. A very substantial number of civil transport airplanes have been manufactured and are being operated in accordance with these codes. Those airplanes are powered with reciprocating engines including turbo-compound design. They embrace twin-engined and four-engined airplanes over a mass range from approximately 4,200 kg to 70,000 kg over a stalling speed range, V_{S0} from approximately 100 to 175 km/h (55 to 95 kt) and over a wing loading range from approximately 120 to 360 kg/m². Cruising speeds range over 555 km/h (300 kt). Those airplanes have been used in a very wide range of altitude, air temperature and humidity conditions. At a later date, the code was applied with respect to the evaluation of certification of the so-called "first generation" of turboprop and turbo-jet airplanes. Although only past experience can warrant the fact that this example illustrates the level of performance intended by the Standards and Recommended Practices of Chapter 5, it is considered to be applicable over a wide range of airplane characteristics and atmospheric conditions. Reservation should however be made concerning the application of this example with respect to conditions of high air temperatures. In certain extreme cases, it has been found desirable to apply additional temperature and/or humidity accountability, particularly for the obstacle limited take-off flight path. This example is not intended for application to airplanes having short take-off and landing (STOL) or vertical take-off and landing (VTOL) capabilities. No detailed study has been made of the applicability of this example to operations in all-weather conditions. The validity of this example has not therefore been established for operations which may involve low decision heights and be associated with low minima operating techniques and procedures.

2. Stalling speed — minimum steady flight speed

2.1 For the purpose of this example, the stalling speed is the speed at which an angle of attack greater than that of maximum lift is reached, or, if greater, the speed at which a large amplitude pitching or rolling motion, not immediately controllable, is encountered, when the manoeuvre described in 2.3 is executed.

Note.— It should be noted that an uncontrollable pitching motion of small amplitude associated with pre-stall buffeting does not necessarily indicate that the stalling speed has been reached.

2.2 The minimum steady flight speed is that obtained while maintaining the elevator control in the most rearward possible position when the manoeuvre described in 2.3 is executed. This speed would not apply when the stalling speed defined in 2.1 occurs before the elevator control reaches its stops.

2.3 Determination of stalling speed — Minimum steady flight speed

2.3.1 The airplane is trimmed for a speed of approximately $1.4V_{S1}$. From a value sufficiently above the stalling speed to ensure that a steady rate of decrease is obtainable, the speed is reduced in straight flight at a rate not exceeding 0.5 m/s^2 (1 kt/s) until the stalling speed or the minimum steady flight speed, defined in 2.1 and 2.2, is reached.

2.3.2 For the purpose of measuring stalling speed and minimum steady flight speed, the instrumentation is such that the probable error of measurement is known.

2.4 V_{S0}

V_{S0} denotes the stalling speed if obtained in flight tests conducted in accordance with 2.3, or the minimum steady flight speed, CAS, as defined in 2.2, with:

- a) engines at not more than sufficient power for zero thrust at a speed not greater than 110 per cent of the stalling speed;
- b) propeller pitch controls in the position recommended for normal use during take-off;
- c) landing gear extended;
- d) wing flaps in the landing position;
- e) cowl flaps and radiator shutters closed or nearly closed;
- f) centre of gravity in that position within the permissible landing range which gives the maximum value of stalling speed or of minimum steady flight speed;
- g) airplane mass equal to the mass involved in the specification under consideration.

2.5 V_{S1}

V_{S1} denotes the stalling speed if obtained in flight tests conducted in accordance with 2.3, or the minimum steady flight speed, CAS, as defined in 2.2, with:

- a) engines at not more than sufficient power for zero thrust at a speed not greater than 110 per cent of the stalling speed;
- b) propeller pitch controls in the position recommended for normal use during take-off;
- c) airplane in the configuration in all other respects and at the mass prescribed in the specification under consideration.

3. Take-off

3.1 Mass

The mass of the airplane at take-off is not to exceed the maximum take-off mass specified in the flight manual for the altitude at which the take-off is to be made.

3.2 Performance

The performance of the airplane as determined from the information contained in the flight manual is such that:

- a) the accelerate-stop distance required does not exceed the accelerate-stop distance available;
- b) the take-off distance required does not exceed the takeoff distance available;
- c) the take-off path provides a vertical clearance of not less than 15.2 m up to $D = 500$ m (50 ft up to $D = 1\,500$ ft) and $15.2 + 0.01 [D - 500]$ m ($50 + 0.01 [D - 1\,500]$ ft) thereafter, above all obstacles lying within 60 m plus half the wing span of the airplane plus $0.125D$ on either side of the flight path, except that obstacles lying beyond 1 500 m on either side of the flight path need not be cleared. The distance D is the horizontal distance that the airplane has travelled from the end of the take-off distance available.

Note.— This need not be carried beyond the point at which the airplane would be able, without further gaining in height, to commence a landing procedure at the aerodrome of takeoff or, alternatively, has attained the minimum safe altitude for commencing flight to another aerodrome. However, the lateral obstacle clearance is liable to be reduced (below the values stated above) when, and to the extent that, this is warranted by special provisions or conditions which assist the pilot to avoid inadvertent lateral deviations from the intended flight path. For example, particularly in poor weather conditions, a precise radio aid may assist the pilot to maintain the intended flight path. Also, when the take-off is made in sufficiently good visibility conditions, it may, in some cases, be possible to avoid obstacles which are clearly visible but may be within the lateral limits noted in 3.2 c).

Note 1.— The procedures used in defining the acceleratestop distance required, the take-off distance required and the take-off flight path are described in the Appendix to this example.

Note 2.— In some national codes similar to this example, the specification for “performance” at take-off is such that no credit can be taken for any increase in length of acceleratestop distance available and take-off distance available beyond the length specified in Section 1 for take-off run available. Those codes specify a vertical clearance of not less than

15.2 m (50 ft) above all obstacles lying within 60 m on either side of the flight path while still within the confines of the aerodrome, and 90 m on either side of the flight path when outside those confines. It is to be observed that those codes are such that they do not provide for an alternative to the method of elements (see the Appendix to this example) in the determination of the take-off path. It is considered that those codes are compatible with the general intent of this example.

3.3 Conditions

For the purpose of 3.1 and 3.2, the performance is that corresponding to:

- a) the mass of the airplane at the start of take-off;
- b) an altitude equal to the elevation of the aerodrome; and for the purpose of 3.2:
- c) the ambient temperature at the time of take-off for 3.2 a) and b) only;
- d) the runway slope in the direction of take-off (landplanes);

e) not more than 50 per cent of the reported wind component opposite to the direction of take-off, and not less than 150 per cent of the reported wind component in the direction of take-off. In certain cases of operation of seaplanes, it has been found necessary to take account of the reported wind component normal to the direction of take-off.

3.4 Critical point

In applying 3.2 the critical point chosen for establishing compliance with 3.2 a) is not nearer to the starting point than that used for establishing compliance with 3.2 b) and 3.2 c).

3.5 Turns

In case the flight path includes a turn with bank greater than 15 degrees, the clearances specified in 3.2 c) are increased by

an adequate amount during the turn, and the distance D is measured along the intended track.

4. En route

4.1 One power-unit inoperative

4.1.1 At all points along the route or planned diversion therefrom, the airplane is capable, at the minimum flight altitudes en route, of a steady rate of climb with one power unit inoperative, as determined from the flight manual, of at least

- 1) $K \left[V_{so}/185.2 \right] 2\text{m/s}$, V_{so} being expressed in km/h;
- 2) $K \left[V_{so}/100 \right] 2\text{m/s}$, V_{so} being expressed in kt;
- 3) $K \left[V_{so}/100 \right] 2\text{ft/min}$, V_{so} being expressed in kt; and K having the following value:

$K = 4.04$ – in the case of 1) and 2); and

$K = 797$ – in the case of 3)

Where N is the number of power-units installed. It should be noted that minimum flight altitudes are usually considered to be not less than 300 m (1 000 ft) above terrain along and adjacent to the flight path.

4.1.2 As an alternative to 4.1.1 the airplane is operated at an all power-unit operating altitude such that, in the event of a power-unit failure, it is possible to continue the flight to an aerodrome where a landing can be made in accordance with 5.3, the flight path clearing all terrain and obstructions along the route within 8 km (4.3 NM) on either side of the intended track by at least 600 m (2 000 ft). In addition, if such a procedure is utilized, the following provisions are complied with:

a) the rate of climb, as determined from the flight manual for the appropriate mass and altitude, used in calculating the flight path is diminished by an amount equal to

- 1) $K \left[V_{so}/185.2 \right] 2\text{m/s}$, V_{so} being expressed in km/h;
- 2) $K \left[V_{so}/100 \right] 2\text{m/s}$, V_{so} being expressed in kt;
- 3) $K \left[V_{so}/100 \right] 2\text{ft/min}$, V_{so} being expressed in kt; and K having the following value:

$K = 4.04$ – in the case of 1) and 2); and

$K = 797$ – in the case of 3)

Where N is the number of power-units installed;

4.2 Two power-units inoperative (*applicable only to airplanes with four power-units*) The

possibility of two power-units becoming inoperative when the airplane is more than 90 minutes

at all power-units operating cruising speed from an en-route alternate aerodrome is catered for. This is done by verifying that at whatever such point such a double failure may occur, the airplane in the configuration and with the engine power specified in the flight manual can thereafter reach the alternate aerodrome without coming below the minimum flight altitude. It is customary to assume such fuel jettisoning as is consistent with reaching the aerodrome in question.

5. Landing

5.1 Mass

The calculated mass for the expected time of landing at the aerodrome of intended landing or any destination alternate aerodrome is not to exceed the maximum specified in the flight manual for the elevation of that aerodrome.

5.2 Landing distance

5.2.1 *Aerodrome of intended landing*

The landing distance at the aerodrome of the intended landing, as determined from the flight manual, is not to exceed 60 per cent of the landing distance available on:

- a) the most suitable landing surface for a landing in still air; and, if more severe,
- b) any other landing surface that may be required for landing because of expected wind conditions at the time of arrival.

5.2.2 *Alternate aerodromes*

The landing distance at any alternate aerodrome, as determined from the flight manual, is not to exceed 70 per cent of the landing distance available on:

- a) the most suitable landing surface for a landing in still air; and, if more severe,
- b) any other landing surface that may be required for landing because of expected wind conditions at the time of arrival.

Note.— The procedure used in determining the landing distance is described in the Appendix to this example.

5.3 Conditions

For the purpose of 5.2, the landing distances are not to exceed those corresponding to:

- a) the calculated mass of the airplane for the expected time of landing;
- b) an altitude equal to the elevation of the aerodrome;
- c) for the purpose of 5.2.1 a) and 5.2.2 a), still air;
- d) for the purpose of 5.2.1 b) and 5.2.2 b), not more than 50 per cent of the expected wind component along the landing path and opposite to the direction of landing and not less than 150 per cent of the expected wind component in the direction of landing.

APPENDIX TO EXAMPLE 1 ON AIRPLANE PERFORMANCE OPERATING LIMITATIONS —

PROCEDURES USED IN DETERMINING TAKE-OFF AND LANDING PERFORMANCE

1. General

1.1 Unless otherwise specified, Standard Atmosphere and still air conditions are applied.

- 1.2 Engine powers are based on a water vapour pressure corresponding to 80 per cent relative humidity in standard conditions. When performance is established for temperature above standard, the water vapour pressure for a given altitude is assumed to remain at the value stated above for standard atmospheric conditions.
- 1.3 Each set of performance data required for a particular flight condition is determined with the powerplant accessories absorbing the normal amount of power appropriate to that flight condition.
- 1.4 Various wing flap positions are selected. These positions are permitted to be made variable with mass, altitude and temperature in so far as this is considered consistent with acceptable operating practices.
- 1.5 The position of the centre of gravity is selected within the permissible range so that the performance achieved in the configuration and power indicated in the specification under consideration is a minimum.
- 1.6 The performance of the airplane is determined in such a manner that under all conditions the approved limitations for the powerplant are not exceeded.
- 1.7 The determined performance is so scheduled that it can serve directly in showing compliance with the airplane performance operating limitations.

2. Take-off

2.1 General

2.1.1 The take-off performance data are determined:

a) for the following conditions:

- 1) sea level;
- 2) airplane mass equal to the maximum take-off mass at sea level;
- 3) level, smooth, dry and hard take-off surfaces (landplanes);
- 4) smooth water of declared density (seaplanes);

b) over selected ranges of the following variables:

- 1) atmospheric conditions, namely: altitude and also pressure-altitude and temperature;
- 2) airplane mass;
- 3) steady wind velocity parallel to the direction of takeoff;
- 4) steady wind velocity normal to the direction of takeoff (seaplanes);
- 5) uniform take-off surface slope (landplanes);
- 6) type of take-off surface (landplanes);
- 7) water surface condition (seaplanes);
- 8) density of water (seaplanes);
- 9) strength of current (seaplanes).

2.1.2 The methods of correcting the performance data to obtain data for adverse atmospheric conditions include appropriate allowance for any increased airspeeds and cowl flap or radiator shutter openings necessary under such conditions to maintain engine temperatures within appropriate limits.

2.1.3 For seaplanes appropriate interpretations of the term landing gear, etc., are made to provide for the operation of retractable floats, if employed.

2.2 Take-off safety speed

2.2.1 The take-off safety speed is an airspeed (CAS) so selected that it is not less than:

- a) $1.20V_{S1}$, for airplanes with two power-units;
- b) $1.15V_{S1}$, for airplanes having more than two power units;
- c) 1.10 times the minimum control speed, VMC established as prescribed in 2.3; where V_{S1} is appropriate to the configuration, as described in

2.3.1 b), c) and d).

2.3 Minimum control speed

2.3.1 The minimum control speed, VMC, is determined not to exceed a speed equal to $1.2V_{S1}$, where V_{S1} corresponds with the maximum certificated take-off mass with:

- a) maximum take-off power on all power-units;
- b) landing gear retracted;
- c) wing flaps in take-off position;
- d) cowl flaps and radiator shutters in the position recommended for normal use during take-off;
- e) airplane trimmed for take-off;
- f) airplane airborne and ground effect negligible.

2.3.2 The minimum control speed is such that, when any one power-unit is made inoperative at that speed, it is possible to recover control of the airplane with the one power-unit still inoperative and to maintain the airplane in straight flight at that speed either with zero yaw or with a bank not in excess of 5 degrees.

2.3.3 From the time at which the power-unit is made inoperative to the time at which recovery is complete, exceptional skill, alertness, or strength on the part of the pilot is not required to prevent any loss of altitude other than that implicit in the loss of performance or any change of heading in excess of 20 degrees, nor does the airplane assume any dangerous attitude. 2.3.4 It is demonstrated that to maintain the airplane in steady straight flight at this speed after recovery and before retrimming does not require a rudder control force exceeding 800 N and does not make it necessary for the flight crew to reduce the power of the remaining power-units.

2.4 Critical point

2.4.1 The critical point is a selected point at which, for the purpose of determining the accelerate-stop distance and the take-off path, failure of the critical power-unit is assumed to occur. The pilot is provided with a ready and reliable means of determining when the critical point has been reached.

2.4.2 If the critical point is located so that the airspeed at that point is less than the take-off safety speed, it is demonstrated that, in the event of sudden failure of the critical power unit at all speeds down to the lowest speed corresponding with the critical point, the airplane is controllable satisfactorily and that the take-off can be continued safely, using normal piloting skill, without reducing the thrust of the remaining power-units.

2.5 Accelerate-stop distance required

2.5.1 The accelerate-stop distance required is the distance required to reach the critical point from a standing start and, assuming the critical power-unit to fail suddenly at this point, to stop if a landplane, or to bring the airplane to a speed of approximately 6 km/h (3 kt) if a seaplane.

2.5.2 Use of braking means in addition to, or in lieu of, wheel brakes is permitted in determining this distance, provided that they are reliable and that the manner of their employment is such that consistent results can be expected under normal conditions of operation, and provided that exceptional skill is not required to control the airplane.

2.5.3 The landing gear remains extended throughout this distance.

2.6 Take-off path

2.6.1 General

2.6.1.1 The take-off path is determined either by the method of elements, 2.6.2, or by the continuous method, 2.6.3, or by any acceptable combination of the two.

2.6.1.2 Adjustment of the provisions of 2.6.2.1 c) 1) and 2.6.3.1 c) is permitted when the take-off path would be affected by the use of an automatic pitch changing device, provided that a level of performance safety exemplified by 2.6 is demonstrated.

2.6.2 Method of elements

2.6.2.1 In order to define the take-off path, the following elements are determined:

a) The distance required to accelerate the airplane from a standing start to the point at which the take-off safety speed is first attained, subject to the following provisions:

- 1) the critical power-unit is made inoperative at the critical point;
- 2) the airplane remains on or close to the ground;
- 3) the landing gear remains extended.

b) The horizontal distance traversed and the height attained by the airplane operating at the take-off safety speed during the time required to retract the landing gear, retraction being initiated at the end of 2.6.2.1 a) with:

- 1) the critical power-unit inoperative, its propeller windmilling, and the propeller pitch control in the position recommended for normal use during takeoff, except that, if the completion of the retraction of the landing gear occurs later than the completion of the stopping of the propeller initiated in accordance with 2.6.2.1 c) 1), the propeller may be assumed to be stopped throughout the remainder of the time required to retract the landing gear;

2) the landing gear extended.

c) When the completion of the retraction of the landing gear occurs earlier than the completion of the stopping of the propeller, the horizontal distance traversed and the height attained by the airplane in the time elapsed from the end of 2.6.2.1 b) until the rotation of the inoperative propeller has been stopped, when:

- 1) the operation of stopping the propeller is initiated not earlier than the instant the airplane has attained a total height of 15.2 m (50 ft) above the take-off surface;
- 2) the airplane speed is equal to the take-off safety speed;
- 3) the landing gear is retracted;

- 4) the inoperative propeller is windmilling with the propeller pitch control in the position recommended for normal use during take-off.
- d) The horizontal distance traversed and the height attained by the airplane in the time elapsed from the end of
 - 2.6.2.1 c) until the time limit on the use of take-off power is reached, while operating at the take-off safety speed, with:
 - 1) the inoperative propeller stopped;
 - 2) the landing gear retracted. The elapsed time from the start of the take-off need not extend beyond a total of 5 minutes.
 - e) The slope of the flight path with the airplane in the configuration prescribed in 2.6.2.1 d) and with the remaining power-unit(s) operating within the maximum continuous power limitations, where the time limit on the use of take-off power is less than 5 minutes.
- 2.6.2.2 If satisfactory data are available, the variations in drag of the propeller during feathering and of the landing gear throughout the period of retraction are permitted to be taken into account in determining the appropriate portions of the elements.
- 2.6.2.3 During the take-off and subsequent climb represented by the elements, the wing flap control setting is not changed, except that changes made before the critical point has been reached, and not earlier than 1 minute after the critical point has been passed, are permitted; in this case, it is demonstrated that such changes can be accomplished without undue skill, concentration, or effort on the part of the pilot.
- 2.6.3 Continuous method
 - 2.6.3.1 The take-off path is determined from an actual take-off during which:
 - a) the critical power-unit is made inoperative at the critical point;
 - b) the climb-away is not initiated until the take-off safety speed has been reached and the airspeed does not fall below this value in the subsequent climb;
 - c) retraction of the landing gear is not initiated before the airplane reaches the take-off safety speed;
 - d) the wing flap control setting is not changed, except that changes made before the critical point has been reached, and not earlier than 1 minute after the critical point has been passed, are permitted; in this case, it is demonstrated that such changes can be accomplished without undue skill, concentration, or effort on the part of the pilot;
 - e) the operation of stopping the propeller is not initiated until the airplane has cleared a point 15.2 m (50 ft) above the take-off surface.
 - 2.6.3.2 Suitable methods are provided and employed to take into account, and to correct for, any vertical gradient of wind velocity which may exist during the take-off.
- 2.7 Take-off distance required

The take-off distance required is the horizontal distance along the take-off flight path from the start of the take-off to a point where the airplane attains a height of 15.2 m (50 ft) above the take-off surface.
- 2.8 Temperature accountability

Operating correction factors for take-off mass and take-off distance are determined to account for temperature above and below those of the Standard Atmosphere. These factors are obtained as follows:

- a) For any specific airplane type the average full temperature accountability is computed for the range of mass and altitudes above sea level, and for ambient temperatures expected in operation. Account is taken of the temperature effect both on the aerodynamic characteristics of the airplane and on the engine power. The full temperature accountability is expressed per degree of temperature in terms of a mass correction, a take-off distance correction and a change, if any, in the position of the critical point.
- b) Where 2.6.2 is used to determine the take-off path, the operating correction factors for the airplane mass and take-off distance are at least one half of the full accountability values. Where 2.6.3 is used to determine the take-off path, the operating correction factors for the airplane mass and take-off distance are equal to the full accountability values. With both methods, the position of the critical point is further corrected by the average amount necessary to assure that the airplane can stop within the runway length at the ambient temperature, except that the speed at the critical point is not less than a minimum at which the airplane can be controlled with the critical power-unit inoperative.

3. Landing

3.1 General

The landing performance is determined:

- a) for the following conditions:

- 1) sea level;
- 2) airplane mass equal to the maximum landing mass at sea level;
- 3) level, smooth, dry and hard landing surfaces (landplanes);
- 4) smooth water of declared density (seaplanes);

- b) over selected ranges of the following variables:

- 1) atmospheric conditions, namely: altitude and also pressure-altitude and temperature;
- 2) airplane mass;
- 3) steady wind velocity parallel to the direction of landing;
- 4) uniform landing-surface slope (landplanes);
- 5) type of landing surface (landplanes);
- 6) water surface condition (seaplanes);
- 7) density of water (seaplanes);
- 8) strength of current (seaplanes).

3.2 Landing distance

- 3.2.1 The landing distance is the horizontal distance between that point on the landing surface at which the airplane is brought to a complete stop or, for seaplanes, to a speed of approximately 6 km/h (3 kt) and that point on the landing surface which the airplane cleared by 15.2 m (50 ft).

3.3 Landing technique

- 3.3.1 In determining the landing distance:

- a) immediately before reaching the 15.2 m (50 ft) height, a steady approach is maintained, landing gear fully extended, with an airspeed of not less than $1.3V_{S0}$;
 - b) the nose of the airplane is not depressed in flight nor the forward thrust increased by application of engine power after reaching the 15.2 m (50 ft) height;
 - c) the wing flap control is set in the landing position, and remains constant during the final approach, flare out and touch down, and on the landing surface at air speeds above $0.9V_{S0}$. When the airplane is on the landing surface and the airspeed has fallen to less than $0.9V_{S0}$, change of the wing-flap-control setting is permitted;
 - d) the landing is made in a manner such that there is no excessive vertical acceleration, no excessive tendency to bounce, and no display of any uncontrollable or otherwise undesirable ground (water) handling characteristics, and such that its repetition does not require either an exceptional degree of skill on the part of the pilot, or exceptionally favorable conditions;
 - e) wheel brakes are not used in a manner such as to produce excessive wear of brakes or tires, and the operating pressures on the braking system are not in excess of those approved.
- 3.3.2 In addition to, or in lieu of, wheel brakes, other reliable braking means are permitted to be used in determining the landing distance, provided that the manner of their employment is such that consistent results can be expected under normal conditions of operation and that exceptional skill is not required to control the airplane.
- 3.3.3 The gradient of the steady approach and the details of the technique used in determining the landing distance, together with such variations in the technique as are recommended for landing with the critical power-units inoperative, and any appreciable variation in landing distance resulting therefrom, are entered in the flight manual.

Example 2

1. Purpose and scope

The purpose of the following example is to illustrate the level of performance intended by the provisions of Chapter 5 as applicable to the types of airplanes described below. This material was contained in substance in Attachment A to the now superseded edition of Annex 6 which became effective on 1 May 1953. It is based on the type of requirements developed by the Standing Committee on Performance* with such detailed changes as are necessary to make it reflect as closely as possible a performance code that has been used nationally. A substantial number of civil transport airplanes have been manufactured and are being operated in accordance with these codes. Those airplanes are powered with reciprocating engines, turbo-propellers and turbo-jets. They embrace twin-engined and four-engined airplanes over a mass range from approximately 5,500 kg to 70,000 kg over a stalling speed range, V_{S0} , from approximately 110 to 170 km/h (60 to 90 kt) and over a wing loading range from approximately 120 to 350 kg/m². Cruising speeds range up to 740 km/h (400 kt). Those airplanes have been used in a very wide range of altitude, air temperature and humidity conditions. Although only past experience can warrant the fact that this example illustrates the level of performance intended by the Standards and Recommended Practices of Chapter 5, it is considered to be applicable, except for some variations in detail as necessary to fit particular cases, over a much wider range of airplane characteristics. Reservation should, however,

be made concerning one point. The landing distance specification of this example, not being derived from the same method as other specifications, is valid only for the range of conditions stated for Example 1 in this Attachment.

This example is not intended for application to airplanes having short take-off and landing (STOL) or vertical take-off and landing (VTOL) capabilities. No detailed study has been made of the applicability of this example to operations in all-weather conditions. The validity of this example has not therefore been established for operations which may involve low decision heights and be associated with low weather minima operating techniques and procedures.

2. Take-off

2.1 Mass

The mass of the airplane at take-off is not to exceed the maximum take-off mass specified in the flight manual for the altitude and temperature at which the take-off is to be made. * The ICAO Standing Committee on Performance, established as a result of recommendations of the Airworthiness and Operations Divisions at their Fourth Sessions, in 1951, met four times between 1951 and 1953.

2.2 Performance

The performance of the airplane, as determined from the information contained in the flight manual, is such that:

- a) the accelerate-stop distance required does not exceed the accelerate-stop distance available;
- b) the take-off run required does not exceed the take-off run available;
- c) the take-off distance required does not exceed the takeoff distance available;
- d) the net take-off flight path starting at a point 10.7 m (35 ft) above the ground at the end of the take-off distance required provides a vertical clearance of not less than 6 m (20 ft) plus $0.005D$ above all obstacles lying within 60 m plus half the wing span of the airplane plus $0.125D$ on either side of the intended track until the relevant altitude laid down in the operations manual for an en-route flight has been attained; except that obstacles lying beyond 1,500 m on either side of the flight path need not be cleared. The distance D is the horizontal distance that the airplane has traveled from the end of the take-off distance available.

Note.— This need not be carried beyond the point at which the airplane would be able, without further gaining in height, to commence a landing procedure at the aerodrome of take-off or, alternatively, has attained the minimum safe altitude for commencing flight to another aerodrome.

However, the lateral obstacle clearance is liable to be reduced (below the values stated above) when, and to the extent that, this is warranted by special provisions or conditions which assist the pilot to avoid inadvertent lateral deviations from the intended flight path. For example, particularly in poor weather conditions, a precise radio aid may assist the pilot to maintain the intended flight path. Also, when the take-off is made in sufficiently good visibility conditions, it may, in some cases, be possible to avoid obstacles which are clearly visible but may be within the lateral limits noted in 2.2 d).

Note.— The procedures used in determining the accelerate stop distance required, the take-off run required, the take-off distance required and the net take-off flight path are described in the

Appendix to this example.

2.3 Conditions

For the purpose of 2.1 and 2.2, the performance is that corresponding to:

- a) the mass of the airplane at the start of take-off;
- b) an altitude equal to the elevation of the aerodrome;
- c) either the ambient temperature at the time of take-off, or a declared temperature giving an equivalent average level of performance; and for the purpose of 2.2:
- d) the surface slope in the direction of take-off (landplanes);
- e) not more than 50 per cent of the reported wind component opposite to the direction of take-off, and not less than 150 per cent of the reported wind component in the direction of take-off. In certain cases of operation of seaplanes, it has been found necessary to take account of the reported wind component normal to the direction of take-off.

2.4 Power failure point

In applying 2.2 the power failure point chosen for establishing compliance with 2.2 a) is not nearer to the starting point than that used for establishing compliance with 2.2 b) and 2.2 c).

2.5 Turns

The net take-off flight path may include turns, provided that:

- a) the radius of steady turn assumed is not less than that scheduled for this purpose in the flight manual;
- b) if the planned change of direction of the take-off flight path exceeds 15 degrees, the clearance of the net takeoff flight path above obstacles is at least 30 m (100 ft) during and after the turn, and the appropriate allowance, as prescribed in the flight manual, is made for the reduction in assumed gradient of climb during the turn;
- c) the distance D is measured along the intended track.

3. En route

3.1 All power-units operating At each point along the route and planned diversion therefrom, the all power-units operating performance ceiling appropriate to the airplane mass at that point, taking into account the amount of fuel and oil expected to be consumed, is not less than the minimum altitude (see Chapter 4, 4.2.6) or, if greater, the planned altitude which it is intended to maintain with all power-units operating, in order to ensure compliance with 3.2 and 3.3.

3.2 One power-unit inoperative From each point along the route and planned diversions therefrom, it is possible in the event of one power-unit becoming inoperative to continue the flight to an en-route alternate aerodrome where a landing can be made in accordance with 4.2 and, on arrival at the aerodrome, the net gradient of climb is not less than zero at a height of 450 m (1,500 ft) above the elevation of the aerodrome.

3.3 Two power-units inoperative (applicable only to airplanes with four power-units) For each point along the route or planned diversions therefrom, at which the airplane is more than 90 minutes' flying time at all power-units operating cruising speed from an en-route alternate aerodrome, the two power-units inoperative net flight path is such that a height of at least 300 m (1,000 ft) above terrain can be maintained until arrival at such an aerodrome.

Note.— The net flight path is that attainable from the expected gradient of climb or descent diminished by 0.2 per cent.

3.4 Conditions

The ability to comply with 3.1, 3.2 and 3.3 is assessed:

- a) either on the basis of forecast temperatures, or on the basis of declared temperatures giving an equivalent average level of performance;
- b) on the forecast data on wind velocity versus altitude and locality assumed for the flight plan as a whole;
- c) in the case of 3.2 and 3.3, on the scheduled gradient of climb or gradient of descent after power failure appropriate to the mass and altitude at each point considered;
- d) on the basis that, if the airplane is expected to gain altitude at some point in the flight after power failure has occurred, a satisfactory positive net gradient of climb is available;
- e) in the case of 3.2 on the basis that the minimum altitude (see Chapter 4, 4.2.6), appropriate to each point between the place at which power failure is assumed to occur and the aerodrome at which it is intended to alight, is exceeded;
- f) in the case of 3.2, making reasonable allowance for indecision and navigational error in the event of powerunit failure at any point.

4. Landing

4.1 Mass

The calculated mass for the expected time of landing at the aerodrome of intended landing or any destination alternate aerodrome is not to exceed the maximum specified in the flight manual for the altitude and temperature at which the landing is to be made.

4.2 Landing distance required The landing distance required at the aerodrome of the intended landing or at any alternate aerodrome, as determined from the flight manual, is not to exceed the landing distance available on:

- a) the most suitable landing surface for a landing in still air; and, if more severe,
- b) any other landing surface that may be required for landing because of expected wind conditions at the time of arrival.

4.3 Conditions

For the purpose of 4.2, the landing distance required is that corresponding to:

- a) the calculated mass of the airplane for the expected time of landing;
- b) an altitude equal to the elevation of the aerodrome;
- c) the expected temperature at which landing is to be made or a declared temperature giving an equivalent average level of performance;
- d) the surface slope in the direction of landing;
- e) for the purpose of 4.2 a), still air; for the purpose of 4.2 b), not more than 50 per cent of the expected wind component along the landing path and opposite to the direction of landing and not less than 150 per cent of the expected wind component in the direction of landing.

APPENDIX TO EXAMPLE 2 ON AIRPLANE PERFORMANCE OPERATING

LIMITATIONS —

PROCEDURES USED IN DETERMINING TAKE-OFF AND LANDING PERFORMANCE

1. General

1.1 Unless otherwise stated, reference humidity and still air conditions are applied.

1.2 The performance of the airplane is determined in such a manner that the approved airworthiness limitations for the airplane and its systems are not exceeded.

1.3 The wing flap positions for showing compliance with the performance specifications are selected.

Note.— Alternative wing flap positions are made available, if so desired, in such a manner as to be consistent with acceptably simple operating techniques.

1.4 The position of the centre of gravity is selected within the permissible range so that the performance achieved in the configuration and power indicated in the specification under consideration is a minimum.

1.5 The performance of the airplane is determined in such a manner that under all conditions the approved limitations for the powerplant are not exceeded.

1.6 While certain configurations of cooling gills have been specified based upon maximum anticipated temperature, the use of other positions is acceptable provided that an equivalent level of safety is maintained.

1.7 The determined performance is so scheduled that it can serve directly in showing compliance with the airplane performance operating limitations.

2. Take-off

2.1 General

2.1.1 The following take-off data are determined for sea level pressure and temperature in the Standard Atmosphere, and reference humidity conditions, with the airplane at the corresponding maximum take-off mass for a level, smooth, dry and hard take-off surface (landplanes) and for smooth water of declared density (seaplanes):

- a) take-off safety speed and any other relevant speed;
- b) power failure point;
- c) power failure point criterion; associated with items d), e), f) e.g. airspeed indicator reading;
- d) accelerate-stop distance required;
- e) take-off run required;
- f) take-off distance required;
- g) net take-off flight path;
- h) radius of a steady Rate 1 (180 degrees per minute) turn made at the airspeed used in establishing the net takeoff flight path, and the corresponding reduction in gradient of climb in accordance with the conditions of 2.9.

2.1.2 The determination is also made over selected ranges of the following variables:

- a) airplane mass;
- b) pressure-altitude at the take-off surface;
- c) outside air temperature;

- d) steady wind velocity parallel to the direction of take-off;
- e) steady wind velocity normal to the direction of take-off (seaplanes);
- f) take-off surface slope over the take-off distance required (landplanes);
- g) water surface condition (seaplanes);
- h) density of water (seaplanes);
- i) strength of current (seaplanes);
- j) power failure point (subject to provisions of 2.4.3).

2.1.3 For seaplanes appropriate interpretations of the term landing gear, etc., are made to provide for the operation of retractable floats, if employed.

2.2 Take-off safety speed

2.2.1 The take-off safety speed is an airspeed (CAS) so selected that it is not less than:

- a) $1.20V_{S1}$, for airplanes with two power-units;
- b) $1.15V_{S1}$, for airplanes having more than two power units;
- c) 1.10 times the minimum control speed, VMC, established as prescribed in 2.3;
- d) the minimum speed prescribed in 2.9.7.6; where V_{S1} is appropriate to the take-off configuration.

Note.— See Example 1 for definition of V_{S1} .

2.3 Minimum control speed

2.3.1 The minimum control speed is such that, when any one power-unit is made inoperative at that speed, it is possible to recover control of the airplane with the one power-unit still inoperative and to maintain the airplane in straight flight at that speed either with zero yaw or with a bank not in excess of 5 degrees.

2.3.2 From the time at which the power-unit is made inoperative to the time at which recovery is complete, exceptional skill, alertness, or strength, on the part of the pilot is not required to prevent any loss of altitude other than that implicit in the loss of performance or any change of heading in excess of 20 degrees, nor does the airplane assume any dangerous attitude. 2.3.3 It is demonstrated that to maintain the airplane in steady straight flight at this speed after recovery and before retrimming does not require a rudder control force exceeding 800 N and does not make it necessary for the flight crew to reduce the power of the remaining power-units.

2.4 Power failure point

2.4.1 The power failure point is the point at which sudden complete loss of power from the power-unit, critical from the performance aspect in the case considered, is assumed to occur. If the airspeed corresponding to this point is less than the take-off safety speed, it is demonstrated that, in the event of sudden failure of the critical power-unit at all speeds down to the lowest speed corresponding with the power failure point, the airplane is controllable satisfactorily and that the take-off can be continued safely, using normal piloting skill, without:

- a) reducing the thrust of the remaining power-units; and
- b) encountering characteristics which would result in unsatisfactory controllability on wet runways.

2.4.2 If the critical power-unit varies with the configuration, and this variation has a substantial effect on performance, either the critical power-unit is considered separately for each element

concerned, or it is shown that the established performance provides for each possibility of single power-unit failure.

2.4.3 The power failure point is selected for each take-off distance required and take-off run required, and for each accelerate-stop distance required. The pilot is provided with a ready and reliable means of determining when the applicable power failure point has been reached.

2.5 Accelerate-stop distance required

2.5.1 The accelerate-stop distance required is the distance required to reach the power failure point from a standing start and, assuming the critical power-unit to fail suddenly at this point, to stop if a landplane, or to bring the airplane to a speed of approximately 9 km/h (5 kt) if a seaplane.

2.5.2 Use of braking means in addition to, or in lieu of, wheel brakes is permitted in determining this distance, provided that they are reliable and that the manner of their employment is such that consistent results can be expected under normal conditions of operation, and provided that exceptional skill is not required to control the airplane.

2.6 Take-off run required

The take-off run required is the greater of the following:

1.15 times the distance required with all power-units operating to accelerate from a standing start to takeoff safety speed; 1.0 times the distance required to accelerate from a standing start to take-off safety speed assuming the critical power-unit to fail at the power failure point.

2.7 Take-off distance required

2.7.1 The take-off distance required is the distance required to reach a height of:

10.7 m (35 ft), for airplanes with two power-units,

15.2 m (50 ft), for airplanes with four power-units, above the take-off surface, with the critical power-unit failing at the power failure point.

2.7.2 The heights mentioned above are those which can be just cleared by the airplane when following the relevant flight path in an unbanked attitude with the landing gear extended.

Note.— Paragraph 2.8 and the corresponding operating requirements, by defining the point at which the net take-off flight path starts as the 10.7 m (35 ft) height point, ensure that the appropriate net clearances are achieved.

2.8 Net take-off flight path

2.8.1 The net take-off flight path is the one-power-unit inoperative flight path which starts at a height of 10.7 m (35 ft) at the end of the take-off distance required and extends to a height of at least 450 m (1,500 ft) calculated in accordance with the conditions of 2.9, the expected gradient of climb being diminished at each point by a gradient equal to:

0.5 per cent, for airplanes with two power-units,

0.8 per cent, for airplanes with four power-units.

2.8.2 The expected performance with which the airplane is credited in the take-off wing flap, take-off power condition, is available at the selected take-off safety speed and is substantially available at 9 km/h (5 kt) below this speed.

2.8.3 In addition the effect of significant turns is scheduled as follows:

Radius. The radius of a steady Rate 1 (180 degrees per minute) turn in still air at the various true

airspeeds corresponding to the take-off safety speeds for each wing-flap setting used in establishing the net take-off flight path below the 450 m (1,500 ft) height point, is scheduled. Performance change. The approximate reduction in performance due to the above turns is scheduled and corresponds to a change in gradient of

$\left[0.5(V/185.2)^2 \right] \%$ where V is the true airspeed in km/h; and

$\left[0.5(V/100)^2 \right] \%$ where V is the true airspeed in knots.

2.9 Conditions

2.9.1 Air speed

2.9.1.1 In determining the take-off distance required, the selected take-off safety speed is attained before the end of the take-off distance required is reached. 2.9.1.2 In determining the net take-off flight path below a height of 120 m (400 ft), the selected take-off safety speed is maintained, i.e. no credit is taken for acceleration before this height is reached.

2.9.1.3 In determining the net take-off flight path above a height of 120 m (400 ft), the airspeed is not less than the selected take-off safety speed. If the airplane is accelerated after reaching a height of 120 m (400 ft) and before reaching a height of 450 m (1,500 ft), the acceleration is assumed to take place in level flight and to have a value equal to the true acceleration available diminished by an acceleration equivalent to a climb gradient equal to that specified in 2.8.1.

2.9.1.4 The net take-off flight path includes transition to the initial en-route configuration and airspeed. During all transition stages, the above provisions regarding acceleration are complied with.

2.9.2 Wing flaps

The wing flaps are in the same position (take-off position) throughout, except:

- a) that the flaps may be moved at heights above 120 m (400 ft), provided that the airspeed specifications of 2.9.1 are met and that the take-off safety speed applicable to subsequent elements is appropriate to the new flap position;
- b) the wing flaps may be moved before the earliest power failure point is reached, if this is established as a satisfactory normal procedure.

2.9.3 Landing gear

2.9.3.1 In establishing the accelerate-stop distance required and the take-off run required, the landing gear are extended throughout.

2.9.3.2 In establishing the take-off distance required, retraction of the landing gear is not initiated until the selected take-off safety speed has been reached, except that, when the selected take-off safety speed exceeds the minimum value prescribed in 2.2 retraction of the landing gear may be initiated when a speed greater than the minimum value prescribed in 2.2 has been reached.

2.9.3.3 In establishing the net take-off flight path, the retraction of the landing gear is assumed to have been initiated not earlier than the point prescribed in 2.9.3.2.

2.9.4 Cooling

For that part of the net take-off flight path before the 120 m (400 ft) height point, plus any transition element which starts at the 120 m (400 ft) height point, the cowl flap position is such that, starting the take-off at the maximum temperatures permitted for the start of take-off, the relevant maximum

temperature limitations are not exceeded in the maximum anticipated air temperature conditions. For any subsequent part of the net take-off flight path, the cowl flap position and airspeed are such that the appropriate temperature limitations would not be exceeded in steady flight in the maximum anticipated air temperatures. The cowl flaps of all power-units at the start of the take-off are as above, and the cowl flaps of the inoperative power-unit may be assumed to be closed upon reaching the end of the take-off distance required.

2.9.5 Power unit conditions

2.9.5.1 From the starting point to the power failure point, all power-units may operate at maximum take-off power conditions. The operative power-units do not operate at maximum take-off power limitations for a period greater than that for which the use of maximum take-off power is permitted.

2.9.5.2 After the period for which the take-off power may be used, maximum continuous power limitations are not exceeded. The period for which maximum take-off power is used is assumed to begin at the start of the take-off run.

2.9.6 Propeller conditions

At the starting point, all propellers are set in the condition recommended for take-off. Propeller feathering or pitch coarsening is not initiated (unless it is by automatic or autoselective means) before the end of the take-off distance required.

2.9.7 Technique

2.9.7.1 In that part of the net take-off flight path prior to the 120 m (400 ft) height point, no changes of configuration or power are made which have the effect of reducing the gradient of climb.

2.9.7.2 The airplane is not flown or assumed to be flown in a manner which would make the gradient of any part of the net take-off flight path negative.

2.9.7.3 The technique chosen for those elements of the flight path conducted in steady flight, which are not the subject of numerical climb specifications, are such that the net gradient of climb is not less than 0.5 per cent.

2.9.7.4 All information which it may be necessary to furnish to the pilot, if the airplane is to be flown in a manner consistent with the scheduled performance, is obtained and recorded.

2.9.7.5 The airplane is held on, or close to the ground until the point at which it is permissible to initiate landing gear retraction has been reached.

2.9.7.6 No attempt is made to leave the ground until a speed has been reached which is at least: 15 per cent above the minimum possible unstick speed with all power-units operating; 7 per cent above the minimum possible unstick speed with the critical power-unit inoperative; except that these unstick speed margins may be reduced to 10 per cent and 5 per cent, respectively, when the limitation is due to landing gear geometry and not to ground stalling characteristics.

Note.— Compliance with this specification is determined by attempting to leave the ground at progressively lower speeds (by normal use of the controls except that up-elevator is applied earlier and more coarsely than is normal) until it has been shown to be possible to leave the ground at a speed which complies with these specifications, and to complete the take-off. It is recognized that during the test manoeuvre, the usual margin of control associated with normal operating techniques

and scheduled performance information will not be available.

2.10 Methods of derivation

2.10.1 General

The take-off field lengths required are determined from measurements of actual take-offs and ground runs. The net take-off flight path is determined by calculating each section separately on the basis of performance data obtained in steady flight.

2.10.2 Net take-off flight path

Credit is not taken for any change in configuration until that change is complete, unless more accurate data are available to substantiate a less conservative assumption; ground effect is ignored.

2.10.3 Take-off distance required

Satisfactory corrections for the vertical gradient of wind velocity are made.

3. Landing

3.1 General

The landing distance required is determined:

a) for the following conditions:

- 1) sea level;
- 2) airplane mass equal to the maximum landing mass at sea level;
- 3) level, smooth, dry and hard landing surfaces (landplanes);
- 4) smooth water of declared density (seaplanes);

b) over selected ranges of the following variables:

- 1) atmospheric conditions, namely: altitude, or pressure-altitude and temperature;
- 2) airplane mass;
- 3) steady wind velocity parallel to the direction of landing;
- 4) uniform landing surface slope (landplanes);
- 5) nature of landing surface (landplanes);
- 6) water surface condition (seaplanes);
- 7) density of water (seaplanes);
- 8) strength of current (seaplanes).

3.2 Landing distance required

The landing distance required is the measured horizontal distance between that point on the landing surface at which the airplane is brought to a complete stop or, for seaplanes, to a speed of approximately 9 km/h (5 kt) and that point on the landing surface which the airplane cleared by 15.2 m (50 ft) multiplied by a factor of 1/0.7.

Note.— Some States have found it necessary to use a factor of 1/0.6 instead of 1/0.7.

3.3 Landing technique

3.3.1 In determining the measured landing distance:

- a) immediately before reaching the 15.2 m (50 ft) height, a steady approach is maintained, landing gear fully extended, with an airspeed of at least $1.3V_{S0}$;

Note.— See Example 1 for definition of V_{S0} .

- b) the nose of the airplane is not depressed in flight nor the forward thrust increased by application of engine power after reaching the 15.2 m (50 ft) height;
- c) the power is not reduced in such a way that the power used for establishing compliance with the balked landing climb requirement would not be obtained within 5 seconds if selected at any point down to touch down;
- d) reverse pitch or reverse thrust are not used when establishing the landing distance using this method and field length factor. Ground fine pitch is used if the effective drag/weight ratio in the airborne part of the landing distance is not less satisfactory than that of conventional piston-engined airplane;

Note.— This does not mean that reverse pitch or reverse thrust, or use of ground fine pitch, are to be discouraged.

- e) the wing flap control is set in the landing position, and remains constant during the final approach, flare out and touch down, and on the landing surface at airspeeds above $0.9V_{S0}$. When the airplane is on the landing surface and the airspeed has fallen to less than $0.9V_{S0}$, change of the wing-flap-control setting is acceptable; f) the landing is made in a manner such that there is no excessive vertical acceleration, no excessive tendency to bounce, and no display of any other undesirable handling characteristics, and such that its repetition does not require either an exceptional degree of skill on the part of the pilot, or exceptionally favorable conditions;
- g) wheel brakes are not used in a manner such as to produce excessive wear of brakes or tires, and the operating pressures on the braking system are not in excess of those approved.

3.3.2 The gradient of the steady approach and the details of the technique used in determining the landing distance, together with such variations in the technique as are recommended for landing with the critical engine inoperative, and any appreciable variation in landing distance resulting therefrom are entered in the flight manual.